ROUTLEDGE INTERNATIONAL HANDBOOKS

Routledge Handbook of Art, Science, and Technology Studies

Edited by Hannah Star Rogers, Megan K. Halpern, Dehlia Hannah, and Kathryn de Ridder-Vignone

Routledge Handbook of Art, Science, and Technology Studies

Art and science work is experiencing a dramatic rise coincident with burgeoning Science and Technology Studies (STS) interest in this area. Science has played the role of muse for the arts, inspiring imaginative reconfigurations of scientific themes and exploring their cultural resonance. Conversely, the arts are often deployed in the service of science communication, illustration, and popularization. STS scholars have sought to resist the instrumentalization of the arts by the sciences, emphasizing studies of theories and practices across disciplines and the distinctive and complementary contributions of each. The manifestation of this commonality of creative and epistemic practices is the emergence of Art, Science, and Technology Studies (ASTS) as the interdisciplinary exploration of art–science.

This handbook defines the modes, practices, crucial literature, and research interests of this emerging field. It explores the questions, methodologies, and theoretical implications of scholarship and practice that arise at the intersection of art and STS. Further, ASTS demonstrates how the arts are intervening in STS. Drawing on methods and concepts derived from STS and allied fields including visual studies, performance studies, design studies, science communication, and aesthetics and the knowledge of practicing artists and curators, ASTS is predicated on the capacity to see both art and science as constructions of human knowledge-making. Accordingly, it posits a new analytical vernacular, enabling new ways of seeing, understanding, and thinking critically about the world.

This handbook provides scholars and practitioners already familiar with the themes and tensions of art–science with a means of connecting across disciplines. It proposes organizing principles for thinking about art–science across the sciences, social sciences, humanities, and arts. Encounters with art and science become meaningful in relation to practices and materials manifest as perceptual habits, background knowledge, and cultural norms. As the chapters in this handbook demonstrate, a variety of STS tools can be brought to bear on art–science so that systematic research can be conducted on this unique set of knowledge-making practices.

Hannah Star Rogers is a Visiting Scholar at the University of Edinburgh, where she researches the intersection of art and science.

Megan K. Halpern is an Assistant Professor in Lyman Briggs College at Michigan State University and a Scholar in Residence at MSU's Center for Interdisciplinarity.

Dehlia Hannah is Mads Øvlisen Postdoctoral Fellow in Art and Natural Sciences at the Department of Chemistry and Biosciences at Aalborg University and a Research Fellow of the Royal Danish Academy of Art and ARKEN Museum of Modern Art in Copenhagen.

Kathryn de Ridder-Vignone is Faculty Senate Chair at the South Carolina Governor's School for Science and Mathematics, where she teaches future engineers, from across the state, about the complexities of science, technology, and engineering in action.

Routledge Handbook of Art, Science, and Technology Studies

Edited by Hannah Star Rogers, Megan K. Halpern, Dehlia Hannah, and Kathryn de Ridder-Vignone

Routledge
Taylor & Francis Group
LONDON AND NEW YORK

First published 2021
by Routledge
2 Park Square, Milton Park, Abingdon, Oxon OX14 4RN

and by Routledge
52 Vanderbilt Avenue, New York, NY 10017

Routledge is an imprint of the Taylor & Francis Group, an informa business

British Library Cataloguing-in-Publication Data
A catalog record for this book is available from the British Library.

Library of Congress Cataloging-in-Publication Data
A catalog record has been requested for this book.

ISBN: 978-1-138-34730-4 (hbk)
ISBN: 978-0-429-43706-9 (ebk)
ISBN: 978-0-367-56492-6 (pbk)

DOI: 10.4324/9780429437069

Typeset in Bembo
by codeMantra

Cover image: © Ali Schachtschneider, 2015, Vivorium. Photography by Z. Wei. Vivorium is a speculative future lifestyle which uses rituals to explore alternative relationships between living and non-living and ourselves and biotechnology.

Contents

Figures

Tables

Foreword by Caroline A. Jones

Ars et scientia

The three words jostling each other in the title of this handbook – "art," "science," and "technology" – each have roots important for English usage: the Latin *ars* referred both to material things crafted with artisanal skills and to the tacit knowledge of making that was required to produce those things. *Scientia,* also Latin, connoted more abstract knowledge, implying by the fourteenth century a cumulative collection of human textual and thus virtual teachings that floated well above the kind of hand-eye coordination that still required learning from actual humans.[1] By contrast, *techne* comes as an interloper into our Latinate languages, imported from the Greek. Embraced as a useful stranger, *techne* became the transformational agent summoned to translate between the two epistemic regimes of making and knowing. Although the Greeks themselves used it to signify much the same thing as art – skilled crafting – it is recorded as early as 1617 in English, where it was beginning to carry a strong connection to those powerful but unlovely things, machines.[2]

Techne also brought a specific temporality to the conversation. In place of the stasis of Latinate art (*ars longa, vita brevis*) and the slow accumulation of *scientia*, the handy Greek "techne" (and its Latinate derivatives "technics," "technical," "technology," and "technological") came to signify a restless, ever-contemporary making. Yesterday's "technology" (moveable type) becomes a forgotten backdrop to what still feels "technological" today (OCR or optical character recognition). The contemporanizing effects of technology unite with its "making" connotations to become that branch of science by which science itself would become culturally applied and ubiquitous, industrialized by the eighteenth-century discipline of engineering (sharing the root of "ingenious" and "ingenuity"). Art would have to run to keep apace as long as contemporaneity was its goal.

"Technology" thus emerged as a powerful site of mobilization and enculturation for the lofty scientific realm. Putting research concepts into practical use or generating theories from the pell-mell engineering of the Industrial Revolution (*On the Motive Power of Heat* is a signal example),[3] the technological-thought-patterns of engineering emerged in the twentieth century as seductive for art as well as science. Attempts to bring the aesthetic criteria of art into the burgeoning domain of industrialized goods yielded the field of *design*,[4] even as the rarefied knowledge-producing forays of science were mined to propel ever new realms of instrumental knowledge in locomotion, electrification, extraction, and agro/animal genetics. Science is humanized by technology, while art gets mechanized – into engineering, user interfaces, and "scalable" media platforms.

We need every one of these words and the precise activities they designate. As historians, anthropologists, sociologists, but also curators and cultural producers, those of us who think about the divides between art, science, and technology want to attend to the unique roles of the professions that such still-separate words designate: artist, scientist, and technologist (Think about it: successful art we put in museums, good science yields laws, but old technology becomes toxic landfill.) Operating in the fecund territory between and among these disciplines does not mean ignoring their rules. And yet, this volume is about the skills that we could share in studying these domains or proliferating collaborations among these disciplines, forging a new field proposed by the novel acronym "ASTS:" Art, Science, and Technology Studies. What will be gained by throwing your lot in with this gang? By analyzing how these professions function as subject-making procedures, both as ongoing practices as well as through the objects they produce, the shared toolkit functions to illuminate the projects of human beings from multiple angles. And art's propensity to ask impertinent questions (can art be made for more-than-humans?) continues to help shake things up.[5]

My historical review itself has a history. Much has changed since historian of science Peter Galison and I collaborated in the mid-1990s to collect ideas on what histories of art and histories of science could bring to a shared toolkit.[6] In contrast to this volume's celebration of "the emergence of ASTS as the interdisciplinary exploration of art-science," we found the history of *how* the binary between art and science is delineated and maintained to be itself of interest. Not that the binary was stable nor were the sides uncontested – but the very declaration of an art or science affinity *did work* for the declarer, if they came from the other side. Hence Francis Picabia's decision to dedicate his book of Dada poetry to three neurological doctors (on two continents) who set out important territory for examining gender, machinery, and medicine in the epoch inaugurated during World War I. And equally, the budding empiricists in the Academy of the Lynx could nonetheless be seen to compromise their emerging Renaissance science with a shameless comparison of (falsely) virginal bees to the celibacy of the ruling Pope. Historical examinations of such moments revealed much. Before science had declared itself to be separate from philosophy, important epistemological instabilities can be seen, such as the early modern designation of a cameo as having been rendered by the divine hand of nature. These surprising crossings of what we now take for granted as art or science tell us a great deal about "art" as a category of material worked by both God and man, and "science" as knowledge that could be tested but might also be divinely propelled.

At the post-modern moment of collaboration between Galison and myself, we were barely four decades out from C. P. Snow's demarcation of the "two cultures."[7] Now another two decades have passed, and Snow's rigid no-man's land between art and science (technology was not yet theorized as a translating medium) seems at once defensive and hyper-vigilant. Perhaps, this volume is an indication of just how irrelevant Snow's middle-class (scientist's) jab at the British (literary) aristocracy has become, when any Anglophone nation's technological sector depends on the brain drain from subjects formerly colonized by that very empire. In the roughly 60 years since Snow, "Culture" itself has been transformed in the work of contemporary anthropologists, who turn the speculum of colonial field work onto contemporary science-as-culture, entering developed nations' science labs and technology accelerators to discover artists already there.[8]

"STS" (science and technology studies) now has its own multi-decades of practitioners, from the "strong program" of SSK in Britain (studying the sociology of scientific knowledge, even failed or wrong-headed science) to the ever-changing amalgams in the US, all dating roughly from the early 1970s. These programs could feature historians, sociologists, philosophers, anthropologists, and perhaps even economists or media theorists, who came together to study how science and technology are always embedded in, and altered by, the societies in which they thrive. The workshop and volume that Galison and I produced in the 90s was aligned with these programs while also making common cause with the social history of art to argue that a seamless methodological toolkit could be applied to disciplines that still maintained their crisp historical distinctness. By contrast, the present volume adds art to the STS mix, but nonetheless eschews *art history as such*. This has the effect of emphasizing curated arguments, contemporary practices, and performative engagements with science today over genealogies and archaeologies of such entanglements. Thus, Hooke's *Micrographia*, which art historian Janice Neri had discussed in terms of building up a final image through "multiple vantage points, under varying lighting conditions, and with lenses of differing powers," contributes art history's precision over terms, to convey to us what Hooke means by using the word "schema" to define his published plates.[9] This kind of argument is fundamentally different from the "ASTS" in this volume, where artist Nina Sellars draws on contemporary theorists such as Karen Barad, Donna Haraway, and Tim Ingold to posit our current transformed relationship to *post-optical* energies, such as the "micrographia" of medical MRIs. Hooke is illuminated by an artistic and methodological probe, not an historical one. On this account, our mediatized phenomenology can no longer give access to a "historical" Hooke.

Is the very emergence of this ASTS volume a welcome symptom of our thrumming hive-mind, by which we are growing and cognizing together, like mycorrhizae in symbiosis with an information- and species-dense forest? Have our interdisciplinary entwinings blurred the original "disciplines" to create this new buzzing, blooming community?

I would argue that this compendious volume, since it brings together very different authors and viewpoints, is in fact more multivalent and polyvocal. Chris Salter cautions us not to imagine this "art-science complex" as some harmonic convergence; it is "in reality a much more messy, conflict prone and turbulent arena," particularly in the universities where these contact zones increasingly proliferate. Hannah Shell notes, for example, that Galison himself has evolved from an early-career historian studying visualization modes to a post-tenure practitioner and advocate for "Visual STS," embracing cinematic and other media forms as unique components of historians' and anthropologists' arguments about science. Shell's proposed "curatorial analytic" conveys her own hybrid status as a maker and theorist of media – not an unusual combination in the world of art practice (from Eisenstein to Bill Viola to Hito Steyerl) – but one that here occupies the still-controversial terrain of academic STS, which still has to prove itself with books and peer-reviewed papers rather than cinematic installations. Shell demonstrates that if we are going to get the useful theories of both Lisa Cartwright and Mary Anne Doane into focus on the same cultural objects, we had best inhabit something that looks like what the volume editors have dubbed ASTS. Her plea for the useful position of *inhabitation* in relation to our scholarly love-objects resonates with the anthropologist's ethics of participant-observation. What academia has to acknowledge is that participation now can be within the still-circulating media of a century ago.

Our "trading zones" (another concept from Galison, put into active use by Nora Vaage)[10] have thus become saturated by media and its makers. In Vaage's anthropologically observed study, this necessarily includes the media of in vivo synthetic biology. How the recondite processes of genetic modification come out of the lab/biotech corporation and into the public sphere of the art gallery is indeed a burning question for ASTS, as Megan Halpern relates in her interrogation of the "tension between explanation and expression" that accompany the art-science interface.

What the emergence of this rich volume on ASTS makes clear is that science has failed to produce anything like the public sphere of art to entertain the cultural and ethical arguments we need to have about our technoscience. Yet, if artists are to be more than translators, they need to be respected for what their knowledge-systems have evolved to accommodate.

"Artistic research" is a dangerous phrase in the academy, accompanied as it is by grant-driven technoscience metrics of deliverables, patents, spin-offs, and quantitative measures of impact. In my own argument, art does better when it indulges doubt, confusion, mulling, and slow encounter rather than urgent action.[11] The most influential of our art forms stimulate us to peel off layers of information, meaning, and evocation in years of re-calling, discussing, and re-encountering the aesthetic stimulus and its proliferating documentation. I call this the *work* of art.[12] At least initially non-verbal, art is also often multi-sensory (haptic/odiferous/sonic). Art can offer those who experience it an intuitive grasp of worldly entanglements and living relations that take decades to fully parse. Its parafictional modes should be honored, even as yoking it to STS requires a clear disambiguation between dreaming the future and laying out the facts.

Notes

1 For "scientia" as cumulative, see John Butler Adam (editor of *The South African Journal of Science*), "The weighty history and meaning behind the word 'science'," reprinted in *The Conversation*, October 1, 2015. http://theconversation.com/the-weighty-history-and-meaning-behind-the-word-science-48280 2015; accessed January 2020.

2 **Technical:** "1617 Hales *Serm*.: 'Not to think themselves sufficiently provided upon their acquaintance with some Notitia, or systeme of some technical divine.'" **Technology:** "1706 Phillips (ed. Kersey), 'a Description of Arts, especially the Mechanical.'" *Oxford Unabridged English Dictionary*, 3248.

3 Nicolas Léonard Sadi Carnot, *Reflections on the Motive Power of Heat*, trans. R.H. Thurston (New York: John Wiley & Sons, 1897).

4 Arindam Dutta, *The Bureaucracy of Beauty: Design in the Age of its Global Reproducibility* (New York and London: Routledge, 2006).

5 See Jones, "Atmospheres and the Anthropogenic Image Bind," in another Routledge volume edited by Subhankar Banerjee, T.J. Demos, and Emily Eliza Scott, *Routledge Companion to Contemporary Art, Visual Culture, and Climate Change*, (2021).

6 Jones and Peter L. Galison, eds., *Picturing Science, Producing Art* (New York and London: Routledge, 1998).

7 C. P. Snow, *The Two Cultures* (Rede Lecture, 1959); published with an introduction by Stefan Collini (Cambridge UK and New York USA, Cambridge University Press, 1989).

8 Stefan Helmreich and Caroline A. Jones, "Science/Art/Culture through an Oceanic Lens," *Annual Review of Anthropology*, 47 (July 20, 2018): 97–115.

9 Janice Neri, (2008). "Between Observation and Image: Representations of Insects in Robert Hooke's Micrographia," in Therese O'Malley and Amy R. W. Meyers, (eds.). *The Art of Natural History*. (New Haven and Washington, DC: Yale University Press and National Gallery of Art, paperback 2010): 83–107.

10 Peter Galison's most extensive deployment of the trading zone concept (a zone of material exchange and discursive translation between theoretical physicists and engineers) can be found in his *Image and Logic: A Material Culture of Microphysics* (Chicago IL: University of Chicago Press, 1997).

11 Jones, "Doubt Fear," *Art Papers* 29, no. 1 (January/February 2005): 24–35.

12 Jones, *The Global Work of Art: World's Fairs, Biennials, and the Aesthetics of Experience* (Chicago IL: University of Chicago Press, 2016).

Foreword by Trevor Pinch

STS and the arts: the beginnings of a dialogue

I am writing this foreword in the midst of a global pandemic. I do not know (in March 2020) if I, or we, will make it through. Never before has the extraordinary fragility and connectivity of our global world – our infrastructures, our medical systems, our social systems, our economies, our very way of being in the world – been so exposed as in the massive breeching experiment which an unruly nonhuman, COVID-19, has unleashed upon us. The contributors to this book bring together two much-needed areas of human endeavor, Science and Technology Studies and Art.

We need more than science, technology, and medicine alone to help us out of the current crisis. What we also need is an understanding of how our science, technology, and medicine are enmeshed with the material and social infrastructures and institutions of our societies. The field that studies this intertwining is called Science and Technology Studies (often known as STS). It is a comparatively new field but it has rapidly grown since the 1970s with handbooks, conferences, and specialized courses. It is a global field, and many of the contributors to this book work in that field.

STS will not alone be enough. We also need art. It is art that provides the way to break through that provides the transcendent experience, the way to see, hear, or feel in a new way. It has the capacity to surprise. It can provide a means to capture something that is hard to express in the logos of academic writing. No one in this book is naïve enough to try to define art. But think of a painting, such as Edvard Munch's, "The Scream," think of a work of literature such as Margaret Atwood's, "The Hand Maid's Tale," think of any of the images of bioart that are presented in this volume. They somehow capture what the detailed academic deconstruction of science, technology, and culture finds hard to accomplish – they cut to the chase. Art is at its best when it is least disciplined and experimental; it has the capacity to discover and display things that more ordered processes miss. The mess, the mix, and the muddied, but not the muddled, are exactly where we need to be.

Science and technology seem the opposite, paragons of discipline, and rationality. But it is exactly this view that STS challenges. Science and technology, it turns out, are built on skills and practices akin to the craft and tacit knowledge of the arts. Science in the making can also be about contingency and happy accident. Scientific advances by necessity involve communities of skilled practitioners working within established traditions, ideas, and practices. A major change in the science is also a major change in the practices. Think of the germ theory of disease. Its acceptance also involved new practices such as the scrubbing of hands and the wearing of surgical gowns. Medicine was transformed. Art too is a form of practice, and we all know of the power of "ways of seeing" that can shape those practices. Thus, this book tries to level the playing field – setting art and science and technology alongside each other.

This is a book to ponder upon and delve into. It tries to discipline the undisciplinable. It tries to braid together the fabrics of materials, practices, knowledges, and institutions from two domains that for too long have been treated as separate. The interweaving of STS with art is a complex project. In their introduction to the Handbook, the editors make a good stab at setting out the signposts for how this may be achieved. They remind us of the rich but often disparate literatures that can help us in this endeavor. They offer concepts and approaches from a variety of fields that might help turn STS into ASTS. The book practices what Bruno Latour might call "overspill" as they exhaustively document many of the art-science collaborations and inspirations that paved the way for this collection.

The book is divided into sections with helpful intermezzos. As a whole, the book offers what STS does best – case studies, whether of specific projects, platforms, or new ways of using, thinking, and teaching about science and art and their relationship. It sometimes delves into history for illumination, and it shows how mundane practices such as a walking tour (Shepherd and Ernsten, this volume) or the organization of a meal (Steinhardt, this volume) can be viewed in a new way through the lens of art. The contributors offer studies over a broad range of artistic and scientific and technological projects: on the art side, this includes visual art, dance, photography, film, literature, design, theatre, and bioart, and on the science side, ecology, oceanography, genetics, biotech and biohacking, big data, artificial intelligence, medical testing, and synthetic biology. The anthropocene and the fragility of our environment and atmosphere in the era of global climate change is a particularly dominant theme. The book explores important and neglected topics such as artistic research (see also Borgdoff, Peters and Pinch 2019) audiences, curatorship, and pedagogy. For me, as a sound studies scholar, the only disappointment was the few examples from sound art.

The abiding questions to ask are: what needs to be overcome to make ASTS happen? And what is there about this particular cultural moment that might make it happen?

First, some personal history. I have been fortunate to have had a long career in STS and to watch the field mature. I am also a musician, and this has enabled me to link my academic endeavors in STS increasingly within the areas of sound studies, sound art and writing about musical instruments. I have encountered many scientists, engineers, artists, and STS scholars who have tried to overcome the divide between the arts and sciences.

Art has always been a counterpoint to STS. Like many scholars who witnessed the birth of the sociology of scientific knowledge, I learnt to read Thomas Kuhn's *The Structure of Scientific Revolutions* (Kuhn 1962) alongside art historian Ernst Gombrich's, *Art and Illusion* (Gombrich, 1960). Artists too shared paradigms. One of the first scientists I ever did a project with in the 1970s on the mysterious spoon-bending capabilities of Uri Geller was Bob Draper, an unknown technician in the Physics Department at the University of Bath who showed me how to use techniques in physics such as electron microscopy to make visual art (Draper went on to a distinguished career in the arts, https://www.brlsi.org/news/2010-05-09/house-manager-bob-recognised-oils-brlsi). I learnt from this Handbook that this is called sci-art. When I arrived at York University in the early 1980s, I found Michael Mulkay, a leading sociologist of science, actively collaborating with Elizabeth Chaplin (Chaplin, 1994), a sociologist of art, and Malcolm Hughes, a leading British constructivist painter. Sociologists of art such as Chaplin and Janet Wolff, whose 1983 book, *Aesthetics and the Sociology of Art*, was widely read at the time, remind us that sociologists have much to contribute. It was the days of radical relativism in the sociology of science and exploration of new literary forms (Gluzman this volume), and scholars such as Michael Mulkay and Malcolm Ashmore encouraged students in their classes to turn to art to address issues such as reflexivity. Michael Lynch, another sociologist and fellow traveler in early STS, had a long-term collaboration with the noted art historian, Samuel Edgerton, who helped inspire much of Lynch's pioneering work on visualization in the sciences (Lynch and Edgerton, 1987). Caroline Jones, the art historian, and her collaboration with historian of science, Peter Galison was on all our radars (Jones and Galison, 1998). Galison and Alexi Assmus (1987) had earlier shown in their study of the development of the cloud chamber in particle physics, the importance of Wilson's photographs of weather. They revealed a long and rich history of back and forth between the arts and sciences, such as the British chemist Luke Howard who influenced artists such as John Constable. Andrew Pickering through concepts, such as the mangle of practice, turned to art for examples of what he called the dance of agency (Pickering and Guzik, 2008). Donna Haraway was a continuous inspiration drawing upon science fiction and art in her work (Haraway, 1990). New younger scholars were emerging, such as Chris Kelty, who took artistic practices in their stride as part of their STS scholarship.

I still remember the thrill at a 4S (Society for Social Studies of Science) meeting of running into then Stanford HPS grad student, Natalie Jeremijenko, and her early radical vision for bringing STS and art together (Jeremijenko, 2004). Natalie, whose work is discussed in the introduction, is a real pioneer in this field, and we owe her a huge debt because she has shown one way to fruitfully combine STS and art in practice in a career that combines engineering and the arts. I visited her at Yale in the 1990s, where she was teaching engineering students to convert Sony robot dogs into feral robot dogs, which would seek out pollutants in the environment – a project combining art and media with the STS activist environmental critiques that become all the more prescient in the era of global warming and the anthropocene. Suddenly, in the late 1990s, art was everywhere, as was Bruno Latour.

Bruno's Iconoclash volume with art curator, Peter Weibel (Latour and Weibel, 2002) put STS on the map for many artists. But it also bred confusion. Some artists were now reading Latour but not STS. In 2003, I was invited to an art opening in Lower Manhattan for the MIT Media Lab-based artist, Chris Csikszentmihalyi, whose work was indeed steeped in STS. The opening of his exhibit reminded me of how different art openings can be to STS gatherings. The theme of the exhibit (blocks away from the World Trade Center) was on the tenuousness of technology infrastructure, and the boutique SOHO gallery, was decked in airplane gewgaws with waiters dressed up as pilots serving the champagne. A different artist who was attending the opening, being aware that I was a card-carrying STSer, zoomed straight on over. He had a big question to ask: "Do you believe in the postmodern science that Bruno Latour advocates?" I felt: where do you begin?

A good place to begin is the introduction to this handbook! It sets out the needed framing properly to formulate the project. Most people in our field of STS have some background in the sciences or technology – if they don't have any, they soon acquire some. To write meaningfully about, say, synthetic biology is hard to do without understanding some of the technical knowledge and practices shared by the field. This need to engage with the content of what we are studying is often called in STS "opening the black box." The same of course applies to art. Serious engagement with art requires understanding artistic practices. I am learning all the time about this. I am currently teaching a course at Cornell on building DIY musical instruments with a sound artist, Marianthi Papalexandri-Alexandri. As we discussed the class assignments, I casually mentioned that students could post videos of their instruments on YouTube, as I had done for my own home-made synthesizer. Wrong! For sound artists such as Marianthi, documenting her projects, curating them into portfolios and videos, was a serious business not to be done on a commercial platform such as YouTube. A high-quality video documentation was required, such as Vimeo. Much of the bridging problem the editors of this volume refer to comes from the myths and images we all have of each others' practices.

What we have to overcome most of all are myths about both science and art enshrined in individual creativity and notions of purity. Art and science are both social enterprises, created by and shared amongst what pioneer STS scholar, Ludwik Fleck, called "thought collectives." And everything that can happen will. Mess, improvisation, repair, and maintenance are the norm. If purity exists, the question is who are the hidden actors and infrastructures that allow for the appearance of purity?

We must also jettison the hackneyed myth of the two cultures. Overlaps, blurring, and interdisciplanarity are the norm. Art, Science, and Technology share much as socially constructed practices; they involve skilled practitioners who work with and experiment with materials to make and build things. They work within frameworks, traditions, infrastructures, and institutions. They form communities of practice who perform and pass on the craft and tacit knowledge at the core of their work. They make and are embedded in institutions and forms of life, whether the art worlds of Howie Becker or the Laboratory Life of Latour and Woolgar. The social and the material are always intertwined whether in a sound sculpture, a particle accelerator, or a photographic collage. Beauty counts – whether in the symmetry of elementary particles or in the aesthetic of minimalism in music. Beauty and aesthetics of course must be unpacked as feminist STS scholars and sociologists of art have long taught us. Communities of practice innovate and produce revolutions as well as produce mundane artifacts. Art can be whatever is hung on our walls, just as science can be knowing how to properly measure your own body temperature. This does not mean that art or science are made up (the wrong sense of constructivism) on a whim or that anything goes – producing a revolution in art is as hard as it is in science. The communities and institutions may be different, but they are socially grounded like all communities: power and credibility, gender, race, and ethnicity are always at stake. Politics and standpoint theories are the way to see what is at stake as STS has taught us. The myth of the individual genius is rightly slain.

Boundary objects, boundary work, trading zones, the role of users, audiences, performativity, agency, and social worlds – the full gamut of STS concepts glitter before our eyes here. Agency is juggled in new ways in assemblages with new sorts of actors, materials, bodies, and performances. There is much to reflect on and get excited about.

And I share the contributors' passion to make ASTS happen. The time is ripe. Making and doing are at the frontiers of STS these days. Big data means new visual and sonic forms of representation. Experimentation is everywhere. New media technologies offer new possibilities for collaboration, curation, and dissemination. Science like synthetic biology invites us to think about construction in new ways. Silicon Valley and the tech titans encourage artists to come play. The global environmental crisis, the anthropocene, global warming, and the immense scourge of the emerging global pandemic drive science, technology, and art ever closer together. STS has never been more vibrant and never needed as much. But we have to make ASTS happen.

It won't happen by falling into the hylomorphism, which anthropologist Tim Ingold (2013) rightly warns us against. It won't happen unless we take on board the wisdom of sociologist Howard Becker's (1984) grounding of art in art worlds. Above all, it won't happen unless we ourselves engage in the making and doing, build the new artworks, the new networks and worlds, the sound installations, and the new forms of performativity and dancing with agency that this book aspires to make happen. As our planet becomes increasingly bleak, we need the hope and inspiration that art can give us. We need to go to it right away.

References

Howard Becker, *Art Worlds*, Oakland: University of California Press, 1984.
Henk Borgdoff, Peter Peters, and Trevor Pinch (eds.), *Dialogues between Artistic Research and Science and Technology Studies*, London: Routledge, 2019.
Elizabeth Chaplin, *Sociology and Visual Representation*, London: Routledge, 1994.
Peter Galison and Alexi Assmus, "Artificial Clouds, Real Particles," in David Gooding, Simon Schaffer and Trevor Pinch (eds.), *The Uses of Experiment: Studies in the Natural Sciences*, Cambridge: Cambridge University Press, 1987, 225–274.
Ernst Gombrich, *Art and Illusion*, Princeton, NJ: Princeton University Press, 1960.
Donna Haraway, *Simians, Cyborgs and Women: The Reinvention of Nature*, London: Routledge, 1990.
Timothy Ingold, *Making: Anthropology, Srchaeology, Art, and Architecture*, London: Routledge, 2013.
Natalie Jeremijenko, *Creative Biotechnology: A Users Manual*, 2004.
Caroline A. Jones and Peter Galison (eds.), *Picturing Science, Producing Art*, London: Routledge, 1998.
Thomas Kuhn, *The Structure of Scientific Revolutions*, Chicago: The University of Chicago Press, 1962.
Bruno Latour and Peter Weibel (eds.), *Iconoclash: Beyond the Image Wars in Science Religion and Art*, Cambridge: MIT Press, 2002.
Michael Lynch and Samuel Edgerton, "Aesthetics and Digital Image Processing: Representational Craft in Contemporary Astronomy," in Gordan Fyfe and John Law (eds.) *Sociological Review Monographs, Special Issue, Picturing Power: Visual Depiction and Social Relations*, 1987, 184–220.
Andrew Pickering and Keith Guzik (eds.), *The Mangle in Practice: Science, Society and Becoming*, Durham, NC: Duke University Press, 2008.

Contributors

Heather Barnett is an artist, researcher, and educator working with natural phenomena and complex systems. Employing live organisms, imaging technologies, and playful pedagogies, her work explores how we observe, influence, and understand the world around us. She is Pathway Leader on the MA Art and Science at Central Saint Martins (University of the Arts London), Honorary Research Fellow with SHOAL Group (Swansea University), and a Higher Education Academy National Teaching Fellow.

Nicole Bennett is a PhD student in the English Department at the University of Wisconsin–Madison, where she studies waste as both a concept and material object, especially in Anglophone fiction and American visual culture produced during the Great Acceleration. Her current research examines the byproducts (mainly plastic and nuclear waste) of scientific advancements made during and since World War II.

David Buckley Borden is an interdisciplinary artist and designer based in Cambridge, Massachusetts. Using an accessible, often humorous, combination of art and design, David promotes a shared environmental awareness and heightened cultural value of ecology. David's place-based projects highlight both pressing environmental issues and everyday phenomena. Informed by research and community outreach, David's work manifests in a variety of forms, ranging from site-specific landscape installations in the woods to data-driven cartography in the gallery.

Regula Valérie Burri is professor of Science and Technology Studies at HafenCity University in Hamburg, Germany. Her research centers on topics such as visual knowledge, science and art, and the governance of science and technology. With backgrounds in STS and in art, she has been co-directing a postgraduate program on artistic research in Hamburg and is currently a project leader in art research. She is the founder of artLAB, a research and teaching format at HafenCity University.

Jane Calvert is a social scientist based in Science, Technology and Innovation Studies at the University of Edinburgh. She enjoys collaborating with scientists, engineers, artists, and designers and led the EPSRC/NSF project "Synthetic Aesthetics." Her current research, funded by a European Research Council Consolidator grant, focuses on attempts to engineer living things in the emerging field of synthetic biology and also examines the ways in which social scientists are being mobilized as part of this endeavor.

Silvia Casini is lecturer in Film and Visual Culture at the University of Aberdeen. Her work is situated at the crossroad of visual culture and science and technology studies. She has authored articles on the aesthetic, epistemological, and societal implications of scientific visualization and has received a Leverhulme Research Fellowship to complete her book project *Giving Bodies Back to Data: Image-makers, Data and Reinvention in Magnetic Resonance Technology*, MIT Press Leonardo book series.

Julian Charrière is a conceptual artist currently living and working in Berlin, Germany. He utilizes a range of artistic approaches including photography, performance, sculpture, and video to address concepts relating to time and society's relationship to the natural world. His work has been shown at numerous museums and festivals worldwide.

Edgar Cardenas holds a PhD in Sustainability from Arizona State University and conducts research at the art–science interface. As a social scientist, he focuses on social creativity and small group dynamics, exploring which processes and mechanisms support creative collaborations. As an interdisciplinary artist, he investigates the ecological, cultural, and technological subtleties of human–environment relationships. He is also a member of the indigenous artist collective, Radio Healer.

Oron Catts is the director and co-founder of SymbioticA (Est. 2000), the Centre of Excellence in Biological Arts, the University of Western Australia. He is an artist, researcher, and curator. He co-founded the Tissue Culture and Art Project in 1996, was a Research Fellow in Harvard Medical School, a Visiting Scholar at Stanford University, a Visiting Professor at Aalto University, and a Professor at Large in Contestable Design at the Royal College of Arts, London. His work was exhibited and collected by the Pompidou Centre, MoMA, Mori Art Museum, NGV, GoMA, National Art Museum of China, and more. His work was covered by *The NY Times*, *Washington Post*, *Wired*, *New Scientist*, *Time*, *Newsweek*, and other TV, radio, print, and online media.

Nathan Cohen is an artist, educator, and writer. His expertise includes contemporary art, exhibition curation, interactive art installation, and painting. Nathan is an established research professional engaged in art and science projects internationally, leading the interdisciplinary MA Art and Science course at University of the Arts London.

Heather Davis is an assistant professor of Culture and Media at The New School. Her current book project examines plastic in relation to petrocapitalism. She is the co-editor of *Art in the Anthropocene: Encounters Among Aesthetics, Politics, Environments and Epistemologies* and editor of *Desire Change: Contemporary Feminist Art in Canada*.

Kathryn de Ridder-Vignone is a faculty member at the South Carolina Governor's School for Science and Mathematics, where she teaches future engineers, from across the state, about the complexities of science, technology, and engineering in action. She holds a PhD from Cornell University's Department of Science & Technology Studies, completed postdoctoral studies in Arizona State University's Consortium for Science Policy & Outcomes, and served as an assistant professor in James Madison University's Department of Integrated Science &

Technology. She began her research interests, the visual culture, expertise, institutions, and emerging technologies, as an undergraduate at the University of South Carolina Honors College. She has worked to organize and facilitate deliberative dialogs for community planning, engineering design, and institutional and programmatic planning at the high school, university, graduate, and adult and informal education levels. Currently, she is co-leading a student research program focused on addressing problems in contemporary transportation systems with a focus on bike–ped infrastructure.

Aaron M. Ellison is the Senior Research Fellow Emeritus in Ecology at Harvard University and a photographer, sculptor, and writer. He studies the disintegration and reassembly of ecosystems following natural and anthropogenic disturbances; thinks about the relationship between the Dao and the intermediate disturbance hypothesis; and reflects on the critical and reactionary stance of ecology relative to modernism, occasionally blogs as The Unbalanced Ecologist, and tweets as @AMaxEll17. Whenever he can, he works wood.

Christian Ernsten is an urbanist who works at the intersection between heritage studies, artistic research methods, and contemporary debates on the Anthropocene. He holds a PhD from the University of Cape Town, an MA from the University of Groningen, and an MPhil from the University of Cape Town. Currently based at Maastricht University, he has held visiting research fellowships at the Conservation Department of the University of Gothenburg, the Amsterdam School for Cultural Analysis at the University of Amsterdam, and the Centre for Uses of the Past at Aarhus University.

Laura Forlano, a Fulbright award-winning and National Science Foundation-funded scholar, is a writer, social scientist, and design researcher. She is an Associate Professor of Design at the Institute of Design and Affiliated Faculty in the College of Architecture at Illinois Institute of Technology, where she is Director of the Critical Futures Lab. Forlano's research is focused on the aesthetics and politics at the intersection between design and emerging technologies. She received her PhD in communications from Columbia University.

Jonas Fritsch is an associate professor in Interaction Design at the IT University of Copenhagen. His research develops a creative approach to interaction design, experience philosophy, and affect theory through practical design experiments with emerging technologies. He is head of the Affective Interactions & Relations (AIR) Lab Research Group, a co-manager in the DFF-funded research project Affects, Interfaces, Events, and an associated partner in the SSHRC-funded international research project Immediations: Media, Art, Event.

Yelena Gluzman is an assistant professor of Science, Technology and Society Studies at the University of Alberta, working in emergent modes of collaborative and experimental STS. Her research has developed critical collaborations with scientists, engineers, experimental subjects, and stenographers, informed by the methodologics of experimental theater and feminist STS. Most recently, she completed a project reconsidering experimental methods in cognitive neuroscience experiments on autism, and is currently working on a project exploring distributed sense-making in "real-time" transcription for d/Deaf students alongside automated talk-to-text alternatives.

James Graham is an adjunct assistant professor at Columbia University's Graduate School of Architecture, Planning, and Preservation. He is also the director of Columbia Books on

Architecture and the City and founding editor of the *Avery Review*, a digital journal of critical essays on architecture.

Megan K. Halpern is an assistant professor in Lyman Briggs College at Michigan State University and a Scholar in Residence at MSU's Center for Interdisciplinarity. Her research interests include art/science collaboration, public engagement with science, feminist approaches to science communication, and research through design. She earned her PhD in Science Communication at Cornell University and completed a Postdoctoral Research Fellowship at Arizona State University's Center for Nanotechnology and Society and Center for Science and the Imagination. Before earning her PhD, Dr. Halpern was a theater artist and the co-founder and Artistic Director of Redshift Productions, a company that created performances inspired by science.

Kevin Hamilton is Dean of the College of Fine and Applied Arts at the University of Illinois, Urbana-Champaign. An artist and scholar, Kevin publishes on bias in algorithmic systems and methodologies of interdisciplinary research; his artworks explore telepresence, cybernetics, race, and landscape. His work earned support from the National Science Foundation, the National Endowment for the Humanities, and the Illinois Arts Council. With Ned O'Gorman, he authored *Lookout America: The Secret Hollywood Studio at the Heart of the Cold War.*

Dehlia Hannah, Ph.D., is a curator and philosopher of nature. She is currently a postdoctoral fellow at The Royal Danish Academy of Fine Arts and ARKEN Museum of Modern Art, Copenhagen, where her Ny Carlsberg funded project Rewilding the Museum (2021–2025) examines the art museum's status within the fragile ecologies of the Anthropocene. She received her PhD in Philosophy and Certificate in Feminist Inquiry from Columbia University, with specializations in aesthetics, philosophy of science and philosophy of nature. Her book A Year Without a Winter (Columbia University Press, 2018) reframes contemporary imaginaries of climate change by revisiting the environmental conditions under which Frankenstein was written and the global aftermath of the 1815 eruption of Mount Tambora. As a curator, her exhibitions and artistic collaborations explore how emerging science and technology inform the aesthetic contestation of ideas of nature. Past exhibitions include Placing the Golden Spike: Landscapes of the Anthropocene (Milwaukee, 2015), and Control: Experiment (Stockholm, 2016), Dressing in a World of Endless Rainfall (Copenhagen, 2016), and Emerge: A Festival of Futures (Phoenix, 2017). Edited books include Julius von Bismarck—Talking to Thunder (Hatje Cantz, 2019) and Julian Charrière—Toward No Earthly Pole (Mousse, 2020). As Mads Øvlisen Postdoctoral Fellow in Art and Natural Sciences at Aalborg University, her most recent project examined the role of thought experiments and imaginary creatures, places, and things in philosophical reasoning.

Stefanie Hessler is a curator, writer, and editor focusing on interdisciplinary and long-term collaborations with artists and researchers. She has curated exhibitions by artists such as Joan Jonas, Armin Linke, Marjetica Potrč, and Christine Sun Kim and worked with institutions such as the São Paulo Biennale, Hamburger Bahnhof in Berlin, Museum of Modern Art in Recife, FLORA in Bogotá, and the Athens Biennale. She is the author of the book *Prospecting Ocean* (2019, MIT Press) and director of Kunsthall Trondheim.

Adrian Holme is an artist, educator, writer, and editor. He lectures on the MA Art and Science, CSM, and has a background in biological science in addition to fine art. His research interests center on alchemy, AI, and the impact of technology upon human agency. Adrian is a lecturer and visual theory coordinator on the BA Hons Illustration, Camberwell College of Arts; an associate editor at the *Journal of Illustration*; and a Fellow of the Higher Education Academy.

Hanna Husberg is a visual artist and is currently holding a Bernadotte Scholarship at Swedish Royal Arts Academy while developing her doctoral research project "Troubled Atmosphere—On Noticing Air" at the Academy of Fine Arts Vienna. Her artistic research has developed through several art projects that, through a focus on air, inquire into how humans perceive, relate to, and imagine their immediate and expanded surrounding.

Stephanie Beth Jordan is an assistant professor in the Media and Information Department and a core faculty member in the Center for Gender in a Global Context at Michigan State University. Through both academic and artistic endeavors, she explores the promises of big data to answer grand challenge questions of climate and culture, informed by ethnographic fieldwork in oceanographic spaces such as ships, research facilities, and laboratories. She earned her PhD from Cornell University.

Eben Kirksey is an American anthropologist who specializes on science and justice. Duke University Press has published his first two books—Freedom in Entangled Worlds (2012) and Emergent Ecologies (2015)—as well as two edited collections: The Multispecies Salon (2014) and The Promise of Multispecies Justice (2022). In academic circles, Prof. Kirksey is perhaps best known for his work in multispecies ethnography—a field that situates contemporary scholarship on animals, microbes, plants, and fungi within deeply rooted traditions of environmental anthropology, continental philosophy, and the sociology of science. The Institute for Advanced Study in Princeton, New Jersey, hosted Kirksey for the 2019-2020 academic year, where he finished his latest book: The Mutant Project. Currently, he is Associate Professor (Research) at the Alfred Deakin Institute in Melbourne, Australia. His personal website is https://eben-kirksey.space/

Alexandra Lakind is a doctoral candidate in Environmental Studies & Education at the University of Wisconsin–Madison. She is engaged in several collaborative activities, which include her recent roles as director of Terra Incognita Art Series and co-editor of becoming-Botanicals with Objet-a Creative Studio. Through academic and performative routes, she hopes to foster supportive communities to process unanswerable dilemmas together.

Jennifer L. Lieberman is an associate professor of English at the University of North Florida, where she specializes in American literary history, race and gender studies, and science and technology studies. She is the author of *Power Lines: Electricity in American Life and Letters* (The MIT Press, 2017), and her other work can be found in such venues as *JLS: The Journal of Literature and Science; Configurations; History and Technology*; *Studies in the Novel*; and *MELUS: Multi-ethnic Literature in the US*.

Jacob Lillemose is a curator at the Medical Museion in Copenhagen (a museum of biomedicine under the University of Copenhagen) where he is currently producing the exhibition The World is in You on the notion of "the entangled body" (opening at Kunsthal Charlottenborg fall 2021). He is the curator of the Danish Pavilion for the Venice art biennale in 2022. He holds a PhD in art history from the University of Copenhagen. His debut novel *Architecture Zero* is forthcoming on A Mock Book (summer 2021).

Chaz Lilly is currently an Assistant Professor of Communications at the University of Louisiana Monroe. He is a doctoral candidate at the University of Texas at Dallas in Art, Technology and Emerging Communication, where he is also a member of the ArtSciLab contributing to research that focuses on experimental publishing and curation.

Lissette Lorenz is a PhD student in science and technology studies at Cornell University. Her current work utilizes ethnographic methods to understand the social impacts of nuclear technologies in Japan. She is interested in how people in Japan make connections between the Fukushima nuclear accident and the nuclear bombings of Hiroshima and Nagasaki. Her previous research as an undergraduate at Oberlin College explored how community theater, and especially Theater of the Oppressed, could serve as a tool for addressing environmental justice issues.

Charlie Lotterman is a graduate student in the Department of Anthropology at Rice University, where his dissertation research centers on human-parasite relations.

Robert Lundberg makes music, photos, and video and thinks about and drinks water. He holds a BFA from The New School and a JD & MS in Law and Environmental Studies from the University of Wisconsin–Madison. He has performed with music outfits JOBS, Skeletons, Nestle, and Leverage Models at sites such as Carnegie Hall, JVC Jazz Fest, Newport Folk Fest, and Big Ears Festival. His recent multimedia projects weave together music, video, and photography around the concept of water infrastructure.

Mary Maggic is a non-binary artist working at the intersection of amateur science and cultural discourse, spanning workshopology, participatory performance, documentary, and speculative fiction. She holds a BSA in Biology and Art from Carnegie Mellon University and an MS in Media Arts and Sciences from MIT Media Lab. Maggic's work has been featured at Haus der Kulturen der Welt (Berlin), Haus der elektronischen Kunst (Basel), Jeu de Paume (Paris), Institute of Contemporary Arts (London), and Spring Workshop (Hong Kong). Maggic is a recipient of the Prix Ars Electronica Honorary Mention in Hybrid Arts and Fulbright Award in Indonesia.

Roger F. Malina is a recovering astrophysicist, former Executive Editor of Leonardo Publications at MIT Press, Directeur de Recherche for the CNRS in France, and Distinguished Professor of Art and Technology and Professor of Physics at the University of Texas at Dallas, where he is also Director of the ArtSciLab, a transdisciplinary research lab.

Owen Marshall is an NSF Postdoctoral Fellow at the University of California, Davis' program in Science and Technology Studies, researching sound and data at the intersection of artistic and scientific practices. His work appears in publications including the *International Journal of Communication*, *Annals of the History of Computing, Technology and Culture*, *Social Studies of Science*, and the volume *Critical Approaches to the Production of Music and Sound*. He also has a forthcoming book on the digital vocal tuning software Auto-Tune.

Agáta Marzecová is an environmental scientist with a background in photography and new media. Working at the intersection of science, art, and theory, her research interest spans from studying historical changes in the environment to analyzing shifts in environmental perception.

Lisa Jean Moore is a medical sociologist and professor at Purchase College, SUNY. Her books include *Buzz: Urban Beekeeping and the Power of the Bee* (2013) with Mary Kosut, and *Catch and Release: The Enduring Yet Vulnerable Horseshoe Crab* (2018).

Cassini Nazir is a designer of conversations, curriculum, and interfaces. He is a Clinical Associate Professor in the School of Arts, Technology, and Emerging Communication at UT Dallas, where he teaches classes in interaction design. He is also Director of Design and Research for the ArtSciLab, a transdisciplinary research lab helping the arts, science, and technology communities by pursuing initiatives of societal urgency and cultural timeliness.

Christian Nold is an artist, designer, and academic researcher building participatory technologies for collective representation. He created large-scale public art projects such as the widely acclaimed "Bio Mapping" and "Emotion Mapping" with thousands of participants across the world. He has written *Mobile Vulgus*, *Emotional Cartography: Technologies of the Self*, *The Internet of People for a Post-Oil World,* and *Autopsy of an Island Currency*. Currently, he is a postdoctoral research associate in the Geography Department at University College London.

Molly Renda served as exhibits program librarian at the NC State University Libraries from 2011-2020, and with Fred Gould was co-director of the Art's Work in the Age of Biotechnology: Shaping Our Genetic Futures project. Her background in painting and printmaking has informed a thirty-year career in graphic design. Renda holds a BFA from the School of Visual Arts where she studied with Bob Blackburn and Dale Henry, and later worked at Blackburn's Printmaking Workshop. She served as executive editor for design and production for DoubleTake magazine (1994–99), published by the Center for Documentary Studies at Duke University. Her book and publication design have been recognized by Communication Graphics, Graphis, the AIGA 50 Books, 50 Covers exhibition, and the Association of American University Presses.

Sandra Rodegher holds a PhD in sustainability and an MA in industrial and organizational psychology. Her research focuses on the impact of power dynamics in deliberative processes and activities. She also uses this knowledge to convene interdisciplinary groups and facilitate the process of creating science communication activity kits intended to engage diverse populations in exploration of complex scientific research.

Hannah Star Rogers is a Visiting Scholar at the University of Edinburgh, where she focuses on the intersection of art and science. She holds a PhD from Cornell University in Science and Technology Studies and an MFA from Columbia University. Her monograph *Art, Science, and the Politics of Knowledge* (MIT Press, 2022) investigates how the tools of STS can be used to understand art and science. Rogers works as a curator for art and science exhibits, and her recent exhibits include *Emerge: Artists and Scientists Redesign the Future, Making Science Visible: The Photography of Berenice Abbott, and Art's Work in the Age of Biotechnology: Shaping Our Genetic Futures.*

Chris Salter is an artist, professor for Computation Arts at Concordia University in Montreal, and Co-Director of the Hexagram network. Salter's performances, installations, research, and publications have been presented at numerous festivals, exhibitions, and conferences around the world including the Venice Biennale. He is the author of *Entangled:*

Technology and the Transformation of Performance (MIT Press, 2010) and *Alien Agency: Experimental Encounters with Art in the Making* (MIT Press, 2015).

Nadim Samman is a curator and art historian based in Berlin. He read Philosophy at University College London before receiving his PhD from the Courtauld Institute of Art. He co-founded and curated the 1st Antarctic Biennale in 2017. In 2016, he curated the 5th Moscow International Biennale for Young Art, and in 2012, the 4th Marrakech Biennale (with Carson Chan). Other major projects include Treasure of Lima: A Buried Exhibition (a unique site-specific exhibition on the Pacific island of Isla del Coco).

Anna Santomauro is a curator, educator, and researcher in micropolitics and socially engaged art. She joined Arts Catalyst in May 2017 as Programme Curator. In 2011, Santomauro co-founded Vessel in Bari, Italy, a nonprofit arts organization dedicated to public programming in relation to contemporary social, political, and economic issues. In 2015–2016, Santomauro was ESP and Public Programmer at Eastside Projects (Birmingham). She is a PhD candidate at the University of Wolverhampton (UK).

Lea Schick is a researcher investigating innovation for sustainable futures in the intersection of art, design, and infrastructure studies. She is teaching sustainable IT and management at the IT University of Copenhagen and working as an innovation specialist at the Alexandra Institute.

Pablo Schyfter is a lecturer in Science, Technology, and Innovation Studies at the University of Edinburgh. His work focuses on topics such as the sociology of knowledge, science and technology studies, engineering studies, and feminist theory. He has researched and worked with synthetic biologists and has explored their collaborations with artists and designers. Schyfter is also trained in drama and theater studies and works to bring performance and its practices into the social sciences.

Carla Sedini is a sociologist and holds a PhD in the Quality of Life in the Information Society (Qua_SI project). She currently is an Adjunct Professor at the School of Design of Politecnico di Milano and at IED School in Milano. Sedini has been a Research Fellow in the Design Department of Politecnico di Milano since 2012. She has been collaborating on several research projects about creative and cultural industries, urban regeneration, and social innovation both in Italian and foreign universities and research centers as well as for private clients.

Nina V. Sellars is a curator of the Harry Brookes Allen Museum of Anatomy and Pathology, the University of Melbourne, and an artist and scholar who works across the disciplines of art, science, and humanities. Sellars was Artist in Residence at SymbioticA, the Centre of Excellence in Biological Arts, the University of Western Australia, funded by the Australia Council (2016–2018), and a Research Fellow at the Alternate Anatomies Lab (robotics and anatomy research group), School of Design and Art, Curtin University, WA (2013–2015).

Hanna Rose Shell is Director of the Stan Brakhage Center for the Media Arts, as well as Associate Professor of Critical and Curatorial Studies in the College of Arts & Sciences. She is jointly appointed in both the Department of Art and Art History, and the Department of Cinema Studies & Moving Image Arts. She is the author, most recently, of *Shoddy: From Devil's Dust to the Renaissance of Rags*.

Nick Shepherd directs the research project on Heritage and the Anthropocene at Aarhus University. He has held visiting positions at Harvard University, Brown University, the University of Basel, and Colgate University. In 2017–2018, he was artist-in-residence at the Amsterdam University of the Arts. In 2014, he started convening regular walking seminars in collaboration with colleagues in academia, the arts, and civil society.

Karolina Sobecka is an artist and designer who has been working at the intersection of art, science and technology, examining social arrangements that exploit, resist or accommodate technological change. Karolina's recent projects are centered on experimentation in the fields of climate and carbon engineering. Karolina's work has been shown internationally and has received numerous awards, including from Creative Capital, Rhizome, NYFA, Princess Grace Foundation, Eyebeam, Vida Art and Artificial Life Awards and Japan Media Arts Festival. http://karolinasobecka.com/

Alex Garcia Topete is a filmmaker, entrepreneur, film festival programmer, and researcher currently pursuing a master's degree in Innovation & Entrepreneurship and a doctorate in Arts, Technology and Emerging Communications at the University of Texas at Dallas. He also serves as Innovation & Collaboration Strategist for the UT-Dallas ArtSciLab, where his research focuses on transdisciplinary intelligence & collaboration methodologies, particularly as they relate to the knowledge industries and their relationship to technology and diverse publics.

Nicola Triscott is a curator, researcher, and writer, specializing in the intersections between art, science, technology, and society. Since 2019, she is the Director/CEO of FACT, Liverpool, UK, an international center for the support and exhibition of film and digital media art. From 1994 to 2019, she was the founding Artistic Director/CEO of Arts Catalyst, London, known internationally for its pioneering work in art and science and ambitious artists' commissions. From 2017 to 2019, she was a Principal Research Fellow at the University of Westminster.

Nora S. Vaage is an art historian turned philosopher of art and culture, with a PhD in philosophy of science and ethics. From this interdisciplinary perspective, she writes and teaches on a number of topics at the intersection between culture, society, and technology. She is particularly interested in questions of values and knowledge views (ethics and epistemology). Prominent research interests include the ethics of emerging technologies and arts, climate change images, metaphors in science and art, and artistic research.

Jennifer Willet is an associate professor in the School of Creative Arts at the University of Windsor (Canada) and an internationally successful artist and curator in the emerging field of bioart. Her work resides at the intersection of art and science and explores notions of representation, the body, ecologies, and interspecies interrelations in the biotechnological field. In 2009, she opened a bioart research and teaching lab INCUBATOR: Hybrid Laboratory at the Intersection of Art, Science, and Ecology at the University of Windsor.

Anne Sophie Witzke is a curator and theorist currently finishing a PhD on ecology and media art practices at Aarhus University. She has worked with contemporary art addressing environmental issues for more than a decade. She was a project lead and co-curator of Rethink—Contemporary Art and Climate Change, one of the first major exhibitions to explore the issue of climate change within contemporary art. Rethink was appointed "the Nordic Exhibition of the Year 2009–2010" and part of the cultural program for COP15, 2009.

Christopher Wood is an artist and researcher interested in imaginaries around technology, especially the ways emerging technology define our experiences of space and time. His practice is based around collaborative workshops, conversations, and interactions. He uses these to develop interactive installations and encounters. He recently completed a Ph.D. in Media & Arts Technology at Queen Mary University of London. Examples of his work can be found at http://chriswood.art

Britt Wray is a science storyteller working in podcast, print, interactive media, television, and academic research. She has a PhD in Science Communication from the University of Copenhagen and can sometimes be found in hosting science programs for the BBC and CBC. She is the author of *Rise of the Necrofauna: The Science, Ethics, and Risks of De-Extinction*.

Andrew S. Yang is a transdisciplinary artist working across the sciences, history, and naturalcultural flux. He has exhibited from Oklahoma to Yokohama, including the 14th Istanbul Biennial (2015), Museum of Contemporary Art Chicago (2016), the Spencer Museum of Art (2019), and the Smithsonian Museum of Natural History (2020). His writing can be found in journals including *Leonardo*, *Biological Theory*, and *Antennae*. He is an Associate Professor at the School of the Art Institute of Chicago.

Adam Zaretsky is a Wet-Lab Art Practitioner mixing Ecology, Biotechnology, Non-human Relations, Body Performance, and Gastronomy. Zaretsky stages lively, hands-on bioart production labs based on topics such as foreign species invasion (pure/impure), radical food science (edible/inedible), jazz bioinformatics (code/flesh), tissue culture (undead/semi-alive), transgenic design issues (traits/desires), interactive ethology (person/machine/non-human), and physiology (performance/stress). His art practice focuses on an array of legal, ethical, social, and libidinal implications (LESLI) of biotechnological materials and methods with a focus on transgenic humans.

Brett Zehner is a media theorist and artist writing on technologies of resistance. Brett's dissertation project, Machines of Subjection, explores the ubiquitous emergence of predictive media in the form of machine learning. This research aims to conceptualize a new form of political power, where individual decision-making is being replaced by the ubiquity of predictive computation. For instance, theories of identity formation and language acquisition must be updated with the emergence of so-called natural language processing and a wide range of real-time perceptive technologies that correspond to statistical aggregation in machine learning.

Ionat Zurr is the Chair of the Fine Arts Discipline at the School of Design & Academic Coordinator and Researcher at SymbioticA, School of Human Sciences, the University of Western Australia. Zurr is an artist, researcher, and curator who co-developed the biological arts initiative, the Tissue Culture and Art Project, since 1996. She is considered a leader in the growing field of Biological Art both as a practitioner and a theoretician.

Introduction

The past, present, and future of Art, Science, and Technology Studies

Hannah Star Rogers and Megan K. Halpern

This handbook introduces Art, Science, and Technology Studies (ASTS) as a new field of interdisciplinary inquiry and practice. Drawing on the methods and concepts derived from Science and Technology Studies (STS), ASTS is predicated on the capacity to see both art and science as constructions of human knowledge-making. As such, it posits a new analytical vernacular in enabling new ways of seeing, understanding, and thinking critically about the world. The rise in work at the intersection of art and science over the last twenty-five years or so has given way to analyses of the longer history of art and science as ways of categorizing knowledge, and these hybrid practices require a commensurate shift in our analytical and conceptual equipage.

We have such a framework in ASTS, an emerging way of knowing that is itself a product of the art–science nexus. This handbook introduces new scholars to this burgeoning area and provides those already familiar with its themes and tensions with a means of connecting across disciplines by proposing organizing principles for thinking about art–science across the sciences, social sciences, humanities, and arts. It has long been recognized that encounters with art become meaningful in relation to perceptual habits, background knowledge, and cultural norms including science, and yet art–science has hitherto not been treated as a discrete set of social practices amenable to study. In some ways, ASTS is an act of revisioning the existing literature through a new lens. Few scholars have probed very deeply into the various works that inform discussions of art–science and those who have found the meaningful texts scattered across many disciplinary homes. Most of these texts are discipline-bound and often speak past each other.

For us, this lack of coherency has long been a source of frustration. But it is also exciting, as it suggests the emergence of a new knowledge field. We envision this handbook as a first attempt to systematize art and STS and to note features of its methods, institutions, cases, and common themes. In it, we organize principles for thinking about art–science into three parts. Part I addresses methods and histories for ASTS. Part II considers the role of audiences and the production of art and science work for public consumption. Part III examines the development and display of projects, along with creative works demonstrating some of these ideas. Themes, genres, project types, and practitioner backgrounds and locations are distributed throughout the book to emphasize the degree of variation in every area of this work.

DOI: 10.4324/9780429437069-1

Before building a picture of the field, we first have to acknowledge the richness of terminology in this space. As we edited this volume, we refrained from standardizing the art–science language of its more than fifty authors in order not to blunt our ongoing empirical project. However, there are some common designations that are worth noting, although they represent theoretically and practically contested spaces. For example, "sciart" refers to artworks created by scientists with an eye toward producing beautiful images. Artist-created works that use science imagery or subjects are often referred to as "artsci." We use the expression "art–science" to refer to works where both artists and scientists contribute their ideas. While some art–science work is visual in nature, it tends to encompass a more expansive set of artistic practices.

We distinguish these terms from ASTS as an analytical rubric. It is important to note that for many involved in ASTS, the study of art–science is often intermingled with its practice. Some of the scholars in this book would contend that in addition to the practical meaning of "art–science" as a type of artwork, there is a secondary theoretical-philosophical meaning that makes it fundamental to ASTS's place in STS. Art–science comprises the shared practices and blurred outcomes that question convenient borders or definitions of those two knowledge communities. Much as in the case of STS, which creates more direct critiques and engages public policy, some ASTS projects use methods that would be recognizable to the subjects of their studies.

What distinguishes ASTS from STS is its analytical treatment of questions of art–science. While using STS as a lens to study art–science is new, ASTS is built on a rich and varied foundation. In this introductory chapter, we outline the foundation of an ASTS canon. We excavate classic texts that have dealt with the art–science phenomenon, consider their epistemological and ontological orientation, and juxtapose them with new works, identifying points of convergence and divergence in methods, concepts, and assumptions. Finally, we note some potential agendas for future ASTS research.

Multi- and interdisciplinary works

Analysis of art–science is necessarily multi- and interdisciplinary. The maintenance of certain boundaries continues to be a feature of art–science work, even as some practitioners work to move away from these divides. Emerging practices of art–science are fertile ground for STS scholars, and conversely, STS enables us to read artworks. In the case of art engaged with the sciences, this often involves basic lessons in science and its history as well as that of art. STS methods are critical to grounding work in the contested space of art–science because their status is negotiated between individuals and institutions. Yet metrics of success and failure vary among the primary and secondary actors who make up networks.

The contributors to this handbook try to reconcile this complexity by providing both detailed case studies and broader contexts in which they become meaningful. Contemporary artists (Gessert 2010) and designers have adopted scientific methods and materials as new media, joining STS scholars in critically engaging the disciplinary power structures that govern knowledge production (Guston 2001; Becker 1982; Halpern 2012). Art history (Ede 2005), aesthetics (Eagleton 1990), and media theory (Becker and McCall 1990) offer crucial resources for understanding the confluence of art, science, and technology and the public in the twenty-first century. STS is especially important to ASTS because it reminds us that science is a social process and a cultural product and that scientific knowledge is socially constructed (Berger and Luckmann 1966; Bijker, Hughes, and Pinch 1987; Lynch and

Woolgar 1990; Bowker and Star 1999). When science is placed on a similar plane as other forms of knowledge production, we may deploy tools developed in other art and humanities fields on science subjects.

Transdisciplinary identities and collaborations

Cases where actors cross disciplinary lines, intentionally or unintentionally, to create new works are a key preoccupation of ASTS. Sometimes, the products and outcomes of those efforts are studied with a view to understanding the ways actors position the work (Rogers 2012). In other cases, emphasis is placed on influences (histories, materials, and practices) identified as coming from the art or science side that created conditions for the production of a particular work (Daston 2008). Other ASTS initiatives seek to recognize and harness potential collaborations between self-identified artists and scientists. Some engagements are facilitated, with a third party brokering the interaction or an institution or funding source providing the impetus for the interaction, as Jane Calvert and Pablo Schyfter show (Chapter 2). Other collaborations can occur "in the wild" around a specific issue, serendipitously or via personal connections, as Megan Halpern (Chapter 18) demonstrates. Such events are usually figured as bringing two different worldviews together, often directed at public understanding of emerging technologies. Both situations involve a single actor or a group of actors creating a work occupying a liminal space between the two areas. Practically, these art–science pieces are often situated in art contexts, although science institutions have sometimes shown an interest in developing collaborations as well. Both situations—self-identifying artists and scientists collaborating together and individuals positioning themselves and their work as multi- or transdisciplinary—are discussed in this book.

Dominant narratives in art–science

Important art–science research preceded ASTS. Classic works such as Lorraine Daston and Peter Galison's *Objectivity* (2007), James Elkins' *Art History and Images That Are Not Art* (1995), and Bruno Latour's *Iconoclash* (Latour and Weibel 2002) all developed important themes that helped inform ASTS as it stands today. On the other hand, another set of themes, including culture clash, instrumentalization, and the lone genius, tend to dominate popular narratives about art–science relationships. These tropes often override new ideas as well as emerging narratives from individual cases. Nevertheless, it is important to examine them, for they form the basis of much of our tacit understanding of the art–science nexus. Their persistence in art–science narratives has importantly shaped the way art–science has been practiced, with perhaps the most ubiquitous example being initiatives in STEAM (science, technology, engineering, art, and mathematics), which play upon some of the most problematic tropes of art–science.

The two cultures metaphor

The "two cultures" metaphor and the associated analogies used to elaborate it are perhaps the most well-recognized characterization of art and science. The idea that these two knowledge communities might be compared in some equivalent way by characterizing them as "cultures" has held lasting appeal. But the limitations of this gloss are readily apparent. STS scholars do not consider science as monolithic and have highlighted the distinctness of practice and worldview in different physical disciplines (Rouse 1992; Bensaude-Vincent 2001; Nordmann 2009). Comparative studies of different art forms are an ongoing concern in the history of art and translate into the need for ASTS scholars to attend to specific differences in given cases.

The influence of the two cultures metaphor has far exceeded its original context. The expression was coined by the English physical chemist and novelist C.P. Snow as the title of a 1963 book that identified a perceived rift between the arts and sciences and suggested a way in which the two might work together. Snow's Rede lecture at the University of Cambridge in 1959 ignited a heated debate with the literacy critic F.T. Leavis. Their long and acrimonious dialog has been a subject of fascination for over half a century, treated in academic and popular literature alike, with over 800 books, articles, essays, and reviews on the subject appearing by the end of the 1970s.[1]

In his lecture, Snow lamented the "gulf of mutual incomprehension" between the arts and sciences (2012, 4). The gulf was ostensibly characterized by overt hostility between literary intellectuals, on the one hand, and physical scientists, on the other. Snow claimed that because he had had success in each sphere, he could walk between them, and spoke of his wish to bridge them. But he felt that science looked to the future, while the arts and humanities dwelt too much on the present and past. The remedy, Snow thought, was for the arts and humanities to turn their attention toward science.[2]

Leavis, Snow's most adamant critic, delivered his riposte three years later. In a lecture entitled "Two Cultures? The Significance of C.P. Snow," Leavis directly attacked the author. As a literary scholar, Leavis found Snow's ideas and, more importantly, his writing, "beneath contempt" (Levin 1965). Leavis claimed the humanities, specifically literature, above all was morally and otherwise superior (Cohen 2001). A bitter fight ensued that drew its ammunition from personal and political arguments rather than the two cultures themselves (Ortolano 2008).

The two cultures metaphor outlived this personal dispute. Revived and rehashed, it became the standard way of talking about the relationship between art and science, even though what constituted these cultures did not remain static. It is found within the current calls for the arts and humanities to justify their existence by partnering with scientific endeavors as well as in heightened appeals to increase participation in STEM through STEAM, which often reduces art and design as tools for marketing the sciences. Two cultures may properly be seen as belonging to a genre of dichotomous reasoning that achieved popular currency as an expedient but ultimately shallow trope (for example, discussions of logic versus creativity and left- versus right-brained personalities). The art–science dyad has been revised as science and art, or as science and the humanities (Kimball 1994; Burnett 1999; Kovác 2002; van Dijck 2003), and reimagined as a clash between art and science and, other times, between science and the humanities. In many versions of the metaphor, "bridging" may occur as an act of reconciliation, an analogy that in this context fails to capture the degree to which art and science are actually intertwined.

The art historian and critic James Elkins (2009) called for an end to attempts at bridging these cultures, noting that artistic treatments of science are often incomplete or incorrect, while scientific discussions of art capture very little of what makes art significant. He recognized two strands of two cultures arguments: the standard narrative that finds intersections between art and science throughout history and the aesthetic argument, in which scientists invoke terms like beauty and elegance to describe scientific theories or experiments. Of aesthetic argument, Elkins notes:

> I don't think that aesthetic concepts like beauty, delight, and elegance really are the workable bridges between art and science. Those words are too unfocused, too vague and ethereal, too well intentioned, emotionally pallid, sentimentally idealistic, formal, and slippery to yoke anything I recognize as science to anything I think of as art.
>
> *(37)*

Beyond the limitations of the "bridge" metaphor and the complications produced by attempting to define the areas on each side of it, the ease and frequency with which the two cultures metaphor has been flexibly interpreted should be pondered. It suggests that the kind of conflict Snow describes is universal. But it may also suggest that the idea of the two cultures is overly broad, especially in some of the more recent incarnations (science and security, for example; see Kennedy 2003). Today, fields as far ranging as medicine and computing invoke the two cultures to describe chasms between different ways of approaching knowledge. As Burnett (1999) writes:

> …in an essay in the *New York Times* on the "New Luddites," Pynchon invoked the specter of what he called the "Snovian Disjunction." It is a disjunction regularly lamented in scholarly symposia, cited by academic administrators, and invoked to help account for everything from the "science wars" to the history of environmental policy.
>
> *(195)*

The "science wars" of the 1980s and 1990s are perhaps the best example of this remapping of the two cultures. They ostensibly pitted "natural scientists and those nonscientists who take a professional interest not so much in the findings of scientific knowledge, but in the workings and nature of science" (Labinger and Collins 2001, 3). In other words, the divide was between scientists and STS scholars, representing philosophy, history, sociology, and other social studies of science. In this perspective, the realists lined up against the constructivists and postmodernists.[3] In the future, ASTS scholars may assert that this division, in which the humanities and arts were pressed onto the side of STS, may have sown the seeds of an alliance against the reductive sciences. Cohen (2001) notes that there are differences between the science wars and the two cultures debates, asserting that with its reconceptualization of science as a social practice with local knowledge, STS has effectively dispatched the two cultures idea:

> The two cultures make sense as a rhetorical strategy and from the point of view of recognizable practices. As a theoretical and epistemological distinction, however, the divide cannot hold up under a revised (science studies) notion of science.
>
> *(11)*

Despite Cohen's confidence, some of the works done by ASTS suggest that STS has not, in fact, put this idea to rest because it has not necessarily finished the work of revising our notions of science. Many of the chapters in this handbook suggest that when scientific forms of knowledge are put into conversation with knowledge produced in the arts, new ideas of science tend to resemble their predecessors, even in circles where the objectivity and primacy of science are questioned or critiqued. One of the most promising outcomes of ASTS research is that putting studies of science in conversation with art may help to more fully elucidate the implicit understandings of 'what science is' that remain beneath the surface of even the most radically constructivist STS. Sections 4 and 5 discuss collaborations between artists and scientists as well as the structures within which these collaborations occur.

One of the more pervasive assumptions in two cultures narratives, drawn directly from Snow's lecture, is that science and technology will solve the world's problems. Stories of lone geniuses dovetail with technocratic predictions of entrepreneurial engineering solutions to intractable socio-technical problems. These issues have been written about at length elsewhere (Segal 1986; Curran 2012; Marwick 2013; Schaffer 2015; Miller 2017; Davenport 2018; Marantz 2019 to name a few). But the other assumption of this techno-utopian narrative is that art and literature ought to fall in line to support scientific progress. For Snow, it was up to art and literature to turn their attention to the sciences and embrace them. In Chapter 14, Stephanie Jordan turns this narrative on its head, using experimental performance to interrogate the techno-utopian dreams of big data in oceanography.

Snow's story that science and technology will save us from ourselves, if only we embrace them and incorporate them into attempts to solve recurring problems, is echoed in E. O. Wilson's *Consilience* (1998). Wilson's hope is that fields like sociology will be subsumed by biology, where scientific explanations will replace what might be considered interpretive insights. The result will be a merging of these fields, with the rules and methods of the natural sciences as a model for what is to come. A tart and smart artistic rejoinder was provided by poet and environmental essayist Wendell Berry (2003). In *Life Is a Miracle: An Essay Against Modern Superstition*, Berry opined that the attitude of science toward what is not known is a great limitation to what it might know. In Berry's view, Wilson's wish to collapse all thought into a single scientific structure is destined to produce a capitalist-oriented outcome: "to reduce the mystery and miracle of life to something that can be figured out is inevitably to enslave it, make property of it and put it up for sale."

Myth of the lone genius

The myth of the lone genius has played a significant role in both art and science. Within the two cultures metaphor, the genius has been held up as one of the more successful "bridges" by transcending the two cultures through the sheer power of their talent and intellect. Art and science are typically understood as the provinces of great individuals who have made singular contributions with the aid of little else beyond their own ingenuity. However, both art and science scholars have attacked the cult of the genius. STS scholars as far back as Thomas Kuhn (1962) argued that science has to be understood as a knowledge-verifying community, rather than an individual practice. The sociologist Howard Becker (1982) did something equivalent for artists, contending that artmaking is a communal activity and that it is impossible to understand art worlds without looking beyond the studios of individual artists. Neither art nor science, it seems, can be understood without an appeal to social organization.

Nor can other forms of context be ignored. Although it is not always acknowledged, art and science have been redefined historically in ways that, in retrospect, make them seem more and less intertwined in different periods. We catch glimpses of different kinds of relationships in the innumerable texts about Leonardo da Vinci and other art–science phenoms. Each time we encounter art–science as a knowledge practice, there is a tendency to treat it as novel and tied to a unique individual, but this isn't necessarily so. There *is* something fulfilling about the works of art–science geniuses that doesn't present itself to us in the multitudes of dichotomous or instrumentalized portrayals of art–science.

It is easy to dismiss such narratives as 'just-so stories,' as plentiful as they are problematic, but we suggest that there is a deeper allure. These stories provide a picture of a time and a place in which art and science were not vying against one another for truth claims, but rather were working in harmony, in part because scientific practices as we know them today did not yet exist. In the concept of the lone genius, it is the context as much as the individual that is fictively depicted. Daston (2005) reminds us that prior to the seventeenth century, facts as we understand them now did not exist. Instead, people relied on experiences to make sense of the world. The decoupling of facts from the act of making them is part and parcel of the rejection of imagination in science. As Daston notes:

> the more scientists insisted upon the obduracy and intransigence of facts, the more they feared the power of their own imaginations to subvert those facts. Why would scientists convinced of the power of ugly facts to murder beautiful theories, as Thomas Henry Huxley famously put it, nonetheless take heroic precautions to protect those burly facts from gossamer-spun imagination?
>
> *(2005, 17)*

Perhaps, the remnants of a time when experiences and interpretations were bound up in observations and experiments appeal to us in the form of heroic geniuses who can be both creative and objective. No doubt, the persistence of this myth owes much to the durability of the "great man" school of history in the face of the thoroughgoing revisionism that has unfolded over the last century.

Instrumentalism and the parasite metaphor

Two cultures logic depicts art as either handmaiden to or parasite on science. And this limited set of potential roles makes it incumbent on ASTS to identify and ruminate on these assumptions, to analyze their origins and in what ways they continue to influence art and science relationships as well as public understandings of collaborations. Science can be seen as playing the role of muse for the arts, inspiring imaginative reconfigurations of scientific themes and exploring their cultural resonance. Conversely, the arts are frequently deployed in the service of science communication, illustration, and popularization. These frameworks for art–science discussions often involve ways in which art or science is appropriated for use by the other, or ways in which art is a parasite on the sciences, or how breakthroughs in science and technology are used to create art.

More recently, to be sure, scholars have made more subtle takes on the art–science relationship. Elkins (2008) lists four ways art and science can be used to illuminate or think about one another: first, science can help explain art, as in the case when ideas about the fourth dimension helped elucidate Marcel Duchamp's *Large Glass*. Next, and possibly more commonly, art can explain science. Daston and Galison's discussion of objectivity in anatomical drawings provides an excellent treatment of one such case (1992), although these scholars presented a far more nuanced account of the ways artists' renderings found in anatomical atlases shape and reveal shifting meanings of objectivity. Third, both art and science can be explained by some other field, for example, philosophy. The fourth way involves situations in which "various disciplines are put in ambiguous conjunction" (11).

Art–science commentator Siân Ede (2002) similarly broke art–science relationships (primarily drawn from the visual arts) into three categories: art that uses science, art that assists science, and finally, metaphors used in both art and science. She emphasized that many commonly used scientific metaphors may rest within some kind of scientific knowledge but do not illuminate anything about science. For example, Heisenberg's uncertainty principle, which states that it is impossible to know simultaneously the exact position and momentum of a particle, is often used to speak about one's inability to know oneself or about the way that observation often changes the nature of that which is observed. In the play *Copenhagen*, playwright Michael Frayn (2000) relied heavily on uncertainty as a metaphor for understanding Heisenberg's motives for visiting his former mentor Niels Bohr during World War II. This use of science as a metaphor in the arts drew praise as well as criticism, notably from feminist theorist Karen Barad (2006), who took to task Frayn's notion of uncertainty. In Chapter 15, Yelena Gluzman points out the lack of reflection on the performance itself, which transforms meanings and embodies metaphors. Whereas Barad grants agency only to the playwright, Gluzman points toward the director, actors, and other creative participants in the production as co-creators of the meaning of the performance. In this way, Gluzman provides a model for how ASTS can inform and expand STS discourse.

Other scholars hold that art is often instrumentalized as science's 'conscience.' This is the argument of artist and theorist Karolina Sobecka (an author of Chapter 4). Maneuvering in this manner, scientists can position themselves as addressing social concerns since their subject is being addressed by artists and STS scholars. Scientists may perceive this division of labor as freeing them from any constraints of social and cultural responsibilities, which may in turn serve to reinforce problematic ideas about objectivity, even as issues long raised by artists and STS scholars continue to be present.

These long-running cultural conversations indicate a persistent need to understand complex entanglements of ideas and practices. Like many scholars who have considered the art–science relationship, the editors of this handbook find the ways these arrangements have been conceptualized to date to be unsatisfying because they do not seem to describe the range of dynamics observed in the historical and contemporary works of artists and scientists. Such ideas may be novel or interesting starting points, but they often gloss or efface a range of questions about structures of power, what counts as knowledge, and the role of communication and aesthetics in knowledge production, among other things. More research is sorely needed to consider the work these metaphors perform in power relationships, work outputs, and conceptualizing new ideas.

The current moment in art and science

In this era of fresh enthusiasm for art–science, ASTS has abundant opportunities to reflect on previously undertheorized work and to analyze new work. Much of the latter engages environmental and biological themes, and the rhetoric around these projects often suggests that interdisciplinary approaches are required to solve the global problems facing humanity. Other projects, like those that draw on the physical sciences, suggest that the knowledge generated at and beyond the edges of what the human eye can see or mind can comprehend, require novel interdisciplinary approaches to knowledge-sharing. Beyond these specific topical interests, an increasing number of organizations and individuals have come to be interested in facilitating collaborations between artists and scientists, which have drawn attention from curators and social scientists and are explored in Sections 4 and 5 of this handbook.

The scientific topics addressed in this book reflect the current moment, but the authors and the work they discuss aim to provide lasting accounts of what lies beneath the contemporary context. It might be tempting to dismiss art–science and ASTS projects as trends whose value will wane when the next wave of interesting interdisciplinary groupings arise or when interdisciplinarity itself falls out of fashion. Yet it would be a mistake not to recognize art–science as an ongoing program with an agenda as old as philosophy itself. ASTS carries with it the assertion that art and science are not pre-existing Platonic categories, but rather labels that have been developed to sort out and make sense of the world. Our aim with this volume is to further map and deepen our understanding of the contingencies of knowledge-making.

Art, science, and technology studies methods

Modes and methods of inquiry define the findings that are possible, and in ASTS, methods take on particular significance because they are both the focus of inquiry and the means of inquiry. Of course, methods are central to art and science communities, and the attention that actors in each of these social worlds give to this question is an overarching concern of ASTS. The fulcrum in art–science collaboration is the question of how to reconcile frames of reference. Methods of science and art are typically received and understood differently within their communities and by members of the public. For their part, science communities have zealously promoted the idea that universal and comprehensive knowledge is available only through their methods and their processes of certifying knowledge. Such claims have tended to cause science methodologies to be understood in terms of producing progressively better ways of knowing the world.

Even as science communities guard their epistemic privilege, however, there are circumstances when this privilege is checked and real interdisciplinarity flourishes. A close comparison of the respective methods of art and science communities can help open pathways for the arts to produce alternative ways of knowing and highlight how trust, objectivity, expertise, and verification are constructed. In this way, ASTS illuminates power structures in order to overturn them. While ASTS draws on such STS methods as oral history, archival research, ethnography, and philosophical and sociological analyses, it contributes more active forms of analysis. ASTS treats arts practice as research, facilitates collaboration, curates art–science exhibitions, and supports participant observation of lab-studios. ASTS offers new conceptual lenses to STS such as the sociology of art (see Chapters 16 and 17), the philosophies of aesthetics (see Chapters 4 and 28), and literary analysis (see Chapter 12) in explaining and expressing ideas formerly explored through textual, as opposed to material, means.

Above all, ASTS aims to decentralize the written word as the paramount mode of expression. As ASTS approaches transdisciplinarity, it embraces a plurality of knowledge-forms and the methods that contribute to generating that knowledge. As such, it represents a challenge to the existing power structures within and without the academy, in part because arts methods have the potential to reach wider audiences than more common forms of scholarly production. Such opportunities also raise the problem of how ASTS may incorporate art without appropriating its methods or subverting experiential and other knowledges of art in the service of a specific set of goals or directed ideas.

Epistemologies and ontologies of ASTS

Building ASTS does not simply mean assembling the various practices, methods, artworks, and texts into a coherent agenda for research and practice. This interdiscipline is also in a unique position to understand how knowledge is made, used, valued, and shared in both art and science contexts. The already-interdisciplinary and multi-method approach of STS is well suited to situate art–science in the histories, sociologies, philosophies, and anthropologies of these two areas of inquiry. In going beyond what STS can accomplish alone, ASTS draws on arts practice and visual, performance, and cultural studies, as much for their epistemological and ontological positions as for their methodological and theoretical content. The nexus of

ASTS practice is a place of significant frictions. After all, what STS considers knowledge does not look much like what, for example, experimental art considers knowledge.

ASTS, then, embraces multiple frameworks that must be examined symmetrically in order to integrate the knowledge and experiences they can offer. It accepts what STS has shown of the simultaneous co-existence of cultures of science, engineering, technology, and modes of collective knowledge-making.[4] In numerous cases including the history of chemistry, the anthropology of weapons systems, and the sociology of the laboratory knowledge, scholars of science studies have found that the contents and practices of science are indelibly shaped by political and cultural context.[5] The authors represented in this book and across ASTS join STS in collectively rejecting the idea that there are known categories or stable social groups that constitute the two areas. Instead, they focus on the way that the practice of categorization awards social power and resources. They do not believe that disputes, disagreements, or differences between art and science groups may be mediated through appeal to an outside standard. Rather, the 'truth' of a claim or correct approach is established through social processes.

In proposing new frameworks for examining art and science, we offer new ways to understand art, science, and art–science that aim to integrate the knowledge and experiences art and science afford. We make a commitment in these pages to treat art and science symmetrically. Such an approach is, in some ways, a return to the roots of STS. Beginning with David Bloor and Barry Barnes, STS scholars demanded that sociology, which had focused largely on examinations of failed scientific theories, provides the same kind of analysis of successful theories. Bloor (1976) contended that the current belief in the 'correctness' of a claim should not be allowed to bias our analysis of how that claim came into being or acceptance by a community or the broader public. Acceptance of knowledge claims is a subject for study, not a precondition for sorting the value of knowledge certification processes or outcomes.

Along with causality, impartiality, and reflexivity, symmetrical treatment of 'truth' and 'error' formed the core of a new sociology of scientific knowledge (SSK).[6] While all of these ideas are contributive to thinking in ASTS, symmetry plays a special role in equalizing the power dynamics between art and science by encouraging an agnostic approach toward truth claims when assessing art and science work. Similarly, studies of art and science can learn much about both by examining artistic and scientific forms of knowledge symmetrically and impartially. In Chapter 15, Yelena Gluzman further attends to the history of SSK and its value in the current considerations of art and science.

Expanding the ambit of STS

ASTS broadens the scope of STS to other forms of knowledge production. As part of the STS project of complicating a vision of scientific knowledge as occupying a privileged position in this culture, STS has looked to other important forms of knowledge including technology, engineering, and experimental equipment design as well as the tacit knowledge of laboratory workers and non-western medical practices.

ASTS seeks to expand the camp of STS yet again. Examining the arts has the potential to problematize science's station and to further art and science collaborations through a more level meeting of these knowledge categories. The privilege accorded to science as the ultimate form of knowledge in our society has been detrimental to both science and other forms of knowledge. It has promoted a mythology of objectivity and a mirage of certainty in what can only be subjective and uncertain. Knowledge produced through artistic pursuit has been subjugated, devalued, and undermined. Now that this facade of science has begun to crumble, we have a moment in which we can once again consider the relationships between and among various forms of knowledge produced in the arts and sciences.

A closer look at SSK, the social construction of technology (SCOT), actor-network theory (ANT), and strategies from aesthetics is helpful in considering methods used by ASTS scholars. One of the reader's first observations will surely be that art is often substituted for technology in ASTS interpretations of these theories. Technologies make arguments for how we should understand the world (Winner 1980). Some of these arguments are 'material' or physical instantiations (technologies, engineering and scientific designs, artifacts, and biofacts), while others are conceptual and consist of a set of practices, protocols, or a system of doing things. We argue that artworks can be studied with the tools of STS and that it is especially appropriate to do so when those artworks have situated themselves in a lineage of scientific and technical interests, practices, and critiques. Both the material- and practice-based modes of argumentation (in short, technologies) are predicated on assumptions about what people need and what the world is. Indeed, artifacts themselves 'construct' the world not only in the sense that they have augmented the conditions of the individual and society but also in the sense that their interpretation by users contains assumptions about the world that material and conceptual artifacts may confirm or serve to reinforce. STS scholars have argued that the turn toward the experiment, that is, the assembling of materials for the performance of a scientific fact, is a defining feature of the operation of the scientific community (Pinch 1993; Shapin and Schaffer 2011). Yet tensions persist around the use of purely mathematical models, as do divisions among experimentalists and modelers. Similarly, artists have sought and leveraged the power of materials in their works, although conceptual art remains an important strain in contemporary art. Even with the caveats of art and science that are not directly engaged with the material, it is clear that the force of materials as an ideology is important in assembling arguments in both areas.

We contend that art shares this feature of allowing us to see how people experience the world. In many cases, artworks affect viewers in ways that would be recognizable to STS scholars who are interested in technology as arguments: they are ultimately contestable ways of understanding the world. Their universality derives from our shared experience or sense that each viewpoint and possibility are valid expressions in our individual and collective aesthetic systems. Arguing that all artworks share these features is impossible in a world of flexible definitions of art, science, and technology. However, seeing artworks as able to occupy the place of technologies in these theories is not the same as saying that these artworks are in all ways the same as technologies. The word "technology" may refer to material objects or it can refer simply to an idea. In historical usage, it has encompassed works of art. Cognates of "technology" (in German, "technik"; in English "technic" or "technique") emerged in the early nineteenth century to refer to skill in the execution of the fine, and later, the mechanical arts. As the historian of science and technology Eric Schatzberg (2006) noted, the semantic ambit of "technology" later vastly expanded to embrace the totality of material culture thanks largely to economist and sociologist Thorstein Veblen, for whom the term played a key role in his social theory of the industrial age (499).

This indeterminacy leaves space for many objects, ideas, and things currently classified as art to be fruitfully studied as part of the ASTS agenda. As analysts, it is sometimes helpful to suspend judgments about whether an artifact is art or science or technology in order to understand how SCOT's social groups or ANT's agency might affect our understanding of the operations of art and science. SCOT claims explanatory power and attempts to show how society chooses a technology, while ANT claims descriptive power as a semiotic-material method for identifying the elements (both conceptual and physical) of a situation. These methods were developed to think about science and technology, but if we apply a symmetrical view to art, science, and technology and do not assign an artifact one or the other of these categories a priori, we can avoid value judgments based on our current contexts and instead seek an understanding of how the relevant social groups or actors see the world.

The Social Construction of Technology

The Social Construction of Technology (SCOT) holds that technology does not determine human action, but that rather, human action shapes and transforms technology. Relevant social groups are a salient feature of SCOT and are the starting point for understanding an artifact's social meaning: "all members of a certain social group share the same set of meanings, attached to a specific artifact" (Pinch and Bijker 1987, 30). For proponents of SCOT, technology cannot be understood without understanding social context. Certain technologies become dominant, they hold, owing not to immanent qualities or some natural process of selection but to social processes of interpretation.

SCOT is defined in opposition to the position that technologies determine societies, an idea applicable to the realm of art. Moreover, its emphasis on the contingent nature of interpretation makes it possible for analysts to consider counterfactuals, and hence the possibility that an artifact clearly seen as science at one time might be considered art at another. Applying Barnes and Bloor's notion of symmetry, if we do not judge an artifact as a technology, it might be interpreted in other ways by a given social group, leading to different levels of use or adoption. This is helpful in the art and science context in understanding why some artifacts are seen as belonging to one category in one time and place and to others in other times and places. Equally, it can explain situations where both art and science lay claim to an artifact, or equally, come to reject it. The history of the interpretation of the works of Leonardo da Vinci (Giorgione 2009) well-illustrates these dynamics, but this is only the best-known of myriad such cases, some of which will be explored in this handbook.

In this manner, the critical qualities of technologies are paralleled by artworks. Changes in the ways art and science communities set standards and frames of reference can lead artifacts to be recategorized and pulled in or pushed out of given categories. Moreover, the creators of artifacts (designers as opposed to users, in SCOT's terms) position their work so it will be interpreted by particular social groups in specific ways. For example, Rogers (2012) noted that Leopold and Rudolf Blaschka, the creators of Harvard's *Glass Flowers* as well as extensive collections of glass marine models held at institutions worldwide, thought of themselves as "scientific artisans." In the nineteenth century, the scientific community accepted the Blaschkas' work for its accurate representations of organisms, making it suitable for study and pedagogical representation. Yet in the contemporary period, Blaschkas are primarily collected and preserved as artisanal craftworks and are interpreted in a lineage of traditional art practice dominated by a familial material-based guild system. The SCOT approach keeps us mindful of such shifts in value and use.

Another SCOT tool relevant to ASTS is interpretative flexibility, the claim that various groups interpret technological artifacts and assign them corresponding meanings that affect their use and adoption (Kline and Pinch 1999). Pinch and Bijker (1987) introduced the concept in a case study of the bicycle air tire. For some people, this innovation represented a convenient mode of transportation, while for others it created technical nuisances such as traction problems. Adoption resulted from negotiations between competing interests that deployed different reasoning and standards of significance. We can readily see how this concept may find application in ASTS, discussed at length in this volume by Leiberman (Chapter 12) and Halpern (Chapter 18).

As an antidote to technological determinism, SCOT insists on the centrality of social groups in shaping technology. But it also offers a way in which a technology may push back in the form of the "affordance," the material features of a given technology that give rise to potential interpretations by social groups. Affordances translate well into ASTS terms because they account for the way that social groups may select material features of an object or rhetoric associated with a particular feature to create arguments for why a given artifact belongs in or out of art or science.

Actor-Network Theory

ASTS also draws on key concepts of Actor-Network Theory (ANT), a constructivist approach to analyzing technology conceived by the sociologists Michel Callon (1986) and Bruno Latour (1987, 1991, 1999). Rather than thinking, as SCOT analysts do, of a group of social groups clustered around an artifact creating interpretations of it, ANT analysts envision a network of equally important factors including objects, humans, ideas, and processes joined through actions. This is known as the principle of generalized symmetry, and in this way of thinking, both humans and non-humans have agency. For ASTS scholars, this offers a way of centering artworks and explaining their continued power even as networks realign around them over time.

Agency can be understood as a way of conceptualizing the power SCOT assigns to the concept of the affordances of a given artifact. As applied by ASTS scholars to the case of the art world, the idea that an artwork has power extending beyond the agency of, for example, the originating artist, is more familiar. Indeed, in this context, the position that artworks exceed their makers is conventional enough. To be sure, it is not entirely uncontroversial. Scholars like Howard Becker (1982) contended that the whole of an artwork's power is derived from its social life and contextualization in the art world, in the art world, a proposition shared by many of the contributors to this volume. We can think here of the capacity of an artwork to effect change or influence audiences.

But the salient point here is that ANT contends that materiality is a form of agency, rather than an interpretation by other entities in the network controlling all possible meanings of a given technology, or, in its application by ASTS scholars, artwork. In this sense, ANT can help make sense of art–science. Sometimes, acceptance and attention by one of the parties of the art–science dyad can heighten the perceived value of an artifact, while in other cases, it may diminish it. The network concept can help scholars consider how social power builds around an object. Conversely, SCOT's social groups are, by definition, constituted of people who interrupt an artifact in a *shared* way different from other defined groups so that less emphasis is placed on how those group interpretations might impact one another.

Symmetry of artistic and scientific knowledge

There are a variety of metrics by which we might argue that science is presently perceived to be more important than the arts in education, social power, and financial access. Scientists in the U.S. context have access to vastly more public funds than artists according to the agencies that serve the two groups.[7] Such asymmetries both reflect and further embed power hierarchies in the current system of public support for art and science.

These differences, however, do not necessarily translate into differences in the intrinsic value of these areas. To understand the relationship between the products of art–science, we must flatten the hierarchical landscape in which art–science resides. ANT's principle of generalized symmetry contributes to our understanding of symmetry because it requires that all the actors and actants be taken into account equally. In short, the extent to which an idea is socially powerful relates to whether it is accepted as knowledge by a given community. In the case of art, symmetry prevents us from saying that an artwork is considered important because it is aesthetically superior or original. It helps to avert the cult of genius in both camps and the idea that the camp from which an idea springs should be the one to judge its validity. When we invoke symmetry in the context of ASTS, we have in mind the idea that art and science should be treated equally in our studies. This means treating both the products of art and science as knowledge products. The current dominance of science over art in public policy is no reason to treat the work, ideas, or individuals engaged in these two practices differently. ASTS analyses do not appeal to either the standards of art or of science as a preferred mode of interpretation. Instead, they engage the social workings of the area of inquiry, rather than comparing their products, taking both art and science as operating through the same social modes, and deriving independent outcomes.

By treating art and science as knowledge systems whose practices can be followed and as communities whose dynamics can be examined, we put STS in conversation with literature from other fields and other studies of interdisciplinary knowledge. Science communication, public engagement with science, and design, especially by way of information technology scholarship, have also contributed to the tools available to ASTS. Art and science are cultural products, so scholarship pertaining to them is as diverse as their potential interpretations. ASTS offers a way of placing scholarship around art and science on an even playing field by asking how they are understood and adopted by communities, not whether claims are correct. The historical and social fact that science is treated as superior to art in many contexts, and the fact that in some communities, science is dismissed as reductive or based only on capitalist ideologies, are not sufficient reasons for creating a hierarchy of knowledge. ASTS scholars strive to focus on the shared and divergent characteristics of these knowledge communities, rather than creating judgments or comparisons about their knowledge claims. These commitments result in a further radicalization of knowledge as culture and deepen our understanding that no universal or absolute standards for art or science exist. Conditional cases must be studied in approaching and understanding the ways knowledge is created, defended, and revised.

Boundary work

Theories that consider where and how boundaries are formed provide compelling ways to interrogate power structures as well as the multifaceted relationships within and across art and science. Processes like legitimation and boundary work lie at the heart of many of the tensions and contestations within art–science. The sociologist Thomas Gieryn (1983, 1999) described boundary work in the sciences as a kind of rhetorical cartography, wherein scientists work to establish and maintain epistemic authority:

> maps do to non-geographical referents what they do to the earth. In essence, they do the same in the arts, often differentiating between art worlds, but also between legitimate and amateur art, setting boundaries around who can and cannot speak to the value of artworks. Boundaries differentiate this thing from that; borders create spaces with occupants homogeneous and generalized in some respect (though they vary in many other ways).
>
> *(1999, 7)*

Boundary work, or the creation and maintenance of divisions between fields of knowledge, occurs within art as well as science, and certainly occurs between the two. The naturalization of the supposed gap between art and science has led to the assumption that there are both quantitative and qualitative differences between the two. We think of them as different forms of knowledge production by nature, but this obscures the way these two areas of knowledge have been and are being constructed and ignores the ways art, science, and a host of related subfields have been defined and redefined as cultural capital has shifted over time. At its heart, Snow and Leavis' bickering over the two cultures that formed the bridging metaphor for the relationship between art and science is part of a process of bounding the categories of art (or in Snow's arguments, the humanities) and science such that science maintains its primacy in the realm of knowledge production. In other words, scientists' "attribution of selected characteristics to the institution of science" were not descriptors of the objective and true nature of science so much as they were ways of "constructing a social boundary that distinguishes some intellectual activities as 'non-science'" (Gieryn 1983, 782).

Tracing the ways boundaries are made and remade reveals the ways a culture or field might develop and sustain itself. Art is typically not seen as a threat to science's authority. But when the two are described in relation to one another, the need to assert epistemic authority reveals itself in the prominent themes discussed above. Gieryn defines boundary work as a process of drawing up of cartographies of credibility in three ways: expulsion, expansion, and protection of autonomy. Expulsion describes instances in which competing authorities seek to legitimate their claims as scientific. Neither side challenges the epistemic authority of science, but they vie for space within that authority and seek to oust the other from that space. Expansion describes instances in which authorities vie for "jurisdictional control over a contested ontological domain" (1999, 16).

These cases do not assume that science has epistemic authority. Instead, they seek to either extend science's authority to new realms or to challenge the privilege given science over truth claims. Finally, protection of autonomy looks a bit different from the other two forms of boundary work. Gieryn describes outside powers seeking to exploit the epistemic authority of science, often compromising the resources or power held by scientists. Scientists may need to work to protect their autonomy over their research in light of corporate or political interests; they may find the need to reestablish their authority in the wake of an attack by the mass media (as when news media present "both sides" of a debate between climate scientists and deniers), or they may wish to distance their work from its consequences, as they often do when the history of unethical or discriminatory behavior in medical testing is exposed.

These descriptions of boundary work make clear that it is not solely the scientists, up in their ivory towers, who engage in the creation of rhetorical cartographies. According to Gieryn, "ordinary folks seek out cultural maps to locate credibility; fact makers produce maps to place their claims in a territory of legitimacy" (1999, 14). Beyond scientists and "ordinary folks," politicians, corporate interests, media, and other groups play their roles in shaping and reifying the boundaries that run through the sciences to demarcate one kind of science from another or science from non-science. Each in each case of boundary work, the clear demarcation of what science is *not* helps point the way toward what science *is*, not only for scientists but for the rest of us as well.

Boundary work also occurs in the arts, and establishment of boundaries to protect and maintain an art world functions in similar ways. Artists and art critics make authoritative claims about what is and is not art and between who is and is not an artist. Audiences and a host of other actors operate within these worlds to establish the canon, and art–science projects can help expose the ongoing boundary-work in this emerging terrain. As ASTS expands, the boundary work that places people, objectives, techniques, and knowledge into these categories can be helpfully explored.

Social worlds

Gieryn's use of boundary work can serve as an important analytical tool for thinking about art and science worlds. Whereas Gieryn conceived boundary work in the context of the social relations of science, the sociologist Howard Becker (1982) applied the concept to the arts in the idea of "social worlds" (Strauss 1978). Becker's ideas also apply well to science communities and are, therefore, useful in ASTS. Social worlds are defined as "groups with shared commitments to certain activities sharing resources of many kinds to achieve their goals" (Becker 1982; quoted in Strauss 1978; Clarke 2005). This lens afforded the opportunity to examine the kind of boundary work that occurs in specific situations in which art, or science, or both, are at stake. Many sociologists in both the arts and sciences, including Gieryn, adopted it. Gieryn described a social world as "a group with shared commitments to the pursuit of a common task, who develop ideologies to define their work and who accumulate diverse resources needed to get the job done" (1999, 412). Gieryn's additions of ideology and resource accumulation as characteristics of social worlds mirrored the thinking of other scholars writing about the concept. The resulting holistic description of the qualities of social worlds (distributed work, shared commitments, shared and developing ideologies, loose organizational structures, mediated communication, and resource accumulation) privilege process over structure.

As analysts, accordingly, we can bound social worlds by the work they do, rather than the structures within which they exist. Social worlds do not prescribe a specific scale or structure, leaving the analyst to describe the structure they find in a field study. Such an approach also emphasizes the relationships between actors, especially actors playing different roles, and facilitates the analysis of communication between actors. Finally, the centrality of process (rather than structure) provides a framework in which social worlds have the ability to form and reform, to shift, and to grow and change over time. Social worlds can be studied at any scale, making the approach even more flexible (Strauss 1978; Gerson 1983; Clarke 1990, 2005). Because social worlds are in constant flux, the stable characteristics described above must be augmented with descriptions of the dynamic processes that occur with the formation and re-formation (and dissolution) of social worlds. Discovering and making truth claims is an integral part of any social world or subworld, and it is tied directly to the idea that members of a social world possess shared commitments and ideologies. "Truth" in this case may be about the particular domain of the social world. For example, articulating a shared belief created by their collective work is itself a part of the work they do together that constitutes a social world: "A belief and then the claim that a particular path will lead to something of human value, and sometimes to significantly great value and even essential truth...seems integral to the formation of any [sub social world]" (Strauss 1982, 175).

Social worlds as a concept also has limitations. It is abstract and flexible, and because the relationships and other characteristics that define social worlds are always in flux, it is not easy to bound social worlds. While flexibility is one of the great strengths of social worlds, it is also a weakness. The lack of formal structure makes it quite easy to claim that anything can be a social world, so there must be additional criteria for what constitutes one. There must be an overall sense of "worldness," a way in which these characteristics and actors fit together as a whole as well as a way in which the members of the world, themselves, recognize their social world. It is this "worldness" that makes social worlds a valuable tool for ASTS.

For ASTS, social worlds raise interesting questions and reveal dynamics surrounding power and legitimacy. Social worlds take audiences as part of the process of legitimation, giving rise to many questions about the role of public in art–science, especially the role audiences and the public play in any given art world or science world. What do these roles have in common across different social worlds? It might seem obvious to state that the role of the audience in art worlds has been considered much more thoroughly than in science worlds, where it has barely been addressed, except to note where some social worlds may be more publicly visible than others (Strauss 1978; Clarke 2005). In most art worlds, the role of the audience (or intended audience) is articulated and included in most discussions. Becker notes the way shared knowledge of conventions allows artists to elicit the desired emotional response from audiences. Van Maanen (2009) also notes the other actors in art worlds that mediate the relationship between the artist and the audience: "In 'a society of any complexity' the roles of artists and audiences are often made functional by means of a third type of role, filled by mediating personnel, such as producers, theatre managers, art dealers and critics" (26). For ASTS scholars, then, a social worlds approach can help reveal who and what are valued as legitimating forces within a particular world, and how negotiating the boundaries of the world shape the knowledge products that it produces.

Boundary objects

Just as ANT suggests that people are not the only actors in a network, boundary work and social worlds must take into account the human and non-human members of social worlds. Often, particular objects become central foci of particular worlds. These boundary objects are a means by which members of different social worlds engage with one another (Star and Griesemer 1989; Bowker and Star 1999; Star 2010).[8] According to the sociologist Susan Leigh Star and philosopher James R. Griesemer (1989), boundary objects are "those scientific objects which both inhabit several intersecting social worlds…and satisfy the informational requirements of each of them" (393).

They offer a map of California as an instructive example of the concept. The map was used differently by different social groups working together at the Berkeley Museum of Vertebrate Zoology. For example, scientists utilized the map, along with scientific and mathematical markings, to share highly technical information, while the collectors and conservationists used and marked the map as an average person might use a road map: to denote places to collect specimens, camp, or conduct other material practices related to their work with the museum. Boundary objects are useful insofar as they facilitate collaboration between actors from different social categories while leaving room for individual interpretation of meanings and uses.[9] The concept of boundary objects has transcended STS and has been broadly applied across many fields. It has already found its place in examining art–science spaces (Halpern 2012; Rödder 2017, to name a few) and has promise as a tool for arts research and practice as well.

Boundary objects possess three characteristics of particular relevance to ASTS. The first, interpretive flexibility, is discussed above in relation to SCOT, but the function is the same. How these objects are taken up is, to a certain extent, open. Second, such objects are often situated between social worlds or interpretive communities, meaning that these objects connect two worlds or groups. Third, they are conceptualized both generally for collaborative work and specifically for work within a particular structure. Together, these characteristics make for objects that allow interdisciplinary groups to collaborate without the need for consensus (Star 2010). Such objects, then, would undoubtedly be employed by a group of artists and scientists working together.

The concept of the boundary objects has been used extensively in a number of fields, not only in STS, its place of origin, but also in the design world, particularly in human-computer interaction and computer-supported cooperative work. In these fields, many scholars built on the foundation of boundary objects. For example, Henderson described "conscription devices." Boujut and Blanco (2003) described "intermediary objects." Lee (2005) aimed to describe artifacts that "can serve to establish and destabilize protocols themselves and that artifacts can be used to push boundaries rather than merely sailing across them" (388). In STS, Joan Fujimura wrote about standardized packages (1992) or "gray boxes" that contained several boundary objects along with a set of standardized methods. This concept has been particularly useful to STS because it describes "both collective work across divergent social worlds and fact stabilization" (169). Like social worlds approaches, the idea of boundary objects has been criticized for its broadness. However, for ASTS, the concept provides a suitable structure for analysis of specific objects within complex social worlds, where epistemological positions vary widely.

Theories of aesthetics

While many aesthetic theories have potential bearing and use in ASTS, some ideas have already proven influential in understanding art–science. This section introduces ideas from visual studies, relational aesthetics, aesthetics, and politics as well as our co-editor Dehlia Hannah's performative experiments as an overview of some possible ways of understanding art–science. As Ede (2005) pointed out in *Art and Science*, for many people the idea of beauty is central to conceptions of art, but contemporary art has moved into other areas even as scientists continue to evoke this notion in their search for "elegant" solutions. Put in a less flattering way, science camps are sometimes accused of having a nineteenth-century aesthetic. This is an unfortunate and incorrect generalization, but it implies a quality that artists frequently observe in the images scientists tend to create and select, one that suggests a quest for beauty.

In the contemporary arts, in contrast, beauty is often not a central goal. The case of nano-images as employed for scientific and public outreach purposes is instructive. As STS scholar and handbook co-editor Kathryn de Ridder-Vignone observed (2012), scientists who selected nano-images for art galleries in order to promote this field of technoscience mimicked conventions they perceived as existing in the art world, including the landscape and close-up. Theories of aesthetics in the area of art–science need to grapple with stereotypes coming from both art and science in order to offer nuanced theories that account for different groups' perceptions of their work, its goals, and results.

Areas of inquiry that have traditionally contributed to STS treat aesthetic theories differently. The pragmatist philosopher John Dewey took up aesthetics in terms of expression and experience, asserting that it was in the interaction between artwork and audience that meaning was made (1934). Dewey's work on aesthetics is relevant to ASTS in any number of ways, particularly because in focusing on the relationship between the audience and the artwork, Dewey understood that context and prior experience shaped the meaning of an artwork. Perhaps more importantly, Dewey did not limit his idea of aesthetic experience to artworks alone, paving the way for discussions of what it means to experience all manner of expressive objects. His pragmatic aesthetic theory is a forerunner of the burgeoning literature on everyday aesthetics (Mandoki 2007; Saito 2007; Puolakka 2014).

Visual studies

The area of visual studies developed significantly over the past forty years beginning with John Berger's *Ways of Seeing* television series (1972), Laura Mulvey's theoretical contributions on cinema and visual pleasure (1975), Svetlana Alpers' textually- and visually-based art cultures (1983), and W.J.T. Mitchell's *Iconology* (1986), which offered a further treatment of the language around images and the textual interpretations that accompany images and condition interpretations of them. Visual studies posit a method of understanding culture through visual means and argue that western culture is dominantly visual. For visual studies scholars, analysis of visual modes and artifacts make sense of many human interactions. Visual studies range from visual anthropology to digital cultures to the lifeworlds of animals. While much early work in this area was an attempt to apply art historical understanding of vision to contemporary culture, scholars of science have also been interested in visual studies of their areas of inquiry. Barbara Marie Stafford's *Artful Science* (1994) considered the shift from oral and image-oriented to text-based cultures in the early modern period, and for ASTS scholars, such works can help understand scientific as well as artistic cultures. Anthropologist Johannes Fabian coined the term "visualism" to emphasize the importance of seeing as a way of knowing in the sciences, particularly around key scientific concepts observation (Rarey 2013). STS scholar Michael Lynch (1990) showed that scientific "seeing," though posed as observation that may be made by a rhetorical "everyperson" or at least anyone experiencing an experiment or encountering a phenomenon, in fact requires training and practice in the face of many possible interpretations. In the scientific sense, one learns to see what is properly observed.

In defining how image-making should be understood and aesthetic theories may or may not apply to specific science or even art–science instances, the views of James Elkins (1995) require consideration. Elkins proposed creating a harder distinction between images and art, a point that is worth considering in the context of images made in science versus art images made in light of scientific concepts and materials. Ideas from visual studies are important for ASTS scholars who want to develop ways of understanding how images constitute science or art and how art and science relate to each other.

Performance studies

Performance studies focus on the concept of performance as central to social life and self-knowledge. There are several intersecting strands of performance studies. Much of the work done in this area stems from anthropology and theater. Victor and Edith Turner (1988) examined ritual and spectacle in contemporary and historical cultural contexts as well as ethnography as performance. Richard Schechner (2003, 2006) is often credited as the founder of the field of performance studies. Schechner's work in performance studies ranged from theatrical performance to ritual to politics and entertainment (McKenzie 2005). His extensive work as a theater-maker as well as a scholar exemplifies the ways research and practice can be bound together.

In many ways, performance studies resemble visual studies, which take a more comprehensive approach to visual means in culture. Performance studies considers theater, musical performances, and art happenings, but also speech acts, gender and identity performances, courtroom and surgery spaces, and the performance of the experiment. The possibility of this type of interpretation to unpack the motives behind interactions is suggested in Kenneth Burke's *Grammar of Motives* (1945). These ideas were further developed in Erving Goffman's

Presentation of Self in Everyday Life (1959), which considered the way that the self is understood in society through theatrically-interpreted interactions between people in face-to-face meetings and encounters. More recently, Judith Butler (1990) and subsequent writers on gender performance produced new critiques of the way that identities could be understood as a ritualized repetition of gender performances occurring in public and private contexts, which are themselves culturally and socially contextual.

In the ASTS context, the idea of the performance of the experiment and the performance of an artwork tend to overlap in such a fashion that the shared characters of these two different lineages of performance become entangled. For example, in the early work of the body performance artists Orlan and Stelarc, technical, scientific, and medical interventions were inseparable from the execution of the artwork. In Orlan's case, this involved the framing of home surgeries as artwork in *The Reincarnation of Saint-ORLAN*. The staging and documentation associated with happenings might be interpreted as part of a medical or aesthetic practice to bring attention to the performance aspects of medical intervention in a feminist context. Stelarc's *Stomach Sculpture* (1993) and *Ear on Arm* (2007) joined ideas about technical experiments and engineering demonstrations of body performances.

These performative actions directly connect with what has become a dominant mode of artistic research in the life science laboratory. In 1997, Eduardo Kac performed *Time Capsule*, inserting a subcutaneous microchip into his body and registering himself in a database of animals on the World Wide Web. It was in the context of this piece, performed at São Paulo's Casa das Rosas, that Kac coined the term "bioart." Art–science performances range from carefully staged natural phenomena such as David Bowen's *Tele-Present Wind* (2018), experimental apparatus connecting laboratory space to performance space as in Guy Ben-Ary's *MEART: The Semi-Living Artist* (2001–2006), and scientific data about sea level rise modeling as in Eve Mosher's *HighWaterLine* (2007).

Among performance artists who have focused on dance and body performance work, Kira O'Reilly has produced a series of innovative pieces. Her work encompasses an interest in permeable bodies in social and technological senses as well as a focus on animals and the non-humans. O'Reilly based her *Inthewrongplaceness* (2005–2009) on her experiences in laboratory environments where she grew living lace out of her own skin cells alongside pig's tissue and performed a dance with the carcass of a pig, questioning the distinctions between self and other and human and non-human. She has worked extensively with and raised questions about the way that humans might work with animals as equals to create art, as in *Falling Asleep with a Pig* (2009), an action/installed performance featuring herself and a sleeping female pig. Performance studies have proved a fruitful ground of intersection between art and science, making them useful for interpreting art–science work.

Relational aesthetics

The concept of "relational aesthetics" refers to efforts by artists to facilitate new interactions among people. This might include new ways of the artist relating to the viewer or new collective experiences among viewers. The curator Nicolas Bourriaud coined the expression in 1996 to describe the work the exhibition *Traffic* performed through its interactive event components. Relational aesthetics turns away from the art object as the meditator of the aesthetic experience and toward the communicative relationships and experience of interaction between people. Ideas about art as an experience focused, facilitated, or furthered by artists date at least to the early twentieth century. Dada (following World War I), Happenings (1950s–1960s), and Fluxus (1960s–1970s) also focused on reconfiguring human relations. Workshop interactions in the area of art–science are sometimes understood as artworks in and of themselves. An intervention at a climate meeting by artists who want to posit new ways of considering participation (Chapter 4) or a collective interaction that considers the relationship between people and environments around curation methods (Chapter 19) may be considered artistic moments. These works should be understood in the artistic trajectories to which they belong and receive more comprehensive study; such context include relational aesthetics like direct interventions, audience responses and participation, and invitations to participate in community and public art. For practitioners of ASTS, conceptualizing these works as sharing some methods and belonging to a loose genre of public art can help offer comparisons and stimulate innovation in this area.

Performative experiments

In her 2013 dissertation and forthcoming book, philosopher and co-editor Dehlia Hannah suggests that artworks in the area of art–science can sometimes be understood as "performative experiments." These are artworks that at once enact and query the logic of scientific experimentation. Such works, she argues, mimic scientific experiments and can transform philosophical understandings of scientific experiment. They embody

> a certain idea of experiment through its physical form…artworks are considered exemplary when they give sensuous embodiment to an idea that has not yet been fully formed in thought. To regard artworks as exemplary for the philosophy of science and technology is to regard them as generative of new ways of thinking about experimentation as a mode of material and conceptual practice that art and science share.

The concept of the performative experiment offers a way to interpret the very direct engagement artists have not only with subjects often zoned as scientific but also the material trappings of the experiment and power imbued in scientific apparatus for the creation of knowledge more broadly. This concept can be helpful to ASTS scholars in exploring the ways that art can offer philosophical investigations of scientific knowledge and in identifying the ways artists critically engage with different aspects of the materials of scientific making.

Aesthetics and politics

Marxist literary critic Terry Eagleton's definition of aesthetics also offers ground for interpretation of art–science work by explicitly connecting aesthetics to Enlightenment logics. For Eagleton, aesthetics are whatever is left out of the Enlightenment project of rendering power through controlling knowledge:

> It is as though…philosophy suddenly wakes up to the fact that there is a dense, swarming territory beyond its own mental enclave, threatening to fall utterly outside its sway. That territory is nothing less than the whole of our sensate life… [The aesthetic] is politically quite indispensable: for how can everything that belongs to a society's sensational life-'experience,' be allowed to fall outside the circuit of its reason?
>
> *(1990, 76)*

The suggestion that whatever mysteries, possibilities, fallacies, and complications beyond the reach of Enlightenment systems of reason are part of aesthetics can help us interpret projects that contain both scientific and artistic components.

Approaches to ASTS

The methodologies, epistemologies, and ontologies described above make for a set of diverse approaches to research and practice. In this section, we further explicate these approaches and address the different facets of ASTS as an art practice, a research object, and a research method. ASTS scholars have called for artists and scientists to resist instrumentalization of the arts by the sciences (Rogers 2020, emphasizing both the continuity of creative and epistemic practices across disciplines (Galison 1997; Jones and Galison 1998; Fan 2004; Salter, Burri, and Dumit 2016; Calvert and Schyfter 2017) and the distinctive and complementary contributions of each. This deeper work has been taken up, in part, by the important and growing body of artists who critique or complicate the sciences. Encounters with art become meaningful in relation to perceptual habits, background knowledge, and cultural norms.

Still other ASTS approaches can be found in the rich but fragmented and underdeveloped body of literature that examines other aspects of the art–science relationship, including the ways art and science have always been intertwined and the often-invisible implications of art–science intersections. This body of work benefits not only STS scholars interested in the arts but also artists and arts scholars who seek to understand or explore relationships between art and science. STS scholars who are striving to compare knowledge systems will also find a new set of cases and tools here that may be used to enrich their own studies. The other reason ASTS is uniquely situated to provide new understandings of art and science owes to its rooting in both areas. These include the comparison of work done on expertise and critique in both the sciences and the arts, the complex social worlds and power structures that have implications for one another, and traditions of literature that both characterize and mischaracterize each area and their accompanying intersections.

ASTS has deep implications for ideas about critique, evaluation, and assessment of knowledge and practices across the arts and sciences. The academy increasingly calls for interdisciplinary research and practice to better understand disciplinary intersections. Attempts to overcome historical separations between disciplinary trajectories have affected some change and new insights by bringing together clusters of scientists and clusters of humanities scholars. Yet sustained engagement across the academy is rare. There are many structural reasons for this, but the result is that many institutions are ill-prepared for interdisciplinarity. Insights gleaned from ASTS scholars who work on institutions and policy can be of great help in this regard. In this way, ASTS can be a model for how to build new social worlds and practices in other disparate and intersecting fields.

Toward an ASTS canon

As ASTS grows, it accumulates foundational works that come to form what might be referred to as a canon. While the notion of a formal canon is problematic for many reasons, the concept of shared referential texts that form the basis of conversations in this area is helpful in contextualizing the chapters in this handbook. Although we do not presume that such a canon currently exists in a complete or uncontested way, the texts and other objects presented here constitute some of the more prevalent ideas implicitly taken up by scholars working in this area as well as art–science projects that have been used for scholarly readings or influenced the trajectory of further art–science projects. Literature dealing with the intersection of art and science works has hitherto focused largely on what art has to offer science and vice versa. In their 1998 edited volume *Picturing Art, Producing Science*, Caroline Jones and Peter Galison offered one of the earliest attempts to curate texts in this area. Probably owing to the stature of Galison's physics work in the STS community, this book received considerable circulation among STS scholars with interests in visual culture and art as subjects for analysis. Particularly influential chapters included Lorraine Daston's "Nature by Design," a discussion of nature as a designer or artists understood by early moderns; Svetlana Alpers' "The studio, the laboratory, and the vexations of art"; and Bruno Latour's "How to be iconophilic in art, science, and religion?" For many, the inclusion of STS luminaries like Latour, Londa Schiebinger, Simon Schaffer, and Donna Haraway in the company of centrally important art theorists like Alpers and Jonathan Crary had the effect of helping to legitimize the study of art as a potential avenue for STS inquiry. In some ways, *Picturing Art, Producing Science* was a response to that now more than twenty years old call to take the tools of STS and art theory and apply them on an emerging group of artworks with a view to understanding how interdisciplinary projects operated and what they revealed about knowledge-making communities and the meanings they produced.

Writing collaborations between artists and social scientists has offered new ways to consider these subjects. Among the earliest books that brought together art, science, and social science perspectives was bioart pioneer Suzanne Anker and sociologist of science Dorothy Nelkin's *The Molecular Gaze: Art in the Genetic Age* (2004), which explored the gene as a cultural icon and the way artists were using, enrolling, and refiguring genetic images and languages in their work as well as the philosophical repercussions and ethics that such artworks might engage. Artist Beatriz da Costa and STS scholar Kavita Philip's edited volume *Tactical Biopolitics: Art, Activism, and Technoscience* (2008) argued for the centrality of biology and contemporary art in addressing political questions of race, feminism, and identity through artistic intervention and reflective consideration. These texts marked the intersection of the ideas of sociologists, particularly of science, and artists collaborating to make the case for artworks involving biology, which was then perceived as the most socially influential science.

Other writers attempted organizations of artworks about science around issues, themes, or scientific disciplines. One example is Stephen Wilson, whose *Art + Science Now* (2010) brought together artworks that directly engaged science and technology in a thematic format. This book was especially helpful for STS researchers rooted in particular science disciplines (biology, physics, mathematics, engineering, and digital technologies, for example) because it allowed them to think about emerging artworks in a familiar context. Such approaches can enable STS scholars to understand that work in this area is not the product of lone artists with an interest in a particular science but a community of artists producing work that might be better understood through STS lenses or that might contribute to ongoing conversations in STS.

Artists themselves were also writing about their own work and the work of their peers in ways that made direct or indirect use of STS ideas. An instructive example is the Critical Art Ensemble (CAE), a tactical media collective that frequently collaborated with other major creatives like feminist artist Faith Wilding and net.art leader Heath Bunting. CAE and its partners had been writing about technology and political issues as they related to their artistic interventions (*Electronic Civil Disobedience*, 1994) for more than a decade. By the early 2000s, the collective was becoming interested in biotechnology, both genetically modified foods (GMOs) and military applications of contemporary biotechnology (*Molecular Invasion and Marching Plague: Germ Warfare & Global Public Health*, 2006). Following the arrest of CAE member Steve Kurtz for the possession of scientific materials for an upcoming art exhibition which law enforcement mistook as a potential activity related to bioterrorism, STS scholars showed increased interest in these works, perhaps because of the way that government regulation was reinforcing already-entrenched boundaries between art and science, which restricted artists' use of certain lab-related materials that were commonplace in certified scientific labs.

Tissue culture and art artists Ionat Zurr and Oron Catts' "Big Pigs, Small Wings: On Genohype and Artistic Autonomy," reprinted in this volume (Chapter 31), appeared in *Culture Machine* in 2004. The article explored the hype around genetics using STS scholar Nik Brown's concept of genohype (2003) and suggested that artworks that undermined this hype would not find ready homes in shows with scientific backing. The artists raised a complaint often heard in STS circles that STS scholarship is often used to defend not only science and technology practices as such but also their potential value to public. This is sometimes shorthanded as "outsourcing ethics," with the implication that considering the impact of a new technology might have the effect of making it seem that the technology is close at hand, even as it may be in an early development stage. In this way, STS scholarship might be used to hype a rather distant future technology that may never arrive at all. This was of particular concern during STS's involvement with studies of genetic/technological innovations and again during the height of nanotechnology interest. The artists faced a problem similar to STS scholars: how to create work and analysis around these subjects without seeming to defend or inflate their potential.

More recently, STS scholars have begun to look at art–science collaborations as spaces for possibilities in STS. Jane Calvert and Pablo Schyfter's influential 2016 article ("What can science and technology studies learn from art and design?"), in this volume as Chapter 2, looks at how STS scholars who seek to work with and understand scientists might learn to build relationships with scientists. Similarly, Chris Salter, Regula Valérie Burri, and Joseph Dumit's chapter "Art, Design, and Performance" in the 2017 STS handbook (139–168) suggests ways STS scholars might work with or learn from artists and designers.

Canonical art–science projects

The textual canon is only part of art–science work. Material products, projects, and artworks produced by those working with science and art are also crucial in informing the work of ASTS scholars. Like any selection of art or texts, it is impossible to offer a comprehensive list. We instead aim to highlight a selection of artists that ASTS scholars and practitioners tend to invoke (or ought to invoke) in comparison and study and that can help orient new scholars to the area. All have extensive bodies of work, but we chose to feature exemplary works that have been particularly influential in this area, even if they are not necessarily the best-known of a given artist's repertoire. This sample illustrates combinations of art and science ideas, practices, and methods that represent a set of connections between earlier art and science movements and developments and more recent artworks. Like all boundary work, bounding the ASTS canon is subject to change over time and within various contexts. It is important to acknowledge the deep roots of art–science by pointing to the likes of Leonardo Da Vinci, or even John James Audubon, both now widely understood as artist-scientists, as well as historical artworks that have been recategorized in terms of the two cultures paradigm of art–science. Such works span the many media discussed in this volume. Just as the anatomical atlas-makers in Daston and Galison's *Objectivity* or the Blaschkas' glass sculptures reveal complex relationships between knowledge-making and image-/model-making, studies of contemporary art–science relationships reveal dynamics that shed light on the objects themselves and on the knowledge communities that make, define, and categorize them (Rogers 2012).

Many works not discussed in these pages are part of the story of ASTS and help us to understand the social construction of art and science, and the art–science relationship, in historical context. Christopher Marlowe's *Dr. Faustus* (as well as Goethe's *Faustus*) and Bertolt Brecht's *Life of Galileo* are frequently cited examples of early "science theatre" (Shepherd-Barr

2006). Similarly, Mary Shelley's *Frankenstein* is now held up as the first work of science fiction, although the genre did not exist when Shelley conceived of the idea and wrote the novel. Such works remind us that the word "scientist" entered popular currency only relatively recently, from around the mid-nineteenth century. For centuries, investigators of nature referred to themselves as "natural philosophers."[10]

There are many recent important examples that involve art and engineering defined in terms more recognizable to contemporary readers. Particularly for those working in art and technology, Bell Labs' *Experiments in Art and Technology* (E.A.T) was an important moment of recognition about the ways that artists and inventors from science and technology backgrounds could collaborate. In 1966, the E.A.T collective brought together engineers and New York City artists including visual makers, choreographers, and composers to produce *9 Evenings: Theatre and Engineering*, which included demonstrations of video projection, wireless sound transmission, and Doppler sonar and involved a number of important artists and engineers. On the art-side, Lucinda Childs, Öyvind Fahlström, John Cage, Alex Hay, Deborah Hay, Yvonne Rainer, Robert Rauschenberg, and Robert Whitman contributed to performances along with engineers including John Pierce, Manfred Schroeder, Bela Julesz, Billy Klüver, Max Mathews, and Fred Waldhauer. Two years later, kinetic artist and astronautical pioneer Frank Malina founded *Leonardo* to serve as an "international channel of communication among artists, with emphasis on the writings of artists who use science and developing technologies in their work."[11]

For those working on art and technology in a critical media or communication context, Ant Farm's 1975 *Media Burn* (2019) continues to resonate. In this performance, "artist dummies" dressed as astronauts famously drove a customized 1959 Cadillac, dubbed the "Phantom Dream Car," into a wall of blazing television sets. In staging this dramatic commentary on the intersection of violence, spectacle, and consumerism in American life, the artists invited the media and created a video styled after news coverage of a space launch. Ant Farm's intermixing of performance, social commentary, and documentary influenced many artists, especially the tactical media movement. One of the best-known such groups are The Yes Men. Active since the late 1990s, this duo (Jacques Servin and Igor Vamos) uses satirical press releases and impersonation tactics in activist performance art that calls attention to corporate and government malfeasance. Servin and Vamos were particularly successful in spoofing websites in the early days of the Internet (Ollman, Price, and Smith 2003).

The tactical media art collective CAE also made use of the affordance of the Internet and other media hacks beginning in the 1990s. In 2000, CAE, Paul Vanouse, and Faith Wilding, in collaboration with local activists and artists, created bikes designed for nomadic broadcast. Another important science-themed tactical media project was Beatriz da Costa's *Pigeon Blog* (2006), which used air quality sensors attached to birds released in urban areas to offer a record of air pollution experienced in a given day. Her collective Preemptive Media with Brooke Singer and Jamie Schulte produced the community activist artwork *A.I.R. (Area's Immediate Reading)* (2006). This project involved prototyping portable air quality measurement kits to monitor air pollutants including carbon monoxide, nitrogen oxides, and indicators for street-level pollution. *A.I.R.*'s GPS unit could be used to read a measurement location to determine possible proximate sources of contaminants.

The practice of bioart emerged simultaneously with tactical media and might be said to have had a precursor in the work of CAE, particularly in the form of their investigations of the biotechnology market around reproduction like *Flesh Machine* (1997–1998). As Howard Becker has suggested for artists, those forming new intellectual and social movements create histories by identifying previous practitioners with shared affinities, interests, and practices.

Such is the case for many bioartists, who often point to photographer Edward Steichen (1879–1973) as a forerunner of their field. In 1936, Steichen displayed his delphinium breeding project in the form of varieties of cut flowers in the MoMA, an episode contemporary bioartists frequently cite as an inspiration for their work. Following the show, Steichen continued his experiments and used the medication colchicine to change the plant's genetic makeup, creating new strains of delphiniums, the first known direct genetic intervention in an artistic context. The resulting variety, the Connecticut Yankee, is still widely available today in the horticultural trade. As Helen Curry (2016) has shown, this process was part of the democratization of the new tools of genetic manipulation that became common in that period.

Early bioartist George Gessert brought the story of Steichen to light in *Green Light: Toward an Art of Evolution* (2010), a book that inspired and shaped the visions of many artists in this area. Gessert used the iris as the medium for creating his artwork. In *Natural Selection* (1994), he engaged the aesthetics of his iris hybridization in the history of science context. In particular, Gessert drew attention to Darwin's understanding of aesthetics as an evolutionary selection-driver and argued for the variety of orientations different cultures have had toward the relationship between nature and art. His work demonstrates two key characteristics of art–science work: direct engagement with scientific materials and processes and efforts to situate the work in a lineage of socially-conscious science history.[12]

The work of polymath and artist Joe Davis has been influential in encouraging artists to work directly with scientific ideas and methods. Davis has created many well-known works now classified as biomedia or bioart and also many others that intersect with other areas of science including ecology, space science, and engineering. In 1986, he collaborated with geneticist Dan Boyd to encode a symbol for life and femininity into an *E. coli* bacterium. The piece, *Microvenus*, was likely the first artwork to directly employ the methods of molecular biology. Davis went on to create a significant and critically acclaimed body of work through his connections to scientists, particularly at Harvard and MIT, including *Bacterial Radio* (2011–2012), a crystal radio system that used a protein derived from marine sponges to create an electrical circuit capable of receiving AM radio transmissions. The piece received the 2012 Ars Electronica Golden Nica in Hybrid Art.

Davis exerted considerable influence in the bioart community as a pioneer. In particular, his insistence on the virtues of being able to speak the languages of both art and science and his philosophy of interdisciplinarity were heeded by many bioartists. In 2000, the *Washington Post* journalist Pamela Ferdinand referred to Davis as the "éminence grise" of the bioart movement. However, the term bioart would not come into use until after Davis' molecular biology works had been circulating for nearly twenty years.

The term "bioart" itself is associated with another pioneering artist working with new genetic technologies and their accompanying hype. In 2000, Eduardo Kac captured media and public attention with *GFP Bunny*, a rabbit (named Alba) genetically modified with a green fluorescent protein, a typical marker for gene expression at the time. The work provoked a flurry of attention, articles, and speaking engagements that gave rise to conversations that themselves became incorporated into installations of the artwork. The image of Alba importantly figured in subsequent discourse around what contemporary art engaged with science and genetics could do to enliven public engagement about the ethical issues in biotechnology.

Another bioart pioneer is Suzanne Anker. Anker has described her practice as investigating the ways in which nature is being altered in the twenty-first century in subjects as diverse as genetics, climate change, species extinction, and toxic degradation. Among her early works in this area was *Zoosemiotics*, produced in 1993 and exhibited at the Hanes Art Center at Chapel Hill in North Carolina. In the work, Anker constructs a text from the chromosomes of such animals which are embodied as a wall mount of small silver objects that viewers will recognize as text even as they are not interpretable (Figure 0.1). This visualization suggests the complications of the metaphor of code and the role of language and semiotics in considering DNA code as the guiding metaphor in the life sciences. In 2001, the piece was exhibited at the JP Getty Museum in Los Angeles in *Devices of Wonder: From the World in a Box to Images on a Screen*, curated by Barbara Maria Stafford and Frances Turpek. More recently, Anker's series *Laboratory Life (for Oryx and Crake)* (2006) referenced the titles of Bruno Latour's early STS text and the first novel in Margaret Atwood's dystopian Madd-Addam trilogy. The works are a series of images of laboratories Anker has visited overlaid with ideas about what those laboratories do and do not explore (Figures 0.2 and 0.3). In addition to her own artwork, Anker developed bioart pedagogy, founding the School of Visual Art's Bioart Laboratory, where she provides students with access to laboratory resources and training in bioart techniques.

Figure 0.1 Suzanne Anker's *Zoosemiotics* (1993). Courtesy of the artist

Figure 0.2 Suzanne Anker's *Vanishing Point* from *Laboratory Life (for Oryx and Crake)*, 2007

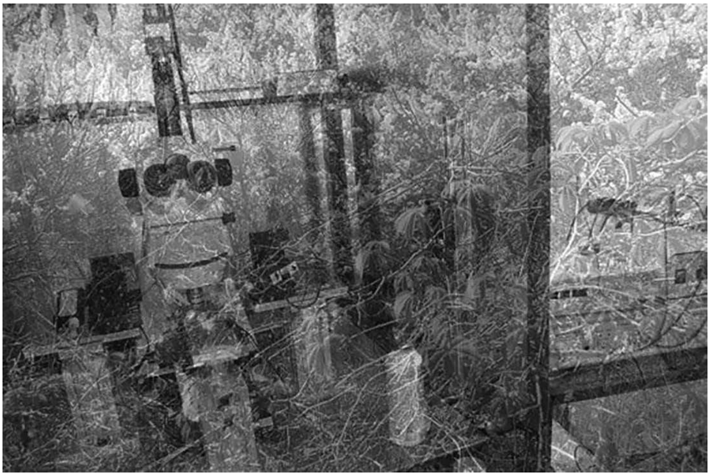


Figure 0.3 Suzanne Anker's *Snowman* from *Laboratory Life (for Oryx and Crake)*, 2007

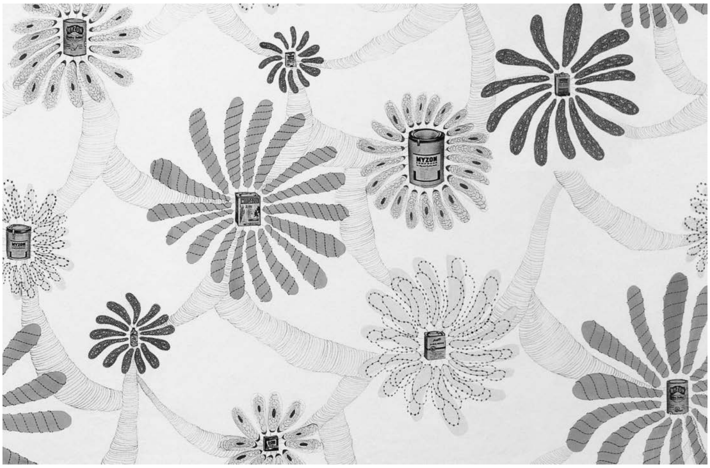


Figure 0.4 Kirsten Stolle. *Miracle Grow* (2012), detail. Courtesy of the artist

Even as the use of Internet-based art and art involving living things has become increasingly prominent, many artists develop critical commentary on corporate science and biotechnology through more traditional mediums. Kirsten Stolle makes use of traditional painting styles and graphic arts in the form of wallpaper to oppose agribusinesses and critique their practices. In *Miracle Grow* (2012), Stolle draws viewers into the details of the artwork through the convention of wallpaper graphics to remind us of the ubiquity of chemical and agrobusiness products in our everyday lives (Figure 0.4). The style of the wallpaper points toward the multigenerational reach of these international corporations. Her *Animal Pharma* (2014) collages consider the potential of genetically modified animals to be figured by biotechnological companies as farms for pharmaceutical products (Figures 0.5 and 0.6). In *Chemical Bouquet II* (2012), Stolle examines the overuse of pesticides and the introduction of GMOs through the lens of ornately framed nineteenth-century floral still-life paintings. Stolle's *still life* is a translation of the sixteenth-century Dutch term *stilleven*. Sometimes used

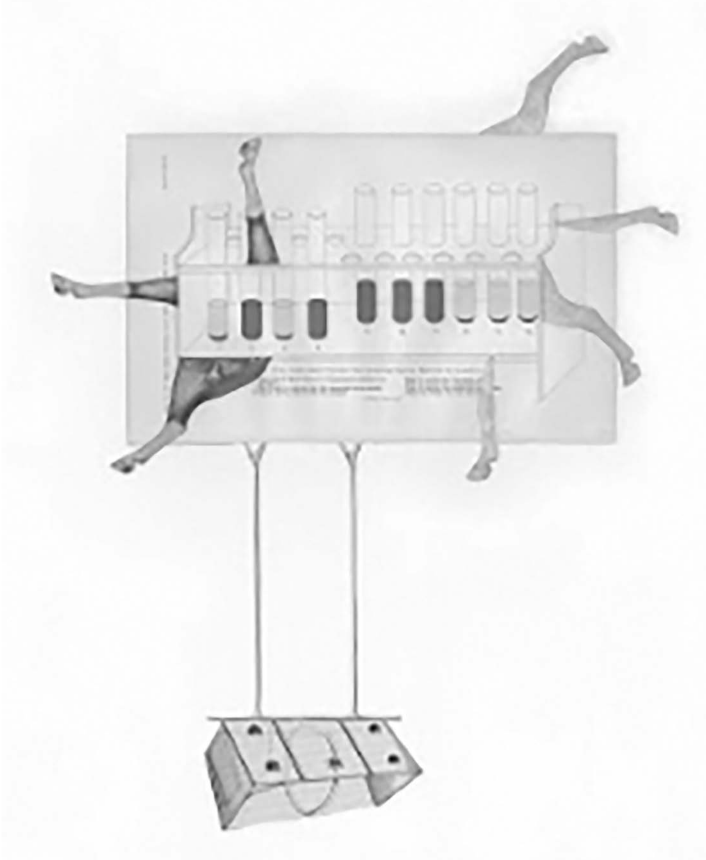


Figure 0.5 Kirsten Stolle. *Animal Pharm 3* (2014). Courtesy of the artist

as painterly technical challenges or to display an individual's skills, the *stilleven* was associated with careful study. In Stolle's rendering, flowers are replaced with bloated cow udders, syringes, and medicinal and botanical plants from the eighteenth through the twentieth centuries (corn, soy, rapeseed, cotton), Agent Orange barrels, and aspirin pills and bottles, all products associated with Monsanto. Stolle's work raised issues about corporate science and more general concerns about marketing and the history and responsibilities of large institutions.

Other artists engage more contemporary art mediums and processes but to many of the same ends. Australian artist Patricia Piccinini entered the contemporary art and biology scene in the late 1990s. Among her first works was *Protein Lattice, Subset- Red Portrait* (1997), a series of images of imagined earless mice with human ears growing on their backs, reminiscent of the mouse engineered by Harvard University tissue culture scientist Charles Vacanti, but interacting with human portrait-sitters. Piccinini is best known for her hyperreal sculptures, which included human figures interacting with beings, who often have human and animal characteristics. Titles such as *Still Life with Stem Cells* (2002) suggest scientific processes as part of the tableaus visitors are seeing and can be read as a critique of such interventions or as a call to pay attention to the care such bodies require from humans.

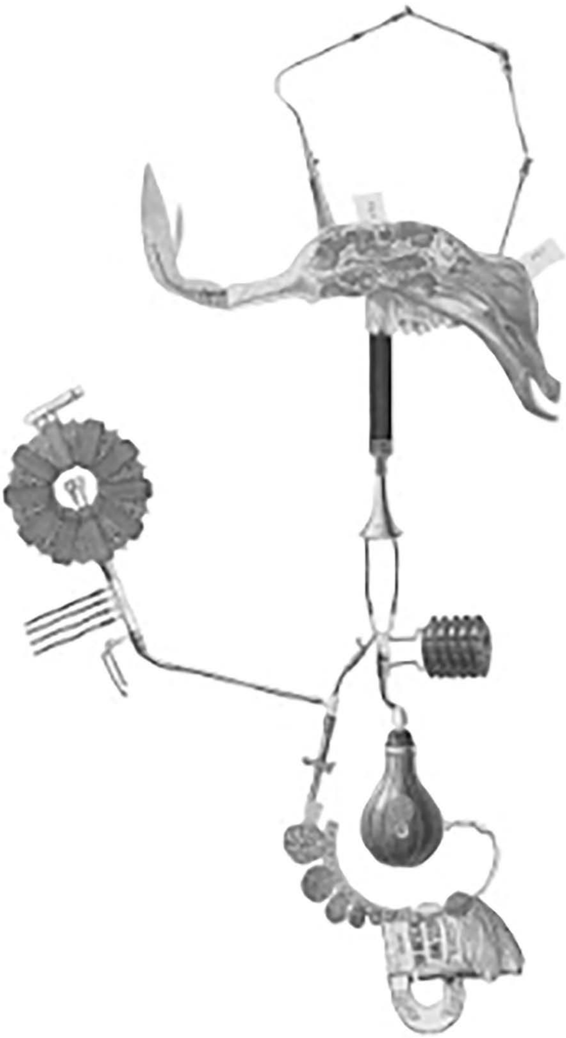


Figure 0.6 Kirsten Stolle. *Animal Pharm 10* (2014). Courtesy of the artist

Piccinini's work has been a touchstone for STS scholars. In the catalog essay accompanying Piccinini's 2007 exhibition *(tender) creature*, Donna Haraway wrote the following encomium:

> Piccinini is a compelling storyteller in the radical experimental lineage of feminist science fiction. In a sense, Piccinini's objects are replete with narrative speculative fabulation. Her visual and sculptural art is about worlding; i.e., "naturaltechnical" worlds at stake, worlds needy for care and response, worlds full of unsettling but oddly familiar critters who turn out to be simultaneously near kin and alien colonists.

At the same time, Piccinini has provoked controversy within and without art communities. Some art critics belittled her work for being detached from the social realities of human suffering from poverty, racism, and nationalist violence. Some artists in this area were critical of

Piccinini because her work does not contain living material or scientific processes. Ironically, however, Piccinini's sculptures were interpreted by others as real laboratory results. Nevertheless, the concept of focusing care on beings created as part of science practices, brought forward by the artist, continues to have resonance in art communities and beyond.

One of the best-known artists working with science and technology is Natalie Jeremijenko, whose contributions range from biology-related artworks to technical hacks. *OneTrees* (1998–1999) was a Bay Area project in which 1,000 Paradox walnuts were planted in areas with different environmental conditions. The artist exhibited the young clones before planting them to point out the difference habitat makes in genetic expression in the accessible form of genetically identical trees. Jeremijenko's *Feral Robotic Dogs* (2006) combined a tactical thought experiment with an engineering-design project. Like *A.I.R.* and *Pigeon Blog*, the project included both physical objects and a web presence and provoked consideration of what it would be like if then-popular toy robotic dogs were in fact "motile" beings waiting in homes and offices to someday take over the world. The project played on assumptions and fears of wild dog behavior and suggested that the toy robots might move as a pack. For the design portion of the project, the toys were outfitted with sensors to locate pollution. Some of the work was performed by students and community members who were encouraged to deploy the toys around their neighborhoods, which would check for environmental contaminants and collectively map their surroundings with GPS technology in the process. Promoted through media events, *Feral Robotic Dogs* brought attention to issues about pollution and how the public receives and understands environmental issues.

Ali Schachtschneider's *Vivorium* (2015), photographed by Z. Wei, graces the cover of this book. Schachtschneider is a fashion-trained designer who explores the aesthetics and consequences of the process of growing materials. She has worked with leading DIY biolab organization GenSpace and cellular agriculture company Modern Meadow. Her experimental work is rooted in extensive research. Engaging a variety of materials and technologies, she conducts hands-on lab-based research as the guiding force in her process. Schachtschneider uses tools from a variety of disciplines including fashion and biology to create extensions of the body. From living entities to grown materials, these extensions suggest alternative ways of understanding the body in relation to the things that surround it. Her work explores alternate futures, provoking critical reflection on the impacts of living materials on lifestyle and design. Schachtschneider's unconventional approach blurs the lines between body, material, object, and performance. In *Vivorium*, Schachtschneider offers a speculative future lifestyle that uses rituals to explore alternative relationships between the living and non-living and imagine a future in which fashion becomes merely an extension of the body. From growing and consuming second-skins to grown materials extending and altering the relationship with materials on the body to swallowable pills that cause cellulose-material to form on the surface of skin, Schachtschneider's work uses biotechnology and biomaterials to explore speculative future rituals of self-fashioning, inviting critical discussion of the ways in which people shape biotechnology in relation to everyday life.

When the canon of artworks in this area is considered, it is important to understand that the specific resources and expertise of artists who work in this area have led to cooperation and sharing. In addition to the creation of artworks in collaborative spaces, many artists have sought to establish residencies at places like CERN and the National Park Service. In her introduction to Section 5, Kathryn Vignone-deRidder further details a selection of supporting institutions. It is notable that in addition to workshops and efforts in established wet labs, artists working in this area found that they needed consistent access to laboratory spaces. The first generation of bioart labs from which much of the early art was launched and new artists trained were founded by bioartists who themselves needed the resources of laboratories. Here, we note artists who, in addition to their own work, have contributed to the community by making facilities available to other artists through residencies and training programs. While the term "bioart" was coined by Eduardo Kac in 1997, artists including Joe Davis, Suzanne Anker, and George Gessert already constituted a community that had been working in this area for at least a decade. A marked feature of the last three decades of bioart has been the emergence of artistic laboratory spaces, which have afforded artists the opportunity to work in biological labs and enabled new kinds of practices. Such spaces are the sites of both physical laboratory resources and practical protocol know-how. They include the University of Western Australia's SymbioticA (2000) led by Oron Catts and Ionat Zurr; Rensselaer Polytechnic Institute's The BioArt Initiative (2007) founded by Kathy High, with Rich Pell, Daniela Kostova, and Boryana Rossa; the University of Windsor's Incubator, founded by Jennifer Willet (2009); Brooklyn-based GenSpace (2010), which sponsors the Biodesign Challenge for which kerasynth was developed; the School of Visual Arts' (SVA) Bio Art Lab (2011) established by Suzanne Anker; and the University at Buffalo's Coalesce (2016), initiated and directed by Paul Vanouse.

Many artists who created works central to this area launched practices from or brought their work to new heights at these growing institutions. Vanouse was an early SymbioticA resident who, as mentioned above, went on to found Coalesce. Joel Ong received a Master of Biological Arts degree at SymbioticA and held a residency at Coalesce. Heather Dewey-Hagborg performed the DNA analysis for *Stranger Visions* at the early GenSpace lab and GenSpace sponsored the Biodesign Challenge, a biotechnology competition for student artists and designers. Rich Pell, founder, director, and curator of the Center for PostNatural History, collaborated with Kathy High and others on the BioArt Initiative and Suzanne Anker's Bio Art Lab at SVA hosted the 2017 Biodesign Challenge student exhibit. Together, these labs form a lattice of resources, technical expertise, social network, and shared research interests that provided the material, technical, and social conditions out of which the field grew.

Catts and Zurr, who together work as *The Tissue Culture & Art Project* (established in 1996), collaborated with Miranda Grounds and Stuart Bunt of the University of Western Australia in Perth to create SymbioticA. Among the important early works to come out of SymbioticA were *Tissue Culture & Art Project's Worry Dolls* (2001) and *Victimless Leather* (2004). An important piece from SymbioticA Research Group that attempted to validate projects in both art and science contexts was *Fish & Chips* (2001), later known as *MEART-The Semi-Living Artist* (2002), which used a robotic hand controlled by cultured fish neurons to draw figures in the gallery. Later versions changed what participants saw in the gallery, but the principle of a remotely-controlled artwork run on neurons from a lab was present in each iteration of the piece.

Vanouse is best known for his work with gel electrophoresis technologies. These devices enabled him to create specific images by using known enzymes and stage "races" between DNA fragments, including *Relative Velocity Inscription Device* (2002), *Latent Figure Protocol* (2007–2009), and *America Project* (2017), which received an Award of Distinction at Prix Ars Electronica, Linz, in 2017. While Vanouse works primarily with lab technologies, Kathy High collaborates with scientists and others with a special focus on ethical concerns in medical research and the use of animals. High has been an important figure in bringing scientists into conversation with artists, thereby facilitating new works through institutions, including her *Bioart Initiative*. High's work with transgenic rats in *Embracing Animal* (2004–2006) investigates the lives of animals used in research investigations of an autoimmune condition that also afflicts the artist. High framed the work in terms of care and honor for the rats. In the gallery, three HLA-B27 transgenic lab rats were given special housing and treated with the holistic medicine the artist herself uses. More recently, High's *Kathy as Bowie* (2015) investigated microbial communities in individual guts, drawing attention to this area as a source of inspiration for artists around self-experimentation and microbes as an art medium.

Environmental artists sometimes apply the socially critical sensibility of bioart in urban space, often on a large scale. Andrea Polli's works express scientific data obtained through collaborations with scientists and engineers as sound art, public works, mobile media experiences, and bioart/biodesign. Polli's *Particle Falls* projected air quality data from onsite sensors in real time onto buildings in major cities including San Jose (2010), Philadelphia (2013), and Paris (2015). Another environmental artist whose work has been installed in cities worldwide is Eve Mosher. Mosher focused attention on the physical spaces expected to be flooded based on climate models. Her first such project, *High Water Line* (2007) in New York City, accurately predicted the storm surge that resulted from Hurricane Sandy in 2012. Artist-activist Ravi Agarwal engages environmental science and the law. Agarwal collaborated with Khoj International Artists Association and Zuleikha Chaudhuri and Anand Grover to produce *In Landscape as Evidence: Artist as Witness* (2019–ongoing), a court scene staged to highlight environmental concerns by considering environmental loss with art at the center of the proceedings.

Artists have also worked with ideas about the environment and space in experiential terms. Olafur Eliasson's work explores subjects of overlapping interest in science and art, and his Studio, founded in 1995, is a laboratory for spatial research. His large-scale installations include staging urban environments as in his 1998 *Green River* art and manipulating gallery environments through light, humidity, and temperature change as aesthetic experience as in *The Weather Project* (2003) at the Tate Modern, London. Eliasson's Institut für Raumexperimente ran from 2009 to 2014 and produced a network of students whose important body of work continued their mentor's interest in spatial concerns as a way of accessing philosophies that animate art and science. In describing *BEOBACHTUNG // OBSERVATION*, a 2018 group show of works produced by Eliasson's former students, Dehlia Hannah wrote that "what is offered is not merely a choice of alternative perspectives from which to view the world, but rather, visions of malleable and heterogeneous selves in the making in tandem with things."

Architecturally trained environmental artist Tomás Saraceno draws on ideas from engineering, physics, chemistry, aeronautics, and materials science. He is best known for his floating sculptures through his ongoing work *Air-Port-City/Cloud City*, part of an investigation of sustainable living, cloud formation, and the atmosphere, a subject further explored in Section 8. Saraceno created the Aerocene Foundation, a community project for artistic and scientific exploration of environmental issues. Saraceno's work contributes to both communities, and while the artist emphasizes sustainable living practices through Aerocene, his work engages other sciences as well. For example, Saraceno scanned, reconstructed, and reimagined spiders' woven spatial habitats and possesses the only three-dimensional spider web collection in existence.

Reproductive technologies and interventions have been a central theme for many artists working with science. Much of this work is feminist in tone, while some of it critiques ideas about eugenics and social selection, often in an absurdist and satirical manner. subRosa's *SmartMom* (1999) was a net.art piece that suggested deploying a battery of sensors and surveillance devices on pregnant people. In 2009, Chrissy Conant created *Chrissy Caviar*, a refrigerated display of her own eggs, along with a depiction of the 45-minute hospital procedure to harvest them, as a wry commentary on commodification of the body and reproduction.

Charlotte Jarvis's *In Posse* (2018–ongoing) is an attempt to create female sperm. The artist collaborated with Susana M. Chuva de Sousa Lopes and Kapelica Gallery/Kersnikova Institute to make semen from "female" stem cells derived from Jarvis's blood, altering their gender and differentiating them into the sperm-producing cells found in male testicles (Figure 0.7). The collection of the blood for experimentation was staged as part of a contemporary reenactment of the ancient Greek festival of Thesmophoria, a women-only fertility ceremony in honor of the goddesses Demeter and Persephone. Jarvis created a film which is part documentary and part aesthetic exploration of the different facets of the project (Figure 0.8). Recontextualizing female sperm inside and outside of the laboratory offered opportunities to think about the same object as scientific and as social, effectively blurring the line between these two interpretive regimes.

Adam Zaretsky works on issues of reproduction in relationship to radical genetic interventions, sometimes in a comic mode that plays up molecular biology's assumptions of sex and reproduction. His initial work considered organisms created for experimentation following his residency at MIT and led to the creation of *WorkHorse Zoo* (2002), a performance

Figure 0.7 Laboratory image from *In Posse* (ongoing), Charlotte Jarvis in collaboration with Susana M. Chuva de Sousa Lopes. Photo credit: Miha Godec

Figure 0.8 Film still from *In Posse* (ongoing); Charlotte Jarvis in collaboration with Susana M. Chuva de Sousa Lopes. Camera: Eleni Papazoglou.

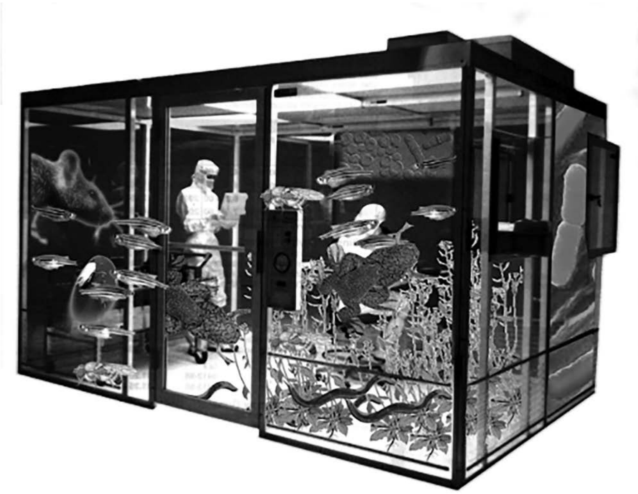


Figure 0.9 Adam Zaretsky and Julia Reodica. *Workhorse Zoo* (2002), design

Figure 0.10 Adam Zaretsky performing *Workhorse Zoo* (2002) at the Salina Art Center in Salina, Kansas.

in which Zaretsky immersed himself in a terrarium alongside a selection of these beings (Figures 0.9 and 0.10). This experience preceded Zaretsky's turn toward embryology and the creation of new beings as an art practice. Through his traveling school VASTAL (Vivoarts School for Transgenic Aesthetics), Zaretsky teaches art and biology at a series of research universities. His controversial experiments with transgenic pheasant embryology brought together persistent concerns in the area of art–science work, notably, the ethics of working with human, animal, and fragmented bodies. Zaretsky's current research focuses on transgenic humans. He proposes a role for artists and designers in avoiding a traditional eugenic outcome by offering alternative human designs.

There are a cluster of art–science projects around the subject of time. Verena Friedrich is a former resident of SymbioticA and the Max Planck Institute who creates time-based installations with organic, electronic, and sculptural media. Her artistic practice involves direct interventions with scientists and hands-on work in laboratories. In 2016, Friedrich created *The Long Now*, a persistent soap bubble, achieved by sealing the bubble in an atmospheric chamber where it can remain indefinitely. Her 2019 work *Office Plants* compares the disparate time scales of plant versus human life. Eric Berger has also worked with concepts of deep time. Along with Mari Keto, Berger developed *Inheritance Project* (2016–ongoing), a series about the nuclear present and deep future. Thomas Feuerstein works with algorithmic art and cause-effect patterns. He combines interdisciplinary knowledge from the arts and humanities as well as computer science and economics to create works like *Mycelium Image Decay* (2007). In this Internet-based work, searches are treated as "food" that stimulates the growth of the mushroom mycelium following the structures of the images and makes them temporarily visible before they are disassembled and composted.

Another important strand of art–science work was stimulated by influential designers Anthony Dunne and Fiona Raby through their development of the area of critical and speculative design (2001, 2013). As professors at the Royal College of Art (RCA) Design Interactions program, Dunne and Raby trained many students whose experimental practices span art and design and engage social features of developing technologies. Among the many outstanding graduates of this program is Alexandra Daisy Ginsberg, whose *The Synthetic Kingdom* (2009) examines design's role in the area of synthetic biology and potential alternative futures. Ginsberg was also the curator and writer of *Synthetic Aesthetics: Investigating Synthetic Biology's Designs on Nature* (Ginsbeurg et al. 2014), a project further detailed in Chapter 2. The critical designs and artwork of RCA graduates Revital Cohen and Tuur Van Balen explore systems of industrial production as cultural, social, and political practices. In 2013, Cohen and Van Balen collaborated on *Kingyo Kingdom*, a widely acclaimed documentary depicting roles Japanese goldfish play in society as they are transformed into cultural, aesthetic, and useful objects. These artists have also worked on projects ranging from synthetic biology design interventions to filmic investigations of world economic relationships through staging fireworks at a mine in the Republic of the Congo (*Trapped in the Dream of the Other*, 2017).

Earth science and the status of energy in our societies have also been inspirational subjects for artists. HeHe, the Paris-based artistic collective of Helen Evans and Heiko Hansen, investigate the social, industrial, and ecological paradoxes found in today's technological landscapes. HeHe take as their subject technological failures and their social causes and consequences, an important preoccupation of STS. Their artworks consider the social and political dimensions of these problems through installations incorporating industrial and scientific equipment and systems components. Lea Schick explores their work on energy further in Chapter 28. Katie Paterson collaborates with scientists on artworks that place the Earth in the context of geological time and change. Ranging from the technical to the contextual, Paterson's work suggests that art can continue a romantic relationship with the Earth even as new technologies arise and new frameworks of understanding are brought in from the sciences. Among her projects are a phone line where callers can hear the sounds of a melting glacier (*Vatnajökull (the sound of)* 2007–2008) and a recast meteorite brought back into space by the European Space Agency (*Campo del Cielo, Field of the Sky* 2012–2014).

The performing arts and music have also made important contributions to art–science. While one could trace the history of science theater back to *Dr. Faustus*, we focus on more recent contributions to the contemporary moment of art–science, with several important exceptions. While their definition as art might be dubious to some, popular culture contributions from film, television, and popular music cannot be ignored as sites of contestation and conversation about the nature and role of science in culture. This handbook does not delve deeply into popular culture, but television programs like *Big Bang Theory* have shaped or reinforced particular conceptions of who scientists are and what they do. Similarly, the genre of procedurals that incorporate forensic and medical sciences, such as the *CSI* and *NCIS* franchises and *Grey's Anatomy* and *House*, have had measurable impacts on perceptions of scientists and the role science plays in law enforcement and medicine. The album *Here Comes Science* from *They Might Be Giants* is a striking example of a pop artist response to public mistrust. Aimed largely at children, much of the album is populated with innocuous songs about what paleontologists do or how water changes from solid to liquid to gas. However, the track "Science is Real" is a naive reassertion of the primacy of science in the face of growing denialism.

In contrast, Icelandic artist Björk's *Biophilia* is a more complex artwork that consists of an album with ten tracks, each with its own downloadable app. Utilizing new musical practices and instruments, the album stemmed from Björk's increasing activism in natural resource conservation and constituted an attempt to integrate nature with scientific, mathematical, and musical concepts. As Susdorf (2017) writes:

> What is worth noticing is that she does not fall prey to the patriarchal presentation of 'nature' as an ultrapositive, romanticised, woman-like figure, overgrown with myths of fertility. On the contrary, she tries to become a scientist but of a special kind. Firstly, the singer starts to listen to the world that surrounds her, rather than to observe and to discursively colonise it. Then, through singing together with her non-human surroundings, she announces the results of the inquiry on the album.
>
> *(113)*

Such endeavors are clearly ripe for further ASTS investigation both as particular artworks and as examples of art–science in practice. Modern dance and performance art have also become a locus for interaction with science and scientists. Famed modern dance choreographer Liz Lerman turned her attention to the human genome project in 2006, when she produced *Ferocious Beauty: Gemone*. In 2008, Lerman began a residence at CERN with her company Dance Exchange, which resulted in her 2010 performance *The Matter of Origins*. Her work with and about scientists was inspired by and has inspired a groundswell of dance–science interactions. In 2000, Megan Halpern, one of the editors of this handbook, co-wrote and produced *Elements*, a live music and dance performance that embodied geophysical concepts while drawing on ancient Greek framings of the elements as earth, air, fire, and water. Halpern's chapter in this handbook also recounts her 2009 facilitation of a collaboration between a choreographer and physicist. These performances raise questions about audience interpretations of abstract art forms like modern dance as well as issues of accessibility for spectators. These performances are artworks, but they are often expected to act as communication tools.

PearlDamour's experimental theatrical production *How to Build a Forest* premiered in 2011 in New York City and then toured several college campuses.[13] The project invited audiences to watch the creation and destruction of a forest over eight hours. Spectators came and went as they pleased and watched from within the installation itself or from the sidelines. Experimental theater about science has a rich history in the United States. During the 1930s, the Works Progress Administration, a government-funded program to stimulate the economy after the Great Depression, commissioned the Federal Theater Project (FTP), led by Hallie Flanagan. The FTP was established to provide employment to out-of-work theater professionals (Shepherd-Barr 2006). Among the many FTP projects were "living newspapers," a form of experimental performance about current events with origins in the Russian Revolution. While many living newspapers focused on social and political issues, Flanagan was also interested in the intersection of science and society and helped define a science focus for living newspapers. In 1938, just before the federal government shut down the FTP's living newspaper unit, the group produced *Power*, by Arthur Arent, which focused on the Tennessee Valley Authority project to provide electricity to the public. Ten years later, Flanagan wrote $E = mc^2$, a play about the risks, rewards, and responsibilities in the development of atomic power. Perhaps the most famous science-related U.S. living newspaper was *Spirochete*, produced by Arnold Sundgaard in Chicago in 1938 in reference to the city's ongoing "war on syphilis" (Vacha 1986; Williams and Mills 2018).

Around the same time Flanagan was developing living newspapers, Bertolt Brecht wrote the first version of his play *Life of Galileo* (a subsequent version was simply titled *Galileo*). This work is of particular importance not only because of its fame and lasting impact on theater but also because Brecht rewrote the play twice, resulting in a total of three versions, each with a different understanding of Galileo's character and a different interpretation of the relationship between scientists and society (Shepherd-Barr 2006). The first version depicts Galileo as a hero who finds a way to propagate his ideas in spite of the church, while the final version depicts him as a self-serving immoral egotist unconcerned with the social ramifications of his work. Brecht's views of science were importantly conditioned by his experiences in the United States during and especially after World War II, when he grew increasingly critical of the Cold War state and science's role in the nuclear age. A prominent figure in theater in both Europe and the United States and well-known for his progressive politics, Brecht saw theater as a tool for teaching and empowering audiences around themes of social justice, present not only in *Galileo* but his other works as well.

The turn of the twenty-first century saw an explosion of science theater in the United States and Europe. It is difficult to pinpoint a cause of this phenomenon, but several funding organizations took a new interest in art–science. The Sloan Foundation, for example, provided money for two established theaters in New York City to develop plays that presented scientists as humans. During that same time period, two scientists crossed boundaries to adapt their ideas about science into drama. Nobel Laureate Roald Hoffman and chemist Carl Djerassi (best known for synthesizing the first oral contraceptive) wrote poetry and plays individually and then collaborated to write *Oxygen*, which premiered in Ithaca, New York in 1999. Djerassi also wrote a number of other plays relating to science and society including *Phallacy* (2004) and *Taboos* (2006), concerning the clash between art and science and the social implications of new reproductive technologies, respectively. The texts and performances of these plays merit consideration not just for their content but because of the ways the authors, both highly renowned scientists, entered new social worlds and established themselves as new kinds of experts. Djerassi's interest in art is perpetuated through an artist residency in Woodside, California, which holds *Scientific Delirium Madness* each summer to bring artists and scientists together to work on individual interdisciplinary projects and encourage future collaborations.

Two plays about science produced around the turn of the millennium won some of the highest honors bestowed on the arts in the United States. Michael Frayn's *Copenhagen* (1998) and David Auburn's *Proof* (2000) achieved great popularity as well as critical acclaim. *Copenhagen* won the Tony Award (the most prestigious US theatrical award) for Best Play in 2000, while *Proof* won a Pulitzer Prize for Drama and a Tony Award for Best Play in 2001. The texts of these plays are quite different, but both explored the psyches of scientist-protagonists and the toll their work took on their lives and relationships.

This is only a small sample of artworks that can be taken up by ASTS, but the breadth and variety of themes they engage as well as their rich histories provide a kind of landscape within which to explore the contours of ASTS as a field. Much has been left out in this short list, but we hope future works will explore more deeply the ideas and works presented in this introduction and expand the field to new areas.

The future of ASTS

The future of ASTS is further development of the many concepts treated in this book. ASTS scholars will continue to develop theory and practice, and gain better understanding of the ways that science and art are constructed and positioned in terms of one another. In so doing, they will have new insights into the nature of collaboration and novel applications of STS methods to art and science questions as well as from art and science studies that reflect new theories and methods back into STS. The groundwork is laid for ASTS to begin longitudinal studies that move away from the treatment of single art and science intersections and engage art and science work together in many contexts. So much lies before ASTS that it seems prudent to suggest some questions around which new clusters of scholarship are developing or are needed.

Art and science collaborations have grown in type and scope, and while these relationships are no longer novel in and of themselves, there is much to learn about the best preconditions for such work and about how interactions might be studied both descriptively and normatively. More work is needed to fully conceptualize questions around collaborations. However, the most pronounced need from the practical side seems to be for a set of tools to study collaborations that value the positions of both the artist and the scientist in considering the results of such enterprises. At the same time, questions about the ways that the practices of art and science can and should be compared as ASTS scholars follow scientists and artists also require further attention. Many years of long- and short-term collaborations have taken place, so enough data now exist to make fruitful comparisons about the effects of this work that accounts for the values of the various stakeholders and output analysis in terms of audience reception theories.

ASTS has an important focus on materials and materiality, setting it apart from some STS work in terms of methods and knowledge products. This means that ASTS can offer new ideas to STS and broaden the scope of work that employs STS tools and methods. In short, the area of concern of knowledge and knowledge products can be expanded to take in art. This will produce new questions for ASTS. When artworks are knowledge products, how do we think, work with, write, and talk about them? Such research needs to happen both through the close examination of individual cases and through comparisons of multiple cases and contexts.

Most of the chapters in this book and the work in this area so far have focused on art that has taken place in workshop settings or been produced out of galleries as a form of street or community art. While there is a great deal of art and science work that has been positioned in galleries, the artists that ASTS is focusing on tend to be those operating outside the museum walls. Yet there is more that can be done to examine the broader appeal of this work. Much of what has been written in ASTS has focused on contemporary art in settings that do not include pop media or popular culture uses of art. As the field grows, ASTS should be increasingly attentive to art and science work that speaks to larger audiences.

This concern relates to questions about the way that the addition of art might help us avoid elitist approaches that might further pull the ladder up into an exclusive space. Some scholars would contend that since art has made approaching the public central to its practices, it may serve to help keep conversations in ASTS extended broadly and focused on publics. This hopeful sentiment is tempered by the idea that for many members of the public, art, like science, remains a space that is exclusive, uninteresting, or difficult to access. Whether ASTS may generate larger audiences through material engagements or its own focus on publics remains to be seen.

Art and science are increasingly being institutionalized, raising questions around the social worlds in which they exist, how they were founded, developed, and continue to be supported as well as the largest institutions they are embedded in, and their potential to persist in conditions of soft money or long-term funding. To some degree, such work has always existed inside of institutions, and there are many organizations like Leonardo with histories that extend beyond the current increase in interest around this work. Still, the proliferation of local and international organizations working in this area calls attention to the future of this work and how it might be best studied.

The conditions that led to this proliferation of organizations should also be analyzed. In some cases, such organizations are directed toward specific subjects for problem or challenge-solving purposes, as with Arizona State University's *Emerge: Artists and Scientists Redesign the Future*. Others are organized around the need for resources, equipment, and infrastructure, which are fundamental to creating new projects in this area. The philosophy of the institutionalization of both art and science has been questioned, particularly around its potential to impact the creativity and originality of the work it produces. Comparative studies are needed to consider how institutions are shaping art and science projects and hence ASTS as a field. Moreover, ASTS's analytical arms have the potential to affect the development of these institutions with studies that reflect on the processes related to creating these works.

At the same time, it is important to continue to consider anti-institutional work and projects that resist institutionalization. As art and science are increasingly validated by institutions, this process has the potential to create barriers to moving out of those spaces. Historically, the difficulties in categorizing such work on the processes of validating work with characteristics of both worlds have led to a flexibility that made it relatively more likely that this type of work could move between formal and informal locations. Whether new organizations focusing on this area may change or solidify these boundaries remains to be seen.

While many organizations do work across countries, art and science organizations have, so far, remained relatively local in the sense that they are often supported by regional funding schemes which lend themselves to specific priorities and distinct organizational characters. Some essential tensions which have long been the case in STS are mirrored in ASTS. For example, STS programs and research have continued to develop around analytical and normative work. While these two categories of STS scholarship surely influence each other, they also have developed along different lines with different goals and this is reflected as a division in the larger STS community. A similar pattern can be observed in the constitutive communities of art and of science that include both the creation of work and the study or reflection on it. Some quarters of ASTS scholarship are understood as drawing on the normative aspects of STS, yet there are surely many ASTS scholars who see themselves primarily as analysts and avoid prescriptive research outputs. However, many ASTS scholars have unabashedly sought to engage the tradeoffs between social impact and critical practice. Compared with STS scholars as a whole, ASTS scholars are more likely to be involved with practical applications of their work and are more likely to be involved in textual and material interventions.

STS recapitulates the existing power structures by treating art knowledge as less valuable than science knowledge. ASTS has a commitment to the idea that science is best understood as a knowledge product created by a community, for which the fullest understanding is available through comparison to other knowledge systems, in this case art. Many ASTS scholars are committed to a position that science could be improved by a reinterpretation of the power structures that hold it up as objectively or self-evidently the best available knowledge. To them, without this imposed hierarchy, art as a form of knowledge becomes unfettered, opening up space for its value as knowledge, and therefore power, to grow. The interest of ASTS scholars in ASTS scholarship is ultimately a prescriptive one for a more inclusive STS and improved conditions for science and art.

Unsettled science and moments of failure represent opportunities for STS scholars to study art–science, and it seems that art often reacts to these opportunities as well. Closed questions are hard to reopen, while emerging technologies and scientific and technological failures and disasters lend themselves to reconsideration of previously settled questions. This suggests that ASTS scholars should look for artists working around the very conditions that STS scholars have looked for openings to comment on. It is in these moments that ASTS scholars are likely to find opportunities to bring their skill sets as practitioners to bear on interesting questions in productive ways.

By assembling these varied theories and practices in one volume, this handbook values work in both art and science networks. It provides a means of exploring the possibilities for ASTS as art–science burgeons. Considering the possible approaches ASTS can take becomes even more relevant as more projects are developed which are designed to be recognized as part of both art and science. Even as ASTS has the potential to contribute in new ways to art and science communities, some shared ideas have already proved useful to many analysts working on these subjects. This handbook contains examples of more traditional forms of engagement by STS scholars with art and science subjects, including ethnographies and interviews, but it also proposes some new forms of interaction, including policy interventions, STS and art workshops conducted with the public, and exhibitions. ASTS encompasses myriad perspectives and, thus, requires myriad approaches. We propose ASTS as a theoretical and methodological framework for studying art or science objects, a language by which we can speak about and research art–science. Ultimately, we see ASTS as a methodology for STS-informed art–science practice. These different ways of engaging with ASTS make for slippery and elusive boundaries, and invite unexpected ideas and interactions. The following discussion of epistemological and ontological concerns lays the groundwork for approaches to ASTS developed in the following chapters.

Acknowledgments

The authors would like to thank Matthew Eisler for his helpful comments and editorial suggestions.

Notes

1 If the Snow–Leavis clash was the most famous public debate about the value of art and science, it was far from the first. Poets and philosophers have argued the subject throughout history (Ortolano 2008, 5). Sandbrook (2006) points to the debate between Matthew Arnold and T. H. Huxley in the 1880s as the precursor to the Snow–Leavis debate, while van Dijck (2003) and Snow themselves trace the art-science divide to the scientific and industrial revolutions. Van Dijck also notes that in the 1830s, the division of educational degrees into the Master of Arts and the Master of Sciences led to a professional split between the two groups.

2 Perhaps, ironically, the sciences have had to increasingly seek the help of the arts to remain relevant in the public eye.

3 Though the science wars had been brewing for some time, they began with Gross and Levitt's *Higher Superstition* (1994) but grew more visible in 1996 with what is now referred to as the Sokal affair. Alan Sokal, a physicist at NYU, wrote and submitted an article to the cultural studies journal *Social Text* (Sokal 1996b). After the article was reviewed and published in the journal, Sokal revealed his article as a parody and wrote extensively about his "experiment" in *Lingua Franca* (Sokal 1996a). Sokal's aim was to see if *Social Text* would publish "an article liberally salted with nonsense if (a) it sounded good and (b) it flattered the editors' ideological preconceptions" (62). The fallout from these two articles was considerable, with academics choosing sides and turning what could have been a fruitful discussion about the relationship between science and science studies into a welter of mudslinging. In 2001, Harry Collins, a science studies scholar, and Jay Labinger, a chemist, compiled an edited volume called *The One Culture?* to help advance a more respectful, serious dialog (Labinger and Collins 2001). Though much of the fire of the original science wars has subsided, in 2008, Sokal published a book in what amounted to an attempt to rekindle the debate (Sokal 2008). A brief new battle emerged in the pages of *Reviews in Anthropology* in 2010 and 2011 (Schultz 2010, 2011; Smith 2011; Sokal 2011).

4 See, for example, Thomas S. Kuhn (1970) and Steve Woolgar and Bruno Latour (1979).

5 See, respectively, Hugh Gusterson (1998) and Michael Lynch (1997).

6 Barry Barnes and David Bloor (1996).

7 To put this in perspective, the National Science Foundation (NSF), one of the smallest of the U.S. federal patrons of science, had a 2016 budget of nearly $8 billion, while the National Endowment for the Arts (NEA) had a 2016 budget of just under $148 million.

8 Between her first article on boundary objects in 1989 and the last in 2010, Star shifted from writing about social worlds to writing about communities of practice. Bowker and Star (1999) used the two concepts interchangeably and noted that they were replacing the concept of social worlds with that of communities of practice. While the use of either term may not change the concept of boundary objects, the social worlds theory is a more apt construct for discussing the intersection of art and science in our cases because "worldness" of a social world carries with it social and organizational structures, such as funding streams and institutions, that support the social worlds. On the other hand, communities of practice may form or dissipate on a more ad hoc basis.

9 Star and Griesemer defined boundary objects as inhabiting several social worlds, but it seems that from a symbolic interactionist perspective, the volunteers and the scientists might inhabit the same social world. Perhaps then, boundary objects would still be useful and necessary in translation across different categories and actors within the same social world, but the objects would still be boundary objects because they crossed between different social categories within the worlds; they helped people who have different occupations within a social world to interact with one another.

10 The word "scientist" is generally credited as being coined by William Whewell in his review of Mary Somerville's *On the Connexion of the Physical Sciences* (1834).

11 Leonardo homepage; https://leonardo.info/leonardo.

12 George Gessert homepage; http://geneticsandculture.com/genetics_culture/pages_genetics_culture/gc_w02/gc_w02_gessert.htm.

13 Information on the performance can be found at http://pearldamour.com/project/how-to-build-a-forest/.

References

Alpers, S. 1983. *The art of describing: Dutch art in the seventeenth century*. Chicago, IL: University of Chicago Press.

Ant Farm. 2019. *Media burn, 1968–1978*. New York: MoMA.

Barad, K. 2006. *Meeting the universe halfway: Quantum physics and the entanglement of matter and meaning.* Durham, NC: Duke University Press.

Barnes, B., and Bloor, D. 1996. *Scientific knowledge: A sociological analysis*. Chicago, IL: University of Chicago Press.

Becker, H. S. 1982. *Art worlds*. Chicago, IL: University of California Press.

Becker, H. S., and McCall, M. M. 1990. *Symbolic interaction and cultural studies*. Chicago, IL: University of Chicago Press.

Bensaude-Vincent, B. 2001. The construction of a discipline: Materials science in the United States. *Historical Studies in the Physical and Biological Sciences*, 31 (2), 223–248.
Berger, P. L., and Luckmann, T. 1966. *The social construction of reality: A treatise in the sociology of knowledge*. Garden City, NY: Anchor Books.
Berry, W. 2003. *Life is a miracle*. Berkeley, CA: Counterpoint.
Bijker, W., Hughes, T. P., and Pinch, T. eds. 1987. *The social construction of technological systems*. Cambridge, MA: The MIT Press.
Bloor, D. 1976. *Knowledge and social imagery*. Chicago, IL: University of Chicago Press.
Boujut, J.-F., and Blanco, E. 2003. Intermediary objects as a means to foster co-operation in engineering design. *Computer Supported Cooperative Work (CSCW)*, 12, 205–219. https://doi.org/10.1023/A:1023980212097.
Bowker, G. C., and Star, S. L. 1999. *Sorting things out: Classification and its consequences*. Cambridge, MA: The MIT Press.
Brown, N. 2003. Hope against hype: Accountability in biopasts, presents and futures. *Sciences Studies*, 16 (2), 3–21.
Burke, K. 1945. *A grammar of motives*. Prentice-Hall, Inc. New York, NY.
Burnett, D. G. 1999. A view from the bridge: The two cultures debate, its legacy, and the history of science. *Daedalus*, 128 (2), 193–218.
Butler, J. 1990. *Gender trouble: Feminism and the subversion of identity*. New York: Routledge.
Callon, M. 1986. Some elements of a sociology of translation: Domestication of the scallops and the fishermen of St Brieuc Bay. *In* J. Law, ed. *Power, action and belief: A new sociology of knowledge*. London: Routledge & Kegan Paul, 196–233.
Calvert, J., and Schyfter, P. 2017. What can science and technology studies learn from art and design? Reflection on 'Synthetic Aesthetics.' *Social Studies of Science*, 47 (2), 195–215.
Clarke, A. E. 1990. A social worlds research adventure: The case of reproductive science. *In* S. Cozzens and T. Gieryn, eds. *Theories of science in society*. Bloomington: Indiana University Press, 15–42.
Clarke, A. E. 2005. *Situational analysis: Grounded theory after the postmodern turn*. Thousand Oaks, CA: Sage Publications.
Cohen, B. R. 2001. Science and humanities: Across two cultures and into science studies. *Endeavour*, 25 (1), 8–12.
Curran, J. 2012. *Misunderstanding the Internet*. 1st ed. London and New York: Routledge.
Curry, H. A. 2016. *Evolution made to order: Plant breeding and technological innovation in twentieth century America*. Chicago, IL: University of Chicago Press.
Daston, L. 2005. Fear & loathing of the imagination in science. *Daedalus*, 134, 16–30.
Daston, L. 2008. *Things that talk*. New York: Zone Books.
Daston, L., and Galison, P. 1992. The image of objectivity. *Representations*, 40 (Autumn), 81–128.
Davenport, C. 2018. *The space barons: Elon Musk, Jeff Bezos, and the quest to colonize the cosmos*. New York: PublicAffairs.
de Ridder-Vignone, K. D. 2012. Public engagement and the art of nanotechnology. *Leonardo*, 45 (5), 433–438.
Dewey, J. 1934. *Art as experience*. New York: Minton, Balch & Co.
Dunne, A., and Raby, F. 2001. *Design noir: The secret life of electronic objects*. Basel: Birkhäuser.
Dunne, A., and Raby, F. 2013. *Speculative everything: Design, fiction, and social dreaming*. Cambridge, MA: The MIT Press.
Eagleton, T. 1990. *The ideology of the aesthetic*. Oxford: Blackwell.
Ede, S. 2002. Science and the contemporary visual arts. *Public Understanding of Science*, 11 (1), 65–78. https://doi.org/10.1088/0963-6625/11/1/304.
Ede, S. 2005. *Art and science*. London: I.B. Tauris.
Elkins, J. 1995. Art history and images that are not art. *The Art Bulletin*, 77 (4), 553–571.
Elkins, J. 2008. *Six stories from the end of representation: Images in painting, photography, astronomy, microscopy, particle physics, and quantum mechanics, 1980–2000*. Stanford, CA: Stanford University Press.
Elkins, J. 2009. Aesthetics and the two cultures : Why art and science should be allowed to go their separate ways. *In* F. Halsall, J. Jansen and T. O'Connor, eds. *Rediscovering aesthetics: Transdisciplinary voices from art history, philosophy, and art practice*. Stanford, CA: Stanford University Press, 34–50.
Fan, F. 2004. *British naturalists in Qing China: Science, empire, and cultural encounter*. Cambridge, MA: Harvard University Press.
Ferdin, P. 2000. In Massachusetts, science gives new life to art. *Washington Post*, 29 Dec.

Frayn, M. 2000. *Copenhagen*. New York: Samuel French.
Fujimura, J. H., 1992. Crafting science: Standardized packages, boundary objects, and "translation." *In* A. Pickering, ed. *Science as practice and culture*. Chicago, IL: University of Chicago Press, 168–211.
Galison, P. 1997. Material culture, theoretical culture, and delocalization. *In* J. Krige and D. Pestre, eds. *Science in the twentieth century*. Amsterdam: Harwood, 669–682.
Gerson, E. M. 1983. Scientific work and social worlds. *Knowledge*, 4, 357–377. https://doi.org/10.1177/107554708300400302.
Gessert, G. 2010. *Green light: Toward and art of evolution*. Cambridge, MA: The MIT Press.
Gieryn, T. F. 1983. Boundary-work and the demarcation of science from non-science: Strains and interests in professional ideologies of scientists. *American Sociological Review*, 48 (6), 781–795. https://doi.org/10.2307/2095325.
Gieryn, T. F. 1990. *Cultural boundaries of science: Credibility on the line*. 1st ed. Chicago, IL: University of Chicago Press.
Ginsberg, D. A., Calvert, J., Schyfter, P., Elfick, A., and Endy, D. 2014. *Synthetic aesthetics: Investigating synthetic biology's designs on nature*. Cambridge, MA: The MIT Press.
Giorgione, C. 2009. *Leonardo da Vinci: The models collection*. Milan: Fondazione Museo Nazionale della Scienza e della Tecnologia Leonardo da Vinci.
Gusterson, H. 1998. *Nuclear rites: A weapons laboratory at the end of the Cold War*. Berkeley: University of California Press.
Guston, D. H. 2001. Boundary organizations in environmental policy and science: An introduction. *Science, Technology & Human Values*, 26 (4), 399–408.
Halpern, M. K. 2012. Across the great divide: Boundaries and boundary objects in art and science. *Public Understanding of Science*, 21 (8), 922–937.
Hannah, D. 2013. Performative experiments: Case studies in the philosophy of art, science and technology. Thesis (PhD). Columbia University.
Henderson, K. 1991. Flexible sketches and inflexible data bases: Visual communication, conscription devices, and boundary objects in design engineering. *Science Technology Human Values*, 16, 448–473. https://doi.org/10.1177/016224399101600402.
Jones, C. A., and Galison, P. L. eds. 1998. *Picturing science, producing art*. New York: Routledge.
Kennedy, D. 2003. Two cultures. *Science*, 299 (5610), 1148. https://doi.org/10.1126/science.299.5610.1148.
Kimball, R. 1994. "The two cultures" today. *The New Criterion*, 12 (6), 10.
Kline, R., and Pinch, T. 1999. The social construction of technology. *In* D. MacKenzie and J. Wajcman, eds. *The social shaping of technology*. 2nd ed. Buckingham and Philadelphia: Open University Press.
Kovác, L. 2002. Two cultures revisited: New widening gaps. *World Futures*, 58, 1–11.
Kuhn, T. S. 1962. *The structure of scientific revolutions*. Chicago, IL: University of Chicago Press.
Labinger, J. A., and Collins, H. M. 2001. *The one culture? A conversation about science*. Chicago, IL: University of Chicago Press.
Latour, B. 1987. *Science in action: How to follow scientists and engineers through society*. Milton Keynes: Open University Press.
Latour, B. 1991. Technology is society made durable. *In* J. Law, ed. *A sociology of monsters: Essays on power, technology, and domination*. London and New York: Routledge, 103–131.
Latour, B. 1999. *Pandora's hope: Essays on the reality of science studies*. Cambridge, MA: Harvard University Press.
Latour, B., and Weibel, P. eds. 2002. *Iconoclash: Beyond the image wars in science, religion, and art*. Cambridge, MA: The MIT Press.
Lee, C. P. 2005. Between chaos and routine: Boundary negotiating artifacts in collaboration. *In Proceedings of the Ninth Conference on European Conference on Computer Supported Cooperative Work, ECSCW'05*. Springer-Verlag, New York, Inc., New York, NY, USA, pp. 387–406.
Levin, H. 1965. Semantics of culture. *Daedalus*, 94 (1), 1–13.
Lynch, M. 1990. The externalized retina: Selection and mathematicization in the visual documentation of objects in the life sciences. *In* M. Lynch and S. Woolgar, eds. *Representation in scientific practice*. Cambridge, MA: The MIT Press, 153–186.
Lynch, M. 1997. *Scientific practice and ordinary action: Ethnomethodology and social studies of science*. Cambridge: Cambridge University Press.
Lynch, M., and Woolgar, S. 1990. *Representation in scientific practice*. Cambridge, MA: The MIT Press.

Mandoki, K. 2007. *Everyday aesthetics: Prosaics, the play of culture and social identities*. 1st ed. Farnham: Ashgate.

Marantz, A. 2019. The dark side of techno-utopianism. *The New Yorker*, 23 Sept.

Marwick, A. E. 2013. *Status update: Celebrity, publicity, and branding in the social media age*. 1st ed. New Haven, CT: Yale University Press.

McKenzie, J. 2005. Performance studies. *In* M. Groden, M. Kreiswirth, and I. Szeman, eds. *The Johns Hopkins guide to literary theory and criticism*. Baltimore, MD: Johns Hopkins University Press.

Miller, C. C. 2017. Tech's damaging myth of the loner genius nerd. *The New York Times*, 12 Aug. https://www.nytimes.com/2017/08/12/upshot/techs-damaging-myth-of-the-loner-genius-nerd.html.

Mitchell, W. J. T. 1986. *Iconology: Image, text, ideology*. Chicago, IL: University of Chicago Press.

Mulvey, L. 1975. Visual pleasure and narrative cinema. *Screen*, 16, 6–18. https://doi.org/10.1093/screen/16.3.6.

Nordmann, A. 2009. Invisible origins of nanotechnology: Herbert Gleiter, materials science, and questions of prestige. *Perspectives on Science*, 17 (2), 123–143.

Ollman, D., Price, S., and Smith, C. 2003. *The Yes Men*. MGM Distribution.

Ortolano, G. 2008. The literature and the science of 'two cultures' historiography. *Studies in History and Philosophy of Science Part A* 39 (1), 143–150. https://doi.org/10.1016/j.shpsa.2007.11.012.

Pinch, T. J. 1993. Testing-one, two, three…testing!' Toward a sociology of testing. *Science, Technology and Human Values*, 18 (1), 27–31.

Pinch, T. J., and Bijker, W. E. 1987. The social construction of facts and artifacts: Or how the sociology of science and the sociology of technology might benefit each other. *In* W. E. Bijker, T. P. Hughes, and T. Pinch, eds. *The social construction of technological systems: New directions in the sociology and history of technology*. Cambridge, MA: The MIT Press, 17–51.

Puolakka, K. 2014. Dewey and everyday aesthetics - a new look. *Contemporary Aesthetics*, 12. https://contempaesthetics.org/newvolume/pages/article.php?articleID=699.

Rarey, M. F. 2013. Visualism. *In* J. Elkins, K. McGuire, M. Burns, A. Chester, and J. Kuennen, eds. *Theorizing visual studies: Writing through the discipline*. New York: Routledge, 278–281.

Rödder, S. 2017. The climate of science-art and the art-science of the climate: Meeting points, boundary objects and boundary work. *Minerva*, 55 (1), 93–116. https://doi.org/10.1007/s11024-016-9312-y.

Rogers, H. S. 2012. *Art and science: The politics of knowledge categorization*. Thesis (PhD). Cornell University.

Rogers, H. S. 2020. STS by material means: Art critiquing science. *In* H. Borgdorff, P. Peters, and T. Pinch, eds. *Dialogues between artistic research and science and technology studies*, 1st ed. New York: Routledge, 76–88.

Rouse, J. 1992. What are cultural studies of scientific knowledge? *Configurations*, 1 (1), 57–94.

Saito, Y. 2007. *Everyday aesthetics*. Oxford: Oxford University Press.

Salter, C., Burri, R. V., and Dumit, J. 2016. Art, design, and performance. *In* U. Felt, R. Fouché, C. A. Miller, and L. Smith-Doerr, eds. *The handbook of science and technology studies*. Cambridge, MA: The MIT Press, 139–169.

Sandbrook, Dominic. 2006. *White heat 1964-1970*. London: Abacus.

Schaffer, A. 2015. The great-man myth. *MIT Technology Review*. https://www.technologyreview.com/s/539861/techs-enduring-great-man-myth/.

Schatzberg, E. 2006. Technik comes to America: Changing meanings of technology before 1930. *Technology and Culture*, 47 (3), 486–512.

Schechner, R. 2003. *Performance theory*. 2nd ed. New York: Routledge.

Schechner, R. 2006. *Performance studies: An introduction*. 2nd ed. New York: Routledge.

Schultz, E. A. 2010. Fear of scandalous knowledge: Arguing about coherence in scientific theory and practice. *Reviews in Anthropology*, 39 (4), 313–343. https://doi.org/10.1080/00938157.2010.524869.

Schultz, E. A. 2011. Risking connection across difference: Reply to Sokal and Smith. *Reviews in Anthropology*, 40 (2), 174–180. https://doi.org/10.1080/00938157.2011.572481.

Segal, H. P. 1986. The technological utopians. *In* J. J. Corn, ed. *Imagining tomorrow: History, technology, and the American future*. Cambridge, MA: The MIT Press, 119–136.

Shapin, S., and Schaffer, S. 2011. *Leviathan and the air-pump*. Princeton, NJ: Princeton University Press.

Shepherd-Barr, K. 2006. *Science on stage: From "Doctor Faustus" to "Copenhagen."* Princeton, NJ: Princeton University Press.

Smith, B. H. 2011. Clearing up after the science wars: A response to Emily A. Schultz. *Reviews in Anthropology*, 40 (2), 165–168. https://doi.org/10.1080/00938157.2011.572475.

Snow, C. P. 2012. *The two cultures*. Cambridge: Cambridge University Press.
Sokal, A. D. 1996a. A physicist experiments with cultural studies. *Lingua Franca*, 6 (4), 62–64.
Sokal, A. D. 1996b. Transgressing the boundaries: Toward a transformative hermeneutics of quantum gravity. *Social Text*, 46/47, 217–252.
Sokal, A. D. 2008. *Beyond the hoax: Science, philosophy and culture*. Oxford: Oxford University Press.
Sokal, A. D. 2011. Beyond the hoax: A response to Emily A. Schultz. *Reviews in Anthropology*, 40 (2), 169–173. https://doi.org/10.1080/00938157.2011.572477.
Somerville, M. 1834. On the connexion of the physical sciences by Mrs. Somerville. *Quarterly Review*, 51, 54–68.
Stafford, B. M. 1994. *Artful science: Enlightenment entertainment and the eclipse of visual education*. Cambridge, MA: The MIT Press.
Star, S. L. 2010. This is not a boundary object: Reflections on the origin of a concept. *Science, Technology, & Human Values*, 35, 601–617. https://doi.org/10.1177/0162243910377624.
Star, S. L., and Griesemer, J. R. 1989. Institutional ecology, 'translations,' and boundary objects: Amateurs and professionals in Berkeley's museum of vertebrate zoology, 1907–39. *Social Studies of Science*, 19 (3), 387–420.
Strauss, A. 1978. A social world perspective. *Studies in Symbolic Interaction*, 1, 119–128.
Strauss, A. 1982. Social worlds and legitimation processes. *Studies in Symbolic, Interaction*, 4, 171–190.
Susdorf, Marek. 2017. Björk's biophilia : A musical introduction to feminist new materialism. *Junctions: Graduate Journal of the Humanities*, 2 (2), 113–126. https://doi.org/10.33391/jgjh.39.
Turner, V. W. 1988 *The anthropology of performance*. New ed. New York: PAJ Publications.
Vacha, J. E. 1986. The federal theatre's living newspapers: New York's docudramas of the thirties. *New York History; Cooperstown, N.Y., etc.*, 67 (1), 67–89.
van Dijck, J. E. 2003. After the "two cultures:" Toward a "(multi) cultural" practice of science communication. *Science Communication*, 25, 177.
Van Maanen, H. 2009. *How to study art worlds*. Amsterdam: Amsterdam University Press.
Williams, K. S., and Mills, A. J. 2018. Hallie Flanagan and the federal theater project: A critical undoing of management history. *Journal of Management History*, 24 (3), 282–299.
Wilson, E. O. 1998. *Consilience: The unity of knowledge*. New York: Knopf.
Winner, L. 1980. Do artifacts have politics?" *Daedalus* 109, (1), 121–136.
Woolgar, S., and Latour, B. 1979. *Laboratory life: The construction of scientific facts*. Princeton, NJ: Princeton University Press.

Section 1

Constructing borders and borders at the intersections of art and science

Hannah Star Rogers

What does it mean to bring art and science together and what is produced? Further, what can STS (Science and Technology Studies) scholars learn from observing art and science in relationship to one another? In this section, artists, STS researchers, and practitioners who have worked with art discuss the relationship between art and science and the relationship between this type of work and STS itself. These chapters are each emblematic of the kinds of work we will see in this handbook because they tell the story of how artists and STS scholars alike have something to say about the intersection of art and science and about its relevance for STS, and vice versa. These chapters are selected to cover a range of mediums, career arcs, and types of analysis. They delve into the role of visualizations in scientific and artistic communities (Chapter 1), collaborative work for policy influence (Chapter 4), an artist and analyst reflecting on her discoveries through film (Chapter 3), and STS scholars considering what their field can learn from the arts (Chapter 2).

STS scholar Silvia Casini investigates the phenomenon of the rising number of data visualizations in scientific and artist communities. She discusses the role of data in some art and science collaborations by considering what counts as data for whom. Casini invokes Donna Haraway's "modest witness" as a way of reminding readers that data is not separable from its collectors and interpreters. Thinking about the way that the data exists in art and science networks necessarily means considering the artists and scientists who are creating and making use of data in their own ways. ASTS (Art, Science, and Technology Studies) scholarship benefits from comparing points of commonality like Casini's data visualizations. By comparing the creation, use, and interpretation of these visualizations in art and in science, new analyses of art and science as categories and as communities become possible.

Hanna Rose Shell is a filmmaker and STS scholar whose work in STS takes the form of both making films and conducting image analysis. In her chapter, she argues for film as a mode of research and a means of expression in STS. In particular, Shell argues for the experiential element in film by contending that researchers must add themselves to the picture to set ourselves in relation to practices and materials such that we experience what we are studying. While not

DOI: 10.4324/9780429437069-2

every use of film may be said to be aesthetic, Shell specifically argues for the potential of film as a research tool with those qualities. The researcher, she explains, can place herself inside the frame in an explicitly artistic use of the medium. Shell defends analysing images, which are often held in STS and other scholarly circles to involve such a multiplicity of meanings as to elude analysis. She does this by attacking the flexibility of language and suggesting that language is as supple a matter as images by examining the trajectory of her own series of film projects.

Artists and theorists Christian Nold and Karolina Sobecka further the STS tradition of seeking to influence public policy around science and technology. They argue that artists can harness the power of their own tools through "aesthetic strategies" that can enable the participation of artists in governance and public policy questions, particularly on questions that are often the domain of scientific or technical experts. The authors suggest two forms of intervention: one offers a mirror to current governance discourse by taking on the form of, to use their example, a conference on atmospheric experiments, but expanding the included experts by diversifying the makeup of the conference to include artists and designers a decision that also expanded the number of women participants. This mirroring shows what Bruno Latour might describe as "otherwise," an alternative way that decisions might be made and attempts to reveal the assumptions about how a given problem (in this case climate change) ought to be addressed.

The second "aesthetic strategy" involves bringing together two ideas that are usually seen as separate and recognizing them as newly relevant when considered together. In this case, "emotional maps" were created by participants under the facilitation of the authors that matched reported states from users with locations. The results were revelations about how problems and issues in a city relate to geography and novel ways of presenting the issues at stake in specific localities. Their work points towards possibilities for expanding artists' roles in STS interventions in public policy. It offers a new type of participant in public policy debates for analysis that may suggest the way that overlapping and competing expertise needs to be incorporated into governance processes.

STS has a great deal to learn from art and science projects, and in some cases, those projects appear to have features that overlap with STS work. This raises questions about the boundaries STS scholars have drawn around their own knowledge production and what counts as STS. Jane Calvert and Pablo Schyfter (2017) use their Synthetic Aesthetics experience of arranging collaborations between synthetic biologists and artists and designers to consider what STS can gain from art. The authors focus on the ways that their interests overlapped with those of the artists and designers working on the project. At the same time, artists who participated in Synthetic Aesthetics approached tasks and, in particular, worked with materials, in ways the authors found novel. Using interview materials and anecdotes, the authors demonstrate what STS scholars might learn from artists and designers based on those experiences.

ASTS scholars hail from STS, art, and theory backgrounds. They work directly with artistic mediums but also shape their artistic practices to science and technology contexts, for use in public policy debates, and to reach the public. As the field develops, more practitioners are likely to be recognized as older boundaries between art engaged with science and technology and STS fall away in the face of studies of practice. Like scientists and technologists who have worked with artists, the potential exists for STS scholars to instrumentalize art for their own ends. At the same time, STS scholars may increasingly look to art for potential methods and find both common ground and novel ways of working with materials and other people. These chapters help to bind the expanse of methods currently in use in ASTS. As more art and science work is analysed, ASTS scholars can look forward to a better understanding of how the categories of art and science operate and how artists and scientists may work together to produce new knowledge.

1

What counts as data and for whom? The role of the modest witness in art–science collaboration

Silvia Casini

> The many stuffs – matter, energy, waves, phenomena – that worlds are made of are made along with the worlds. But made from what? Not from nothing, after all, but from other worlds.
>
> *Goodman (1975)*

Making and experiencing world(s)

Upon entering the white room, the visitor finds herself in a net of interwoven elastic black ropes stretching from floor to ceiling and from wall to wall. The gossamer thin filaments of webs arranged in a labyrinth-like geometry are disorienting. Is this a representation of a spider's comings and goings, of neural networks or a monumental installation of galaxies forming along filaments like droplets on a spider's web? Whether or not the artist meant to posit an analogy between the origin of the universe, ourselves, and the spider's web, the visitor embarks on a journey where interdependent life systems are the result of chance and play not just of careful reasoning and planning. Is it a world in which humans could live? And how?

The immersive environment created by the artist Tomás Saraceno for the 53rd edition of the Venice Biennale, *Making Worlds/Fare Mondi*, curated by Daniel Birnbaum in 2009, looks like a cosmic landscape or a neuronal network. Saraceno's *Galaxies Forming Along Filaments* and *Like Droplets Along the Strands of a Spider's Web* (2008) can be experienced haptically: when touching the cords, visitors experience a vibration propagating through the network, thus sensing the entanglement of the elements composing this artist's world. Tomás Saraceno's work of art is a universe of autonomous sense with its own rules. Saraceno's installation gives me the opportunity to raise two points that are at the core of this chapter and that will enable the reader to gain a firm understanding of the emerging field of inquiry and collaborative practice called art–science. Firstly, art (like science) is a way of world-making (Goodman 1978). Secondly, the visualization and use of data is a common denominator of some art and science practice.

The benefits of visualizing data include the ability to see the similarity of structures that are mirrored in many network-like systems in the world. Different systems such as the human brain, the internet, transportation grids, and even social structures operate under the paradigm of the network (Lima 2011). The visualization of data, which is one of the key

DOI: 10.4324/9780429437069-3

techno-cultural phenomena of our age (Manovich 2011), can enable or hinder both the perception and understanding of structure and dynamics in complex network systems. The impact of data visualization has extended beyond areas of scientific inquiry: their aesthetic has also caught the attention of artists, whose work is characterized by the representation of network topologies and complex patterns of nodes (Talasek 2015: 2295). Saraceno's installation shows how art–science collaborative work enables users to experience a complex network of data (itself a world) with the sensory-motor apparatus.

In this chapter, I introduce the concept of the "modest witness" in art–science projects to understand how facts are generated from data, validated, and then circulated within and beyond the laboratory into the public arena. The expression "modest witness" is used ironically by the feminist, cultural theorist, and philosopher Donna Haraway to unveil the key figure in the Scientific Revolution of the seventeenth century that was coined by Robert Boyle, one of the fathers of the experimental method.

The modest witness was the scientific observer whose disinterested observation of phenomena has been presented as central to the scientific method (Haraway 1997).[1] This term described those who were witnessing the experiment, and by doing so, contributing to establishing it as truth. In her essay "Modest_Witness@Second_Millenium," Haraway first deconstructs the figure of the "modest witness" and then reconfigures it as a kind of "*mutated* modest witness," who could help bring better technoscience and better worlds into being (Schneider 2005: 91). The modest witness, far from being an objective observer whose testimony is crucial, can determine what counts as knowledge and for whom.

Theoretical or curatorial work engaging with art–science using the framework of data visualization should ask the question of what counts as data and for whom, specifically in the material culture of the laboratory and the studio. Data visualization does not simply illustrate a phenomenon but intervenes in the knowledge-making and interpretative process. Artists and scientists use data visualization tools to construct knowledge about ourselves and the world. Art and science collaboration deals, selectively, but consistently, with processes that touch on people's lives, including the constitution of subjectivities and the distribution of power within society. These exchanges and processes are based on data creation, visualization, and circulation.

The term "visualization" varies across knowledge domains. It can be defined as any message presented in a format suitable for display, which provides evidence to the viewer. Visualizations can have descriptive, aesthetic, instructive, explanatory, interpretative, evaluative, and persuasive intents (Hegarty 2011; Polman and Gebre 2015; Tufte 2001). They can also function as bridges between communities of users from different backgrounds (for example, scientists and artists) and their ways of seeing (Wise 2006). In this sense, visualization works as a boundary object favouring a common understanding despite users' different views (Star and Griesemer 1989). Scientists seem to treat visualizations not simply as an aid to science, but rather as ways of thinking through a data set and coming up with possible ways of interpreting and displaying data. Lynch and Vignone point out how scientists recur to visualization beyond mimesis and convention to render familiar to the lay audience phenomena that are "strange" – for example, because they are out of scale (too small to be perceived by the naked eye) as in the case of nano images (de Ridder-Vignone and Lynch 2012).

Visualizations are how science creates its objects, conducts its inquiries, and advances its arguments. The use of images in scientific practice has raised the interest of scholars in different fields, particularly since Martin Rudwick's (1976) seminal paper on the emergence of a "visual language" for geologists in the eighteenth and nineteenth centuries. As the history of science and technology has shown, scientific practice has always been about creating new worlds and new objects, so that they become visible, or about throwing new light onto familiar things, so that the way we look at the changes. Well-known examples from different historical periods are Leonardo da Vinci's anatomical drawings, Galileo Galilei's observations of the moon surface made visible by his telescope, and Santiago Ramón y Cajal's drawings of neurons and neural functions visualized and lit up in colourful brain scans. All these visualizations enable us to interrogate, rather than simply represent, the object made visible. Visualization, therefore, both in the arts and in the sciences, works as a "question-generating machine" (Rheinberger 1997: 32).

A conceptual framework to assess and challenge power relationships in art–science

The art historian Jean Clair, who curated the exhibition *L'âme au corps: arts et sciences 1793–1993* (Galeries nationales du Grand Palais, Paris, October 1993–January 1994), laments that the divorce of art and science, which is a spiritual catastrophe, is caused by two circumstances. Firstly, since Romanticism art has given away the monopoly of objectivity to the sciences, keeping for itself only the soft hypertrophy of the ego characterizes the self-styled genius of the artist. Science, conversely, is lost in its graphs and fragmented specialties, and has cut itself off from the real world:

> But once the sciences have occupied the various fields of knowledge with their authority, the artist, kicked out from a kingdom he once shared on equal terms and sent back to the empiricism of the craftsman ("stupid as a painter"), the artist cannot help but give himself to soliloquy or prophecy, in search of a status but also of a lost profession.
>
> *Clair (2016: 16)*[2]

Clair claims that art would be the biggest loser should the lack of a dialogue between art and science take over. Clair uses the tools offered by art history to demonstrate that this divorce has been only a momentary split. Referring to the drawings of the neurons made by Ramón y Cajal, regarded as the father of modern neurosciences, Clair demonstrates how drawing, in particular, has always been in a dialogue with science.

Along with art history, the conceptual tools offered by the fields of Science and Technology Studies (STS) and historical epistemology can bring to the foreground how art is not necessarily ancillary to science but rather complementary and essential for a more balanced and cohesive society. Scholarly work in STS and science epistemology has explored the connections between the cultures of experimentation in science and art, examining the material practice and the experiential dimension of artists and scientists working in the laboratory and the studio (Patterson 2015; Rheinberger 1997; Schatzki and Knorr Cetina 2000). Both art and science see, interpret, and construct worlds. The past decades have seen a proliferation of science-art initiatives, drawing attention to the processes enacted and to the artefacts produced within art–science projects.

The fact that collaborative art and science projects are increasingly popular softens Clair's pessimism in relation to the possibility of a dialogue between art and science. Nevertheless, his attention to drawing and craftsmanship, which is the belief that art has to do with skill and talent acquired through study and practice, is useful to move away from the Romantic idea of the artistic genius. Data visualization is also an example of craftsmanship rather than innate talent. The technical ability to turn data into a visualization can be achieved by means of an apparatus (instruments and/or imaging procedures) or simply by hand (Bredekamp and Schneider 2015).

Science activities are increasingly characterized by aesthetic concerns. Scientists often use aesthetic values in the evaluation and choice of how to visualize data. In the early days of nuclear imaging development, for example, physicists rendered their data in both numerical and visual form. Physicists relied on numbers, while radiologists on images, preferably in black and white rather than colours for they were accustomed to read X-rays (Joyce 2006). The science photographer Felice Frankel recommends scientists to pay attention to the role of aesthetic elements such as composition, colour, and refinement in displaying and interpreting data (Frankel and Depace 2012).

My present reflections are grounded in extensive work I have conducted both as a researcher and as a curator of art–science work, particularly in the field of biomedical imaging. For almost a decade, I have been working on the epistemological, aesthetic, and historical role played by data visualization practices across contemporary biomedicine, neuroscience, and the arts. Making a short experimental video on the experience of undergoing a scan with magnetic resonance imaging (MRI) led me to the curatorship of the MRI-based work of the French sculptor Marc Didou (Casini 2008, 2017), one of the few artists whose way of working in his chosen medium (sculpture) has been influenced by the encounter with MRI technology. Secondly, my ongoing study of data visualization practices in the biomedical physics laboratory at the University of Aberdeen has facilitated the call for an artist-in-residence project.

For this second project, my focus has been on what and how scientists visualize when an emerging image-generating technique is under development, when the protocol for image generation/data interpretation has not yet crystallized into a visual output. What do scientists see? And how is what they see reinvented? What visual practices and theories do visual artists adopt when they use biomedical imaging techniques to engage with and reconfigure the neurosciences and other biomedical imaging fields? To engage with this set of questions, I conducted extensive archival research, oral history interviews, and fieldwork with contemporary image-makers in the laboratory and the art studio. In both cases, I witnessed how the role of the artist, curator, or scholar in art–science projects is crucial to any understanding of power relationships between the various actors involved.

As I discuss in what follows, the main roles that the artist or humanities/social sciences scholar can undertake are that of the attached observer, of the active participant, or of the scholar embedded in the laboratory. Sometimes these roles can overlap. The role of the "attached observer" (Leach 2006) envisages the scholar embedded in the laboratory as an anthropologist doing ethnographic work, taking down notes of how facts are produced in the everyday life of the laboratory (Latour and Woolgar 1979). Another role can be that of an active participant in a research project in which the artist and scientist co-design the project methodology. Active participation can help unveil hidden agendas and assumptions at work in the laboratory (Calvert and Schyfter 2017). The output of the collaboration is a co-authored hybrid, which does not necessarily mean that the art and science contribution is equally distributed. Art and design practice has a "speculative, experimental and open-ended character" (Ingold 2013: 8) that can inform researchers in STS conducting collaborative work with scientists (Calvert and Schyfter 2017). The last role is that of the "embedded-humanist" in the laboratory. The embedded humanist observes and intervenes in scientific practice to shape the course of action of a project/experiment, and then studies the product of the intervention. The goal of this type of engaged intervention is not just to share knowledge or methods but to potentially change the course of a research project or of a specific experiment (Fisher et al. 2015).

Besides investigating the role of artist/humanities-social science scholars in the laboratory, attention has been devoted to the roles played by scientists. In this chapter, I suggest that in the context of art–science collaboration, scholars and artists can play a new role besides those I discussed above: the role of the "modest witness." By bringing together Donna Haraway's figure of the modest witness and a diverse body of scholarly literature on data-centred research in experimental systems (Halpern 2015; Leonelli 2016; Rheinberger 2011), this chapter argues that unveiling the role of the modest witness is a required action for any scholar and/or artist engaged in art–science. It is also imperative that one is willing to explore the power relationship issues at stake in the laboratory and then in the actual art–science collaboration. This conceptual framework can enable researchers to address matters of concern rather than just matters of fact in the situated laboratory and art–science settings.

My argument unfolds in two sections: one more focused on the figure of the modest witness and the second on data visualization and affectivity. Firstly, I trace the birth of the witness in Robert Boyle's experimental method using the critical framework provided by Shapin and Schaffer's work. I then examine Haraway's ironical proposal of the "modest witness" and the possibility it opens up for re-thinking not just the role of scientists in the laboratory but also that of scholars and artists engaged in art–science collaborative projects. Secondly, I use Leonelli's framework of data-driven science to discuss what kind of "things" take on the role of data once the artist/scholar enters the laboratory as a new type of "modest witness." Visualization and affectivity play a crucial role in how data is formed, displayed, and contested inside the laboratory.

The birth and re-incarnation of the modest witness

Witnessing can take multiple forms. In law, the witness is the person who gives testimony under oath and penalty of perjury in a court of law. The statement of truth at the end of a witness statement should say: "I believe that the facts stated in this witness statement are true." Partially, this legal definition rubs off on how scientific practice understands the role of the witness. Firstly, the witness is one of the ways in which scientific knowledge is generated and then consolidated into facts for dissemination beyond the closed circuit of the laboratory. Correct the sentence as follows: Secondly, the witness is a way of exploring what counts as data and of assessing the power relationship and epistemological assumptions that are at work in art-science projects.

Power relationships in art–science collaboration can take many forms. One should look at what counts as truth (knowledge), and at how power is structured and organized in relation to the specific collaboration. Investigating and thinking through the act of witnessing is intimately connected to the questions of what the data represents and for whom it is intended. The artist or scholar's act of witnessing is the first means by which power dynamics in art–science settings can be made explicit and, possibly, even challenged. Namely, it gives the witness the possibility to re-work the hierarchy of priorities and roles by bringing into a network the various "actants" (objects, bodies, instruments, spaces; Law and Hassard 1999) to work towards a project whose output is not predetermined. Furthermore, it gives the opportunity to re-tell the history of technological innovation in such a way that it counts for peripheral narratives that do not enter official records. Finally, it offers ways of presenting data that eschew the experimental protocol established in the laboratory.

In order to understand how facts are generated and validated, it is useful to revisit Robert Boyle's experiment with the air pump. During the Restoration period in England, immediately after the Civil War, the natural philosopher Robert Boyle (1627–1691) played a key role in the establishment of the experimental method. By means of scientific investigations and experiments, Boyle contested the blind acceptance of authority in matters of science and demanded that the question "why?" should be addressed in every inquiry into the truth of matters. His revolution in chemistry was to attempt a systematic organization of knowledge gained through experiments. The first tenet of Boyle's philosophy is that observation and experiment should have epistemic priority over theory. Interested in alchemy and versed in, among other disciplines, hydrodynamics, Boyle conducted a variety of experiments with his vacuum pump.

In the book *New Experiments Physico-Mechanical, Touching the Spring of the Air, and Its Effects* (1669), Boyle described his experiments with the vacuum chamber or air pump. These experiments led to the formulation of the so-called Boyle's law that describes the inversely proportional relationship between the absolute pressure and the volume of a gas if the temperature is kept constant within a closed system. His experimental results led him to think of matter as composed of minute particles that he called "corpuscles."[3] Boyle was interested in exploring the interaction between invisible forces with material objects in the physical world. Boyle highlighted the role played by spiritual entities in nature: for him, it was God who first impressed motion upon atoms and then continued to direct and organize the primary corpuscles' velocity and direction of motion (Clericuzio 2001: 473).

In their discussion of Boyle's air pump experiments and of the dispute between Boyle and Hobbes, Shapin and Schaffer demonstrate how the experimental and empirical method of science is far from being "natural," being rather the product of social conventions at work in a specific epoch in the history of science. For Shapin and Schaffer, the divergent view of natural knowledge was at the centre of the dispute between the political philosopher Thomas Hobbes and the natural philosopher Boyle around the distribution of scientific and political power. The production of scientific facts required Boyle to carefully perform his experiments in semi-public assemblies until all those present arrived at a consensus about the findings. Facts were generated by collective acts of eye witnessing in a public space (Shapin 1984), although not everyone was let in nor every testimony was considered to be of equal worth. Only men who held upper-class positions in society were qualified to count as witnesses to the experiments because the community of witnesses was the collective body through which facts were established.

The three technologies required to create facts were a material technology (the air pump) that leaked and was therefore faulty; a literary technology that would enable those who were not direct witness to get to know the phenomena generated by the first technology (the witnesses had to write a report on the experiment using an unadorned, concise, and impersonal writing style); and a social technology that established scientific conventions for evaluating knowledge claims (Shapin and Schaffer 1985: 25). Each of Boyle's three technologies worked as an objectifying resource by making the facts appear to be data, not artefacts (77).[4] Facts spoke for themselves and the scientist was a merely "modest witness." The air pump, however, generated not a fact but a visual experience that needed to be turned into a matter of fact by a witness (Shapin 1984: 508).

The visual experience created by the air pump is at the centre of the painting by Joseph Wright, *An Experiment on a Bird in the Air Pump* (1768, oil on canvas, The National Gallery, London). Made around one hundred years later after Boyle's use of the air pump, the painting showed how the transformation of data into facts was far from being straightforward even in the presence of witnesses, the new epistemological subjects. In Wrights' painting, a small group of people, including women and children, are gathered together to watch the demonstration of a vacuum created by the air pump. This more or less realistic depiction of Boyle's experiment portrays the variety of expressions of the lay public witnessing the event – from absorption to indifference and disquiet – rather than the acceptance of the spectacle of science unfolding in front of their eyes. In the words of Baudot:

> If (…) Boyle's air pump narratives record matters of fact and reject metaphysical interpretations of emptiness, Wright develops (…) an equivocal style in which a thing is (a) just a thing; (b) a symbol of something else; and (c) a symbol for a multiplicity of possible things.
>
> *Baudot (2012: 3)*

This visual experience was not omni-comprehensive in so far as it could not count for the immaterial bodies produced by the air pump that is the vacuum.[5] The dispute between Boyle and Hobbes centred on what constitutes truth. For Boyle, vacuum exists because of the air pump experiments. For Hobbes, not only nature abhors vacuum but also "truth" itself depended only on the credible witnessing act – hence, the fact was co-produced by the public, a statement that was unacceptable for Hobbes who believed in the primacy of philosophy as the ground on which truth claims could be made.

Donna Haraway draws on Shapin and Schaffer's work to deconstruct the figure of the modest witness. In the demonstrations of Boyle's air pump, what was at stake was much more than the existence or nonexistence of the vacuum in nature (Haraway 1997). Placed within the literary and social technologies of "testimony," the air pump acquired the power to establish factual data independent from the endless political polemics and religious disputes of the time. As she highlights, the mode of spectatorship of the air pump experiment was neither modest nor objective; rather, it was part of the performance of facts. The spectacle of science was taken out of the laboratory to be legitimated by the certain public as can be the case even nowadays with certain spaces and exhibitions devoted to the acritical display of the marvels of cutting-edge science and technology.

The modest witness is a style of thought in which knowledge production is unbiased, factual, and objective.[6] By means of removing oneself as much as possible from the experiment, working with and arranging data as if they were a-contextual, collating the data in an impersonal style of writing devoid of metaphors, scientists reinforce their power by seemingly presenting themselves as authoritative and detached. Therefore, the modest witness becomes a disembodied voice from nowhere endowed with the power to establish facts. The world of facts seems to speak for itself rather than the scientist articulating her embodied and partial knowledge. Haraway seeks to give the modest witness a more situated presence in the world of science and technology with the goal of making a difference in the world by means of "(…) seeing; attesting; standing publicly accountable for, and psychically vulnerable to, one's visions and representations" (Haraway 1997: 155). Artists might be able to facilitate the re-embodiment of scientists themselves into the modest witness whenever they are involved in art–science collaboration.

The concept of situated presence is not a feature of our contemporary age, given that the bodily engagement with nature was a key component of the birth of modernity (Smith 2004). In her attempt to synthesize the visual and scientific traditions in early modernity, namely, Smith identifies in the neglected bodies of the artisans the impetus for the early modern worldview. The manual labour of the craftsman and of the medical practitioner such as Vesalius (versus the Galenic tradition) emphasized the primacy of direct observation and cumulative practical experience over the textual transmission of information and theoretical knowledge.

In relation to the question of what their perceived role is in a scientific setting, artists give a variety of answers (Debatty et al. 2011). Some want to trigger a sense of mystery for the universe we inhabit, others talk about being part of a collective endeavour without any specific individual role, and others see themselves as educators or enablers of citizen-science projects such as those implemented by the Critical Art Ensemble (CAE).[7] In *Free Range Grain*

(2003–2004), Beatriz da Costa, a former student of student of Haraway and a member of CAE, together with Shyh-shiun Shyu set up a portable and public laboratory that used molecular biology techniques to test food for the more common genetic modifications (GM). Users were invited to bring food to the laboratory that they thought it could be suspect. The idea was to enable the general public to test foods themselves instead of relying on the labelling provided by corporations and governments. Opening the doors of the laboratory is at the core of the 2013 documentary web series *DIYSECT*, created by the filmmaker Benjamin Welmond and the artist-biologist Mary Maggic Tsang. The series focuses on DIY biology and art with the help of biohackers, synthetic biologists, writers, and curators. The goal is to increase public access and foster a discussion on the societal changes brought by biotechnology and the growing practice of non-institutional biohacking.

Bioartist Adam Zaretsky envisages a role akin to that of the modest witness when he talks about "My self-appointed role is always to try to communicate an immersed and informed, 'demystified' version of the libido which drives the obscure processes of scientific research to the public and scientists themselves" (2011: 101). Taking up Haraway's reconfigured role of the modest witness can enable those involved in art–science collaboration (artists/scholars and scientists alike) to stop being removed from their own practice to take responsibility for the entanglement between researchers and data. Taking up this role is the first step towards a kind of art–science that moves beyond public engagement to become self-reflexive and interventionist in the very space of the laboratory. The second step for artists, as I shall discuss in the following section, is to focus on data visualization to operate *within* science rather than *around* it, bringing to the fore the affective dimension of data in scientific practice.

What counts as data and for whom? The role of the modest witness in art–science collaboration

Data (literally, "the givens") is one of the most taken-for-granted words in all the sciences: short and unpretentious, it expresses the simplest and apparently most straightforward elements of empirical research. Whether inscribed as magnetic signals, digital information, traces on photographic emulsions, sketches or scribbles on notecards, or meticulous entries in laboratory notebooks, data supply the essential raw materials for all scientific activity, from observing to theorizing. Data-driven science is the novel paradigm for research implying that knowledge can be extracted from data without reliance on preconceived hypotheses.

The work of the philosopher of social sciences Sabina Leonelli on data production in biology and data journeys across laboratories is a good starting point for understanding the epistemological implications of data-driven science. She points out that data are either objects treated as evidence for making claims about phenomena or handled in such a way to facilitate their circulation for further analysis among researchers and research groups (Leonelli 2016: 78). The definition of data in Leonelli is connected to their portability. Data do not have "intrinsic representational powers" but rather "acquire evidential value through mobilization" (198).

Latour claims that scientific images are inscriptions that enable scientists to work with two-dimensional objects rather than with the full subject in all its complexity. These inscriptions act as "immutable mobiles" – things that do not lose their meaning in transmission:

> Inscriptions are mobile (…) immutable when they move (…) flat (…) [their scale] may be modified at will (…) They can be reproduced and spread at little cost (…) they can be reshuffled and recombined (…) [they can] be made part of a written text. (…) some

> aspects of scientific study are enhanced when rendered as representations. (…) You cannot measure the sun, but you can measure a photograph of the sun with a ruler.
>
> *Latour (1986: 18–20)*

Leonelli argues that the same objects can function or not as data depending on the situation. Thus, data should be understood as a "relational category." In her work, data need to be de-contextualized so they can be circulated and then re-contextualized and used by other researchers. Certain infrastructures, such as databases, are crucial to enable this procedure.

The artist or scholar can re-contextualize data. To do so, one needs to engage with the following questions: what counts as data (automated data analysis, databases, data produced by means of technology in a laboratory setting) and what counts as scientific knowledge; how this relates to the social worlds within which data are produced (Leonelli 2016). These are issues that scientists must tackle whenever they are working on an experiment, building a new technology, or developing a new theory.

The role of the modest witness explored in the previous section is intimately connected to the question of whose data, how they are created, and for whom is the data intended. In the experiment set-up by Boyle, for example, the modest witnesses prompt the lay public and scientists alike to face the issue of how to make knowledge claims in an unstable environment. In an experiment, one produces traces that are connected to the process under investigation. These traces, however, have a volatile character. To preserve these traces for further work, one needs to make them stable to transform them into data. The problem is that the transformation of traces into data often implies a gain in durability but a loss in materiality. The point of importing the figure of the modest witness from the field of STS to art–science collaboration is to assess whether the epistemological assumptions at work in scientific practice can be made explicit, discussed, and even challenged.

The focus of this chapter is on data visualization, however, rather than on data alone. Whether in the form of a photograph, a diagram, or a graph, data visualization in science is both a discursive tool with which to share experimental outcomes to colleagues without the need to reproduce the experiment, and a rhetorical way to convince audiences reaching out beyond the strict scientific circle of those who are already part of the experimental setting. Visualization plays a key role in how data travel across laboratories and from the laboratory to the wider cultural arena – popular magazines, scientific journals, exhibitions, and public engagement initiatives are means through which data travel and solidify into knowledge. Visualization is also a crucial component of how data are formed inside the laboratory. Data are produced by human interactions with research instruments. Therefore, they are relational entities rather than a straightforward representation of the phenomenon under investigation. Data visualization is not only a practice to make visible that which is not in sight, but much more a vital process capable of producing new relations – cognitive and affective – between data and people.

Data visualization cannot be discussed without attention to its socio-cultural and historical specificities: the process of turning data into visual output is profoundly historical, locally constructed, and co-evolving with the specific circumstances in which it is situated (Harding 2008).[8] Going back to Leonelli, scientific practice should be studied by looking at the "situation," which is defined as "the dynamic entanglement of conceptual, material, social, and institutional factors involved in developing knowledge and clearly positions research efforts in relation to the publics for whom such knowledge is expected to be of value" (Leonelli 2016: 8). Scientific data visualization emerges from highly specific situations and processes that are fragmented and recursive, exhibiting a rhizomatic pattern (Rheinberger 2010: xii).[9]

By working through data and ways to reconfigure them, scholars and practitioners involved in art–science collaborative work are in the position of making visible the choices that scientists make in the laboratory. Like data visualization does not speak for itself but always embodies a specific voice – usually from the dominant group among various stakeholders (for example, a certain research group). The choices made by scientists with respect to data emerge from intellectual, technical, political, or economic struggles, all of which entail power imbalances. These choices remain hidden in the final published output.

This invisibility happens because in scientific practice, "facts" included data visualization strategies, which are constructed, then stabilized, and black-boxed. In science studies, Bruno Latour defines black-boxing as the way scientific, technical, and social work is made invisible by its own success. When a machine runs efficiently, when a matter of fact is settled, one needs to focus only on its inputs and outputs, and not on its internal complexity. Thus, paradoxically, the more science and technology succeed, the opaquer and obscure they become (Latour 1999: 304).

Latour uses the metaphor of the black box to describe scientific practice – to make science is to construct and close a black box. Laboratory findings and events, for example, are often black-boxed and presented as facts. The black box can be reopened on a number of occasions. Firstly, when a controversy arises, the solution provided falls apart, and there is the need to re-examine the assumptions made. Secondly, a black box can be opened by looking at the early stages of the development of a technology, for example, before the data visualization protocol becomes standardized. Thirdly, a black box can be opened by artists who enter experimental systems as if they were spaces of imagination. Artists as modest witnesses can challenge the assumptions made or intervene in any given data visualization pipeline within the laboratory to examine what is inside the box. For example, a technology used in everyday laboratory work can function as a black box, which can be reopened, and thus, become an object of epistemic interest.

Furthermore, visualization, like images, is entangled with memory and affect. Though the conventions of visualization that one sees reappearing in scientific images emphasize simplicity and condemn embellishments, critical theories of data visualization and design, particularly in feminist studies, have long insisted upon the embodied, visceral character of our cognition and vision (Haraway 1988; Harding 1991). The capacity of data to act, to affect, and to be affected demonstrates how data are things whose vitality exceeds their use (Amoore 2013: 133).

In data-driven science, affectivity plays a role. The affective turn has emerged as a mood of inquiry focusing on emotion and affects to generate and reconfigure knowledge (Clough and Halley 2007; Massumi 2002; Wilson 2010). The affective register of laboratory labour can emerge both through undertaking laboratory ethnography and through archive-based work. Affectivity is connected to materiality, with reference not just to bodily processes but also to the material world as a site of affective exchange between and human and non-human agents (including machines and their components). Digging up archival objects, and engaging with images and instruments in the workshop and the laboratory, is a way to evoke and explore the affective dimension of data. As Turkle argues, thought and feeling are inseparable in objects: "We think with the objects we love; we love the objects we think with" (2007: 5).

STS scholars undertaking laboratory fieldwork in different disciplines (from neuroscience to molecular biology and space exploration) have demonstrated how often scientists articulate their science through their bodies and feelings. Gesture, affect, and imagination all contribute to shaping scientific knowledge. For example, Morana Alač, Natasha Myers, and Janet Vertesi all address multimodal embodied practice in the laboratory, basing their works upon extensive laboratory fieldwork in neuroscience, molecular biology, and space exploration, respectively. Myers (2015), for example, describes how molecular biologists feel their way through data to interpret molecular forms. Vertesi (2014) explores the intimacy that space scientists develop with their instruments through their sensorial apparatus, not only for vision, but also for haptic and remote sensing.

Art–science scholars and practitioners can foreground behind-the-scenes work conducted by scientists in the laboratory. Digging up design sketches, old photographs, laboratory notes, and newspaper clippings might seem to be marginal at first look – the "cursed" part of scientific research – which then turns out to be the driving forces and narratives behind the development of a certain technology or of a certain scientific theory. These "things" are repositories of memory and affective labour.

For example, the manual labour involved in the creation of each component of a new technology (from the design and assemblage of hardware to writing the code, to the methods for turning data into images) is not simply a way of taking care of the technological object but much more a way of taking care of the end users of this technology (researchers, patients, and so on). Regardless of how collective the labour is, it is always framed around the final publication in which the manual labour mentioned above ends up being significantly neglected. The modest witness, embedded in the laboratory as an attached observer from the humanities, social sciences, or the arts, can bring to the foreground this highly unstable, affective immersion in the spectacle of data-driven science.

The alive space of laboratory experimentation is characterized by the assemblage of instruments, technologies, way of seeing, different expertise, codes, data, and bodies. Laboratory ethnography and the archive become the repositories of socio-technical and affective imaginaries rather than dead documents and objects waiting to be brought back to life. The material coming from the laboratory and the archive brings to the foreground the historical socio-cultural and affective tropes embedded in data visualization. Artists can contribute to digging up the histories of archival objects, embodied and emotional laboratory work, and less institutional narratives related to scientific practice and data visualization. The modest witness, being an artist or a humanities/social sciences scholar, can highlight how affectivity is part of the laboratory experimental culture. It also acknowledges how affectivity can lead to a scientific practice where matters of concern are on equal footing to matters of fact.

Conclusions

Artists and humanities/social sciences scholars can open up the black box of data visualization, questioning the given chain of facts production and validation to highlight or defuse any self-referential mechanism at play in scientific practice. However, they can do so only if they can access the data and also the decision regarding where, by, and for whom the data is produced, interpreted, and disseminated. They can intervene by taking on the role of the "modest witness" to investigate, make explicit, and to determine those who are qualified to enter the laboratory. For example, artists and scholars alike can reveal who is entitled to use and create new technologies, to establish and validate a protocol, to generate data, and then to disseminate them. Observing, thus, becomes a way of taking responsibility.

The new modest witness willing to understand and enable the formation of interdisciplinary knowledge practices in art–science should not focus her gaze on the scale of disciplinary silos or paradigms. Rather, as the historian of science Hans-Jörg Rheinberger has demonstrated in his work on modern experimental systems, one should be aware of the spaces and practices of experimentation characterized by uncertainty – where the liveliness of data and experimentation has not yet been stilled by epistemological resolution (Rheinberger 2011: 315). Each experimental system contains narratives in excess, both old stories and fragments that might contribute to future stories (Rheinberger 1994: 78). The new modest witness is called to testify how the epistemic boundaries of the experiment remain always in flux.

Exploring the affective dimension of science practice and its narratives brings out the socio-cultural and political aspects of science in the making. Scientists might be encouraged not only to become aware of the broader history of their practices but also to reconnect to the personal and emotional dimension of science. When successful, the modest witnesses can foster the conceptual shift from "matters of fact" to "matters of concern" that Latour talks about (Latour 2004). Matters of fact do not engage with network complexity and power dynamics. Phenomena are observed in a "clinical" way, positioned by the norms created by certain theories, and validated throughout certain experimental protocols. Matters of concern engage with the broader, relational contexts that phenomena inhabit as integral parts of the world, as the installations by Tomas Saraceno show. These worlds can not only be inhabited but also be contested.

Notes

1 Haraway takes the expression "modest witness" from the book *Leviathan and the Air-Pump: Hobbes, Boyle, and the Experimental Life* by Shapin and Schaffer (1985).
2 My translation from the original text in Italian: "Ma una volta che le scienze avranno occupato con autorità i diversi campi del sapere, l'artista, scacciato da un regno che condivideva da pari a pari, rimandato all'empirismo dell'artigiano ('stupido come un pittore'), non potrà far altro che darsi al soliloquio o al vaticinio, alla ricerca di uno status ma anche di un mestiere perduto."
3 Boyle articulated his theory of matter in *The Origin of Forms and Qualities* 1666. See Davis (1999).
4 Here, "data" is to be understood in its etymological sense, that is, "the givens."
5 Latour describes Hobbes's horrified reaction at Boyle's masterpiece, the air pump (Latour 1993: 20).
6 Objectivity itself has a history as Daston and Galison pointed out in their historical typology of all the things that objectivity has referred to across the centuries from truth-to-nature through mechanical objectivity to trained judgement (Daston and Galison 2007).
7 Formed in the 1980s, The Critical Art Ensemble (CAE) is a collective of tactical media practitioners specialized in, among others, computer graphics, film/video, photography, text art, and performance. CAE's focus has been on the exploration of the intersections between art, critical theory, technology, and political activism.
8 See, in particular, the section entitled "Co-evolving Science and Society," pp. 75–97.
9 Rheinberger, historian and philosopher of the biological sciences, uses the Deleuzian locution "rhizomatic structure" to describe scientific knowledge.

References

Amoore, L. (2013). *The Politics of Possibility: Risk and Security beyond Probability*. Durham, NC: Duke University Press.

Baudot, L. (2012). An Air of History: Joseph Wright's and Robert Boyle's Air Pump Narratives, *Eighteenth-Century Studies*, 46(1), pp. 1–28.

Bredekamp, H. and Schneider, B. (2015). Introduction: The Image – A Cultural Technology. A Research Program for a Critical Analysis of Images. In: H. Bredekamp, V. Dünkel, B. Schneider, eds., *The Technical Image. A History of Styles in Scientific Imagery*. Chicago, IL: Chicago University Press, pp. 1–5.

Calvert, J. and Schyfter, P. (2017). What Can Science and Technology Studies Learn from Art and Design? Reflections on "Synthetic Aesthetics", *Social Studies of Science*, 47(2), pp. 195–215.

Casini, S. (2008). Magnetic Attractions: Sculpture, Magnetic Resonance Imaging and Cinema. In: S. Casini, ed., *Marc Didou*. Exhibition catalogue, ed., Belfast: Queen's University, pp. 4–18.

Casini, S. (2017). Scanning, Framing and Close-up: Reimaging the Brain in 265 Looping Snapshots, *Leonardo Journal*, 50(2), pp. 127–131.
Clair, J. (2016). Le farfalle dell'anima, *Museologia Scientifica Memorie*, 15, pp. 13–18.
Clericuzio, A. (2001). Gassendi, Charleton and Boyle on Matter and Motion. In: C. Lüthy, J. Murdoch, J. Emery and W. Newman, eds., *Late Medieval and Early Modern Corpuscular Matter Theories Vol. 1*. Leiden, Boston, MA and Koeln: Brill Publisher, pp. 467–482.
Clough, P. T. and Halley, J. (2007). *The Affective Turn: Theorizing the Social*. Durham, NC: Duke University Press.
Daston, L. and Galison, P. (2007). O*bjectivity*. New York: Zone Books.
Davis, E. (1999). *The Works of Robert Boyle*. New York and London: Routledge.
de Ridder-Vignone, K. and Lynch, M. (2012). Images and Imaginations: An Exploration of Nanotechnology Image Galleries, *Leonardo*, 45(5), pp. 447–454.
Debatty, R., Evans, C., Garcia, P. and Thumb, A. (2011). *New Art/Science Affinities*. Pittsburgh: Carnegie Mellon University.
Fisher, E., O'Rourke, M., Kennedy, E., Evans, R., Gorman, M. and Seager, T. (2015). Mapping the Integrative Field: Taking Stock of Socio-Technical Collaborations, *Journal of Responsible Innovation*, 2(1), pp. 39–61.
Frankel, F. and Depace, A. (2012). *Visual Strategies: A Practical Guide to Graphics for Scientists and Engineers*. New Haven, CT: Yale University Press.
Goodman, N. (1975). Words, Works, Worlds, *Erkenntnis*, 9(1), pp. 57–73.
Goodman, N. (1978). *Ways of Worldmaking*. Indianapolis, IN: Hackett Publishing.
Halpern, O. (2015). *Beautiful Data: A History of Vision and Reason since 1945*. Durham, NC: Duke University Press.
Haraway, D. (1988). Situated Knowledges: The Science Question in Feminism and the Privilege of Partial Perspective, *Feminist Studies*, 14(3), pp. 575–599.
Haraway, D. (1997). *Modest_Witness@Second_Millennium. FemaleMan©_Meets_OncoMouse™: Feminism and Technoscience*. New York and London: Routledge.
Harding, S. (1991). *Whose Science? Whose Knowledge? Thinking from Women's Lives*. New York: Cornell University Press.
Harding, S. (2008). *Sciences from Below. Feminisms, Postcolonialities, and Modernities*. Durham, NC and London: Duke University Press.
Hegarty, M. (2011). The Cognitive Science of Visual-Spatial Displays: Implications for Design, *Topics in Cognitive Science*, 3(3), pp. 446–474.
Ingold, T. (2013). *Making: Anthropology, Archaeology, Art and Architecture*. London: Routledge.
Joyce, K. (2006). From Numbers to Pictures: The Development of Magnetic Resonance Imaging and the Visual Turn in Medicine, *Science as Culture*, 15(1), pp. 1–22.
Latour, B. (1986). Visualisation and Cognition: Drawing Things Together. In: H. Kuklick, ed., *Knowledge and Society Studies in the Sociology of Culture Past and Present, Vol. 6*. Greenwich, CT: Jai Press, pp. 1–40.
Latour, B. (1993). *We Have Never Been Modern*. Cambridge, MA: Harvard University Press.
Latour, B. (1999). *Pandora's Hope: Essays on the Reality of Science Studies*. Cambridge, MA: Harvard University Press.
Latour, B. (2004). Why Has Critique Run Out of Steam? From Matters of Fact to Matters of Concern, *Critical Inquiry*, 30(2), pp. 225–248.
Latour, B. and Woolgar, S. (1979). *Laboratory Life: The Construction of Scientific Facts*. Princeton, NJ: Princeton University Press.
Law, J. and Hassard, J. (1999). *Actor Network Theory and After*. Oxford: Blackwell.
Leach, J. (2006). Extending Contexts, Making Possibilities: An Introduction to Evaluating the Projects, *Leonardo Journal*, 39(5), pp. 447–451.
Leonelli, S. (2016). *Data-Centric Biology: A Philosophical Study*. Chicago, IL: Chicago University Press.
Lima, M. (2011). *Visual Complexity: Mapping Patterns of Information*. Princeton, NJ: Princeton Architectural Press.
Manovich, L. (2011). What Is Visualisation?, *Visual Studies*, 26(1), pp. 36–49.
Massumi, B. (2002). *Parables for the Virtual: Movement, Affect, Sensation*. Durham, NC: Duke University Press.
Myers, N. (2015). *Rendering Life Molecular: Models, Modelers and Excitable Matter*. Durham, NC: Duke University Press.

Patterson, Z. (2015). *Peripheral Vision. Bell Labs, the S-C 4020, and the Origins of Computer Art*. Cambridge, MA: MIT Press.
Polman, J. and Gebre, E. (2015). Towards Critical Appraisal of Infographics as Scientific Inscriptions, *Journal of Research in Science Teaching*, 52(6), pp. 868–893.
Rheinberger, H.-J. (1994). Experimental Systems: Historiality, Narration and Deconstruction, *Science in Context*, 7(1), pp. 65–81.
Rheinberger H.-J. (1997). *Toward a History of Epistemic Things. Synthesizing Proteins in the Test Tube*. Stanford, CA: Stanford University Press.
Rheinberger, H.-J. (2010). *An Epistemology of the Concrete. Twentieth-Century Histories of Life*. Durham, NC and London: Duke University Press.
Rheinberger, H.-J. (2011). Infra-Experimentality: From Traces to Data, from Data to Patterning Facts, *History of Science*, 49(3), pp. 337–348.
Rudwick, M. (1976). The Emergence of a Visual Language for Geological Science 1760—1840, *History of Science*, 14(3), pp. 149–195.
Schatzki, T. and Knorr Cetina, K. (2000). *The Practice Turn in Contemporary Theory*. New York and London: Routledge.
Schneider, J. (2005). *Donna Haraway: Live Theory*. New York and London: Continuum.
Shapin, S. (1984). Pump and Circumstance: Robert Boyle's Literary Technology, *Social Studies of Science*, 14(4), pp. 481–520.
Shapin, S. and Schaffer, S. (1985). *Leviathan and the Air-pump: Hobbes, Boyle, and the Experimental Life*. Princeton, NJ: Princeton University Press.
Smith, P. H. (2004). *The Body of the Artisan: Art and Experience in the Scientific Revolution*. Chicago, IL and London: The University of Chicago Press.
Star, S. and Griesemer, J. (1989). Institutional Ecology, 'Translations' and Boundary Objects: Amateurs and Professionals in Berkeley's Museum of Vertebrate Zoology, 1907–39, *Social Studies of Science*, 19(3), pp. 387–420.
Talasek, J. D. (2015). Data Visualization Nurtures an Artistic Movement, *Proceedings of the National Academy of Sciences*, 112(8), p. 2295.
Tufte, E. (2001). *The Visual Display of Quantitative Information*. Cheshire, CT: Graphics Press.
Turkle, S. (2007). *Evocative Objects. Things We Think with*. Cambridge, MA: MIT Press.
Vertesi, J. (2014). *Seeing Like a Rover: How Robots, Teams, and Images Craft Knowledge of Mars*. Chicago, IL: University of Chicago Press.
Wilson, E. (2010). *Affect and Artificial Intelligence*. Seattle: University of Washington Press.
Wise, M. (2006). Making Visible, *Isis*, 97(1), pp. 75–82.
Zaretsky, A. (2011). Comment. In: R. Debatty, C. L. Evans, P. Garcia, A. Grover, and Thumb, eds., *NA/SA (New Art/Science Affinities)*. Pittsburgh, PA: Miller Gallery at Carnegie Mellon University + CMU STUDIO for Creative Inquiry, p. 98.

2

What can science and technology studies learn from art and design? Reflections on 'Synthetic Aesthetics'

Jane Calvert and Pablo Schyfter

Introduction

In 2009, we embarked on a project called 'Synthetic Aesthetics', which paired synthetic biologists with artists and designers. As the social scientists on the project, we initially assumed we would base our analysis on observation of the pairs and their collaborations, but we soon found that we had much in common with the artists and designers. In different ways, we seemed to be trying to do similar things. This led us to the question that motivates this chapter: what can STS (Science and Technology Studies) learn from art and design?

We focus here on the work of three pairs of Synthetic Aesthetics participants, who explored topics as diverse as futility and time, living machines and evolution, and our coexistence with our bacterial symbionts. We found that this work had notable similarities with STS in respect to two shared objectives: 'opening up' and 'critique'. There were also differences, of course, primarily because the artists and designers on the project made tangible artefacts, while we did not.[1] Some also aspired to get their hands 'wet' and use scientific tools and materials in their work. Another difference is that play, humour and irony were central to their work, but not to ours. We raise the (slightly uncomfortable) question of whether artists and designers are more successful in their engagements with synthetic biology than we are.

To address the question of this chapter, we argue that as STS researchers, we can learn from the artists and designers on the Synthetic Aesthetics project in several ways. We can learn from their acknowledgement of the extent to which they become implicated in scientific research agendas. Looking at how they negotiate their relationships of obligation can help us reflect on our own. We also think there are opportunities for learning that could result from the bringing together of critical design and approaches to the upstream governance of technologies (such as Constructive Technology Assessment (CTA) and Responsible Research and Innovation). We are wary, however, of instrumentalising art and design for STS purposes. Drawing inspiration from work on interactions between social science and design (particularly Michael, 2012a, 2021b), and on interdisciplinary entanglements (e.g. Fitzgerald and Callard, 2015), we argue that one of the most valuable things we can learn is to embrace

DOI: 10.4324/9780429437069-4

the experimental and unexpected nature of collaborations with artists and designers. On these grounds, we argue that working with artists and designers can enrich social scientific work by helping us develop an emergent form of critique, where the outcomes are not obvious from the outset, but emerge from the process of collaboration itself.

Synthetic Aesthetics

The Synthetic Aesthetics project had its origin in a 'sandpit': an intensive, competitive, week-long residential grant-writing event called 'New Directions in Synthetic Biology' that was held just outside Washington D.C. in 2009. Synthetic biology, which can roughly (and controversially) be defined as the application of engineering principles to living systems (see Endy, 2005), was at this time a nascent discipline that was rapidly rising in importance in the global funding system.

Sandpits require participants to develop cross-disciplinary research projects over the course of the week. These projects are subjected to real-time peer review, and successful projects are selected on the final day. Five projects were funded from the $10 million made available by the US's National Science Foundation and the UK's Engineering and Physical Sciences Research Council. Four of them were science projects and the fifth, Synthetic Aesthetics, aimed to bring together the synthetic biology and art and design communities in ways that were mutually transformative by initiating paired exchanges between these two groups. The team that emerged to lead the project was made up of two synthetic biologists (Drew Endy and Alistair Elfick), two STS researchers (the authors of this chapter) and one designer (Daisy Ginsberg).

The origin of the Synthetic Aesthetics project in a 'sandpit' meant that it was somewhat unconventional from the start (one of the ways in which we secured funding was by performing a dance based on the myth of the Golem). The project escaped many of the demands placed on research funded through more conventional mechanisms, and it felt refreshingly open-ended and unconstrained. Another distinctive feature was that it was not conceived of as a social science research project, but as a collaboration between three different disciplinary groups.

In early 2010, the project team advertised for participants, and we received over 200 applications from writers, dancers, artists, designers and architects as well as a range of scientists and engineers. From these, we selected six artists and designers and six synthetic biologists, and paired them according to their interests and expertise.[2] We tasked the pairs with investigating design and synthetic biology, with the explicit freedom to take their work in any direction they chose. The artists and designers spent two weeks in the science laboratory, but, rather more unusually, the exchanges were reciprocal, so the scientists and engineers spent an equal amount of time in the art studio. We refer to these paired reciprocal exchanges as the 'residencies' below.

Methodological preliminaries

At the start of the project, we – the STS researchers on the project – planned (perhaps naïvely) simply to observe and document the interactions between the synthetic biologists and the artists and designers, and interview all the participants in a methodologically conventional manner. But once we started work, we were immediately struck by the similarities between our objectives and those of the artists and designers. Although they were a diverse group, they all, like us, wanted to forge new collaborations with synthetic biology. The three on whom we focus in this chapter also aimed, as we did, to critically interrogate the science by provoking reflection about its social and political complexity, explore implicit assumptions and possible alternatives to these assumptions, and question the dominant futures imagined by the scientists and engineers.

Because of these unexpected similarities, our work in the project became a shared investigation into the nature of synthetic biology, using the tools of STS and art and design, rather than an investigation into the collaborations between scientists and artists. This reflects ongoing anthropological movements towards studying *with* people instead of making studies *of* them (Ingold, 2013) and from thinking in terms of 'epistemic partners' rather than 'informants' (Holmes and Marcus, 2008).

More practically, once we started our fieldwork, we realised that the way we had set up the project challenged any routine methodological positioning of ourselves as ethnographic observers. In the exchanges, we had inadvertently created a situation in which the scientist or engineer in their laboratory was being followed by their paired artist or designer, both of whom were being followed by a social scientist (one of the authors of this chapter). All of us, in turn, were being followed by Daisy Ginsberg who was taking photos, filming interactions and asking challenging questions. As a critical designer with an interest in 'guerrilla tactics', she liked to joke that one of her aims was to subvert the social scientific ethnography. This set-up of three new people descending on a science laboratory was repeated in all the other residences. The situation was reversed in the art studio, where the scientist/engineer became one of the 'followers'. This meant that difficult questions arose about who was studying whom. In a sense, we were all studying each other.

Despite our shift in methodological focus towards a shared endeavour, we persisted with our planned interviews and ethnography. We observed and documented the six four-week exchanges and conducted semi-structured interviews with each of the twelve residents on at least two different occasions. Finally, at the end of the project, the team wrote a book intended for a broad audience (Ginsberg et al., 2014) in which the art/science pairs co-authored chapters on their joint work. These chapters were a further exercise in collaboration and provide data on which we draw here.

Reference points

There is a great deal of literature on art/science collaboration (e.g. Dixon et al., 2011; Kac, 2006; Stracey, 2009), but this is not our primary focus here. We are interested in the similarities and differences between STS and art/design collaborations with scientists and engineers rather than art/science interactions *per se*. In this way, we are building on recent work that has started to explore the complementarities between social science and art and design, particularly Michael (2012a, 2012b), Horst and Michael (2011) and Horst (2011), as well as Barry et al. (2008) and Born and Barry (2010), who outline three 'logics of interdisciplinarity' that inform our analysis.

These three logics provide different rationales for interdisciplinarity: to help scientific research become more accountable to society (the logic of accountability), to facilitate the contribution of scientific research to economic growth (the logic of innovation) and to produce 'new objects and practices of knowledge' (Barry et al. 2008: 42) through interdisciplinary research (the logic of ontology). According to the logic of ontology, something that would not have happened otherwise comes about through collaboration. As Born and Barry explain (in relation to art/science interdisciplinarity): 'science is understood not as self-sufficient or complete, but as transformed and enhanced through its engagement with art, just as art is transformed and enhanced through engagement with science' (2010: 105). The logic of ontology is, for us, the most interesting and powerful form of interdisciplinarity, and we return to it below.

Critical design

Alongside these academic reference points, it is also necessary to introduce the field of critical design. This is, of course, just one approach to contemporary design, but we focus on it here because Daisy Ginsberg, the design fellow on the project, was very influential on its direction and was trained as a critical designer by Antony Dunne and Fiona Raby, widely regarded as leading figures in the field.

Critical designers distinguish their work from commercial design because they use design as a tool to provoke reflection about the social, political and economic complexity of technology. They produce speculative objects that make abstract ideas tangible and open to discussion. They argue that this can 'help us see that the way things are now is just one possibility and not necessarily the best one' (Dunne and Raby, 2013: 66). Rather than making predictions, critical designers explore possible futures using design as a means of investigation (Ginsberg, 2014).

We can think about critical design in the light of Latour's discussion of designed artefacts. Latour shows how design helps us see that what we might have thought were 'objects' or 'facts' are actually 'things' or 'matters of concern'. He argues that design brings to the fore the 'disputed assemblages' (Latour, 2008: 6) that constitute artefacts, but are often overlooked. Design can demonstrate that 'many participants are gathered in a thing to make it exist and to maintain its existence' (Latour, 2004: 246). To put it in Latour's terms, it is almost as if critical designers set out to create 'matters of concern'. They often refer to their work as 'design for debate' (Dunne, 2008), and they aim to create things around which we can have a discussion, around which we can gather.

It is helpful to give an example of a critical design artefact, and we have chosen one that was important to the Synthetic Aesthetics project because it led us to recruit Daisy Ginsberg into the team. In 2009, Daisy and her colleague James King worked with a group of undergraduate synthetic biologists at the University of Cambridge who engineered the bacterium *Escherichia coli* to express a range of colours that are visible to the naked eye. They thought this application could potentially be useful in detecting levels of pollution and producing an output that was easily readable. Daisy and James speculated about other possible uses of this technology,[3] and they imagined a future (circa 2039) specially designed probiotic drink that interacts with human gut bacteria to produce an easily visible output reflecting one's disease state – coloured faeces. They produced a suitcase of (fake) excrement and took it across the Atlantic to the International Genetically Engineered Machine (iGEM) competition at the Massachusetts Institute of Technology. They had not paid the fee to present at the conference, so they gave guerrilla-style presentations, taking small groups of conference-goers (including one of us) aside in the breaks and presenting their design future. The climax of each of these mini-presentations involved opening the suitcase to reveal the coloured turds – the imagined future designed output.

This 'Scatalog' challenges taboos, particularly because the excrement it imagines is something that is visceral and smelly and very different from the image of synthetic biology that is usually projected, in which we either see images of shiny, clean laboratories or equally shiny double helices. Since 2009, the Scatalog has become (in)famous in the synthetic biology community. In fact, at a plenary session at a synthetic biology conference in 2011, scientists from the Beijing Genomics Institute used it in their presentation to represent the desired endpoint of their ongoing research. (It was rather unsettling for the critical designers to see what they thought of as an ironic intervention being embraced by the international scientific establishment.)

The project

With these preliminaries in place, we now turn to Synthetic Aesthetics project itself and its reciprocal exchanges between scientists and engineers and artists and designers. All six pairs produced thought-provoking work, but for reasons of space, we reluctantly leave out discussion of those collaborations involving a composer, an architect and a product designer (see Ginsberg et al., 2014). We give brief snapshots of the remaining three projects, which we expand on below in our discussion of the similarities and differences between their work and ours.

Oron and Hideo

The first pair is Hideo Iwasaki, a microbiologist from Waseda University in Tokyo, and Oron Catts, a bioartist who has built his own unique institutional niche – a laboratory/studio space called 'Symbiotica' – at the University of Western Australia. Hideo works on cyanobacteria, which are photosynthetic bacteria that have circadian rhythms, and the pair quickly decided to use cyanobacteria in their collaborative work. Cyanobacteria are potentially useful in many applications, including bioremediation, so the pair started by discussing the idea of engineering cyanobacteria to digest the silicon in discarded computer chips. One of the products of this breakdown would be gold, but they realised that another would be 'fool's gold', which looks like gold but is widely regarded as a useless substance. They explored the idea of engineering the metabolic pathway so it would preferentially produce fool's gold. This provoked them to ask what would happen if synthetic biology was directed towards the production of useless products. This is a particularly pertinent and destabilising question in a field that is heavily oriented around applications and utility.

After further discussion, the pair decided to focus their work on the topic of time, as manifested by cyanobacteria. They were particularly interested in exploring the links between biological and geological time, the sweep of which extends from the beginning to the end of the Earth. They started from the observation that cyanobacteria operate at many different timescales. They have rapid metabolic processes and exhibit slower daily rhythms in their circadian cycles. But they also act on a much longer timescale because they were the organisms that first converted the Earth's atmosphere to oxygen and made it habitable for life as we know it. The early Earth was covered in 'living rocks', clumps of minerals deposited by photosynthesising cyanobacteria. Similar rocks can be found in the bleak and beautiful saline lakes of Western Australia, where the pair carried out a stretch of their collaborative work.

One of the aims of Oron and Hideo's project was to introduce humility by challenging us to look at all human activities, including synthetic biology, from the perspective of geological time. As they put it in their jointly written chapter: '[i]n a few million years, the human era may be just another thin layer in the rock formation, a humbling thought' (Catts and Iwasaki, 2014: 187). This perspective is not one we normally adopt when we think about emerging technologies, so their work encourages a radical shift in our present-oriented perception of synthetic biology.

Sascha and Sheref

The next collaboration involved a protocell scientist, Sheref Mansy, the head of a laboratory in the green and mountainous region of Trento, Italy. He was willing to combine the demands of running a laboratory with collaborating with his paired artist, Sascha Pohflepp. Sheref's research involves the creation of extremely simple living systems from non-biological components. He is interested in finding the absolute minimum that is needed for something to be alive. Sheref's research focus led the pair to explore questions about the defining features of life, and they developed a shared interest in evolvability as a key feature that distinguishes living from manufactured systems.

The second leg of their exchange took place at Mediamatic, an art and technology studio in Amsterdam, and a very different environment from Sheref's laboratory in Italy. ('I've just told my lab I'm doing crazy shit for a couple of weeks', Sheref explained.) Here, the pair decided to focus on the question: 'are inanimate machines only an interlude in history?' They were struck by the fact that we relied on what they termed 'animate machines' (horses, oxen etc.) for long periods of our history, and even when non-living machines took over, these were often modelled on living things (e.g. horsepower is still the standard of measurement for engine power). They became interested in what kinds of living machines synthetic biology might deliver, and what would happen if these machines evolved. They even explored the idea of an evolving steam engine.

What is notable about this project is that it addresses a contradiction at the heart of synthetic biology. If we take evolution to be a defining characteristic of life, then to be alive, a 'living machine' must evolve; but if it evolves, it may no longer possess the stable, predictable properties we expect of our machines. In their jointly written chapter, Sascha and Sheref argue that synthetic biologists must inevitably 'share authorship with the innumerable forces that drive Darwinian evolution' (Pohflepp and Mansy, 2014: 242).

Sissel and Christina

The final pair was Christina Agapakis, then a PhD student in synthetic biology at Harvard University, and Sissel Tolaas, a smell artist based in Berlin. Sissel's mantra is 'nothing stinks, only thinking makes it so'.[4]

In their project, they decided to explore our contradictory relationship with bacteria. They became intrigued by the fact that we live in a world filled with microorganisms, but we consider bacteria to be dirty and hazardous, and we seek to exterminate them using cleansers and medical technologies. The medium through which they decided to explore these ideas was cheese. This is because some of the bacteria that give cheeses their distinctive smells are also found on human skin, probably due to early artisanal cheese-making practices where people used their bare hands. In their project, Sissel and Christina extracted bacteria from different areas of human skin (including noses, toes and armpits) and used it to make cheese in the laboratory.

This project is playful, but it raises profound questions about the reality of the human microbiome and the relationship between humans and bacteria, pointing to the fact that bacterial and human cultures co-evolve. It also challenges the boundaries between our bodies and the food that we eat, since bacteria do not distinguish between them in the same way as we do.

Similarities

Opening up

Turning to the similarities between these three art/design projects and our STS work, one that quickly became evident was our shared desire to 'open up' synthetic biology to a broader range of perspectives and expand existing ways of imagining the field. Stirling (2008) describes 'opening up' as drawing attention to the often implicit assumptions that underlie discussions of a technology. He shows how, in policy contexts, opening up can enable new questions to be asked, marginalised perspectives to be included and alternative technological pathways to be explored. Although the artists and designers were not aware of Stirling's work, we do think that there are important resonances between STS and art and design in this respect. The aspiration to 'open up' synthetic biology was a feature of all three of the pairs' projects.

We have seen how Oron and Hideo confront our narrow conceptions of synthetic biology and its future by adopting the perspective of geological time. But more broadly, much of Oron's work is motivated by his desire to bring new voices into the discussion of the life sciences and to explore the ambiguities that emerge. In an interview, he explained: 'I think art is in this really privileged position to engage in questioning and opening up areas of exploration as opposed to smoothing over them' (OC interview Perth). This desire to open up new areas to artistic exploration was one of the main reasons why he wanted to be part of the Synthetic Aesthetics project. He said:

> I think there is an urgent need for artists to explore major issues that are being raised by synthetic biology because, if we are not there at the very beginning, it will be too late to be able to show alternative ways in which this knowledge can be applied.
>
> *(OC interview Perth)*

Oron also argued that the ability to open up the discussion of technology was a feature of art rather than design. He elaborated:

> Very few professions actually are allowed to spend their time engaging in developing something only for it to be contested. Designers and engineers are trained to find solutions that are going to bring closure in a sense; they're not interested as much in the idea that what you're engaging with is designed to be questioned.
>
> *(OC interview Perth)*

In their collaborative work, Oron and Hideo wanted to initiate a critical discussion that did not have a defined endpoint, but was characterised by continuous exploration.

Sascha and Sheref saw their own interdisciplinary interaction as a form of 'opening up'. Sheref had applied to be part of the project because he hoped that his interactions with artists and designers would 'stimulate creativity, different perspectives, different thoughts' (SM interview Trento). He stressed the importance of creativity to his scientific work and hoped engagement with creative professionals would help him do better science. At the start of the residency, he explained what he wanted to get out of the project:

> I would love – it's asking for a lot so if this doesn't happen then I won't be disappointed – but I would love if there was a moment in which I thought, 'ah, I'd never looked at it in that way, but perhaps that's something that I should think about more'. That would be great.
>
> *(SM interview Trento)*

Sascha, like Oron, drew a distinction between art and design. He explained that he wanted to participate in Synthetic Aesthetics as an artist because design was about finding solutions and 'problem-solving, improving the world, you know, which is a very noble effort, but it's more about constraints, whereas art is more about actually opening, posing questions than delivering answers' (SP interview Trento).

Sissel and Christina engaged in opening up by finding novel artistic uses for established biological tools and techniques. Much of Sissel's work has followed from being given access to sophisticated technologies from the scent and flavour industry and using them in idiosyncratic ways. She regarded her project with Christina in the same light. Having experienced the synthetic biology laboratory, she was struck by the apparent narrowness of the field. By repurposing synthetic biological knowledge, she hoped to show the possibilities overlooked by scientists and engineers by exploring new, in this case more playful, directions for their research. Again, it is worth noting that the distinction between art and design was raised in this collaboration. As Sissel noted, the artist can 'dare to be less practical' (ST interview Boston).

Critique

A second similarity we found between our STS work and that of the artists and designers is what we are calling 'critique'. What is meant by critique is obviously the moot point here, and we return to this issue below, but we start by drawing on our actors' use of the term.

Oron and Hideo talked about critique more explicitly than any of the other pairs. At one point, Oron reflected: 'I suppose the greatest challenge from my perspective is how to engage critically' (OC interview Perth). He went on to explain that any engagement with a field like synthetic biology normalises it, even if that work explicitly aims to be critical, and that by being part of the project, there was a danger that he could end up providing a service without much influence.

One form of critique found in the pair's work is the attention they draw to hubris and control. In their joint chapter, they write: 'there is a need to question the underlining hubris of human intentions to control life. In this context, we hope to demonstrate that time can be used as an instrument for humility' (Catts and Iwasaki, 2014: 185). These concerns resonate strongly with work by Wynne (1992) and Jasanoff (2003), who argue that it is necessary to acknowledge the limits of prediction and control in science and engineering. Jasanoff advocates 'technologies of humility', which she describes as attempts 'to come to grips with the ragged fringes of human understanding – the unknown, the uncertain, the ambiguous, and the uncontrollable' (2003: 227).

Sascha and Sheref did not talk about critique as often as Oron and Hideo, but in some ways, their project in itself is a critique of the whole synthetic biology agenda because they point to the contradictions of trying to design 'living machines', which is the guiding objective of much synthetic biology. As mentioned above, their central focus was on evolution as a defining feature of life, and their final output, an exploration of the nature of living machines, shares many themes with critical work in STS. Their co-authored chapter cites Lily Kay and Bruno Latour. In this particular case, the boundaries between their contribution and ours become very blurred.

Sissel and Christina did not explicitly discuss critique, but one of the most interesting aspects of their work was that it allowed them to draw critical conclusions about the metaphors and analogies used in synthetic biology. The field makes heavy use of metaphors from engineering and is saturated with analogies to resistors, capacitors and electronic circuits. By pointing to the interconnectedness and complexity of the bacterial cultures in their cheeses, Sissel and Christina were able to provoke different ways of thinking. They write in their joint chapter: 'rather than modeling synthetic biology on computer engineering, cheesemaking might be an engineering paradigm that allows for the design, construction, and maintenance of complex living worlds performing incredible feats of metabolism' (Agapakis and Tolaas, 2014: 282). This is a profound challenge to the way synthetic biology is currently framed.

Differences

Making

Moving on to consider the differences between our STS work and that of the artists and designers, one that is superficially obvious is that artists and designers make things that have a materiality and a physicality that our academic contributions usually lack. We recognise that the recent turn to 'making' in STS aims 'to use material forms of engagement with technologies to supplement and extend critical reflection' (Ratto, 2011: 253), and we see Synthetic Aesthetics as continuous with this endeavour, but the artists and designers in the project prioritised making in a way few social scientists would. For example, in JC's first conversation with Sascha *en route* to Trento, the question he most wanted to ask of the other residencies was: 'what are they going to make?'

This emphasis on making appears to be interconnected with ideas about what it is to be an artist or designer. Maeda (2010), for example, says 'Being an artist, I feel that art comes from the inexplicable urge to manifest a feeling, intent, or question as a specific, tangible experience'. Some artists and designers also argue for the unique contribution that making brings to their engagements with science and technology. Dixon maintains that 'only a material confrontation can be surprising and astonishing' (2008: 685), and Carey et al. say that it is because they produce artefacts that designers 'can present a powerful vision of the future, facilitating visceral and tangible forms of engagement with innovation and possibility' (2014: 176).

The power of a non-verbal output is clearly demonstrated by Sissel and Christina's project. The cheeses have been catalysts and focal points for discussions around synthetic biology in Berlin cheese shops, synthetic biology conferences and larger events like the South by Southwest festival in Texas. In each case, they have driven discussions that extend far beyond the cheeses themselves to encompass questions about humans' relationship to bacteria; the complex interplay between science, technology, consumer products and food; and the role that synthetic biology may play in our lives. All these issues are made tangible through the medium of cheese.

The potential for art to provide an alternative, non-verbal, form of expression was particularly important for Oron, who argued that 'the issues that synthetic biology raises are way beyond science and engineering, so there's a need to try and culturally articulate stuff that we don't even have a language to describe' (OC interview Perth). He maintained that words are not necessarily the best form of expression and put the point directly (during an interview, tellingly) by saying 'I'm really interested in doing stuff, not just talking about it!' (OC interview Perth). This point was also made by Daisy who said that 'too much self-reflection is a problem' because this inhibited making.

Oron did point out that one downside of non-verbal work is that there is the danger of 'misunderstanding or misframing or misusing the artistic work for purposes which are totally opposing the intentions of the artist' (OC interview Perth). Although written texts can and often are misinterpreted, the danger of this happening with artworks is even greater. For example, the Scatalog appeared in the UK newspaper the *Daily Mail* under the heading

'Scientists create yoghurt that changes the colour of your poop to diagnose illness' (Wrenn, 2012), demonstrating the willing propensity of some groups to believe speculative technological futures.

Because of its ability to provoke thought and discussion, one of the residents described artistic work as: 'really vivid science studies' (HI interview Perth), but interestingly, they did not regard us as fellow makers. While they were making, we seemed to be merely writing. We do not necessarily concede to this categorisation, but we do want to note that making was a way in which the artists and designers in the project contrasted us to their paired synthetic biologists, who similarly put an emphasis on constructing artefacts.

To add an additional twist to their emphasis on making, bioartists such as Oron use the same tools and materials in their work as those used in the laboratory by scientists. In this way, their approach is much more 'hands-on' than most STS work. As Oron explained, what interested him was 'how we can actually use the very same technology and the very same question of manipulating life forms as a vehicle for expressing those questions' (OC interview Perth). Kelty similarly notes how bioart makes use of 'green fluorescent proteins, petri dishes, tissue culture manuals, and genetics databases', but 'configures them in ways that try to provoke, transgress or re-design our understandings of life' (2010: 7). And Sissel and Christina's collaboration was a clear example of repurposing the tools of science for a different, artistic, end.

Both Daisy and Oron were committed to the transformative power of laboratory work. They argued that by getting ones hands 'wet' (or 'dirty' perhaps), one becomes implicated in the process of manipulating life. This makes it hard to take a distanced, detached stance; a stance often attributed to us as social scientists, who seemed to spend most of our time on the sidelines, taking notes. There was also an implication that this hands-on involvement allowed for a deeper critique than we could ever accomplish as STS scholars. We return to this issue of being a 'participant' rather than a 'spectator' below.

Play and humour

As well as regarding themselves as 'makers', the artists and designers also thought of themselves as provocateurs, jesters or saboteurs, again in contrast to us. Of course, STS has a tradition of playful work exhibited by authors like Haraway, Ashmore, Mulkay and Woolgar. And we have tried to adopt 'trickster' roles ourselves in our interactions with synthetic biologists, with mixed results (see Balmer et al., 2015). But play, humour and irony were central to the work of the artists and designers on the project, as shown by Daisy and James King's guerrilla tactics at the undergraduate synthetic biology conference described above, Oron and Hideo's attempt 'to 'engineer futility' into cyanobacteria (Catts and Iwasaki, 2014: 198), and the audacity of armpit cheese.

More successful?

As we became aware of these similarities and differences between STS and art and design, our work in the project started to become accompanied by a slightly uncomfortable question: are artists and designers more successful in their engagements with synthetic biologists than we are? The answer to this question rests on what is meant by 'success', of course, but as a starting point, many synthetic biologists seem to be happier to collaborate with designers than with social scientists, and these collaborations often exhibit less divergence in expectations. This is partly because design is central to engineering, so the value of a designer's contribution is perhaps easier for synthetic biologists to acknowledge than the more amorphous contribution that a social scientist makes in their papers and talks (the former often taking many years to reach publication).

Artists and designers are also often considered to possess skills that the STS researcher is perceived to lack. Sheref, for example, wanted to collaborate with an artist because of the creative input that they would bring; something that is not so readily associated with an STS researcher. There also seemed to be an expectation that artists and designers would be playful, challenging and sometimes subversive in their engagements with synthetic biology, an expectation that is not generally associated with social scientists.

Another measure of the success of the artists and designers is that the tangible artefacts they produce have an immediacy and an ability to travel (Wilkie, 2011) and are more discussed by the synthetic biology community than our social scientific papers. But this raises questions about whether the critical interventions of the artists and designers are more likely to become folded into the mainstream of the field (as we saw with the uptake of the Scatalog by the Beijing Genomics Institute). Does this warmer welcome for designers come at the cost of being taken less seriously? Are artists and designers more likely to be co-opted, assimilated and neutralised than STS researchers are? We return to these questions below.

Since designers and artists can be seen as simultaneously less threatening and more obviously useful in synthetic biology, this raises questions about whether they are in competition with us, filling a space that might otherwise be filled by social scientific enquiry. Some writing by critical designers seems to support this suggestion. For example, Daisy writes that 'An emerging role for the designer is a form of social critic' and says her aim is to 'develop a type of applied, speculative bioethics. Researching science and engaging in discussion with scientists' (Ginsberg, 2014: 66) – something that sounds very much like certain approaches in STS. Similarly, on the back cover of their book *Speculative Everything*, we are told that 'Dunne and Raby continue to inspire and challenge us to consider design as a unique mode of sociocultural inquiry'. Is this encroachment of design onto the 'sociocultural' territory something we should fear or embrace?

Perhaps some of the competition we felt was based on the fact that Synthetic Aesthetics was not an art/science project; it was an art/science/social science project. This meant that the interactions were between three disciplinary groups, rather than two – the latter being far more normal in interdisciplinary work. This resulted in unusual group dynamics, constantly shifting allegiances, and a tendency for all of us (artists, designers, synthetic biologists and STS researchers) to attempt to articulate the distinctive contributions of our own (hybrid) disciplinary perspectives.

There was an asymmetry in this threesome, however, because the artists and scientists were funded to spend time in each other's workspaces and expected to come up with an output that was coproduced. The pairs worked closely together, and they all produced jointly authored papers with surprising ease. One reason why their collaborations may have been successful is because the residencies were set up so that they *had* to collaborate. Perhaps this shows how important the starting positions are in a cross-disciplinary collaboration. STS researchers are rarely funded specifically to produce a joint output with a scientist or engineer. And we have never come across a project where a scientist has to spend the same amount of time in an STS department as the STS researcher spends in their scientific fieldsite.

What can we learn?

We now turn to our central question: what can we learn from the artists and designers in the Synthetic Aesthetics project? By raising this question, we are not intending to set up a hierarchy with art and design above STS or to imply that art and design have nothing to learn from

STS. Instead, our aim is to reflect on what were, for us, novel and stimulating interactions, and draw out some features we think might be interesting or useful for other STS researchers.

We realise that asking 'what can STS learn?' raises questions about what STS is. We are loath to attempt to make an authoritative statement on this issue, particularly since STS is notoriously heterogeneous and, as we see it, incorporates a spectrum of work from the theoretical to the descriptive, the critical, the normative and the activist (See Rip, 1999; Sismondo, 2008). But it is the case that this interdisciplinary project did make us re-identify with our own field and reflect on its nature – one of the results of our reflection being this chapter.

With these caveats in place, we lay out three ways in which we think we can learn from the artists and designers. The first is in terms of the ways in which they negotiate their relationships with scientists and engineers. The second is in respect to our work on the governance of emerging technologies. Finally, we reflect on what we might achieve together: an emergent form of critique.

Being implicated

In Europe and the United States, there are increasing pressures on STS researchers to become tagged onto scientific grants to deal with the 'ethical, legal and social issues' (Balmer et al., 2015). STS scholars can become heavily involved in the topics we study and can come to play a role in the development of new scientific fields. The artists and designers in the project were very aware of the extent to which they are implicated in similar ways. This draws attention to what Barry et al. (2008) call the 'subordination-service mode' of interdisciplinary work. Both STS researchers and artists and designers working in new technological fields are often expected to perform a service role and facilitate the progress of science to market. Looking at the ways in which artists and designers deal with their complicity can help us reflect on our own.

Oron and Hideo were wary that their collaborative work would become folded into the construction of synthetic biology. In their joint chapter, they write: 'synthetic biology is a contemporary example of a field that employs artists and designers as part of a concerted effort to engineer public acceptance for a technology that does not yet exist' (Catts and Iwasaki, 2014: 194). Oron was concerned that the Synthetic Aesthetics project would be interpreted in this way. However, he was also keenly aware that he had chosen to be implicated because he had chosen to use the tools and materials of synthetic biology to produce art. In an interview, he explained:

> The artists who are involved with it are implicated within the whole process; they can't take a distanced stance, they actually have to engage, they can't be self-righteous about it.
>
> *(OC interview Perth)*

This raises important questions about the tension between distance and critique. In the previous section, we asked whether the greater success artists and designers had in their collaborations with synthetic biologists brought with it the danger of their work being co-opted and assimilated. Although some artists and designers celebrate their closeness to the science, is critique actually stronger from outside, when there is some distance? These are long-standing questions in STS, and reflecting on the ways in which artists and designers are enrolled in synthetic biology throws our own forms of critical engagement into relief.

Artists and designers do adopt a range of strategies to protect their autonomy. For example, by having his own laboratory dedicated to artistic research, Oron is not dependent on a scientific sponsor or collaborator to carry out his bioart. Dunne and Raby suggest another approach – to 'work independently with scientists as advisors rather than creative partners' (2013: 54) – on the grounds that in this situation, they are freer to set their own agenda. This arrangement was clearly precluded by the set-up of Synthetic Aesthetics because the work had to be collaborative. The reciprocity of the exchanges meant that the lines of obligation were not straightforwardly unidirectional, however, and the creative process was a shared one. We elaborate on the significance of this point below.

Upstream governance

We think the second area of cross-learning between STS and art and design is in respect to the upstream governance of emerging technologies. For STS researchers coming across critical design, it is striking how much it has in common with approaches such as CTA (Schot and Rip, 1997), Anticipatory Governance (Barben et al., 2007) and more recent formulations in terms of Responsible Research and Innovation (Owen et al., 2013). It is under these headings that STS researchers often contribute to deliberations about technological choices. All of these approaches aim to create novel opportunities for diverse groups to come together in the early stages of the development of a technology. They use tools such as scenarios to elicit alternative visions of the future, which can help articulate a wider range of pathways than would be envisaged otherwise.

In recent discussions of Responsible Research and Innovation, the similarities to critical design are notable. For example, Owen et al. say that their aim is 'to explore other pathways to other impacts, to prompt scientists and innovators to ask "what if…"' (2013: 38). Similarly, in their description of their critical design work, Dunne and Raby explain how it often takes 'the form of scenarios, often starting with a what-if question' and that these questions 'are intended to open up spaces of debate and discussion' (2013: 3). They even say that they want their work to 'play a role in the democratisation of technological change by widening participation in debates about future technologies' (2013: 49). This quotation could come straight out of a description of CTA. Because of these similarities, there seems to be rich potential for bringing these areas of investigation together.

There are already openings for this type of work. For example, CTA-informed socio-technical scenarios workshops have started to make use of prototypes (Rip and te Kulve, 2008), and technology assessment has embraced the speculative in the form of 'vision assessment' (Grunwald, 2004). A suggestion that emerges from the Synthetic Aesthetics project is that we could build on these approaches to develop methods that harness the skills of artists and designers in their imagination of alternative futures and their abilities to express things in a tangible form. The physicality of the outputs could broaden discussions in unanticipated ways, leading to novel means of envisioning the future of engineering living things.

This would be a nice neat conclusion of this chapter: that we do our social scientific research but introduce an object – a suitcase of poo, for example – to provoke conversations. But because of our unexpected, surprising and sometimes unsettling experiences of working with artists and designers, we are not entirely satisfied with this conclusion, since there is a danger of putting art and design into an instrumental role, performing a service for STS. Simply tasking designers with making speculative prototypes for discussion does not embrace the ways in which art and design could be part of an ongoing discussion from which something more unexpected could arise. Despite the emphasis given to making by the artists and designers on the Synthetic Aesthetics project, what we gained most from our collaborations with them were not primarily 'things' we could wheel out to stimulate debate, but thought-provoking conversations that introduced ideas and assumptions different from our own.

This resonates with the 'critical making' movement discussed earlier because rather than prioritising the object, the emphasis here is placed on the process on 'the act of shared construction, joint conversation, and reflection' (Ratto, 2011: 253). And it is precisely the collaborative process that we have come to value most through our involvement in Synthetic Aesthetics. This emphasis encourages us to take up Ingold's call to embrace 'the speculative, experimental and open-ended character of arts practice' (2013: 8) and the possibilities it allows. Like Barry and Born, we think that art/science projects can 'contribute to the generation of something new within scientific practice itself, challenging the boundaries of disciplinary authority' (2010: 114). Instead of seeing artists and designers primarily as producers of artefacts, we can perhaps make the most out of our collaborations if we start to see them as epistemic partners on an exploratory journey.

An emergent form of critique

This leads us to our central argument: by working with artists and designers, we can develop what we are tentatively calling an emergent form of critique, which could expand our critical capacity, and provide alternative entry points into discussions of synthetic biology.

We have been inspired here by Michael's discussion of the emergent potential of speculative design. Michael describes how this approach to design is not concerned with 'problems or facts, but about the process of emergence of new relations which, potentially at least, can reconfigure what the very "fact" or "problem" might be' (2012a: 175). He shows how speculative design enables 'inventive problem making', which 'opens up a space for a reframing of the issues' (Michael, 2012b: 539). He argues that speculative designers pursue the unexpected, expressive and creative, and that we should embrace this in our collaborations with them. So, rather than social science 'learning from' art and design, he thinks we should talk of a 'mutual "becoming with" of these disciplines', involving 'artefacts that embody openness, ambiguity, playfulness' (Michael, 2012a: 177–178).

Michael's experiences resonate with ours on the Synthetic Aesthetics project, but a key difference is that our project engaged closely with critical design, and Michael draws a distinction between speculative and critical design. He thinks that a limitation of the critical design is that it has a predefined target of critique. His concern is that 'critique does not well accommodate the possibility of a co-emergence of researcher-and-researched' since 'the problem is pre-figured in critique, rather than inventively emergent' (Michael, 2012a: 180, note 2). He maintains that since speculative designers do not set their work so directly against a particular sociotechnical future, the discussion can be more open-ended than is possible in critical design.

Questions arise, however, about whether we can (or whether practitioners do) distinguish speculative and critical design so strictly. Dunne and Raby, the founders of critical design, call their book *Speculative Everything*, and they describe themselves as speculative designers (2013: 100).[5] They also distinguish their interest in 'problem finding', from the 'problem solving' of commercial design (2013: vii). 'Problem finding' seems very close to what Michael describes as 'inventive problem making'.

We think the key issue is whether there is a difference between designs that have a specific target of critique and those that enable a more generative discussion. It could be argued that the Scatalog described above has a target of critique – the clean, shiny image of high-tech synthetic biology, which it makes mundane in a memorable manner. But as we have shown, it can be read in multiple ways by different actors. The cheese is even less directed against a specific target of critique. It challenges simplistic 'flattened' electronic analogies that we see in synthetic biology, but it does far more than this in its ambivalent disgustingness and potential edibility.

Reflecting on the Synthetic Aesthetics project overall, we think that Daisy's work (which she labels as critical design) does exhibit the emergent characteristics that Michael sees in speculative design. We also find these characteristics in the work of the residents. Although Sascha, Sissel and Oron self-identified as artists rather than critical or speculative designers, the features of their work that they argued distinguished it as 'art' (its capacity to initiate new conversations, to be contested, to pose questions rather than deliver answers) are exactly those that we are identifying as features of an emergent form of critique. We think that how the work is labelled is less important than whether it provokes an ongoing exploration and discussion.

Another way of thinking about the distinction between speculative and critical design is in terms of the collaborative nature of the development of the art/design artefact. While a critical designer's work is often produced by a designer working alone and is later exhibited in a museum or gallery, in what Michael calls speculative design, the process does not rest so heavily on the designer bringing their expert skills to bear; it is more open-ended, and the design object is coproduced with publics or users. A key feature of Synthetic Aesthetics, however, was that the work was essentially collaborative. The project did not support works of commentary produced by stand-alone artists or designers, but required the production of something that was jointly created with the paired scientist/engineer. If the relevant difference is an issue of expertise and whether it is asserted or shared, then sharing was paramount in the Synthetic Aesthetics project. Because of their shared endeavours, we think the residents' work exhibited the inventive problem making that Michael celebrates as well as the creation of new objects and practices that is central to Barry et al.'s (2008) 'logic of ontology'.

For example, without Hideo's expertise in cyanobacteria and their circadian rhythms, the pair's investigation of the temporal scope of these organisms would not have come about, and the poetic and humbling form that this project eventually took would not have transpired without the collaboration. Sascha and Sheref's work was highly dependent on their initial discussions of the features of living things that is central to protocell research, but it is very unlikely that either Sascha or Sheref would have come up with the idea of an evolving steam engine independently. Sissel and Christina's production of human bacterial cheeses was dependent on the unlikely partnership of synthetic biology concepts and practices in scent design.

Future directions

Inspired by the work of these pairs, and our own interactions in the Synthetic Aesthetics project, we conclude by sketching the outlines of what we mean by an emergent form of critique – something that we hope to develop in future work.

We are calling this an 'emergent' form of critique because it is necessarily coproduced. It is not the result of one group imposing their critical tools and perspectives; it is the outcome of a shared endeavour that brings people together from different disciplines. What is generated is then more than (and different from) anything that could result from a single discipline. This relates to our discussion of 'making' above because if what is important is what emerges from these shared collaborative endeavours, then it becomes less relevant who is a 'maker' and who is not.

In using the word 'critique', we are drawing on Latour, who rejects the familiar notion of critique as 'predicated on the discovery of a true world of realities lying behind a veil of appearances' (2010: 474–475) and instead advocates one that is more about unexpectedness, openness and overspilling. It is 'associated with *more*, not with *less*, with *multiplication*, not *subtraction*' (Latour, 2004: 248, emphasis in original). Latour argues:

> The critic is not the one who debunks, but the one who assembles. The critic is not the one who lifts the rugs from under the feet of the naive believers, but the one who offers the participants arenas in which to gather.
>
> *(2004: 246)*

One way we want to explore and take forward this notion of critique is by attempting to create spaces where mutually transformative discussions can happen between STS, art/design and science/engineering as well as other groups.

We think that an emergent form of critique requires a type of collaboration that is experimental and that this could be an ethos for interdisciplinarity more generally, beyond that of STS and art/design. Here, we are building on work such as that by Marcus (2013), who aims to experiment with collaborative forms of anthropological knowledge production and raise new questions in the process, and Fitzgerald and Callard (2015), who work closely with neuroscientists and argue that 'novelty, serendipity and contingency might conjure a more constructive space of shared collaboration' (p. 5). Such experimental collaborations are necessarily risky because the outcomes will not be obvious from the outset, but will emerge from the process of collaboration itself.

If we are going to commit to being part of such experimental collaborations, we may also have to think of ourselves more explicitly as 'participants' than 'spectators' (Barad, 2007) in technoscientific worlds because it is only if we participate that we can create something new together – whether this be knowledge, practices or things. We may have to admit our complicity and become part of the fields we study. We will lose distance, but we may gain something more unexpected.

What we take away from our involvement in the Synthetic Aesthetics project is that experimental collaborations with artists and designers can be playful, challenging and sometimes transcendent. We might not always know exactly what we are doing, and we may have to walk forward without being sure that the ground is solid beneath our feet. But by working *with* artists and designers instead of making studies *of* them, we can together start to develop an emergent form of critique, which could allow new discussions and explorations of sociotechnical complexity, and perhaps bring something new into being.

Acknowledgements

We are grateful to all the participants in the Synthetic Aesthetics project, particularly Daisy Ginsberg, Sheref Mansy and Christina Agapakis, who made very useful comments on drafts of this chapter. We would also like to thank Mike Michael, Sergio Sismondo and Hannah Rogers. We dedicate this chapter to Sascha Pohflepp (1978-2019).

Funding

This research was supported by the Engineering and Physical Sciences Research Council (EP/H01912X/1 – Synthetic Aesthetics) and the European Research Council (ERC 616510 – Engineering Life).

Notes

1 Although we recognise the recent interest in making in STS, a topic we address below.
2 One of the pairs, Oron Catts and Hideo Iwasaki, applied together.
3 http://www.echromi.com/
4 https://artofchange21.com/en/conversation-with-the-artist-sissel-tolaas/
5 Under the heading of 'conceptual design', Dunne and Raby list speculative design, critical design, design fiction, design futures, antidesign, radical design, interrogative design, design for debate, adversarial design, discursive design, futurescaping and design art (2013: 11).

References

Agapakis C and Tolaas S (2014) The Inside-out Body. In: Ginsberg D et al. (eds) *Synthetic Aesthetics: Investigating Synthetic Biology's Designs on Nature*. Cambridge, MA: The MIT Press, pp. 255–266.

Balmer A et al. (2015) Taking Roles in Interdisciplinary Collaborations: Reflections on Working in Post-ELSI Spaces in the UK Synthetic Biology Community. *Science and Technology Studies* 28(3): 3–25.

Barad K (2007) *Meeting the Universe Halfway: Quantum Physics and the Entanglement of Matter and Meaning.* Durham, NC: Duke University Press.

Barben D et al. (2007) Anticipatory Governance of Nanotechnology: Foresight, Engagement, and Integration. In: Hackett E et al. (eds) *The Handbook of Science and Technology Studies*. Cambridge, MA: The MIT Press, pp. 979–1000.

Barry A, Born G and Weszkalnys G (2008) Logics of Interdisciplinarity. *Economy and Society* 37(1): 20–49.

Born G and Barry A (2010) Art-Science: From Public Understanding to Public Experiment. *Journal of Cultural Economy* 3(1): 103–119.

Carey W et al. (2014) Living among Living Things. In: Ginsberg D et al. (eds) *Synthetic Aesthetics: Investigating Synthetic Biology's Designs on Nature.* Cambridge, MA: The MIT Press, pp. 169–180.

Catts O and Iwasaki H (2014) The Biogenic Timestamp: Exploring the Rearrangement of Matter through Synthetic Biology and Art. In: Ginsberg D et al. (eds) *Synthetic Aesthetics: Investigating Synthetic Biology's Designs on Nature.* Cambridge, MA: The MIT Press, pp. 195–204.

Dixon DP (2008) The Blade and the Claw: Science, Art and the Creation of the Lab-Borne Monster. *Social & Cultural Geography* 9(6): 671–692.

Dixon DP, Straughan ER and Hawkins H (2011) When Artists Enter the Laboratory. *Science* 331(6019): 860.

Dunne A (2008) Design for Debate. *Architectural Design* 78(6): 90–93.

Dunne A and Raby F (2013) *Speculative Everything: Design, Fiction and Social Dreaming.* Cambridge, MA: The MIT Press.

Endy D (2005) Foundations for Engineering Biology. *Nature* 438(7067): 449–453.

Fitzgerald D and Callard F (2015) Social Science and Neuroscience beyond Interdisciplinarity: Experimental Entanglements. *Theory, Culture & Society* 32(1): 3–32.

Ginsberg D (2014) Design as the Machines Come to Life. In: Ginsberg D et al. (eds) *Synthetic Aesthetics: Investigating Synthetic Biology's Designs on Nature*. Cambridge, MA: The MIT Press, pp. 39–70.

Ginsberg AD et al. (2014) *Synthetic Aesthetics: Investigating Synthetic Biology's Designs on Nature.* Cambridge, MA: The MIT Press.

Grunwald A (2004) Vision Assessment as a New Element of the FTA Toolbox. In: *Proceedings of the EU-US Scientific Seminar: New Technology Foresight, Forecasting & Assessment Methods*. Seville, Spain, pp. 53–67.

Holmes D and Marcus G (2008) Collaboration Today and the Re-imagination of the Classic Scene of Fieldwork Encounter. *Collaborative Anthropologies* 1: 81–101.

Horst M (2011) Taking Our Own Medicine: On an Experiment in Science Communication. *Science and Engineering Ethics* 17(4): 801–815.

Horst M and Michael M (2011) On the Shoulders of Idiots: Re-thinking Science Communication as 'Event'. *Science as Culture* 20(3): 283–306.

Ingold T (2013) *Making: Anthropology, Archaeology, Art and Architecture*. London: Routledge.

Jasanoff S (2003) Technologies of Humility: Citizen Participation in Governing Science. *Minerva* 41(3): 223–244.

Kac E (2006) *Signs of Life: Bio Art and Beyond*. Cambridge, MA: The MIT Press.

Kelty CM (2010) Outlaw, Hackers, Victorian Amateurs: Diagnosing Public Participation in the Life Sciences Today. *Journal of Science Communication* 9(1): 1–8.

Latour B (2004) Why Has Critique Run Out of Steam? From Matters of Fact to Matters of Concern. *Critical Inquiry* 30(2): 225–248.

Latour B (2008) A Cautious Prometheus? A Few Steps toward a Philosophy of Design. *Keynote Lecture for the Networks of Design Meeting of the Design History Society*. Falmouth, Cornwall, 3rd September 2008.

Latour B (2010) An Attempt at a 'Compositionist Manifesto'. *New Literary History* 41(3): 471–490.

Maeda J (2010) On Meaningful Observation. Seedmagazine.com. Available at: http://seedmagazine.com/content/article/on_meaningful_observation1/.

Marcus G (2013) Experimental Forms for the Expression of Norms in the Ethnography of the Contemporary. *HAU: Journal of Ethnographic Theory* 3(2): 197–217.

Michael M (2012a) De-signing the Object of Sociology: Toward an 'Idiotic' Methodology. *The Sociological Review* 60(S1): 166–183.

Michael M (2012b) 'What Are We Busy Doing?' Engaging the Idiot. *Science Technology Human Values* 37(5): 528–554.

Owen R et al. (2013) A Framework for Responsible Innovation in Responsible Innovation. In: Owen R et al. (eds) *Responsible Innovation: Managing the Responsible Emergence of Science and Innovation in Society*. Chichester: Wiley, pp. 27–50.

Pohflepp S and Mansy S (2014) Living Machines. In: Ginsberg D et al. (eds) *Synthetic Aesthetics: Investigating Synthetic Biology's Designs on Nature*. Cambridge, MA: The MIT Press, pp. 247–258.

Ratto M (2011) Critical Making: Conceptual and Material Studies in Technology and Social Life. *The Information Society* 27(4): 252–260.

Rip A (1999) STS in Europe. *Science, Technology and Society* 4(1): 73–80.

Rip A and te Kulve H (2008) Constructive Technology Assessment and Sociotechnical Scenarios. In: Fisher E et al. (eds) *The Yearbook of Nanotechnology in Society, Volume I: Presenting Futures*. Berlin: Springer, pp. 49–70.

Schot J and Rip A (1997) The Past and Future of Constructive Technology Assessment. *Technological Forecasting and Social Change* 54(2–3): 251–268.

Sismondo S (2008) Science and Technology Studies and an Engaged Program. In: Hackett E et al. (eds) *The Handbook of Science and Technology Studies*. Cambridge, MA: The MIT Press, pp. 13–33.

Stirling A (2008) 'Opening up' and 'Closing Down': Power, Participation and Pluralism in the Social Appraisal of Technology. *Science, Technology & Human Values* 33(2): 262–294.

Stracey F (2009) Bio-art: The Ethics behind the Aesthetics. *Nature Reviews Molecular Cell Biology* 10(7): 496–500.

Wilkie A (2011) Regimes of Design, Logics of Users. *Athena Digital* 11(1): 317–334.

Wrenn E (2012) Scientists Create Yoghurt That Changes the Colour of Your Poop to Diagnose Illnesses. *Daily Mail*, 18 June.

Wynne B (1992) Misunderstood Misunderstanding: Social Identities and Public Uptake of Science. *Public Understanding of Science* 1(3): 281–304.

3

The skin of a living thought

Art, science, and STS in practice

Hanna Rose Shell

> A word is not a crystal, transparent and unchanged, it is the skin of a living thought and may vary greatly in color and content according to the circumstances and the time in which it is used.
>
> —*Oliver Wendell Holmes Jr.*

In 1918, Supreme Court Justice Oliver Wendell Holmes Jr. delivered these eloquent lines in the context of what might otherwise have appeared a rather dry decision about stock dividends and income tax. And yet in so doing, he also evocatively articulated the extent to which words are open-ended, existing in a state of flux as regards their relationship to the discursive and sociotechnical environments in which they lurk. It is due to this skinliness, their approximation of processes of thinking neither fixed nor diffuse, that the legal code as written should be understood in practice. Holmes contrasts the productive open-endedness of words to that which is "crystalline, transparent and unchanged." If "a word is *not* (my emphasis) a crystal" in his sense of signifying a fixed and permanently objective reality, then a camera *objectif* seems as if it does so with precision. Crystal, transparent, and unchanged, fixed – if not in time – at least in frame (Figure 3.1).

Struck as I am by his profundity here, his address of the material object itself as in contrast to that of the written word, I take Holmes' verbal *tournage* as provocation. "The skin of things" first served as a guiding concept in my early scholarship on taxidermy as a form material memory (Shell 2004). And here it provokes a set of reflections on my couple decades of multimodal scholarly production in Science and Technology Studies (STS). I hope these reflections on my movement among words and images, stillness and motion, embodiment and disembodiment, provoke humanists and artists alike to take seriously the analytic capacity of photographic images and filmic documents as the means for making new forms of knowledge in this and related disciplines (Galison 2014; Shell 2014a).

The point is to be attuned to the multivalences (polyvocality) of words as much as of images, objects, tastes, and so forth as articulations of meaning. While Holmes's opinion has generally been understood in terms of an argument for legal realism, it inspires as a frame for thinking about multimodality in scholarship – not generally so much as specifically when it dovetails with the study of the visual and material contours of science and technology. I use

DOI: 10.4324/9780429437069-5

Figure 3.1 The Skin of a Living Thought I. My inquiry into the relationship between skins and thoughts, began with taxidermy, a subject I pursued through an extensive series of medium and large format photographs made in natural history museums, as well as scholarly research and writing. As in much of my work, I combined traditional and popular scholarly writing, with intense image making. Of the relationship between animal hides and "living thoughts," William Temple Hornaday (taxidermist, conservationist, and the subject of my publications between 2000 and 2004) wrote that an animal's "skin is its soul, and when mounted by skillful hands, it becomes comparatively immortal." (Photograph by Hanna Rose Shell, Redpath Museum, Montreal, Canada, 1998.)

it to open up this chapter. Whether or not images "speak" (and this is the mode often used to argue for or against the analytic capacity of visual practice), they are in many ways no more slippery than the words we often so wrongly presume to have crystallized.

My process is of a lived synthesis of theory and practice; for me, a range of media practices and processes, from archival research, to photography and filmmaking, performance and more traditional writing, constitute practice. In this context, my work deals with the history and cultures of science and technology of the "sociotechnical" in the sense of philosopher Gilbert Simondon's discussion of elements, individuals, and ensembles (Simondon 1989). The past is a site through which to more richly inhabit the present and, in turn, for the present to provide a vital lens on the past, uncovering historical shifts in understandings of self, nature, technology, and mediation.

In what follows, I consider multiple bodies of my work and the productive duality of making and knowing within each: first, a project about the history of chronophotography (motion photography); second, a project about camouflage and photographic surveillance; and third, an extended project about textiles and technologies of recycling. I introduce two concepts, and terms, that have emerged as part of my process, and propose their broader application in STS: that of *creative inhabitation* and *curatorial analytic*.

Chronophotography: entanglements of stillness and motion

Chronophotography, a set of photographic techniques developed in the late nineteenth century and intended for the scientific study of organic movement, is often presented as a precursor to the development of cinematic apparatus and the modern picture. "Serial photography" is another way it is often described. How are we to understand the chronophotographic impulse of nineteenth-century physiology in relation to – on the one hand – matters of technology and laboratory practice, and – on the other hand – experiences of movement, matters of phenomenology, identity, and emergent aesthetics of attraction and illusion? Scholarly work in the areas of STS, the history of science and technology, and cinema studies had addressed these topics in prose (Cartwright 1995; Doane 2002). Transposition and historical (re) enactment, along with dialectical montage, provided my own entry point (Eisenstein 1949).

The overall *Chronophotography* project – a film, multichannel installation, and scholarly publication – began with a quandary about the aesthetics of, in theorist of film and photography Siegfried Kracauer's words, "capturing material phenomena for their own sake" (Kracauer 1960a, 39). It was early in the new millennium when I got interested in scientific cinematography. More specifically – more materially – it was fish. I got interested in fish – fish skins and fish fins, the cameras studying them, and then the cameras studying the scientists operating them. I began to make a film about laboratory practice at a fish physiology laboratory, wherein physiology consisted in the study of movement as passage through time and space. I became interested in the role that filmic apparatus – and high-speed video cameras in particular – played in producing knowledge about how underwater organisms navigate hydrodynamic currents.

In the George Lauder laboratory, researchers used high-speed video cameras to capture information about the way trout navigated through the water in such a way as to maximize energy efficiency (Lauder 2008). Cinematic data was analyzed in order to model the generation of the so-called vortices. In other words, scientists were making films out of fish, and those films, in turn, became data for use in answering questions about animal behavior in nature and possible applications of this information to human technologies (e.g., submarine efficiency). I found this process captivating and beautiful. I began thinking about the pre-history of cinematography: the birth and development of serial photography via the locomotion studies of the American Edward Muybridge and Frenchman Etienne-Jules Marey (Marey 1895; Lajoux 1994). And it was while looking at the published writing and correspondence of the latter, French physiologist-inventor–photographer Marey, I came upon an image first published in the preeminent French scientific publication *La Nature* in 1890, depicting an aquarium laboratory built into the wall of a villa overlooking the Bay of Naples (Marey 1890). In it, as it is described in the accompanying article, he is using one of his new-fangled proto-cinematographic, "moving band" cameras to try to figure out how marine creatures move through underwater environments. Marey documents sea creatures' motion through space and time using this modified photographic apparatus.

I wanted to get inside of it, to get into the picture. My drive was for what I am calling *creative inhabitation* thereof. Could I find a way to *inhabit* (intellectually or otherwise) the scientific scenarios depicted therein? I made a film – or as it turned out, a series of films – that explored and expressed the relationship that this one historical image might have to my experience as scholar-practitioner in the present: as observer, filmmaker, and critical thinker (Shell 2012a). As in multimodal scholarship more generally, the project's production as a whole drew together institutions (the Lauder Laboratory and Harvard University, The Marey Museum in Beaune, the Cinématheque Française in Paris, and the Stazione Zoologica Napoli in Naples) and individuals both historical and contemporary – scientists, engineers, museum professionals, and artists. Audio-visual outcomes included a single-channel film and a multichannel installation. I will touch on both.

Moving between past and present, text and image, travelogue and reverie, the short film *Locomotion in Water* (Shell 2005a) interweaves the reflections of the nineteenth-century chronophotographer with the animating impulses of a modern-day filmmaker (Shell 2005b). My understanding here is of montage motivating phenomenological experience and historical archaeology. For example, a shot of an octopus slurpily oozing its way out of its plastic container and wriggling across the stone floor of the fish market is followed directly by Marey's own fiber paper prints of octopus motion made more than a century earlier.

The finished film has lent itself to a range of interpretations, eliciting multiple emotional as well as analytic responses. For some, it is a direct experience of organic propulsion. To others, it is an entrée into the filmmaker's own time spent on the pier. Experimental avant-garde filmmaker Abigail Child described it as, in her words, "an unmasking of the abject." In regard to the project, the philosopher Stanley Cavell called attention to the intersection and cohabitation of

> ideas and passions . . . caught in moving color or in stilled silhouette . . . a dream or a ballet . . . modes of study and perception reflect[ing on] one another here . . . aesthetics, science, history, biography, philosophy.

This multiplicity of responses is the result of the overlapping capacities of the filmic image – as descriptor, classifier, and theorizer (Shell Prelinger article).

My goal, beyond *inhabitation* of that seminal image from 1890, was to pick up and curate traces, palpable documents, of the past, to resolve the historical remnants into a form of analysis capable of productive interaction with the conditions of the present. An installation, "Aqua Kinema" (literally "water movement"), was completed with four projections of image and object-based montage. Multiple channels, screening concurrently, took four different approaches to the problem of understanding a particular moment of history. The first was the immediacy of the digital representation of movement and the dreamy evanescence of history and the flickering, archival photograph. The second was the resuscitation and integration of archival photographs of a handwritten letter from 1890. The third was the juxtaposition of contemporary laboratory practice with its historical antecedents, drawing on the rhythms of a modern scientist's use of high-speed video and prismatic mirrors to study rainbow trout's fin movement and underwater eddy formation. Fourth, and last, was the experience of the fish market in Naples as I found it in the present. I recast the shots, separating, labeling, and organizing, curating them, with the effect of an imbrication of past and present, also in evidence in the later projects.

Camouflage: history, multimodality, and creative inhabitation

The concept of *creative inhabitation* emerged as an abiding gesture as well as the ideal outcome of a search to "get inside" a simultaneously historical and technological subject of study. In

Chronophotography, I had set out to uncover theretofore-unconsidered aspects of early scientific cinematography. In *Camouflage*, I considered the relationship between such technologies of observation and the comprehension and cultivation of technologies of concealment.

Based on a curatorial mode of research, study, and argument and showing the extent to which science, technology, and art are inextricably linked, I showed – in a book, exhibitions, a film, and workshops – how camouflage is an adaptive logic of escape from photographic representation. I articulate the means and media by which it developed in counterpoint to technological advances in photography, innovations in warfare, and mysteries of natural history and experimental art. A central part of this body of work came together in a book, *Hide and Seek: Camouflage, Photography and the Media of Reconnaissance*, published in 2012 (Shell 2012).

The project disclosed three conceptually linked "species" of photographic camouflage. With these in mind, it considered late twentieth- and recent twenty-first-century incarnations of camouflage practice, as camouflage became simultaneously the mechanism of mass surveillance, on the one hand, and the means and media of individually articulated resistance, on the other hand.

My process in framing the argument combined a range of media practices that incorporated these materials in a multifaceted way, together revealing historical, technological, and epistemological relationships between the natural and military sciences from the mid-nineteenth to the mid-twentieth centuries. The static, serial, and dynamic critical modes of camouflage coincided with different trends in the visual arts – from painting, to film, to sculpture, as well as military practice (Shell 2009). Experimental film action movies, pedagogical training videos, kinetic art, and the direct animations of the 1930s are practices I trace to these impulses and ideologies.

A personal film became central to the development of my argument as well as providing its own tightly crafted mode of inquiry and its embodiment. *Blind* (2012, based on a 2008 collaboration with the architect Dan Hisel and environmental historian Etienne Benson [McQuaid 2008]) is a film about the phenomenology of camouflage. *Blind* both documents and is itself an experiment in hide and seek. The film, along with the multimedia performances and environmental interventions out of which it emerged, became a way to project myself into my subject, to creatively inhabit and materially transform: I call this process *creative inhabitation* (Figure 3.2).

Related installation and public performance works have been shown at the Harvard Museum of Natural History as well as (with Luke Fischbeck, Sara Rara, and Sumi Ink Club) at Machine Project, Los Angeles (Carp 2012). This multimodal scholarly process lent itself to a product that could inspire further art and curatorial projects. For example, the work has been part of a show at the Clark Museum, at the Imperial War Museum in London, and in a New York gallery. It also served as the inspiration for a 2018 film and 2019 exhibition in Montreal. The material forms camouflage has historically and continues to leave behind include paintings, stuffed rabbits, instructional films, sniper suits, and woolen blankets. Working with such things, the provocation of their vibrant materiality, and resultant critical sympathies, drove formulations of argument and narrative.

Textile skins: the materiality of clothes' recycling and the curatorial analytic

The last of the three projects under discussion in this essay take up the study of recycled textiles, investigating the technological aspect of their processing and rebirth. From their origins

Figure 3.2 The Skin of a Living Thought II. "The sooner you develop a consciousness of the importance of camouflage, and accustom yourself to the discipline of protective concealment, the better it will be for you and others on your side," wrote French architect Jean Labatut in a lecture to students in 1943. For me, accessing such a "camouflage consciousness" through art-making, performance, collaborations such as this one, called Industrial Melanism, with musician Luke Fischbeck, enabled the formation of my scholarly argument as presented in my book Hide and Seek: Camouflage, Photography and the Media of Reconnaissance. (Photograph by Hanna Rose Shell, Machine Project, Los Angeles, California, 2012.

in the first days of human culture, textiles for personal wear have been portable technology, shaped by the demands of a mobile body, and inscribed with markers of that body and its sociopolitical environment's history. My approach is inspired by phenomenology and media studies, as well as post-constructivism in STS (Barad 2007; Bennett 2009; Marks 2000). The bodies of work include multiple short films, photographic and scholarly essays, an exhibition, and a book (Shell 2006, 2007, 2014c, 2016, 2017, 2020).

Recycled matter, as understood collectively, is both a principle of manufacture and its interpretation. Objects and media – whether officially sanctioned as "art" or "trash" or whatever in between – archival photographs, documents, or field recordings – are critical in this work (Figure 3.3).

Figure 3.3 The Skin of a Living Thought III. Secondhand textiles, which eventually became the subject of the film Secondhand [Pèpè] and book Shoddy: From Devil's Dust to the Renaissance of Rags, originally emerged for me as something palpably alive through photography. I made this photograph a city block beyond a now-defunct Salvation Army that contained both a thrift store, and shelter and rehabilitation services for the unhoused. Its evocation of a (more-or-less dead) body, stayed in my mind, as I developed the concept into films, essays and eventually a book. This is my identification of what I have come to refer to as "textile skins." (Photograph by Hanna Rose Shell, Central Square, Cambridge, MA, 1996.)

Working with things – their materiality, and their resistance to any simple or single "voice" – drives argument and narrative. A full study of the technology of textiles reuse required close looking and touching, as much if not more so than reading and combing through archives. Most central was the exhumation and re-articulation of photographic, filmic, audio, and other experientially bound documents thereof through a curatorial process that is simultaneously a mode of analysis (what I refer to as a *curatorial analytic*). I organized a radio show, collaborated with Cuban artists and Haitian dealers, while also assembling a collection of films on the topic of rags and immigrants going back as far as 1908; home movies; and ephemera. As the two converged in situ in a rag warehouse in which a millionaire rag dealer employed Haitian sorters and shredders, this opened up for me a whole world and way of seeing. In this, both recycling and reprocessing of textiles became conceptually interconnected with the reuse of archival film as well as sonic materials.

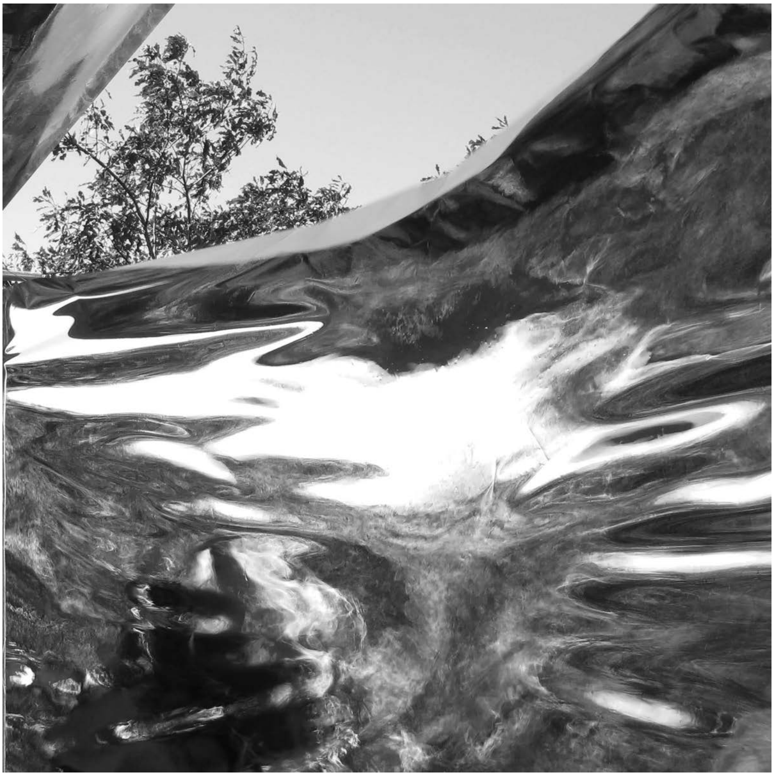


Figure 3.4 The Skin of a Living Thought IV. Here a camouflage-suit wearing participant in The Camoufleurs, is reflected in the mylar camouflage 'blind' designed by architect Dan Hisel and erected on a remote island in Boston Harbor. The reflection creates a secondary, and here a filmic, skin that obscures the human subject. It also literally became the cover imagery for my book Hide and Seek. (Documentation from: The Camoufleurs, Benson, Hisel, & Shell, Bumpkin Island, MA, 2008.)

Through film, in particular, the film co-directed with Vanessa Bertozzi *Secondhand (Pepe)*, I explored the meaning of these textile media through engagement with two different genres and historical epochs of recycled textiles (Shell 2006; Shell and Bertozzi 2007; McNeil 2008). In the more recent work, culminating in the book *Shoddy: From Devil's Dust to the Renaissance of Rags*, I take an even deeper look at the materiality of technology in this regard. "Shoddy" came into existence as a noun in the early years of the nineteenth century to refer to a repurposed textile material produced from old rags and tailors' clippings. Industrial-style recycling was born alongside the development of specially fabricated machinery for the sorting, grinding, scouring, and baling of old, used, usable wool. Textile media are here understood as both the material out of which new entities are produced and the means by which information is encoded and transmitted; this a technology of skins, a fabrication of our most proximate biological, cultural, and psychological environments (Figure 3.4). This particular thought was explored in another film of mine, *Shoddy Aliens* (Shell 2017), as well as essays in the journals *History and Technology* and *Cabinet* (Shell 2014c, 2017).

As in the other projects, the filmic is engaged with as a stripping of matter from form, as part of a project intended to, to return to Kracauer again, "redeem this world from its dormant state, its state of virtual nonexistence" (Kracauer, 1960b, 300). The historical record, the people I've met, the materials I've collected, and my senses and experiences of wool, of machinery, of rotting old clothes and detritus participate actively in my *creative inhabitation* of the inquiry. Meanwhile, the rag, the ragged – in its very interstitiality, its peculiarly evocative nature – reveals the centrality of reuse in mediating our relationships to nature, technology, and each other. Archival visual materials and photographic documentation of contemporary life, on the one hand – specific moments, touches, angles, traces in sound and images – grant a material thickness. These, in turn, serve as the means by which I develop and test interpretive frameworks and the formation of both narrative and argument, a culmination of which is the volume *Shoddy: From Devil's Dust to the Renaissance of Rags* (Chicago: University of Chicago Press, 2020), which I both *illustrate* with a range of archival photographs and *argue* drawing on the very filmic and photographic documentations I made of textile remnants and personal narratives.

The skin of a living thought: on film and STS

In this most recent project as well as in those preceding it, my work as STS scholar is built from my dual identities and material practices – as artist, on the one hand, and historian of science and technology, on the other hand. As in the other projects, the filmic is engaged with as a stripping of matter from form but also as an object of inquiry and composition – to, as Kracauer might have had it, "redeem this world from its dormant state" (Kracauer, 1960b, 300). We can also consider Oliver Wendell Holmes Jr.'s own father's words, written about photography nearly six decades before the court case with which this essay began: "Every conceivable object of Nature and Art will soon scale off its surface for us" (Holmes, 1864).

Films and filmmaking serve as means of documentation and mode of argumentation (Shell 2014b). Films – both as found (archival) and as created (authored) – have a status both material and metaphorical as simultaneously slippery and crystalline. Traces and lenses of nature, on the one hand, and ways of knowing and transforming it, on the other hand, skins and films both exist at the locus of commingling the subjects and objects of scientific and technical knowledge production. Textual, archival, audio-visual, and even sensory traces become units of analysis and building blocks of exhibition and argument that, in turn, expose new hermeneutic possibilities by means of which art and the science–technology matrix can reflect on one another, to productively commingle: a *curatorial analytic*. These are resituated in such a way as they are made to speak, live, breathe – and even to evanesce – most authentically, with the effect of opening up new modes of experiencing and interpreting the historical, aesthetic, and phenomenological complexities of science and technology (Figure 3.4).

Acknowledgments

I presented a version of this chapter at a symposium at Yale University at the Whitney Humanities Center on Theory/Practice: Expanding Scholarship in the Age of Digital Media in March 2018, and I am grateful to the organizers and participants in the workshop, especially Dudley Andrew, Charles Musser, and Laura Wexler. Additional invaluable feedback emerged in the seminar on Multimodal Scholarship I co-organized and convened with Charles Musser at the Society for Cinema and Media Studies Annual Conference held in Seattle in March 2019. Thank you, as always, to my collaborators Vanessa Bertozzi and Luke Fischbeck, and all the museums and institutions that have participated along the way.

Sources

Barad, K., 2007. *Meeting the Universe Halfway: Quantum Physics and the Entanglement of Matter and Meaning*. Durham, NC: Duke University Press.
Bennett, J., 2009. *Vibrant Matter: A Political Ecology of Things*. Chapel Hill, NC: Duke University Press.
Carp, A., 2012. "Hiding in Plain Sight." *Paris Review*, June 5.
Cartwright, L., 1995. *Screening the Body: Tracing Medicine's Visual Culture*. Minneapolis: University of Minnesota Press.
Doane, M., 2002. *The Emergence of Cinematic Time: Modernity, Contingency, the Archive*. Cambridge, MA: Harvard University Press.
Eisenstein, S., 1949. "A Dialectic Approach to Film Form." In *Film Form: Essays in Film Theory*, ed. and trans. Jay Leyda. Boston, MA: Mariner Books, 1969, pp. 45–63.
Galison, P., 2014. "Visual STS." In *Visualization in the Age of Computerization*, ed. Annamaria Carusi, Aud Sissel Hoel, Timothy Webmoor, and Steve Woolgar. New York: Routledge, pp. 197–225.
Holmes, O.W. Sr., 1864. "The Stereoscope and the Stereogram" first published in *The Atlantic* (June 1859), reproduced in Holmes's book *Soundings from the Atlantic*. Boston, MA: Ticknor and Fields, pp. 124–165.
Holmes, O.W. Jr., 1918. *Towne v. Eisner*. no. 563. Argued Dec. 12, 1917, decided Jan 7, 1918.
Kracauer, S., 1960a. "The Issue of Art." In *Theory of Film: The Redemption of Physical Reality*. Princeton, NJ: Princeton University Press, 1997, p. 39.
Kracauer, S., 1960b. "Film in Our Time." In *Theory of Film*. New York: Oxford University Press, p. 300.
Lajoux, J.D., 1994. "Etienne Jules Marey, les origines du cinema." In *Le Cinéma et la Science*, ed. A Martinet. Paris: CNRS Editions, pp. 33–45.
Lauder, G.V., 2008. "Advances in Comparative Physiology from High-speed Imaging of Animal and Fluid Motion." *Annual Review of Physiology* 70: 143–163.
Marey, E.J., 1890. "Locomotion dans l'eau." *La Nature* 911: 375–378.
Marey, E.J., 1895. *Movement*, trans. E Pritchard. New York: Appleton Co.
Marks, L.U., 2000. *The Skin of Film: Intercultural Cinema, Embodiment, and the Senses*. Raleigh, NC: Duke University Press.
McNeil, J., 2008. "The Afterlife of American Clothes." *Reason*. August–September.
McQuaid, C., 2008. "Artists Colonize a Harbor Outpost." *Boston Globe*. August 30.
Shell, H.R., 2004. "Skin Deep: Taxidermy, Embodiment and Extinction." In *The Past, Present and Future of Natural History*, ed. A Leviton. San Francisco: California Academy of Sciences, pp. 88–112.
Shell, H.R., 2005a. *Locomotion in Water*. Boston, MA: Fabrik Films.
Shell, H.R., 2005b. "Things Under Water: Etienne-Jules Marey's Aquarium Laboratory and Cinema's Assembly." In *Dingpolitik: Atmospheres of Democracy*, ed. B Latour and P Weibel. Cambridge, MA: The MIT Press, pp. 326–332.
Shell, H.R., 2006. "Textile Skin." *Transition* 13: 152–163.
Shell, H.R., 2009. "The Crucial Moment of Photographic Deception: Abbott Handerson Thayer's Law of Protective Coloration." *Cabinet: A Quarterly Journal of Art and Culture* 33 (Spring): 17–30.
Shell, H.R., 2012a. "Cinehistory and Experiments on Film." *Journal of Visual Culture* 11: 288–306.
Shell, H.R., 2012b. *Hide and Seek: Camouflage, Photography and the Media of Reconnaissance*. New York: Zone Books.
Shell, H.R., 2014a. "Beyond Words: Audio-Visual Media in the History of Technology." *Technology and Culture* 55 (April): 477–478.
Shell, H.R., 2014b. "Films in the Archive: The Prelinger Collection and Hollywood in Detroit." *Technology and Culture* 55 (July): 711–715.
Shell, H.R., 2014c. "Shoddy Heap: A Material History between Waste and Manufacture." *History and Technology* 30: 374–394.
Shell, H.R., 2016. "Devil's Dust." *Cabinet: A Quarterly Journal of Art and Culture* 60 (Fall): 1–8.
Shell, H.R., 2017. *Shoddy Aliens*. Boston, MA: Fabrik Films.
Shell, H.R., 2020. *Shoddy: From Devil's Dust to the Renaissance of Rags*. Chicago, IL: University of Chicago Press.
Shell, H.R., and Bertozzi, V. 2007. *Secondhand [Pepe]*. New York: Third World Newsreel.
Simondon, G. 1989. (1958). *Du Mode d'existence des objets techniques*. Paris: Aubier.

4

Aesthetic strategies for engaging with environmental governance

Christian Nold and Karolina Sobecka

Introduction

Art has been alternatively portrayed as a transformative source of new ways of doing and thinking, or dismissed as having little agency to change the world. Artists have found their work underpinning new technological or media trends, or co-opted as 'a gloss for dispossession, displacement and, ultimately, social cleansing' (Prichard, 2017, para. 1). This text discusses how artists can proactively use their work on their own terms, by employing aesthetic strategies to engage in alternative environmental governance.

There is a tradition of 'artist critique' within the avant-garde that positions the artist as outside of the system they address, allowing them to make critical pronouncements and point out the contradictions of modern life (Chiapello, 2004). But in the last decades, artists are increasingly getting involved in new roles and categories of collaboration to position their practice in a different relation to a variety of actors. Art and science collaborations have become established by large institutions (Art At Cern, 2016; Wellcome Trust, 2019) and international prizes (Ars Electronica, 2019), and become a new genre of artistic practice. Artist-initiated art–science projects often focus on ethical and political issues in emerging science and technology, such as Oron Catts and Ionat Zurr's 'Disembodied Cuisine', an early exploration of the ethics of laboratory-grown meat, or Heather Dewey-Hagborg's 'Stranger Visions' for which she created 3D-printed portraits based on the DNA of strangers (2014). Yet, institutionally initiated collaborations often see artists uncritically serving the agenda of the institution. For example, the artist role is often assumed to be that of a science communicator, or an illustrator of scientific concepts employed in the promotion of science's societal benefits. In Silicon Valley, technology companies are offering residency opportunities for artists to play and experiment with their tools. They give artists access to new technologies and media, but rarely space to reflect critically on the historical, material, or labour underpinnings of these technologies and corporate practices. Further, resident artists' experimentation is supported with an eye of channelling it towards innovation, thereby placing artists into a similar role as the company's R&D researchers. Not only are artists paid a lot less, but their involvement is additionally being capitalized on by associating the company with cutting-edge culture (Clements, 2012). In other contexts, artists are employed to carry out

DOI: 10.4324/9780429437069-6

community engagement in areas where regeneration projects have created local backlashes. In those situations, artists are deployed as social workers and cultural gentrifiers, without their explicit knowledge (Prichard, 2019).

The sketch above represents an overview of areas where artistic methods and practices are adapted in various contexts. Calvert and Schyfter (2017) suggest that these collaborations can be broadly divided into three categories. The first category follows a 'logic of accountability' that uses interdisciplinarity to '*help scientific research become more accountable to society*' (2017, para. 198). The second category follows a 'logic of innovation' that harnesses creative transgression and channels it into economic growth. In the third category, Calvert and Schyfter propose a 'logic of ontology' that generates '*something that would not have happened otherwise*' (ibid), meaning that art is world-making and creates new 'realities' (ontologies). While the first two logics of accountability and innovation are recognizable in the examples above, the third, of creating new realities, is less clearly visible or articulated in the literature.

In the last decade, Science and Technology Studies (STS) has started to engage with the world-making potential of artistic practices, as can be seen in the interdisciplinary exhibition and book *Making Things Public: Atmospheres of Democracy* (Latour and Weibel, 2005). This approach is part of a shift away from critiquing science and technology production and towards trying to find new methods for building 'common worlds' with the natural sciences (Latour, 2004). Social science researchers are starting to adopt 'inventive methods' (Marres, Guggenheim and Wilkie, 2018) and proposing the need for 'ontological interventions' (Law, 2004) that use aesthetic sensitivities to actively transform case studies (Nold, 2018b). In this vein, Lury and Wakeford (2012) offer social science researchers a catalogue of inventive approaches derived from media objects and art for materially engaging in transformative practices.

Yet, so far, it has largely been social scientists describing the ontological potential of artists' practices as outsiders rather than as practitioners (Beyes and Steyaert, 2011). The result is often an exoticization of creative practitioners that makes it harder to integrate these practices with STS methods. What is missing from these accounts are artists' descriptions of the dynamics of material things as well as the practical limits and potentials of their practices. In this text, we draw on our dual roles as artists and social scientists to bridge this gap by reflecting on how our work functions. We propose an approach for a more fruitful relationship between STS and art. To do this, we adopt the term 'aesthetic strategies' to describe the use of formalized creative approaches that come from the realm of art but aim beyond visual concerns towards inventively performing social and material realities. We frame 'aesthetic strategies' as a concept that can stand outside of us and can communicate towards a wider community in order to support explicit impacts on the world. We relate this approach to a lineage of socially engaged art from the 1970s, such as Stephen Willats (2000), and media activism from the 1990s, such as Tactical Media (Garcia and Lovink, 1997), which tried to codify aesthetic practices to achieve broader political impacts. Tactical Media used the military metaphor of tactics as a way of gaining short-term advantage, while strategic power remains in the structural apparatus. Yet, Garcia argues that this focus on short-term artistic tactics often resulted merely in 'small scale homeopathic interventions' (2014, p. 14) that did not achieve depth or long-term engagement with real-world problems. Thus, in our approach, we foreground artists using strategies to build towards long-term gains by engaging with the structures of institutional governance. We prefer the term 'strategy' over 'method' since it has a clear trajectory and direction in mind, while avoiding being prescriptive and claiming knowledge creation.

Combining the terms 'aesthetics' and 'strategy' acknowledges that aesthetics is not simply related to the judgement of appearance but can be instrumentalized towards specific goals and impacts. Researchers are revisiting notions of aesthetics as a theoretical and practical basis for transforming the world using design interventions (Wilkie, 2016). Jaques Rancière defines aesthetics as the 'distribution of the sensible', and writes that both art and politics use it as a mode of governance based on shaping the regimes of visibility. In his view, aesthetics determines what presents itself to sense experience, working through delimiting of 'spaces and times, of the visible and the invisible, of speech and noise, that simultaneously determines the place and the stakes of politics as a form of experience' (Rancière, 2015, p. 13). For Rancière, it is through these aesthetic means that one can intrude into stable political and material orders and reshape them. In this paper, we demonstrate how aesthetic practices intersect with environmental governance, and how they can be intentionally used to modulate it.

Case studies

This text brings together two examples of aesthetic strategies developed by the authors: of 'mirroring' and 'friction synthesis', and reflects on how they function. In particular, the case studies show how these strategies support engagement in alternative decision-making processes within environmental governance. These are merely two examples of the many current and potential aesthetic strategies. We hope by formally outlining them that it may encourage others to build on these examples. Each case study begins by outlining the strategy as an abstract concept, before describing a specific example of the strategy being used within a particular site. The final section of each study discusses how this strategy functions and how generally applicable it might be (Figure 4.1).

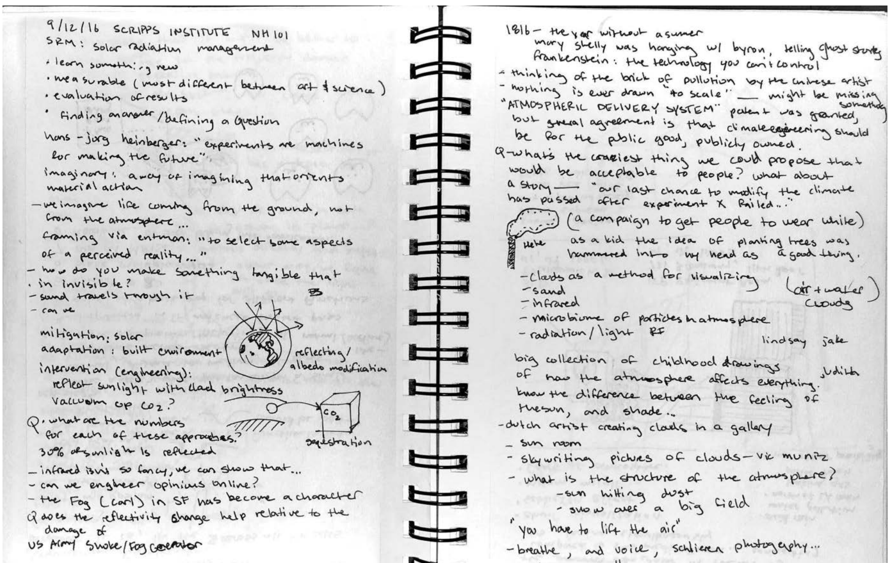


Figure 4.1 Sketchbook notes from the mirroring workshop (2016)

Strategy: mirroring

This strategy involves restaging an institutional process which might not be explicitly defined as environmental governance, but is part of the bureaucratic protocols that channel actions and decisions. The strategy involves re-enacting a 'target process' on a public stage, by focusing on pragmatic and mundane aspects which are not controversial, yet which shape the possibilities of actions. This might mean restaging the physical or institutional setting, the event structure, or the invited participants. For example, the geographical and institutional setting is well known to imbue a process with epistemic authority (Gupta and Möller, 2019) – in particular, when it is associated with a prestigious institution in the global north. Therefore, restaging a process in the global south can reflect on the colonial underpinnings of knowledge and governance and make visible counternarratives that draw on local, situated knowledge. Similarly, mirroring can also be used to restage the demographic make-up of invited participants, the incentives offered for taking part as well as the way a process is facilitated and framed. The mirroring strategy thus highlights the often unacknowledged pragmatic aspects of environmental governance that nevertheless shape its scope and limits.

Example of the strategy

This example focuses on a mirror event, organized by Karolina Sobecka, which restaged the LEISE (Low Environmental Impact Solar Radiation Experiments) workshop that took place at the Institute for Advanced Sustainability Studies (IASS), in Potsdam, Germany, in September 2016. We refer to the IASS workshop as the 'original'. The event brought together scientists and engineers from the geoengineering community to work in small groups on writing up examples of potential geoengineering experiments. The goal of the workshop was to create a report that would clarify what geoengineering field experiments could consist of, with the result being a shared resource that should '*act as a foundation for discussions among a wide range of stakeholders about the value and risks of SRM research, about experimental priorities, research governance, and ethics*' (Institute for Advanced Sustainability Studies, 2016, para. 3). The participants were guided to produce a list of potential low environmental impact Solar Radiation Management (SRM) experiments (Institute for Advanced Sustainability Studies, 2016).

Sobecka took the IASS workshop as an object of mirroring to examine how such a process might be 'performative': what it allows and disallows, how it might predispose specific outcomes, how it contributes to problem framings becoming coherent and integrated into the circulated narratives and shared assumptions. The mirroring event took place two days after the original, at the Scripps Institution of Oceanography, California. This workshop convened participants with a goal of producing a list of experiments that could potentially be performed on the atmosphere. One of the most prominent alterations to the structure of the workshop was the change in the disciplinary and gender breakdown of participants, who in this version included artists and designers, and significantly more women than in the original workshop.

The proposals and ideas discussed during the mirroring workshop largely focused on affective or sensory experience of the atmosphere, such as being able to make it audible or capturing and reproducing the ambience and materiality of momentary atmospheric conditions. The approaches and motivations of the participants were diverse, and the group-work consisted of collective brainstorming, without narrowing the pool of ideas or focusing on designing specific experiments. The atmosphere was framed as a multiplicity of things: a connective tissue, a system of pneumatic physical exchanges or respiratory exchanges, a communication medium that carries messages, or an entity that you can hear, which prompted questions of what the atmosphere might 'say' about the changing weather patterns, emissions, or the planetary and social metabolisms. The result was a sense of the multivalency of the atmosphere that leads less to a concern with its control through technical means than to searching for rootedness in an everyday sense of a relationship with it. The event wasn't targeted towards generating ways to address climate disruption, but the multifocal discussions visualized the interconnections between the human, social, and physical earth system that might bear a new conceptual relationship to it.

The mirroring strategy reveals that both workshops were defining goals, visions, and the future path of intentional interactions with the atmosphere. The organizers of the original workshop described it as 'not' involved in the governance of geoengineering research. However, by defining a narrow set of possible experiments of technical intervention, and recording it in a document, it cemented a vision of actionable solutions, exercising a 'world-making' power.

The original workshop participates in naturalizing geoengineering imaginary, contributing to its integration in the popular imagination, first through its socialization in the community of experts and then, packaged in the report which is to be referred to as a 'foundation for discussions about the value and risks of SRM research', through the repetition of problem framings and solutions in both the public realm and the realm of climate governance. In contrast, the mirroring workshop made visible a diversity of possible alternative relationships to the earth's atmosphere, which compel a deeper consideration of values guiding decisions on climate action, and goals that orient and prioritize characteristics of desirable futures. While the solutions put forth through the established processes and institutions have the air of realism and inevitability because they are extensions of what we already have, alternatives that come from different knowledge practices, and ones that activate different engagements, are usually relegated to contexts associated with fictive proposals: utopian fictions and art exhibitions. The mirror workshop overcomes this dynamic by creating a public stage for articulating new approaches and framing those as fundamentally the same as the visioning operations of the dominant modes of governance, albeit not supported and legitimatized by them. It compels consideration of the structures that enable some visions to survive as promising or even necessary, while others are disempowered as naïve or unrealistic. The outcome of the mirror workshop is not a cohesive vision of engineering the sky, but rather a reverie demonstrating logics not consistent with the dominant ways of thinking, what might be called a 'poetic displacement', through which as Rancière suggests, both art and politics can change the status quo.

How does the strategy function and what does it do?

The gesture of publicly organizing an 'alternative' version of a process questions the singular legitimacy of the official process and the authority of its outputs. The mirroring strategy works through the interconnected operations of reflection and duplication. It enables critical reflection on the workings of institutional processes. Mirroring as an optical operation involves not only doubling but also transformation, it inverts, offsets and scales, reshapes and reveals different worlds. Taking as its focus the pragmatic and mundane aspects of a process, the mirroring strategy engages with the procedural modes of governance, which leave participants out of decisions about fundamental values or directions, employing them instead in new implementations of environmental governance. Institutional processes can be thought of as procedural or algorithmic: operations of rules and affective settings that don't set aims or create bias but transmit them. The mirroring strategy cuts the connections to the goals a process was originally subordinated to, and instead floods it with alternative matters, values, and actors. The mirror process transforms the process it replicates by creating a space for both sets of participants to consider their roles and agency, and by transforming what the public sees. In this way, the strategy is reshaping the regimes of visibility, which is, for Rancière, how 'theatre' as a mode of aesthetic practice can exercise political agency. The stage, according to Rancière, '*is simultaneously a locus of public activity and the exhibition-space for "fantasies"*' (2015, p. 13), and therefore it 'disturbs *the clear partition of identities, activities, and spaces*' (ibid). Such stagings, or '*performative experiments*' as Dehlia Hannah calls them, '*play up and render conspicuous specific aspects, phases, and problems*' (2013, p. 11). The mirroring strategy highlights the influence of roles and identities of participants, of the choreographies of collective visioning and decision-making activities, and of the institutional stagecraft, staging them all as implicitly contributing to steering. Mirroring reproduces the staging of the original event and provides a space for making those trappings available for public examination and alteration. Moreover, it allows for a 'transgressive appearance of unauthorized speakers on the public stage' (Rancière, 2015, p. 18). Thus, the democratic function of the decision-making process can be recovered by '*lending its canonical forms*' (ibid) to be occupied by non-experts.

Through mirroring, the institutional choreographies can be stripped of a sense of inevitability and naturalness. Re-enacting the workshop reveals its performative qualities and produces a multiplicity of alternatives that can open up and redirect the process, potentially emerging as ways of shaping our relationship to the atmosphere in different ways (Figure 4.2).

Strategy: friction synthesis

The second strategy, friction synthesis, is based on the merging of two categories or entities that are usually kept apart. It is designed for dealing with category mistakes that are common in modernist dualism where mind and body, inside and outside, individual and collective, are treated as binary opposites. This kind of dualism can be seen in many places from medicine, technology, and the environment. A key part of this strategy is demonstrating that dualism doesn't work very well and that a synthesis is feasible in practice and can create interesting outputs. Yet, while the resulting synthesis is internally coherent, it still embodies a tension between these elements and creates a discomfort in relation to the institutional actors that find this synthesis exciting but also challenging to categorize. The strategy thus functions through this combination of attraction and discomfort.

Example of the strategy

This example from Christian Nold is the Bio Mapping process, device, and workshops (Nold, 2004) that spanned a decade and involved thousands of people across the world. Bio Mapping allows people to take part in 'emotionally mapping' and articulating a local area using a unique device. The Bio Mapping device combines the wearer's body measurement with galvanic skin response as an index of physiological arousal and a geographical positioning system. This is plotted together on a geographical map to display where people walked and to indicate their arousal at that location. Upon returning from their walk, the data is displayed to the participants, who take turns to verbalize their sensation and add textual observations on a map. The map combines both the quantitative data of the galvanic skin response and the qualitative data of people's recollections from their walks.

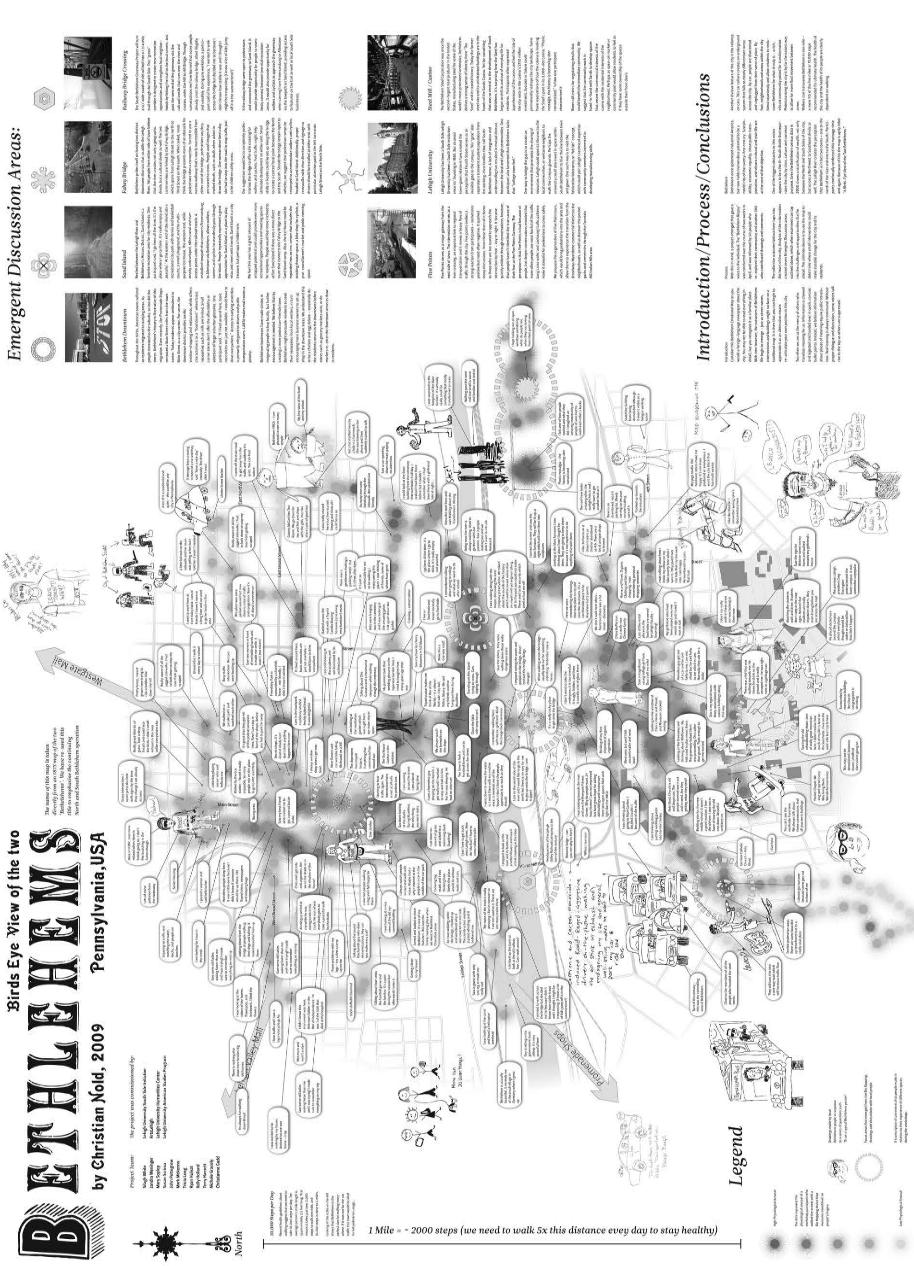


Figure 4.2 'Birds Eye View of the Two Bethlehems' (2009) showing the aggregated quantitative and qualitative data and perceptions of a hundred local participants. The right side of the map highlights problems such as lack of pedestrianization, low-income food provision, and the need for cycle lanes

The key aspect of the Bio Mapping strategy is that it combines three modes of legitimation. Firstly, the project involves over a hundred people in each location whose data and annotations are combined and designed into a single map. The involvement of so many local people including representatives such as politicians allows the maps to claim to speak about collective emotions and public opinions as 'Emotion Maps' (Nold, 2006). Secondly, galvanic skin response is part of the lie detector test and in the public imagination is seen as providing access to our unconscious. The project thus appears to make private emotion – publicly visible and useful. In this way, the project chimes with the public, commercial, and institutional imaginaries of cybernetic governance. Thirdly, the Bio mapping data consists of XML data that can be aggregated and visualized in technical Geographical Information Systems. This triple combination of mass participation, emotion imaginaries, and technical interoperability means the Bio Mapping project is 'readable' within existing technical and institutional epistemic systems of governance. This meant that the project attracted masses of interest both from the media and from the specialists such as architects, planners, and politicians.

However, galvanic skin response is actually 'noisy' data that is hard to interpret and cannot fulfil the technocratic dream of objectively disclosing a person's emotional state (Nold, 2018a). Instead, it functions best as a performative trigger for participants to recount their narratives. It is only by people articulating their own bodies, in conjunction with their physiological data, that a meaningful and coherent articulation of emotion and the environment become possible. The strategy thus functions as a bait: it attracts those who believe a device might be able to objectively extract emotion. Instead, the workshops demonstrate that the arousal data is useful as a trigger for recollection, and it is rather the participant's reflection that is fundamental to articulating their emotional relationship with the environment. In this way, the strategy seduces technocratic governance to support public art projects and provide them with legitimacy while opening themselves up towards qualitative methods and political complexity.

This adopted legitimacy meant the printed Emotion Maps could be used to foreground local controversies such as the neglect of young people in Stockport, the gentrification of Greenwich, or the urban neglect of Brentford. The workshop process involved the participants gathering evidence, discussing these issues, and then coming up with alternative proposals that were incorporated into these maps. This meant the maps combined aesthetic representations with concrete demands for local change that exceeded the boundaries of what many imagined as the limits of an art project. The result was that Bio Mapping creates a frictional synthesis between quantitative and qualitative, body and mind, art and politics. The power of the project lies precisely in the way this combination is held in tension. In Bethlehem (US), this synthesis managed to bring together the city mayor, the economic development team as well as cycling and low-income pressure groups:

> Bethlehem is hoping Nold's work can serve a practical purpose. His visit comes at a time when the city is trying to gauge how pedestrian-friendly it is. […] So the city is committed to Nold's work, […] So much so that Mayor John Callahan has agreed to be the first person to wear one of Nold's devices when the group meets again.
>
> *Coombe (2009, para. 16)*

In this example, the local actors used the Bio Mapping process to collaboratively develop plans for pedestrianizing one of the town's bridges, creating cycle routes, and supporting low-income food provision in the town centre.

How does the strategy function and what does it do?

'Friction synthesis' is a way of forcing a combination between quantitative and qualitative, objective and subjective modes into a powerful yet hard to institutionally 'use' representation. This approach builds on multiple representational modes such as quantification that actors such as planners recognize as well as public participation that politicians recognize. The project thus combines the perceived authority of technical measurement with the democratic legitimation of having many public participants. Yet, by staging the authority of technical measurement as contestable, the strategy demonstrates the arbitrariness of modernist dualisms and instead offers a performative enactment that dissolves distinctions between mind and body.

This strategy is not a critique or revolutionary confrontation, but the building of new ontologies of urban experience in order to fight for incremental gains in locally situated contexts. The strategy reveals the technological black box that purports to 'make collective emotion visible' and instead presents a new ontological reality of collective emotion that is contestable by local participants. In terms of incremental gains, the 'friction' of the strategy allows demands from local actors to be legitimated and reformulated so that they can be slid into the workings of governance systems. The process legitimizes actors that are often excluded and allows them to negotiate on the new ontological terrain created by the aesthetic strategy (Nold, 2018a). This approach has so far generated significant international and local coverage, thus making these demands hard to dismiss. Friction synthesis represents an ambiguous agency that is both inside and outside of recognizable systems. This tension means that it is difficult for actors using dualistic notions to fully co-opt this strategy into their repertoire and means that it can maintain an opening for future renegotiations with governance.

Discussion

Both of the case studies show what aesthetic strategies can do when applied to governance processes of the global and local environment. What they have in common is that they highlight blind spots in the way institutional governance excludes public and disciplinary positions. As these examples show, alternative publics and actors can bring contradictory perspectives, sensory observations, and new approaches to the governance of environments. The strategies thus both point to this exclusion and rectify it by offering material alternatives. Yet, they do so without polemical critiques. Instead, both strategies involve an interest in existing governance structures and a direct engagement with stakeholders and alternative publics, who are all invited to become a part of an 'extended peer community' (Healy, 1999) where nuanced and sensory collective processes can generate new paths of action.

These strategies are more than a hat tip to the liberal logic of accountability that calls for increased inclusion and diversity of voices. Our argument is that aesthetic strategies involve an ontological restructuring of governance processes to make new realities possible. While both case studies engage with iconic devices of governance – the public meeting and the map, the aesthetic strategies remade these devices and reflected them back as altered versions that 'do' governance differently. In the mirroring strategy, the environment became multivalent, embodied, and relational, while in the friction synthesis strategy, the environment became a collective body of sensation and political opinion. By performatively restaging implicit visioning processes and building technologies that create politics from the body upwards, new kinds of politics became possible. Governance is thus recognized as more than cognitive deliberation but something that requires experimental and material staging, a process in which artists and designers are critical (Marres, 2013). By engaging with governance differently, we can begin to take over and inhabit these institutional structures. Rather than creating 'accountability' or 'innovation', these strategies generate material spaces that didn't exist before using a 'logic of ontology' (Calvert and Schyfter, 2017). Demonstrating that aesthetic strategies are 'world-making' gives them legitimacy and agency without requiring claims towards artistic autonomy. Instead of pretending to be outside of the system, these strategies create new worlds within it.

But could our aesthetic strategies be used against their intended purpose? Climate denial think-tanks routinely use a kind of 'mirroring' as a strategy to sow confusion and undermine scientific insights. For example, the Heartland Institute produced a 2003 report entitled 'Non-Governmental International Panel on Climate Change' (NIPCC) that reproduced the look and most of the content of the official Intergovernmental Panel on Climate Change (IPCC) report, but lauded opposite conclusions on the anthropogenic nature of climate change (Dunlap and McCright, 2010). Could our strategies also be co-opted? While their form or stated claim can always be appropriated, we suggest that the mechanisms we propose have a limited potential for misuse. While the strategies we're describing don't have any embedded ideological 'soul', they have aesthetic affordances that shape relationships in the world. They have a specificity that allows them to function and that constraints their use. The mirroring strategy outlined in this text has different properties from the mirroring of the climate deniers. While the climate deniers are merely trying to produce a facsimile in order to create doubt, confusion and avoid critical analysis, our mirroring stages an infrastructural governance process in a performative way in order to reflexively foreground it. With friction synthesis, the strategy's 'friction' indivisibly fuses qualitative and quantitative data to make it hard to co-opt the strategy without losing its public impact or political 'bite' (Nold, 2018a). In both cases, it is the specificity of these aesthetic affordances that gives the strategies their uniqueness and allows them to create new ontological realities.

We propose that aesthetic approaches need to move beyond momentary tactical interventions towards legitimizing and maintaining strategies of alternative representation and ontological intervention into governance processes. By articulating these approaches as strategies, we point to the modes of legitimization that render them meaningful such as formalization, circulation, and categorization. Our hope is that the description of these strategies might help build a network of like-minded researchers for gathering a collection of other aesthetic strategies. It is here that a collaboration between STS and artists can be productive for providing inspiration and legitimacy when engaging with governance in order to open up structures and build alternative worlds within them.

References

Ars Electronica (2019) *Ars Electronica*. Available at: https://ars.electronica.art (Accessed: 21 April 2019).

Art at Cern (2016) *Art at Cern*. Available at: https://arts.cern/ (Accessed: 19 June 2018).

Beck, S. and Mahony, M. (2018) 'The politics of anticipation: The IPCC and the negative emissions technologies experience', *Global Sustainability*, 1, pp. 1–8. doi: 10.1017/sus.2018.7.

Beyes, T. and Steyaert, C. (2011) 'The ontological politics of artistic interventions: Implications for performing action research', *Action Research*, 9, pp. 100–115. doi: 10.1177/1476750310396944.

Calvert, J. and Schyfter, P. (2017) 'What can science and technology studies learn from art and design? Reflections on "Synthetic Aesthetics"', *Social Studies of Science*, 47(2), pp. 195–215. doi: 10.1177/0306312716678488.

Chiapello, E. (2004) 'Evolution and co-optation', *Third Text*, 18(6), pp. 585–594. doi: 10.1080/0952882042000284998.

Clements, A. (2012) 'Good intention and big ideas: Feel good grants that exploit artists and reduce arts funding', *Hyperallergic*. Available at: https://hyperallergic.com/54228/good-intentions-and-big-ideas-feel-good-grants-that-exploit-artists-and-reduce-arts-funding/ (Accessed: 21 April 2019).

Coombe, T. (2009) 'British artist wants to map the feel of Bethlehem', *The Morning Call*. Available at: http://articles.mcall.com/2009-04-01/news/4342987_1_christian-nold-map-volunteers (Accessed: 17 February 2016).

Dewey-Hagborg, H. (2014) *Stranger Visions*. Available at: http://deweyhagborg.com/projects/stranger-visions (Accessed: 21 April 2019).

Dunlap, R. E. and McCright, A. M. (2010) 'Climate change denial: Sources, actors and strategies', in Lever-Tracy, C. (ed.) *Routledge Handbook of Climate Change and Society*. Abingdon: Routledge, pp. 240–259.

Garcia, D. (2014) 'From tactical media to the neo-pragmatists of the web', *Leonardo*, 19(4), pp. 4–15.

Garcia, D. and Lovink, G. (1997) 'The ABC of tactical media', *nettime*. Available at: https://www.nettime.org/Lists-Archives/nettime-l-9705/msg00096.html (Accessed: 21 April 2019).

Gernot, B. (1993) 'Atmosphere as the fundamental concept of a new aesthetics', *Thesis Eleven*, 36(1), pp. 113–126.

Gupta, A. and Möller, I. (2019) 'De facto governance: How authoritative assessments construct climate engineering as an object of governance', *Environmental Politics*, 28(3), pp. 480–501. doi: 10.1080/09644016.2018.1452373.

Hannah, D. (2013) *Performative Experiments: Case Studies in the Philosophy of Art, Science and Technology*. New York: Columbia University.

Healy, S. (1999) 'Extended peer communities and the ascendance of post-normal politics', *Futures*, 31(7), pp. 655–669. doi: 10.1016/S0016-3287(99)00025-7.

Institute for Advanced Sustainability Studies (2016) *Workshop: Low Environmental Impact SRM Experiments*. Available at: https://www.iass-potsdam.de/en/node/2855 (Accessed: 21 April 2019).

Latour, B. (2004) 'Why has critique run out of steam? From matters of fact to matters of concern', *Critical Inquiry*, 30(2), pp. 225–248.

Latour, B. and Weibel, P. (eds) (2005) *Making Things Public: Atmospheres of Democracy*. Karlruhe and Cambridge, MA: MIT Press.

Law, J. (2004) *After Method: Mess in Social Science Research*. London and New York: Routledge.

Lury, C. and Wakeford, N. (eds) (2012) *Inventive Methods: The Happening of the Social*. London and New York: Routledge. doi: 10.4324/9780203854921.

Marres, N. (2013) 'Why political ontology must be experimentalized: On eco-show homes as devices of participation', *Social Studies of Science*, 43(3), pp. 417–443. doi: 10.1177/0306312712475255.

Marres, N., Guggenheim, M. and Wilkie, A. (eds) (2018) *Inventing the Social*. Manchester: Mattering Press.

Nold, C. (2004) *Bio Mapping*. Available at: www.biomapping.net (Accessed: 25 February 2015).

Nold, C. (2006) *Greenwich Emotion Map*. Southampton: Independent Photography.

Nold, C. (2018a) 'Bio Mapping: How can we use emotion to articulate cities?' *Livingmaps Review*, 4, pp. 1–16.

Nold, C. (2018b) 'Practice-based ontological design for multiplying realities', *Strategic Design Research Journal*, 11(2), pp. 58–64. doi: 10.4013/sdrj.2018.112.02.

Philipkoski, K. (2002) *RIP: Alba, The Glowing Bunny*, *Wired Magazine*. Available at: https://www.wired.com/2002/08/rip-alba-the-glowing-bunny/ (Accessed: 17 June 2018).

Prichard, S. (2017) *Artwashing: Social Capital & Anti-Gentrification Activism*, *Colouring in Culture*. Available at: http://colouringinculture.org/blog/artwashingsocialcapitalantigentrification (Accessed: 19 July 2019).

Prichard, S. (2019) *Art, Activism & Politics in the Place Where We Live*. Available at: http://colouringinculture.org (Accessed: 21 April 2019).

Rancière, J. (2015) *Dissensus: On Politics and Aesthetics*. London and New York: Bloomsbury Publishing.

Rheinberger, H. (2011) 'Consistency from the perspective of an experimental systems approach to the sciences and their epistemic objects', *Manuscrito*, 34(1), pp. 307–321.

Wellcome Trust (2019) *Wellcome Trust*. Available at: https://wellcome.ac.uk/ (Accessed: 21 April 2019).

Wilkie, A. (2016) 'Aesthetics, cosmopolitics and design', in *Proceedings of DRS2016: Design + Research + Society - Future-Focused Thinking*, pp. 873–879. doi: 10.4324/9781315748177.

Willats, S. (2000) *Art and Social Function*. London: Ellipsis.

Section 2
Making multidisciplinary histories

Hannah Star Rogers

How does history figure in the emerging area of Art, Science, and Technology Studies? This section investigates the ways that history is used in Art, Science, and Technology Studies (ASTS). History is already being used in ASTS as a method, an explanatory tool, a departure point, and an inspiration. To speak of history in ASTS is to invoke the history of art, the history of science, and the relational and intersecting histories of the two. The history of science and the history of art meet frequently in ASTS work where practitioners may be of interest to both groups in the past.

ASTS research is bringing these views together to consider how practitioners may position themselves as artists and as scientists. Take, for example, the case of two glassmakers, Leopold Blaschka (1822–1895) and his son Rudolf (1857–1939). The Blaschkas created important scientific collections for research institutions worldwide, including the Glass Flowers at Harvard University and the glass marine organisms at Cornell University. Working from published scientific descriptions of organisms and atlas drawings, they created models from glass, animal glue, and paint that were acquired by institutions in Europe, the United States, Japan, Australia, and India (Reiling 2003; Daston 2008). These glass models are an example of a class of objects that in some contexts are seen as art and in other contexts are seen as contributions to science. Accordingly, such objects can only be adequately viewed through the lenses of both the history of art and the history of science (Rogers 2012).

Further uses of history surround ASTS, from situating collaborative projects in their historical contexts to considering the history of methods used in sociologically-oriented art and science workshops. The minimally explored histories of women and marginalized people (based on race, class, nationality, and intersections of these and other cultural limitations) making science through images, text, models and much more zoned artistic offer fertile ground for ASTS scholars to explore and draw attention to the work of unknown and lesser known contributors to art and science. ASTS histories must attend to feminist, marxist, and ecologically-aware historical lenses to full appreciate the multidiscipinary contriutations of all of the involved actors.

History in the ASTS context may also refer to the history of the contemporary understanding of the area of art and science or "doing history" as a form of practice-based research. Exemplary of the new ways of doing history in the area of art and science is Pamela Smith's research in making and knowing (2016). In Smith's work, recreations of processes are central to recovering knowledge and methods of the past, as opposed to a focus solely on the text, pointing towards an exciting direction for activating history. This section begins with

DOI: 10.4324/9780429437069-7

a historical account of the formation of the area of contemporary art and science, what the artist and theorist Chris Salter has termed the "art-science complex." This is comprised of genealogical and epistemological assumptions about the histories, theories, methods, and practices involved in the collaborative attempts to bring together artists and scientists for new forms of knowledge production. This chapter is an attempt to account for patterns in the ways that the arts and sciences are posed in relation to one another and the complexities of attempting to simultaneously work with representational knowledge and aesthetic strategies.

Communication scholar and practitioner Britt Wray investigates ways of creating and understanding affect and emotion in viewers of art and science. Wray presents the case of "Aurator," a visual and audio experience where people can document their thoughts about synthetic biology (or potentially other emerging sciences) to create a persistent collective narrative. She created this practice-based project as part of her studies of science communication around considerations of participation and flexible historical narratives brought together by the people involved in creating synthetic biology. In her chapter, she argues that a feminist ethics of care is helpful as science communication practitioners work towards new forms of contemporary history-making. Wray shows how such a purpose-built tool can broaden ideas about the roles and goals of science communication to include ideas about emotion and affect.

Artist Nina Sellers offers another use of history in her consideration of the ways that the seventeenth-century natural philosopher Robert Hooke's work with lenses and images has influenced interpretations of difference. As Sellers puts it, "with each innovation in optics and imaging we are not only seeing more, but also differently." Image production through scientific tools has been a persistent concern in Science and Technology Studies (STS), so Hooke and the ways that the microscope functions as an experimental technology and an image-making solution have been recurring examples (Hacking 1983, 149–156, 186–210; Lawson 2015). Sellers understands Hooke as formulating a new way of visualizing the world, which might be framed as an aesthetic breakthrough. Sellers offers this history of Hooke to contextualize her own artmarking with two examples from her practice: *Lucida* (2012) and *Sentinels* (2018). Sellers's chapter elucidates her research process and Hooke's influence while demonstrating how those creating art in ASTS practice use history.

The multidisciplinary group of Eben Kirksey, Dehlia Hannah, Lisa Jean Moore, and Charlie Lotterman offers a nuanced account of bringing historical practices into the present through performing and creating. Like Smith's making and knowing approach, the authors consider the new knowledge created through knowledge of practice rather than, for example, text or theory. They take the study of a specific historical medical practice as a departure point for critical conversations about gender/queering and ecological consequences through the spread of a pathogen carried by frogs used for diagnostic purposes. The authors investigate the use of a pregnancy test common in the 1950s in which female Xenopus frogs were injected with a potentially pregnant woman's urine to determine her status. If the test was positive, the frog would lay eggs. Through this enactment, the authors consider Hannah's concept of the performance of experiment as "an intervention that blurred the boundaries between performance art, science, and ethnography." By using an obsolete medical test, the authors broach the idea that science is historically contextual, showing how performance can be an important tool in considering global scientific flows and their consequences.

The history of art and the history of science have been important in the formation of early ASTS work, as they offered a shared method with which to explore these overlapping areas. As this section shows, history has many uses in ASTS. Yet, many more remain unexplored. Across the chapters to come, readers will note a variety of uses of history. These methods have already been shown to be flexible as rhetorical tools for making and defending arguments. Given the robust use of history in ASTS to date, we can expect that more uses will emerge as the field develops.

5
The art–science complex

Chris Salter

In 2015, the European Commission launched their innovative STARTS (Science Technology Arts) programme, a large-scale initiative whose aim is to "enhance creativity in industry and society." STARTS is only one in a series of initiatives embedded within the even larger EU Horizon 2020 funding scheme, a multiyear, 80 billion Euro programme whose not insignificant goals are to "drive European growth and create jobs" (European Commission 2018). STARTS is also the name for a larger umbrella of initiatives, including an annual prize, conferences, networking activities, and the like. Its main goal is to encourage collaborations and synergies between independent artists, start-ups, and SMEs (small-medium enterprises) using "the arts as catalysts for efficient conversion of science and technology knowledge into products, services, and processes" (European Commission 2018).

Not surprisingly, the artistic projects being exhibited reflect the techno-scientific priorities of the larger Horizon 2020 scheme: "'key enabling technologies' (KET) like environmental sensing, micro and nano-electronics, advanced materials, Big Data and artificial intelligence, advanced manufacturing and the general transformation of European industry and society through information and digitization" (2018). One project called "Environmental Dress," "is a piece of smart clothing that uses a number of sensors to measure the aggressiveness of our surrounding environs, detecting environmental variables and alerting us to them." "Flone" aims to convert a mobile phone into a "stand-alone flying apparatus" in order to "make air space accessible to everyone as a research platform, providing a range of applications for them to operate with a smartphone alone" (EU Vertigo program website 2018).

From reading the press releases on STARTS, one would assume that we are in a brave new world where the miraculous powers of science meet the imaginative forces of the arts. This combination appears to be a novel synthesis spawning not only new artistic experiences but as an added plus, also new industries, jobs, and competitive edge for the EU. But STARTS is not the first initiative to meld art, science, and innovation – it is one in a long line of post-war attempts predominantly although not exclusively in Europe, North America, Asia (mainly Japan and Korea), and Australia to legitimize the institutional arrangement of artists, engineers, and (mainly) natural scientists in the name of innovation, interdisciplinary knowledge creation, and socio-economic benefit.

DOI: 10.4324/9780429437069-8

How then would an interrogation of this arrangement be useful to Science, and Technology Studies (STS) scholars looking to understand art and technology? Part of the motivation for this chapter emerges from a call that Regula Burri, Joseph Dumit, and I made in a chapter for the fourth edition of the *Handbook for Science and Technology Studies* entitled "Art, Design Performance" to examine more seriously the histories of techno-scientific art practice given their long-time entanglement with "questions of infrastructure, invention, innovation, and experimental practice" (Salter et al. 2017, 151). In fact, early STS researchers like Peter Galison, Bruno Latour, Andrew Pickering, or Lucy Suchman have more recently moved from their earlier investigations of laboratory practices into exploring the arts as well as design from curatorial, dramaturgical, or socio-political contexts. The questions that artistic practice raises about the nature of experiential knowledge, the frictions and disunity of the sciences and the arts, and the problematic of innovation and contemporary economy are of keen interest to STS.

This chapter examines the makeup of this "art–science complex": a certain set of genealogical and epistemological assumptions about the histories, theories, methods, and practices involved in the collaborative attempts of artists and scientists. Here, I point out that despite radically different contextual, socio-technical-political, and aesthetic motivations and institutional setups, a certain narrative continues to operate that seeks to smooth out the frictions in what is in reality a much more messy, conflict-prone, and turbulent arena. In effect, in order to understand what lies beneath the art–science rhetoric, we must examine more carefully the inherent frictions of socio-technical networks linking artists, scientists, research, and innovation agendas. Such frictions include the problematic of "epistemic cultures" (Knorr-Cetina 2009), especially in how knowledge is constituted in the arts as compared to the sciences. These socio-technical networks also reveal larger issues of dynamics, disruption, and change in the sociology of innovation as well as the ongoing tension between the production of durable, representational knowledge versus aesthetic strategies inherited from the genealogies of the avant-garde such as ambiguity, confusion, and agonism (Barry and Born 2013).

At the same time, I speak from direct experience. I have worked as both an artist and a scholar for more than twenty years internationally within the realm of art, science, and technology and from this experience have seen the possibilities and mistakes in collaborative relationships and projects between artists, designers, social, natural, and human scientists. In this, I should thus state that I am neither opposed to collaborations between artists and scientists (of all stripes – nature, social, and human) nor against the need to conceptually and financially support these initiatives through both public and private means. Ideas, concepts, and methods that emerge from disciplines outside of the narrow realm of institutionally taught and sanctioned "fine arts" are an important, indeed *critical* element in the renewal of artistic theory and practice, particularly as increasing market-driven pressures and the reduction of public funding under neo-liberal socio-economic agendas make commercially driven products the *de facto* models for many forms of cultural production. This chapter thus aims to discuss a series of critical concepts from STS that I hope will inspire future work in examining the potentially productive and yet, epistemically, ontologically and ethico-aesthetically complex links between art, science, technology, innovation, and governmental cultural and economic policy.

The grand narrative of art, science, and technology

Since the 1990s, there has been an increasing body of literature around the topic of art and science (Bijvoet 1997; Edwards 2008; Reichle 2009; Scott 2010; Orrghen 2017). This literature complements work in the 1960s and 1970s from earlier pioneers such as Frank Popper, Frank Malina, György Kepes, and others. While there are different takes and foci (digital, new media or "information arts," biological arts or art with life, eco-art, "artistic research," and "sciart"), there is also a set of common assumptions and characteristics that inflect much of this literature.

The first involves the genealogy of this complex that usually goes something like the following story. The historic alliance between art and science usually begins with the emergence of early twentieth-century European avant-garde modernism, anchored in the Bauhaus, but also Futurism, Constructivism, DADA, and Expressionism. This first phase runs roughly between 1923 and 1938 and is associated with the early modernist avant-garde's interest in experimentation with the new emerging technologies of the industrial era. This history then carries through the post-war period into the United States with Bauhaus exiles like László Moholy-Nagy (first director of the short-lived New Bauhaus), Josef and Anni Alpers (Black Mountain College), or Kepes, the Hungarian visual artist who collaborated with Moholy-Nagy and went on to found one of the most well-known international centres for art and science – the Centre for Advanced Visual Studies at MIT in 1967.

The second phase, stretching roughly from the late 1950s to the mid-1970s and particularly anchored in the 1960s, is mainly linked to the emergence of electronics and computing. Here, the art–science movement intensifies. Yet, one can see two seemingly contradictory trajectories. One is the mounting interest in the artistic use of computing and information technology through the lens, methods, and techniques of cybernetics. While cybernetics was birthed in what Paul Edwards has called the "closed world" context of the Cold War (Edwards 1997), its interdisciplinary tentacles lead to an interest in cybernetic principles such as feedback, control, and interaction that influenced a wide range of curators and artists/designers/technologists, including Jack Burnham, Jasia Reichardt, Frank Popper, and John Brockman as well as John Cage, Frank Malina, Nam June Paik, Buckminster Fuller, Charles and Ray Eames, Robert Rauschenberg, Allan Kaprow, Nicolas Schöffer, Billy Klüver, Steina and Woody Vasulka, and Roy Ascott, among others.

The other trajectory, however, is that of 1960s counterculture: a trajectory that is defined by its anti-(Vietnam) war, anti-consumerist mindset combined with artists' interest in using technology to alter the self and consciousness through pharmacological and perceptual experimentation as well as through political protest. At the same time, these two trajectories merge in the founding of institutions and programmes in museums, universities, and alternate cultural structures dedicated exclusively to art, science, engineering, and technology such as EAT (Experiments in Art and Technology), the artist residency programme at Bell Labs, the Art and Technology programme at the Los Angeles County Museum of Art, the Architecture Machine Group at MIT, and others.

The movement then slows down in the late 1970s within a larger set of institutional, cultural, and technological shifts, namely, the perceived failure of the art and technology movement. Famously noted by the art critic and art and technology curator Jack Burnham in an 1980 essay "Art and Technology: The Panacea that Failed," "Today's science has spawned a wealth of technical gadgetry, while on the other hand, modern visual artists have been notoriously unsuccessful in utilizing much of it in the making of socially acceptable art." Burnham, who was one of the main leaders of the 1960s art and technology movement, principally argued that art's "internal semiotic consistency" ultimately prevented it from becoming "absorbed by other disciplines" (e.g., science and technology) "no matter how powerful or persuasive" (Burnham 1980).

Yet, the configuration of art, science, and technology once again rises like a Phoenix, gathering speed in the 1990s with the rise of personal computing, the widespread use of the Internet, and the increased miniaturization of electronic and computing technologies. Within this third phase from 1980 to 2001, a new generation of what Michael Century called "studio-laboratories" – "a new class of hybrid innovative institution where new media technologies are designed and developed in coevolution with their creative application" – arises (1999).

Century identifies the rise of a host of third-wave institutions such as the Ars Electronica Festival, the ZKM and IRCAM, NTT's ICC in Tokyo, Xerox PARC's PAIR (Parc Artist in Residence) programme and the MIT Media Lab in the United States, the Banff Centre for New Media in Canada, and others as part of this "studio-laboratory" trajectory that was already cemented in the earlier narrative of the 1960s. It is also during this period where philanthropic organizations such as the Rockefeller Foundation (which under the supervision of Howard Klein and consultant Nam June Paik had been responsible for the infrastructural development of experimental television laboratories used by video artists in US Public Television stations during the 1970s and 1980s), the Daniel Langlois Foundation in Montreal, the Wellcome Trust and NESTA in the UK, as well as private sponsors and philanthropic foundations, begin to support the development not only of independent artists working with technologists and scientists but also a range (in the case of Langlois) of institutions outside of the North American/European axis – among them centres in Senegal, Seoul, Singapore, Lima, Yogjakarta, and others.

Interestingly, this phase accompanies not only the rise of what Manuel Castells has called "networked culture" but also ends abruptly with the collapse of the dotcom bubble in 2001. This is usually where the narrative stops, although clearly the rise of Web 2.0 (social media), the increasing diffusion of digital and biological technologies across all sectors of life particular synthetic biology, big data and artificial intelligence, growing interest in ecological crisis, the renewed rise of nationalism, the collapse of the world financial sector in 2008, and more recently, the COVID-19 pandemic and the Black Lives Matter movement enact a fourth phase in the story that is just beginning to be told.

This grossly abridged narrative described above has appeared in accounts from art historians, media art historians, cultural critics, media studies scholars, and even artists (Wilson 2002; Grau 2004, 2010; Hansen 2006; Paul 2015). It has also found its way into influential commissioned reports and policy studies on the future of the arts, new media, and new communications technology (Century 1999; National Research Council 2003; Naimark 2003). Interestingly, all three of the aforementioned studies concerning new media art and information technology were commissioned by the Rockefeller Foundation in the late 1990s and 2000s under the former cultural director Joan Shigekawa. These studies justify the historical narrative by rooting current art–science technology initiatives in the Bauhaus, the New Bauhaus, the CAVS, and other studio-laboratories.

Yet, what these studies also suggest, perhaps unknowingly, is a certain conception of technological history as teleological and deterministic – that is, the concept that new tools inevitably will create new artistic possibilities that artists take up and then consequently, drive subsequent tool development. For example, the National Research Council's 2003 *Beyond Productivity* report's argument for the development of new ICT tools and services is drawn from the historical narrative of previous artistic entanglements with science and technology: "much pioneering exploration of ITCP has taken place in studio-laboratories, which build on the tradition of earlier centers of crossdisciplinary research and education in the arts, design, and new technology of the time" (2003, 5).

What this narrative takes less into account, however, is the highly specific context of political economy, communities of practice, local knowledge, and the socio-technical effects that accompanied these histories. For example, while the Bauhaus anchors many of these discussions, there is usually no articulation of *which* Bauhaus is referred to, considering the fact that this institution went through several dramatic ideological transformations between 1919 and 1933. Is it the Weimar Bauhaus founded by Walter Gropius and lead briefly first by the painter and mystic Johannes Itten? This version of the Bauhaus was conceived as a trade school focusing on hands-on learning through a detailed understanding of materials and fusing art and design with industrial procedures and demands. Or, was it the Bauhaus lead by Moholy-Nagy that was focused on more formal experimentation with new methods, tools, and technologies – what Moholy-Nagy later called "the new vision"? Or was it the penultimate manifestation under the socialist architect Hannes Meyer that converted the Bauhaus into a mainly architectural training facility to propagate objective and scientific design and building procedures. In fact, with its emphasis on objectivism and rationality, Meyer's Bauhaus incarnation would most likely offend many champions of art science who hold up a particular vision of the arts as autonomous and critical of the normative "scientification" of the sciences (human, natural, and social).

The historical narrative also seems to emphasize the so-called impact narratives of technology in which technologies themselves are seen as "primary agents of historical change" (Sterne 2003, 7). New processes, tools, and procedures, however, do not just fall from the sky and search out artists to use them. Instead, such techniques are built on previous and existing histories, labour, and practices. Indeed, if the social world is continually inscribed into the mediating effects of technologies and their take-up and use, then these technology-driven narratives assume a rather strange understanding of social-technical processes as somehow divorced from their socio-technical contexts.

At the same time, the art–science narrative also proposes a certain problematic view of the histories of ideas and techniques as a continuous linear process in search of what Michel Foucault called "the never-ending tracing-back to the original precursors." These histories remain unbroken by "phenomena of rupture and discontinuities" and the "incidents of interruption" that signify radical shifts, breaks, "mutations," and transformations of the social-technical order (Foucault 1972, 4).

Art and science = innovation

The second characteristic that leads on from the first is the long-promoted concept that art–science collaborations will causally lead to new innovation. The concept is clearly embedded in the EU STARTS programme that I opened this chapter with. In fact, the STARTS project has long featured as a key innovation initiative at the Ars Electronica, the largest festival in the world dedicated to art, technology, and society. This entanglement has been both critically and more often than not, uncritically celebrated, as if Marshall McLuhan's argument that artists function as distant early warning systems for new scientific and technological change were a justification for the rampant instrumentalization of artistic processes for predominantly economic benefit. But, in examining the work of theorists from Gabriel Tarde and Joseph Schumpeter to Christopher Freeman and Henry Chesbrough, it is evident that the concept of innovation itself operates on a shifting contextual ground.

For example, the mid-nineteenth-century French sociologist Gabriel Tarde claimed a strong differentiation between invention and imitation in which invention involves the creation of new, unplanned things that do not emerge out of the blue but are, in fact, "built upon elements of earlier imitation (…), and comprised of these compositions which in turn are imitated and become new elements of more complex structures" (Tarde 2003, 69). In contrast, the art historian Renato Poggioli argued in his 1968 book *Theory of the Avant-Garde* that artistic-technological innovation within early twentieth-century avant-garde art was framed in the language of the natural sciences – experimentalism, proving grounds, and laboratories (Poggioli 1968).

The concept of innovation that is most often referred to and which has been subjected to the above critiques is one driven by market capitalism in which innovation resides in the power of the market to decide the ultimate success or failure of new things. Beginning in the 1920s, the Austrian economist Joseph Schumpeter developed a theory of discontinuous change based on the power of entrepreneurial agency. In what Schumpeter described as the carrying out of "new combinations" ("To produce other things, or the same things by a different method, means to combine these materials and forces differently"), the successful entrepreneur produces new things and judges their success by the opening of new markets (Schumpeter 1983, 493–495).

Innovation, for Schumpeter, constitutes new products and the utilization of new inputs in production as well as the creation and exploitation of new markets, new types of organizations, and management styles and structures. Given these definitions, one can see why Schumpeter also makes a claim to distinguish innovation from invention, "for as long as inventions are not carried into practice, they are economically irrelevant" (577). As Carlotta Perez well articulates, ideas outstrip markets since "the space of the technologically possible is much greater than that of the economically profitable and socially acceptable" (Perez 2010, 2).

STS has been long preoccupied with a critique of this kind of purely market-driven, linear concept of innovation. In fact, the Science Studies unit at the University of Edinburgh morphed into Science Technology and Innovation Studies (STIS) in 2008, demonstrating the increasing importance of innovation theory to the social-technical understanding of science and technology. There are many competing theories of innovation that have anchored STS discussions. For example, the "systems of innovation" (SI) argument states that firms don't innovate in a vacuum – they depend on an entire network of actors. This system consists of "interconnected institutions that create, store and transfer the knowledge, skills and artifacts which define new technologies" (Metcalfe 2000). The "systems" approach attempts to understand the ways in which institutional stakeholders (and not just markets) shape innovation. Other STS discourses on innovation suggest that innovation is guided by evolutionary theories of technical change that conceptualize technological change as open-ended "where no optimal solution to a technical problem can be identified" (Edquist 1997).

As the neo-Schumpeterian economist Christopher Freeman described in his work on innovation systems, the concept of innovation is neither singular nor linear but involves different spatio-temporal scales where the results of technologically lead processes cannot be foretold or even expected in advance. In contrast to the rhetoric of radical newness, innovation is in reality, highly *path-dependent* – things tend to follow previous historical trends rather than current ones, even if they may portend to be more innovative and new. This challenges the idea that every new innovation will follow the same path of take-up and acceptance.

Innovation is also perceived as dynamic and can thus be incremental (small step changes in existing products) in addition to its usual understanding as "radical" – that is, entailing large-scale Kuhnian "paradigm shifts" with existing ways of doing things (Kuhn 1968). At the same time, innovation is also not isolated to single instances, singular personalities (e.g., "the genius" of Steve Jobs), or even single locations (Silicon Valley). Instead, like science itself, it is seen as a collective endeavour involving "other agents of change: suppliers, distributors and many others, including consumers" (Perez 2010, 3).

Another more recent discussion of innovation comes from work in the area of "open innovation" (Chesbrough 2006). In contrast to the older notion of "closed innovation" in which ideas are developed, implemented, marketed, and distributed within the rigid boundaries of the institutions that developed them, "open innovation" assumes that "firms can and should use external ideas as well as internal ideas and internal as well as external paths to market" (Chesbrough 2006, xxiv). Open innovation thus challenges the assumption that innovation primarily takes place within the strict confines of existing institutional arrangements.

An interesting example of such open innovation involving many "agents of change" is detailed by the management researcher Andrew Nelson who has examined the emergence of the Centre for Computer Research in Music and Acoustics (CCRMA), at Stanford University. Today, CCRMA is one of the premiere music technology research centres internationally. The centre and in particular, John Chowning, its founder and director until 1991, is known in international music technology circles as the inventor of FM Synthesis, a particular type of computer audio technique that utilizes frequency modulation to produce complex arrays of audible frequencies through mathematical operations on a fundamental building block of sound: the sine wave. While FM audio synthesis is a rather obscure technical concept, Chowing's almost accidental discovery while "fooling around" with computers one late night at Stanford's Artificial Intelligence lab (SAIL) in 1967, was patented and then licensed to the Japanese conglomerate Nippon Gakki, better known as Yamaha, in the late 1970s – a license that enabled Yamaha to produce the DX-7, the first low cost, commercially available digital synthesizer that eventually became one of the biggest selling synthesizers in history.

Chowning's invention (or innovation in accordance with Schumpeter as it indeed created a new market in digital musical instruments), while an aesthetic and technological breakthrough, was not done in isolation. Stanford had already promoted large-scale collaborations between the university and industry as early as the 1930s through the tenure of engineering dean and later provost Frederick Terman, the most famous of these being the development of commercial audio oscillators by Stanford alumni William Hewlett and David Packard.

Chowning's work also ultimately benefitted from the users of the tools themselves – not only the end users of Yamaha DX series synthesizers after their commercial release in the mid-1980s but also the communities of practice that grew up around CCMRA in the late 1960s. These end users were not adopting their techniques to existing technological paradigms (in the current sense of developing platforms looking for content, like VR) but rather letting musical interests drive new explorations in computation that then resulted in the need for specific tools and then only later, actual technological development. *In other words, there was no innovation agenda a priori to the artistic act.*

Instead, the "innovation" emerged from a series of intertwined factors: access to infrastructure and people, an open environment between departments and faculties that allowed "fooling around" (as Chowning called his research) within an already-existing experimental setting with the necessary computational equipment and infrastructure (SAIL) and, perhaps even more importantly, the burgeoning experimental music scene in the Bay Area at the time. In other words, "innovation" was not a goal in Chowning's early research. Instead, he sought an exploration of the aesthetic potential of newly emerging computing technologies in order to expand musical compositional possibilities – something that occurred within a specific set of institutional and socio-cultural contexts.

Moreover, another enabling context that Nelson claims for Chowning, and in general, CCRMA's model of art, engineering and science is what he and Cyrus Mody have called "radical interdisciplinarity" – where "seemingly diverse disciplines come together on equal footing and … participants from these disciplines are forever changed as a result of the interaction"

(Nelson 2015, 5). Mody and Nelson's claim for CCRMA's bringing together of disciplines on "equal footing" stems from the centre's nascent origins during the tumultuous political climate of the Vietnam War. To hold the institution together, Stanford began to see the need to integrate humanistic (including the arts) and social scientific inquiry together with the (predominantly) defense contractor-supported and engineering departments in order to both "dampen the campus unrest" and respond to the increasing interdisciplinary mandates of US government funding agencies. According to Mody and Nelson, at the time, many Stanford students and humanistic researchers argued that "the pressing social problems of the day were so complex as to require equal partnerships, not hierarchical relationships, ranging all across the social and natural sciences, engineering, and the humanities" (Mody and Nelson 2013, 260–261). Stanford's interdisciplinary impetus that marked the AI laboratory where Chowning did his research during this period and which later spawned CCRMA thus "represents a fundamental transformation of disciplines through the combinations that it engenders" (2015, 5).

Interdisciplinarity conquers all

As Nelson's discussion of interdisciplinarity within CCRMA makes clear, the concept is specifically tied to institutional organization and settings – in this case, the early Stanford context of the looseness of interdepartmental barriers, the nascence of theory and practice in computer music (and computer science), the socio-political climate-demanding disciplines as equal partners with each other, and a general interest in engineers exploring novel concepts and applications that enabled Chowning to work within the setting of an artificial intelligence laboratory on experimental sound development with computers. Yet, in the art–science literature, the unbridled use of the term "interdisciplinarity" is a constant trope in which its epistemic problematics are rarely interrogated. Furthermore, more nuanced discussions of the question of interdisciplinarity in art and science and the social/natural/human sciences within academic research and policy contexts (Wallerstein 1996; Barry and Born 2013) indicate that the concept itself is highly contingent and contested. As Barry and Born state, "interdisciplinarity has come to be at once a governmental demand, a reflexive orientation within the academy and an object of knowledge" (2013, 4).

Sociologist Immanuel Wallerstein's report for the Calouste Gulbenkian foundation on restructuring the social sciences (1996) already argued that while the trend is towards the "multiplication" of interdisciplinary models and programmes within academic and research organizations, such programmes consume vast quantities of human and financial resources particularly in neo-liberal university contexts increasingly focused on the financial bottom line. In other words, such new interdisciplinary models are not just spontaneously birthed and effortlessly structured overnight (Wallerstein 1996).

Perhaps most influential (and controversial) was Michael Gibbons et al.'s (1994) study *The New Production of Knowledge: The Dynamics of Science and Research in Contemporary Society*. Gibbons et al. (1994) proposed the argument that current knowledge societies were moving from what is called *Mode 1* knowledge to a new paradigm and what they called *Mode 2*. In brief summary, while Mode 1 problems are discipline-based and driven by the interests of a specific community, Mode 2 is interdisciplinary, heterogeneous, and "based on the context of application" (Gibbons et al. 1994).

At first glance, Mode 2 knowledge appears to ideally fit the standard art–science rhetoric: inter- or trans-disciplinary, reflexive, heterogeneous (meaning that different kinds of knowledge can sit side by side with each other) and "socially accountable." But the reality of contemporary academic and cultural institutions worldwide suggests a different story.

In contrast to the Mode 2 discussion, Barry and Born's five-year ethnographic study of interdisciplinarity in climatology research, ethnography in the IT industry, and art science demonstrates that interdisciplinarity is neither monolithic nor inevitable. Instead, it follows multiple trajectories and dynamics, in particular how it has come to be seen "as a solution to a series of current problems, in particular the relations between science and society, the development of accountability, and the need to foster innovation in the knowledge economy" (2013, 1). More specifically, while respecting Gibbons and Nowotny's work, Barry and Born interrogate the "unity" as well as the teleological account suggested by Mode 2 knowledge that interdisciplinarity is a necessary next step in the evolution of knowledge production.

A series of modes and logics operate, however, below the surface of interdisciplinary discourse. While the *integrative-synthesis* mode articulates thinking from two or more disciplines in almost mirror fashion, the *subordination-service* model suggests that one or more disciplines act to take up slack or make up for a lack of some specific component in a main discipline. An example of the subordination-service model is when natural scientists claim that art allows them to more beautifully visualize scientific phenomena or when engineers in research settings take on a service role in providing equipment or human resources for an artistic project that may have scant research outcomes but instead intrinsic artistic merit. In the *agonistic-antagonistic* mode, however, the gloves come off and a dialogue, criticism or opposition to the epistemological boundaries of established disciplines takes place. This mode entails "a commitment or desire to contest or transcend the given epistemological and/or ontological assumptions of specific historical disciplines, a move that makes the new interdisciplinary irreducible to its 'antecedent disciplines'" (12).

Along with the interrelationships between disciplines, Barry and Born also identify an even more important set of "logics" that they argue operate interdependently around the issue of how interdisciplinarity actually transforms research practices. The "logic of accountability" suggests how research is increasingly demanded to make itself accountable to society – the so-called public face of science. This logic not only appears in countless "sciart" projects, predominantly supported in the UK by such funders as NESTA and the Wellcome Trust but also in the descriptions of other initiatives. For example, one of the explicit successes of the Swiss supported "Artists in Labs" programme was that "public access to science was improved due to the robust scientific knowledge embedded in the interpretative prototypes that were built by the artists" (Scott 2010). In other words, funders, scientists, and artists alike seek to extend the possibilities of science communication into an accessible and, in the eyes of many scientists, representational and demonstrable package by strategically instrumentalizing the arts in the name of public accountability for the sciences.

The "logic of innovation" is perhaps best exemplified by Michael Century's argument for the existence of the studio-laboratories – where art and science collaborations like STARTS, historical initiatives at Bell Laboratories in the 1960s, or any of the myriad of art–science technology residencies in science and innovation contexts have functioned partially as innovation motors for the economy. Century is not the only one to point this out. In speaking about Xerox PARC's famed PAIR programme that paired up artists and PARC researchers, the former Chief Scientist John Seeley Brown stated that

> The output of these pairings is both interesting art and new scientific innovations. The artists revitalize the atmosphere by bringing in new ideas, new modes of seeing and new contexts for doing, All of these innovation mulch the soil and plant new and unexpected seeds.
>
> *Harris (1999, xii)*

The third logic, that of ontology, is perhaps the most radical and the one which is more often than not, not accounted for. It suggests that a fundamental resistive mode operates in art–science and other interdisciplinary knowledge configurations – one producing "hybrid or relational objects that cannot be broken down into distinct natural, technical and social components" and in which the relations between research subjects and research objects are transformed (2013, 19). Like Mody and Nelson's concept of radical interdisciplinarity, the logic of ontology seeks to reorganize the power relationships that take place within interdisciplinary knowledge configurations. Barry and Born's use of the term "ontological" suggests a fundamental reordering of the process of knowledge production and dissemination – rather than "ontological frameworks that do not embrace the complexity of the natural and human-made environment" (2013, 30n20). The space of ontology in arts and sciences collaborations thus aims to open up new directions not only in how knowledge is produced (method) but also in how the process of production changes both the process and the results of the inquiry in a fundamentally open manner. "At its core are long-standing concerns to shift the ontological grounds of what art is or can be, evident in recent decades in diverse practices that probe the relations between both art and technology and art and the social" (Barry et al. 2008, 38).

One of the aims of Barry and Born's work is to point out the reconfiguring of social-technical relations that may take place in interdisciplinary knowledge production and to articulate that *interdisciplinarity itself* does not necessarily equate with the notion of *collaboration between different disciplines*. Their work also rigorously argues that some of our assumptions about interdisciplinarity are, in fact, mistaken: for instance, the idea that disciplines are closed and homogeneous, while interdisciplinary collaborations are more "open." Yet, individual disciplines within themselves are porous and, simultaneously, subject to the same epistemic rules and formations as the space between disciplines are.

Art/science and the realm of genius

Clearly, artistic and scientific practices might provide different ways of understanding and intervening in sites where science and technology are constructed. At the same time, while STS has long discussed the inherent social aspects of science, the discussion of art science usually proposes a rather outmoded and romantic vision of science that is individualistic, celebrating the inherent genius and unbounded creativity that the scientist (or artist) in their laboratory/studio undertakes. This is routinely seen in the continual reference to the figure of Leonardo da Vinci – the prototypical vision of the ideal Renaissance artist scientist. For example, the main art–science peer-reviewed journal (*Leonardo*) is named after the Italian scholar and references abound in the popular books of scientists such as Arthur I. Miller, E. O. Wilson, and others. For example, the physicist Miller writes that in the Renaissance, to the "great masters" of Leonardo and Dürer, "there was no distinction between art and science. They carried out scientist investigations and painted pictures in the same spirit of inquiry and with the same creative fire" (Miller 2014, 1).

Of course, this is a somewhat facetious argument that ignores the specific historical and economic context of the Renaissance or what, in fact, science and art within that historical period actually meant (more on this later). Despite the continual assertions of the Leonardo "cult," the concept of science as an individual activity has long been debunked beginning with Ludwik Fleck in the 1930s and continuing today. In *Genesis and Development of a Scientific Fact* (1938), Fleck, one of the few historical examples of a scientist writing a reflexive study of the formation of scientific knowledge and practice, argued quite bluntly that "The futility of work that is isolated from the spirit of the age is shown strikingly in the case of that great herald of excellent ideas Leonardo da Vinci, who nevertheless left no positive scientific achievement behind" (Fleck 2012, 256).

What Fleck insisted on instead was that science was a fundamentally *social* process made possible by what he termed "thought collectives": a "community of persons mutually exchanging ideas or maintaining intellectual interaction" (228). Science is thus an organized effort "involving a division of labor, cooperation, preparatory work, technical assistance, mutual exchange of ideas, and controversy" (240). Furthermore, by the time scientific concepts have circulated through thought collectives, they return radically altered, almost to the point in which their origin no longer matters.

If scientific practice has thus been seen as a social enterprise, conducted by collectives of scientists and their students and peers, artistic practice is still mainly viewed as constituted by singular authorship, individual genius, and intuitive inspiration. Even from the so-called artistic research standpoints, in which a research process drives artistic production, these viewpoints still hold. "Because artistic creative processes are inextricably bound up with the creative personality and with the individual, sometimes idiosyncratic gaze of the artist, research like this can best be performed 'from within'" (Borgdorff 2016, 50). This is despite the fact that contemporary artists involved in scientific and technologically complex projects (or market-driven contexts) wholly depend on the expertise of their own "thought collectives": not only curators and peers but also teams of designers, researchers, fabricators, students, and managers.

The laboratory and the studio

This individualist vision of science and art leads to yet another element of the narrative: the idea that the individual scientist's site of practice (the laboratory) parallels the site of the artist's practice (the studio). Firstly, this equivalency suggests that all artists are visual artists that use studios (in the context of the performing arts, for example, the studio concept does not figure within practice whatsoever). Secondly, as historians of science have described, although the earliest organized laboratories date back first to the sixteenth century, denoting the workshops of alchemists, apothecaries, and metallurgists, the laboratory as we mainly understand it today as a physical infrastructure equipped for scientific experiments and for the training of future scientists is a relatively recent invention, essentially traceable to the last third of the nineteenth century.

The founding of the Friedrich Wilhelm University by Friedrich Wilhelm von Humboldt and other German laboratories such as that of the chemist Justis Liebig in Giessen Germany around 1820 brought into place the modern notion of the laboratory not only as a bureaucratically organized institution with different instruments and divisions of labour but also as an "exchange or transit point of discourses, concepts and recipes, where ideas and physical materials could be confronted with each other and combined in increasingly new ways" (Schmidgen 2011).

Even more important is the fact that laboratories became new centres of *teaching* – a critical difference between the vision of the private artist studio as a site of autonomy away from the bureaucratic and epistemic strictures of academic education – a concept still promoted in some core art and design *hochschulen* (now called universities after the Bologna accords) in Germany. As Henning Schmidgen in his work on the history of the laboratory has argued, Liebig's and other motivated university professors saw the laboratory as a new site to combine experimentation with teaching, thus bringing together knowledge production (*episteme*) with handicraft (or practical knowledge – *techne*) in one and the same activity. The end goal was the same: the gaining and transmission of new knowledge – or what we today call research.

In contrast, what we understand as the model of the artist studio today is a far cry from its origins in the *bottegas* or active workshops of the Renaissance period where masters engaged in a similar imparting of knowledge and practical skills to their apprentices. As the concept of the *studiolo*, a closed-off place for private contemplation and meditation inside patron's homes grew, the separation between the *techne* of the bottega and its workaday environment for teaching and the studiolo as a site of devotion for (and eventually, to) the artist became apparent. Despite the fact that there are countless examples of artist studios that through their organization and modus operandi have critiqued what Caroline Jones (in reference to Andy Warhol's Factory) has called "The dominant topos of the American artist was that of a solitary (male) genius, alone in his studio, sole witness to the miraculous creation of art!" (Jones 1990, 101), the myth of the individual artist studio continues. This becomes even more absurd when one examines star artists like Jeff Koons, Damien Hirst, Yayoi Kusama, Olafur Eliasson, Jenny Holzer, and others whose studios (like Warhol's) approach industrial-scale operations dependent on complex logistical, technological, and material labour and expertise.

Of course, there are some similarities between laboratories and studios, particularly those new-fangled studio-laboratories. The laboratory, like the studio, has been continually discussed as a site of concrete material practices in which new natural-cultural hybrids are constructed, nursed, shaped, and reconfigured through instruments and infrastructures. As Knorr-Cetina writes, laboratories are constructed environments that "improve upon the natural order in relation to the social order" and focus on the "malleability of natural objects. Laboratories use the phenomenon that objects are not fixed entities which have to be taken as they are or left to themselves" (Knorr-Cetina 1992, 116).

But even here the topos of experimentation, stabilization, and transformation of natural or even artificial objects and processes is shaped by a very different set of conditions. In a meeting I organized between sociologists and historians of science, artists, architects, neuroscientists, computer musicians, and physicists at the digital arts centre V2 in Rotterdam in 2010, several of the artists present who were interested and inspired by scientific phenomena articulated that their work was subjected to forces and agencies exterior to their control and that they sought to lose the idea that artists were the sole agents in creating their work. In contrast, Andrew Pickering claimed that there was a significant difference in how scientists versus artists dealt with material objects.

> The artworks we have discussed are more like evolutionary things that are not reaching a stage where we have some kind of material thing which we as human beings can control. This is very different from science…when you are doing research you want an end, you want a result, you want to stabilize something.
>
> *Salter et al. (2012, 4)*

Myths of unity

Last but certainly not least is the perpetual argument that art and science themselves are *unified* disciplines. Certainly, the arts are not unified – there is as much a distinction among the training, methods, and practices of dancers and visual artists as there is between molecular biologists and particle physicists. Yet, most of the rhetoric surrounding this proposition assumes that science functions under a singular set of methods and procedures shared equally among scientists – a concept that has long come under fire from not only sociologists and anthropologists of science but also (natural) scientists themselves. What is most critical is an understanding of the political valences and ramifications of different knowledge cultures – or what Knorr-Cetina labelled *epistemic cultures*. The sciences (although one might claim all practices) "are pursued by groupings of specialists who are separated from other experts by institutional boundaries deeply entrenched in all levels of education, in most research organizations, in career choices, in our general systems of classification" (Knorr-Cetina 2009, 2).

The arguments for unity can also be seen as historically contingent. Galison, for instance, has written that the concept of the unity of the sciences stems from the late nineteenth century and then soon after from Vienna Circle philosophers of science like Rudolf Carnap and Otto Neurath. The yearning for German reunification in both the pre-twentieth century and then in the unified but turbulent Germany of the Weimar republic stems hand and hand with unity as a "scientific-philosophical ideal" (Galison and Stump 1996, 3–5). Furthermore, through epistemic cultures and hence, differences in scientific approaches and practices, the sciences are actually more subject to *disunity* than to unity. This is due to the differentiation that is present within epistemic cultures – the "different architectures of empirical approaches, specific construction of the referent, particular ontologies of instruments and different social machines" (Knorr-Cetina 2009, 3). In other words, "the disunified, heterogeneous assemblage of the subcultures of science is precisely what structures its strength and coherence" (Galison and Stump 1996, 13). Indeed, disciplines are routinely characterized by internal differences; the existence of a discipline does not always imply that there is acceptance of an agreed-upon set of problems, objects, practices, theories, or methods, nor even a shared language or set of common institutional forms.

The through-line across many of these discussions is that the sciences themselves (like the arts) are a situated, local, context-dependent, and historically contingent set of practices difficult to generalize. As both Lucy Suchman and Donna Haraway describe differently in their work on the situatedness of knowledge, action, and observation (Suchman 1987; Haraway 1988), situatedness signifies a view "up close" in which particular concrete circumstances bring forth concepts, methods, theoretical claims, and experiments. Likewise, Sandra Harding's (1988) work in post-colonial STS has focused on the difference from a cultural perspective. Harding's main objective is the decentring of predominantly male science narratives. Instead, we need to place a new emphasis on heterogeneity, diversity, and a plurality of perspectives – a focus that, despite the intense interest in post-colonialism from art history, strangely enough has yet to barely penetrate the art–science literature.[1]

The almost eternal belief in unity is also accompanied by another argument perpetuated by both academic researchers and artists alike. While the unified sciences have seemingly established methods for producing knowledge, the arts are "subjective" in that they have no established or rigorous methods that enable comparison and evaluation among competing ideas. This argument, of course, is based on a notion that "objective," agreed-upon methods ensure a form of truth telling – the sciences need shared methods among them in order to guarantee facts and eventually, the truth regimes that come with such facts.

But this subjective/objective dichotomy has long been criticized in both the social and even natural sciences as well. On the one hand, there is the argument stemming from Haraway that such "objective" knowledge is a political ruse that serves to reinforce male, predominantly white-driven visions of science as simply another power grab. Instead, a "'feminist objectivity' is about limited location and situated knowledge, not about transcendence and splitting of subject and object. It allows us to become answerable for what we learn how to see" (1988, 583).

More extreme is the famous claim from Paul Feyerabend that the concept of unified and shared scientific methods writ large is a fantasy left over from positivism. Science is more akin instead to a form of "epistemological anarchy." Scientific facts are made to be "independent of opinion, belief, and cultural background," while methods are meant to remove the possibility that other influences (cultural, religious, purely intuition-based) could blur boundaries between different disciplines. Moreover, the notion of a method as a durable, unchanging set of concepts for conducting science does not hold up under historical scrutiny. Hypotheses have been used to contradict existing, well-established theories, counter-rules rupture existing notions of facts, and political and social contexts establish what is deemed proper over irrational science. The things that "make science" – discoveries, rules, conjectures, the so-called uninform procedures, and even experiments – "have no common structure." The principle of "anything goes" is thus the only ultimate "method" that science can carry forth since "all methodologies, even the most obvious ones, have their limits" (Feyerabend 1993, 22–23).

If, as Feyerabend and later his contemporaries argue

> the wide divergence of individuals, schools, historical periods, and entire sciences makes it extremely difficult to identify comprehensive principles either of method, or of fact. The word 'science' may be a single word – but there is no single entity that corresponds to that word,

then let us return to the arts (1993, 238). Surely, if philosophers and sociologists of science have long criticized the unity of the sciences and their "uniform procedures," instead emphasizing their heterogeneity and contextual dependences, then the art–science promoters would have recognized that the arts also subscribe to such a diversity of procedures? But in the literature on art science or more generally, the field known in the German, Dutch, and Scandinavian countries as "artistic research," these arguments have gone somewhat unnoticed.

In *The Conflict of the Faculties*, for example, Henk Borgdorff claims that artistic research is "positioned at the intersection of art and academia – at a place where the art world and the world of academic research meet" – but he gives no clear sense of what this "art world" is (is it the visual arts, digital arts, underground electronic music?). The art world is itself a heterogeneous entity, with its boundaries continually shifting. Moreover, although he is certainly cognizant of it, claims of unity of methods and disciplines also sneak into Borgdorff's argument – for example, "to adopt one-sidedly the 'natural science' model, the 'social science' model, or the 'humanities' model [...] will produce a myopic understanding of what is really going on in the arts" (2016, 50). The belief in an established, uncritical form of objectivity also seeps through in claims that "objectivity [...] becomes an urgent concern, as one criterion for sound academic research is a fundamental indifference as to who performs the research. Any other investigator ought to be able to obtain the same results under identical conditions" (50).

All of this is to argue that while the ideas critiquing unity and objectivity are more or less common knowledge to philosophers of science and STS, many artists, art historians, and curators (not to mention politicians) continue to hold the belief that science is a singular, unified field with exact and shared guarantees over what constitutes legitimate knowledge and what does not. In the light of Feyerabend's searing critique not only of method but also the supposed "rationality" that constitutes science, it is important to recognize not only the disunity of the sciences but also the arts, particularly as the majority of art and science accounts tend to mollify difference in favour of suspicious universalism. In other words, why don't specific *practices* take centre stage over worn-out disciplinary generalizations?

Artes liberales versus artes mechanae

At this stage, it is worth reminding ourselves that despite the fuzzy rhetoric, what we consider *science* now as a disciplined, methodologically rigorous area that is opposed or even some say, incommensurable with the intuitive, autonomous, and individual vision of the arts, was originally something very different going back to the Renaissance, the medieval ages, or the Greeks, within the European context. This history is critically important for both dispelling the myths that art and science are historically the same thing (like that expressed by pop science art gurus like Arthur Miller) and articulating the specificity of practices – how did certain concepts and practices emerge in specific historical periods. Peter Weibel mapped this idea in a little known 2012 essay "The Post Media Condition." While the Greek word *techne* embodied craft, skill, art, and practical knowing, both Plato and Aristotle held such practical knowledge in contempt, with Plato pushing it to the bottom of his knowledge hierarchy. Already discussed by Pythagoras and Plato, later the medieval *Quadrivium*, which was attributed to Boethius, constituted four "sciences" (music, geometry, mathematics, and astronomy) meant to join with the other *artes liberales* of the *Trivium* (rhetoric, logic, grammar).

The *Trivium* and *Quadrivium* were thus distinguished from their bastard and "lower" counterparts: the seven practical *artes mechanicae*, namely, architecture, sculpture, weaving and masonry, cooking, agriculture, martial arts and others. As Weibel argues:

> The seven liberal arts (grammar, dialectics, rhetoric, arithmetic, geometry, music theory and astronomy) also formed the curriculum of the monastic and convent schools, and, from the 13th century, of the universities. The artes mechanicae (architecture, painting, sculpture, agriculture) continued to be derided as banausoi technai or artes vulgares et sordidae for the unliberated, for wage labourers and slaves.
>
> *Weibel (2012)*

In the enlightenment period, however, a shift began to take place. Through his and d'Alembert's *Encyclopedia*, Diderot already began to articulate a new merger of the *artes mechanicae* and the *artes liberales*. To Diderot, art was seen as instrumental, practical action, while science was seen as a contemplative, speculative practice. But art itself joined with science through interest in speculation, *in imagining what could be*. In fact, according to historian of science Eric Schatzberg, Diderot argued "that one cannot advance the practical side of an art without speculation, nor fully grasp the speculative side without practice" (Schatzberg 2012, 558).

In effect, Diderot wanted not only to eliminate the hierarchy between the practical and the speculative arts but also to find their commonalities: namely, both science's and art's need to construct instruments and procedures to make sense of observations collected "on the nature, function, use and qualities of beings and their symbols" (Diderot 2003). According to Diderot:

> Then they gave the name of science or art to the center or focal point to which they linked the observations they had made, in order to create a system of instruments, or of rules which were all directed toward the same object. That is the most general meaning of art.

Yet, the affinities between science and art soon broke apart with the appearance of a new category – the so-called fine arts or what we know today as the visual arts of painting and sculpture along with music performance or architecture. With this new categorization, there was once again a split between the mechanical arts, those arts done merely by craftsmen or artisans and the fine arts, those done by individuals endowed with creative inspiration and genius. The mechanical arts (and its artisans) were thus increasingly reduced to "mere technique," and the fine arts became the domain of bourgeois, middle-class men, and science (once called natural philosophy) became the supreme domain of knowledge production. "The new divisions in effect gutted art as a concept for understanding industrial technology and its relationship to new forms of natural knowledge" (2012, 559).

This distinction grew steadily across the industrial epoch of the nineteenth century as the term *science* (from *scientia* or knowledge in Latin) was increasingly used to oppose the artisanal acts of the mechanical arts. Science

> was a form of middle-class knowledge that could be applied to manufacturing. This reconceptualization of the relationship of science to art as one of applications represented a significant shift from the Enlightenment representation of science and art as interacting along a continuum
>
> *(560)*

More critically, at the same time and under the increased material brutality of capitalist industrialization, science also moved away from its earlier interest in speculative thought and increasingly became a form of "bureaucratized knowledge – what was increasingly termed 'applied science.'" Finally in the 1930s, another fundamental shift occurred as science became instantiated in the sudden widespread use of the word "technology" – "a science that concerned the useful arts" (562). It is here that an even more radical split took place than before between the fine arts and useful science: power and prestige were shifted from art to science and from human beings to increasingly mechanized forms of material production.

Conclusion

Where do we go from here? I began this chapter with a description of the EU STARTS initiative for two specific reasons. The first is to demonstrate that the art–science complex is alive and well not only in funding bodies but also in university curricula; policy agencies; and, most especially, the concepts, ideas, and visions of curators, artists, and scientists. Despite the shifts of research funding towards increasingly quantified and metricized results, the interest in new transdisciplinary agendas will not go away anytime soon, particularly as evolving socio-technical conditions continue to amplify the pressure on the arts to be ever more useful (i.e., accountable) to society and economy. This is partly true – the arts in the United States alone in 2015 generated some $166.3 billion in economic activity (Americans for the Arts 2017).

Furthermore, as an Arts Council England/NESTA report on "Experimental Cultures" argues, innovation in the arts is essential for a continual renewal of the field. Indeed, as the arts are challenged to "cultivate a culture of experimentation within organisations – from opportunistic and small-scale testing to the larger and more structured experiments" and "to ensure that there is an infrastructure for shared learning in the arts and cultural sector, similar to that which exists in science and technology research and development (R&D)," it is essential to understand what happened before, how it happened, why it happened, and what worked versus what didn't, the so-called best practices(Armstrong et al. 2018).

The second reason is that like many of its predecessor projects, STARTS also demonstrates the ambiguous relationship between the history of science and technology practices, creativity, and innovation, particularly in relationship to the arts. Indeed, the increasing blurring taking place between the arts and the creative industries is, at best, highly problematic. Part of my attempt to present a different history of the art–science complex is thus to provide a corrective to the ongoing neo-liberalization of creativity that is made possible by keeping such art–science connections black-boxed – as somehow a motor in the "natural process" of linear, market-driven innovation, as the work of individual geniuses outside of their social-technical contexts and as seeing interdisciplinarity itself as a frictionless social configuration where everyone speaks the same languages and has the same set of values and criteria for what constitutes knowledge or "success." Instead, as this chapter implies, we need more sophisticated histories and analytic tools to not only reveal the emperor's new clothes in these discussions. But we also need to reflect more deeply on these histories for strictly pragmatic means: to advance collaborative relationships between all of the arts and the sciences as well as policy-based discourses and actions that go beyond worn-out clichés, binary oppositions, and mistaken assumptions on both sides of the still problematic "two cultures" that C. P. Snow wrote about some fifty years ago. Thus, this chapter serves as both a manifesto and a plea for future STS scholars interested in the links between the arts, technology, culture, and society. The gambit is to get down in the trenches so to speak and do the hard work of building anew a more nuanced, complex, and filigreed set of arguments that do not repeat the same histories and mistakes of the past while proposing new ways of thinking about how techno-scientific art practice can be furthered in a more rigorous and diverse manner, both in scholarship and in material action.

Note

1 There are exceptions to this, but they mainly have played out in Indigenous anthropological studies of media as well as in science studies.

References

Americans for the Arts. 2017. https://www.americansforthearts.org/. Accessed June 15, 2018.

Armstrong, H. et al. 2018. "Experimental Culture: A Horizon Scan Commissioned by Arts Council England." Report Published by the Arts Council England.

Barry, A., and G. Born, eds. 2013. *Interdisciplinarity: Reconfigurations of the Social and Natural Sciences*. London: Routledge.

Barry, A., G. Born, and G. Weszkalnys. 2008. "Logics of Interdisciplinarity." *Economy and Society* 37.1: 20–49.

Bijvoet, M. 1997. *Art as Inquiry: Toward New Collaborations between Art, Science, and Technology*. New York: Peter Lang.

Borgdorff, H. 2016. *The Conflict of the Faculties*. Leiden: Leiden University Press.

Burnham, J. 1980. "Art and Technology: The Panacea That Failed." In *The Myths of Information: Technology and Postindustrial Culture*, Ed. K. Woodward. Madison, WI: Coda Press, pp. 200–215.

Century, M. 1999. "Pathways to Innovation in Digital Culture." Report for the Rockefeller Foundation. www.nextcentury.ca/PI/PImain.html. Accessed June 26, 2018.

Chesbrough, H. W. 2006. *Open Innovation: The New Imperative for Creating and Profiting from Technology*. Cambridge, MA: Harvard Business Press.

Daston, L. 2008. *Things that Talk*. New York: Zone Books, pp. 223–256.

Diderot, D. 2003. "Art (Applied Natural History)." In *The Encyclopedia of Diderot and d'Alembert Collaborative Translation Project*. Ann Arbor: Michigan Publishing, University of Michigan Library. http://hdl.handle.net/2027/spo.did2222.0000.139

Edquist, C. 1997. "Systems of Innovation Approaches - Their Emergence and Characteristics." In *Systems of Innovation: Technologies, Institutions and Organization*, Ed. C. Edquist. London and Washington, DC: Pinter, pp. 1–35.

Edwards, D. 2008. *Artscience: Creativity in the Post-Google Generation*. Cambridge, MA: Harvard University Press.

Edwards, P. N. 1997. *The Closed World: Computers and the Politics of Discourse in Cold War America*. Cambridge, MA: MIT Press.

EU Vertigo Program Website. 2018. https://vertigo.starts.eu/. Accessed June 28, 2018.

European Commission. 2018. STARTS.EU. https://www.starts.eu/. Accessed on June 28, 2018.

Feyerabend, P. 1993. *Against Method*. London: Verso.

Fleck, L. 2012. *Genesis and Development of a Scientific Fact*. Chicago, IL: University of Chicago Press.

Foucault, M. 1972. *The Archaeology of Knowledge*. Trans. A. M. Sheridan Smith. New York: Pantheon Books.

Galison, P. and D. J. Stump. 1996. *The Disunity of Science: Boundaries, Contexts, and Power*. Stanford, CA: Stanford University Press.

Gibbons, M., C. Limoges, H. Nowonty and S. Schwarzman. 1994. *The New Production of Knowledge: The Dynamics of Science and Research in Contemporary Societies*. London: Sage.

Grau, O. 2004. *Virtual Art*: *From Illusion to Immersion*. Cambridge, MA: MIT Press.

Grau, O., ed. 2010. *Media Art Histories*. Cambridge, MA: MIT Press.

Hacking, I. 1983. *Representing and Intervening*. Cambridge: Cambridge University Press, pp. 149–156 and 186–210.

Hansen, M. 2006. *New Philosophy for New Media*. Cambridge, MA: MIT Press.

Haraway, D. 1988. "Situated Knowledges: The Science Question in Feminism and the Privilege of Partial Perspective." *Feminist Studies* 14.3: 575–599.

Harding, S. 1998. *Is Science Multicultural? Postcolonialisms, Feminisms, and Epistemologies*. Bloomington: Indiana University Press.

Harris, C., ed. 1999. *Art and Innovation: The Xerox PARC Artist-in-Residence Program*. Cambridge, MA: MIT Press.

Jones, C. A. 1990. "Andy Warhol's 'Factory': The Production Sire, Its Context and Its Impact on the Work of Art," *Science in Context* 4.1: 101–132.

Knorr-Cetina, K. 1992. "The Couch, the Cathedral, and the Laboratory: On the Relationship between Experiment and Laboratory in Science." In *Science as Practice and Culture*, Ed. A. Pickering. Chicago, IL: University of Chicago Press, pp. 113–118.

Knorr-Cetina, K. 2009. *Epistemic Cultures: How the Sciences Make Knowledge*. Cambridge, MA: Harvard University Press.

Kuhn, T. 1968. *The Structure of Scientific Revolutions*. Chicago, IL: University of Chicago Press.

Lawson, I. 2015. "Crafting the Microworld: How Robert Hooke Constructed Knowledge about Small Things." *Notes and Records: Royal Society Journal of the History of Science* 70.1: 23–44.

Metcalfe, S. 2000. "Science Policy and Technology Policy in a Competitive Economy." In *Systems of Innovation: Growth, Competitiveness and Employment*, Ed. C. Edquist and M. McKelvey. Cheltenham and Northampton: Elgar Reference Collection, pp. 403–420.

Miller, A. I. 2014. *Colliding Worlds: How Cutting-edge Science Is Redefining Contemporary Art*. New York: WW Norton & Company.

Mody, C. M. and A. J. Nelson. 2013. "'A Towering Virtue of Necessity': Interdisciplinarity and the Rise of Computer Music at Vietnam-Era Stanford." *Osiris* 28.1: 254–277.

Naimark, M. 2003. "Truth, Beauty, Freedom, and Money: Technology-Based Art and the Dynamics of Sustainability." A Report for Leonardo Journal. www.artslab.net. Accessed June 28, 2018.

National Research Council. 2003. *Beyond Productivity: Information Technology, Innovation, and Creativity*. Washington, DC: National Academies Press.

Nelson, A. J. 2015. *The Sound of Innovation: Stanford and the Computer Music Revolution*. Cambridge, MA: MIT Press.

Orrghen, A. 2017. "Surveying the Literature on Technoscience Art: From Pioneer Stories to Collaborations between Artists, Scientists and Engineers as the Object of Study." *Digital Creativity* 28.2: 157–176.

Paul, C. 2015. *Digital Art*. London: Thames and Hudson.

Perez, C. 2010. "Technological Revolutions and Techno-economic Paradigms." *Cambridge Journal of Economics* 34.1: 185–202.

Poggioli, R. 1968. *The Theory of the Avant-garde*. Trans. Gerald Fitzgerald. Cambridge, MA: Harvard University Press.

Reichle, I. 2009. *Art in the Age of Technoscience: Genetic Engineering, Robotics, and Artificial Life in Contemporary Art*. Trans. Gloria Custance. Vienna: Springer.
Reiling, H. 2003. "Better Than Nature." In *NEO*, Eds. Jan Brand and Alex de Vries. Utrecht: Central Museum, pp. 221–235.
Rogers, H. 2012. *The Practices of Art and Science*. Doctoral Dissertation.
Salter, C., R. Burri and J. Dumit. 2017. "Art, Design Performance." In *Handbook of Science and Technology Studies*, 4th Edition. Ed. Ulrike, Felt, Fouché Rayvon, and Smith-Doerr Laurel. Cambridge, MA: MIT Press, pp. 139–168.
Salter, C., H. Smoak and M. Van Dartel. 2012. *The Vibrancy Effect*. Rotterdam: Nai Publishers.
Schatzberg, E. 2012. "From Art to Applied Science." *Isis* 103: 555–563.
Schmidgen, H. 2011. "The Laboratory." Accessed June 20, 2018. http://ieg-ego.eu/en/threads/crossroads/knowledge-spaces/henning-schmidgen-laboratory
Schumpeter, J. 1983. *The Theory of Economic Development*. Trans. Redvers Opie. New Brunswick, NJ: Transaction.
Scott, J., ed. 2010. *Artists-in-labs: Networking in the Margins*. Vienna: Springer.
Smith, P., and The Making and Knowing Project. 2016. "Historians in the Laboratory: Reconstruction of Renaissance Art and Technology in the Making and Knowing Project." *Art History* 39.2: 210–233.
Sterne, J. 2003. *The Audible Past: Cultural Origins of Sound Reproduction*. Durham, NC: Duke University Press.
Suchman, L. 1987. *Plans and Situated Actions: The Problem of Human-machine Communication*. Cambridge: Cambridge University Press.
Tarde, G. de. 2003. *Die Gesetze der Nachahmung*. Frankfurt/M.: Suhrkamp.
Wallerstein, I. 1996. *Open the Social Sciences: Report of the Gulbenkian Commission on the Restructuring of the Social Sciences*. Stanford, CA: Stanford University Press.
Weibel, P. 2012. "The Post Media Condition." Available at http://www.metamute.org/editorial/lab/post-media-condition. Accessed on June 20, 2018.
Wilson, S. 2002. *Information Arts*. Cambridge, MA: MIT Press.

6

Infrastructural inversions in sound art and STS

Owen Marshall

Figure 6.1 Annea Lockwood's "Piano Garden". Photo Credit: Chris Ware, 1971, Ingatestone, Essex, UK, http://www.annealockwood.com/downloads/garden003.jpg

> Dig a sloping trench and slip an upright piano in sideways so that it is half interred.
> A small grand piano may be set down amongst bushes etc.
> Plant fast growing trees and creepers around the pianos.
> Do not protect against weather and leave the pianos there forever.
>
> Lockwood (1969)

So reads Annea Lockwood's score for "Piano Garden", one of the composer's series of "piano transplants" produced beginning in the late 1960s. Lockwood's other transplants involved setting defunct pianos on fire, sinking them into the mud of a shallow pond, and letting them be consumed by rising tides. It was not for lack of technical skill or classical

DOI: 10.4324/9780429437069-9

training that Lockwood, who had studied composition at the Royal College of Music, arrived at these extended techniques. Nor was it an act of revenge against these formidable instruments. Inspired by the groundbreaking heart transplant performed by Christian Barnard in 1967, Lockwood instead saw her transplants as surgical interventions, figuratively and literally re-embedding instruments deemed beyond repair into natural environments, allowing new hybrid timbres to organically emerge either gradually or violently. Lockwood's decompositions seeded and tended the natural/cultural no-man's-lands of the Western classical music tradition—a terrain long shaped by social and material demarcations of cloistered religious orders, the enclosure and privatization of common properties, and the rise of the militarized state (Conrad, 2019, p. 397). As literalized duets with non-human processes of growth and destruction, Lockwood's transplants invited audiences to listen in new ways.

Lockwood, along with other twentieth-century artists such as Luigi Russolo, John Cage, and Pauline Oliveros, is recognized as a key contributor to the dynamic and loosely defined field of practice known as "sound art". For Lockwood, this term refers to works that approach sound as "a medium *per se*, like video, lasers", though she also speculates that "perhaps the term was pragmatically conjured up for/by museum curators to account for sound's acceptance into their world" (Licht, 2007, p. 10). It is exactly this interest in sound-as-medium, meant in a way that apparently was not reducible to music or spoken word that initially put sound artists at odds with the institutional-commercial art world. Unlike a painting, sculpture, or text, sound per se is difficult to install in a gallery.

Practitioners of Science and Technology Studies (STS) will feel at home with the sorts of questions raised by Lockwood's work as well as various socio-material and historical boundaries with which it and similar sound artworks contend. Indeed, sound art and STS have much in common. They are, first of all, both fundamentally interdisciplinary fields. Just as STS lies at the interstices of the history, philosophy, sociology, and anthropology of science, so does sound art combine musical, sculptural, and performative practices from a wide range of artistic traditions. Second, both STS and sound art take a fundamentally critical approach to their respective topics and materials. As a field of knowledge production about knowledge production, the relation between STS and techno-science is analogous to the sound artist's relation to sound and art (particularly the ways in which they are conventionally combined in the form of music). Taking sound as both medium and topic, sound art explores the limits and possibilities of acoustic phenomena beyond such idioms as speech and song. In the same way that STS works seek to historically and culturally situate the equations and inscriptions with which we describe the natural world, so do sound artworks tend to raise questions of spatiotemporal contingency in a way that less mutable (and more *muteable*) artistic mobiles might not.

One way of characterizing the shared sensibilities between sound art and STS is through the concept of "inversion". In music theory parlance, an inversion refers to a chord voicing, wherein the position of the lowest note has been raised by an octave. A chord's inversions tend to sound more interesting, though usually less stable, than its "root" position. STS scholars talk about "infrastructural inversions" or ways of foregrounding the socio-material arrangements that make technoscientific facts and artifacts possible (Bowker and Star, 1999). These two kinds of inversion, music-theoretical and infrastructural, provide a useful index of the differences between traditional musical composition and sound art approaches. Sound artists intervene at the level of infrastructure at least as often as at the level of tonal relations. For example, in his famous piece "I Am Sitting in a Room" (Lucier, 1969), Alvin Lucier provides an explanation of his performance that winds up becoming the raw material for the work itself:

> I am sitting in a room different from the one you are in now. I am recording the sound of my speaking voice and I am going to play it back into the room again and again until the resonant frequencies of the room reinforce themselves so that any semblance of my speech, with perhaps the exception of rhythm, is destroyed. What you will hear, then, are the natural resonant frequencies of the room articulated by speech. I regard this activity not so much as a demonstration of a physical fact, but more as a way to smooth out any irregularities my speech might have.
>
> *Lucier and Simon (1980, p. 30)*

By the end of the piece, Lucier's voice has dissolved into an otherworldly cloud of overtones shaped by the performance space itself. The text is slowly transposed from the range and timbre of the so-called original instrument—the composer's voice—to that of an instrumentalized infrastructural assemblage. The concert hall and recording/playback equipment, designed for acoustic transparency, is finally given a solo performance. As with Lockwood's piano, Lucier is not so much interested in effacing his voice as transplanting it, smoothing the irregularities of his speech—including his characteristic stutter—by hybridizing it with the performance space.

From the music of the spheres to auditory display

If contemporary sound art and recent work in STS converge on similar themes, this is in part because the historical roots of experimental science and music as a sound-based art form are deeply intertwined. In the classical curriculum of premodern Europe, music was not "organized sound" as the turn of the century composer Edgar Varése influentially defined it. It was instead, alongside arithmetic, geometry, and astronomy, one of the four mathematical arts constituting the quadrivium. In this worldview, music was not simply something that one listened to, but rather a fundamental ontological category rooted in the Pythagorean tradition. Johannes Kepler famously used theories of musical interval, supplemented with astrological reasoning and the use of a monochord, to derive his laws of planetary motion from the observations of Tycho Brahe (Gingerich, 1992, p. 56). The Copernican revolution ushered in a new scientific paradigm, but it did so in a way that was deeply rooted in the ancient Greek metaphysical concept of the music of the spheres.

By the early seventeenth century, this conception had begun to change radically. The first sentence of the first book written by René Descartes, his 1618 *Compendium of Music* signaled this shift in music's status from an unchanging quadrant of divine order—part of the structure of nature—to the mere expression of a material phenomenon: "The OBJECT of this Art is a Sound" (Descartes, 1653, p. 1). Historian Peter Pesic argues that this material redefinition of music as a sound-based art helped lay the groundwork for Cartesian natural philosophy that would go on to structure modern scientific thought (Pesic, 2014, p. 90). Stillman Drake, an authority on Descartes' contemporary Galileo Galilei, makes even stronger claims about the musical origins of experimental science during this period. Writing about Galileo's musician father Vincenzo's involvement in a controversy over the proper way to tune musical instruments, Drake argues:

> The first conscious experiments to test a pre-existing mathematical theory were probably the musical experiments of Benedetti and Vincenzo Galilei… In any event, the manipulation of physical equipment set up to test a mathematical law had come much

> earlier than Newton, even earlier than Galileo; and it came because of the conflict between numerology and physics in the field of music.
>
> *Drake (1970, p. 499)*

At the heart of the conflict Drake mentions was the ambiguous status of music—either as a numerical expression of natural order or as an artistically ordered physical phenomenon (i.e., sound) subject to empirical understanding. Music's transformation into something that could be thought of as "sound art", then, was directly implicated in the emergence of a scientific worldview, wherein numbers were understood as empirically descriptive, rather than divinely causal, phenomena. The shift from sound as a kind of music to music as a kind of sound indexes the emergence of STS's empirical topic broadly construed. The historiography of musical and scientific instruments, for example, can be fruitfully combined into what John Tresch and Emily Dolan term a "new organology" (Tresch and Dolan, 2013).

Returning again to the twenty-first century, we find that this account of the origins of modern scientific and musical practices has echoes in the growing use of non-speech audio to convey scientific data, a practice known as "sonification" or auditory display. While sound and listening have been important factors throughout the history of science, the proliferation of inexpensive digital audio processing and playback devices since the 1990s has made it easier for artists and researchers in an era of Big Data to map numbers onto specific audio parameters such as pitch, loudness, and timbre. Here, the premodern expectation of a *musica universalis* persists in the technoscientific imaginary, though its ontological and epistemological roles have been inverted. Music as such is no longer at the beginning of the world's causal chain, an image of divine harmonic order underlying all of creation. It is instead seconded to the end stages of the knowledge production process—the domain of the knowledge consumer or engageable "public".

It is in these sound-based art–science collaborations that the differing goals and representational practices of researchers and sound artists often strike a dissonant chord. Even the most successful sonification projects seem to inevitably arrive at a sort of aesthetic and epistemological incommensurability between the people who produce the data and the people who turn it into sound. Ironically, it is typically the outreach-oriented scientists who want their data to be recognizable as conventional and aesthetically pleasing music. The sound artists, meanwhile, tend to be committed to an avant-garde "experimental" approach (the very sensibility that led them to work with scientists in the first place), which leads them away from conventionally pleasing or recognizable musical forms. The scientists may want their research to sound like Mozart, but they will often get Stockhausen instead. When a group of engineers and physicists at the large hadron collider (LHC) decided to present their data as music in 2014, for example, the result was a pleasingly tonal piece for a chamber ensemble. When they invited the experimental rock band Deerhoof to interpret the LHC the following year, however, the result was a freeform improvisation preceded by ambient electrical noises performed next to the detector itself.

Though they often work at cross-purposes, scientists and sound artists come together with a shared goal of transcending disciplinary barriers in a mutually beneficial way. The inevitably problematic implications of this transcendental impulse are important to unpack, however, in order to understand the current relation between science and sound art. Alexandra Supper has shown how practices of data sonification are predominantly constructed as "sublime" experiences, or ways of cultivating emotional investment and awed responses from non-expert audiences (Supper, 2013). Between the sublime and the ridiculous, however, there is but one step. Skepticism regarding the idea of using sonification for serious scientific work is sufficiently widespread that the keynote speaker at the 2017 meeting of the foremost data sonification professional organization, International Conference on Auditory Display, had to ask, "why is sonification a joke?" (Scaletti, 2017).

Delimited by these absurd and sublime expectations, sonification's horizons of possibility rarely seem to reach beyond such liberal technocratic auspices as the TED Talk stage or public radio programming. It is precisely these limitations, however, that make the new quadrivium of sound, art, science, and technology such a rich site for STS inquiry. As Trevor Pinch and Karin Bijsterveld have pointed out, the history of the sonic arts is particularly rife with "breaching experiments" or cases of violated social expectations that reveal unspoken assumptions (Pinch and Bijsterveld, 2003). The original breaching experiments were developed in the early 1950s by the sociologist Harold Garfinkel, who would ask his students to do things like "tip" their family members or reverse opponents' chess moves in order to study how they responded. This was roughly the same period in which John Cage debuted his famous "silent" piece 4'33", which attuned audiences to ambient soundscapes while also raising fundamental questions about what counts as a musical composition. All this is to say that even when the role of sound in scientific knowledge production is taken as a joke, there is still much to be gained in "getting" it.

Beyond sonification proper, the horizon of possibility for sound art practices in technoscientific contexts has already been considerably broadened by STS studies of the role of sound in the production and circulation of scientific knowledge (Mody, 2005; Roosth, 2009; Bruyninckx, 2015; Helmreich, 2016). Parallel work in the interdisciplinary field of Sound Studies has shown how sound technologies such as the synthesizer, the mp3 compression codec, the tonometer, and the vocoder have emerged from and troubled the boundary between music and science (Pinch and Bijsterveld, 2004; Jackson, 2008; Mills, 2012; Sterne, 2012). Ethnographic and historiographic accounts of the twentieth-century electronic music and sound art, meanwhile, have documented the mutual influence of scientific and experimental music research at institutions such as Bell Laboratories, Paris' Institute de Recherche et de Coordination Acoustique/Musique (IRCAM), and the Stanford AI Lab (SAIL) and Center for Computer Research in Music and Acoustics (CCRMA) (Born, 1995; Nelson, 2015). The next step would be the development of a "making and doing" approach that deliberately presents *sound art as STS,* and vice versa. Whether this would take the form of audio recordings, installations, sound walks, or other sonic idioms yet-unrealized, the increasing ubiquity of inexpensive and hackable digital audio technologies—personal phones and "smart" speakers being the most obvious examples—would seem to point readily to an STS practice that takes sound as a medium beyond the limits of speech.

Bibliography

Born, G. (1995) *Rationalizing Culture: IRCAM, Boulez, and the Institutionalization of the Musical Avant-Garde*. Berkeley and Los Angeles: University of California Press.

Bowker, G. C. and Star, S. L. (1999) *Sorting Things Out*. Cambridge, MA: MIT Press.

Bruyninckx, J. (2015) 'Trading Twitter: Amateur Recorders and Economies of Scientific Exchange at the Cornell Library of Natural Sounds', *Social Studies of Science*, 45(3), pp. 344-370. doi: 10.1177/0306312715580404.

Conrad, T. (2019) *Writings*. Brooklyn, NY: Primary Information.

Descartes, R. (1653) *Renatus Des-Cartes Excellent Compendium of Musick with Necessary and Judicious Animadversions Thereupon/by a Person of Honour*. London: Printed by T. Harper, for H. Moseley.

Drake, S. (1970) 'Renaissance Music and Experimental Science', *Journal of the History of Ideas*, 31(4), pp. 483–500.

Gingerich, O. (1992) 'Kepler, Galilei, and the Harmony of the World', in Coehlo, V. (ed.) *Music and Science in the Age of Galileo*. Dordrecht, Netherlands: Springer Science+Business Media, pp. 45–66.

Helmreich, S. (2016) 'Gravity's Reverb: Listening to Space-Time, or Articulating the Sounds of Gravitational-Wave Detection', *Cultural Anthropology*, 31(4), pp. 464–492.

Jackson, M. W. (2008) 'Music and Physics: A Cultural, Interdisciplinary History', *Berichte zur Wissenschaftsgeschichte*, 31(2), pp. 94–112. doi: 10.1002/bewi.200801312.

Licht, A. (2007) *Sound Art: Beyond Music, between Categories*. New York, NY: Rizzoli.

Lockwood, A. (1969) *Piano Transplants*. Essex: Ingatestone.

Lucier, A. (1969) '*I Am Sitting in a Room*'. Waltham, MA: Brandeis University Electronic Music Studio.

Lucier, A. and Simon, D. (1980) *Chambers*. New York, NY: Columbia University Press.

Mills, M. (2012) 'Media and Prosthesis: The Vocoder, the Artificial Larynx, and the History of Signal Processing', *Qui Parle: Critical Humanities and Social Sciences*, 21(1), pp. 107–149.

Mody, C. C. M. (2005) 'The Sounds of Science : Listening to Laboratory Practice', *Science, Technology, and Human Values*, 30(2), pp. 175–198. doi: 10.1177/0162243903261951.

Nelson, A. J. (2015) *The Sound of Innovation: Stanford and the Computer Music Revolution*. Cambridge, MA: MIT Press.

Pesic, P. (2014) *Music and the Making of Modern Science*. Cambridge, MA: MIT Press.

Pinch, T. J. and Bijsterveld, K. (2003) '"Should One Applaud?": Breaches and Boundaries in the Reception of New Technology in Music', *Technology and Culture*, 44(3), pp. 536–559. doi: 10.1353/tech.2003.0126.

Pinch, T. J. and Bijsterveld, K. (2004) 'Sound Studies', *Social Studies of Science*, 34(5), pp. 635–648.

Roosth, S. (2009) 'Screaming Yeast: Sonocytology, Cytoplasmic Milieus, and Cellular Subjectivities', *Critical Inquiry*, 35(2), pp. 332–350.

Scaletti, C. (2017) *Why Is Sonification a Joke?* State College, PA: International Conference for Auditory Displays.

Sterne, J. (2012) *MP3: The Meaning of a Format*. Durham, NC: Duke University Press.

Supper, A. (2013) 'Sublime Frequencies: The Construction of Sublime Listening Experiences in the Sonification of Scientific Data', *Social Studies of Science*, 44(1), pp. 34–58. doi: 10.1177/0306312713496875.

Tresch, J. and Dolan, E. (2013) 'Toward a New Organology: Instruments of Music and Science', *Osiris*, 28(1), pp. 278–298.

7

Emotion, affect and participation

Why science communication practitioners should embrace a feminist ethics of care in their work

Britt Wray

Introduction

The role of emotion and affect in science communication is a little studied phenomenon. Though recognized as being involved in shaping public perceptions of science (for audiences), it is not clear what role emotion and affect play in forming what gets communicated about science by experts before audiences appear to engage with a scicomm project. In order to probe this as a researcher-practitioner, I created a practice-based project that took form of an "i-doc" called Aurator to examine how experts who communicate publicly about synthetic biology accept, resist and transform their participatory roles as communicating experts in a science communication project. "I-docs" are "interactive documentaries" that turn the traditional "viewer" into a "user" or "co-producer" who has some agency in the way they experience – and in some cases contribute to – the documentary (Gaudenzi 2013). "I-docs" are an emerging form of artwork in a fast-moving creative digital field and can include web-docs, transmedia docs, cross-platform docs, locative docs, documentary games and more (ibid). Due to the vast amount of experimentation taking place with this medium in art and technology circles, I consider science communication that takes place in an "i-doc" as an example of art/scicomm as opposed to more straightforward scicomm or even more exploratory art/science. I situate Aurator within this art/scicomm genre.

I understand art/scicomm to be a subfield of science communication within which works of science communication are generated that, at least in part, are made using artistic methodologies, sensibilities or aims. This is understood in contrast to works of scicomm that are made using expository methods that are more familiar to mass media communication such as journalism and broadcasting across a variety of platforms. It is also different from science communication that might be produced in the form of dialogic or civic events, educational festivals, informal events at museums and the like. I would not automatically include scientific exhibitions made in institutions such as museums and galleries in the art/scicomm category on the sheer basis of their using the exhibition format (which the art world heavily relies on) unless the individual works being exhibited somehow make use of artistic methodologies themselves.

 DOI: 10.4324/9780429437069-10

Art/scicomm is also different from the vastly encompassing world of art/science, where artistic and scientific methodologies co-mingle across disciplinary divides to produce works that may have diverse communication goals or aims that have little to do with communicating science. The key to understanding art/scicomm is that, like all scicomm, it has a specific goal to communicate particular aspects of science and its related issues, in a certain way. Not all art/science necessarily wants to communicate about science; it might just borrow inspiration from science in its theme or method, for example. In my case, I created Aurator using methodologies inspired by interactive documentary and audio diary methods. The mixed methods I employed, combining art and social science research, are hard to draw a boundary around. However, they sit within an artistic framework given their overall experimental nature and use of an explicitly artistic medium (the i-doc).

In my art/scicomm research, I identified events throughout Aurator's production that shaped the experts' participation to see if they were constitutive of emotional and affective experiences and what effect they had. After analyzing the data for key trends that relate to shifting participation as well as emergent themes such as performativity, authenticity and duration, I found that affect and emotion directly impact what gets communicated in scicomm productions long before audiences are factored in. I argue that this puts a special burden on science communication practitioners to develop an ethics of *caring for science communication*, inspired by feminist literature on ethics of care, that recognizes the material and performative nature of scicomm, which I will describe.

Feminist scholarship has concerned itself with a feminist politics of care, born from an interest in the types of care women and other marginalized, historically oppressed groups have been socially expected to provide for a variety of aspects of daily life, while their labor has long been de-valued. This invisibility of care, and how technologies continue to render female and marginalized people's labor as something to take for granted, has inspired the work of several feminist STS (Science and Technology Studies) scholars. For example, Lucy Suchman's critique of "smart technologies" has shown how the efforts to demonstrate the agency of "assistive technologies" to the "service economy" make critical assumptions about whose interests they should be serving as they de-value domestic work and mask the complex forms of human labor that go into making the devices possible (Suchman 2007). Although "smart" interfaces in software for "assistive technologies" can be said to provide care to the consumers they are assisting, Suchman demonstrates how they undercut care to certain populations, and in particular laborers, in their design and use. She asks, "what kind of social relations are assumed to be desirable … whose interests are represented, and whose labours are erased?" (2007: 224). In this sense, care is not something that appears in a system at some moment and forever thereafter will exist in that system; rather, it is an interwoven fabric of provision for some and neglect for others. The fabric of this negotiation, in its asymmetry, is something that can be re-imagined and re-assembled. A feminist ethics of care, in other words, recognizes that care is a dynamic process full of ambivalences, not a singular monolithic thing.

Interactive audio diary documentary

The case study that this chapter is centered on is the production process behind an art/scicomm project called *Aurator.* Aurator is an interactive audio diary archive that works as a web and mobile platform for listening and speaking back to the privately recorded thoughts and feelings (i.e., audio diaries) of a select group of multidisciplinary experts who work in synthetic biology. When the user arrives at the site, they are dropped into an atmosphere that could conjure a sense of moving through abstracted space gases and constellations, at a dreamy pace. It has a cosmically ambient "look and feel." Aurator's production was an experiment where I solicited audio diaries on a weekly basis over three months from several synthetic biologists, a social scientist, an artist, a biohacker, an entrepreneur, a watchdog and a bioethicist after having sent them each an audio recorder in the mail. I prompted these communicating experts with weekly recording assignments that asked them to reflect on their personal feelings about various questions or issues that were connected to synthetic biology and then record their thoughts as responses. Their audio diaries were edited, curated and entered into Aurator's online interactive platform, where they can be listened and responded to by any user who visits the site at www.aurator.org.

As an i-doc, Aurator makes each communicating expert a co-producer of the stories contained therein because they contribute self-recorded audio diaries as media content, while people who visit the site become both users who navigate the archive and co-producers who can add their own audio diaries and responses to the communicating experts' recordings. It therefore attempts to bring the communicating experts' diverse perspectives into conversation with each other in a way that allows the public to engage with them in an open-ended, unfinalizable and polyphonic (multi-voiced) fashion over time.

When making Aurator, I conducted interviews with the communicating experts before and after the three-month solicitation period to see how the diary-making process affected them, and I used the content of the audio diaries themselves as data for analysis. Together, these data provided rich insights into whether and how the communicating experts had emotional or affective experiences while participating in the art/scicomm project as well as what that did to shape the outcomes of their participation and therefore Aurator as a whole.

Emotion and affect

I am not particularly interested in contributing to affect or emotion theory with this research. Rather, I am contributing to an understanding of how expert participants experience intensities (emotions, affects) during productions where science is being communicated and how that impacts the way that science communication gets produced. Emotion and affect theory helps clarify the way these intensities can be recognized, which is why I call upon a limited subset of that available theory in this research. However, I have only sought an understanding here of how emotions and affects function as *feelings* that can *make a difference* in what happens in a given setting. Anything more theoretical than that is unnecessary for my task.

Affect is often misunderstood as being synonymous with emotion. However, some have described affect as something that can be sensed and experienced as intensities in an embodied way at an individual level (Massumi 2002). In this definition, affect is a precursor to emotion and can lead to emotional experiences, but is not the same as emotional experience. Not all definitions of affect in the literature line up, though. The *Oxford Dictionary* defines "affect" as "to touch the feelings of; move emotionally" and as "emotion or desire as influencing behavior." In another definition, Margaret Wetherell outlines affect as operating on two different levels: one that directly relates to familiar emotions and one that roams more broadly into wilder spaces, where some type of influencing force or intensity *makes a difference* (2012). In the first level, one can find emotional states and the movements they cause in the body and mind. This includes every aspect of recognizable emotion (for example, anger, fear, happiness) and also considers bodily perturbations such as blushing, arousal, tears and associated brain activity. The second level of the definition describes much more general movements, influences and changes in an individual. For example, your parents affect the way you are brought up, and hunger affects your mood. To be affected therefore is to be touched by a force – *an intensity* – that causes something to happen.

Wetherell's understanding of affect is helpful to me here in how it depicts emotion as a type of affect (layer one) and therefore mobilizes both terms of *emotion* and *affect* in the same concept, simplifying the way it can be identified in data. Any discrete emotion becomes an instance of affect, and so do more generalized but nonetheless *affecting* forces. Therefore, when analyzing communicating experts' participation during Aurator's production, I looked at affect as the general process of *making a difference* by using Wetherell's sense of the terms.

Wavering participation

I refer to the role that is offered to the communicating experts here as the "script" of participation. For example, at its most basic, the script outlines that the communicating expert should have listened to each weekly prompt I sent them, reflected on it and then recorded their response to it over twelve consecutive weeks. That was the agreement they entered into when they said they wanted to participate, and places where they deviated from this (either with less, more or simply different forms of participation) became sites of analytical interest.

I cannot account here for all of the interesting examples of inhabiting, resisting and subverting the script that my participants performed due to space limitations (this case study is only an adapted excerpt from a much larger PhD thesis) but I will highlight a few examples. A variety of emergent themes demonstrate factors that caused communicating experts to accept the script of participation. These include their reported curiosity about the novelty or "coolness" of the audio diary methods; perceived usefulness of the communication experience for their own work (such as learning new methods and research skillsets through exposure to my research methods); the ability for their participation to deepen and expand what the communicating expert is already busy doing with their work; the opportunity to act on one's self-identification as a science communicator (Baram-Tsabari and Lewenstein 2017); and the hope to become a "visible scientist" (Goodell 1977) who may *move* or *affect* others by communicating publicly about science.

Furthermore, communicating experts may add new meaning or functions to their participation that was not originally suggested to them if they feel particularly well cared for during the engagement process. For example, of all the diarists, the biohacker was the most consistent in sending audio diaries to me. He always uploaded them on time and, unlike others, never once made brief recordings as though he was trying to "cross it off the list" of tasks. He often sent me audio diaries that were over an hour long of him just talking to himself. He would sometimes divulge very personal information and would later tell me, in our post-project interview, that the act of making the diary recordings was "like seeing a therapist, except a therapist for science."

The biohacker explained that the research process allowed him to share ideas – wild, meandering and farfetched ideas – that are not often readily listened to by others. He explained that he felt free to do this because he knew that no matter what, there would be at least one person in the world who would listen and care about what he had to say without criticizing it. This brought him a sense of comfort that in turn motivated him to keep participating. Therefore, from our interactions (where I was the researcher/practitioner and he was the subject) emerged a relationship dynamic that was built on a type of care expressed through my commitment to listening. That feeling of being cared for by a "science therapist" created a safe space that he otherwise did not have access to. It gave him a venue to work through his "crazy ideas" that he may have, in other relational circumstances, kept bottled in.

The biohacker also explained that the diary method created space for him to think expansively and then have those thoughts flow back into his work in novel, experimental and productive ways. A passage from our post-project interview explores how:

WRAY: "When you say you think about the diaries as science therapy, there's a reason people go to therapy. Now I know you didn't have a reason to seek this out as therapy since I approached you, but did it have any benefit for you, the way that therapy can have benefits?"

BIOHACKER: "Well sure, especially delving into more theoretical or imaginative thought patterns has pushed me to explore that stuff even more. Especially in my science and my art. And it is something that I have, you know, have really started to try to take advantage of."

WRAY: "Can you draw a line between things you've done recently in your work and the audio recording process? Work that the diary recording process catalyzed for you to do?"

BIOHACKER: "Yeah totally."

WRAY: "Like what?"

BIOHACKER: "…I remember once you asked me to describe the future, where people use gene engineering, what that would be like and explaining stuff for the audio diary, and when I was recording I really started to create this world in my mind, right? This like, it became a world to me … that could be developed into something. So then, I started working on making this at-home DIY CRISPR system. I also wrote a grant about whole body microbiome transplants to obfuscate your microbiome and I made what I thought was a really interesting video about somebody from the future who is being chased down by the government because he engineers his cells… Yeah so, I really, really started to get way more into exploring these futuristic science and speculative science works and uh, really create more of a world around it."

WRAY: "So these audio diary recordings were priming the pump for that work to come out of you?"

BIOHACKER: "Yeah totally."

WRAY: "You weren't doing that kind of work before the recordings began?"

BIOHACKER: "No I wasn't. The recordings, like I said, allowed me to explore those ideas more without fear of being criticized."

The biohacker directly attributes the diary method as the origin point for three projects of his. Not only that, but the "at home CRISPR system" he mentions became a renowned and highly controversial project in the biotech community – an experimental kit for the DIY "do-it-yourself" community that allows amateurs to carry out gene-editing experiments on bacteria or yeast with CRISPR/Cas9 technology outside of a traditional laboratory. He ran a successful crowdfunding campaign on Indie Gogo, and the money allowed him to manufacture and distribute DIY CRISPR kits around the world to anyone who ordered one. Within one year, several hundred kits had been built and shipped to customers internationally. By now, he tells me, many thousands have been sold.

A small sampling of headlines that speak to the tone of the media coverage about the DIY CRISPR kit include "Is Do-It-Yourself CRISPR as Scary as it Sounds?"[1]; "Inside the Garage Labs of DIY Gene-Hackers Whose Hobby May Terrify You"[2]; "What Happens if Someone Uses this DIY Gene Hacking Kit to Make Mutant Bacteria?"[3] With this kit, the Biohacker claims that he took the world that he had envisioned in his audio diaries – a world where people can engineer cells at home – and started to turn it into something real.

Was the audio diary method really so generative that it was responsible for the DIY CRISPR kit and all of the ensuing debates about its safety? By that I mean, had the biohacker never participated in the audio diary project, would these kits not exist? Although the biohacker contributes his origination of the idea for the kits to the time he spent dreaming about speculative science projects while recording audio diaries for my PhD project, as a researcher, I cannot take this at face value. Perhaps, he could have dreamt the same idea up over drinks with a friend or awoken one morning with the idea fully formed in his mind. The audio diaries could simply be the place where the idea emerged, which would have emerged anyway. But there is something to be said for the function of *safety and care* that the biohacker felt which allowed him to take creative risks during the diary recording process, which he attributed to knowing I would listen to his "crazy" ideas without judgment. The fact that he draws an explicit line between his audio diaries and how they generated new ideas that led to projects like the DIY CRISPR kit should signal to science communication practitioners the enormous degree of unpredictable emergence that can come from experimental and intimate research methods, such as audio diary methods (intended for use in an i-doc), that one can tap into when practicing art/scicomm.

Having a "science therapist" worked well for the biohacker, but my keenness for listening to the experts caused others to drop out. One day during the diary solicitation period, the watchdog wrote me to say that he had uploaded several diaries at once, including soundscapes he made and stories he captured while traveling in Tunisia. I was thrilled to hear of his efforts to add new unpredictable forms of participation into the project and was excited to hear what he had been inspired to record. I listened through the five recordings he sent me that day: two of which corresponded directly with weekly prompts I had sent him and the rest of which were of his own creative visions. These included a beautiful soundscape of the medina in Tunis, a story about a man who owned a perfume shop and whose livelihood he perceived as being threatened by synthetic biology, as well as a recording of a talk he gave at the World Social Forum.

Unfortunately, there were many problems with the watchdog's recordings from a technical standpoint. These were issues that made the audio quality suffer (handling noise, wind, etc.) but amidst those mishaps there were still some usable audio clips. I emailed the watchdog to let him know that I had loved his recordings and looked forward to hearing more, including unpredictable recordings that I hadn't prompted him to make. But I gently asked him to revisit the training video I had put on YouTube that explains how to use the recorders to ensure the best audio output. As an off-site media producer, there was only so much I could do to safeguard the sound quality, so I referred him to the training materials once more. I should have kept quiet because I never received an audio diary from him again after that. I didn't even receive an email from him explaining why he was no longer participating or updating me about his thoughts on the project. It wasn't until the audio diary solicitation process was completed during our post-project interview that I learned what had gone wrong.

The watchdog said:

> I think particularly after I sent you the initial stuff and you said that the recording was not good enough quality, I clearly had to go back and re-watch your video and kind of relearn what I was supposed to do… It was like, ugh, I haven't got the time to go back and listen to that and practice! And all of that kind of became a bit of a barrier… for a while I really was carrying the recorder around in my bag everywhere I went…I was initially like 'this is a great empowering little tool', and then it was like 'oh no, I don't know what I'm doing.'

Research on audio diaries supports the observation that the demand on participants to record can cause attrition (Bolger et al. 2003; Mazetti and Blenkinsopp 2012). Learning that I carelessly exacerbated this effect by asking him to be more careful in his mode of participation was one of the most disappointing moments during the production process. For some period of time, the watchdog had the recorder on his person "everywhere he went" and saw it as "a great empowering little tool," and yet, I only received one batch of diaries from him because *I* had made him *feel* that he was incompetent by requesting that he revisit the training video. I bemoaned the wasted research opportunity caused by my ignorance and paradoxical lack of care. By trying to care for the outcomes of his science communication and that of Aurator in my quest for sound quality, I had shown a lack of care for my participant's time and sense of his own abilities. When care is administered to one site, it is often taken from another.

How experts perceive their audience and themselves over time

Audience operates in multiple states at once. It is both an expected, imagined phenomenon that is always present as a disembodied idea during the preparation of an engagement or science communication project, and a material, physical phenomenon when real members of the audience get access to the event. I found that perceptions of these multiple states of audience create different emotions and affects for communicating experts that can influence the way they accept, change or resist the script they're offered as a participant.

Deborah Martinson, whose work has shown that diarists often perform their written or spoken diaries with a particular audience in mind, argues, "diary writers, as autobiographical subjects, find themselves on 'multiple stages simultaneously', caught in an ideological double bind, as it were, to maintain modes of social and moral conformity as well as to speak out and assert themselves" (2003: 9). There is always a construction of personal experience at play when one makes a diary that is supposed to encapsulate how they feel, think or relate to a particular idea based on who they are and how they have lived, which lends a dimension of creativity to the process of diary making. "The construction of personal experience as directed by the participant (as opposed to the researcher) can be viewed as a performance and, moreover, a creative endeavor in the form of a verbal monologue" (Crozier and Cassell 2016: 399). In the case of the communicating experts I was working with, it is clear that their perceived audience affected their participation in very different ways.

In this study, all of the communicating experts except for one of the synthetic biologists said that they imagined they were talking to me when they were making their recordings, not a disembodied imaginary public audience. That synthetic biologist, on the other hand, said he always imagined he was addressing a large public audience in addition to me. I was not surprised by his emphasis on public performance, since he said he was initially motivated to participate due to the potential for his recordings to end up in a media production that would attract audiences to his science communication. This was evidenced by him telling me he wanted to join the project after he watched the science documentary *Particle Fever*, and felt incredibly moved by it. He similarly wanted to move others to care about science. He also spoke of his desire to make a science podcast-like project with this research that "lots of people will listen to." Inherent in the idea of attracting a large audience are several notions: that one will be able to present facts, generate some kind of effect on people's thinking, as well as become a "visible scientist" (Goodell 1977). In order to want to be a "visible scientist," one must regard themselves as worthy of making science visible. In other words, they must identify as being a capable science communicator and as having learned at some point in their career that they possess these skills (Baram-Tsabari and Lewenstein 2017). Indeed, the synthetic biologist had just won a national science communication competition in Denmark that was broadcast on national television. His self-concept as a science communicator was growing.

Science communication practitioners should be attentive to their communicating experts in order to not, for example, foolishly take for granted that bestowing one's participants with a device that allows them to record themselves intimately, privately and autonomously, will necessarily produce an archive of authentically performed selves. They may be performing to accommodate a variety of imagined or material audiences. With this project, I discovered that those performances may differ according to whatever the expert's agenda is, whether and how they self-identify as a visible science communicator, and how much time has passed between making the diary and recounting it later, realizing the implications of what they once said.

There runs a risk that communicating experts have well-defined expectations of who their audience will be, only to later be surprised by who is actually engaging with the products of their participation, depending on what they said. For example, very soon after Aurator went live, I got an email from the social scientist asking me if I would be willing to remove a significant portion of her diaries from the site. She explained that she now had some serious reservations about what she had shared in her recordings. Seeing it all on a website several months after she recorded her diaries made her realize that what felt very private at the time of recording actually was not private at all, even though she knew this day would come at some point, when her recordings would be shared with people beyond just my research group. She said she wished she had been less critical and less frank in her responses. The candidness of her contributions was now causing some anxiety. Similarly, when the biohacker first encountered his diaries on Aurator, he told me he cried twice as he listened through them. "When I listened, it made me cringe a little thinking about how people will react to it. Especially given that the diaries were done a year or two ago and stuff has changed since then," he said. This echoes the social scientist's experience of finding her diaries on Aurator and immediately feeling exposed and vulnerable to powerful people, such as funders and scientific colleagues, who may judge her for what she said about synthetic biology. It generated uncomfortable affects, moving her to ask me to remove some of her diaries, which I did, but not without reducing the content quality of Aurator. The biohacker, on the other hand, said he wanted to keep his diaries online even though listening to them in the public sphere affected him so much that he was moved to tears.

This dissonance between what a communicating expert may understand intellectually about participating and what they may feel in more sensual terms (i.e., that they have privacy and safety to be deeply critical of norms, people and structures in their field) is a serious risk of using audio diary methods. It destructively affected the social scientist's participation, making her concerned for her reputation amidst colleagues. These methods could put the real-world things at stake for diarists. Even if those stakes are imagined by the communicating experts and not acted upon by those who have the power to revoke precious things from them, it could still introduce considerable worries into their life and work. This points to the material dimensions of audience and how it can generate unpredictable feelings in science communication and art/scicomm projects: affects and emotions that demand being ethically responded to by the project's producer.

Because audio diaries give enormous control to the diarist, as the researcher is not present when recordings are made, the researcher has a minimized effect on what data is collected. This is advantageous for the researcher, Monrouxe argues, because it allows for private and sensitive information to be accessed that the diarist might not feel up for sharing if they were not the one fully in control. Or, that would be practically impossible to record with another person present (2009). However, what might be good for the researcher in a given situation, particularly if they are interested in extracting intimate and affective stories from their diarists as I have been in this project, might not always be good for the diarist. This inability to care equally for both the diarist and producer's needs in all cases at all times clarifies a crucial tension with this method. There is an insurmountable tradeoff that forces an engagement producer to determine their own ethics of care and act accordingly. Who will they show more care for in the way that they produce the engagement project – their subject or their production?

Communicating experts may feel happy, proud, surprised, concerned, embarrassed, vulnerable or regretful to discover what they once revealed while producing science communication long after saying it. Therefore, there are several ethical issues involved with using these methods for science communication, which calls upon experimental practitioners to learn how to *care for science communication.*

Caring for science communication

As explained in the introduction, a feminist ethics of care puts an emphasis on recognizing whose lives, desires and actions are being valued within a given system and how that can change by shifting attention. Speaking to this quality, Puig de la Bellacassa writes, "A feminist ethos of representing care is not reduced to the application of an established theory but it has to be constantly rethought, contested and enriched" (2011: 96).

As Martin et al. have written, "we cannot but care: care is an essential part of being a researcher and a citizen" (2015: 626). However, in science communication, we can (and should) learn to render more explicit awareness about how we provide care asymmetrically for our participants, our projects and our potential future audiences when producing science engagement events and art/scicomm projects. In the context of science communication, it is therefore crucial to ask: who has the power to care? Who sets caring relations into motion? And who defines how it can take place? In my experience, the science engagement event producer bears the majority of this responsibility since they have the most power to affect all relations in the science communication project, although every actor involved plays an important part.

Care – the sensibility that allowed the biohacker to feel safe and secure enough in my imagined presence as I became his "science therapist" to add a wealth of recordings for Aurator and create new real-world projects was the same sensibility that broke down in my interactions with the watchdog, leading to his rejection of the script. The fact that I abided by the social scientist's request to remove some of her diaries was also an act of care in the interest of acting ethically towards her, based in a recognition of the amount of power I had over her in that scenario. But the removal of some of her diaries can be seen as making Aurator less valuable overall as a probing art/scicomm project. Care is therefore not a stable quality that is inherently possessed by the practitioner, affecting all actants the same way (Mol et al. 2010). My findings suggest that practitioners should exercise a feminist conception of care when creating fora for science communication by caring for how care is being negotiated between different aspects of their project at all times. I encourage practitioners to bear the burden of developing a compassionate, flexible and response-able personal ethics of *caring for science communication,* where "Response-ability encourages a practice of making oneself available to respond without knowing ahead of time which phenomena will call one's attention or what form the response should take" (Martin et al. 2015: 635).

In my case, it was the very nature of my project as a work of art/scicomm that allowed me to discover what I did about the nature of care, its compromises and its specific relevance to science communication practitioners and researchers. From the beginning, the project was intentionally positioned to gather communicating experts' thoughts about synthetic biology, with rather intimate diary methods, for the purpose of producing an artwork (the i-doc). The link between the audio diaries and the content of the i-doc makes it impossible to imagine how Aurator could have been made without the use of diary methods, and thus, the artwork is inseparable from them. Although I didn't know this at the beginning, it is the very intimacy of the diary methods that allowed for so many interesting observations to be made along the way about the ethics of care in science communication. If there were no diary methods, there would be no "science therapist" for the biohacker, no concern from the social scientist about what she'd divulged, nor frustration from the watchdog who felt technically incompetent and so on. And yet, all of these occurrences were material to the i-doc that was produced and key to what was learned from the process of producing it. As a result, there is something to be said about where art/scicomm projects can lead a practitioner or researcher. Their experimental nature can bring about the possibility for highly unexpected outcomes that require ethical responses and, in doing so, create the conditions for new knowledge to be learned about how people communicate about science that "straight" science communication research might not, on its own, be able to access.

Science communication and art/scicomm projects that are intended to be open and emergent, have an inescapably dynamic and unruly nature. What is needed to deal with the unforeseeable complexities of this, is a practice of *caring for science communication* that explicitly acknowledges, prepares for and responds to the fact that emotional and affective phenomena have direct impacts on our science communication activities, which may require compromising, tenuous or differing ethical responses at varying times. This research also demonstrates that we need to be mindful of caring for the emotional states of communicators and not only audiences that are involved in science communication experiences. Focusing solely on the affective responses of audiences risks missing a significant part of the emotional equation. Being open to the performative character of science communication, which demands various types of emergent care along the way that could not have been predicted at the start, is a way of caring in itself. This kind of performativity, which is influenced by emotion and affect but also other material dimensions like one's perception of who their audience is and how things change over time, is at the core of what it means to do science communication. It is not that we do things as science communicators, come to regret them after we've learned from them and later say we should have done them differently. Instead, we learn from what happens along the way, train our sensitivities from the experience and move on in order to care for our science communication more fully with each step. In this way, the emotions and affects involved in science communication are "an ethico-political issue – one that is more complex than it might initially seem to be" (Puig de la Bellacassa 2011: 86).

Notes

1 https://www.statnews.com/2016/03/14/crispr-do-it-yourself/ Accessed October 28, 2016.
2 http://fusion.net/story/285454/diy-crispr-biohackers-garage-labs/ Accessed October 28, 2016.
3 http://motherboard.vice.com/read/what-happens-if-someone-uses-this-diy-gene-hacking-kit-to-make-mutant-bacteria Accessed October 28, 2016.

References

Baram-Tsabari, A. and Lewenstein, B. (2017). Science Communication Training: What Are We Trying to Teach? *International Journal of Science Education, Part B. Communication and Public Engagement* 7(3), pp. 285–300.

Bolger, Niall, Davis, A. and Rafaeli, E. (2003). Diary Methods: Capturing Life as It Is Lived. *Annual Review of Psychology* 54(1), pp. 579–616.

Crozier, S. and Cassell, C. (2016). Methodological Considerations in the Use of Audio Diaries in Work Psychology: Adding to the Qualitative Toolkit. *Journal of Occupational and Organizational Psychology* 89(2), pp. 396–419.

Gaudenzi, S. (2013). *The Living Documentary: From Representing Reality to Co-Creating Reality in Digital Interactive Documentary.* Doctoral thesis. http://research.gold.ac.uk/7997/.

Goodell, R. (1977). The Visible Scientists. *Sciences* 17(1), p. 6.

Martin, A., Myers, N. and Viseu, A. (2015). The Politics of Care in Technoscience. *Social Studies of Science* 45(5), pp. 625–641.

Martinson, D. (2003). *In the Presence of Audience: The Self in Diaries and Fiction*. Athens: Ohio State University Press.

Massumi, B. (2002). *Parables for the Virtual: Movement, Affect, Sensation*. 1st edition. Durham, NC: Duke University Press Books.

Mazzetti, A. and Blenkinsopp, J. (2012). Evaluating a Visual Timeline Methodology for Appraisal and Coping Research. *Journal of Occupational and Organizational Psychology* 85(4), pp. 649–665.

Mol, A., Moser, I. and Pols, J. eds. (2010). *Care in Practice*. 1st edition. Bielefeld: Transcript Verlag.

Monrouxe, L. (2009). Negotiating Professional Identities: Dominant and Contesting Narratives in Medical Students' Longitudinal Audio Diaries. *Current Narratives* 1(1), pp. 41–59.

Puig de la Bellacasa, M. (2011). Matters of Care in Technoscience: Assembling Neglected Things. *Social Studies of Science* 41(1), pp. 85–106.

Suchman, L. (2007). *Human-Machine Reconfigurations: Plans and Situated Actions*. Cambridge: Cambridge University Press.

Wetherell, M. (2012). *Affect and Emotion: A New Social Science Understanding*. New York: SAGE Publications.

8

Robert Hooke's *Micrographia*

A historical guide to navigating contemporary images

Nina Sellars

> [T]rue Philosophy… is to begin with the Hands and Eyes, and to proceed on through the Memory, to be continued by the Reason; nor is it to stop there, but to come about to the Hands and Eyes again, and so, by a continual passage round from one Faculty to another, it is to be maintained in life and strength.
>
> *Hooke (1665, p. 7)*

Curious in(ter)ventions

In 1694, at the age of sixty, nearly thirty years after he published his illustrated book, *Micrographia*, and only several years before he went blind, Robert Hooke, the natural philosopher and Curator of Experiments at the Royal Society of London, presented a new invention to his esteemed colleagues (Hooke 1694, pp. 292–296). It was a camera obscura, of sorts, which he said he had designed with seafarers and wayfarers in mind. Essentially, he considered the instrument an aid to 'curious navigators' and travellers that would allow them to visually document new worlds, irrespective of their drawing ability (Hooke, p. 295). Simply described, Hooke's apparatus was a wearable camera obscura.[1] In this chapter, I explore the idea of this seemingly improbable instrument being symptomatic of Hooke's previous engagement with microscopy. I want to suggest that the instrument provided Hooke with a way to revisit, and possibly reconcile, the paradoxical world he encountered through the compound lens of his light microscope, which he experienced in his making of *Micrographia*.[2] Printed in London in 1665, *Micrographia* is one of the first illustrated books on microscopy and certainly the most well known.[3] It was an instant bestseller, introducing the culture of the day to an extraordinary new vision.[4] I argue that *Micrographia*, when examined together with Hooke's camera obscura, can provide an insight into our contemporary engagement with images: both in the realm of science and also with images considered more broadly, i.e., in our current visual and media culture. The images I focus on in this chapter are representations (which lay claim to mirroring the real via the direct observation of specimens) rather than schematics (the graphs, symbols, diagrams that are made for the aim of simplifying quantitative abstracted data).

Firstly, let me offer a brief methodological introduction to situate my argument: I am a scholar and visual artist who works across the fields of art and science, and my understanding

DOI: 10.4324/9780429437069-11

of optical technologies and drawing is through my interdisciplinary engagement with the instruments. I have based my career on exploring the history of anatomy and its visualization, at times working as a body dissector, anatomical illustrator, and lecturer in anatomy and classical drawing, both for artists and scientists, which I combine with my research interest in optics. Moreover, my current biological arts practice depends on microscopy (I tissue culture human fat cells in vitro for my art installations, e.g., *Sentinels* 2018). To elucidate my approach to laboratory-based arts and demonstrate the ways in which Hooke appears meaningful to my practice, this chapter includes a discussion of two of my artworks: the light installation, *Lucida* (2012), and biological art installation, *Sentinels* (2018). These works developed from my long-term interest in questioning the traditional history and historiography of anatomy and both were made, at least in part, in laboratories, biology and physics, respectively.[5] Yet, this point is not to imply that I anachronistically think of Hooke working in a laboratory setting or consider him to be an anatomist. Rather, I look to Hooke to gain an insight into how certain ways of seeing are formed (from a contingent coalescing of practices, materials, and ideas) and performed (sustained as enactments of visual knowledge, which can be also viewed as iterations that are open to change, i.e., offering us the possibility of seeing, and doing, otherwise).[6]

Hooke's practice of 'true philosophy' which, if understood in terms similar to those presented by historian of science, Peter Dear, in his take on the 'experimental philosophy' of the era, would emerge as 'a kind of dialectical interaction between natural philosophy and instrumentality' that could be viewed as an antecedent to modern science (Dear 2005, p. 405). By this, I mean that the philosophy would display the same unresolvable tension raised by the incompatibility of the discourses (with Dear's use of the expression 'natural philosophy' being applied here in its original conception, i.e., as a purely contemplative concern). Although Hooke embraced the Royal Society's call for the practice of experimental philosophy, his 'true philosophy,' as outlined in the epigraph above, appears more of an 'actively thinking' than a 'utilitarian doing.' Or to put it another way, Hooke appears to be undertaking a contemplative thinking with the hands rather than implementing his prior observations of the world to fabricate a projected construct of the mind with an intended 'use' value. Even the circulatory nature of his project denies an instrumental aim. Dear notes that during the Scientific Revolution, 'natural philosophers' would tend to oscillate between representations of their work, as a discourse of contemplative knowledge and a discourse of practical or useful knowledge, creating an 'uneasy alliance' between the two mutually denying extremes (Dear 2005, p. 390). Yet, Hooke's 'true philosophy' appears different again, and it is this slippage that I find of interest. Especially when reflecting on the possible ways in which artists can work within the domains of science, in particular, the life sciences, where I urge artists to deflect calls to be 'useful.' Here, I echo a sentiment that is foundational to the SymbioticA biological arts laboratory, The University of Western Australia, where 'projects are made intentionally for cultural and artistic purposes with no expectation of utilitarian ends' (Catts & Zurr 2018, p. 52). Indeed, there is great value to be found in creating 'thoughtful absurdities' that occasion us as a society to think critically and engage meaningfully (i.e., with 'life' in all its multifarious and surprising emergences) (Catts 2012, p. 31).

Examining the foundations of the ideology of modern science is of particular importance when raising questions about the contemporary life sciences, as it is a field in which the uneasy convergence of contemplation *and* utility, as outlined by Dear, easily translates into supporting calls for the 'manipulation of life' and its commercialization. Interrogating our era's complex and often contested notions of 'life,' and giving thoughtful consideration to the social and ethical responsibilities that arise from our apparent embrace of its technoscientific manipulation, appears a key concern and motivation for philosophers and biological artists of the twentieth and twenty-first century (Agamben 1994; Catts & Zurr 2018; Zylinska 2009). Equally, and here my focus on *Micrographia* becomes more relevant, there is a need to critically engage with the visual materials that give rise to the knowledge of these disciplines and, in doing so, consider how these images influence society once they begin to circulate beyond the domain of science (in a sense, to take seriously the 'life' of images). I follow this idea, taking a notable point of departure from the scientific method in the theoretical underpinnings of my artworks as I bring the critical viewpoints of cultural studies and media theory into the methodology of my practice-led research. Essentially, I pursue my arts practice as a way of actively thinking through, and engaging with, ideas visually.[7] In a similar manner, when I turn to historical archives such as *Micrographia*, I view them as artefacts of a process and as an opportunity to undertake a close reading of the visual vocabulary of the material. Indeed, being literate in visual vocabularies, and their modes of production and history, is a key quality that artists can bring to the study of archives, opening them to new understandings and critique. In this way, I suggest reading this chapter not only as a historical guide to navigating contemporary images but also providing an insight into charting a particular approach to participating across the arts and sciences.[8]

Seeing

Simply described, microscopes magnify the appearance of small objects. However, in the example of Hooke, I want to suggest that it is more interesting to question the set of actions that were required in the making of *Micrographia's* magnified visions. In taking this approach what appears of particular significance is the coupling and choreography of observer and instrument in the act of observation. Hooke's experience of microscopic vision can be thought of as fundamentally altering his engagement with the world. In this way, microscopy is considered as not only modifying sight but also impacting on the body as a whole. I explore this theory through an investigation of Hooke's making of *Micrographia* and expand on the idea to connect it to Hooke's invention of a wearable camera obscura. I conceptualize Hooke's camera obscura as an extension and amplification of his phenomenological experience of microscopy and as a logical sequel to being immersed in the microscopic view. The premise of my argument is as follows: microscopy can be said to have reconfigured the intuitive understanding of space, removing touch from the process of vision, and separating form from matter through the creation of virtual images in the compounding of lenses.

To frame the discussion, I propose a particular concept of light – *the task envelope of light* – which I introduce here as a way to link the optics of Hooke's light microscope; the perspectival images contained within *Micrographia*; and Hooke's later invention of the wearable camera obscura. My intention is to provide a space in which to visualize the unfolding of Hooke's practice of 'true Philosophy' and trace its passage through his experiments with microscopy. (Keep in mind that I am a visual artist who desires ways in which to think through ideas visually.) Here, light becomes both an environment and agent (and *Micrographia's* perspectival illustrations record the mark of light's affect). This idea extends from my research into anatomy in which I consider light and anatomy not as isolated scientific entities, but rather as being embedded in their shared history of relational use, specifically, in the production of anatomical images (Sellars 2012, p. 8). I think of an anatomical image as not only conveying anatomical knowledge but also capturing traces of the initial interaction between the optics of anatomy and light (which, in turn, shapes the knowledge the image contains).[9] Conceptually, *the task envelope of light* disperses the agency of image-making (away from the human) while locating each 'performance of anatomy' (the physical cut of dissection and imaging) within its distinct (light) environment: in effect, the images suspend the 'imaging event' spatiotemporally, thereby opening it to critique. Similar to Donna Haraway's notion of 'situated knowledges,' each imaging event occurs at a particular time and place and within a particular technological and cultural context, providing a 'partial perspective' (Haraway 1988, pp. 575–599). This passage suggests that 'the task envelope' I have in mind comprises an operational space that is defined by instrumentalized light and inclusive of a skilled observer, in this instance, Robert Hooke (1665).

The term 'task envelope' is usually associated with the instructional specifications of robotic machinery; it delineates the area covered by a piece of equipment when it is in use and determines an envelope of operational space. The specifications are generally provided for safety reasons, indicating where the body should *not* be in relation to working equipment. However, in the context of my research, my use of the term is inclusive of the body, as I conceptualize the body of the viewer forming part of an operational *optical* space. I argue that the task envelope of a light-based technology defines a perceptible limit to both the observer's action and understanding by determining what they see and by instigating how they see it. In this chapter, I provide only a minimal excursion into the idea (to facilitate this brief discussion of perspective and microscopy). Provisionally, we can think of the task envelope as setting the parameters of both a conceptual framework within which to formulate questions and, at the same time, as detailing the physical qualities of light shaping how knowledge is enacted and conveyed. Yet, this definition belies the dynamic quality of the concept that I wish to retain, and it proves useful here to align with a contemporary theory of note – *agential realism*.

To a certain extent, parallels can be drawn between the idea I put forward, *the task envelope of light*, and that of the influential theory, *agential realism*, presented by theoretical quantum physicist and feminist theorist, Karen Barad (Barad 2007). Most notably, both of the concepts call on the physical qualities of light (interacting with matter) to provide the organizing principles for their methodologies. Barad employs the optical phenomenon of diffraction, as a way to analyse patterns of difference and to offer a viable alternative to Western thought's historical reliance on the optical metaphors of reflection, i.e., metaphors identifying sameness (Barad 2007, p. 72). In part, Barad is responding to the call made by feminist theorist and philosopher, Donna Haraway, for scholars to critically engage with metaphors of diffraction – both to highlight the subtle relational nature of differences and to provide a counterpoint to self-reflexive theory (Haraway 1997). Yet, Barad extends Haraway's remit by incorporating an understanding of diffraction phenomena that is informed by quantum physics.[10] In the field of quantum mechanics, '[d]iffraction experiments are at the heart of the "wave versus particle" debates about the nature of light and matter' and make explicit the entangled state of phenomena (inclusive of the diffraction apparatus) (Barad, p. 72).[11] There is no 'outside' or 'inside' to the diffraction phenomenon. Indeed, for Barad, the world is a dynamic shifting topology of 'intra-acting' entities, not an amalgam of pre-existing discrete elements upon which one can simply reflect (from above, beyond, or outside the event) (Barad, p. 33).[12] 'Intra-actions include the larger material arrangement (i.e., set of material practices) that effects an *agential cut* between "subject" and "object" (Barad p. 139).' Barad's use of the term, *agential cut*, refers to the enactment of boundaries from within (and as part of) phenomena (compared to the usual Cartesian understanding of the world that takes the distinction between 'subject' and 'object' as a given). To be clear, a Cartesian world contains 'things' awaiting discovery, whereas, in Barad's concept of *agential realism*, 'things' don't pre-exist: they are agentially enacted.[13]

At first glance, my delving into the spaces of representationalism (i.e., the perspectival illustrations of *Micrographia* that detail Hooke's observations) would seem to indicate that my concept – *the task envelope of light* – embraces the classical geometrical optics of *reflection*, with all the problems this approach seems to entail, for example, the belief in there being a definitive separation between knower and known, premised on the existence of an observation-independent reality, which, in turn, gives no account nor accountability for how 'boundaries, properties, and meanings are differentially enacted' (Barad, p. 151). Moreover, and perhaps even more challenging to my argument, I have signalled my interest in critical theory, i.e., the very same self-reflexive theory that Haraway and Barad want us to evade. Nevertheless, I assert that my aim *is* to provide a performative account of *Micrographia*: viewing its illustrations not simply as *reflections* of a microscopic world but in terms that are comparable to Barad's notion of the *agential cut* in which 'cuts are agentially enacted not by willful individuals but by the larger material arrangement of which "we" are a "part"' (Barad, p. 178). The images in *Micrographia* perceived as momentary stabilizations – what Barad would refer to as 'exteriority-within-phenomena' – which provide a provisional resolution. Here, I am moving towards an idea expressed by media theorists, Sarah Kember and Joanna Zylinska, in their collaborative text, *Life after New Media: Mediation as a Vital Process* (2012). In the text, they offer a way of understanding our experience of life, considered as a 'being in' and a 'becoming with' our technological world, arising from 'a network of interlocked processes of mediation in which biological, political, technical, social and economic flows interconnect and intra-act' (Zylinska 2013). Media present as *cuts* made in the flow of mediation that are enacted by human and nonhuman agents alike. In their example of photography, the role of the *cut* is 'to divide photography into photographs, but then to reconnect the latter to its beyond: i.e., photographic duration whose stabilisations into artefacts are only ever temporary' (Kember & Zylinska 2012, p. 82). For Kember and Zylinska, 'an in-cision is also de-cision' entailing an ethical imperative (2012, p. 82). Similarly, Barad does not absolve us of ethical responsibilities in the reconfigurings of which we are a part. In my use of the term, *to cut*, which I derive from the literal definition of anatomy, the ethical dimension of the *cut* forms an integral component.[14] A vital process, the *cut* of anatomy is a twofold act: the physical action of cutting the body asunder and the visual cut of image-making which carves out a particular representation of the body. Yet, the *cut* of anatomy also reconnects the image to its beyond, not foreclosing on possibilities and the ethical imperative to cut well, i.e., to cut better in future iterations. This understanding echoing Kember and Zylinska's call – 'Cut. Cut again. Cut Better' (2012, p. 204). I will return to these ideas and elaborate on *the task envelope of light*, but firstly, I want to address further the following question: why is an artist who is interested in anatomy concerned with the work of Robert Hooke?

Although Hooke is not considered an anatomist and *Micrographia*, celebrated for its images of insects and plants and for its study of optics, does not contain any images of human anatomy, the moment that Hooke represents is of great consequence for the very project of anatomy. Anatomy is a science predominantly based on visual observation and uniquely reliant on images for the circulation of that knowledge. Arguably, no other optical instruments have influenced visualizations of anatomy more than perspective and microscopy, with the majority of modern scientific imaging technologies not just being derived from these two ways of seeing, but increasingly appearing as a fusion of the two, i.e., the online anatomies that provide virtual fly-throughs of even the smallest anatomical architectures. (Even beyond the subject of anatomy, this coupling appears as a visual trope of contemporary imaging.) I think of Hooke as someone signalling the emergence of this way of seeing and of *Micrographia* as being the first instance of its dissemination in society more broadly. Indeed, *Micrographia* exposed the culture of the day to an extraordinary new concept of sight that effectively disrupted both the prevailing sensibility of scale and the intuitive understanding of space.[15] The publication assisted in shaping and accentuating seventeenth-century society's engagement with microscopic vision: habituating the eye to looking into the intangible, while tethering this new vision to the sixteenth-century illustrational paradigm of perspective. This initial sense of wonder may be lost on the twenty-first-century reader, but *Micrographia* offers the opportunity to question the continuing influence of this seventeenth-century event and ask whether repetitions are occurring which, at the same time, contain important differences.

What is significant in the example of *Micrographia* is that Hooke trained originally as an artist and was a drawer and visual communicator of great skill who was able to convey in images his own personal experience of seeing differently or otherwise.[16] Here, my use of the term 'seeing differently' relates to my interest in a particular line of media theory and cultural studies exemplified by the theorists, Gary Hall and, the above-mentioned, Joanna Zylinska. Hall and Zylinska work in the field of new media, but they are influenced by the philosophy of Jacques Derrida (Hall 2002; Zylinska 2005). In their work, I see Hall and Zylinska as extending an invitation not only to theorists but also to artists to experiment critically and creatively with theory and practice – to both question and transform the ways in which knowledge is enacted and conveyed. I pursue this idea in my close reading of *Micrographia*'s illustrations, giving thoughtful attention to the conditions and assumptions that underpin a particular way of seeing. This point indicates that when I suggest that Hooke conveys in images his personal experience of seeing differently, I mean this information to be inclusive of elements beyond what he may have intended. Seeing is a complex historical and cultural process, which exceeds any one individual's phenomenological grasp. In this way, the 'differently' as used in this chapter relates more to Derrida's philosophy of deconstruction and its application of the term, 'différance,' to indicate a non-oppositional understanding of difference.[17] Compared to, for example, the use of the term by the philosopher of science, Ian Hacking, in his text, 'Do We See Through Microscopes,' in which he questions the possibility of 'seeing differently,' or rather asks whether we can say with any certainty at all that we 'see' or 'see directly' through light microscopes (Hacking 1985). Hacking enters the (metaphysical) dispute of scientific realism/anti-realism, positioning himself as a realist (towards entities), and his accumulated acts of 'seeing differently' are undertaken for a resolution of the dialectic. There is no such resolution or synthesis offered in doing deconstruction.

In returning to *Micrographia*, the impact of the microscopic view can be discerned in several ways. Firstly, it can be seen in the treatment of visual space, as the images present a microscopic view embedded in a perspectival construct that I conceptualize as a hybridization of vision. We can think of this hybridization of vision as arising from the mixing of two *task envelopes of light* – perspective and microscopy. This meld becomes a question of physics, yet Hooke, a complex biological-cultural entity, also forms part of the task envelope. Both of the optical instruments offer Hooke a distinct mode of visualization that is defined by their individual technological configuring of light, which in many ways appear juxtaposed: the traits of one exposing the qualities of the other. For example, microscopy's optical flattening of space, which I will argue Hooke treats as a visual compression of the three-dimensional matrix of perspective, appears to conflict with Hooke's sculptural modelling of the specimens. Here, it is important to keep in mind that the hybridization that I am referring to is not a fusion of illustrational techniques, that is to say, a simple pastiche of drawing methods, occurring on the surface of the paper. It is rather a combination of optics that influenced Hooke's perception and created an inherent tension. In this way, the images can be thought of as indicative of Hooke trying to make sense of this new vision.

In microscopy, the magnification of sight enables visual access to what lies beyond our physical grasp (and our everyday notion of 'seeing'). In contrast, perspective images evoke palpable realities (and yes, here, we are problematically close to entering a debate on what is 'real' and returning to questions raised by Hacking). In these pictorial spaces, illuminated objects appear suspended in a three-dimensional matrix, with their surfaces eliciting a tactile quality through their interaction with light, captured in the illustration's conveyance of texture. By purposefully using a low-magnification (50×) compound light microscope, when more powerful magnifications were available to him (which is an important point that I will return to in a moment), Hooke positions himself on the threshold between these two ways of seeing. What Hooke encounters is an *almost* intangible, *almost* invisible realm. Indeed, my fascination with Hooke is that he appears to embody a vision on the precipice of this change; transitioning from a perspectively framed viewpoint inherited from the Renaissance to the disorientating immersion of the microscopic view. When Hooke translates his microscopic view into his drawings, a kind of conversion takes place, as he effectively solidifies the virtual forms through the process of perspective, thus making the intangible appear tangible and within reach. Yet, my reference here to the virtual subtly shifts the focus of the discussion: moving it away from the magnification of sight enabling visual access to what lies beyond our physical grasp, to instead emphasize the sense of touch, and its apparent loss, in relation to the Western understanding of form and matter.[18]

As noted by the art historian, Barbara Maria Stafford, in her research on optical technologies – in perspectival images 'representation was a physical, tangible act of illustrationally taking empirica in one's arms'; however, 'with the popularization of microscopy… touch dropped out of our visive experience of the world' (Stafford 1993, p. 36). I suggest that this occurred not only because of the intangible size of the specimens but also as a result of the optical separation of form from matter. This phenomenon transpired because the optics of the compound microscope transformed the object under observation into a state of a virtual specimen, as in the process of increasing magnification. With his knowledge of optics, Hooke knew that when something is being viewed through sets of multiple lenses, what is actually being observed is a virtual image, which exists between the lenses. The process of compounding lenses essentially makes an image into an object; that is to say, the look of the specimen (comprising volumes without mass) supplants its referent and becomes the thing under observation. This is where the division of space and the certainty of location, as well as our notion of the real, start to become problematized in relation to scientific methodology. Here, I introduce my artwork, *Lucida*, which explores the ambiguous nature of image objects and also provides an entry to a discussion of *things*, seen and unseen

Lucida

In its design, I think of *Lucida* as a reconfiguration of a microscope that places the viewers within the instrumentation, creating a camera obscura (room) microscope hybrid of sorts.[19] Both of these technologies – the microscope and camera obscura – comprise light, lens, space, image, and observer, but in differing arrangements, with each instrument determining a distinct real-time viewing event: I think of this 'hybrid' vision working also to amplify their similarities and differences. Here, I am travelling not too far from the ways in which I imagine Hooke interrogating his earlier adventures in microscopy through his later invention of the wearable camera obscura. That is to say, Hooke creates a reiteration of a visual question to be engaged from an alternative perspective. However, compared to the fully immersive world of Hooke's instrument, which he designed for the individual to experience, *Lucida* presents a relatively expansive environment that allows for a collective witnessing. In *Lucida*, generating sight is a whole-body experience, as gallery visitors are free to move around the darkened space to inspect the magnified images of microscopic structures, which seemingly protrude from the gallery walls, as well as the pared down instrumentation from which they emanate. Yet here within lies the confusion. In *Lucida*, there are no material *things* being imaged as such (or at least not in terms that we think of in regard to *reflection* or *likeness*). Indeed, determining exactly what is being imaged, and locating where the various images, and their 'host' specimens, reside becomes somewhat difficult to define. Essentially the artwork functions as an autonomous image-making machine, creating analogue images in real time, without generating a permanent record.

In practice, the images emerge from the 'intra-action' of light (a plasma arc coupled to fibre optic cables), glass (two 9 cm^2 clear plates purposefully made for the installation), and movement (incremental steps provided by stepper-motors) located within the enclosed walls of the darkened gallery (which contain also the gallery visitors who form part of this operational optical space). The small intensely bright light sources are directed at micro-fractures residing within the clear (rotating) glass plates, thereby enabling their previously invisible internal structures to be exteriorized as real-time images – measuring approximately 2 m^2 (Figure 8.1). Rarely synchronizing, as the separate glass plates move at different speeds and in opposing directions, they create a choreography that is controlled but not prescriptive. I had a dual intent in making *Lucida:* to extend the public experience of viewing microscopic anatomies (i.e., microscopic structures) beyond that of looking at documentation of some past imaging event and to provide a space in which to actively think through, and engage with, ideas visually. (Yet, in indicating this dual aim, I am not suggesting that the outcome was set in advance: artworks tend to exceed the resolve of the artist.) My broader concern at the time of making *Lucida* was to explore our contemporary fascination with transparency and the virtual, and our acceptance of both, as viable methods of observation, which I conceptualized as originating from the nineteenth-century microscopy and the century's emergent science of cytology – i.e., the study of cells. The increased magnification made possible by nineteenth-century advancements in optical technology 'seemed to make life itself

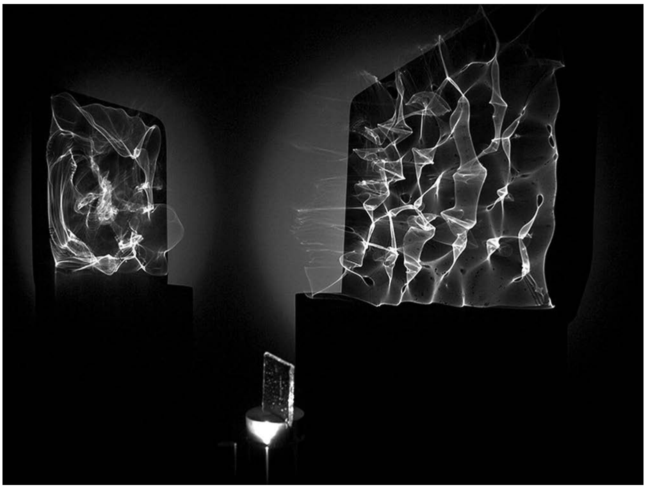


Figure 8.1 *Lucida* (installation at Fehily Contemporary, Melbourne, Australia) by Nina Sellars. (2012) © Nina Sellars

transparent, to enable the viewer to look into and through the object, not at it' (Armstrong 2008, p. 329). Essentially, I wanted to make strange our naturalized perception of this way of seeing in the twenty-first century and be immersed in 're-eventing' its emergence.

Things

From a contemporary standpoint, it can be said that to study a particular thing as isolated and objectified is to adopt a traditional scientific approach to a subject (here we see a Cartesian world of 'things' awaiting discovery, accompanied by an understanding of 'objectivity' that is 'assumed to be abstract, timeless, and monolithic' (Daston & Galison 2007, p. 51).[20] Through a process of systematic observation, documentation, and archiving, the data collected about a thing can be assembled into a body of knowledge. Embedded in this method is the expectation that there is an inner world of an observer, which is separate from an outer world to be observed; that is to say, the role of the observer is to be a detached subject who acts as the rational witness. This methodology is reliant on a demarcation of disparate spaces, aimed at defining a 'there to my here.' As Barad reminds us, '[r]epresentationalism takes the notion of separation as foundational' (Barad, p. 137). In microscopy, a slippage nevertheless occurs, as notions of interior, exterior, depth, and orientation become harder to determine and maintain. This phenomenon can be considered to be not only inherent to the observed object and to the technology of the microscope but also to the viewer's perceptual immersion in a magnified vision. As the world, which we experience in both spatial and temporal terms, is radically disrupted in the microscopic view, visual leaps are made from one scale to another that effectively suspend our sense of continuity and destabilize our concept of location. In contrast, linear perspective illustrations visually stabilize the viewer and provide a sense of spatiotemporal coherence. (Perspective being the exemplary Cartesian imaging space in which one can present 'discovered' things.)

Indeed, the key element of perspective, which proved so vital to early scientific illustration, was not the optical technology's ability to show objects three dimensionally, but rather its capacity to depict objects as existing together in continuous relative space. The study of anatomy provides a key example: perspective enabled the internal spaces of the body, and the organs they contain, to be 'realistically' depicted in their respective spatial relations. In other words, a perspectival representation does not show simply a cluster of objects; instead, it displays a coherent space, from a fixed viewpoint, with objects existing in it.

The art critic John Berger in his oft-cited book, *Ways of Seeing*, provides a description of the seemingly 'ocularcentric' nature of perspective:

> The convention of perspective, which is unique to European art and which was first established in the early Renaissance, centres everything on the eye of the beholder. It is like a beam from a lighthouse – only instead of light travelling outwards, appearances travel in. The conventions called those appearances reality. Perspective makes the single eye the centre of the visible world. Everything converges on the eye as to the vanishing point of infinity.
>
> *Berger (1972, p. 16)*

Yet, relating this idea to my previous mention of texture makes clear that perspective also connects to the sense of touch – perspective is a *haptic* vision. As I have already implied, alongside its 'ocularcentric' nature, it could be argued that perspective as a convention relies on our real-world experience of touch, which is gained through our interaction with, and movement through, the actual concrete places we encounter in our daily life. For example, you can never see more than three sides of an opaque cube, this is true both in perspectival images and in reality, but we know that a cube has six sides from tactile experience. As we turn an opaque cube in space, we observe a resolving sequence of views that coalesce into a dimensional object. The same can be said of our understanding of cubes on a larger scale, as we walk in and around architectural spaces. Therefore, by incorporating tactile memory, shapes in perspectival images can be perceived as tangible objects. Indeed, this act of visualization effectively animates the image, as we intuit the movements required to physically negotiate the virtual realm as though it were a real-world scene. Returning once again to the example of anatomy, the study of anatomy is founded on the ability to confirm visual knowledge with the touch of one's hand (with this understanding being the premise for perspective).

The low magnification of Hooke's microscope means that the specimens displayed in *Micrographia* appear tethered to a perspectival world, but monstrously outsized, as they seemingly struggle to escape through the picture plane. Some insects are depicted with their legs severed by the harsh cut of the perspectival framing, i.e., the great belly'd gnat (Schem. XXIX). Others such as the louse (Schem. XXXV) seem trapped just beneath the picture plane, whereas a fly's head (Schem. XXIV) ruptures the surface of the image as if breaking through the illustration (Figure 8.2). If we remain focused for a moment on the image of the

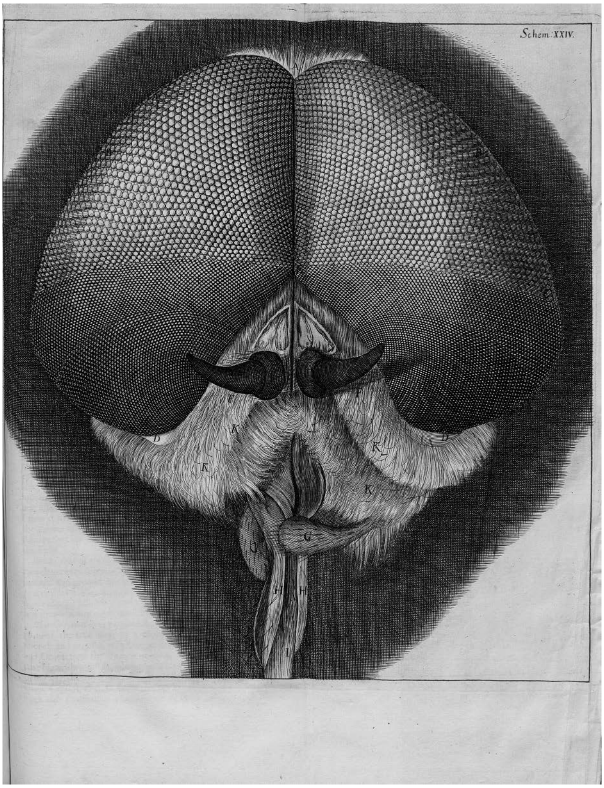


Figure 8.2 Schem: XXIV head of a grey drone-fly. *Micrographia: Or some physiological descriptions of minute bodies made by magnifying glasses: With observations and inquiries thereupon* by Robert Hooke. (1665) © Rare Books Collection. University of Melbourne.

fly, in particular the antenna portrayed on the right, we can explore further the characteristic qualities of light as seen represented in the pictorial space of perspective. For example, the directional fall of the antenna's *cast shadow* makes clear the positioning of the fly's head in relation to the microscope's source of illumination (which enters the scene from a point, slightly raised, on the left). Moreover, at the base of the antenna, i.e., the part closest to the surface of the eye, the *cast shadow* appears sharp, yet as the antenna curves away from the surface of the eye, its shadow seems to soften as the light diffracts at the edges. What we are observing are the physical qualities of light, captured in the pictorial space of perspective. This example also highlights an important often-overlooked fact.

Renaissance perspectival representations were the first images to show light acting as a physical, rather than spiritual, entity (Shlain 1991). Whether as an artefact of the process or appearing by design, light, depicted in perspectival images, became an entity that appeared not only to *flow on*, but also *reflect off* surfaces, thereby interconnecting objects in space through relative illumination. In reality, a directly lit (opaque) object reflects light (to varying degrees, depending on the colour and texture of its surface) and this reflected light, though diminished in intensity, can enter the *form shadows* of objects located nearby. An object's *form shadow* provides information about the characteristic physical qualities of the object; however, when *reflected light* (from another object) enters the *form shadow*, it conveys information about the second object as well. A general guide I use in relation to the study of an object's *form shadow* is that *all information exists in the half-light* (Sellars 2012, p. 63). By this, I mean that all the information about the object itself, that is to say, the shape of the form and the texture of its surface, is revealed at the edge of a *form shadow* (just after its *core shadow)*, where the form turns from the shadow into the light.[21] However, *reflected light* on an object is the conveyance of (visual) information from one surface onto another surface through the transmission of light. The luminous glow created by *reflected light* entering an object's *form shadow* reveals, to a certain extent, the colour and surface quality of the second object as well as its proximity. Returning to the image of the fly, the cleft between the eyes provides a point at which to study the play of *reflected light*; here, light reflects between the two convex surfaces of the eyes – light hits the eye on the right directly, then reflects into the *form shadow* of the eye on the left. (Here, it should be noted that we are conceptualizing light as travelling in straight lines, which is expressed schematically using ray diagrams: this notion of light is not suitable for explaining the optical effect of diffraction.)[22] Foremost for illustrators, if the path of light is ever perceived as broken or illogical in a perspectival image, the illusion of plasticity and dimension collapses. Put simply, light is the architect of perspective. (This analysis could lead us to explore the mediation of light in the 'mark making' of illustrations; however, this would be a chapter in itself.)

The most striking component of *Micrographia* is the large foldout folio illustrations: challenging the capacity of the archive to contain this new vision, they far exceed the size of the book. It is important to remember that these are Hooke's illustrations, which he made while he observed the (often living, yet immobilized) insects through the eyepiece of the microscope (Inwood 2002, p. 67).[23] Like the specimens, he too was caught between two very different ways of seeing. In the text, Hooke also juxtaposes notions of the microscopic with terms that link to perspective, i.e., when he states that 'penetrating into the center and innermost recesses of the earth, and all earthly bodies; nay, it would open not onely a cranney, but a large window (as I may so speak) into the Shop of Nature' (Hooke, p. 177). However, here the window of perspective, albeit large, does not provide a view out onto the world, but rather has the viewer positioned outside, looking in. In another section, Hooke expresses his desire to 'Microscope in these smaller creatures, quietly peep in at the windows, without frighting her out of her usual byas' (Hooke, p. 146). Nevertheless, I suggest that for Hooke it would have also seemed that these 'earthly bodies' were meeting him half way, with his realization that these virtual-object images were in actuality residing inside the drawtube of his compound microscope. Remember too that Hooke designed elements of the optics and was aware of the physics. I suggest in the making of *Micrographia*, Hooke was attempting to create a space, both ontological and epistemological, in which to locate this new visual knowledge.

In his writings on art and geometry, the art historian, William Ivins, provides an interesting theory in regard to vision and our intuitive understanding of space, which relates well to my examination of Hooke's practice. Ivins states that 'the eye has a point of view' and 'sees "there" where it is not' (Ivins 1946, p. 5). He argues the 'result is that visually things are not located in an independently existing space, but that space, rather, is a quality or relationship of things and has no existence without them' (Ivins p. 5). But what happens to the quality of space when 'there' is to be defined by a virtual object? And, further, what happens when an exact 'there' appears to exist simultaneously in two separate locations? We accept logically that this is the case with compound microscopy, but this acceptance is accompanied by the realization that the two 'theres,' so to speak, look nothing alike. In the example of Hooke, we have to say 'almost' nothing alike, as the low (50×) magnification of his microscope only allowed him to view the familiar as enlarged and intricately detailed. Therefore, for Hooke, this virtual object, the parasitic image, is unable to become completely separated visually from its host specimen, as it is still recognizable and appears somewhat related. This process must have frustrated Hooke's logic of space as well as his understanding of sight. This returns us to the question of Hooke's choice of instrumentation.

Seeing Things

In the following excerpt from *Micrographia*, Hooke describes the technological extension of the eye, stating that:

> The next care to be taken, in respect of the Senses, is a supplying of their infirmities with Instruments, and, as it were, the adding of artificial Organs to the natural; this in one of them has been of late years accomplisht with prodigious benefit to all sorts of useful knowledge, by the invention of Optical Glasses. By the means of Telescopes, there is nothing so far distant but may be represented to our view; and by the help of Microscopes, there is nothing so small, as to escape our inquiry; hence there is a new visible World discovered to the understanding (Hooke 1665, p. 5).[24]

The preceding statement from *Micrographia* implies that his aim was to extend vision to its furthest possible limits. Yet, if this was indeed the case, then why did he not use a single lens microscope that would have offered him a much higher magnification, in fact almost five times more than the compound microscope? The instrument was available to him, and he had used it before, and beneficially it would have optically flattened the space more than the compound microscope, somewhat alleviating the tension of being *between* these two ways of seeing. (Without space, perspective does not exist.) In addition, as the instrument had only one lens, no virtual images could be generated through the compounding of lenses, thereby negating any confusion about what is real (although again, Hacking would question this assertion). What then were the disadvantages for Hooke in using the single lens microscope? I suggest that a partial answer can be found in examining the design of the single lens microscope and then considering the phenomenological engagement that was incited by the two separate instruments.

The single lens microscope comprises a little droplet of polished glass, with a diameter of less than three millimetres, which is contained in a hand-held mount to be positioned close to the eye. The instrument appears more akin to a miniature magnifying glass than to our current idea of a microscope. However, it could achieve a magnification of 240×. In the Preface to *Micrographia*, Hooke instructs on how to make a simple lens; however, he also describes the instrument as 'very troublesome to be us'd, because of their smallness, and the nearness of the Object' (Hooke 1665, p. 5). In a lecture in 1678, Hooke again indicated his aversion to the simple lens microscope stating:

> I have found the use of them offensive to my eye, and to have much strained the sight, which was the reason why I omitted to make use of them, though in truth they make the object appear much more clear and distinct, and magnifie as much as the double Microscopes: nay to those whose eyes can well endure it, 'tis possible with a single Microscope to make discoveries much better than with a double one…
>
> *Hooke (1678, p. 16).*

I suggest that Hooke's discomfort with the single lens microscope was because it gave no externalized space for him to conceptualize the image. That is to say, the image neither resembled the original specimen nor existed as a virtual image; therefore, in Ivins terms, there seemingly was no 'there' to define this act of seeing. Perhaps, the single lens microscope provided Hooke no buffer to the effects of magnification as the image effectively affronted his eye – locating a 'there' likely to be injurious to the eye – whereas the compound microscope could provide a place for the virtual image object to be contained. In the latter, the image, as object, exists in the drawtube casing in-between the lenses, somewhat assisting in defining a 'there' to the observer's 'here,' but with all the complications that a virtual 'there' provides. Nevertheless, I propose that this provision of space was an important element for Hooke, providing him with the ability to conceptualize things as residing in a coherent space, as being somewhere, but also as being somehow contained. I imagine it to be all the more important when the image no longer resembles the original specimen, as would be the case with the single lens microscope, which rendered the familiar, strange.

In considering Hooke's use of the single lens microscope, in comparison with the compound microscope, I return to examine the choreography of observer and instrument in the act of observation. Here, I adopt an approach influenced by media theorist, Marshall McLuhan: particularly his idea that the formation of a new technology provides relief from an over-stimulated sense or function by disconnecting it from the body (McLuhan 1964). According to McLuhan, the process numbs us to the realization that the new technology is an extension of ourselves; therefore, it appears to us as an *other* which fascinates, automatically creating a *closed system* between body and technology (McLuhan 1964). I consider Hooke's use of a single lens microscope as an instance of an overstimulated sense. However, rather than providing relief through technological extension, by 'the adding of artificial Organs to the natural,' I conceptualize it is a sustained irritation (Hooke 1665). By this, I mean the use of the single lens microscope can be visualized as a tugging, pulling, and extending of the cornea, which artificially amplifies its ability to focus, though never severing its anatomical connection to the eye. In contrast, it can be imagined that the compound microscope effectively disconnected, and provided relief for, Hooke's over-extended eye by providing a space for the optical image to reside away from the eye's surface. For Hooke, this freestanding instrument constitutes the *other*, a technology that fascinates him.

Pursuing this idea further, we can turn to McLuhan's argument that an opportunity to stand outside the *closed system* is presented at the moment when two mediums combine and develop into a new form through a process of *hybridization* (McLuhan 1964). He states that the alternating perspectives provided by the initial contrast have the effect of heightening our awareness, as the traits of one medium expose the qualities of the other. As previously mentioned, I see such an opportunity arising with the initial contrast that took place in early microscopy, when the microscopic view met with perspective. Moreover, Hooke seemingly exemplifies the frustrations and fascinations that McLuhan highlights in relation to technology. Indeed, I consider Hooke's invention of a wearable camera obscura to be a form of McLuhanian *closed system*. However, I also explore the device in terms of Hooke's phenomenological experience, as being both embodied and embedded in a (mediated) world, and as an iteration of his 'actively thinking' method of 'true philosophy.'[25] I imagine Hooke in the Heideggerian understanding of *being-in-the-world* in that he is literally thrown into a process of making sense of the world that begins with being perplexed by his own existence (Heidegger 1927). In this way, the wearable camera obscura becomes a way of making sense of the immersive visual experience of microscopy.

The only image of Hooke's invention is a woodcut print that accompanies the written submission he made to the Royal Society (Hooke 1694). The picture is of a man walking through a landscape while wearing the camera obscura, but the instrument itself is illustrated as a cutaway that allows the user to be fully seen, so in effect his upper body appears as the internal workings of an image-making machine (Figure 8.3). Seemingly, Hooke's fascination with microscopy has now driven the body into the optical instrument. It is not that the

*Figure 8.3 An Instrument of Use to take the Draught, or Picture of any Thing…*by Robert Hooke. (1694) © The Royal Society

wearable camera obscura magnifies his view, but it does replicate the enveloping, mediated vision provided by microscopy. I suggest that Hooke's conversion of the camera obscura into a wearable technology enabled him to be immersed in a technologically mediated vision. It was as if Hooke had made a model that allowed him to imagine his body positioned inside the drawtube of a compound microscope, where he could move through the virtual image. In practice, the lower half of the body appeared to be providing locomotion for a somewhat distended cyclopic head – which had absorbed the other four main senses. As with microscopy, Hooke's sense of touch is limited to experiencing the world through mediated sight, disconnected from the immediacy of material things, as he can no longer touch what he can see. The whole process can be understood as Hooke taking the *task envelope* of microscopy and reconfiguring its relationship to the body and to space. It is also an attempt to find another way of exploring the perceptual and conceptual tensions raised by microscopy. Therefore, Hooke's camera obscura can be thought of not only as an amplified visual experience and a new way of experiencing images but as also offering another possible way of experiencing the body as a whole – similar to that engendered by microscopy.

Hooke is once again immersed in a vision where notions of interior, exterior, depth and orientation are hard to define, and the demarcation of disparate spaces, aimed at defining a 'there to the observer's here,' is equally slippery to explain. The world for Hooke appears collapsed onto the glass ground plate, which acts as a screen, bringing everything close to hand as both hand and eye are set the same task of seeing. The world effectively becomes an image to Hooke. A visual experience opens up that is more akin to a twenty-first century heads-up display than to a seventeenth-century camera obscura. It challenges the expectation that there is an inner world of an observer that exists separately from an outer world to be observed. Vision is no longer of something, but is rather defined as an (all-encompassing) experience. To add to the confusion, there is also the task of having to determine where vision, in this extended technological eye, is actually located. Does it reside on the glass plate, in the fingertips, or is it circling indefinably within the interior space of the instrument?

Making Hooke's vision even more complex is that the image most likely appeared to Hooke as inverted and reversed on the camera obscura glass ground plate. Interestingly, and taking a slight tangential step into experimental psychology, this disorientating view would have had a durational limit because, depending on how committed Hooke was to his experiment, his brain would eventually adapt to the 'artificial organ' by self-correcting the vision. However, once the device was removed, the brain would go through the process again in reverse (Kohler 1962, pp. 62–86). Of course, this was unlikely to be Hooke's intention, though he did seem to expect some dedicated wearing of the instrument. In one passage, Hooke describes a mariner standing on the deck of his boat wearing the instrument, glancing 'time to time' at the coastline, while remaining stationary in his relative position as the ship traverses the sea (Hooke 1694, p. 295). He states that in wearing his device, 'the Mariner may easily and truly draw the Prospect and from Time to time denote the Rising thereof, as he does nearer and nearer approach it, and the Depression, or Sinking of it, as he does recede' (Hooke, p. 296). Not only does this vision seemingly have no fixed horizon to allow for an image to be made, negating any practical claim as a recording instrument, Hooke also appears to equate vision to the drawtube focus of the compound microscope, with the mariner's vision drawing in and out with the tide.

Hooke's wearable camera obscura is not fiction, it did exist, but my question is whether it was really designed for travellers wanting to document their sightseeing. Or did Hooke provide this description only as a playful justification for his experimentation with altered perception? Perhaps, Hooke himself was perplexed by what may have been an inexplicable desire to construct this device. In part, this is why I find Hooke of interest, as he is positioned on a threshold, effectively opening up a space of visual and conceptual uncertainty, which can be questioned and explored. Keeping this in mind, my objective in conclusion is to suggest similarities between Hooke's phenomenological experience of imaging and our own contemporary engagement with images. In addition, I return to the ethical imperative *to cut better* in the discipline of anatomy.

Seeing things differently

I am not saying that what is being experienced today in our twenty-first-century engagement with images (both in the realm of science and more broadly, i.e., in our current visual and media culture) is an re-enactment of the original hybridization of microscopy and perspective, important differences appear – differences that I relate to Hooke's experimentation with the camera obscura (which I consider as an example of Hooke's 'true philosophy'). Importantly, and somewhat similarly to Hooke, the methods that we now use to create and view images are appearing to complicate prior notions of reality, for example, augmented reality, mixed reality, and virtual reality. As it could be said that, to a large extent, we no longer look at images, but rather, we interact with images in multiple dimensions and in multisensory ways. Indeed, it would appear that any contemporary definition of the word image will need to question where the image appears, how it appears, and how it relates to (our general understanding of) reality, i.e., is the viewer assimilated into the view of the image, or more interestingly, is the image behaving as an object. Moreover, my conceptual framework – *the task envelope of light* – proves less effective in resolving questions about image-making in our 'post optics' era, as increasingly images arise from algorithmic data, not the indexical capture of light reflecting off surfaces. Yet, a broken framework still provides ways in which to think through ideas (i.e., the break in itself provides insight). I close this chapter with my latest biological artwork, *Sentinels*, which, in part, arose from one such example: when I began to think about light sources that penetrate (the body) rather than illuminate (its surfaces). I am referring to the diagnostic imaging technologies that employ frequencies from the extremes of the electromagnetic spectrum, specifically X-ray, computerized tomography (CT), and magnetic resonance imaging (MRI). (Yes, I have a very generous understanding of what counts as light.)[26] MRI is of particular interest as it also resides in the category of 'post optics,' i.e., MRI images do *not* originate from optical information, but instead are generated from data sets of Cartesian coordinates. These data sets represent parallel, sequential layers of the body, which can be digitally restacked and realigned to form virtual volumetric images. The neuroscientist, Richard Wingate, states, 'a computerised reconstruction produces a facsimile of material substance that can be rotated, re-rendered, paused or magnified' (Kwint & Wingate 2012, p. 27): his description (of a brain model) exemplifying the vision that I envisaged as originating with Hooke.

One of the most interesting qualities of MRI is its acute sensitivity to recording adipose tissue (unlike X-ray and CT); however, it is often treated as an artefact and removed algorithmically in the digital pre-processing of the image. Historically, fat rarely appears in the visual archives of anatomy or at least rarely in a way that appears meaningful, and MRI algorithms seemingly repeat the cut, thus creating a strange continuity of vision that aligns the computer-generated volumetric imagery composed of MRI data sets with the normative representations of the anatomical body presented in the perspectival illustrations of anatomy atlases. Seemingly, fat exists in an anatomical body, but is not *of* anatomical knowledge. This absence raises the dual question: what is our investment in unseeing fat in the study of anatomy and the implications of its exclusion within the life sciences? Keep in mind also that anatomy is the field of study that not only underpins Western medical knowledge but also increasingly informs the contemporary understanding of the body more generally (Kuriyama 1999, p. 117).

Sentinels

In making the biological art installation, *Sentinels*, my aim is to question the cultural and scientific implications of the relative absence of fat in the history of anatomy and the significance for contemporary discourses about the human, the non-human, and the post-human. In the context of its inaugural showing, as part of the exhibition, *HyperPrometheus: The Legacy of Frankenstein*, Perth Institute of Contemporary Art, Australia, the work was meant as a provocation for us to think beyond anatomy as our normative frame of reference. The installation displays human pre-adipocyte tissue culture (aka fat – living, and growing, in vitro) embedded in a replica of an archaic Greek kouros statue, cast in (GelMA) hydrogel. The sixth-century BCE kouroi predate the arrival of anatomy; however, they were the first statues in archaic Greece to show movement: one leg placed further forward, as if tentatively entering into this new understanding of the body. The installation centres on a custom-made incubator: appearing either side are nine-foot high real-time video projections showing selected elements inside the incubator (Figure 8.4). On the left, the gel kouros being drip fed nutrients in its wet environ; on the right, the original vial in which the human pre-adipocytes were transported on dry ice from the United States (the now empty vial positioned in the incubator alongside the living korous). The visible section of the vial label reads: 'Primary Subcutaneous Normal, Human, Lot # 63569630, store at <−130°C.' When contrasted with the kouros, the sentinel-like figure of the cell vial is suggestive of a period post-anatomy.

The biological installation, *Sentinels*, is part of an ongoing series of artworks that I intend as thoughtful (fat) interventions in the historical archives of anatomy, i.e., its museum collections and compendia. These are small gestures, not grand statements, and in no way are to appear 'useful.' Similar to my take on Hooke's true philosophy, they signify an attitude of 'actively thinking' rather than an act of 'utilitarian doing.' In regard to the performance of anatomical knowledge, I want to suggest that we have the possibility of seeing, and doing, otherwise.

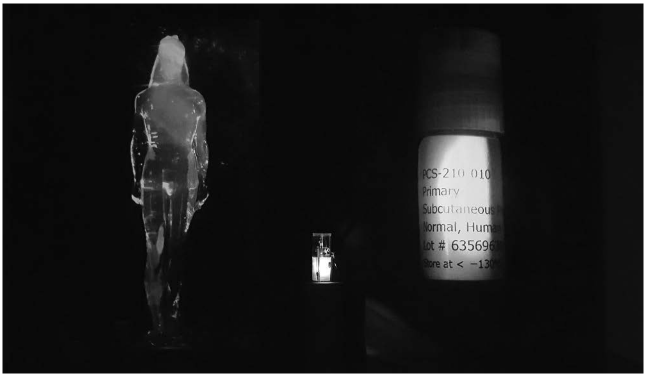


Figure 8.4 *Sentinels* (installation at Perth Institute of Contemporary Arts, Western Australia) by Nina Sellars. (2018) © Nina Sellars

Notes

1 A standard portable camera obscura, though it may be movable, is not wearable and requires both instrument and observer to remain still: stillness being the basic prerequisite for capturing an image, i.e., to draw a 'realistic' representation by means of tracing the outline of the projected 'real'-world scene as it appears on the ground glass plate of the camera obscura apparatus. Notably, Hooke presents the simultaneous movement of instrument and observer as a design feature of his wearable camera obscura, thus compromising its utilitarian value as a recording device.

2 Hooke describes two iterations of his camera obscura. The earlier design is recorded in his Royal Society lecture notes of 1681. See Robert Hooke, 'A Continuation of the Former Subject of Light. Being the Lectures Read in June, 1681,' *The Posthumous Works of Robert Hooke.* Edited and Published by Richard Waller (London: Printed by S. Smith and B. Walford, 1705), 127–128, plate 1, Figure 7. Here, Hooke provides instruction on how to construct an experimental apparatus for explicating functions of the eye (these notes appear after his description of his undertaking of a detailed dissection of an eye). The latter design, a drawing instrument (i.e., the wearable camera obscura discussed in this chapter), was presented in a lecture to the Royal Society in 1694. See Robert Hooke, 'An Instrument of Use to Take the Draught, or Picture of Any Thing. Communicated by Dr Hook [sic] to the Royal Society Dec. 19, 1694,' William Derham, *Philosophical Experiments and Observations of the Late Eminent Dr. Hooke* (London: Innys, 1726), 292–296. The ways in which the two designs vary are important – in the earlier design, Hooke indicates that only the face of the observer peers into the apparatus, whereas in the later design, i.e., the wearable camera obscura, the entire upper body of the ambulant observer, i.e., their face, head, arms, and torso, appear enclosed within the instrument. Keep in mind that this would also capture what are traditionally considered as the five key senses of the body: sight, hearing, touch, taste, and smell. Moreover, it could be suggested that the enclosed capsule created an environment in which oxygen and carbon dioxide exchange would become restricted, altering the pH levels within the body of the instrument wearer, leading to dizziness and confusion.

3 R. Hooke, *Micrographia: Or Some Physiological Descriptions of Minute Bodies Made by Magnifying Glasses with Observations and Inquiries Thereupon.* 1st ed. (London: Martyn and Ja. Allestry, Printers to the Royal Society London, 1665). Available from: https://www.bl.uk/collection-items/micrographia-by-robert-hooke-1665/ [Accessed 20 July 2019].

4 For an example of its reception, two diary entries from the seventeenth-century politician and diarist, Samuel Pepys, express his first-hand engagement with *Micrographia*. On 20 January and 21 January 1665, Pepys writes that having purchased a copy, he 'there took home Hooke's book of microscopy, a most excellent piece, and of which I am very proud.' *Micrographia* then crosses the threshold of Pepys' home and continues to enchant him. The following day, Pepys' diary entry reads: 'Before I went to bed I sat up till two o'clock in my chamber reading of Mr. Hooke's *Microscopical Observations,* the most ingenious book that ever I read in my life' (Pepys 1665).

5 The artwork, *Lucida*, was initiated while I was Artist in Residence at the Pilchuck Glass School, Seattle, USA, 2008, and was further developed with the assistance of the Solid-state Spectroscopy Group, Laser Physics Centre, Research School of Physics and Engineering, Australian National University, 2010 and 2012. Craig MacLeod (technician/mechanical engineer) assisted with the fabrication of the instruments, and Associate Professor, Matthew J. Sellars (quantum physicist), was the advising scientist. A prototype of *Lucida*, titled *Lumen*, was exhibited at GV ART, London, as part of the group exhibition, *Art and Science: Merging Art and Science to Make a Revolutionary New Art Form*, 2011, curated by Robert Devcic and Professor Arthur I. Miller. *Lucida* was exhibited at Fehily Contemporary, Melbourne, as part of my solo exhibition, *The Optics of Anatomy and Light*, 2012.

The artwork, *Sentinels*, was created while I was 'Artist in Residence' at the SymbioticA biological arts laboratory, The University of Western Australia, and the Solid-state Spectroscopy Group, Laser Physics Centre, Australian National University, 2018. *Sentinels* was made for the exhibition, *HyperPrometheus: The Legacy of Frankenstein*, Perth Institute of Contemporary Art (PICA), curated by Laetitia Wilson, Oron Catts, and Eugenio Viola, as part of SymbioticA's *Unhallowed Arts* Festival, 2018. The *Sentinels* installation at PICA contained human pre-adipocytes (i.e., precursor fat cells) living and growing in a hydrogel (GelMA). The GelMA hydrogel was generously provided by Dr Christoph Meinert, Centre in Regenerative Medicine, Institute of Health and Biomedical Innovation, Queensland University of Technology. Assistance in the production of *Sentinels* at SymbioticA, UWA, was provided by Mike Bianco, Oron Catts, Callum Siegmund, Nathan

Thompson, and Dr Ionat Zurr. At the Solid-State Spectroscopy workshop, ANU, assistance was provided by Matthew Berrington, Craig MacLeod, and Assoc. Prof. Matthew J. Sellars. My initial fat tissue culture research and development – 'Fat Culture' – was undertaken while I was Artist in Residence at SymbioticA, 2016, funded by the Australia Council, with further in-kind support provided by SymbioticA, UWA, 2017 and 2018. The *Sentinels* installation was featured in the ABC short documentary, *Art Bites Biogenesis: Sentinels*, produced by Blue Forest Media, 2019 (First aired 10 August 2019. Available on demand via ABC iview, geo-locked to Australia.) Advice on adipose tissue provided by my 'fat' mentors, J. William Futrell and Ramón Llull.

6 Here, my understanding of the term 'performed' is derived from the notions of 'performativity' that appear in the studies of media theory and cultural studies (Austin; Barad; Butler; Derrida). 'Performativity is an empowering concept, politically and artistically, because it not only explains how norms take place but also shows that change and invention are always possible' (Kember & Zylinska 2012, p. 189). This idea expresses exactly the attitude I adopt in my approach to Hooke's work. Moreover, the term 'form' appears closer in meaning, i.e., being only a transitory stage in the world's ongoing 'performativity' of which we too are merely a fluid (resolving/dissolving) part.

7 I don't mean to simply illustrate the work of theorists, but rather to actually think through your work – toss ideas around visually, see things a little differently, and ask questions through your practice, but feel no obligation to proffer solutions. I return here also to the media theorist, Joanna Zylinska, and her text, *Life after New Media: Mediation as a Vital Process* (2012), co-written with Sarah Kember. In the text, Zylinska's thoughts on creative practice, in particular her engagement with photography, are outlined:

> [t]o be interesting, creative practice, including photography, for her has to mobilise complex thought processes, although without doubt it should do *more* than just illustrate already worked-out ideas and concepts. The very nature of this 'more' constitutes part of the invention process activated throughout this project.
>
> (Kember & Zylinska 2012, p. 198)

The project referred to here is Kember and Zylsinska's Creative Media project. Kember and Zylinska state that '[w]orking in and with media is for us first and foremost an epistemological question of how we can perform knowledge differently through a set of practices that also "produces things"' (Kember & Zylinska 2012, p. 188). Kember's creative practice is writing fiction and Zylinska's is photography.

8 'Art' can be many things, but the genre of 'art & science' remains intrinsically linked to institutions, and this relationship and its history need to remain open to interrogation.

9 I view light-based technologies as influencing the way in which anatomical knowledge is enacted and conveyed (with each light-directing technology creating, and delineating, a *task envelope of light*, distinct to each instrument). For example, the quality of illumination evidenced in perspectival illustrations of the Renaissance era supports the Vesalian method of teaching anatomy (Andreas Vesalius being the founder of modern anatomy and author of *De humani corporis fabrica* (1543), the first anatomical atlas to use perspectival images). Perspective is a light-based technology that offers a 'haptic' vision, an idea I will return to in this chapter to give further explanation. The notion of a haptic vision matched Vesalius's dictum that the study of anatomy should combine visual observation with 'hands-on' dissection, and Hooke used perspective to make the microscopic world appear palpable, i.e., within reach of the hand. For now, think of perspective as being an invitation to touch. (In regard to the notion of *the task envelope of light*, X-ray penetration of the body captured on photographic film in the twentieth century provides another example for comparison. Transparency became a diagnostic tool with the invention of the X-ray enabling the anatomy of a living body to be viewed.)

10 Here, we should be clear that Barad, similarly to Haraway, is not interested in defining differences as absolutes, but rather in mapping where the effects of differences appear (in their ongoing intra-actions). See note 12 for the definition of Barad's neologism, 'intra-action.'

11 Diffraction patterns are exhibited not only by light waves but also water waves and sound waves. (Moreover, we could add matter, electrons, and neutrons.) 'Diffraction has to do with the way waves combine when they overlap and the apparent bending and spreading out of waves when they encounter an obstruction' (Barad, p. 28).

12 The neologism 'intra-action' is a key component of Barad's theory of agential realism.

> The neologism "intra-action" *signifies the mutual constitution of entangled agencies*. That is, in contrast to the usual "interaction," which assumes that there are separate individual agencies that precede their interaction, the notion of intra-action recognizes that distinct agencies do not precede, but rather emerge through, their intra-action.
>
> (Barad, p. 33)

13 It is important to understand the terms 'agency' and 'reality' as used in the context of Barad's 'agential realism' framework: '[a]gency is an enactment' not an attribute of individual subjects or entities, and 'reality' consists of phenomena, i.e., the entangled effects that differences make (Barad, p. 178). In a broader sense, '[r]ealism, then, is not about representations of independent reality but about the real consequences, interventions, creative possibilities, and responsibilities of intra-acting within and as part of the world' (Barad, p. 37).

14 Historically, anatomy is a discipline informed by a series of 'cuts' – both physical and visual. At its etymological origins in ancient Greek, the word *anatomy* literally means *to cut* the body asunder. This makes anatomy directly related to the act of dissection (late Latin – anatomia, from Greek – ana-'up'+tomia 'cutting' from temnein 'to cut').

15 It has been noted that texts such as 'Gulliver's Travels could not have been written before the period of microscopic observation, nor by a man who had not felt at once the fascination and the repulsion of the Nature which that instrument displayed' (Nicholson 1935, p. 50).

16 Hooke was said to be a prodigious drawer and model maker as a child and for a time was apprenticed to the portrait painter, Sir Peter Lely. See Richard Waller, 'The Life of Robert Hooke,' *The Posthumous Works of Robert Hooke*. Edited and Published by Richard Waller (London: Printed by S. Smith and B. Walford, 1705), ii.

17 The 'a' in *différance* is a deliberate misspelling by Jacques Derrida of the French word, *différence*. The 'a' is a 'graphic intervention' in the word (i.e., it is seen when written, but not heard when spoken). Derrida uses this (f)act as a way to subvert what he sees as the traditional privileging of speech over writing (one example of the sets of binary hierarchies that characterize the Western tradition, in which one element is elevated as primary, while the other is seen as derivative or supplementary – in this instance, speech is considered primary). The term *différance* plays on the dual definition of the French word *différer*, which means both 'to defer' and 'to differ' – for Derrida, *différance* indicates both a deferral of meaning and meaning through difference. Neither a word nor concept, *différance* gestures at a diverse assemblage of qualities that govern the production of (con)textual meaning (Derrida 1982, pp. 3–27). The term implemented by Derrida as a way in which to suspend the force of the asymmetrical binary hierarchies of metaphysical thought that are exposed in the process of doing deconstruction (Derrida 1981, p. 43). See also, G. Hall, Cultural Studies and Deconstruction. In G. Hall and C. Birchall, eds., *New Cultural Studies: Adventures in Theory*, 1st ed. (Edinburgh: Edinburgh University Press, 2006), 31–52.

18 The understanding of 'form and matter' that underpins Western knowledge comes from Aristotle's theory of hylomorphism. *Hylomorphism*, from the Greek *hyle* (matter) and *morphe* (form). Anthropologist, Tim Ingold, provides an introduction to the theory of hylomorphism. T. Ingold, *Making: Anthropology, Archeology, Art and Architecture* (London and New York: Routledge, 2013), 20–31. The section also includes a discussion of key concepts that outline ways in which to overcome hylomorphism that have been proposed by philosophers, Gilbert Simondon, and Deleuze and Guattari. Returning to the above note (17), if considered in Derridean terms – i.e., as an example of the sets of binary hierarchies that characterize the Western tradition in which one element is elevated as primary, while the other is seen as derivative or supplementary – form is seen as the primary element and matter the inert passive receiver of form.

19 For an excellent evaluation of instrumentation, in particular, the camera obscura as well as notions of the 'observer,' see J. Crary, *Techniques of the Observer: On Vision and Modernity in the Nineteenth Century* (Cambridge, MA: MIT Press, 1990).

20 Daston and Galison have made explicit the importance of interrogating notions of 'objectivity' in relation to the given era, and that it has a history, i.e., objectivity is *not* to be thought of as being 'abstract, timeless, and monolithic' (Daston & Galison 2007). Barad provides a definition of objectivity in relation to the concept of *agential realism* (Barad 2012, 361). For Haraway, '[f]eminist objectivity means quite simply *situated knowledges*' (Haraway 1988, p. 581).

21 A *core shadow* is the darkest section of the *form shadow*, which appears just prior to the point where the *form shadow* turns into the light. Perhaps, the term *core shadow* is best understood in relation to a similar term used in astronomy, *terminator*, which indicates the dividing line between the illuminated side and the dark shadow side on a planetary body.

22 The two main divisions of basic optics are geometric (ray) optics and physical (wave) optics. Geometric optics provides an insight into the basics of light reflection and refraction and the use of simple optical elements such as mirrors, prisms, and lenses (and are explained visually using ray diagrams). Physical optics provides an insight into the phenomena of light wave interference and diffraction. For comparison, quantum optics deals specifically with photons (particles of light) in their interaction with matter. Photons behave like a particle and a wave, simultaneously.
23 However, the engraver of *Micrographia's* final plates, i.e., the person who translated Hooke's drawings into etchings, is unnamed in the text.
24 For a discussion of the impact of these technologies on the era's understanding of the eye and the separation of optics and sight in mediated vision, please see '*Baroque Science*' (Gal & Chen-Morris 2013, pp. 7–8).
25 In its 'continual passage,' a further iteration of Hooke's 'true philosophy' might find Hooke taking a stance similar to that of Haraway in her writings on situated knowledges. The construction (of the wearable camera obscura) perceived as an act of 'loving care' undertaken 'to learn how to see faithfully from another's point of view, even when the other is our own machine' (Haraway 1988, p. 583). Here, the *other* (the microscope) presents less as an extension or reflection of ourselves, which 'fascinates,' and more as a respectful meeting that elicits an expression of thoughtfulness towards the *other* (i.e., by way of the construction of the camera obscura), which, at the same time, decentres the human or at least their importance.
26 J. D. Wilson, A. J. Buffa and B. Lou, *College Physics*, 8th ed. (Upper Saddle River, NJ: Pearson Prentice Hall, 2009), 679.

> The electromagnetic spectrum is continuous. An electromagnetic wave (light) consists of time-varying electric and magnetic fields that propagate at a speed of *c* (3.00 × 108 m/s) in a vacuum. The different types of electromagnetic radiation (such as UV, radio waves, and visible light) differ in frequency and wavelength.

References

Agamben, G., 1994. *Homo Sacer: Sovereign Power and Bare Life.* Trans. D. Heller-Roazen, 1998. Paolo Alto, CA: Stanford University Press.
Armstrong, I., 2008. *Victorian Glassworlds: Glass Culture and the Imagination 1830–1880.* Oxford: Oxford University Press.
Barad, K., 2007. *Meeting the Universe Halfway: Quantum Physics and the Entanglement of Matter and Meaning.* Durham, NC: Duke University Press.
Berger, J., 1972. *Ways of Seeing.* London: Penguin.
Catts, O., 2012. Bulletproof Skin vs. Utility Proof Art or When a Symbolic Gesture Is Seen as Real Action. *In*: G. J. van Trier and J. Essaïdi, eds. *Bulletproof Skin: Exploring Boundaries by Piercing Barriers.* 1st ed. Eindhoven: Jalila Essaïdi, 29–31.
Catts, O. and Zurr, I., 2018. Artists Working with Life (Sciences) in Contestable Settings. *Interdisciplinary Science Reviews*, 43(1), 40–53.
Crary, J., 1990. *Techniques of the Observer: On Vision and Modernity in the Nineteenth Century.* Cambridge, MA: MIT Press.
Daston, L. and Galison, P., 2007. *Objectivity.* New York: Zone Books.
Dear, P., 2005. What Is the History of Science the History Of? Early Modern Roots of the Ideology of Modern Science. *Isis*, 96(3), 390–406. Available from: https://doi.org/10.1086/447747/ [Accessed 20 July 2019].
Derrida, J., 1981. *Positions.* Chicago, IL: University of Chicago Press.
Derrida, J., 1982. *Margins of Philosophy.* Trans. Alan Bass. Chicago, IL: University of Chicago Press.
Gal, O. and Chen-Morris, R., 2013. *Baroque Science.* Chicago, IL: The University of Chicago Press.
Hacking, I., 1985. Do We See Through a Microscope? *In*: P. Churchland and C. A. Hooker, eds. *Images of Science: Essays on Realism and Empiricism.* Chicago, IL: University of Chicago Press, 133–153.
Hall, G., 2002. *Culture in Bits: The Monstrous Future of Theory.* London and New York: Continuum.
Hall, G., 2006. Cultural Studies and Deconstruction. *In*: G. Hall and C. Birchall, eds. *New Cultural Studies: Adventures in Theory*, 1st ed. Edinburgh: Edinburgh University Press, 31–52.
Haraway, D., 1988. Situated Knowledges: The Science Question in Feminism and the Privilege of Partial Perspective. *Feminist Studies*, 14(3), 575–599.

Haraway, D., 1997. *Modest_Witness@Second_Millenium: FemaleMan_Meets_OncoMouse: Feminism and Technoscience.* New York: Routledge.
Heidegger, M., 1927. *Being and Time.* Trans. J. Macquarie and E. Robinson. Reprint 2008. New York: Harper Perennial.
Hooke, R., 1665. *Micrographia: Or Some Physiological Descriptions of Minute Bodies Made By Magnifying Glasses with Observations and Inquiries Thereupon.* 1st ed. London: Martyn and Ja. Allestry, Printers to the Royal Society. Available from: https://www.bl.uk/collection-items/micrographia-by-robert-hooke-1665/ [Accessed 20 July 2019].
Hooke, R., 1678. *Lectures and Collections; Microscopium.* London: J. Martyn, Printer to the Royal Society. Available from: https://archive.org/details/LectionesCutler00Hook/ [Accessed 07 July 2019].
Hooke, R., 1694. An Instrument of Use to Take the Draught, or Picture of Any Thing. Communicated by Dr. Hook (sic) to the Royal Society Dec. 19, 1694. *In*: W. Derham, ed. *Philosophical Experiments and Observations of the Late Eminent Dr. Hooke.* London: Royal Society, 1726. Available from: http://echo.mpiwg-berlin.mpg.de/ECHOdocuView?mode=imagepath&url=/mpiwg/online/permanent/library/RT3R12V8/pageimg&viewMode=images [Accessed 20 July 2019].
Ingold, T., 2013. *Making: Anthropology, Archeology, Art and Architecture.* London and New York: Routledge.
Inwood, S., 2002. *The Man Who Knew Too Much: The Strange and Inventive Life of Robert Hooke 1635–1703.* London: MacMillan.
Ivins, W., 1946. *Art & Geometry: A Study in Space Intuitions.* New York: Dover.
Kember, S. and Zylinska, J., 2012. *Life after New Media: Mediation as a Vital Process.* Cambridge, MA: MIT Press.
Kohler, I., 1962. Experiments with Goggles. *Scientific American*, 206(5), 62–86.
Kuriyama, S., 1999. *The Expressiveness of the Body and the Divergence of Greek and Chinese Medicine.* New York: Zone Books.
Kwint, M. and Wingate, R., 2012. *Brains: The Mind as Matter.* London: Wellcome Trust.
McLuhan, M., 1964. *Understanding Media: The Extension of Man.* New York: New American Library.
Nicholson, M., 1935. *The Microscope and the English Imagination.* Northampton, MA: Smith College, the Department of Modern Languages.
Shlain, L., 1991. *Art & Physics: Parallel Visions in Space, Time, and Light.* Reprint. New York: Harper Perennial, 2007.
Sellars, N., 2012. *The Optics of Anatomy and Light: A Studio-based Investigation of the Construction of Anatomical Images.* Ph.D. Monash University.
Sellars, N., 2018. Sentinels. *In*: O. Catts, R. Cook, and L. Wilson, eds. *UNHALLOWED ARTS.* 1st ed. Perth: UWA Publishing, 100–103.
Stafford, B., 1993. *Body Criticism: Imaging the Unseen in Enlightenment Art and Medicine.* Cambridge, MA: MIT Press.
Wilson, J. D., Buffa, A. J. and Lou, B., 2009. *College Physics.* 8th ed. Upper Saddle River, NJ: Pearson Prentice Hall, 679.
Zylinska, J., 2005. *The Ethics of Cultural Studies.* London and New York: Continuum.
Zylinska, J., 2009. *Bioethics in the Age of New Media.* Cambridge, MA: MIT Press.
Zylinska, J., 2013. Interview with Joanna Zylinska by Laureano Ralón [blog]. *Figure/Ground.* Available from: http://figureground.org/interview-with-joanna-zylinska/ [Accessed 20 July 2019].

9

The *Xenopus* pregnancy test

A performative experiment

Eben Kirksey, Dehlia Hannah, Charlie Lotterman, and Lisa Jean Moore

On the morning of August 29, 2012, we conducted a pregnancy test at home with a live African clawed frog (*Xenopus laevis*). Under the watchful gaze of interested artists, a radio journalist, and frog enthusiasts who gathered in a Brooklyn cooperative house, we injected a woman's urine into a dorsal lymph node of a frog named Loretta. Held firmly between sterile gloved hands, Loretta did not seem to notice when the fine needle of the syringe pierced her skin. But as a milliliter of fluid entered her body, she contracted her legs and extended her claws in an apparent expression of discomfort. A wave of anxiety and mixed emotions passed through the room as Loretta's movements quieted and she was returned to her water-filled tank, where she would be monitored for the following twenty-four hours via a live webcast on Ustream. We generated public field notes on a blog as we settled in to wait for Loretta to lay eggs—an event that would indicate that the woman was pregnant.

At first blush, the decision to conduct a pregnancy test in a semipublic forum, to unnecessarily extend its duration over a twenty-four-hour period, and to use a live animal long retired from this particular line of biomedical service appears ridiculous, even unethical. Our performance exhibited human debts to *Xenopus* frogs—creatures that continue to be widely used as model organisms in the fields of developmental biology, endocrinology, and neuroscience.[1] By injecting a frog in a semipublic space, we intended to render visible the ongoing violence taking place in laboratories behind closed doors. *Xenopus* frogs have long suffered so that humans might craft new social realities and science fictions. Starting from a position of noninnocence, confronting the routine violence of experimental practices face-to-face with a captive frog, we considered how humans have become dependent on complex entanglements with animals, ecosystems, and emergent biotechnologies.[2]

The *Xenopus* pregnancy test was used by one of us who wanted an answer to a very personal question: am I pregnant? By restaging this outmoded test, we denatured assemblages of technology, biology, and knowledge that standardize answers to this question. We considered how technology can expand or contract the temporal gap between the biochemical condition of being pregnant and the social experience of pregnancy. We explored this gap with what philosopher Dehlia Hannah calls a performative experiment, an appropriation of conventional scientific practice for purposes of art or parodic performance.[3] Performative experiments take place in contemporary art worlds when material practices of scientific

DOI: 10.4324/9780429437069-12

experimentation become aesthetic forms. In addition to drawing on theoretical resources from what has been called the performative turn in science and technology studies, the notion of the performative experiment also draws on queer theory—particularly the work of Judith Butler.[4] Like queer enactments of gender, these art interventions exhibit the performativity of conventional science and thereby make scientific modes of knowledge production and claims available for critical inspection.[5]

Bringing forgotten twentieth-century scientific techniques into the domain of art, our experiment considered how human existence has become contingent on the use and abuse of animals in biomedical laboratories.[6] Our performance was haunted by what Joseph Dumit calls *implosion histories*—stories, accounts, and connections that were initially paralyzing because of their enormity. Dumit insists that we remain ever attentive to the riot of stories that hover around everyday objects and scenes: "Following connections is the only way to proceed, no matter how worrisome the result."[7] Rather than sticking with a clearly articulated hypothesis, we traced the contingencies of unexpected connections in multispecies worlds. Delving into the scientific literature, we found studies showing that *Xenopus* frogs, which originate from Africa, can be asymptomatic carriers of a deadly fungal disease. *Xenopus* became linked to an out-of-Africa hypothesis of disease emergence that repeated tired colonial tropes about the "diseased continent."[8] While studying how this outbreak narrative predictably stigmatized individuals, populations, locales, and lifestyles, we became determined to better understand the fungus. While humans are not harmed by this fungus, it has driven amphibians extinct as it spread around the world. As we conducted the *Xenopus* pregnancy test, to learn about our bodies and ourselves, we also used DNA test kits to search for fungal spores. Our mode of inquiry thus remained resolutely empirical, even as we explored the contours of hope and anxiety in biotechnical assemblages.

Bringing scientific tools to the art gallery, staging confrontations with complex facets of empirical reality also opened up an opportunity to imagine how the world might be otherwise. Tim Ingold has recently called on anthropologists to develop their "speculative ambitions." The task for the anthropologist, according to Ingold, is

> to open up a space for generous, open-ended, comparative yet critical inquiry into the conditions and potentials of human life. It is to join with people in their speculations about what life *might* or *could* be like, in ways nevertheless grounded in a profound understanding of what life is like in particular times and places.[9]

Departing from the discipline of anthropology, this article opens up a number of methodological questions: What sort of tactics and techniques must be added to the toolkit of multispecies studies? Rather than pretending to stand apart and aloof from our subjects of study, how might we more fully embrace the performative aspects of multispecies research practices? How might we use performative experiments to probe speculative horizons?

"There can be no science without speculation," in the words of Michael Fortun, just as "there can be no economy without hype, there can be no 'now' without a contingent, promised, spectral and speculated future."[10] Speculation in the biological sciences has linked the discovery process to commercial agendas. New findings have resulted in the production of lucrative drugs or biomedical interventions.[11] As human reproduction became technologically mediated, consumers of emergent "hope technologies," in the words of Sarah Franklin, found new possibilities for parenthood and kinship.[12] But these same liberatory reproductive technologies generated new eugenic trends in humans and produced new forms of suffering in animals. These technologies also generated mass death in ecological assemblages. Working from a position of noninnocence and complicity—inheriting histories of animal experimentation and living with ecologically destructive processes—our performative experiment explored a series of speculative questions: How do biotechnical assemblages structure human hopes? Can we share the suffering created by our hope technologies? As biotechnology and global commerce change the conditions and potentials of life, how might we bring a renewed sense of responsibility to the realm of ontological choreography?

Ontological choreography

Working at assisted reproductive technology clinics in the 1990s, Charis Cussins developed the idea of "ontological choreography" to describe "the coordinated action of many ontologically heterogeneous actors in the service of a long-range self."[13] Thompson described how different actors were "coordinated in highly staged ways" to produce parents and children.[14] This "deftly balanced coming together of things" united actors "that are generally considered parts of different ontological orders (part of nature, part of the self, part of society)."[15] If reproductive technologies now standardize the ways that humans are produced, our experiment with *Xenopus* frogs illustrated how we might choose to destandardize this production process.[16] Delving into the archives, we explored historical alternatives to choreographing the ontology of pregnancy.

The peculiar biotechnical affordances that make *Xenopus* useful in human pregnancy testing were discovered by South African researchers in the mid-1930s. If a potentially pregnant woman's urine contains human chorionic gonadotropin (HCG), a hormone that is produced by the human body after a fertilized egg attaches to the uterine wall, then an injected frog lays eggs (Figure 9.1).[17] The frog pregnancy test became part of standard medical diagnostic protocol, a hope technology for expectant mothers, which was used behind closed doors by doctors throughout the United States and Europe. *Xenopus* frogs can live up to thirty years

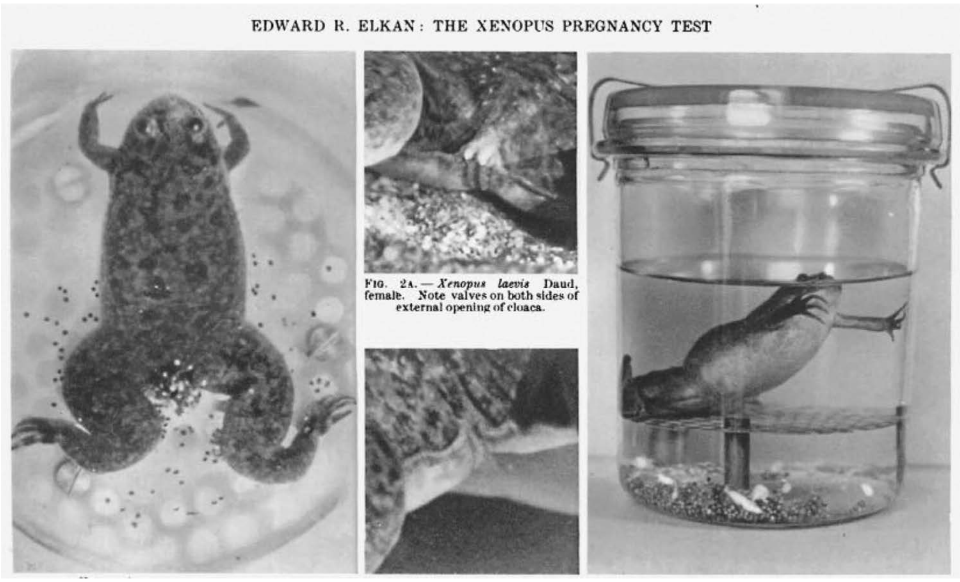


Figure 9.1 Images from a 1938 article in the *British Medical Journal* by Edward R. Elkan that helped popularize the Xenopus pregnancy test among physicians

in captivity if treated well, and each individual frog can be reused for a pregnancy test every two to three months, as soon as the female becomes gravid with eggs. In contrast to other early twentieth-century pregnancy tests, which required killing and dissecting the animals, the frogs were not permanently harmed during this bioassay.

Ontologies of human pregnancy have shifted over time, as multiple species have appeared and disappeared in distributed biotechnical assemblages. Before the *Xenopus* test, in the late 1920s, the "A-Z test" was widely used, which involved repeatedly injecting five female mice with a woman's urine over several days. The mice were killed, dissected, and then examined to see if their ovaries were enlarged. Swollen ovaries signaled a pregnancy.[18] The Friedman test substituted rabbits for the mice in the late 1920s and led to the association in popular culture of rabbit killing with pregnancy testing. *Xenopus* initially became popular because it offered faster turnaround time and better sensitivity compared with earlier animal models, enabling diagnosis of pregnancy shortly after a missed menstrual period—as early as two weeks after the implantation of the fertilized egg.[19] The fact that Xenopus did not have to be killed in order to determine the status of a pregnancy also "improved the public face of pregnancy testing beyond the laboratory."[20]

New kinds of pregnancy tests produced what Franklin calls "biological relativity" in a topsy-turvy world with an oscillating, fluctuating, and unstable sense of normality.[21] Pregnancy tests with animal models were gradually abandoned in the 1970s and 1980s as chemical tests became the norm in laboratories and later in the home. David Lynch, the director of the edgy and uncanny television series *Twin Peaks*, helped popularize the plastic pee-on-a-stick test with his 1997 television advertisement for Clearblue Easy. Lynch took the commission because it involved "the psychological torture of a beautiful young woman, a theme he has explored in other media."[22] Lynch's Clearblue Easy advertisement played with the speculative gap that emerges with pregnancy tests—capturing the agonizing suspense of waiting (in private) through a white woman's face reflected in a bathroom mirror. "When you're waiting to find out if you're pregnant or not, nothing else in the world matters until you know," the narrator of Lynch's commercial says, while a clock ticks loudly in the background and possible results flash on the screen: "yes, no, yes, no, yes, no…" Sarah Abigail Leavitt's careful exegesis of this commercial considers the intense affects that bounce around during these sixty seconds: "Though it takes only a minute, it will be the longest minute of this woman's life, for so much hangs in the balance."[23] The viewer does not learn whether the smile on the woman's face at the end of the commercial is one of relief or anticipation.

Time slowed down as we took the *Xenopus* pregnancy test out of the archives. This bioassay requires waiting much longer than the pee-stick test. Results with a frog can take as long as twenty-four hours to emerge. The *Xenopus* pregnancy test also delays the moment in a woman's cycle at which knowledge is possible. It works reliably only two or three weeks after a missed period, in contrast to a plastic pee-stick test, which can deliver a result even before an anticipated period. While using this test, we viscerally experienced the appreciable distance between the biochemistry of pregnancy and the complex, embodied, and interpersonal experience of being pregnant. *Xenopus* frogs and the pee-stick test both detect HCG. Quantitative tests of HCG, performed after blood is drawn at a doctor's office, can detect elevated hormone levels even earlier than the plastic pee-stick. The *Xenopus* test is thus slightly less sensitive than the pee-stick, which is itself less sensitive than a blood test. Therefore, the test itself—the chemical technology or animal assay—determines the temporal point in the progression of pregnancy at which a yes or no answer can be given. In other words, these pregnancy testing technologies can serve to narrow or widen a speculative gap, depending on how one chooses or happens to choreograph an ontological state.

Speculative gaps

Playing with speculative gaps, the uncertain and difficult space between the present and the imagined future, can yield unnerving results. As one of us began trying to conceive a child, the speculative ambitions of this project took a very personal turn. We experimented with possibilities of queer kinship and self-fashioning while pushing the work of participant observation into uncomfortable realms—exposing private dreams to public inspection and critique. Dreams of fostering a potential human life were harbored by one of us who was partnered in a lesbian relationship. The imagined child took shape in the couple's eyes and minds as they bought clothes and toys suitable for various stages of life—tiny shoes that she would outgrow before she could walk, a dress that would be out of style by the time she grew into it, a fierce fuchsia ski jacket that they agreed would only work for a boy. They looked around at the children of heterosexual friends and neighbors, envying the ease with which biology helped to decide for them the shape of their eyes, the color of their skin, whose relatives they resembled. Every male friend became a candidate in the category of "uncle" or bio-daddy, whose influence in the imaginary child's family constellation they would chart with quick back-of-the-envelope calculations. Men on the street were reduced to their genes. Potential sperm donors were everywhere, and nowhere, to be found.

Amid indecision, a tattooed dyke doctor told the couple "whatever you'll do, you'll regret it—so just get some sperm and get on with it!" Ultimately, the couple purchased sperm in the summer of 2012 from a commercial bank, a queer marketplace where genetic material is coded by markers of race and class. The business plans of these facilities involve adding value to raw DNA—making it better by enhancing associations with the genetic inheritability of desirable phenotypes and social traits.[24] A relentless on-slaught of choices presented themselves for queer self-fashioning. In the end, the couple chose a donor with whom neither of them shared ancestry simply because they thought he was the most beautiful. As their reproductive project proceeded, the couple embraced relations of kinship and affiliation that extended beyond their monogamous partnership.

Biological ties are often decentered in gay and lesbian notions of kinship, according to Kath Weston's book *Families We Choose* (1991), since they are based on choice and love rather than shared genetic inheritance. Likewise, multispecies families—which involve companions like birds, dogs, cats, or frogs—involve queer sensibilities because they involve relations of care and love that reach beyond fixed blood ties.[25] Power asymmetries among species, like the power asymmetries, that bind children to parents in human families, meant that Loretta had no choice but to participate in our experiment. We purchased her with a credit card from 1 to 800-*Xenopus*, the toll-free hotline for a specialty laboratory animal supply company (Figure 9.2). Still, Loretta helped illustrate a deep kinship shared by humans and frogs—a similar biochemical makeup shared across divergent evolutionary lineages, with reproductive functions triggered by shared hormones. Once viewed as primitive creatures by experimental biologists, *Xenopus* frogs were formerly thought to be unable to experience feelings of pain or fear. But recent research has led to the revision of these earlier assumptions. According to a laboratory manual published in 2010 by the Taylor and Francis Group, "*Xenopus* have all of the neuroanatomical pain pathways as seen in mammalian species, and thus, like mammals, they are capable of experiencing pain."[26]

Sharing suffering, according to Donna Haraway, involves paying attention to laboratory actors in precarious situations and "the practical and moral obligation to mitigate suffering among mortals."[27] With this in mind, we injected ourselves with saline solution before

Figure 9.2 An African clawed frog (*Xenopus laevis*) resting underwater in an aquarium at Ueno Zoo, Tokyo. Photo by Peter Galaxy. Creative Commons Attribution-Share Alike 2.5 Generic, 2.0 Generic, and 1.0 Generic license.jpg

beginning our experiment with Loretta. The injections stung a little. They felt like a tuberculosis test, where a little bit of liquid is injected under the skin. By involving our own bodies in this art project—by being on the receiving end of saline injections, and by turning a potential pregnancy into a public spectacle—our intention was not to celebrate the heroics of self-experimentation. Rather than harboring a fantasy of ending all suffering by laboratory animals, or even claiming to "feel the pain" of the individual frog in our care, our intent was to situate human modes of self-fashioning within long legacies of animal experimentation. We experienced disquiet as our own bodies were turned into art objects. Our disquiet redoubled as we imagined and speculated, across species lines, about Loretta's own subjective experiences during our experiment.

Pulling Edward R. Elkan's 1938 article out of the archives, we carefully followed his instructions during our performative experiment. We purchased our equipment—syringes and rubber gloves—from a corner drug store in New York City, no questions asked. State law mandates that anyone in New York can buy up to ten syringes a day, even without a prescription. Rather than protecting us from any infections that Loretta might have had, the gloves were to protect her from any toxic soap or detergent lingering on our skin. After we collected urine from our potentially pregnant team member in a clean cup and suctioned up the urine in a syringe, we injected Loretta. After placing her back in her tank and starting a live public webcam feed on Ustream, we went our separate ways to await the results. The prospective parents sent out an e-mail to friends and family, inviting them to become part of an expanding public witnessing the experiment:

> Dear Friends,
>
> Please join us in an extended moment of suspense: two weeks ago, X was artificially inseminated with sperm from an anonymous donor and she may be pregnant. This morning a small group of academics, artists, journalists and frog enthusiasts convened in Brooklyn to stage a historical reenactment of a pregnancy test that was developed in the 1930s. We injected one cubic centimeter of X's urine into a pet adult female *Xenopus*

> *laevis* frog named Loretta. If she is pregnant, the frog will respond to the presence of human chorionic gonadotropin (HCG) in her urine by laying its own eggs within the next 24 hours.
>
> We invite you to follow a live-streaming video of Loretta as she sits in a tank in Brooklyn. You'll see the white amphibian with distinctive little black claws doing very little. (That doesn't mean the link is broken; it just turns out that the frog doesn't do much.) If you see anything odd in the tank, please feel free to comment on the blog—or better yet, call us!
>
> We thought this would be a more interesting, communal, and differently synchronous way to think through animal labor, reproductive history, gender norms, and the many other different constellations of kinship, human and animal alike, that get formed in the process of reproducing. And it was a lot more stimulating and interactive than dropping ten bucks at our local drug store for a home pregnancy test.
>
> With anticipation, X&Y

The e-mail excerpted above initiated the transformation of a private query into a participatory public spectacle. The eighteenth-century experimental demonstrations of London's Royal Society—where, for example, birds expired within the vacuum of a glass jar—also involved staging spectacles for a live human audience.[28] If these earlier experiments were performed for a restricted public of "modest witnesses," white adult males of the upper class, our own enactment of the *Xenopus* pregnancy test was open to the more democratic and unruly public space of the Internet.[29] While a restricted public gathered to witness the injection of Loretta, the public webcast circulated among an extended network—which included some of our colleagues and children, their friends, and friends of friends—some 130 people according to Ustream's viewer statistics. Our performance brought the typically private matter of conception to an experimental arena where approaches to witnessing competed with social norms for engaging with art, colleagues, roommates, friends, and strangers.

As we all followed the Ustream webcast in real time, a riot of questions emerged: Who is watching, and who may witness? How are desire and aversion informing the scene? How easy will it be to achieve consensus about the mechanical operations observed? With the e-mail imploring friends and family to "call us if you see anything," the couple was redistributing the authority to witness, bringing queer eyes to scientific territory that has historically been dominated by straight guys. The first blog post, just hours after Loretta was injected, opened up technical issues:

> OK, so we've found images of the frog eggs on Google and they are not easy to miss. Look for little tiny marble-like formations at the bottom of the tank. If you do see anything, text and let us know!! Eager eyes be on and offline all night awaiting Loretta's produce.

Others quickly chimed in:

> Is that something?
> No wait, I think that is a smudge on the screen
> "Move Loretta! See if she moves then we can tell. I wish she could hear me." "Did something just happen on the live feed?"
> "That looks like egg mass . . . " "WAAAAAAAAAAAAAAAAAAAAA!!!!!!!!!!!!!!"

At this point, the expectant couple placed a call to Grayson Earle, a new media artist who was looking after Loretta and the live video feed. They asked Grayson to "ground truth" the online observations. After taking a peek in the tank, Grayson reported that there were no eggs: "There's a little algae in there though, not sure. I'm so glad you two decided, after all, to take the traditional route to having a baby. :-)" After waiting overnight, the couple consulted with a medical doctor who advised that they take a home pregnancy test. "Once we knew we'd have to do it, we ran over to a friend's house as fast as we could to find out," the couple wrote in a blog post.

> Sadly, after peeing on three sticks, we had to accept that Loretta had been right all along. It was shocking, somehow, after such a wonderful day of waiting, and it was hard to know that we now would have to share our disappointment with so many others who'd come along for this wild ride with us. But all things considered it was quite amazing to have shared this moment of hope with everyone who turned up and tuned in to this process.

Plastic sticks can produce loneliness, isolation, and alienation—when used in a bathroom, separated from friends and family (Figure 9.3). Turning one's private life into a public spectacle certainly also involves issues and dilemmas. Pee-stick tests can also afford women much-needed freedom from scrutiny. The lesbian couple at the center of this particular performative experiment had the difficult experience of sharing their disappointment with an emergent public that had come together around a moment of hope. Even still, the results of our performative experiment include not only a negative pregnancy test but the emergence of a constellation of enduring intimacies—a breaking down of barriers that usually separate species, academic disciplines, and private/public distinctions in interpersonal and professional spheres. As the speculative space containing the couple's fragile hopes collapsed into disappointment, our performative experiment explored stories about ecological entanglements that were initially paralyzing because of their enormity. We began to investigate speculation that the *Xenopus* pregnancy test had gone wildly awry to cause the mass extinction of amphibians.

Figure 9.3 The negative pee-stick tests used by the couple after their performance of the Xenopus pregnancy test

Multispecies migrations

Drastic declines in frog populations were noticed worldwide starting in the 1970s—particularly in Australia and the Americas. Upward of 165 species of amphibians are believed to have already gone extinct. About 1,895 amphibians, more than one-third of all described frogs, salamanders, and caecilians, are formally listed as threatened or endangered.[30] Scientists described a new species of fungus in 1999, a kind of chytrid called *Batrachochytrium dendrobatidis*, and identified it as a key threatening agent responsible for frog declines. Biologists immediately began to search for a mechanism facilitating the global spread of this chytrid fungus. Ché Weldon, a South African scholar, published a peer-reviewed article in 2004 linking the *Xenopus* pregnancy test with the emergence of this deadly amphibian disease. Taking tissue samples from amphibian specimens in South African museum collections going back to 1871, Weldon found that the earliest frog testing positive for pathogenic chytrids was collected from the Western Cape in 1938, just as they were being exported from this site for use in pregnancy tests around the world. By transporting *Xenopus* around the planet, Weldon surmised, humans inadvertently helped spread a plague among frogs.[31]

Weldon's out-of-Africa hypothesis of disease emergence followed the predictable script of an outbreak narrative by stigmatizing particular locales and lifestyles as dangerous, dirty, and diseased.[32] Africa, long imagined as the "diseased continent" in popular culture, often appears in the epidemiological literature as the source for diverse maladies—like the Ebola virus and HIV/AIDS.[33] Histories of colonialism and Cold War politics have produced the idea of the Third World as an epidemiologically risky space. While popular films and fictions paint Africa as a diseased continent, dominant narratives often fail to account for the global political and economic arrangements that foster health and well-being in the so-called civilized nations and allow for the proliferation of illness in underdeveloped countries. With Weldon's out-of-Africa hypothesis, *Xenopus* frogs were stigmatized in the scientific and popular literature. The name of this creature means "strange foot" (*xeno* = strange, *pus* = foot) in Latin, and it began to feature in xenophobic outbreak narratives that wove mythic colonial tales together with the authority of science.[34] *Xenopus* was branded as the "Typhoid Mary of amphibians."[35]

Working to disrupt dominant scientific accounts and popular outbreak narratives, Eben Kirksey designed a performance art piece to think with care about how *Xenopus* is helping generate ongoing changes in distributed ecological assemblages. This piece, called "Multispecies Migrations," was part of a group exhibit at Proteus Gowanus gallery in Brooklyn probing how "movements are affecting our future on the planet, bringing crisis and calamity aplenty."[36] Living *Xenopus* frogs, purchased for $2.88 each from local pet stores, were displayed in mason jars alongside pictures of microscopic spores of the pathogenic chytrid fungus. Posting a free classified ad on *Brokelyn*, a web magazine for New York City residents, Kirksey offered to demonstrate basic laboratory skills that would enable ordinary people to conduct pregnancy tests in their own homes:

> New York City pet stores sell *Xenopus laevis* frogs for cheap. In the 20th century this frog was widely used as a pregnancy test. Unbeknownst to anyone in this era, *Xenopus* can carry a deadly frog disease, the chytrid fungus. Help us discover if *Xenopus* is spreading chytrid around New York City. Please visit your local pet shop and buy a frog! Sold under the common names of "Underwater Frog", or "African Clawed Frog", baby *Xenopus* are available for just a few dollars in stores in all five boroughs. Choose the color you'd like— white albinos and speckled brown frogs are both available. Write down the phone

> number and address of your local store and bring a frog along to the Proteus Gowanus gallery. We'll test to see if your frog has the fungus, and show you how to treat your new friend if it is a carrier. We'll also show you how to do the frog pregnancy test in the comfort of your own home. This crowd sourced research project will be part of an academic study. All participants are potential coauthors of a paper that will be submitted for publication.[37]

This artwork, in part, had a didactic intent: the gallery performance explored speculation about the technological and ecological assemblages that were resulting in the extinction of amphibians. Using DNA test kits from the Amphibian Disease Laboratory at the San Diego Zoo, we also checked the microbiomes of all the frogs—a total of twenty-one animals, including Loretta—for pathogenic chytrid fungi. We used the DNA test kits to test outbreak narratives orbiting around *Xenopus* frogs. None of the frogs in our crowd-sourced fungal survey tested positive for chytrid spores. All of the frogs collected from New York City pet stores and the 1–800-*Xenopus* hotline were free of this pathogenic fungus. This performative experiment in Proteus Gowanus thus added a new twist to the entangled tale of frogs and their chytrid companions.

The empirical evidence from this experiment helped destabilize the story about an outbreak from the "diseased continent" facilitated by a pregnancy test gone awry.[38] Biological scientists have since argued against Weldon's hypothesis with their own evidence. For example, one team found the deadly chytrids on the skin of a Japanese giant salamander collected as a museum specimen in 1902, much earlier than Weldon's specimens from South Africa. Widespread and low-level infection patterns in Asia suggest that this chytrid species has been there for a long time, which would confound the out-of-Africa scenario. Genome sequencing data, from a study published in March 2013, reveal much genetic variability and ontological indeterminacy within different chytrid strains. One strain of these dynamic microbes, the global pandemic lineage, is highly pathogenic and has been killing frogs in Europe, Africa, Latin America, and the United States. Other chytrid strains are relatively benign and restricted to particular locales—one is isolated in Brazil, another is restricted to southern Africa and Spain, while another is found only in Switzerland. This study of pathogenic chytrid genomes reports that "it is premature to conclude a geographic location for the origin of *Batrachochytrium dendrobatidis*."[39]

While Weldon's hypothesis was wrong in some of the details and was shot through with tired colonial narrative tropes, perhaps, he was on the right track with his speculative ambitions. By noting the possibility that a twentieth-century biotechnology scheme might have gone wildly awry, Weldon helped focus attention on how the life sciences are inadvertently contributing to ecological problems. Promiscuous liaisons in marketplaces for biomaterials and live foodstuffs, involving the mixing and mingling of cosmopolitan animals from diverse corners of the globe, have likely become places that have generated new deadly kinds of chytrids. Global capitalism has intensified the speed of chytrid spread. Specialty food markets—involving the global trade of live bull-frogs (*Rana catesbeiana*) for frog legs as well as Louisiana crayfish (*Procambarus clarkii*)—are constantly whisking chytrids around the world.[40] The global pandemic lineage likely emerged as a result of human commerce.[41] Researchers "predict the evolution of further hypervirulent fungal lineages across a diverse range of host species and biomes in the absence of tighter biosecurity."[42]

The velocity of the biomaterials marketplace and the vested interests promoting the global circulation of chytrids along with multiple species of live animals are paralyzing. We find it difficult to imagine a plausible future when government regulations will definitively bring the tighter biosecurity needed to stop the spread of pathogenic fungi.[43] By reenacting the *Xenopus* pregnancy test, we situated ourselves within worrisome histories, producing a confrontation with surprising, intolerable, and unbearable consequences of contemporary political and economic arrangements. As power continues to function predictably, perhaps, it is time to scale up the scope of our imaginings while engaging in concrete practices of care in multispecies worlds.

Conclusion

Science fictions and speculative fabulations, as Haraway has eloquently demonstrated, can engender the capacity to care for "critters of technoculture" rather than just "point toward future utopia or dystopia."[44] Even though the deadly chytrid fungus did not originate from Africa, and the frogs in our own study were fungus-free, *Xenopus* can still harbor asymptomatic fungal infections. This fact led some national and state governments to propose final solutions. Xenophobia led to xenocide. After finding escaped *Xenopus* frogs in Golden Gate Park, the California Department of Fish and Game initially proposed to drain the park ponds, killing the ecosystem along with the "fiendish amphibians."[45] Instead, park workers began using nets and traps baited with chicken, euthanizing some twenty-five hundred frogs with nerve poison after yanking them out of the pond.[46] Despite this eradication campaign, chytrids and wild *Xenopus* frogs continue to proliferate in California, Europe, and beyond. Escaped *Xenopus* frogs now live in unusual circumstances all around the world: drainage systems along the US–Mexico border, the canals of Holland, and underground water cisterns of Welsh castles.[47] Thinking with care about these errant critters of technoculture should avoid the perils of apocalyptic visions as well as the seduction of proposing final solutions.[48]

We live in a time when a multitude of terrifying and paralyzing stories compete for our attention. Global climate change is outpacing all attempted solutions. Capitalist enterprises that are rapidly destroying forests and wetlands in diverse corners of the globe may well be unstoppable. Social and economic inequalities—structured by pervasive racisms and legacies of colonialism—are being exacerbated in metropolitan centers of power and on the margins of the modern world system. Technologies continue to promote the reproduction of some kinds of people and certain charismatic species while pushing others toward death. These facts have led many to feelings of futility and complacency. Performative experiments, which need not be confined to the domains of biology and technology, can help address the imaginative dimensions of these problems. Staging performative ethnographic interventions in multispecies worlds, in the words of Kirksey, can help transform "feelings of futility into concrete action, cynicism into happiness and hope."[49]

Our present study used an experiment to diagnose problems—related to changes in ecological dynamics in distributed assemblages, animal experimentation, and the choreography of pregnancy and queer kinship. Looking beyond this particular intervention, our research practice also offers an opportunity to speculate about how other inherited technologies might also be reconfigured with a reflexive do-it-yourself spirit.[50] Scholars working in the field of multispecies studies have the opportunity to design and implement their own future performative experiments to imagine what life mediated by technoscience *might* or *could* be like.[51] Performative experiments offer an opportunity to study elusive facets of life and multispecies contact zones with new techniques and dispositions.[52] Collaborations with experts from other fields, or even other species, can help multispecies scholars pursue a range of epistemological and political aims: sensing the world in new ways, interacting with other modes of being, and animating emergent modes of flourishing in multispecies worlds. Frontier practices of the twenty-first century are always announcing new worlds, proposing the novel as the solution to the old, figuring creation as radical invention and replacement, rushing toward a future that wobbles between ultimate salvation and destruction but has little truck with thick pasts or presents.[53] Conducing performative experiments against this backdrop might help generate responsible science fictions and speculative fabulations.

Our experiment explored the contours of hope and anxiety in personal and biopolitical worlds. We found that technology can serve to widen or narrow speculative gaps, depending on how one chooses to choreograph an ontological state. Pregnancy testing technologies come prepackaged with different speculative affordances. While promising speedy results and early detection, contemporary tests inadvertently prolong a state of indeterminacy—yes, no, yes, no—spreading out feelings of uncertainty over the course of several weeks. These tests have made it possible to detect early biochemical changes in a woman's body, making the social and psychological experience of miscarriage more common. Reproductive technologies have thus put women into a difficult social state that Barbara Katz Rothman describes as a "tentative pregnancy."[54] These technologies produce provisional, unsettled, and speculative states of being.[55] Contemporary pregnancy tests are thus just the beginning of a long period of indeterminacy, or being "a little bit pregnant."

Standardized reproductive technologies impose biopolitical norms: legions of un-born disabled children with chromosomal anomalies and neural tube problems have been eliminated from the human population by technical procedures that prompt parents to abort non-normative fetuses.[56] Reproductive technologies foster certain kinds of bodies while pushing others toward different conclusions such as termination.[57] Against the backdrop of scholarship about how technological standards produce different kinds of humans, our enactment of the *Xenopus* pregnancy test extends the rights of reproductive choice beyond women's bodies. Women now have the opportunity to choose among distinct biotechnical assemblages with distinct ontological and ethical affordances. By choosing the *Xenopus* pregnancy test, women can opt to minimize the uncertain and indeterminate state of the tentative pregnancy.[58] Choice, however, can be as much an ethical burden as an opportunity for forms of freedom. Women can choose to come face-to-face with animal laborers, to learn how to care for living diagnostic technologies, and to experiment with modes of living differently within multispecies assemblages.[59]

The *Xenopus* pregnancy test can be enacted responsibly only when one uses frogs that are certifiably fungus-free. Even if these frogs are not involved in an out-of-Africa story of disease emergence, they can still be asymptomatic carriers of pathogenic chytrids—reservoirs of microbes with the potential to kill other species of frogs. DNA testing technologies that can detect pathogenic chytrids are relatively cheap and can be purchased online from Pisces Molecular.[60] Infected frogs can be easily treated with a diluted solution of over-the-counter antifungal cream.

The *Xenopus* pregnancy test illustrates how humans have become fundamentally "prosthetic creatures" with an ontology that has "coevolved with various forms of technicity and materiality, forms that are radically 'not-human' and yet have nevertheless made the human what it is."[61] The animal familiars who make us what we are, the companion species that have helped stabilize our bodies and ourselves, inherit complex entanglements.[62] Taking the *Xenopus* test out of the medical archives and reanimating it in the present offer an opportunity to learn new technical skills—to acquire knowledge of unfamiliar bodies and epidemiological networks that might allow for more responsible modes of living with others in multispecies worlds.

Acknowledgments

Tammy Pittman of Proteus Gowanus gallery and Krista Dragomer opened up a generative space for experimenting with ideas in formation. Grayson Earle offered tactical support in the Treehaus when our intervention proved too controversial for the art world. Michael Khadavi, formerly the director of the Amphibian Steward Network at Tree Walkers International, helped us with the crowd-sourced fungal survey. The *Cultural Anthropology* editorial collective—namely, Cymene Howe, Dominic Boyer, and James Faubion—offered up generative feedback on an earlier draft of this essay. Leigh Claire La Berge participated in the critical conception of this performative experiment in more ways than one and provided substantial feedback on its transformation from an event into a paper. Above all, we thank Loretta, and a multitude of chytrids, for playing a role in our performative intervention. The authors were able to meet to draft and revise the manuscript as a result of travel and fellowship grants provided by the Thomas A. Barron endowment to Princeton University and the Australian Research Council (DE140100918).

Notes

1 Between 1998 and 2009, the number of published studies using *Xenopus* in PubMed, the US National Library of Medicine's definitive database of biomedical research, increased fivefold. Green, *Laboratory* Xenopus.
2 Wolfe, *What Is Posthumanism*?; Haraway, *Modest_Witness@Second_Millennium*; Haraway, "Manifesto for Cyborgs."
3 Hannah, "Performative Experiments."
4 Crease, *Play of Nature*; Butler, *Gender Trouble*; Pickering, "After Representation."
5 Hannah, "Performative Experiments."
6 Dumit, "Writing the Implosion"; Kirksey, Costelloe-Kuehn, and Sagan, "Life in the Age of Biotechnology."
7 Dumit, "Writing the Implosion," 349.
8 Wald, *Contagious*, 235.
9 Ingold, *Making*, 4.
10 Fortun, "Mediated Speculations," 146.
11 Sunder-Rajan, *Biocapital*; Haraway, *Modest_Witness@Second_Millennium*.
12 Franklin, *Biological Relatives*, 258.
13 Cussins, "Ontological Choreography," 600.
14 Thompson, *Making Parents*, 8.
15 Cussins, "Ontological Choreography," 600.
16 Rapp, *Testing Women*, *Testing the Fetus*; Franklin, *Biological Relatives*.
17 Elkan, "*Xenopus* Pregnancy Test."
18 Kelley, "Aschheim-Zondek Test for Pregnancy."
19 Elkan, "*Xenopus* Pregnancy Test."
20 Olszynko-Gryn, "Pregnancy Testing in Britain," 2–3.
21 Franklin, *Biological Relatives*.
22 Reproductive themes and sexual undercurrents were also prominent in Lynch's early work—such as *Eraserhead*, a 1977 cult classic that features images of flying sperm creatures and monstrous infants.
23 Leavitt, "Private Little Revolution," 333.
24 Moore, *Sperm Counts*.
25 Kirksey, *Emergent Ecologies*, 135–36.
26 Green, *Laboratory* Xenopus, 110.
27 Haraway, *When Species Meet*, 70.
28 Shapin and Schaffer, *Leviathan and the Air-Pump*.
29 Haraway, *Modest_Witness@Second_Millennium*.
30 "Frightening Statistics," Amphibian Ark, www.amphibianark.org/the-crisis/frightening-statistics/ (accessed September 14, 2004).

31 Weldon et al., "Origin of the Amphibian Chytrid Fungus."
32 Wald, *Contagious*.
33 The familiar phrase "there is always something new coming out of Africa" originated in Greece no later than the fourth-century BC. Whereas *something new* meant strange hybrid animals to Aristotle, twentieth-century writers and filmmakers began using the phrase with a sense of admiration. Feinberg and Solodow, "Out of Africa," 255.
34 Wald, *Contagious*.
35 Lisa Brenner Katz, "An Animal Once Used as a Pregnancy Test May Be 'the Typhoid Mary of the Frog World,'" May 16, 2013, www.scpr.org/blogs/news/2013/05/16/13693/an-animal-once-used-as-a-pregnancy-test-may-be-the/ (accessed January 14, 2016).
36 "Migrations," *Multispecies Salon*, www.multispecies-salon.org/migrations/ (accessed January 14, 2016).
37 The ad was posted on brokelyn.com/, July 15–August 15, 2012.
38 Wald, *Contagious*, 235.
39 Rosenblum et al., "Complex History," 9385.
40 Schloegel et al., "Novel, Panzootic, and Hybrid Genotypes"; McMahon et al., "Chytrid Fungus *Batrachochytrium dendrobatidis*."
41 Rosenblum et al., "Complex History."
42 Farrer et al., "Multiple Emergences," 18732.
43 Ibid.
44 Haraway, "Speculative Fabulations," 248–49.
45 Matier and Ross, "Killer Frogs of Lily Pond."
46 Ibid.
47 Tinsley and McCoid, "Feral Populations of *Xenopus* outside Africa."
48 Haraway, *Modest_Witness@Second_Millennium*; Haraway, "Speculative Fabulations."
49 Kirksey, *Emergent Ecologies*, 219. See also "Desert," *Anarchist Library*, theanarchistlibrary.org/library/anonymous-desert (accessed September 19, 2014).
50 da Costa and Philip, *Tactical Biopolitics*.
51 Ingold, *Making*.
52 Hodgetts and Lorimer, "Methodologies for Animals' Geographies."
53 Haraway, "Speculative Fabulations."
54 Rothman, "Tentative Pregnancy."
55 Ibid.
56 Rapp, *Testing Women, Testing the Fetus*.
57 Casper and Moore, *Missing Bodies*.
58 Rothman, "Tentative Pregnancy."
59 Haraway, *When Species Meet*.
60 Pisces Molecular, LLC, www.pisces-molecular.com (accessed January 14, 2016).
61 Wolfe, *What Is Posthumanism?*, xxv.
62 Haraway, *When Species Meet*.

References

Butler, Judith. *Gender Trouble: Feminism and the Subversion of Identity*. New York: Routledge, 1990.

Casper, Monica J., and Lisa Jean Moore. *Missing Bodies: The Politics of Visibility*. New York: New York University Press, 2009.

Crease, Robert P. *The Play of Nature: Experimentation as Performance*. Bloomington: Indiana University Press, 1993.

Cussins, Charis. "Ontological Choreography: Agency through Objectification in Infertility Clinics." *Social Studies of Science* 26, no. 3 (1996): 575–610.

da Costa, Beatriz, and Kavita Philip. *Tactical Biopolitics: Art, Activism, and Technoscience*. Cambridge, MA: MIT Press, 2008.

Dumit, Joseph. "Writing the Implosion: Teaching the World One Thing at a Time." *Cultural Anthropology* 29, no. 2 (2014): 344–62.

Elkan, Edward R. "The *Xenopus* Pregnancy Test." *British Medical Journal* 2, no. 4067 (1938): 1253.

Farrer, Rhys A., Lucy A. Weinert, Jon Bielby, Trenton W. J. Garner, Francois Balloux, Frances Clare, and Jaime Bosch. "Multiple Emergences of Genetically Diverse Amphibian-Infecting Chytrids

Include a Globalized Hypervirulent Recombinant Lineage." *Proceedings of the National Academy of Sciences of the United States of America* 108, no. 46 (2011): 18732–36.

Feinberg, Harvey M., and Joseph B. Solodow. "Out of Africa." *Journal of African History*, no. 43 (2002): 255–61.

Fortun, Michael. "Mediated Speculations in the Genomics Futures Markets." *New Genetics and Society* 20, no. 2 (2001): 139–56.

Franklin, Sarah. *Biological Relatives: IVF, Stem Cells, and the Future of Kinship*. Durham, NC: Duke University Press, 2013.

Green, Sherril L. *The Laboratory* Xenopus *sp.* Boca Raton, FL: CRC Press, 2010.

Hannah, Dehlia. "Performative Experiments: Case Studies in the Philosophy of Art, Science, and Technology." PhD diss., Columbia University, 2013.

Haraway, Donna. "A Manifesto for Cyborgs: Science, Technology, and Socialist Feminism in the 1980s." *Australian Feminist Studies* 2, no. 4 (1987): 1–42.

Haraway, Donna. *Modest_Witness@Second_Millennium. FemaleMan_Meets_OncoMouse: Feminism and Technoscience*. New York: Routledge, 1997.

Haraway, Donna. *When Species Meet*. Minneapolis: University of Minnesota Press, 2008.

Haraway, Donna. "Speculative Fabulations for Technoculture's Generations: Taking Care of Unexpected Country." In *The Multispecies Salon*, edited by Eben Kirksey, 242–61. Durham, NC: Duke University Press, 2014.

Hodgetts, Timothy, and Jamie Lorimer. "Methodologies for Animals' Geographies: Cultures, Communication, and Genomics." *Cultural Geographies* 22, no. 2 (2014): 285–95.

Ingold, Tim. *Making: Anthropology, Archaeology, Art, and Architecture*. London: Routledge, 2013.

Kelley, Kristin. "The Aschheim-Zondek Test for Pregnancy." *Embryo Project Encyclopedia*, September 25, 2013. embryo.asu.edu/handle/10776/2078.

Kirksey, Eben, Brandon Costelloe-Kuehn, and Dorion Sagan. "Life in the Age of Biotechnology." In *The Multispecies Salon*, edited by Eben Kirksey, 185–220. Durham, NC: Duke University Press, 2014.

Kirksey, Eben. *Emergent Ecologies*. Durham, NC: Duke University Press, 2015.

Leavitt, Sarah Abigail. "A Private Little Revolution: The Home Pregnancy Test in American Culture." *Bulletin of the History of Medicine* 80, no. 2 (2006): 317–45.

Matier, Philip, and Andrew Ross. "The Killer Frogs of Lily Pond." *SFGate*, March 12, 2007. www.sfgate.com/bayarea/matier-ross/article/THE-KILLER-FROGS-OF-LILY-POND-San-Francisco-2610411.php.

McMahon, Taegan A., Laura A. Brannelly, Matthew W. H. Chatfield, Pieter T. J. Johnson, Maxwell B. Joseph, Valerie J. McKenzie, Corinne L. Richards-Zawacki, Matthew D. Venesky, and Jason R. Rohr. "Chytrid Fungus *Batrachochytrium dendrobatidis* Has Nonamphibian Hosts and Releases Chemicals That Cause Pathology in the Absence of Infection." *Proceedings of the National Academy of Sciences of the United States of America* 110, no. 1 (2013): 210–15.

Moore, Lisa Jean. *Sperm Counts: Overcome by Man's Most Precious Fluid*. New York: New York University Press, 2007.

Olszynko-Gryn, Jesse. "Pregnancy Testing in Britain, c. 1900–67: Laboratories, Animals, and Demand from Doctors, Patients, and Consumers." PhD diss., Cambridge University, 2014.

Pickering, Andy. "After Representation: Science Studies in the Performative Idiom." *PSA: Proceedings of the Biennial Meeting of the Philosophy of Science Association* 1994, no. 2 (1994): 413–19.

Rapp, Rayna. *Testing Women, Testing the Fetus: The Social Impact of Amniocentesis in America*. New York: Routledge, 1999.

Rosenblum, Erica Bree, Timothy Y. James, Kelly R. Zamudio, Thomas J. Poorten, Dan Ilut, David Rodriguez, and Jonathan M. Eastman. "Complex History of the Amphibian-Killing Chytrid Fungus Revealed with Genome Resequencing Data." *Proceedings of the National Academy of Sciences of the United States of America* 110, no. 23 (2013): 9385–90.

Rothman, Barbara Katz. "The Tentative Pregnancy: Prenatal Diagnosis and the Future of Motherhood." *Birth* 14, no. 1 (1986): 52–53.

Schloegel, Lisa M., Luis F. Toledo, Joyce E. Longcore, Sasha E. Greenspan, Conrado A. Vieira, Maria Lee, Serena Zhao, Catherine Wangen, Claudia M. Ferreira, Marcio Hipolito, Angela J. Davies, Christina A. Cuomo, Peter Daszak, and Timothy Y. James. "Novel, Panzootic, and Hybrid Genotypes of Amphibian Chytridiomycosis Associated with the Bullfrog Trade." *Molecular Ecology* 21, no. 21 (2012): 5162–77.

Shapin, Steven, and Simon Schaffer. *Leviathan and the Air-Pump.* Princeton, NJ: Princeton University Press, 1985.

Sunder-Rajan, Kaushik. *Biocapital: The Constitution of Postgenomic Life*. Durham, NC: Duke University Press, 2006.

Thompson, Charis. *Making Parents: The Ontological Choreography of Reproductive Technologies.* Cambridge, MA: MIT Press, 2005.

Tinsley, R. C., and M. J. McCoid. "Feral Populations of *Xenopus* Outside Africa." In *The Biology of* Xenopus, edited by R. C. Tinsley and H. R. Kobel, 143–76. Oxford: Oxford University Press, 1996.

Wald, Priscilla. *Contagious: Cultures, Carriers, and the Outbreak Narrative*. Durham, NC: Duke University Press, 2008.

Weldon, Ché, Louis H. Du Preez, Alex D. Hyatt, Reinhold Muller, and Rick Speare. "Origin of the Amphibian Chytrid Fungus." *Emerging Infectious Diseases* 10, no. 12 (2004): 2100–05.

Weston, Kath. *Families We Choose: Lesbians, Gays, Kinship.* New York: Columbia University Press, 1991.

Wolfe, Cary. *What Is Posthumanism?* Minneapolis: University of Minnesota Press, 2010.

Section 3
Methods and modes

Megan K. Halpern

In a field that includes historians and philosophers, social scientists and scientists, and sculptors and performers, can there be common ground in the way we work? Without that common ground, can we have a unified understanding of our work? If our methodologies range from art practice to social science to laboratory experiments, what unifies our field? This section asks what it means for art, science, and technology studies to have its own methods and methodologies. The chapters that follow include discussions of literary analysis, art practices as forms of inquiry, art practices as scholarly work, and methods for infusing Science and Technology Studies (STS) theory into design practice. These chapters, along with the range of methodologies employed throughout this handbook and broadly within Art, Science, and Technology Studies (ASTS) and its adjacent fields, have several things in common. First, they have what all methods must have: a diligence and attention to their own internal logics. This does not mean they adhere to a particular, universal standard of logic, but to the internal rules and practices that ensure the qualities the method demands. Second, these multiple ways of doing ASTS align with the multiple ways of knowing we embrace within ASTS. That is to say, they take symmetry as a starting point.

In many ways, all of the chapters in this handbook could be considered methods chapters, so it comes as no surprise that this section is overflowing with thoughtful discussions about how to – how to practice art–science, how to teach art–science, how to study art–science. The authors come from varied backgrounds; these scholars cross disciplinary boundaries from information science, STS, communication, and design, and they have backgrounds in the literature, theater, computer science, and visual art. They were selected for their range and for the specific ways they articulate their methodologies. Though they range widely in style and topic, the chapters themselves all help advance the way we *do* ASTS. Some, like Jennifer Leiberman's chapter (Chapter 12) on interpretive flexibility in American literature, draw on the arts better understand STS, while others, like Regula Valérie Burri's chapter (Chapter 10) on ArtLAB, focus on methods to think and work across art/science boundaries.

Of course, there are internal tensions between different methodologies and debates about methodologies to be had among ASTS scholars, but because the field is nascent, the points of friction may not yet have revealed themselves. Perhaps these chapters can open discussions that begin to unpack, for example, how art practice as research is disseminated and how it can

DOI: 10.4324/9780429437069-13

be valued within multiple institutions. As the field develops, the circle we draw around these tensions and debates demands, for example, that we value performance as a way of generating knowledge in the same way we might value ethnography as a way of generating knowledge. This section, with its brief introduction and six chapters, does not promise to codify any particular sets of methods and methodologies, but rather to introduce some possibilities and offer paths for future ASTS scholars to wander.

ASTS becomes more complicated because while performance can generate knowledge, it can also be a way to share knowledge. Where ethnographic observations may become field notes, and then manuscripts, they may also become performances, as Yelena Gluzman's chapter (Chapter 15) does. But performances can also generate knowledge that later must be written about, as Stephanie Jordan's chapter (Chapter 14) does. And this is where ASTS offers unique insights into knowledge and method more broadly. Where do we draw the line between knowledge generation and communication? How does this line get drawn? Even if particular methods can be used for both, as is the case with Gluzman's performative work, communication via artistic practice may not suffice in academia, which is why Gluzman includes the script of her performance, but also writes about the theoretical and methodological considerations that drove her to generate the script in the first place.

The first two chapters, Chapter 10, by Regula Valérie Burri, and Chapter 11, by Laura Forlano and Carla Sedini, both take up questions about research methods as pedagogy, leading to new ways of teaching art–science research and practice. Burri takes head on the question of how art practice can be a research process, by which new knowledge is generated. She draws on the experiences of students and scholars involved in artLAB, an art-as-research program introduced at HafenCity University in Hamburg, Germany. Burri's claim that "heterogenous knowledges are at play" in artLAB projects drives home not only the epistemic impulses that drive projects forward, but also the ways similar ideas must be translated and communicated differently for different audiences. She also brings into focus how explicit knowledge, tacit knowledge, and practical knowledge intermingle to generate new insights and understandings. Through these multiple knowledges, Burri shows us the ways artworks can "disclose hidden structures and create alternative realities" and that, like more traditional forms of social inquiry, they "have the potential to point to power structures and change perceptions of sociomaterial realities."

Forlano and Sedini's chapter similarly focuses on multiple projects within academic environments, but they aim to reveal the ways STS can inform and transform design pedagogy and practice. Critical making, they suggest, is a trading zone within which the rich theoretical background of STS can be brought to bear on design research and practice. They are particularly interested in how the hybrid vocabularies generated in trading zones can allow for the development of new fields of study "better suited to understanding complex, socio-technical systems in more visible and tangible ways." Through explorations of several research projects and pedagogical practices that draw on theories of the posthuman and more than human, this chapter, like Burri's, reveals the ways interactions between art or design and STS "create space for more diverse ways of expressing and creating knowledge through more visible and tangible forms of scholarship." Additionally, by using the conceptual framework of trading zones, Forlano and Sedini draw on a robust STS concept to help explain and explore how the intermingling of design (or arts) practices and STS occurs, providing examples of how to approach purposefully combining design practice with STS concerns.

While Forlano and Sedini draw STS theories into design practices, Jennifer Lieberman's chapter (Chapter 12) draws on literary analysis as a resource for understanding technology. Making sense of the social relations within which technologies are developed, evolved, and used is one of the major projects of STS, so there is a wealth of opportunity to be found in the analysis of literature as a window to the social and cultural meanings of technologies. As Lieberman notes, "literary depictions of technologies can help us uncover a range of social meanings that those items did or could have." Her use of late nineteenth- and early twentieth-century literature to investigate the STS concept of interpretive flexibility provides an illustration of how literary analysis can widen the aperture of a concept to let in so much more light. Her cases range widely, from feminist visions of community kitchens to Jack London's imaginative visions of power and electricity, to Amiri Baraka's inventive reimagining of the typewriter. Lieberman notes, "Literature invites credulity; it allows us to entertain different perspectives than our own." And through these perspectives, she invites readers to imagine alternative sociotechnical configurations involving technological systems that have long been stabilized. Such imaginings, she says, shed light on not only how such systems developed and stabilized, but also what flexibility remains in our current and future systems.

Though it might seem Lieberman is doing something quite different from Hannah Star Rogers, who, in Chapter 13, builds on what has been termed the "material turn" in STS, in the end, both chapters provide new insight into common STS areas of concern by putting them in conversation with related concerns in the arts. Rogers argues that artists are often engaged in the same kinds of arguments as STS scholars, but that those arguments are unique in their materiality. "Artists are practicing STS by material means," Rogers observes, often using the very objects and technologies their work questions and critiques. Through her experiences curating art–science exhibitions that consider biotechnology, Rogers outlines the ways these artists not only do the work of making STS claims and raising STS questions about science, but also, through their material choices, challenge the boundaries drawn around science. Rogers writes: "The artists in question share in STS's concerns: who gets to set the agenda of science and participate in its workings, how does science create and maintain its knowledge corpus and related power." Rogers raises an interesting distinction when she discusses the ways artists interact with audiences, and how their artworks might be interpreted by members of the public. Through these artworks, artists build relationships directly with exhibition visitors, who represent a much broader audience than readers of scholarly STS work. The fruits of her examination of these material methods of engagement as well as her reflection on the arguments she makes through her curatorial decisions are greater opportunities for STS scholars to embrace embodied, material methods for making their claims and for artists engaged in these boundary-breaking works to reflect on their potential role in shaping scientific practice and contributing to STS conversations.

Both Stephanie Jordan (Chapter 14) and Yelena Gluzman (Chapter 15) offer opportunities for creating and expressing knowledge through performance. Since performance is underrepresented thus far in ASTS, having two such different approaches to performance illustrates the wealth of knowledge theater and performance studies have to offer ASTS. Jordan and Gluzman's chapters offer a starting point for future performance, STS. Both of their artworks were presented in scholarly settings, and both transgressed the norms of academia to present opportunities for embodied knowing. Perhaps because both artist-authors draw deeply on feminist theory, their embodied performances are situated in feminist concerns and methods. Jordan offers an experimental, performative brunch in the midst of a bustling academic conference. Her aim is to explore radical hospitality and to welcome whatever expressions and ideas manifested themselves at the table. She draws on artistic practices to produce new STS knowledge. Like the BioArt Rogers describes in her chapter, the materiality of Jordan's project drives the arguments she makes. As she says, "Artful practice produces new relationalities, new vocabularies, and allows us to conceive of longstanding philosophies (in this case, unconditional hospitality) in their radical forms as found in the art world then apply these sensibilities to STS in generative ways." Jordan notes that the performance does not answer questions, but rather generates new intellectual connections about hospitality and infrastructure. Ultimately, the radical hospitality enacted in her performance provided a metaphor for the ways privilege reifies itself in open fora, showing that the power dynamics inherent larger social systems will reproduce themselves in new situations.

In a similar setting, but with different form and intention, Yelena Gluzman painstakingly transformed a conference talk into a participatory performance that, as Gluzman put it, "theatrically encouraged speakers to attend to this extra-ordinary experience of speaking and listening, while asking them to consider the ordinary theatricality of scholarly communication." While Jordan's performance also invited participation and reflection, it asked participants to reflect on a subject close to her research: hospitality, and on the power structures that impact and interfere with radical hospitality, Gluzman's co-performed talk turned that reflection on the way we scholars share knowledge with one another. Her project is layered with methodological considerations. She asks how STS can practice reflexivity daily through theatrical performance. Understanding the theatrical and performative nature of scholarly talks, Gluzman sought to transform the event. As she writes, she was "attempting to shift the dramaturgy of the event from a distantiated act of *scholarly communication* (reporting on phenomena elsewhere) to that of a *research encounter* (a shared attention to and analysis of a staged, unfolding and immersive phenomenon)" (italics in original). In both her analysis of the piece and the piece itself, which is printed in full in her chapter, her wide-ranging discussion of theatricality, performativity, and feminism allows her to play with the categories of creating and sharing knowledge, and to question the popular notion of reflexivity in STS. In the script, select members of the audience share the lines, **"performance both constitutes the objects of knowledge and is itself the process of knowing"** (bolded in the original, to indicate this line would be read aloud). While print cannot capture the experience of participating in the performance of her piece, it can serve as a record of the event and a catalyst for other performed reflections on how we engage with knowledge.

Taken together, these six chapters provide an indication of the depth and breadth of ways to do ASTS. Each author enters the conversation from a particular perspective; some bring STS methods into art or other fields, while others bring artistic practice into STS. But in all cases, the work transcends its original purpose. Forlano and Sedini's use of trading zones is quite apt because, while these chapters may begin by introducing some aspect of one field into another (or multiple others), they culminate with the generation of knowledge, practices, and objects that belong in many fields and speak to many audiences. Each of these chapters transcends the mundane, instrumentalist applications of art–science. They also transcend their specific topics and media, providing a view into how ASTS works to challenge conventional understandings of art, science, method, and knowledge. In this way, they set a high bar for ASTS methodologies, suggesting that as the field moves forward, not only must we value different forms of knowledge, but also the methods by which knowledge is generated must be valuable across these varied ways of knowing.

10
Doing research by means of art

Regula Valérie Burri

Introduction

Art practices can be seen as epistemic practices that assemble materials, tacit knowledge, bodies, and aesthetic judgments in experimental setups. In these spatial and temporal settings, such entities are associated, enacted, and performed in ways that follow inherent and implicit logics. From these enactments, new forms of knowledges and insights may emerge which are perceived not only in cognitive but also in sensual and often tacit ways. Art making can thus be viewed as a practice of knowledge production emerging in a research-like process. This chapter shares the understanding of art practices as ways of doing research. Building on Science and Technology Studies (STS) scholars such as Law (2004) and Lury and Wakeford (2012) who have suggested to invent new methods in order to grasp the multiple social realities, this chapter views art practices as innovative and challenging approaches to explore sociomaterial worlds.

Despite this ascribed potential of art as a mode of knowledge production, the epistemic role of art has been mostly neglected in STS. By including art historians or design theorists in their reflections, earlier STS works have explored the aesthetics in scientific practices (e.g., Jones, Galison, & Slaton 1998) or have pointed to the salient role of the studio as key site of material production (Farías & Wilkie 2016). A few scholars have pointed to existing relations between art and STS (Fischer 2003), inquired into art, science, and publics (de Ridder-Vignone 2012), and studied boundaries (Star Rogers 2012) and collaborations between scientists and artists (Gabrys & Yusoff 2012; Halpern 2012). Latour's practice experiments that took the form of exhibitions to discuss images, democracy, and modernity attracted much attention (Latour & Weibel 2002, 2005; Latour 2016). Only recently, however, the importance of the very practices of art for STS was highlighted (Salter, Burri & Dumit 2017; Sormani, Carbone & Gisler 2018; Borgdorff, Peters, & Pinch 2020).

In contrast to STS, the field of "Artistic Research," which has emerged in European art school contexts since the turn of the millennium, has been reflecting on the role of art in the research process. The next section of this chapter will briefly introduce these debates by focusing on a much-discussed key issue in this field – the definition of "artistic research". Drawing from such debates, the third section of the chapter will present a

DOI: 10.4324/9780429437069-14

research and teaching format called artLAB, in which research in sociomaterial worlds is carried out by using art approaches. A few exemplary projects that were developed in artLAB will be discussed in the fourth section. The conclusion will reflect on some of the benefits derived from including art practice in social inquiries about science, technology, and society.

Art as research

Scholars in the emerging field of Artistic Research have been intensively reflecting on the epistemological qualities of art in the past few years (Borgdorff 2010; Schwab 2013). While conventional art theory and art history have not been discussing the ways art would serve as an instrument in knowledge production, artists and scholars mainly based in European art institutions became more broadly interested in the role of art in the research process around the turn of the millennium.

The key issue addressed, and controversially discussed, in the field of Artistic Research is the definition or status of art as research. Some theorists reject to define "artistic research," pointing to the problematic aspects of structuring "what transgresses structure" (Dombois et al. 2012: 10). In their view, art is research that "opens access not to a field that can be delimited, but to the exploration of the surrounding space" (Dombois et al. 2012: 11). Art research, in this perspective, can thus not be defined, but rather expresses the individual attitude of an artist.[1] Other theorists claim that artists have always been researchers, thus considering any art practice as a genuine practice of research (e.g., Mersch & Ott 2007). In this perspective, all artists can be seen as researchers.

Yet, other scholars see art research as a practice of its own. Henk Borgdorff (2012), one of the prominent theorists in the field, outlines several criteria to understand art as a research practice:

> Art practice qualifies as research if its purpose is to expand our knowledge and understanding by conducting an original investigation in and through art objects and creative processes. Art research begins by addressing questions that are pertinent in the research context and in the art world. Researchers employ experimental and hermeneutic methods that reveal and articulate the tacit knowledge that is situated and embodied in specific artworks and artistic processes. Research processes and outcomes are documented and disseminated in an appropriate manner to the research community and the wider public.
>
> *Borgdorff (2012 [2006]: 53)*

In this statement, Borgdorff denominates four criteria that define art as a research activity: First, there is an intention to increase knowledge when using art in the research process; second, a particular research question is addressed; third, experimental and hermeneutic methods are employed to make tacit knowledge explicit; and finally, the research process and the results are documented and made available for others. If art practice meets these criteria, art can be considered as research in this perspective. "Artistic research" is considered here as a practice of its own; in other words, not all art is defined as research, but only art that takes the mentioned criteria into account.

While theorists thus represent opposed views of how to define art as research, they nevertheless share the idea that art is related to a specific kind of knowledge. Art practice includes aesthetic and tacit knowledge – it both draws on and articulates visual and implicit knowledge. Inspired by such approaches, I initiated an experimental research and teaching format called artLAB. By drawing from these debates in the field of Artistic Research, and standing in for an STS perspective, it aims to inquire into sociomaterial worlds by means of art inquiry.

artLAB – a research and teaching format

The experimental research and teaching format artLAB was established at HafenCity University Hamburg (HCU), Germany, a few years ago. HCU is a small university dedicated to the study of metropolitan cultures. Given its thematic focus and interdisciplinary orientation, it has been an ambitious and prestigious project and quite unique in the European university landscape when it was founded by the city of Hamburg during the first decade of the millennium. HCU offers degrees in a variety of design and construction disciplines such as architecture, civil engineering, urban planning, and urban design. It also has the science-oriented study programs "geodesy and geoinformatics" and "resource efficiency in architecture and planning," and a humanities-based program called "culture of the metropolis." In order to get their degrees, all HCU students are required to attend additional classes in a complementary general studies program during their studies – two at both the bachelor and the master level. This interdisciplinary general studies program offers around 20–25 seminars each semester from which students can choose their preferred ones. The program is structured into three thematic fields: science/technology/knowledge, economy/politics/society, and art/culture/media. While some of the seminars are offered by HCU staff, many courses are taught by lecturers from other academic and non-academic realms – most of them being based in the humanities and social sciences.[2]

artLAB was offered within this general studies program for the first time in fall 2012. HCU offered the institutional space in which such an experiment was made possible. Having a background in both STS and art, I was interested in elaborating a format dedicated to the exploration of the science/art nexus that should transcend the theory/practice divide. Students should not only reflect on research issues by drawing on debates in STS and Artistic Research but also carry out their own research. This ultimately means exploring if and how it was possible to do research with/through art. Assisted by Danish artist Martine Heuser, who collaborated in artLAB for several years, the first exhibition took place in the gallery *linksrechts* in Hamburg. It gathered various student artworks, ranging from photo works to video/audio installations and mixed-media sculptures.

Since this first successful exhibition, artLAB has been evolving into a format that is greatly accepted and popular among students. It has thus been held regularly every summer and winter term. In addition to reading and discussing some seminal literature, participants in artLAB are encouraged to design and conduct their own art research project that takes the above-mentioned criteria of art as a research practice formulated by Borgdorff (2012) into account. The research should have the purpose to produce knowledge, it should address a relevant question and use experimental and hermeneutic methods, and it should finally be documented and disseminated. Rather than exclusively discussing existing artworks, as art theorists and historians would do, theory thus serves as one point of reference for the production of artworks. Each semester is usually dedicated to one specific topic such as "entanglements," "displacements," "relations," and "networks." The artworks that are developed are shown in a gallery or art space at the end of each semester. They are also debated publicly when students present their works to an expert jury during the exhibition.

Heterogeneous knowledges

In such a setting, heterogeneous knowledges come into play during the entire research process. In the initial *explorative research phase*, students explore their subjects by making a broad research in both the scientific and art fields. They study scientific and art literature as well as artists working on similar subjects. In other words, it is mostly cognitive knowledge that serves as a ground for the elaboration of the more specific research questions.

The second phase of the *project realization* implies all sorts of knowledges. The art research includes experiential, tacit and embodied knowledges, aesthetic judgments, cognitive knowledges, and body technologies along with material and technical know-how. All these knowledges are drawn on and enacted in the process of conducting the research and creating an artwork.

The experience with many artLAB projects has shown that there are two modes of how students develop the research, each one drawing on specific epistemic practices. In the first mode, the results gained from a scientific research that is carried out at the beginning are translated into an artwork. Scientific insights serve here as an intermediate step, and they are visualized, interpreted, materialized, and transgressed in an artwork. The second mode of developing the art research is closer to the ways artists work since art practices are adopted from the very beginning of the research process, thus looking for insights through the material aesthetic practices right from the beginning.

In the *final phase* of the research process, students document the process through the writing of a text that includes the research question, the methods used, and the findings. In Artistic Research, such documentation is seen as an important step to address the academic audience, while an artwork mostly speaks to the art world. Although language can never replace an artwork, it helps to "get across to others what is at issue in the research" (Borgdorff 2010: 58). In a teaching context like artLAB, the documentation serves students in particular to think through their projects and reflect on both the subject and the research practice. The written texts of artLAB students are exhibited in the galleries along with the corresponding artworks, and they are also published in a booklet that is edited after each exhibition (e.g., Burri 2020).

The final phase of the research process also includes the presentation of the artworks to an expert jury. The jury consists of experts in the field of Artistic Research or experts of art who are also familiar with the academic world. Like the written documentation, the project presentation helps students to reflect on their work and articulate their practice. In both the text productions and the presentations, again mostly cognitive and explicit knowledge informs the reflections and discussions. This knowledge is often gained interactively by exchanging thoughts and arguments among experts and peers.

In the entire process of art research, heterogeneous knowledges thus come into play. Explicit knowledge, as expressed in the literature and debated in the argumentation with experts, exists along with implicit knowledge – referred to as tacit knowledge by Polanyi (1967) – and how-to knowledge. In the enactment and interplay of all these knowledges and material practices, further knowledge is produced that may enable new insights and understandings of the subject.

Learning and teaching art research

By developing such research projects by means of art, students broaden their perspectives in a variety of ways. While mostly architects and civil engineers have not been conducting any research studies prior to the artLAB experience, other students like urban planners and geoinformation scientists are well acquainted with scientific research practices. Nevertheless, the artLAB projects contribute to the practice of conducting a research study for all students. At the same time, students open up their perspective on how subjects can be studied and approached. Architects who have a good notion of the challenges that materials expose learn to explicitly reflect on their approaches, civil engineers and geoinformation scientists who are trained in precise mathematical thinking are invited to explore their creative skills, and urban planners broaden their skills by understanding aesthetic knowledge as a potential resource to draw on. The creative approaches to study research subjects also foster an understanding of inter- and transdisciplinary work modes because of the different methods applied, the particular exhibition sites, and the peer discussions among students from different disciplines. For many students, it is one of their few study projects that transgresses their conceptual work and becomes realized and materialized on site. Given the heterogeneous knowledges and creative skills implied, teaching in this context not only provides knowledge about art research but also creates a space in which such particular experiences are made possible.

The next section will inquire into the knowledge production of art research projects by discussing exemplary artworks that were developed in artLAB and by analyzing how they have produced particular insights and understandings of sociomaterial realities.

artLAB in action

The artLAB projects discussed here inquire into subjects that are at the core of STS and concern the production and social life of artifacts, as well as the emergence and existence of sociomaterial worlds that come along with unintended side effects. The presented projects were chosen based on the criteria originality and quality. The projects give an exemplary insight into artLAB works. Given their subjects, they also demonstrate a close proximity to STS research questions. They demonstrate the different knowledges that come into play in the art research process and show what can be gained from such projects.

The production and social life of artifacts

The project MORAL GAME by students Dennis Thomsen and Jonathan Davis was part of an artLAB exhibition in a temporary art room in Grindelallee, Hamburg, in July 2018. It inquired into the construction of algorithms that are used in self-driving cars. In an attempt to open the black box of the technology – which is a genuine intention of STS (Pinch & Bijker 1984; Latour & Woolgar 1986; Latour 1987) – the two students raised an old philosophical problem that has currently re-gained relevance in the fabrication of automated vehicles: How should an actor decide in case of an inevitable conflicting situation? Are two lives worth more than one? What are the ethical principles on which such decisions are based?

While philosophers for a long time have been studying this problem on mere theoretical grounds, the development of automated cars put software engineers into the situation of having to decide in a very practical way. Because the ways algorithms are programmed can decide about life and death in road traffic, engineers' problem includes the very real consequences of their decisions. When the first self-driving cars were released and tested in real-live environments, and especially after some accidents happened – including the first deadly crash in Tempe, Arizona (Wakabayashi, 2018) – the problem was not any longer considered a mere academic one but has been widely debated in the media since.

Instead of continuing these discussions on an abstract level, the artLAB project MORAL GAME assigned the exhibition visitors the role of actual decision-makers. Similar to a computer game, a screen monitor displayed a computer-animated self-driving vehicle approaching a road obstacle. This obstacle could only be avoided when crashing into a truck on the left side or passing over some children on the right side of the obstacle. When arriving at the obstacle, the screen displayed three alternating arrows: a red one pointing left, a blue one pointing right, and a yellow one pointing ahead – three different options of how to continue the game. "YOU CHOOSE," the monitor displayed. The visitor was thus invited to push either the red, the yellow, or the blue button on a panel in front of the monitor. If the left red button was pushed, the self-driving car turned left and crashed into the truck. "TRUCKDRIVER DIES !!!," the screen alerted. Pushing the blue button to the right made the car driving into the children, noting the horrible consequences: "8 KIDS DIE." Finally, if the yellow button in the middle was pressed, the vehicle would smash into the obstacle and overturn: "YOU DIE." Each decision was scored under by a computer game sound effect. After displaying the fatal consequence of each decision, a site showing the programming codes would appear during a tiny moment before the game would start anew (Figure 10.1).

This project opens the black box of the automated vehicles in various ways. By offering three options of how to decide, it points to the alternatives that are built into the algorithms. These different options of how to proceed and act go along with the imperative to make decisions – not just in the situation of playing but also when software engineers are constructing the codes. Such decisions, the artwork suggests, should not be left to software engineers but discussed more broadly in society. The ephemeral display of the software codes and the specific construction of the control panel can as well be seen as ways of opening up the technology. While the viewing of the codes pointed the visitors to the underlying algorithms that are programmed in specific ways, the control panel used in the project was not a closed element that would hide the plugboard, the cables, and all other technical components but instead revealed how all these elements were wired together – thus deciphering the constructedness of the technology.

MORAL GAME thus contributed to opening up and disclosing the technology of self-driving cars and their built-in ethical values and real-life social implications. In addition, and in contrast to discussions and written debates, it provided visitors with a hands-on, in situ experience. Rather than considering the issues from a merely intellectual point of view, the art game would draw the visitor into the situation. The visitor was challenged to take over the role of the software engineer and make decisions on which algorithms should come into

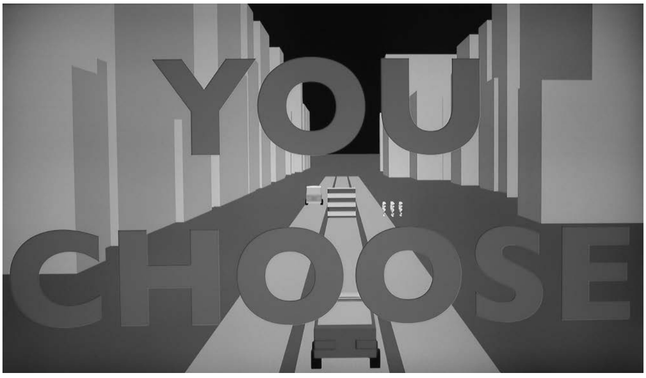


Figure 10.1 Art project MORAL GAME by Dennis Thomsen and Jonathan Davis. Photo: Regula Valérie Burri

play. This role-taking was initiated by the whole setup of the game – including the monitor displaying the videos, the control panel with its push buttons, the letters requesting "YOU CHOOSE," and finally, the game sound effects, which highlighted each decision but also contributed both to make the visitor feel like being in an actual decision situation and to encourage him or her to act. MORAL GAME was thus an immersive project that invited and seduced the visitor to participate and interact.

Another project that dealt with the production and social life of artifacts was called MATERIAL POLITICS and was carried out by student Waseem Sabbagh. It was shown in an artLAB exhibition organized in an old brick stone building that was used by artists, designers, and media people in Wartenau, Hamburg, in February 2017 (Burri 2017). This project dealt with one of the most genuine questions of STS by inquiring into the ways politics are expressed in material artifacts. In STS, this issue has been discussed by Langdon Winner in his famous article "Do Artifacts have Politics?" (1986), which pointed to the ways tangible things are intrinsically political because they embody social relations, in other words power relations.

Waseem, who is a native from Israel with an Arabian background, followed up on this question by inquiring it empirically. He was interested in the ways politics are materialized in forms of built artifacts by taking his home country as an example. Waseem's interest was also shaped by his perception that politics in Germany are rather perceived as media discourses, while in his home country, they are affecting daily life in materialized forms. Drawing from his daily experiences when traveling in his country, he observed how state politics are manifested in multiple materialized ways. In their long-term and enduring histories of conflict, Israel, Palestine, the Lebanon, and Syria have set up barriers, fences, gates, barbwires, checkpoints, control towers, and insurmountable walls. Such artifacts make an imposition on the traveler by prohibiting that a person passes wherever and whenever s/he wants.

Waseem experienced the effects of these artifacts and their politics as sometimes frustrating – not only in political terms but also in daily life because they were causing waiting times. In his art research, he documented these artifacts with his photo camera. To present the images in the exhibition, he constructed one element of a grid fence wall that was more than two meters high. The photos were attached between the front part and the back part of the fence so that visitors could look at them from each side of the element (Figure 10.2).

Figure 10.2 Art project MATERIAL POLITICS by Waseem Sabbagh. Photo: Regula Valérie Burri

Just as Winner (1986) has suggested, Waseem's work showed how artifacts embody politics. Through material objects like fences and barriers, a state confronts citizens with its territorial claims. The artifacts organize their environment and impose a social behavior. People may have to queue up to pass a barrier or take a detour to proceed more quickly. In any case, the artifacts go along with a social ordering. There is a clear assignment of who is allowed to pass and who isn't – thus ordering people into different social groups. By (re-)constructing and maintaining the boundaries between demarcated territories in material terms, the social order is simultaneously (re-)produced (Jasanoff 2004). The photos shown in the exhibition made such aspects visible by joining images of a variety of artifacts that Waseem encountered in Israel. The grid fence wall element he constructed in the exhibition could be read as symbolizing the material demarcation character of the objects that would allow no trespassing.

The project MATERIAL POLITICS contributed to raise awareness of the important role of tangible things in the ways politics affect people's lives in this region.[3] In the exhibition, the work created a situation that would allow visitors to experience the facing of a wall element. In addition to pointing to the material embodiment of politics in Israel (and elsewhere), the artwork thus provoked a different experience than a written text could have enabled. Such an experience may have changed visitor's perceptions of both artifacts and politics.

Emergence of sociomaterial worlds and their unintended side effects

Other projects explored the sociomaterial realities we live in and showed how these are closely intertwined with unwanted and problematic impacts of technologies. One of these projects titled RECORDED was developed by Bulgarian student, Elena Pfeif. It was also shown in the artLAB exhibition that took place in Grindelallee, Hamburg, in July 2018. This work explored surveillance cameras in public spaces. It inquired into the prevailing existence of such cameras and raised questions about the antagonistic relations between security and control on the one hand and privacy protection on the other hand.

Studies at the intersection of STS and surveillance and security studies have been inquiring into the widespread use of remote video surveillance cameras (Vogel et al. 2017). The role of such visual technologies in public space has also been controversially and extensively debated in the European media and among civil activists. While the city of London, as the most prominent example, has established video cameras all over the urban space, other cities have been more contained in this respect. Nevertheless, the city of Hamburg, in which the artLAB project was realized, has installed a large amount of surveillance cameras in the urban area. According to an official statement of the city government in 2015, there were at least 11,000 cameras surveilling the public space and additional 2,500 cameras in publicly inaccessible areas of administrative buildings, the airport, and jails. These were complemented by several camera dummies in administrative buildings (Grieß, 2015). In addition to these public cameras, some cameras of private shop owners and real estate holders are unintentionally filming parts of the public space, for example, when they monitor the entrance doors of warehouses.

Elena's project focused on surveillance cameras that stream their visual materials online. Such webcams do not always have the primary aim to control human actors but are also used to monitor the weather and make the data publicly accessible. Nevertheless, by doing so, individuals are often part of the scenery. They are therefore also depicted in the image, mostly without being aware that they are filmed. The cameras are often placed in unremarkable sites in inconspicuous ways and thus usually remain unnoticed.

Elena went in search of such life cams. She monitored the streamed images of cameras she could find online and located their geographical positions. On her way to a camera, she simultaneously monitored its streamed pictures online. Once she was near the camera and got into its picture, she could see how she herself appeared on the display of her smart phone that showed the camera's images. She captured that moment by taking a screen shot. Without changing her position, she then searched the camera that was recording her and took a photo of it. This work thus resulted in two shots of each camera – one of the camera's streamed pictures, and one of the camera as an artifact. In the exhibition, the pictures of ten cameras were displayed, which were chosen according to aesthetic criteria. In each photo, both Elena's and the camera's respective positions were marked by a red dot to highlight the locations of both her and the apparatus (Figure 10.3).

This project points to the existence of surveillance cameras in our daily lives. By locating and picturing the cameras, it makes visible what is normally invisible. It reminds us that we are potentially being filmed at any moment. The project can be understood as a surveillance of surveillance and a recording of what is being recorded. It turns the monitoring gaze back to the camera. It raises questions about the images taken by the camera: Who is producing such images? Why are such images taken? Who is seeing them? What are the implications of installing such cameras in public spaces? The red dots in the exhibition images, as well as the project's title RECORDED, can be read as a sign of camera recordings and a reminder that

Figure 10.3 Art project RECORDED by Elena Pfeif. Photo: © Elena Pfeif

these pictures may not just be streamed but also recorded. They are a reference to the following questions: Is the material archived and used for other purposes? What are the consequences for individuals appearing on the screen? And finally, what happens to the visual data?

Next to other artists working on such issues, these questions are also asked in STS and in surveillance and security studies. Although Elena's project raises much-debated questions and, similar to written studies, discloses the wide distribution of surveillance cameras, it adds to research by exploring the effects of life cams from within. The analytic focus is not put on the camera and its image alone, as a scientific perspective would take, but is complemented with the researcher's experience of being filmed. By showing the produced images through this mirrored gaze in the exhibition – the camera sees the researcher who sees the camera – the project offers a new perspective and allows to enwrap with the situation.

A further project that deals with the unintended side effects of sociomaterial worlds was 80 PLACES 80 OBJECTS (transl. by the author) by German student Patrick Giese. His work was part of an artLAB exhibition that took place on the Elbe river island of Wilhelmsburg, Hamburg, in June 2013 (Burri 2013). Wilhelmsburg, which then used to be a rather marginalized area, was also one of the sites of intervention of the International Building Exhibition (IBA) that ended in the same year.[4] IBA Hamburg was focusing on three thematic streams, which all were dealing with metropolitan developments in the twenty-first century: "Cosmopolis," "Metrozones," and "City in Climate Change" (IBA 2013). artLAB students were challenged to consider one of these subjects in their art research.

At the same time of the IBA, the International Garden Exhibition (IGS) was equally taking place in Wilhelmsburg. Both exhibitions had chosen this island in an attempt to raise attention on this marginalized urban area and make a dynamic impact in terms of city development. Both exhibitions opened up new spaces for action and representation, though it was also criticized that local citizens would not profit from these events in the long run. In his project, Patrick was interested in the side effects of the temporary appropriations of the new urban spaces. In particular, he was inquiring into the subject of waste that would be left by IBA and IGS visitors.

Urban waste has been problematized as a matter of concern by STS and urban studies scholars (e.g., Calafate-Faria 2016). It is also a concern for cities like Hamburg that strive for more sustainability and resource efficiency. In an attempt to exchange knowledge and coordinate efforts transnationally, several initiatives have been launched at the European level. For example, some universities, municipalities, associations, and organizations have been working together in a consortium within a EU-funded project on urban waste. It "aims to help develop strategies aimed at reducing the amount of municipal waste production as well as strategies to further develop re-use, recycling, collection and disposal of waste," thus developing "waste prevention and management strategies" (urban-waste.eu, retrieved March 18, 2021). The city of Hamburg, which was the site of research of Patrick's art research, shares the view that sustainable action is of great importance to cities (hamburg.de/nachhaltigkeit, retrieved March 18, 2021) (Figure 10.4).

The project 80 PLACES 80 OBJECTS inquired into such issues by tracking the traces people would leave when visiting the sites of IBA and IGS. Every evening at the closing time of the exhibitions, Patrick collected objects that people had left on the exhibition terrain. Taking this collection of mostly thrown away things as a material resource, he created an artwork by making a composition of the finds. The work turned out to be a globe. The project thus made an obvious reference to IGS. IGS used an official poster that showed a globe covered with gardens, and its slogan suggested "In 80 Gardens Around the World" (in German), which was alluded to in Patrick's project title 80 PLACES 80 OBJECTS. The artwork

Figure 10.4 Art project 80 PLACES 80 OBJECTS by Patrick Giese. Photo: Regula Valérie Burri

pointed to the ways IGS visitors appropriated and impacted the exhibition space. By using their waste as art materials, the globe made the behavior of the exhibition visitors visible. It demonstrated how wasteful and careless people acted by leaving their things and pointed to the environmental footprints that are produced by such traces.

While environmental impacts are well known and studied in STS and other fields, this project added a new perspective. The assembling of the wasted objects created new relations among them and, in the shape of a globe, raised the question of how we treat our world. By using tangible objects that had been left by visitors, the artwork – in contrast to written studies – did talk about the issue in a rather concrete, and not abstract, way. By implicitly saying "look, this is your waste," it showed that we all leave traces and affect the environment. In that sense, the artwork was visually persuasive (Burri 2012).

Conclusion

The works that were developed in artLAB show that art practices include heterogeneous knowledges. While cognitive knowledge plays a role in the initial research, in the presentation to the experts of the jury, as well as in the written documentation, aesthetic, sensual, and experiential knowledges come into play during the entire process of art research. Explicit, how-to knowledge and implicit knowledge are thus all involved in this process. In other words, the three classical Aristotelian types of knowledge discussed in epistemology – theoretical knowledge (propositional knowledge, i.e., knowledge about facts), practical knowledge (skills, i.e., how-to knowledge), and wisdom (acquaintance with a situation) (Borgdorff 2010: 55) – are intermingled in art practices.

In contrast to conventional scientific research, where bodies and subjectivities are eliminated in the research process (Daston & Galison 2007), art research takes embodied knowledges and subjective judgments as resources on which to draw during the entire research process. Instead of negating what cannot be negated, art practices include aesthetic and experiential knowledges in their experimental practices and setups. These knowledges are embodied and are often played out haptically and performed when working and tinkering with materials.

While all art practices draw on such knowledges, art research includes reflection on the knowledge produced through practices of art. It asks what kind of knowledge is generated by using art in the research process, assuming that the conducted research will provide new insights into the studied subject. The knowledge produced in such a process is not necessarily made explicit, although it may be described by the artist in a documentation, as Borgdorff (2012) suggested, or debated with experts and visitors. Nevertheless, this knowledge is implicitly embedded in the artworks. Art historian Gottfried Boehm (1993) called the knowledge "sunked-in" [*eingesenkt*] in the materials.[5] It is an integral part of the artwork and can be experienced by engaging oneself with it. As the artLAB projects showed, artworks offer various possibilities of such engagement, which all may contribute to new insights and understandings.

- First, artworks visualize certain phenomena, and by doing so, they disclose underlying, implicit structures. All the discussed projects, in one way or the other, made things visible, thus unraveling a variety of issues, ranging from the constructedness of algorithms in self-driving cars (project MORAL GAME) to the politics of artifacts (project MATERIAL POLITICS) and the omnipresence of both surveillance cameras (project RECORDED) and urban waste (project 80 PLACES 80 OBJECTS). By making these things visible, artworks raise questions and may increase awareness about their subjects. While STS and other social sciences reveal hidden structures by means of words, artworks may unfold them because of their "visual persuasiveness" (Burri 2012).
- Second, artworks evoke atmospheres and spaces, which may elicit particular feelings and provoke their own truths. In contrast to written work, the displaying of materials produces a multifaceted space-time that can be perceived with multiple senses. Looking at pictures of border fences while standing in front of a fence element (project MATERIAL POLITICS), for example, involves both the visual and the tactile sense and may evoke a different experience than just looking at printed photographs or reading about the barriers. For Klein (2017), such an "aesthetic sensory experience" is a specific mode of perception.
- Third, artworks, and not only those that draw on immersive technologies, invite and seduce to enwrap with a situation. The seduction may take multifaceted forms by drawing, for example, on appealing images (project RECORDED), unknown sites and irritating situations (project MATERIAL POLITICS), unexpected but known materials (project 80 PLACES 80 OBJECTS), interactivity, and sounds, but also provocation when the visitor's actions are claimed to decide about life and death (project MORAL GAME). Artworks allow embodied, hands-on, in situ experiences for both the researcher and the exhibition visitor. They are research "from within" and reveal the researcher's experience with the materials. For the artist/researcher, research "from within" allows an artistic experience. Klein (2017) called the artistic experience a mode of perception which would mean "to look at oneself from outside a frame and simultaneously enter into it." At the same time, the research "from within" also draws the visitor into the situation. The contemplator may simply feel addressed when looking at wasted materials (project 80 PLACES 80 OBJECTS) or identify with the artist/researcher depicted in the exhibited images (project RECORDED). Or the visitor is invited to participate and interact in a literal sense, for example, by a role-taking that requires to act (project MORAL GAME). The embodied experience is though most often enabled through the three-dimensionality of an artwork, thus allowing to feel like in a "real" situation, for example, facing a wall (project MATERIAL POLITICS).
- Finally, artworks intervene into the social world and create alternative realities. The engagement with an artwork or art research process encompasses an implicit or explicit

interpretation of it. Artworks assemble things in different ways and establish new relations among them, thus offering fresh perspectives, sometimes on known issues. When, for example, littered waste is recombined in a globe (project 80 PLACES 80 OBJECTS), we possibly look at our planet and our own waste practices in a more critical way. Artworks may challenge established ways of seeing and change prevailing perceptions, thus offering new insights and knowledge.

New insights are also produced in conventional scientific research. What then is the value of using art in research on science and technology? As shown in this chapter, art practices add to the more cognitive modes of knowledge production in STS. They include various knowledges and draw on aesthetic and performative approaches in the creative process. Art practices allow various forms of engagement, which include multisensory approaches of perception and interpretation. Art research has thus the potential to offer a more comprehensive understanding of the sociomaterial worlds we live in. In addition, artworks reach other and often broader audiences than written scientific work because they are shown outside narrow expert circles and accessible for the general public. They thus facilitate the inclusion of more people and wider publics in the reflection on science and technology.

Finally, art interventions can be regarded as forms of political engagement with sociomaterial worlds. As the artLAB projects have shown, they can disclose and uncover hidden structures and create alternative realities. Just like critical social inquiry, they have the potential to point to power structures and change perceptions of sociomaterial realities. Art research is thus another, complementary way of doing research. It does not replace but adds to STS research. In such a perspective, art research can be seen as a particular contribution in STS to both the understanding and shaping of technosocieties.

Notes

1 Although the field is called "Artistic Research," I prefer the notion "art research" because "artistic" has a connotation of something just pretending to be art, what has not been the intention of the theorists in art schools who have been using the term.

2 In the university's founding years after 2006, the general studies program has been larger. Bachelor students had to enroll in three courses instead of two, and the courses were assigned more credit points. The general studies program was subject of long-lasting controversies among the disciplines, all of them suffering from financial cuts.

3 An interesting STS article has investigated the use of maps in the construction of national territories in Israel, though the emphasis is put rather on the visual rhetoric than the material aspects of maps (Leuenberger & Schnell 2010).

4 IBA Hamburg described the building exhibitions as being "like laboratories set up for a limited time," which would be "among the most influential tools known to town planners" (internationale-bauausstellung-hamburg.de, retrieved March 18, 2021). The first IBA had taken place in Dortmund, Germany, in 1901. Since then, IBAs have been organized periodically in mostly German towns. While at the beginning, they took place in one single year, recent exhibitions extend over a period of several years and transgress the national boarder (open-iba.de, retrieved March 18, 2021).

5 I came across this reference when reading a text of Swiss artist Markus Schwander (2010).

References

Boehm, Gottfried (1993) Kunst als Erkenntnis. In Siegfried Mauser (ed) *Kunst verstehen, Musik verstehen: ein interdisziplinäres Symposion*. Lilienthal: Laaber-Verlag, pp.63–76.

Borgdorff, Henk (2010) The Production of Knowledge in Artistic Research. In Michael Biggs and Henrik Karlsson (eds) *The Routledge Companion to Research in the Arts*. London and New York: Routledge, pp.44–63.

Borgdorff, Henk (2012 [2006]) The Debate on Research in the Arts. In *The Conflict of the Faculties: Perspectives on Artistic Research and Academia*. Leiden: Leiden University Press, pp.28–55.

Borgdorff, Henk, Peter Peters and Trevor Pinch (eds) (2020) *Dialogues between Artistic Research and Science and Technology Studies*. London and New York: Routledge.

Burri, Regula Valérie (2012) Visual Rationalities: Towards a Sociology of Images, *Current Sociology* 60(1): 45–60.

Burri, Regula Valérie (ed) (2013) *artLAB # 02 – Arbeiten zur künstlerischen Forschung von Studierenden der HafenCity Universität Hamburg* (student works on Artistic Research). Hamburg. ISBN 978-3-941722-20-0.

Burri, Regula Valérie (ed) (2017) *artLAB # 08 – Arbeiten zur künstlerischen Forschung von Studierenden der HafenCity Universität Hamburg* (student works on Artistic Research). Hamburg. ISBN 978-3-941722-60-6.

Burri, Regula Valérie (ed) (2020) *artLAB # 14 – Arbeiten zur künstlerischen Forschung von Studierenden der HafenCity Universität Hamburg* (student works on Artistic Research). Hamburg. ISBN 978-3-947972-11-1.

Calafate-Faria, Francisco (2016) Marginal Attachment and *Countercycling* in the Age of Recycling. In Michele Lancione (ed) *Rethinking Life at the Margins: The Assemblage of Contexts, Subjects, and Politics*. London and New York: Routledge, pp.153–168.

Daston, Lorraine and Peter Galison (2007) *Objectivity*. New York: Zone Books.

de Ridder-Vignone, Kathryn (2012) Public Engagement and the Art of Nanotechnology, *Leonardo* 45(5): 433–438.

Dombois, Florian, Ute Meta Bauer, Claudia Mareis and Michael Schwab (eds) (2012) *Intellectual Birdhouse: Artistic Practice as Research*. London: Koenig Books.

Farías, Ignacio and Alex Wilkie (eds) (2016) *Studio Studies: Operations, Topologies, and Displacements*. London and New York: Routledge.

Fischer, Michael M. J. (2003) *Emergent Forms of Life and the Anthropological Voice*. Durham, NC: Duke University Press.

Gabrys, Jennifer and Kathryn Yusoff (2012) Arts, Sciences and Climate Change: Practices and Politics at the Threshold, *Science as Culture* 21(1): 1–24.

Grieß, Andreas (2015) Videoüberwachung: Hamburgs dunkle Augen. *Zeit Online* (September 30, 2015).

Halpern, Megan K (2012) Across the Great Divide: Boundaries and Boundary Objects in Art and Science, *Public Understanding of Science* 21(8): 922–937.

IBA (2013) *IBA Hamburg International Building Exhibition: Building the City Anew*. November 2013. IBA Hamburg. Retrieved from https://www.iba-hamburg.de/files/downloads/Presse/Infomaterial/Intern-Bauausstellung/131126_IBA_Hamburg_Basic-Information.pdf (March 18, 2021).

Jasanoff, Sheila (ed) (2004) *States of Knowledge: The Co-Production of Science and Social Order*. London and New York: Routledge.

Jones, Caroline A., Peter L. Galison and Amy E. Slaton (eds) (1998) *Picturing Science, Producing Art*. New York: Routledge.

Klein, Julian (2017) What Is Artistic Research? *Journal for Artistic Research* (published in section network, reflections, jar-online.net, April 23, 2017).

Latour, Bruno (1987) *Science in Action: How to Follow Scientists and Engineers through Society*. Cambridge, MA: Harvard University Press.

Latour, Bruno (ed) (2016) *Reset Modernity!* Cambridge, MA: MIT Press.

Latour, Bruno and Steve Woolgar (1986 [1979]) *Laboratory Life: The Construction of Scientific Facts*. Princeton, NJ: Princeton University Press.

Latour, Bruno and Peter Weibel (eds) (2002) *ICONOCLASH: Beyond the Image Wars in Science, Religion, and Art*. Cambridge, MA: MIT Press.

Latour, Bruno and Peter Weibel (eds) (2005) *Making Things Public: Atmospheres of Democracy*. Cambridge, MA: MIT Press.

Law, John (2004) *After Method: Mess in Social Science Research*. London and New York: Routledge.

Leuenberger, Christine and Izhak Schnell (2010) The Politics of Maps: Constructing National Territories in Israel, *Social Studies of Science* 40(6): 803–842.

Lury, Celia and Nina Wakeford (eds) (2012) *Inventive Methods: The Happening of the Social*. London and New York: Routledge.

Mersch, Dieter and Michaela Ott (2007) Tektonische Verschiebungen zwischen Kunst und Wissenschaft. In Dieter Mersch and Michaela Ott (eds) *Kunst und Wissenschaft*. München: Wilhelm Fink Verlag, pp.9–31.

Pinch, Trevor J. and Wiebe E. Bijker (1984) The Social Construction of Facts and Artefacts: Or How the Sociology of Science and the Sociology of Technology Might Benefit Each Other, *Social Studies of Science* 14(3): 399–441.

Polanyi, Michael (1967) *The Tacit Dimension*. London: Routledge & Kegan Paul.

Salter, Chris, Regula Valérie Burri and Joseph Dumit (2017) Art, Design, and Performance. In Ulrike Felt, Rayvon Fouché, Clark A. Miller and Laurel Smith-Doerr (eds) *The Handbook of Science and Technology Studies*. 4th edition. Cambridge, MA: MIT Press, pp.139–167.

Schwab, Michael (ed) (2013) *Experimental Systems: Future Knowledge in Artistic Research*. Leuven: Leuven University Press.

Schwander, Markus (2010) *Erkenntnis einsenken. Untersuchungen über Methoden künstlerischer Forschung.* Basel: FHNW – Hochschule für Gestaltung und Kunst.

Sormani, Philippe, Guelfo Carbone and Priska Gisler (eds) (2018) *Practicing Art/Science: Experiments in an Emerging Field*. London and New York: Routledge.

Star Rogers, Hannah (2012) *Practices of Art and Science.* Dissertation Cornell University, Ithaca, NY.

Vogel, Kathlen M., Brian Balmer, Sam Weiss Evans, Inga Kroener, Miwao Matsumoto, and Brian Rappert (2017) Knowledge and Security. In Ulrike Felt, Rayvon Fouché, Clark A. Miller and Laurel Smith-Doerr (eds) *The Handbook of Science and Technology Studies*. 4th edition. Cambridge, MA: MIT Press, pp.973–1002.

Wakabayashi, Daisuke (2018) Self-Driving Uber Car Kills Pedestrian in Arizona, Where Robots Roam. *The New York Times* (March 19, 2018).

Winner, Langdon (1986 [1980]) Do Artifacts Have Politics? In *The Whale and the Reactor. A Search for Limits in the Age of High Technology.* Chicago, IL: University of Chicago Press, pp.19–39.

11

More than human trading zones in design research and pedagogy

Laura Forlano and Carla Sedini

How might rich, critical and nuanced concepts from Science and Technology Studies (STS) be integrated into art and design practice? Conversely, how might methodologies from art and design practice be introduced into STS? What hybrid languages, images and objects might populate these porous boundaries between these fields? Who thrives at the margins (Rosner, 2018) making lives and livelihood in regions that are not well understood? Will these spaces continue to be reconfigured, re-populated and reimagined as sites of experimentation or will they ultimately break down and fade away? This chapter argues for continuing the difficult work at the crossroads of STS and design.

Since the establishment of the Bauhaus school of design in 1919, designers have been advocating for the unity of art and technology (Gropius, 1919). This chapter is concerned with the trading zones[1] (Galison, 2010) or interdisciplinary spaces of critical making (Ratto, 2011) that are currently emerging between STS and art and design practice. We argue that trading zones between STS and design allow for the development of hybrid vocabularies that can support the emergence of new disciplines and fields of study that are better suited to understanding complex socio-technical systems in more visual and tangible ways. In particular, in this chapter, we are particularly interested in trading zones around theories of the posthuman and the more than human.

The exciting trading zones – defined as "locations in which communities with a deep problem of communication manage to communicate" (Gorman, 2010) – that are emerging at the intersection of STS and art and design practices have given rise to new subdisciplines such as design anthropology (Gunn, Otto, & Smith, 2013; Smith et al., 2016), visual sociology and the digital humanities (Sayers, 2018). Drawing on Galison's original definition of trading zones, we emphasize that STS and design are not rigidly separated disciplines with strict delineations but, rather, fields and practices with many fuzzy and blurry boundaries. In order to facilitate activity within a trading zone, Galison argues that we need interlanguages and "in between" vocabularies such as jargon (simple), pidgin (more complex) and creole (new languages) (Gorman, 2010). An example of a successful creole might be the development of a new field or discipline such as biochemistry, which brings together biology and chemistry.[2] At the cross-section between STS and design, there are signs that we are already on our way to creating such creole knowledges and practices.

 DOI: 10.4324/9780429437069-15

STS has traced how new instruments of vision have allowed for the emergence of new forms of knowledge. Here, we draw on Puig de la Bellacasa's notion of *touching visions* in order to illustrate the ways in which visual and tactile engagements with socio-technical imaginaries can be mobilized to explore alternative possible futures drawing on theories of the posthuman (Braidotti, 2013; Puig de la Bellacasa, 2017). This chapter describes two research projects – The Driverless City and Made in Chicago/Made in Milan – as well as a set of design pedagogy exercises that were generated through the work of the Critical Futures Lab,[3] a research laboratory at the Institute of Design at Illinois Institute of Technology. Specifically, we argue that by working with STS theories in multiple formats and media – from narratives, stories and films to objects, prototypes, visualizations and images – it is possible to create hybrid vocabularies, representations and things that trouble (Haraway, 2016) traditional binary categories. These speculative hybrids draw on both *visual* and *tactile* media to go beyond the trappings of linguistic boundaries, allowing for the exploration of multiple forms of subjectivity, emergent forms of knowledge, alternative possibilities for the economy and the creation of other kinds of worlds.

Trading STS theory into art and design practice

Overall, the fields of art and design are oriented towards the craft, processes and methods associated with their diverse approaches, media and subdisciplines. For example, art might be practised through drawing, painting, sculpture, ceramics, photography or film. And, design might be practised through graphic design, product or industrial design, interaction design, service design, design strategy or systems design. However, the subjects and topics that one might engage in as an artist or designer are diverse, requiring deep research and investigation. Theories, concepts and topics from STS have great potential to support the creation of rich, nuanced, critical art and design practices. This is because STS scholars conduct in-depth, long-term investigations about topics, which can be mobilized in the field of design where short but generative projects are quite common.

The field of design, specifically, human-centred design (HCD), has been broadly criticized for its overwhelming focus on the universal, discrete, individual subject and their needs in order to create solutions to problems. Currently, the efficient optimization of the productive individual as well as the optimization of things and spaces that support hyper-individualization is driving many design and engineering decisions. This techno-utopian solutionism (and the related socio-technical imaginaries) (Jasanoff & Kim, 2015) is the product of many decades of investment in science and technology, which is uncritically assumed to result in "innovation" and "progress." Rather than emphasizing these rational, logical and linear trajectories towards seemingly certain futures, it is necessary to interrupt these discourses, embrace partial truths and connections and develop situated knowledges that acknowledge complexities, uncertainties and failures. This is essential in order to develop a more realistic picture of emerging technologies as well as to open up greater space for reimagining and re-conceptualizing narratives about the future. In part, this shift is away from autonomous individual actors and towards understanding the non-linear, shifting and dynamic compositions of complex socio-technical systems. Such systems have no centre (Slavin, 2016), and thus, they are not well addressed by HCD methodologies.

In order to destabilize and complicate narratives about emerging technology, the purpose of this chapter is to explore the ways in which concepts around the cyborg (Haraway, 1991), the posthuman (Bogost, 2012; Braidotti, 2013; Latour, 2005; Thrift, 2011) and more than human (Puig de la Bellacasa, 2017) might be explored in the field of art and design. Theories of the posthuman and more than human span a wide variety of fields and disciplines from philosophy to geography and STS. All of these fields approach posthumanism slightly differently given their specific histories, interests, ethics and commitments. As social scientists and design scholars, our work is aligned with the more political and activist strands of this research from feminist technoscience and new materialism, which supports intervention in the world for the purpose of advocating around social, economic and environmental justice. There are two primary reasons for thinking with the posthuman in art and design practice: (1) technological changes such as artificial intelligence and machine learning continually challenge and reconfigure what it means to be human as well as expand the boundaries around what it means to be a machine[4] and (2) environmental changes such as the impact of climate change as well as related crises of the anthropocene that mark the devastating impact of humans on the planet.[5] Overall, we argue that the integration of theoretical concepts around the posthuman into the design process is essential for the evolution of the field and for the creation of "a world where many worlds fit" (Escobar, 2018)[6]: specifically, one that includes all of its human and non-human inhabitants.

There is already a growing community of design scholars engaged in introducing these theories to art and design practice (DiSalvo & Lukens, 2011; Ferrando, 2013; Forlano, 2016b, 2017b; Jönsson, 2014; Lindström & Ståhl, 2017; Smith, Bardzell, & Bardzell, 2017). Over the past 10 years, Forlano's previous work has explored aspects of the posthuman, including wireless infrastructures (Forlano, 2009), smart cities (Forlano, 2015), autonomous vehicles (AVs) (Brown, Du, Forlano, Henderson, & Guthman, 2016), automation and the future of work (Forlano & Halpern, 2016), distributed design (Forlano & Mazé, forthcoming), computational fashion (Forlano, 2016a), and networked medical devices (Forlano, 2017a, 2018). These projects have investigated the posthuman across a range of scales from the human body to organizations and urban infrastructures.

Furthermore, we are also cognizant of the critiques of posthumanism from the critical race, gender, class and disability studies as well as queer studies (Kafer, 2013; Weheliye, 2014). Some of these critiques are also taken up in discussions around decolonizing design (Tunstall, 2013) and design justice (Costanza-Chock, 2018, 2017). Despite these essential critiques, we find the posthuman a generative body of theory for the transformation of art and design practice in order to move beyond theories and methods that focus on the discrete individual and towards a deeper understanding of relations that allow for the possibility of grappling with the complexity of socio-technical systems. As Keller Easterling argues, "The *more than human* doesn't negate human design; it only multiplies those designs in a larger field so that there are always many instead of only one" (2016). This emphasis on multiplicity allows for the creation of design practices that can incorporate these critiques in order to design for worlds where many worlds fit. Yet, in order to fully translate and integrate theories of the posthuman into art and design practice, it is necessary to develop and build new vocabularies, metaphors and exemplars.

Trading art and design practice into STS

In the mid-2000s, the prominent STS philosopher Bruno Latour declared that critique had "run out of steam" (Latour, 2004) and simultaneously began engaging in more generative approaches to the field, including the impressive "Making Things Public" exhibition and catalogue (Latour & Weibel, 2005). Over the past several decades, STS scholars have begun incorporating art and design practices into their work, creating new spaces for experimentation – conference sessions, journals, workshop and websites – that draw on inventive methods (Lury & Wakeford, 2012), critical technological practices (Agre, 1997), practice-based research (Koskinen, Zimmerman, Binder, Redstrom, & Wensveen, 2011; Vaughan, 2017), design as inquiry (Redström, 2017), research through design (Zimmerman, Forlizzi, & Evenson, 2007), critical making (Ratto, 2011), critical design, critical fabulation (Rosner, 2018), participatory design (Sanders, 2002; Schuler & Namioka, 1993), speculative design (Dunne & Raby, 2013) and speculative civics (DiSalvo, Jenkins, & Lodato, 2016) to name just a few of the many approaches. For example, since 2015, the Society for the Social Studies of Science has been hosting exhibitions in order to provide a venue for the presentation of work under the framing of "Making and Doing" rather than traditional conference papers, panels and presentations. In 2016, *The Handbook of Science and Technology Studies* focused on reflecting on methodologies, including art, design, performance and other experimental approaches with a series of interrelated chapters (Felt, Fouché, Miller, & Smith-Doerr, 2016; Vertesi, Ribes, Forlano, Loukissas, & Cohn, 2016).

These experimental practices offer creative ways to engage with theories and concepts from STS for the purpose of building conversations that engage participants, stakeholders and publics around matters of concern (Latour, 2004) and, more recently, what are being referred to as matters of care (Puig de la Bellacasa, 2017) in the building of diverse future economies (Gibson-Graham, 2006, 2008) for more than human worlds. In exploring these experimental practices, concepts such as conceptual matter (Sayers, 2018), material speculation (Wakkary, Odom, Hauser, Hertz, & Lin, 2015), material participation (Marres, 2012), epistemic things (Rheinberger, 1997) and touching visions (Puig de la Bellacasa, 2017) are valuable for understanding the ways in which visual and tangible engagements can be understood to produce alternative forms of knowledge. Specifically, Puig de la Bellacasa's *touching visions* capture "caring thinking and knowing as touch" (2017). She writes:

> touch expresses a sense of material-embodied relationality that seemingly eschews abstractions and detachments that have been associated with dominant epistemologies of knowledge-as-vision. Touch becomes a metaphor of transformative knowledge at the same time as it intensifies awareness of the imports of speculative thinking
>
> *Puig de la Bellacasa (2017)*

In this way, touching visions are tied to practices of speculation as knowledge-making.

In this chapter, we activate the trading zones between STS and art and design by drawing on examples from research and pedagogy. Our examples take on multiple forms from narratives, stories and films to objects, prototypes, visualizations and images. As touching visions of the more than human, these engagements seek to move beyond the traditional languages and practices of the field of design and towards a deeper engagement with emergent concepts in STS. In particular, our examples seek to illustrate the ways in which theories around cyborgs, the posthuman and the more than human can support the building of worlds in which alternative economies can thrive.

While the field of design has been deeply embedded in (and even responsible for) the proliferation of stereotypical modernist, universal, scientific modes of defining human subjectivity, its history also reveals important counter-examples and practices of resistance. These counter-examples resist the dominant modes of designing and critique the status quo. We take inspiration from these counter-examples, including critical design, design fiction, critical making, critical fabulations, speculative design, experiential design and critical futures. Of course, while these practices resist dominant modes, they are also quickly co-opted.

In the following section, we detail examples from research and pedagogy. Several of these examples are from The Driverless City project, while others are part of a transnational research project called Made in Chicago/Made in Milan, which is a partnership between the Institute of Design at Illinois Institute of Technology and Politecnico di Milano. The examples from design pedagogy were part of Forlano's graduate-level design courses in "Designing Futures" and "Principles and Methods of User Research" at the Institute of Design at Illinois Institute of Technology. Through this analysis, we aim to enliven the trading zones between STS and art and design around theories of the more than human.

The more than human in design research

The following examples, drawn from research, illustrate the ways in which critical theoretical perspectives from STS around the more than human offer new possibilities for the field of design. Similarly, these examples explore experimental practices from art and design that contribute to more diverse modes of knowledge-building in the field of STS. By working at these intersections, we explore the ways in which design can be used to shape alternative possible futures in which many worlds fit. These many worlds can be imagined, visualized and prototyped through a variety of methods. But in order to bring them to life as critical artefacts that resist the techno-utopian and capitalist status quo, it is necessary to move beyond the colloquial languages that are typical in the field of design. For example, when designers say "human," "gender," "technology" or "community" what concepts, definitions and histories of these terms are being included in their consideration? Design must abstract messy, situated contexts and needs into clearer, broader, more universal solutions. This requires a degree of concreteness and specificity, distilling social complexity into design principles, frameworks, tools and methods that support the designing of things.

On the other hand, artistic practices allow for ambiguity, reflection, mess and blurriness; or, put another way, a lack of specificity with respect to how they might be described. While artistic practices might also benefit from a deeper engagement with STS theory, they are already rooted within histories of resistance to the status quo whether politically, philosophically, socially, economically, etc. This does not mean that all artistic practices are critical of the status quo or that art is not embedded within its own capitalistic economies. However, ultimately, when compared to designers, artists have a greater deal of control over the ways in which they conduct research for their projects, the concepts they work with, what they choose to put into the world, and the meanings that might be associated with their work. (This does not mean that others – curators, buyers, patrons and audience – do not participate in shaping the meanings associated with artistic practices.)

Both art and design practices intervene in the world with images, things and performances that have a great degree of interpretive flexibility (Pinch & Bijker, 1984). But, in that, design is attempting to study human needs and address them through solutions – ultimately, designing new cultures, societies and civilizations in the process – design requires a better vocabulary for the designing of people in an age of complex socio-technical systems. Unfortunately, in their focus on mediums, methods and skills, the great majority of design curriculums have not integrated sufficient histories, knowledges and attitudes from the social sciences and humanities. Furthermore, they have not narrowed the focus on the kinds of concepts, theories and ideas that might actually challenge the long-standing assumptions of the field. As a result, design students have very little to work with when it comes to their ways of understanding people and the world when they begin designing.

This new vocabulary, building on STS, can bring greater nuance, variety and meaning to the artefacts of design, thereby resisting the binaries that have dominated Western, Enlightenment thinking along with current notions of what it means to be human as well as where and how the boundaries are drawn (Colomina & Wigley, 2016a, b; Rhee, 2018). A new vocabulary for design will be full of hybrid concepts, offering greater specificity informed by rich theoretical concepts. While this may make designing more difficult, it will also allow it to expand beyond the problematic assumptions (Cogdell, 2010) that have guided modernism over the past hundred years. In this way, all design can be discursive (Tharp & Tharp, 2019), contributing to re-working the world in ways that truly matter.

This section offers examples from two projects that translate concepts from critical theory around the posthuman and more than human into design research projects as part of visualizations and videos as well as prompts and scenarios. While the visualizations serve the purpose of making sense of complex socio-technical systems, the speculative videos invite audiences to imagine alternative possible futures for their cities. Similarly, the prompts and scenarios are intended to be used as part of codesign or participatory design workshops in order to scaffold the discussion of complex concepts, ideas and trends.

The Driverless City

The Driverless City "Mind Map," which was published in *The New York Times* in Fall 2017, visualizes complex socio-technical systems around four themes – street, delivery, parking and mobility – related to the integration of AVs into urban environments. With respect to exploring new vocabularies around the more than human in design, the mind map allows for social, technological, economic, political and environmental matters of care to be visualized together, thereby bumping up against one another in new and unexpected ways. The mind map exists not as a static prediction of the future of AVs but, rather, a dynamic object with which to question linear, techno-deterministic logics and narratives of the future of cities. Rather than merely passive readers/viewers of the mind map, the public is invited to participate in the tracing of pathways through the map as well as adding their own contributions around issues and topics that impact them and their communities.[7]

Beyond the mind map, The Driverless City project created four short videos using a speculative approach in order to engage with alternative possible futures for the city of Chicago. These videos are built on Marshall Brown's *Scenariograms*, which are videos that are used to bring to life visionary urban futures (2014). Our qualitative interviews with government officials and business leaders provided some of the factual material to confirm some of our ideas and create an engaging narrative. For example, in our "Delivery Space" video, which was featured in the Vienna Biennale, we speculate about the phenomenon of truckhousing, the idea that goods might be stored in trucks rather than in warehouses, in our script:

> By 2036, pockets of Chicago and new centers Naperville and Joliet had become so congested with last-mile delivery vehicles that aerial drones began replacing autonomous vehicle delivery, thus, reducing the need for the sprawling warehousing and distribution centers that populated the Chicago Metropolitan Area throughout the 20th century.

The video then goes on to speculate about the demand for "hyper-specialized goods," "in-place retailing" and "networked markets for recycling." And, due to claims that driverless cars may make driving safer, we create a scenario around the disappearance of road kill, the overpopulation of certain species and the emergence of a new economy around seasonal hunting and trapping to replace lost jobs in trucking and warehouses. However, again, rather than playing a prescriptive role, these videos are intended to provoke thinking and raise questions about "new forms of production, and civic life." Thus, thinking through the future possibilities of socio-technical systems around the AV is an exercise in considering our values and choices today. Here, similar to the mind map, the videos juxtapose unusual facts, issues, possibilities, risks and opportunities. They are recognizable but, at the same time, ambiguous, ironic and, at times, strange and startling. This combination of qualities makes them useful as generative objects rather than projective visions of the futures.

Lastly, The Driverless City project created a "Scenario Builder" that is designed to facilitate the exploration, imagination and reflection about AVs. After experimenting with existing future-focused design tools such as "The Thing from the Future," [8] designed by Stuart Candy and Jeff Watson at the Situation Lab, in February 2016, we designed our own generative device specifically focused on AVs and urban futures. This device, which consists of a set of 200 "chips" – small copper tokens with walnut borders (similar in size and shape to poker chips) designed and fabricated by the industrial designer Martin Kastner from Crucial Detail – allows participants to build their own scenarios about the future of mobility, urbanism and social life. Each of the "chips" had one word etched on each side, which represented actors (including humans and non-humans), locations, moods, issues, affordances and infrastructures. In order to use the Scenario Builder, participants randomly select five chips and create a story in response to a question about the future of mobility, urbanism and social life. The stories enable stakeholders to imagine and prototype the alternative possible urban futures that could co-evolve with advances in transportation such as AVs.

While the mind map and videos are both primarily visual design interventions, the participatory modes of engagement, especially in the case of the mind map, allow these to materialize touching visions of AVs and urban futures. Furthermore, by making some of the actors, issues and infrastructures tangible – in the form of chips in the Scenario Builder – participants can manipulate and build their own stories, and knowledges, that capture personal, situated engagements with urban futures. It is through these visual and physical manifestations about AVs and urban futures that we can begin to build a new vocabulary for the design field around the more than human that captures the nuance that is necessary in order to consider the possibilities of emerging technologies (and, perhaps even, reject them all together in favour of social alternatives).

Made in Chicago/Made in Milan

The Made in Chicago/Made in Milan project began as a collaborative partnership between the Institute of Design at Illinois Institute of Technology and Politecnico di Milano in July 2017. Together, over the course of one year, the two schools began researching local manufacturing ecosystems in Chicago and Milan, respectively, which resulted in the publication of several reports (Forlano, Marshall, & Heidaripour, 2018). The project combined qualitative interviews along with visits to field sites and codesign workshops in order to understand and map the work of local organizations in design and manufacturing. In the following section, we describe some of the methodologies that were used to engage stakeholders in conversations about their local economies.

Similar to the "Mind Map," speculative videos and the "Scenario Builder" from The Driverless City project described above, in the Made in Chicago/Made in Milan project, we used a variety of different kinds of socio-technical trend cards as cultural probes (Gaver, Dunne, & Pacenti, 1999) in order to stimulate conversation and engage stakeholders, especially non-designers, around specific issues and matters of concern related to local economies. Gaining a deeper understanding of socio-technical trends in the design field contributes to the envisioning of alternative possible futures through the creation of scenarios in participatory workshop settings.

Here, we drew on an approach to designing futures called the Advanced Design Discipline (ADD), which incorporates design-driven innovation processes, research tools and markets of reference (Celi, 2016). ADD is oriented towards the imagination of future products, processes and services to respond to complex and uncertain current situations, and it is particularly useful when several stakeholders are involved in the design process. This approach makes sense in the context of theories around the sociological imagination, which C. Wright Mills defined as "the awareness of the relationship between personal experience and the wider society" (Mills, 1959). With respect to the identification of trends, signs and signals that document the existence of a trend must be based on shared problems, behaviours and (in some cases) solutions, which must be significantly numerous and diffused. Therefore, trends are based on the interpretation of present signs or anticipations of the future (Celi & Rudkin, 2016).

Beginning in Spring 2018, we held two short codesign workshops in Chicago around topics related to local design and manufacturing, including the future of work and the development of more diverse economies. For the first workshop, we prototyped a prompt called "Hack Cards" in order to help participants explore different points of view, including human and non-human perspectives. The "Hack Cards" allowed participants to intervene in a variety of scenarios from different stakeholder perspectives, including the following actors: The Planet, Infrastructure, Media, Class Systems, Robot, Pet, Family, CEO, Non-Profit, Policy Maker, Supervisor and Inter-planetary Agency. The scenarios were set on an alien planet that was experiencing significant transformations around labour, employment and work. Based on the initial paper prototype of these cards, we discussed the use of different definitions and embodiments of hacking, including: to gain access to unauthorized things; DIY or workarounds; to cut down; and, humour (Coleman, 2012). Additionally, we created ways for participants to create their own hack cards in the form of blank "wild cards" or by allowing for different combinations of existing cards.

After the two workshops in Chicago, we held a workshop in Milan in June 2018. The purpose of the workshop was to bring together key stakeholders in the Bovisa neighbourhood surrounding the university as well as local organizations that are active in the art and design field. For this workshop, civic design was selected as a topic because of its relevance to the overall project around local design and manufacturing with a specific focus on the local economy, innovation and social inclusion. After a mapping activity and qualitative interviews, we conducted a workshop in which different stakeholders (students, entrepreneurs, makers, professionals, etc.) were invited to participate. The four-hour workshop was aimed at envisioning a living laboratory[9] in the Bovisa area of Milan, where the Politecnico di Milano School of Design is located. The participants in the workshop generally represented the Milanese creative ecosystem, which includes design students (Italian and foreigners), professionals (designers, makers, architects, entrepreneurs, etc.) and municipality delegates. Each table was arranged around a specific theme, including food, mobility, fashion and jewellery, music and entertainment and communication.

In order to guide the conversation during the workshop, we developed a set of twelve socio-technical trend cards. The trends were selected from a platform called Nextatlas,[10] which was launched in 2015. The platform is based on crowdsourced contents and a data science method that uses proprietary algorithms and artificial intelligence methodologies to detect new trends considered likely to become mainstream (Celi & Rudkin, 2016). The twelve socio-technical trend cards were designed starting from the keywords, which we identified as relevant for our topics and purposes. These keywords were based on:

1 The general field of activity where our participants worked and were interested in (food, fashion, mobility, entertainment and communication);
2 The way in which they did it (in terms of tools, technologies and materials);
3 The target audience they focused on;
4 Their goals and orientations (such as sustainability, inclusion and empowerment).

Thanks to the systematization of these elements, we selected twelve trends, which were edited and translated into Italian. After this process, we tried to visualize each one, pairing them with evocative pictures taken from case studies by Nextatlas as well as from our own research. The following twelve trends were identified:

- Unexpected Gardens: gardens arising in unexpected places, such as the abandoned ones, but also schools or balconies;
- Creative Activism: creatively rethink our relationships with power, economy and money;
- Millennial Arts and Crafts: deconstruction practice of the original tradition;
- Rurbanism: contemporary urban reinterpretation of traditional and aesthetic agricultural concepts;
- Smart Biking: bicycles are at the core of a new definition of sustainability, which aims to be not only environmental, but also cultural and cognitive;
- Beautiful Info: the aesthetics of data will be one of the most discussed topics not only in graphic design, but also in fashion, product design, art, etc.;
- Translating Machines: they were born from research on speculative design whose purpose is to translate the sensory material from one state to another, in a synaesthetic way;
- Biodesign: convergence between design and synthetic biology;
- Superlocal Design: "super local" designers are both locally rooted and open to experimentation in order to design site-specific solutions;
- City Fluency: urban dwellers create personal mobility strategies, mixing up private, shared and public transport;
- Brand-Led Activism: the world political situation is influencing brands to actively engage to demonstrate their distance from certain behaviours and values;
- Augmented Tradition: the internet makes it possible to focus on cultural peculiarities, which become an element of conversation.

Many of these trends integrate multiple, different concepts into hybrid entities for thinking with. The visual and tangible nature of the cards allows them to be manipulated and reorganized during the codesign workshop, creating new meanings and relations. In addition, several of these trends specifically extend thinking around the more than human, i.e., biodesign, unexpected gardens. The use of these socio-technical trend cards along with other exercises and instructions allowed participants to engage in conversation about questions such as: "What kind of living laboratory do you propose? Which activities should this living laboratory implement?"

The more than human in design pedagogy

This section offers four examples that translate concepts from critical theory around the posthuman and more-than-human into classrooms and workshops for pedagogical purposes. These examples – from Forlano's Designing Futures graduate course at the Institute of Design at Illinois Institute of Technology – illustrate the ways in which field research and secondary research as well as speculative narratives and prototypes can be used to interrogate emerging technologies as well as query plant, animal and non-human existences, thereby bringing to life alternative possible futures.

What a chicken wants

The majority of HCD projects are strongly tied to the desires of people. This exercise, based on a 2016 article in *The Atlantic* (Semuels), asks participants to reimagine traditional ethnographic and qualitative research practices in order to understand the lives of chicken. For example, researchers might conduct interviews with animal experts as one mode of understanding non-human lives but they might also observe animals in their environments or form intimate, caring relationships with animals. Much like Nippert-Eng's *Watching Closely* (Nippert-Eng, 2015), which describes a variety of approaches for observing gorillas at the Lincoln Park Zoo in Chicago, this exercise challenges participants to find alternative ways of gathering data, using research tools, visualizing patterns and understanding needs. These more than human approaches – in collaboration with sheep, birds, rocks and other non-humans – have been pioneered in the design field by Anne Galloway's More Than Human Lab[11] (2013) among others (Jönsson, 2014; Lindström & Ståhl, 2017). Furthermore, the exercise is provocative in that participants must question their assumptions about their research subjects, themselves and ways of becoming that challenge nature/culture distinctions. One of the meaningful outcomes of the exercise is a set of questions that might drive future research inquiries around the more-than-human. For example, researchers might ask: How do I know if a chicken is healthy, happy and living well? Are health and happiness human constructions or do all animals require a sense of well-being? Do I care about the state and lives of animals and other non-humans? If not, why not? What might allow me to form deeper relationships with the world that I live in? Overall, these questions challenge conceptions of human exceptionalism and strive to underscore our interconnected relationship to non-humans, including plants, animals and the environment.

Alternative superhero stories

Social and economic justice advocates are engaged in a constant struggle for alternative possible futures (Imarisha & Brown, 2015). This exercise uses Walidah Imarisha's "Unafraid" (Imarisha, 2017) as an example of a superhero narrative that resists American stereotypes of pro-Western heroes that emerged following World War II and envisions alternative roles for those with special powers, in this case, intervening on immigration issues between the United States and Mexico. While the "superhero" format can be critiqued as overly invested in the powers of techno-utopian progress and rampant individualism, this exercise invites participants to select a superhero from any context, culture or time-period along with an issue, stakeholder or community of interest. Participants are challenged to use the superhero narrative in order to illustrate the complex challenges and to reimagine the abilities/disabilities of superheroes in order to address the issues that have been identified. Importantly, this exercise invites participants to take creative risks by moving into a speculative space of narrative fiction. This is essential in order to resist the HCD field's overwhelming methodological focus on seemingly scientific methods around data collection, analysis and prototyping solutions. The resulting narratives are spaces of inclusive possibilities rather than solutions to problems.

Speculative objects for science fiction

Drawing on Dunne & Raby's *Speculative Everything* (Dunne & Raby, 2013), this exercise invites participants to create a three-dimensional physical object that might live in an existing science fiction world; a script for an extension of an existing science fiction world, i.e., the next episode, chapter or film; or a performance of a new scene for an existing science fiction world. In order to complete the exercise, it is necessary to conduct a detailed analysis of a scene or a series of scenes of an existing science fiction focusing on the values that are being communicated through the characters, props, language and environment. Participants are expected to use unusual, lo-fidelity materials in order to bring their objects to life. How might a speculative object act as a design intervention into an issue, topic or domain? How might it provoke or raise questions about ethics, politics and responsibilities? What questions are raised by engaging in the making of the object that you would not be able to address through other means, i.e., text, diagram. Do you feel uncomfortable making this object? Why or why not? This exercise allows participants to reflect on their own assumptions, biases and ethical commitments. Examples of previous projects along these lines include Meat Up[12] as well as several projects included in the BioDesign Challenge.[13]

Cyberculture histories

Techno-utopian imaginaries circulate quickly and widely in mainstream discourse. This exercise invites participants to use secondary research to visually map the history of well-known concepts and claims about the future in order to illustrate the social construction of discourses about emerging technologies and futures. This is important because of the overwhelming focus on primary research in the design field. By using secondary research to investigate the histories of mainstream discourse, students can develop critical thinking skills that they can apply to future projects. Participants are challenged to answer the following questions: What is the origin of this phrase? Who coined the phrase, when and why? How does this phrase get repeated, deployed and used today? What is it associated with and/or advocating for? What are the assumptions embedded in this phrase? In your research, have you discovered any new phrases that are associated with the future? What are they? Can you create a new phrase about the future based on an alternate set of perspectives or possibilities? The result of this exercise is a visual "mind map" or diagram (Forlano & Ruecker, 2018).[14] Here is a list of selected concepts and phrases: *the future is already here, it's just not evenly distributed; the best way to predict the future is to invent it; the ghost in the machine; the cathedral & the bazaar; free as in freedom, not as in free beer; uncanny valley; grey goo; the map is not the territory; on the Internet, no one knows you are a dog; a general assembly; the elementary particles; we need to become radical nowist; crossing the chasm; disruptive, scrum, agile; and, there's plenty of room at the bottom.*

Taken together, these, more than human approaches to design pedagogy, draw on language and concepts from STS in order to remake design education in ways that allow it to contend with the challenges of designing for complex socio-technical systems. These visual and tangible exercises combine design approaches with critical theories from STS that invite students to think about the world beyond human exceptionalism, national borders, viable business models and Silicon Valley hype cycles. Rather than remaining safely within the boundaries of HCD, which emphasize feasibility, viability and desirability, these exercises embrace critical and speculative design approaches that carve out space for more reflective, discursive and conceptual approaches. Engaging in these approaches requires interrogating the forms as well as the language of design. It is only by challenging the assumptions of HCD that we can truly rethink and reinvent the field of design in a more than human world and move towards the possibility of inventing many worlds and many futures.

Conclusion

In this chapter, we have argued that the trading zones between STS and art and design practice are populated with a range of practices that playfully, productively, purposefully experiment with theories and methods. These trading zones are essential for the field of STS because they create space for more diverse ways of expressing and creating knowledge through more visible and tangible forms of scholarship. They are also necessary for the field of design because they offer more critical, nuanced and specific ways of thinking about the world. Together, at these intersections, it is possible to craft new languages, concepts and vocabularies that bring to life hybrid disciplines and fields that better suited for grappling with emerging issues, arrangements, dilemmas and scales of socio-technical systems.

Of primary interest to our considerations here are the ways in which theories of the more than human from STS might find their ways into art and design practices. The more than human, as conceived by feminist new materialists, offers ways of thinking beyond the boundaries of the human and notions of human exceptionalism that have long captured HCD. By expanding the focus of design towards complex socio-technical systems composed of human and non-human relations, it is possible to pose new questions about the nature of people and the world in order to challenge some of the problematic assumptions that are currently made by designers.

In this chapter, we draw on examples from research and pedagogy from several projects in order to illustrate the ways in which touching visions of the more than human can be explored at the intersections of these fields. We argue that these examples are initial steps towards the creation of new hybrid concepts, vocabularies and knowledges around the more than human in order to circumvent the existing limitations of language and the binary oppositions inherited from Western, Enlightenment thinking. By scaffolding conversations between different fields, these emergent vocabularies and practices can pave the way towards the formation of new disciplines and subfields that have the potential to create design for the pluriverse, the creation of a world where many worlds fit.

Acknowledgements

For The Driverless City project, we would like to thank the inaugural Nayar Prize at Illinois Institute of Technology as well as co-Principal Investigators Marshall Brown, Ron Henderson, Lili Du and Jack Guthman. Maryam Heidaripour served as a Research Assistant on The Driverless City project in 2015–2016, creating the visual design for the "Mind Map" and the initial prototypes of the "Scenario Builder." Additional details about the project and team can be found at http://thedriverlesscity.com. For the Made in Chicago/Made in Milan project, we would like to thank our respective schools – the Institute of Design at Illinois Institute of Technology and the School of Design at Politecnico di Milano – for their support of this project. Furthermore, in Chicago, we would like to thank the following students for their participation in this project as well as for their work on the "Hack Cards" concept: Maryam Heidaripour, Theresa Lafranchise, Urba Mandrekar, Becky Marshall and David Pollack. In Milan, Vanessa Monna served as the designer and collaborator on the project from which the "Socio-technical Trend Cards" concept emerged.

Notes

1 Laura Forlano, the first author, was first introduced to the concept of trading zones in a conversation with Matt Ratto in Toronto in 2011 while she was conducting research on coworking spaces and emerging design practices as part of a Fulbright grant.

2 Ibid.

3 The Critical Futures Lab, directed by Laura Forlano at the Institute of Design at Illinois Institute of Technology,

> occupies the liminal spaces between critical social science theory and generative design methods. Through prototypes, experiments and explorations — bridging creative thinking and critical making — the Lab engages with complex socio-technical (political, cultural, economic, ethical and environmental) questions about the conditions of everyday working and living in cities in the context of ongoing economic and environmental crises. These varied and multidisciplinary activities — informed by science and technology studies, media studies and communications — intend to bring together diverse viewpoints in order to raise vital questions and alternative possibilities. In particular, the Lab is concerned with the ways in which the digital is materialized, contextualized and embodied across a variety of scales, from city infrastructures to the built environment, and from interactive objects to digital bodies.

See http://criticalfutureslab.org. Accessed on December 7, 2018.

4 For example, frequent arguments about robotics and artificial intelligence continually attempt to prove that machines can "become human" by demonstrating their cognitive and creative abilities.

5 Another argument for thinking with the posthuman, but one that we do not specifically embrace, is transhumanism – for example, the movement known as the Singularity – which is primarily concerned with using technology to extend human capabilities and lifespans well beyond current limitations.

6 Here, Escobar is quoting the words of the Zapatista from Chiapas, Mexico, from their statements at the 2001World Social Forum, which was held in Porto Alegre, Brazil.

7 We held a workshop using this approach at the Institute of Design at Illinois Institute of Technology in January 2018.

8 See http://situationlab.org. Accessed on September 14, 2016.

9 European Network of Living Labs definition:

> Living Labs (LLs) are defined as user-centred, open innovation ecosystems based on systematic user co-creation approach, integrating research and innovation processes in real life communities and settings. LLs are both practice-driven organisations that facilitate and foster open, collaborative innovation, as well as real-life environments or arenas where both open innovation and user innovation processes can be studied and subject to experiments and where new solutions are developed. LLs operate as intermediaries among citizens, research organisations, companied, cities and regions for joint value co-creation, rapid prototyping or validation to scale up innovation and businesses. LLs have common elements but multiple different implementations.

https://enoll.org/about-us/

10 https://www.nextatlas.com/

11 See http://morethanhumanlab.org. Accessed on December 18, 2018.

12 See http://www.core77designawards.com/2014/recipients/meat/. Accessed on July 19, 2018.

13 See http://biodesignchallenge.org/illinois-institute-of-technology. Accessed on July 19, 2018.

14 Several examples of these Cyberculture Histories were published in an interview in Diseña in September 2018:
http://revistadisena.uc.cl/index.php/Disena/article/view/137/129. Accessed December 18, 2018.

References

Agre, Philip. (1997). Toward a critical technical practice: Lessons learned in trying to reform AI. In G. C. Bowker, S. L. Star, L. Gasser and W. Turner (Eds.), *Bridging the Great Divide: Social Science, Technical Systems, and Cooperative Work*. Mahwah, NJ: Erlbaum, 131–157.

Bogost, Ian. (2012). *Alien Phenomenology, or What It's Like to be a Thing*. Minneapolis: University of Minnesota Press.

Braidotti, Rosi. (2013). *The Posthuman*. Boston, MA: Polity.

Brown, Marshall. (2014). *Scenariograms: A Video Technique for Visionary Urbanism*. Paper presented at the Urban Futures, Squaring Circles, Europe, China, World, 2050, Lisbon, Portugal.

Brown, Marshall, Du, Lili, Forlano, Laura, Henderson, Ron, & Guthman, Jack (Producer). (2016). The Driverless City. Retrieved from https://http://www.id.iit.edu/driverlesscity.

Celi, M., & Rudkin, J. (2016). Drawing food trends: Design potential in shaping food future. *Futures, 83*, 112–121.

Cogdell, Christina. (2010). *Eugenic Design: Streamlining America in the 1930s*. Philadelphia: University of Pennsylvania Press.

Coleman, Gabriella. (2012). *Coding Freedom: The Ethics and Aesthetics of Hacking*. Princeton, NJ: Princeton University Press.

Colomina, Beatriz, & Wigley, Mark (Eds.). (2016a). *Are We Human?: The Archeology of Design*. Zurich: Lars Müller Publishers.

Colomina, Beatriz, & Wigley, Mark (Eds.). (2016b). *Are We Human?: The Design of the Species_2 Seconds, 2 Days, 2 Years, 200 Years, 200,000 Years*. Zurich: Lars Müller Publishers.

Costanza-Chock, Sasha (Ed.). (2017). *Design Justice in Action* (Vol. 3). Detroit, MI: Design Justice Network.

Costanza-Chock, Sasha. (2018). Design Justice, AI, and Escape from the Matrix of Domination. *Journal of Design and Science*. doi:10.21428/96c8d426

DiSalvo, Carl, Jenkins, Tom, & Lodato, Thomas. (2016). *Designing Speculative Civics*. Paper presented at the Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems. San Jose, CA.

DiSalvo, Carl, & Lukens, Jonathan. (2011). Nonathropocentrism and the nonhuman in design: Possibilities for designing new forms of engagement with and through technology. In M. Foth, L. Forlano, M. Gibbs & C. Satchell (Eds.), *From Social Butterfly to Engaged Citizen: Urban Informatics, Social Media, Ubiquitous Computing, and Mobile Technology to Support Citizen Engagement*. Cambridge, MA: MIT Press, 421–435.

Dunne, Anthony, & Raby, Fiona. (2013). *Speculative Everything: Design, Fiction, and Social Dreaming*. Cambridge, MA: MIT Press.

Easterling, Keller. (2016). No You're Not, *e-flux Architecture*. Retrieved from http://www.e-flux.com/architecture/superhumanity/66720/no-you-re-not/.

Escobar, Arturo. (2018). *Designs for the Pluriverse: Radical Interdependence, Autonomy, and the Making of Worlds*. Durham, NC: Duke University Press.

Felt, U., Fouché, R., Miller, C. A., & Smith-Doerr, L. (Eds.). (2016). *The Handbook of Science and Technology Studies*. Cambridge, MA: MIT Press.

Ferrando, Francesca. (2013). Posthumanism, transhumanism, antihumanism, metahumanism, and new materialisms. *Existenz, 8*(2), 26–32.

Forlano, Laura. (2009). WiFi geographies: When code meets place. *The Information Society, 25*, 1–9.

Forlano, Laura. (2015). Towards an integrated theory of the cyber-urban. *Digital Culture & Society, 1*(1), 73–92.

Forlano, Laura. (2016a). *Aesthetics, Cosmopolitics and Design Futures in Computational Fashion*. Paper presented at the Design Research Society, Brighton, UK.

Forlano, Laura. (2016b). Decentering the human in the design of collaborative cities. *Design Issues, 32*(3), 42–54.

Forlano, Laura. (2017a). Data rituals in intimate infrastructures: Crip time and the disabled cyborg body as an epistemic site of feminist science. *Catalyst: Feminism, Theory, Technoscience, 3*(2), 1–28.

Forlano, Laura. (2017b). Posthumanism and design. *She Ji: The Journal of Design, Economics, and Innovation, 3*(1), 16–29.

Forlano, Laura. (2018). Posthuman futures: Connecting/disconnecting the networked (medical) self. In Z. Papacharissi (Ed.), *A Networked Self: Human Augmentics, Artificial Intelligence, Sentience*. New York, NY: Routledge, 39–50.

Forlano, Laura, & Halpern, Megan. (2016). Reimagining work: Entanglements and frictions around future of work narratives. *Fibreculture, 26*, 32–59.
Forlano, Laura, Marshall, B., & Heidaripour, M. (2018). *Making Diverse Economies: A Study of Local Making and Manufacturing in Chicago*. Chicago: Institute of Design, Illinois Institute of Technology.
Forlano, Laura, & Mazé, Ramia. (forthcoming). Demonstrating and anticipating in distributed design practices. *Demonstrations: Journal for Experiments in the Social Studies of Technology*. Inaugural Issue.
Forlano, Laura, & Ruecker, Stan. (2018). The imaginary framing and the lived experience of technologies: Interview with Laura Forlano. *Diseña, 13*, 58–83.
Galison, Peter. (2010). Trading with the enemy. In M. E. Gorman (Ed.), *Trading Zones and Interactional Expertise: Creating New Kinds of Collaboration*. Cambridge, MA: MIT Press, 25–52.
Galloway, Anne. (2013). Emergent media technologies, speculation, expectation, and human/nonhuman relations. *Journal of Broadcasting & Electronic Media, 57*(1), 53–65.
Gaver, Bill, Dunne, Tony, & Pacenti, Elena. (1999). Design: Cultural probes. *Interactions, 6*(1), 21–29.
Gibson-Graham, Julie Katherine. (2006). *A Postcapitalist Politics*. Minneapolis: University of Minnesota Press.
Gibson-Graham, Julie-Katherine. (2008). Diverse economies: Performative practices for other worlds'. *Progress in Human Geography, 32*(5), 613–632.
Gorman, Michael E. (2010). *Trading Zones and Interactional Expertise: Creating New Kinds of Collaboration*. Cambridge, MA: MIT Press.
Gropius, Walter. (1919). Bauhaus manifesto and program. *Weimar: The Administration of the Staatliche Bauhaus*. Retrieved from http://gropius.house/location/bauhaus-manifesto/. Accessed on March 22, 2021.
Gunn, Wendy, Otto, Ton, & Smith, Rachel Charlotte. (2013). *Design Anthropology: Theory and Practice*. New York, NY: Bloombsbury.
Haraway, Donna Jeanne (Ed.). (1991). A cyborg manifesto: Science, technology, and socialist-feminism in the late twentieth century. In *Simians, Cyborgs and Women: The Reinvention of Nature*. New York, NY: Routledge, 149–181.
Haraway, Donna Jeanne. (2016). *Staying with the Trouble: Making Kin in the Chthulucene*. Durham, NC: Duke University Press.
Imarisha, Walidah. (2017). Unafraid. *The New Inquiry*. October 2, 2017. Retrieved from https://thenewinquiry.com/unafraid/. Accessed on March 22, 2021.
Imarisha, Walidah, & Brown, Adrienne Maree. (2015). *Octavia's Brood: Science Fiction Stories from Social Justice Movements*. Oakland, CA: AK Press.
Jasanoff, Sheila, & Kim, Sang-Hyun. (2015). *Dreamscapes of Modernity: Sociotechnical Imaginaries and the Fabrication of Power*. Chicago, IL: University of Chicago Press.
Jönsson, Li. (2014). *Design Events. On Explorations of a Non-anthropocentric Framework in Design*. Copenhagen, DK: The Royal Danish Academy of Fine Arts.
Kafer, Alison. (2013). *Feminist, Queer, Crip*. Bloomington: Indiana University Press.
Koskinen, Ilpo, Zimmerman, John, Binder, Thomas, Redstrom, Johan, & Wensveen, Stephan. (2011). *Design Research through Practice: From the Lab, Field, and Showroom*. New York, NY: Elsevier.
Latour, Bruno. (2004). Why has critique run out of steam? From matters of fact to matters of concern. *Critical Inquiry, 30*(2), 225–248.
Latour, Bruno. (2005). *Reassembling the Social: An Introduction to Actor-Network-Theory*. Oxford: Oxford University Press.
Latour, Bruno, & Weibel, Peter. (2005). *Making Things Public: Atmospheres of Democracy*. Cambridge, MA: MIT Press.
Lindström, K., & Ståhl, Å. (2017). Plastic imaginaries. *Continent, 6*(1): 62–67.
Lury, Celia, & Wakeford, Nina. (2012). *Inventive Methods: The Happening of the Social*. New York, NY: Routledge.
Marres, Noortje. (2012). *Material Participation: Technology, the Environment and Everyday Publics*. London: Palgrave Macmillan.
Mills, C. Wright. (1959). *The Sociological Imagination*. Oxford: Oxford University Press.
Nippert-Eng, Christena. (2015). *Watching Closely: A Guide to Ethnographic Observation*. Oxford: Oxford University Press.
Pinch, Trevor J., & Bijker, Wiebe E. (1984). The social construction of facts and artefacts: Or how the sociology of science and the sociology of technology might benefit each other. *Social Studies of Science, 14*(3), 399–441.

Puig de la Bellacasa, María. (2017). *Matters of Care: Speculative Ethics in More Than Human Worlds*. Minneapolis: University of Minnesota Press.
Ratto, Matt. (2011). Critical making: Conceptual and material studies in technology and social life. *The Information Society, 27*(4), 252–260.
Redström, Johan. (2017). *Making Design Theory*. Cambridge, MA: MIT Press.
Rhee, Jennifer. (2018). *The Robotic Imaginary: The Human and the Price of Dehumanized Labor*. Minneapolis: University of Minnesota Press.
Rheinberger, Hans-Jörg. (1997). *Toward a History of Epistemic Things: Synthesizing Proteins in the Test Tube*. Stanford, CA: Stanford University Press.
Rosner, Daniela K. (2018). *Critical Fabulations: Reworking the Methods and Margins of Design*. Cambridge, MA: MIT Press.
Sanders, Elizabeth B.-N. (2002). From user-centered to participatory design approaches. In J. Frascara (Ed.), *Design and the Social Sciences: Making Connections*. New York, NY: CRC Press, 1–8.
Sayers, Jentery. (2018). *Making Things and Drawing Boundaries: Experiments in the Digital Humanities*. Minneapolis: University of Minnesota Press.
Schuler, Douglas, & Namioka, Aki. (1993). *Participatory Design : Principles and Practices*. Hillsdale, NJ: L. Erlbaum Associates.
Semuels, Alana. (October 11, 2016). What a chicken wants. *The Atlantic*.
Slavin, Kevin. (2016). Design as participation. *Journal of Design and Science, 1*(1). doi:10.21428/a39a747c.
Smith, Nancy, Bardzell, Shaowen, & Bardzell, Jeffrey. (2017). *Designing for Cohabitation: Naturecultures, Hybrids, and Decentering the Human in Design*. Paper presented at the Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems. Denver, CO.
Smith, Rachel Charlotte, Vangkilde, Kasper Tang, Kjærsgaard, Mette Gislev, Otto, Ton, Halse, Joachim, & Binder, Thomas (Eds.). (2016). *Design Anthropological Futures*. New York, NY: Bloomsbury.
Tharp, Bruce, & Tharp, Stephanie. (2019). *Discursive Design: Critical, Speculative, and Alternative Things. Design Thinking, Design Theory*. Cambridge, MA: MIT Press.
Thrift, Nigel. (2011). Lifeworld Inc—and what to do about it. *Environment and Planning D: Society and Space, 29*(1), 5–26.
Tunstall, Elizabeth (Dori). (2013). Decolonizing design innovation: Design anthropology, Critical anthropology, and indegenous knowledge. In W. Gunn, T. Otto & R. C. Smith (Eds.), *Design Anthropology: Theory and Practice*. New York, NY: Bloomsbury, 236–254.
Vaughan, Laurene. (2017). *Practice-based Design Research*. New York, NY: Bloomsbury Publishing.
Vertesi, Janet, Ribes, David, Forlano, Laura, Loukissas, Yanni, & Cohn, Marisa. (2016). Engaging, designing and making digital technologies. In U. Felt, R. Fouché, C. A. Miller & L. Smith-Doerr (Eds.), *The Handbook of Science and Technology Studies*. Cambridge, MA: MIT Press, 169–194.
Wakkary, Ron, Odom, William, Hauser, Sabrina, Hertz, Garnet, & Lin, Henry. (2015). *Material Speculation: Actual Artifacts for Critical Inquiry*. Paper presented at the Proceedings of The Fifth Decennial Aarhus Conference on Critical Alternatives. Aarhus University, Aarhus, Denmark.
Weheliye, Alexander G. (2014). *Habeas Viscus: Racializing Assemblages, Biopolitics, and Black Feminist Theories of the Human*. Durham, NC: Duke University Press.
Zimmerman, John, Forlizzi, Jodi, & Evenson, Shelley. (2007). *Research through Design as a Method for Interaction Design Research in HCI*. Paper presented at the Proceedings of the SIGCHI conference on Human Factors in Computing Systems, San Jose, CA.

12

Discovering alternative technological futures through literature

Jennifer L. Lieberman

Technology is a pervasive concept. But, like pornography, it can be difficult to define: we presume that we know it when we see it. Since technology is one of the subjects of this chapter, it is important to note that the colloquial understanding of the term as a material, cutting-edge invention or innovation is not quite accurate enough to encapsulate the concept. As Erik Schatzberg, Leo Marx, and Ruth Oldenziel have argued, technology is an elusive construct whose definition has changed over time.[1] For the purposes of this piece, I define it as anything that we use to mediate our environment. A tree is not in itself a technology, yet when intentionally planted to protect against erosion, it becomes one. We tend to imagine that the technologies we regularly use are constructed in the best or only or most rational way. But there are always different technological choices available, and studying the intersection where literature and Science and Technology Studies (STS) meet can help us identify and examine those alternatives. In this chapter, I discuss how literary writing can inflect our understanding—and even development—of technology. Where other scholars (notably including Bruno Latour and Steve Woolgar[2]) have shown that inscription is a crucial aspect of technological and scientific production, this piece attends to the more-abstract relationships between nontechnical writing and technology.

As I will show in the pages that follow, the relationship between literature and technology is diffusive but non-negligible. Reflect upon our own experiences as readers. We do not generally read contemporary novels and exclaim, "that describes my relationship to technology perfectly!" Rather, we identify with, or worry about, or care for characters; we feel suspense for plot; meanwhile, realistic details, including technological descriptions, often fall into the background as we read. As such, we cannot expect historical narratives to serve as time capsules, which somehow preserve their culture's understanding of technology in a way that we can excavate. Rather, literary depictions of technologies can help us uncover a range of social meanings that those items did or could have. Writers help raise questions about the built environment that can help us envision meaningful change. For example, in "South of the Slot" (1909), Jack London focuses on the tangible metal slot that divides the city and creates a wrong side of the tracks and a right side. His depiction of advancing transportation technology starkly contrasts technical and promotional literature that emphasizes the "annihilation" of space and time, focusing on connection and drawing attention away from

DOI: 10.4324/9780429437069-16

disconnection (Macdougall, 2013). In cases like this one, literary and technical writing give us complementary—and equally important—perspectives of the same evolving technology.

Literature is not exceptional in this regard; such insights would not necessarily elude scientists or engineers. However, literature offers a medium through which audience members expect to imagine change, even if those changes do not seem possible from our current vantage points. Literature invites credulity; it allows us to entertain different perspectives than our own. Other media can accomplish similar results, as we can see in the other essays in this handbook. In fact, literature scholars like myself often define literature broadly to include art, film, and other "texts" that may not seem particularly literary according to colloquial definitions of the term. If literature in the conventional forms of novels, essays, short stories, poetry, or drama offers something unique, it might be a particular suppleness that allows for new interpretations and insights every time we revisit the same words on the same page.

To demonstrate the interplay between literature and technology, this chapter begins by discussing two well-known Progressive Era (late nineteenth and early twentieth century) authors who included discussions of technological choice in their work: Charlotte Perkins Gilman and Jack London. Gilman is best known for her early short story, "*The Yellow Wall-Paper*" (1899), about a woman suffering both from postpartum depression and from the contemporary treatment for that disease; London is remembered today for his works about wild animals and equally wild men. Yet, both writers also wrote critically about their material worlds. Their narratives can help to expand our understanding of artifacts and systems in the past and present. Before concluding, I turn to a third case study of Afrofuturism. For those unfamiliar with the genre, "Afrofuturism" was a term coined by Mark Dery in 1995 to describe art forms that draw on African or African American traditions to imagine futures that would be particularly liberatory, fun, or poignant for people—particularly, Black people—who have historically been underrepresented in science fiction and marginalized or harmed by actual science. This final case focuses primarily on Amiri Baraka, who addressed the issue of technological choice more explicitly than most.

In the parlance of present-day STS scholars Pinch and Bijker, the cases I discuss in this chapter illuminate the "interpretative flexibility" of different inventions. That is, Gilman, London, Baraka, and other Afrofuturists helped readers to see "that there is flexibility in how people think of or interpret artifacts but also that there is flexibility in how artifacts are *designed*. There is not just one possible way or one best way of designing an artifact" (Pinch and Bijker, 2012). Such flexibility can be erased by what these scholars call "closure" and "stabilization," which happens when "relevant social groups"—defined as "institutions and organizations … that share the same set of meanings, attached to a specific artifact"—agree that a technical problem has been rationally solved. According to Pinch and Bijker, that agreement occurs when that problem itself has been reframed, or when a new rhetorical frame that renders the perceived problem irrelevant.

To demonstrate the usefulness of these concepts, Pinch and Bijker chronicle the history of the bicycle—a commonplace technology that might seem to embody proof of linear, technological progress. As they argue, the design of contemporary bicycles seems in hindsight to be a rational improvement from the Penny Farthing bicycle with its distinctively enormous front wheel and notoriously unwieldy navigation.[3] However, they demonstrate that the eventual adoption of the low-wheeled bicycle with air tires arrived only after several nonlinear modifications in bicycle design and changes in cultural expectations about that method of transportation. For example, bicycle designs seemed risqué for women—both when their gowns made bicycling difficult and when men coded this activity as sexually gratifying for women. When ideas about women changed, this problem no longer needed to be addressed in bicycle design. While innovation and modification can still take place in such cases, the terms *closure* and *stabilization* signify a general consensus that such changes will be comparatively minor. Pinch and Bijker set out to demonstrate that the theoretical tools of social constructionism could also help scholars comprehend technology in a new and powerful way; I argue that the methods they developed can help us, in turn, understand the significance of literary interventions from an interdisciplinary perspective.

While this chapter emphasizes interpretative flexibility, other relationships between literature and technology exist—and they are rife for future exploration, as well. Sometimes scientists and technologists write literature, or they craft fantasies that structurally resemble literary narratives in their futurism.[4] Sometimes, innovators cite literature as their original source of inspiration.[5] When inventors credit authors in this way—as when, say, Werner von Braun traces his interest in rocketry back to Jules Verne—they are not insinuating that literature gave them fully formed ideas for new technologies to build. Rather, these technical thinkers are implying that fiction has helped to remind them of the social lives of objects and of the possibility to create previously unimagined things. In addition to helping to identify interpretative flexibility, literature can also inflect technological development in more diffusive ways. As Ronald R. Kline and I have argued elsewhere,[6] literature can also inflect "sociotechnical imaginaries," or a society's understanding of the good life that is, over time, concretized in policy and technological design (Jasanoff and Kim, 2009). This relationship is not unidirectional. Just as literature can help illuminate different possibilities for creating or understanding technology, technology shapes the form and content of literature, as well as its materiality (or the way we read it). When we read at the intersection of literature and STS, new patterns and possibilities become legible. This chapter models just one method for examining these two subject areas together.

Charlotte Perkins Gilman and the kitchenless home

Consider first the case of Charlotte Perkins Gilman, who recognized that the human-built world could take a different form because of her own personal experience of oppression. As a white woman who had suffered from severe depression, Gilman understood that the physical parameters of middle-class American life were not designed optimally for her health, happiness, or success. She famously questioned the design of a technology long thought to be stabilized: the architecture of the single-family house. In her fiction and nonfiction, Gilman promoted the radical, feminist idea of the kitchenless household. She imagined communities built around a centralized kitchen which could distribute food to private homes, just as central power stations deliver electricity to the public.

Both Gilman and the electrical industry recognized reluctant homemakers as what we might now call a "relevant social group" who had a shared cultural meaning of the kitchen as a burdensome space. However, the design solutions proposed by "architectural feminists"[7] diverged dramatically from those espoused by prominent inventors and entrepreneurs. In "The Woman of the Future," Edward Marshall's interview with Thomas A. Edison that was published in the October 1912 installment of *Good Housekeeping*, Edison promotes the more-popular solution.[8] In this interview, Edison agrees with Gilman insomuch as he notes that "the modern woman not only does not wish to be, but will not be, a servant." However, he argues that the only way to avoid women's servitude is to slightly modify the traditional configuration of the home with upgraded electrical appliances. Edison suggests that electrical appliances are the only available solution, because he assumes that women are "vastly man's inferior" and believes that the mere proximity to electricity will help improve women's neural connections). (One subsection of this interview is shockingly titled, "women to be able to think straight.") This argument was controversial enough that Marshall warned his audience that it would make "women's wrath … rise at first"—until his readers realized that they could eventually become the equals of men by owning electrical appliances. Gilman's writing flies in the face of such capitalistic and misogynistic narratives that suggest that the best way to "liberate" women from drudgery would be to buy new, cutting-edge appliances. Her account draws attention to technological alternatives available in that she urges her readers to question an invention that has long been stabilized. As she explains in her most influential treatise, *Women and Economics* (1898):

> Take the kitchens out of the houses, and you leave rooms which are open to any form of arrangement and extension; and the occupancy of them does not mean 'housekeeping.' In such living, personal character and taste would flower as never before; the home of each individual would be at last a true personal expression….
>
> This is especially needed for women, who are generally considered, and who consider themselves, mere fractions of families, and incapable of any wholesome life of their own … It is a glaring proof of the insufficient and irritating character of our existing form of marriage that women must be forced to it by the need of food and clothes, and men by the need of cooks and housekeepers. We are absurdly afraid that, if men or women can meet these needs of life by other means, they will cheerfully renounce the marriage relation.
>
> *(Gilman, 1898)*

In this passage, Gilman identifies an architectural choice that was not apparent to most Americans at the time. She argues that the expectation that every home must include a kitchen inhibits the development of "personal character and taste." By eschewing the kitchen, she suggests that individuals and families could turn homes into malleable spaces that are rife for self-expression and self-actualization. In other words, she argues that the status quo harms individual growth more than the socialization of kitchen work would.

Gilman repackaged the above argument from *Women and Economics* into multiple fictional examples, including her first novel, *What Diantha Did* (1910). This novel follows the titular character, Diantha Bell, as she sets out in pursuit of both marriage and employment. She embodies the movement to reimagine domestic labor as a science, and her astuteness and success simulate the success of Gilman's protofeminist ideas. Where Gilman emphasizes the refinement of individualized taste in *Women in Economics*, she underscores the financial benefits of socializing kitchen work in *What Diantha Did*. Midway through the novel, after Diantha gains some notoriety for being particularly smart and industrious, she is awarded an opportunity to address an audience of middle-class families who are a part of the "Home and Culture Club." To this socially conservative audience, she explains:

> For, say twenty families, we have twenty kitchens with all their furnishings, twenty stoves with all their fuel; twenty cooks with all their wages; in cash and barter combined we pay about ten dollars a week for our cooks—$200 a week to pay for the cooking for twenty families, for about a hundred persons!
>
> *(Gilman, 1910)*

This argument resembles a treatise in its reliance on *logos*, but the fictional medium affords Gilman the opportunity to acknowledge dissenting opinions and to simulate the process of persuading skeptics. The narrator intersperses the crowd's reactions to Diantha's speech, dramatizing the push and pull of proposal and dissent that precedes consensus. After Diantha makes the above argument, the crowd responds with uncomfortable silence: "Nobody said anything, but the visible attitude of the house seemed to say that it led straight to perdition." Such interjections allow Diantha's audience to serve as avatars for skeptical readers. When these characters become convinced by the ingeniousness of Diantha's plan, the reader might follow suit. For example, after Diantha senses the hesitancy of the glaring crowd, she explains: "The solution for which so many are looking is no new scheme of any sort; and in particular it is not that oft repeated fore-doomed failure called 'co-operative housekeeping.'" Gilman expects that her audience might be critical of "co-operative housekeeping" as a failed utopian venture, and she oscillates between Diantha's speech and the audience's reaction to elucidate how the kitchenless household would differ from that former, failed proposition.

As in *Women and Economics*, Gilman insinuates that kitchenless-ness could protect and even improve the ability of individuals and families to express themselves. Diantha continues her speech, adding:

> Every family is a distinct unit … Its needs are separate and should be met separately. The separate house and garden should belong to each family, the freedom and group privacy of the common milkman, by a common baker, by a common cooking and a common cleaning establishment. We are rapidly approaching an improved system of living in which the private home will no more want a cookshop on the premises than a blacksmith's shop or soap-factory. The necessary work of the kitchenless house will be done by the hour, with skilled labor; and we shall order our food cooked instead of raw. This will give to the employees a respectable well-paid profession, with their own homes and families; and to the employers a saving of about two-thirds of the expense of living, as well as an end of all our difficulties with the servant question. That is the way to elevate—to enoble domestic service. It must cease to be domestic service—and become world service.
>
> *(Gilman, 1910)*

Diantha's audience responds to her explanation warmly: "At this a wave of relief spread perceptibly." The form of the novel allows Gilman to represent resistance to her architectural feminism and to model how conservative concerns might be quelled. In multiple works, from the realistic *What Diantha Did* through her early utopias, Gilman rehearses the virtue of reimagining the American home. By reframing the home as a space that could be redesigned entirely, she suggests that Americans could improve the quality of meals through specialization, liberate women who are poor cooks from the emotional burden of constant failure, and enhance the institution of marriage by allowing men and women to develop relationships with one another without the exchange of protection and domestic service.

Gilman seems to expect that the most vociferous critique of kitchen removal will be the flattening of individual preference. Each of her pieces defensively insists that the kitchen diminishes individual freedom—especially, but not only, for women. While she advocates for reconceptualizing the home, she remains flexible about the optimal design. In her first utopian novel, *Moving the Mountain* (1911), she includes a very small kitchen in each home alongside the centralized and specialized kitchen to allow her characters to enjoy preparing their own food on the rare occasions when they choose to do so. To read Gilman's catalog of work today is to recognize the myriad ways that the material world might have been rebuilt so as to avoid creating what Ruth Schwartz Cowan (1983) would identify as "more work for mother" with a commodity-intensive lifestyle that continues to devalue domestic labor.

Jack London and agricultural engineering

Like Gilman, Jack London was also interested in identifying alternative choices that could reorganize the human-built world in ways that he perceived to be healthier for the white working or middle class. Where Gilman was interested in the constraints of the traditionally designed home, London was interested in electrical applications—and where technological choice is at the foreground of Gilman's novel, it plays a comparatively subordinate role in London's work. For example, the final novel that London published during his lifetime, *The Little Lady of the Big House* (1915), features a protagonist named Dick Forrest who excels at efficiency and optimization. This novel is at bottom a tragic love story about a husband (Forrest) and his wife, Paula, who falls in love with another man, Evan Graham. Forrest's preoccupation with improving agricultural efficiency is the character flaw that costs him his wife; Paula climactically kills herself to avoid damaging his reputation by running away with Graham.

Although Forrest's obsession with efficiency is his tragic flaw, the technological alternative that he describes is no less evocative than the idea of the kitchenless household. While his agricultural acumen is more often asserted than demonstrated, Forrest does show off one genuine innovation midway through the novel: "the one-man and no-horse farm where the farmer sits on the porch." The scheme is a large tractor with a button-operated ignition that turns on with "juice from a power company." Attached by a sturdy cable to a pole in the center of the field, the tractor plows in a circular route that converges on the pole. Forrest exhibits his invention to a potential investor, Mr. Gulhuss, who recognizes an apparent flaw in the design: "As it is, a circle in a square field loses some acreage." They estimate that three acres will be lost for every ten-acre plot. Dick explains that this loss can be negated by abandoning the conventional layout of the American farm:

> But the farmer has to have his front porch somewhere on his ten acres. And the front porch represents the house, the barn, the chicken yard and various outbuildings. Very well. Let him get tradition out of his mind, and, instead of building these things in the center of his ten acres, let him build them on the three acres of fringe. And let him plant his fruit and shade trees and berry bushes on the fringe. When you come to consider it, the traditionary [sic] method of erecting the buildings in the center of a rectangular ten acres compels him to plow around the center in broken rectangles.
>
> *(London, 1916)*

In this passage, London questions long-held assumptions that set needless limitations on future design. To improve one apparently isolated technology, the tractor, he suggests that we might have to raise new questions about seemingly ancillary issues, like the landscape design of the American farm. While this tractor concept might be obsolete today, this type of questioning models the process of discovering technological alternatives. And, perhaps more importantly, the tractor and farm are not the only conventions that London interrogated. He offers a more enduring and provocative example of technological choice in his depiction of energy generation and use—especially in his 1910 novel, *Burning Daylight*, and his 1914 novel, *The Valley of the Moon*.

As I argue in my book, *Power Lines: Electricity in American Life and Letters, 1882–1952* (2017) London offers a particularly interesting case study for illuminating the possible relationships between literature and energy. Although he is often remembered today for his writing about the northwestern frontier, he had biographical reasons for discussing technical systems and artifacts in his fiction: before he became a writer, London tried to become an electrician by working in a power station that provided energy for electric railways. That experience did not leave him with much in the way of technical expertise, as he spent his entire time in the power station shoveling coal. Yet, it might explain why he would bring the theme of power generation and distribution into novels that were more concerned with human happiness than with technological development.

Beyond his personal aspirations, London also had cultural reasons for incorporating developing power systems into his novels. During the turn of the twentieth century, London witnessed (and even took part in) the growing excitement about electrification. He likely would have read opinion pieces in local papers on the subject of adopting private or public power as they were peppered throughout the pages of local newspapers[9]—and London was an avid reader. In the San Francisco Bay area and Oakland, where he grew up, he would have witnessed the stringing of power cables and other components of power, communication, and transportation infrastructure. In this time period, local power companies crowed about the turn toward long-distance power transmission, touting it as a symbol of American ingenuity and as a linear improvement from previous forms of energy consumption.

Although electrical industry insiders tried to keep the public focused on long-distance power transmission as an optimal end goal for electrification, several design options were still available to people who desired power as London was writing *Burning Daylight* and *The Valley of the Moon*. During this time, Americans in coastal, urban areas were increasingly afforded access to power from central stations. Still, those who wanted power had alternative means of generating energy for home use. As Ronald R. Kline has argued in his 2002 study of the early days of rural electrification, when "electrical firms were reluctant to serve farmers … [p]rosperous farmers responded by finding innovative ways to make their own electricity or to obtain it from a high-voltage line or high-line." "Isolated plants" could also be built or purchased; these were especially useful to larger farms or mills that did not wish to be or could not be connected to a larger central station. These options were intentionally downplayed by an electrical industry that sought to promote centralized power transmission. As one expert reported to the American Institute of Electrical Engineers in 1912, among engineers the "isolated plant" was often denigrated or displaced because "The central station looms so large" (Moses, 1912). *Burning Daylight* and *The Valley of the Moon* draw attention to some alternative forms of energy generation and consumption that power companies might wish to obscure.

London engages with this debate by ventriloquizing the electrical industry's narrative about the linear progression of American energy generation and consumption in *Burning Daylight*. The main character, Elam Harnish (also known as "Burning Daylight" or "Daylight"), begins the novel as a frontiersman who uses clothing, his own body, and firewood for warmth and power. When he senses a coming gold rush, he upgrades his source of motive power and creates an electrical mining system that will preserve trees and extract gold from the land without ecological devastation. After hitting pay dirt, Harnish then invests his money in developing a long-distance, high-power transmission enterprise that resembles the western electrification projects of the day. The third-person narrator describes this sprawling endeavor as such:

> Not content with manufacturing the electricity for his street railways in the old-fashioned way, in power-houses, Daylight organized the Sierra and Salvador Power Company. This immediately assumed large proportions. Crossing the San Joaquin Valley on the way from the mountains and plunging through the Contra Costa hills, there were many towns, and even a robust city, that could be supplied with power, also with light
>
> *(London, 1910)*

Up to this point in the novel, Harnish's personal life maps onto the linear narrative of progress that the electrical industry promulgated: he seems to "evolve" from the use of combustible energy itself to the local power plant to the long-distance power system. However, London confounds this story of electrical progress by crafting characters that ultimately question the value of the large-scale system: Harnish eventually gives up his long-distance power system at the behest of his love interest, Dede Mason.

When Harnish first proposes marriage to Dede, she encourages him to stop his addictive cycle of wealth accumulation and to rediscover his "creative joy." Although present-day readers might expect a Jack London hero to feel most nostalgic for the outdoors, Harnish explains that he felt the most satisfied when he built his small electric outfit for mining. *Burning Daylight* ends with Harnish giving up his power company and moving, with Dede, to a small farm in Sonoma Valley, where he builds a Pelton wheel for power. It is unclear in the novel if the mechanism of the closing scene converts kinetic energy into electricity or if it directly powers equipment in the Harnish household. In either case, this turn to a private source of power challenges the popular idea that larger-scale energy systems are always preferable.

London constructed a similar narrative about energy generation and consumption in his personal favorite of his own novels, *The Valley of the Moon*. Like *Burning Daylight*, this novel is not *about* electricity or any technology, but it invokes the context of electrical development nonetheless. The first chapter opens in a dry cleaner, where the transparently named heroine, Saxon, attempts to maintain the factory-like regularity of ironing starched shirts despite a distracting conversation. London sets the scene of the sweatshop: "The long summer day waned, but not the heat, and under the raw flare of electric light the work went on" (London, 1914). When Saxon leaves for the day, her walk home is similarly marked by electricity: "Two blocks from the laundry, where an arc-light showed a gang of toughs on the corner, Saxon quickened her pace." But her home is described as "[d]ark," and lit by a "solitary gas-jet." The comingling of comparatively new electrical light systems and old gaslights realistically captures what David Edgerton (2007) calls "the shock of the old," or the fact that people continue to use old technologies even as new ones are introduced—or, more strongly, the fact that the old technologies we continue to use might be more important in our lives and culture than invention or innovation, although both of those processes have garnered outsized attention in our cultural understanding of technology.

Ultimately, the contrast between electric and gas lights in the first chapter of the novel represents more than the "reality effect" of establishing a plausible and visualizable setting[10]; it underwrites one of the key tensions in the novel. When London depicts the white, working-class experience of electrification, he is identifying what social construction of technology scholars would now call a relevant social group's perception of a problem with electricity: to this social group, electricity is expensive and associated with the exploitation of poor, white characters, including Saxon, her beau and eventual husband Billy, and their friends. A power company called Niles Electric even kills workers in one union-busting conflict midway through the novel.

Later in *The Valley of the Moon*, London imagines both a rhetorical and a design-based solution to this perceived problem. While the contrast between electric lights and gas jets in the first chapter may appear subtle, electricity takes on a more prominent role near the climax and conclusion of the novel. After a series of misadventures, Saxon and Billy decide to leave Oakland on foot in order to find a more salutary way of life, eventually finding a car to help on their mission. Like their pioneering parents, they aspire to settle free government land in California. Along the way, they encounter "new" largely segregated populations whose agricultural practices the protagonists are alternatively dismayed and amazed to discover on their journey. They meet Portuguese, Dalmatian, and other immigrant farmers who Billy dehumanizes with a comparison to pigs; they also befriend nativist white agricultural engineers whose farming techniques blend irrigation and electrification. To Saxon and Billy, these electrified farming practices signify efficiency and racial superiority. These are the science-informed techniques that the children of Western colonizers can use to successfully live off the land when their parents failed. As one white farmer describes the electrical irrigation system: "'Isn't it beautiful, eh?—beautiful! beautiful!' [the farmer] chanted in an ecstasy. '… It makes a gold mine laughable.'"

Some of these white-owned electrified farms are connected to the electrical and social power systems that Billy and Saxon had tried to escape by leaving Oakland. The narrator describes the infrastructure that makes these intensive farming techniques possible:

> North they drove, through days of heat and dust, across the California plains, and everywhere was manifest the 'new' farming—great irrigation ditches, dug and being dug, the land threaded by power-lines from the mountains, and many new farmhouses on small holdings newly fenced.
>
> *(London, 1914)*

This application of electricity is glamorized in contrast to the exploitative use of electricity in Oakland from the early pages of the novel. In this way, these passages subtly support the electrical industry's claim that central power stations are optimally useful. Considering that *Burning Daylight* was published four years earlier and included no mention of such rural power lines, this detail might also indicate the expansion of electrical networks outside of urban centers in the early 1910s. In either case, Billy and Saxon want to live disconnected from these cables, without surrendering the conveniences afforded by electrical power.

Ultimately, Saxon and Billy find land that they feel rightful ownership to because it was never populated with Mexicans, "Asiatics," or "Europeans"—indigenous Americans are not mentioned at all. The narrator explains: "The scant population consisted of original settlers and their descendants. More than one old man or woman Saxon talked with, who could remember the trip across the Plains with the plodding oxen." London builds upon this white-supremacist fantasy by adding another fantastical element to the novel's conclusion, when Billy and Saxon find a hidden reservoir of water that they can claim ownership to. Indeed, water rights are an important subtheme in the novel, and that problem is solved fantastically rather than realistically: the reservoir allows them to generate their own power and irrigate their own land.

Although key elements of this conclusion are unrealistic, London's example in *The Valley of the Moon*—as in *Burning Daylight*—still draws attention to actual technological choices that were available at the time of his writing. Americans did not have to buy electricity from power companies. They could choose to generate their own power in different ways. These examples also demonstrate why the study of literature can benefit from such a reading in conversation with technology studies. Because London has been (mis)remembered as *only* a literary naturalist (or a writer who was interested in the degenerative forces of urban life and the inherent wildness of men), previous literary critics have interpreted these novels as paeans to a foregone past.[11] When we come to London's agricultural novels with such expectations, the Edenic conclusions to *Burning Daylight* and *The Valley of the Moon* might seem to realize the pre-industrial fantasy that underwrote London's earlier fiction. However, both novels imagine an alternative future instead of a return to the past. Both were written as long-distance power systems were being developed by engineers and by a near-monopoly of electrical concerns. By turning (rather than re-turning) to an alternative form of energy use, both novels demonstrate that Americans had more choices than those that the electrical industry advertised. Potential consumers still might have asked whether energy generated locally for personal use might better serve their purposes than central-station power. Once again, perspectives and choices that are underrepresented in STS can become apparent when we read literary and technological history together.

Amiri Baraka and the Afrofuturists

Gilman and London both published during a time when writing about inventions was a relatively new subgenre, often considered the fare of lowbrow dime novels that we now call "Edisonade." Although they wrote about worlds that had some fantastic elements, both writers were famous for writing in the genre of "literary realism," which was considered highbrow and ethically important from the 1870s through the 1910s. Public figures including William Dean Howells, the editor of the influential journal *The Atlantic Monthly*, assured readers that writing about real life was the best way to cultivate taste and empathy. Throughout the twentieth century, realism lost some of its allure, and literary explorations of technological possibilities began to form newly named subgenres. After Edisonade came "scientifiction," Hugo Gernsback's portmanteau that eventually cleaved into the better-known genre of "science fiction"; from these traditions emerged steampunk, cyberpunk, and the newest, most optimistic of these subgenres, solarpunk. Afrofuturism is sometimes understood to be a part of this evolving literary tradition, though I contend that it is more accurate to think of the genre as coeval, as it migrated from the musical experimentation of artists like Sun Ra into the pages of writers such as Ishmael Reed or Nalo Hopkinson. Afrofuturism provides a particularly interesting final case for this chapter because, like the examples provided by Gilman and London, it tends to elucidate the perspectives of people who have been disenfranchised by existing technological regimes and to imagine alternative technosocial forms. Gilman wrote from the perspective of women who were limited by patriarchal and parochial thinking about domestic space; London wrote from the perspective of the white working class; and, as the name suggests, Afrofuturists wrote from the perspective of the African diaspora, imagining alterative futures that were not fettered by white supremacy or colonialism.

LeRoi Jones, who changed his name to Amiri Baraka, offers a particularly explicit, evocative, and outlandish example of creative, Afrofuturist nonfiction in his 1969 essay, "Technology and Ethos." Crucially, Baraka is not always categorized as an Afrofuturist, and technology was not a common subject of his oeuvre; he fits more neatly into the Black Arts movement, a political literary movement that began in the 1960s. Nonetheless, Baraka demonstrates astounding insights in this piece that resonate with STS and Afrofuturist literature alike.

Throughout "Technology and Ethos," he uses unconventional spelling and italicization to challenge writerly norms as he explains why we should all challenge technological norms:

> Nothing *has to* look or function the way it does. The West man's freedom, unscientifically got at the expense of the rest of the world's people, has allowed him to xpand his mind–spread his sensibility wherever it *cd* go, & so *shaped* the world, & its powerful artifact-engines.
>
> *(Baraka, 1971)*

Baraka suggests that the technological world is more malleable than most might imagine. And he does more than critique how those power structures were designed to disenfranchise him or people who look like him: he also piques his readers' excitement about building a new world.

Contemplate, for example, Baraka's multisensory vision of a system that could replace the typewriter—an outsized idea that imagines what communication could look like if we transcended the Cartesian mind/body duality and tried to communicate more than our thoughts:

> A typewriter?–why shd it only make use of the tips of the fingers as contact points of flowing multi directional creativity. If I invented a word placing machine, an "expression-scriber," if you will, then I would have a kind of instrument into which I could step & sit or sprawl or hang & use not only my fingers to make words express feelings but elbows, feet, head, behind, and all the sounds I wanted, screams, grunts, taps, itches, I'd have magnetically recorded, at the same time, & translated into word–or perhaps even the final xpressed thought/feeling wd not be merely word or sheet, but *itself*, the xpression, three dimensional–able to be touched, or tasted or felt, or entered, or heard or carried like a speaking singing constantly communicating charm.
>
> *(Baraka, 1971)*

Baraka was not, to my knowledge, a tinkerer with the technical skills to create his speculative "expression-scriber." According to Stephen Hilgartner's idea of visionaries at the vanguard, Baraka would not plausibly be able to create the invention he describes (Hilgartner, 2015). If Baraka could not build the emancipatory material world he imagined, he could nonetheless remind us that such a world is possible. In a society that often imagines technology as an autonomous entity that impacts society, rather than as an inextricable part of society, that reminder is a revolutionary act in itself.[12]

While Baraka's example is more hyperbolic than the texts I analyzed above, he demonstrates how technologies like the typewriter can be oppressive and racialized in insidiously subtle ways. Baraka's essay also anticipated certain key arguments that would be expanded and formalized in the discipline of STS years later. Seventeen years before Langdon Winner asked whether or not "artifacts have politics," Baraka assured his readers that they do[13]; fifteen years before Trevor Pinch and Wiebe Bijker investigated the "social construction of facts and artefacts," Baraka asserted that technologies develop in specific social contexts that influence both use and design.

Other Afrofuturist texts might be less explicit than Baraka about the power dynamics their imaginary worlds entail. Nalo Hopkinson is one such writer, whose work explores other ways of being in our bodies and in the material world, much as Baraka predicted decades earlier. Her work—and the work of others in this genre—explores the multiplying potentialities that can follow from different types of technosocial experimentation. For example, in a widely acclaimed short story, "Ganger (Ball Lightning)" (2000), Hopkinson imagines an invention, "the Senstim Co-operation's 'wetsuits'," which are designed to increase sensitivity during sex. The story begins when Cleve asks Issy, "suppose we switch suits." This proposal would allow them to experience sex from each other's perspective—or at least from the perspective of the opposite gender. As Issy glibly puts it, "The innie become an outie, the outie become an innie…"

Issy and Cleve have radically different experiences during their voyeuristic encounter. Cleve has an abject reaction to the feeling of female embodiment—and not only because he rejects the experience of penetration. He shudders, "God, I don't want to ever feel anything like that again. I had breasts, Issy. They swung when I moved." Issy comforts her distraught partner, but laments the loss of what she describes as "the hermaphroditic feeling": "For a few seconds, she'd felt something of what he felt when they had sex. For a few seconds, she'd felt the things he'd never dared to tell her in words." Although Issy seems to enjoy the experience, she eventually teases Cleve for wanting to try the skin suits to begin with, saying: "Ninety-six degrees in the shade, and we're wearing rubber body bags" (Hopkinson, 2000).

Hopkinson's story brings together elements of Baraka's euphoric, Afrofuturist essay and of Donna Haraway's *A Cyborg Manifesto*—both texts that encourage readers to imagine how we might foster different relationships among bodies, things, and worlds. Whereas Baraka and Haraway emphasize the affirmative aspects of such a reimagining, Hopkinson creates a nuanced depiction of the conflicted relationships that arise from changing human–technology relationships. While the possibility for gender play seems liberating to both characters at first, the reactions to the experience are intensely idiosyncratic.

"Ganger (Ball Lightning)" has a less realistic referent than does Gilman's remodeled home or London's rewired farm—or even than Baraka's "expression-scriber"—it nonetheless raises questions about how existing or not-yet-existing technologies become integrated with our sexuality or our sense of self. While any literary work can invite such reflection, the comparatively new genres of science fiction or Afrofuturism can be particularly fertile places to look for creative interpretations of technological regimes, as we mine the intersections between literature and technology.

Conclusion

Literature is, above all else, a dynamic art. While the words of a narrative may be fixed on a page, each reading forges a new interaction between author, reader, and text. Thus, literature offers us something more than a reflection of how readers understood their world in the past; it provides us with insight into the different possibilities that once seemed (and might yet be) attainable. In this respect, when we read Gilman with an eye for technological choice, we can understand her as an activist who wrote fiction and nonfiction to advocate for physical changes to single-family homes—modifications that she believed would improve the health of American women. And, while few adopted the kitchenless household design, the present-day boom in meal-delivery services suggests that the core desires she discussed remain relevant today.

Similarly, the technological alternatives that London envisions in *Burning Daylight* and *The Valley of the Moon* remain relevant today. While the long-distance power transmission system has been stabilized for most Americans, increasingly dangerous storms threaten the robustness of these systems. For example, after Hurricane Maria caused a devastating blackout across all of Puerto Rico, the difficulty of getting the system back on-line has prompted a turn toward thinking about the benefits of localized power generation. Climate change has reopened technical problems that have long seemed closed or stabilized. As we seek to imagine alternative futures, we find this a fruitful moment to turn to narratives that deal with the interpretative flexibility.

Finally, Baraka, Hopkinson, and other writers of science fiction or Afrofuturism draw attention to power dynamics that can seem invisible in other contexts. Gilman's and London's narratives imagined new ways for white women or lower-class people to garner social power. Baraka and Hopkinson do more than add a corrective from a Black perspective—they lay bare the assumptions that underwrite our technosocial lives. Baraka does not suggest that the typewriter is a particularly oppressive technology, in the way that Gilman suggests that the kitchen functions; nonetheless, he demonstrates that it is a *limiting* technology whose purported usefulness inhibits us from recognizing other possibilities. Hopkinson raises similar questions about the myriad devices that are designed to heighten sexual pleasure, including her science-fiction skin suits, as well as "strap-ons or cuffs padded with fake fur." She encourages readers to wonder if these prostheses are merely tools that enhance our experiences or if they change our embodiment in more profound ways.

There are myriad authors who warrant our attention—many more than I could address in this short chapter. Contemporary pieces such as Emily St. John Mandel's *Station Eleven* (2014) or Ted Chiang's virtuosic novella *The Truth of Fact, The Truth of Feeling* (2013) address issues of technological choice, today, for example. While London and Gilman's examples can help us see how literary interpretation can benefit from understanding STS, Baraka and Hopkinson demonstrate how STS can benefit from reading literature from different perspectives—especially those perspectives that challenge received norms. Such insightful narratives attest that we should be reading widely as we address the technological issues of our present and future. What texts or technologies might you read differently, with an eye toward building a different world?

Notes

1 See Schatzberg, Eric. "*Technik* Comes to America: Changing Meanings of *Technology* before 1930." *Technology and Culture* 47 (July 2006): 486–512; Marx, Leo. "*Technology*: The Emergence of a Hazardous Concept." *Social Research* 64 (Fall 1997): 965–988; and Oldenziel, Ruth. *Making Technology Masculine: Men, Women, and Modern Machines in America, 1870–1945*, Amsterdam: Amsterdam University Press, 1999, especially pp. 40–42.
2 Latour, Bruno and Steve Woolgar. *Laboratory Life: The Construction of Scientific Facts*, Princeton, NJ: Princeton University Press, 1979: 45–53.
3 For a humorous and realistic account of riding a Penny Farthing bicycle, see Twain, Mark. "Taming the Bicycle." https://www.loa.org/news-and-views/1355-mark-twain-taming-the-bicycle
4 See, for example, Milburn, Colin. "Modifiable Futures: Science Fiction at the Bench." *Isis* 101.3 (2010): 560–569.
5 See, for example, Disch, Thomas M. *The Dreams Our Stuff Is Made of: How Science Fiction Conquered the World*, New York: Free Press, 1998.
6 Lieberman, Jennifer L. and Ronald R. Kline. "Dream of an Unfettered Electrical Future: Nikola Tesla, the Electrical Utopian Novel, and an Alternative American Sociotechnical Imaginary." *Configurations* 25.1 (2017): 1–27.
7 On architectural feminism, see Hayden, Dolores. *The Grand Domestic Revolution: A History of Feminist Designs for American Homes, Neighborhoods, and Cities*, Cambridge, MA: MIT Press, 1981.
8 "The Woman of the Future." *The American New Woman Revisited: A Reader, 1894–1930*, edited by Martha H. Patterson, New Brunswick, NJ: Rutgers University Press, 2008: 258–266.
9 On this deceptive public relations campaign, see Thompson, Carl D. *Confessions of the Power Trust*, New York: Dutton, 1932: 321–323.

10 See Barthes, Roland. "The Reality Effect." In *The Rustle of Language.* Trans. Richard Howard, Los Angeles, CA: University of California Press, 1986: 141–148.
11 See Gair, Christopher Hugh. "'The Way Our People Came': Citizenship, Capitalism, and Racial Difference in *The Valley of the Moon*." In *Rereading Jack London*, edited by Leonard Cassuto and Jeanne Campbell Reesman. Stanford, CA: Stanford University Press, 1996: 141–157.
12 For more on Baraka and Technology, see Fouché, Rayvon. "Say It Loud, I'm Black and I'm Proud: African Americans, African American Artifactual Culture, and Black Vernacular Technological Creativity." *American Quarterly* 58 (September 2006): 639–661.
13 See Winner, Langdon. *The Whale and the Reactor: A Search for Limits in an Age of High Technology.* Chicago, IL: University of Chicago Press, 1986.

References

Baraka, Imamu Amiri. "Technology and Ethos." *Raise Race Rays Raze: Essays since 1965.* New York, NY: Random House, 1971: 155–157.
Cowan, Ruth Schwartz. *More Work for Mother: The Ironies of Household Technology from the Open Hearth to the Microwave*, New York, NY: Basic Books, 1983.
Dery, Mark. "Black to the Future: Interviews with Samuel R. Delany, Greg Tate, and Tricia Rose." In *Flame Wars: The Discourse of Cyberculture*, edited Mark Dery, Durham, NC: Duke University Press, 1994: 179–222.
Edgerton, David. *The Shock of the Old: Technology and Global History since 1900.* Oxford: Oxford University Press, 2007.
Gilman, Charlotte Perkins. *Moving the Mountain.* New York, NY: Charlton, 1911.
Gilman, Charlotte Perkins. *What Diantha Did.* 1910. Reprint. Durham, NC: Duke University Press, 2005.
Gilman, Charlotte Perkins. *Women and Economics.* Boston, MA: Small, Maynard, & Co., 1898.
Hilgartner, Stephen. "Capturing the Imaginary: Vanguards, Visions and the Syntheticbiology Revolution." In *Science and Democracy: Making Knowledge and Making Power in the Biosciences and Beyond*, London: Routledge, 2015: 33–55.
Hopkinson, Nalo. "Ganger (Ball Lightning)." *Dark Matter: A Century of Speculative Fiction from the African Diaspora*, edited by Sheree R. Thomas. New York, NY: Warner Aspect 2000 (2000): 134-151.
Jasanoff, Sheila and Sang-Hyun Kim. "Containing the Atom: Sociotechnical Imaginaries and Nuclear Power in the United States and South Korea." *Minerva* 47.2 (2009): 119–146.
Kline, Ronald R. *Consumers in the Country: Technology and Social Change in Rural America*, Baltimore, MD: Johns Hopkins University Press, 2002.
Lieberman, Jennifer. *Power Lines: Electricity in American Life and Letters, 1882–1952*, Cambridge, MA: MIT Press, 2017
London, Jack. *Burning Daylight.* New York, NY: Macmillan, 1910.
London, Jack. *The Little Lady of the Big House.* 1916. Rpt. Orinda, CA: Sea Wolf Press, 2018.
London, Jack. *The Valley of the Moon.* New York, NY: Macmillan, 1914.
MacDougall, Robert. *The People's Network: The Political Economy of the Telephone in the Gilded Age*, Philadelphia, PA: University of Pennsylvania Press, 2013.
Marshall, Edward. "The Woman of the Future." 1912. Reprint. *The American New Woman Revisited: A Reader, 1894–1930*, edited by Martha H. Patterson. New Brunswick, NJ: Rutgers University Press, 2008: 258–266.
Moses, Percival R. "Some Notes on Isolated Plants." *Proceedings of the American Institute of Electrical Engineers* 31.1 (1912): 67–98
Pinch, Trevor J. and Wiebe E. Bijker. "The Social Construction of Facts and Artifacts: Or How the Sociology of Science and the Sociology of Technology Might Benefit Each Other." In *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology*, anniversary edition, edited by Wiebe E. Bijker, Thomas P. Hughes and Trevor Pinch, Cambridge, MA: MIT Press, 2012: 17-50.

13

Art's Work in the Age of Biotechnology

How art can make arguments in science and technology studies

Hannah Star Rogers

Under three glass cloches are versions of the scent of an extinct plant made possible by synthetic biology and art. This is *Extinct Perfume*, speculative aromas based on fragments of DNA from the extinct flowering plant *Hesperelaea palmeri* created by Christina Agapakis, a synthetic biologist and designer at Ginkgo Bioworks.[1] The pressed plant was stored in an herbarium for nearly 150 years before Agapakis obtained samples for genotyping. Using the plant's genome and living botanical relatives, she worked with paleogeneticists and perfumers to produce an experience of the plant's scent from the samples. Her work functions as a provocation and critique of attempts to recreate extinct organisms from DNA fragments. While *Extinct Perfume* is positioned in the liminal and exciting space of art–science work, its goals are not only artistic and technical. The work also engages audiences with ideas about de-extinction, its technical limitations, and the aesthetic desires it promises to fulfill, in whatever limited way.

In art that engages with science, both the importance of the public in relation to the politics of contemporary science and the potential to extend the public understanding of science and art are always close at hand.[2] *Extinct Perfume* is exemplary of this dynamic. The artist presents her work as art, but this particular piece required considerable technical skill in cutting-edge synthetic-biology techniques. In a sense, *Extinct Perfume* is also an exploration of an emerging science, engaging themes from the philosophy of science and social choice around public policy. In the latter two respects, *Extinct Perfume* looks a lot like a Science and Technology Studies (STS) inquiry. A critical assessment of science and technology can be produced through textual or material means: both can help make arguments. STS scholars have been particularly aware of both the ways in which technologies make arguments and the roles that materials-based experimental performance can play in the establishment of scientific findings. Artists' materials can be analyzed by STS scholars using a given theory that they developed to understand the scientific uses of such materials, including hitherto unexplored uses.

Exhibits on the history of technology make arguments about the future of technology. Arguments about the future of technology—in this case, biotechnology—constitute histories of the subject. Curators must necessarily take a stance and mark their controlled public space as a site of intervention. As an STS scholar, I use curatorial practices that are guided by this sensibility, which is increasingly informing projects that aim at public transparency. My own

 DOI: 10.4324/9780429437069-17

efforts have been in the area of art, science, and technology, an area that, though fraught with power differentials, has the potential to address complex problems. *Art's Work in the Age of Biotechnology: Shaping Our Genetic Futures*, a pop-up exhibit I curated at the Contemporary Art Museum (CAM) in Raleigh, North Carolina, in April 2017, elicited discussion about genetics in society through provocative contemporary art and offered viewers new ways to think about their role in the genetic revolution. The exhibit reflected my attempt to wind together the history of genetics and the history of art to offer a more complete interdisciplinary history—one that would continue to influence contemporary bioart. Along with the turn toward material practice in a variety of humanities fields and the urgency of science and technology policy for emerging technologies, exhibits in the area of technology can be interpreted as social and political interventions.

As the curator of art–science exhibitions using STS ideas, I have been interested in exploring the potential for a biotechnology exhibition to frame the subject as political and help to explore and contest the power vested in biotechnology, rather than presenting a one-way flow of information. My hope is that this project creates an opportunity to explore how exhibition visitors understand artworks and technical materials. As Megan Halpern and I note in the introduction to this book, STS scholarship can elucidate how knowledge products might be understood in symmetrical ways (Barnes, Bloor, and Henry 1996). What is in the mind of a curator or scholar, however, can be broadened through the knowledge available via the arguments that artists make through their creations or, in the case of conceptual art and some modes of critical design, through their suggestion of creations. Text is not the only way to make arguments. Materials, too, have the potential to impact conversations in new ways.

The focus of this chapter is contemporary artists who are engaged with the life sciences. The connections between these cultural workers and STS scholars are many, as both the workers and the scholars address many of the same themes, rely on much of the same literature, and can participate in exchanges that would be fruitful not only mutually but also for public discourse, in general. Though my focus here will be limited to a selection of artists from *the Art's Work in the Age of Biotechnology Field Trial* held in 2017 at the CAM in Raleigh, NC, in preparation for the major multisite exhibition *Art's Work in the Age of Biotechnology* (2019–2020), the argument for the inclusion of artists in STS work certainly extends to the many other artists focused on other forms of science. The artists in this exhibition are engaged with science and technology as both mediums and objects of critique. Often, they share STS scholars' thematic concerns, as a review of *The Handbook of Science and Technology Studies* (2017) makes clear. For example, Rappert, Balmer, and Stone (2017) discuss the military, the formation of STS in relation to war, and the body as a site for understanding military action. These interests, along with corporate and military control of science, have been the subject of artworks ranging from ®TMark's *Mutual Funds* (2000) to CAE's *The Marching Plague* (2006). Bioart has featured feminist work from the outset (Kelley 2016). Researchers and practitioners have also expressed a special interest in how gender and surveillance align around pregnant bodies. Examples of this theme include the subRosa cyberfeminist collective, led by artists Faith Wilding and Hyla Willis. Their net art piece *SmartMom* from 1999 anticipated the extensive digital pregnancy-monitoring systems that have since emerged. The piece critically blended ideas about surveillance and women's bodies with the new technical possibilities of the Internet. Technologies of reproductive control have been of interest to STS scholars including Sarah Franklin (1993, 2007). Her Cambridge-based ReproSoc group curated *Life in Glass*, an exhibit addressing representations of in vitro fertilization and other assistance technologies. The role and the reuse of model organisms in shaping laboratory biology have been important to STS scholars (Rader 2004; Ankeny 2010) and bioartists alike. For example, bioartist Adam Zaretsky investigated model organisms in his classic performance piece *WorkHorse Zoo* (2002), which took the form of a live-in installation.

Some STS scholars have focused on particular model organisms. Examples of this trend include Rob Kohler's *Lords of the Fly* (1994), Joanna Radin's work on the standardization of laboratory mice (2004), and Nicole Nelson's work on the nature of animal modeling (2018). Ideas about animals as models in relation to humans have been further theorized by Angela Creager and William Jordan in *The Animal/Human Boundary* (2003). Indeed, the number of artworks in this area is overwhelming. They range from Verena Kaminiarz's *May the Mice Bite Me If It Is Not True* (2008) and *Death Masks* (2008) for laboratory mice to Kathy High's *Embracing Animal: Rat Love Manifesto* (2005). In this last work, rats not only model diseases from which the artist herself suffered but also receive her own homeopathic cures.

STS scholars and artists have also dealt with specific technologies and their relationship to the law. In *Truth Machine: The Contentious History of DNA Fingerprinting* (2008), Kathleen Jordan, Michael Lynch, Ruth McNally, and Simon A. Cole give a complex account of how legal strictures, scientific information, and social understanding of "DNA fingerprinting" come together. Similar themes, particularly as they concern technology's flexibility, are the collective subject of *Latent Figure Protocol* (2007–2009) by Paul Vanouse. In this work, Vanouse explores the visual output of DNA images and their effects on the public by creating recognizable symbols using gel electrophoresis. Vanouse's process uses enzymes to cut the DNA into fragments for gel electrophoresis and, particularly, when proprietary enzymes common in crime labs render image comparison null, thus complicating the replication of the tests. More recently, Vanouse has explored ways to alter these technologies to emphasize genetic sameness over difference, as in *America Project*, winner of the 2017 Prix Ars.

STS scholarship has also considered how metaphors that shape our understandings of climate change and ideas about our own ability to intervene in public scientific discourse. This line of inquiry concerns works that help conceptualize climate change while offering a critical edge to claims that technology can solve the problem. Two works that exemplify this scholarship are Catts' *Autotroph* (2010) and Sobecka's *Cloud Machine* (2012). Of course, many diverse issues are central to the STS perspective, and many STS artists regard themselves as activists who have a specific agenda at the site of a political or ethical question in which science or technology is central. Other artists think of their work as a form of research, or even explicitly as an experiment, about what art can add to public conversations in which science is a central player.

To see these artists as outside the STS community is a form of boundary-making in itself, and a great deal can and probably will be written about this question as Art, Science, and Technology Studies (ASTS) develops as a discipline. One easy way to spot the difference between the two disciplines is to consider the materials (e.g., the tools) that go into making STS arguments. These materials go beyond recorders, laptops, and everyday office supplies that feature so prominently in STS research proposals, which are like scientists' immutable mobiles (Latour 1986), a vital feature of the production and dissemination of knowledge. Nor is it likely for STS practitioners to argue that ideas conveyed through linguistic means are less potent than materials, but few of us would expect our rhetorical tools to displace the potential of materials. Traditional informants (scientists, engineers, and technicians) have much in common with artists who make arguments through artworks. Like the materials of our traditional informants, the materials that artists manipulate are often supported with the written or spoken word. In this sense, artists fit neatly into STS, especially as it concerns the interplay between artifacts and practice.

Bodies are the object of so much biological research, yet the experience of the body is often left to artists. If we propose to study life, we must insist on visions from both art and science. It is these simplistically categorized divisions that my 2017 exhibit *Art's Work in the Age of Biotechnology* (or *Art's Work* for short) served to complicate: divisions between bodies and experiences, between the public and experts, and between a biologically deterministic view of our futures and a view predicated on people's ability to freely make social choices. Accordingly, I, along with the *Art's Work* team, chose these artworks in order to complicate simplistic divisions, to raise questions about the roles of science and art, and to promote co-operation among knowledge communities that are not easily categorizable. Science, as well as art, is in the eye of the beholder.

In order to consider how artists work on subjects that STS scholars typically claim as their own, this chapter focuses on a specific group of works that appeared in the *Art's Work* exhibit. A close examination of these artworks will expose some of the overlapping interests and approaches in the two areas, while revealing differences, as well. Biotechnology and art are fascinatingly intertwined, from our aesthetic appreciation of plants and animals to breeding regimens to art about ethics in the genomic age. While my primary goal in *Art's Work* was to create an opportunity for people to consider artworks related to biotechnology, the 2017 exhibit also served to elicit discussion about genetics in society through provocative contemporary art and to offer people new ways to think about their roles in the genetic revolution. The exhibit, however, did not serve as a science-communication tool, if one understands this term to mean a translation of scientific information into a more attractive, agreeable, or relatable form. Rather, *Art's Work* created a space in which different kinds of conversations could take shape regarding the meaning of biotechnology in society and in individuals' lives. Through these works, artists argue for modes of seeing the world that align directly with ideas in STS.

In short, artists are practicing STS by material means. The artists share STS concerns: who gets to set the agenda of science, who gets to participate in its workings, and how does science create and maintain knowledge and related power? By considering the materiality of the artworks in my exhibit, we get a sense of the possibilities and the limitations that characterize STS ideas. As an STS scholar and curator working at the intersection of art and science, I am mindful that installations can be made to fit into the knowledge networks of art, science, or combinations of both. Viewers' perceptions of art and science shape the politics of meaning ascribed to the artworks in the exhibit. Dimensions of both biotechnology and art were on display in *Art's Work*. Many of the works showed the fruits of art–science collaborations. When based on STS research, analyses of the relationship between art–science collaborations and the exhibit's individual artworks reveal affinities between these two areas of knowledge. *Art's Work* argues that when we think of art and genetics together, we reach toward understandings about the human condition, the material of our bodies, and the consequences of biotechnology in ways that are possible only through the combination of bench science and contemporary art.

Art's Work began with Vanouse's classic work *Latent Figure Protocol* (2007–2009) and opened into the space to unfold new ways of thinking about biotechnology and its implications. The artworks in this exhibit recontextualize genetic information by bringing it out of the lab and into everyday situations. This evidence from performative intervention asks visitors to consider the construction of DNA fingerprinting technology and does so by casting into relief the technology's corporate connections and legal-status complications. The dimensionality of the technology takes shape when Vanouse hacks gel electrophoresis technology, explains its use, and illuminates the social interpretation of the images it produces. At CAM, this work documented the artist's technical and political talent for creating specific images rooted in the reverse-engineering of technology (Figure 13.1).

Figure 13.1 Christina Agapakis' *Extinct Perfumes*. Perfumes created by Symrise: Isaac Sinclair, Fanny Grau, and Maurice Roucel. Scans of horticultural specimens at the 2017 CAM Raleigh exhibit *Art's Work in the Age of Biotechnology*. April 7, 2017. Photo credit: York Wilson

The boundary-crossing artworks in *Art's Work* challenge us to examine what might seem to be a discrete boundary between art and science. These artworks collectively suggest that the categories of art and science are not determined by universal axioms or by practices that circumscribe bodies of knowledge. The artworks further suggest that their respective subjects can be integrated on material, practical, and epistemic levels. The epistemic level, in particular, is noteworthy, as it can reinforce the ideas that overlap between these categories. As analysts, we can observe the distance the artworks go in deconstructing or making use of the boundary-making project of art and science. However, the artworks themselves aim critically at technical and aesthetic subjects rather than directly expose definitional complications.

The task of deconstructing boundaries has been central to STS practice for many years and can help us understand the rhetoric that artists use to situate their works. Agapakis' *Extinct Perfume* displayed three speculative aromas based on fragments of DNA from the extinct flowering plant *Hesperelaea palmeri* stored in an herbarium for nearly 150 years. The perfumes are the results of a collaboration between a designer, botanists, biochemists, biological engineers, and perfumers from Symrise. In displaying alternatives, the artist asks what we lose when a species is lost and only DNA remains. She offers us a sense of the plant through our senses, which triggers a bodily experience of the loss of a species. The implicit questioning of science of the kind performed by Harvard University's George Church, who has attempted to produce the genome of a wooly mammoth, is readily recognizable in STS circles. This activism overlaps with the interventions of STS scholars who have worked both in politics and with the public to bring forward new ways of connecting people to science through careful critiques of different aspects of the scientific process and its public reception.

Continuing through the *Art's Work* exhibition, Richard Pell, director and founder of the Center for PostNatural History (CPNH) in Pittsburgh, Pennsylvania, presented an artwork derived from his CPNH collection, *Spectres of the PostNatural*, for the exhibition, which consisted of stereoscopic images of specimens from CPNH. CPNH works with scientists and artists to preserve specimens that tell the story of human interactions with other organisms. CPNH explores the complex interplay between culture, nature, and genetic interventions by preserving and documenting organisms of postnatural origin. With a collection including genetically modified mosquitoes and dogs that have been bred for aesthetics and utilitarian traits, Pell has accomplished with a collection of specimens what many STS scholars have done by collecting stories: he has curated a series of case studies that argue his thesis that we are living in a post-natural world. His argument is outward-facing, positioned to attract a public audience to his exhibits in order to make the case that we do not stand outside the natural world but have already and are currently shaping the genetic landscape in direct ways. Pell is not concerned with a normative view of this situation: he styles himself an observer of the phenomena of inheritable genetic intervention by humans. The authority vested in Pell through his natural-history style stems in part from a materiality of wonder: glass cabinets and installations featuring museum conventions house common and uncommon specimens that invite observation and reflection.

In *Spectres of the PostNatural*, Pell used anaglyph imagery, which was combined with blue-and-red paper glasses, to render images in 3D, thus offering the museumgoers a traditional technique for seeing specimens. In contrast to the many digital, virtual, and augmented means commonly encountered in galleries, Pell's piece was simple and harkened back to 1950s films. His specimens offered no suggestion of a futurist bent. Indeed, Pell's central point is that human's alteration of organisms' genetic codes is a long-term project. This point has been made by many STS scholars who place the controversial work of genetic modification into a longer history of humanity's active and passive manipulation of material things for scientific and cultural ends (Kohler 1994; Franklin 2007).

Continuing up the stairs of the CAM exhibition space, Adam Zaretsky's *DNA Food Art* unfolded as a highly interactive hands-on experience. Like many exhibition lab demonstrations and performances aimed at children, *DNA Food Art* brought the techniques of biotech out of the lab and into public space. The artist does a common citizen-science project of isolating DNA in a way that even scientists who regularly work with these techniques may find surprising: he uses common household items like contact-lens cleaner, salt, and Woolite. Rather than collect one type of DNA in one small tube, Zaretsky aims to show the sameness of DNA derived from all kinds of sources. The value of citizen science has been extolled by STS scholars who have studied its outcomes and who have subsequently tried to engage everyday people in science policy. Zaretsky's artwork is aesthetically and philosophically provocative (Figure 13.2).

Figure 13.2 Adam Zaretsky performs *DNA Food Art* with Jon Davis' *Animating DNA: The Blueprint of Life in Motion* in the top left at the 2017 CAM Raleigh exhibit *Art's Work in the Age of Biotechnology*. April 7, 2017. Photo credit: York Wilson

Like his artwork, Zaretsky's art-making style is provocative, mixing a performative aspect with messiness. Part cultural worker, part science worker, and part circus worker, Zaretsky is a hands-on engager with things, and he wants people who see his artwork to be hands-on engagers, too. Thus, they get a chance to engage with the artwork by using everyday materials to isolate DNA from a monstrous collective blender mix. The result is that these people end up handling materials that account for considerable social and scientific foment and that are in the strands in all our cells. The protocol is not dissimilar from the often-used technique of deriving DNA as a classroom demonstration from a single person or a strawberry, usual presented to students in clean separate plastic tubes. But Zaretsky's work takes a turn here which separates his piece from oft-repeated version and gives the artists an opportunity to talk about rather different subjects than the more familiar experiment, which is employed as a physical prompt to teach children basic definitions around DNA. In his artwork, DNA isolation is done from a large number of samples producing a mass of material. This technique is used partly to make it possible for kids to touch a mass of DNA, but also because the artist is suggesting that the way clean, perfect lab spaces test only tiny quantities of DNA is at odds with the real, big goopiness of real living things. Zaretsky emphasizes the sharedness of DNA across lifeforms rather than the disaggregation of individual sequences. Zaretsky then spends time discussing the similarities of the DNA in living things and the bodiliness of the life sciences.

In *DNA Food Art*, Zaretsky inverts our expectations about the goals of DNA technologies and raises the possibility that these protocols could point to neglected aspects of life, such as under-explored rhetorical themes or unusual conclusions about the nature of living things. This facet of Zaretsky's work is clearly reflective of the STS agenda, which is to show that contested scientific ideas may be resistant to easy experimentation-based change insofar as a single experimental result does not set the stage for a complete paradigm shift. Zaretsky's work makes an implicit argument that the technologies being developed to distinguish one DNA molecule from another might be employed in the service of other goals. The argument, which is made via materials other than text, reinforces the STS notion that an experiment might not be an experiment. In other words, the artwork further undermines a determinist view of the world, complicating the idea that scientists, by conducting experiments, can grasp new truths.

Such artworks offer the public new ways to think about their role in the genetic revolution. The artworks underscore the assertion that people are not merely observers in a miniaturized scientific setting but are actors engaged in the life-sized world of living things. Interactive artworks like Zaretsky's performance recontextualize genetic information by bringing it out of the lab and into everyday situations. Sticky fruit and the DIY DNA isolation prompt visitors to view the subject in a new light. Viewers' material intervention in the processing of DNA is reminiscent of citizen-science projects, which, by putting everyday people into contact with scientists, their materials, and their ideas, promote particular science worldviews as a form of informal science education. Zaretsky's invention might be thought of as an alternate form of citizen science, or perhaps more correctly, citizen art. This citizen art positions the viewer as a participant and pivots the resulting conversations around alternative, sometimes politically charged, perspectives of science. The focus, as with citizen science, is hands-on learning. The aim is to broaden people's knowledge of many topics that bear on collective and individual well-being.

The works on display in the 2017 exhibit at CAM Raleigh were analytical and speculative. They inquired into practices and possibilities influencing the contextual meaning of art and science. The artists used critical designs and new technologies to raise these questions in immediate and material ways. *MyoTomato* is one such work. This artwork was created by students School of Visual Arts in New York City completed by 2016, under the guidance of bioartist Suzanne Anker. It was created as part of the Genspace-sponsored annual Biodesign Challenge, led by director and founder Daniel Grushkin. The team of students created a speculative design: a bioengineered tomato plant that produces myoglobin, a protein normally found in meat. This artwork actualizes people's fears about "Frankenfoods"—a topic that is often covered in STS courses, particularly as it relates to anti-GMO activism. Here, the tomatoes are real and very much like the tomatoes in a local market. Encountering *MyoTomato* brings to the fore an essential tension that STS has analyzed: how to render visible the invisible scientific intervention into the genetic code of living things. *MyoTomato* pulls viewers in both directions. Its provocative title and accompanying artworks, which consist of *MyoTomato* logos and references to Campbell's soup cans and ketchup bottles, suggest that myoglobin tomatoes are a delicious innovation fit for an edgy marketing campaign. At the same time, however, the technical description of these bovine-gene tomatoes suggests a disgusting or horrific scientific creation. The resulting tension between delicious novelty and monstrous meddling plays out even as the tomatoes themselves appear ordinary (Figure 13.3a and 13.3b).

Collectively, these artworks provoke visitors into thinking about their power in relation to genetics and about how non-scientists can shape debates and intervene in social and technical processes important for biotechnology. In order to encourage visitors to see themselves not only as social participants involved in interactive artworks prepared by artists but also as actors possessing the agency to hold views and intervene in conversations about scientific and technical subjects because of their bearing on public life, I made a concerted effort to create an exhibit that would promote reflection in visitors. For example, I created a mechanism by which visitors to the gallery would be asked to write down on a post-it their ideas about our genetic futures. Each post-it would then be posted to a wall. Another mechanism with the same aim was an informal visitor survey administered by the CAM's middle-school docents, who used an iPad system to collect visitor feedback. This feedback process, while strengthening the interactivity of my exhibit, was also a way for CAM to test a potential feedback system for a future major multisite exhibition scheduled for 2019 and 2020. My exhibit's survey questions, by promoting substantive dialogue between the visitors and the volunteer docent, helped connect the visitors to artworks. Here, the artworks figured as provocations

(a) (b)

Figure 13.3 Two components of the 2017 CAM Raleigh exhibit *Art's Work in the Age of Biotechnology*: (a) public wall for reflections on genetic futures; and (b) middle-school docents. April 7, 2017. Photo credits: York Wilson

to be questioned, and the questions served to encourage visitors to reflect on their experience of the artwork.

It is fair to ask whether or not the survey questions might have functioned, by themselves, as effective segues to broader and deeper conversations about the ideas raised in the Art's Work at CAM. Although I phrased the questions in ways that would draw out the visitors' experience of these artworks, the artworks provide more than a sufficient departure point for such conversations. The artworks function as a shared basis for conversations that are much more inclusive of scientific laypeople than has been the case with many previous attempts to hold dialogue about emerging technologies. For example, one frequent practice for engaging the public in these kinds of conversations involves scientists who provide lectures or written material to members of the public before engaging them in conversation. This approach is thought to level the knowledge playing field and enable members of the public to productively engage with experts. In practice, however, the approach has the effect of placing the scientists, who are often the producers and purveyors of "all that is true," in unduly powerful positions. Audience members might feel that they have little to add to an expert's discourse or, if they hold views fundamentally different from those of an expert, the audience members might be reluctant to express their views in the intimidating presence of the experts. By starting from artworks that ask questions about the social contexts and the values involved in science-related public policy, the public and the scientist no longer appeal to proper facts when engaging in conversation with one another. Instead, the artworks place front and center the ideas that we want to solicit from the public about these topics. Artworks like the ones in my 2017 exhibit can prime members of the public for participation in conversations about science and society because these individuals, though likely unfamiliar with such weighty scientific matters as the protocols governing synthetic biology, are likely to have substantive views about the importance or the triviality of, for example, bringing an extinct plant back to life.

It should be no surprise to STS scholars that materials have a power harnessed regularly by scientists. With only a slightly expanded view, materials can also be seen as the purview of artists in making arguments. Material matters have been the refrain of much recent STS work, beginning with Bruno Latour (2007) and John Law (2007), and have stretched into what has been termed "the material turn" in STS and beyond. Sherry Turkle's *Evocative Objects* (2011) has shown us the value of working with ideas that take shape when we tinker with, play with, model, and extrapolate from materials and objects. With some exceptions, STS scholarship continues to regard materials as either actants or means of scientific knowledge. Rarely, though, does STS scholarship regard people's manipulation of materials as a potential medium for public intervention into scientific and technical debates. These facets of STS scholarship are precisely what makes art-engaged science so interesting for STS scholars. Artists work with materials and, from this work, derive ideas that often overlap with knowledge outside the arts. Further, the material nature of artists' work gives them access to public dialogues that we, as STS scholars, have sought to cultivate in the general public, particularly with regard to science policy.

There are other reasons for STS scholars' commitment to the creation of inclusive audiences interested in science. The usual concerns over the exclusionary nature of academic texts are, in some respects, addressed by public-facing art projects, and there is a great deal that STS can learn, especially in those wings of the discipline that make policy influence a priority, from a close study of the work of artists. While the materials produced by scientists tend to follow a design meant to shut down debate, many artists produce materials with the opposite aim: one of opening up debate, of furthering the public imagination.

Artist and theorist Natalie Jeremijenko has suggested that what artists have that is not present in the work of scientists is access to the public's imagination. It seems to me that art's potential for the suspension of disbelief, for speculation without harm or commitment, differentiates artistic output from a considerable amount of STS scholarship that takes itself rather seriously. Scientists have long made use of artists to communicate scientific ideas to laypeople, and this use has long been mistaken for the beautification and the simplification of hard-science ideas. In reality, the merging of art and science has the overlooked yet powerful ability to expose people to new ideas. This desirable outcome stems, in part, from contemporary art's ability to promote open minds and to lower the stakes of "getting it right"—in the sense of being true to the details of scientific concepts. For most of the public, expressing an idea about an artwork is less intimidating than expressing an idea about a new science. There are exceptions, but the issue of access to public imagination has, nonetheless, made art a place in which people from all walks of life can explore new ideas. To great effect, new strands of ASTS have begun to harness ideas from art and design, particularly the workshop format, with a central aim being to exercise people's imagination. More practitioners in the social and natural sciences will surely prove to be able contributors to ASTS, but its basic ideas have hailed, by and large, from practitioners in art and design. Borrowing methods is the stock and trade of STS scholarship (one is reminded of Picasso's adage that great artists steal), and we ought also to be mindful of the traditions and efforts that make up the field of art. In doing so, we stand to learn a great deal from art methods even as we reflexively avoid instrumentalization.

Acknowledgments

Many thanks to the following individuals: all of the artists whose work appeared at the Contemporary Art Museum (CAM) of Raleigh: Paul Vanouse, Richard Pell, Christina Agapakis, Kirsten Stolle, Adam Zaretsky, Jon Davis, and Cyanotype; to the project team, including Molly Renda, Fred Gould, Todd Kuiken, Chris Vitello, Elizabeth Pitts, and Sharon Stauffer; the staff of CAM Raleigh; all of the scientists, artists, social scientists, and humanists who participated in the workshop; and the members of the public who visited, interacted with, and contributed to the 2017 CAM exhibition.

Notes

1 This work is an early version of *Resurrecting the Sublime* (2019), a collaboration between synthetic biologist and designer Christina Agapakis, IFF-supported olfactory researcher and artist Sissel Tolaas, and artist Daisy Ginsberg.

2 There is substantial research to suggest that informal science education, particularly in museum contexts, is unlikely to radically shift an individual's attitudes toward science in a single encounter or even a short series of encounters, yet the idea that these experiences have influences has persisted in science and art institutions and among museum professionals and art–science creators.

References

Ankeny, R. 2010. Historiographic reflections on model organisms: Or how the mureaucracy may be limiting our understanding of contemporary genetics and genomics. *History and Philosophy of the Life Sciences*, 32 (1), 91–104. Retrieved from http://www.jstor.org/stable/23335054.

Barnes, B., Bloor D., and Henry, J. 1996. *Scientific knowledge: A sociological approach*. Chicago, IL: University of Chicago Press.

Franklin, S. 1993. Procreation stories: Visual culture and reproductive politics. *Science as Culture*, 3 (4), 477–482.

Franklin, S. 2007. *Dolly mixtures: The remaking of genealogy*. Durham, NC: Duke University Press.
Kelley, L. 2016. *Bioart kitchen: Art, feminism, and technoscience*. London: I. B. Tauris.
Kohler, R. 1994. *Lords of the fly: Drosophila genetics and the experimental life*. Chicago, IL: University of Chicago Press.
Latour, B. 2007. Can we get our materialism back, please? *Isis*, 98 (1), 138–142.
Law, J. 2007. Actor network theory and material semiotics. Version of April 25, 2007. Retrieved from http://www.heterogeneities.net/publications/Law2007ANTandMaterialSemiotics.pdf.
Lynch, M., Cole, S. A., McNally, R., and Jordan, K. 2008. *Truth machine: The contentious history of DNA fingerprinting.* Chicago, IL: University of Chicago Press.
Nelson, N. 2018. *Model behavior: Animal experiments, complexity, and the genetics of psychiatric disorders*. Chicago, IL: University of Chicago Press.
Rader, K. 2004. *Making mice: Standardizing animals for American biomedical research, 1900–1955*. Princeton, NJ: Princeton University Press.
Vogel, Kathleen M., Brian Balmer, Sam Weiss Evans, Inga Kroener, Miwao Matsumoto, and Brian Rappert. 2017. Knowledge and security. In *The Handbook of Science and Technology Studies, Fourth Edition,* ed. Ulrike Felt, Rayvon Fouché, Clark A. Miller, and Laurel Smith-Doerr. 973-1002. MIT Press.
Turkle, S., 2011. *Evocative objects*. Cambridge, MA: MIT Press.

14

Recipes for Technoutopia

On hospitality and infrastructure as experimental performance

Stephanie Beth Jordan

> Let us say yes to who or what turns up, before any determination, before any anticipation, before any identification, whether or not it has to do with a foreigner, an immigrant, an invited guest or an unexpected visitor, whether or not the arrival is the citizen of another country, a human, animal or divine creature, a living or dead thing, male or female.
>
> *(Derrida and Dufourmantelle, Of Hospitality)*

The table's function in the production of ideas cannot be understated. It is a boring thing in the Susan Leigh Star (1999) sense, one that makes possible new materials and worlds, heavily employed in both its literal and figurative sense by scholars like Heidegger (1962), Arendt (1958), and Foucault (2002). The table is a surface upon which many things happen: it is a place of event and a place of routine, we eat upon it, write and make art upon it, build and fix things on it, sell things over it, and hide things under it. Looking at the table phenomenologically, Sarah Ahmed (2006) describes the table as a half-glimpsed object, one that typically rests in the background yet it powerfully defines orientations, objects, and others: what is kept at a distance and what is ready-at-hand, who comes to sit upon the chairs, to move them, to feel at home or alien occupying them.

The undressed gray plastic table in a conference room serves a utilitarian purpose. The conference table begs a particular spatiality and temporality: it is often situated at the front of a room where multiple speakers will sit behind it in a straight row in wait to discuss their work one-by-one in front of an audience seated in rows or parallel chairs. At times, the table serves largely and laughably as an oversized surface upon which the water cup of the current presenter is placed. At the 2017 Annual Meeting for the Society of the Social Studies of Science in Boston, MA, I rolled a conference room table to the side of the room, not the front, and upon it I placed linens from my home, a hot home-cooked brunch to serve 50, and chairs along all of its edges. Guests, elsewhere known as conference attendees, were dropped into this space and their attention taken around the table. The conference program read, "On Hospitality and Hope: Where Scientific Infrastructures Define Their Insiders and Outsiders" with an abstract that made no mention of its interactivity or intention. This

DOI: 10.4324/9780429437069-18

table now was the platform upon which an infrastructure of hospitality was constructed and performed. Informed by radical, queer, trans and intersectional feminist activists, artists, and academics, the scripts of the performance and its materials were carefully chosen abstractions and metaphors reflecting six years of ethnographic investment into the ocean and climate sciences.

I chose to create an infrastructure of radical hospitality because, in the formulation of scientific purpose in these ethnographic sites (and arguably elsewhere), there is a pervasive interest in building innovative technologies that will engage and allow for new people, new ideas, and new methodologies to enter the practice of science and answer questions that were previously unfathomable. Many innovators promise that the bonds that break modern society can be liberated through technological intervention, an inclusive vision that finds empowerment not in the interactions of humans to each other but in the interactions of humans to computing systems. This externalization or delegation of responsibility echoes the dynamics of "response-ability" asserted by Karen Barad (2007, 2010) and Donna Haraway (2015) as the privileged ability to sense, respond and be proactive.

I designed this experiment to beg the question of responsibility and response-ability: how do we imagine better futures and who finds those futures hospitable? Often, we assign futures promissory descriptive words: "open," "participatory," "inclusive," "empathetic" and "innovative." Self-driving cars will solve traffic problems, blockchain will hold industries audit-able and accountable, drones will rectify the human error of war, Wikipedia will level the playing field on access to information across the globe. Innovations act as a hero to future world-building. The recipe for the future, by this logic, is a technoutopia. The experimental performance transforming a conference table into a brunch table asks: what are its ingredients and the labor of its production? Who is the chef, the served, the hungry? What spoils utopias?

The production of radical hospitality

Guests sat around a dressed table for a feast as a thought-experiment on the desire to accommodate that rings throughout many modern technological ventures for openness, diversity, and participation. As host, I ushered the guests in physically and ideologically, telling them as I led them to their seats that anything unexpected that happens while sitting around this table would be accepted affirmationally as a welcome introduction to the experience of the brunch. This exercise is what Levinas (1969) and Derrida (1998) call *unconditional hospitality*. Through scripted performance, I described the brunch table and the labor of its production and invited guests to share their associations of the table to their own knowledges, research, and intuitions. I sat off-center and encouraged conversations. We introduced ourselves by first name only. I discussed the modes of production of my hospitality: my socioeconomic status and the vectors of capitalism at my disposal, my cultural upbringing, the ethical stance and value I place on organic and local goods and the ethos behind the vegetarian spread in front of us, my labor and skills and instructions I am able to access and follow, the laws and rules and regulations of the spaces I navigated to produce that table, describing what I value in my aesthetics and utility and how these choices led to the design and use of the table, what materials were at hand and what needed to be bought or borrowed. I consulted others about these decisions prior to laying them: who I was able to consult and who was available and interested were contingent.

The brunch itself was contingent, unexpected, ephemeral, un-documented, and unable to be replicated. Those who showed up to the table, in each of the three iterations of the performance that were held, brought new cultures of interaction and set new tones. It was my aim to force an infrastructural inversion [c.f. (Bowker, 1994)] where culture and constraints would be vocalized and problematized during the performance. By engaging with infrastructure as experimental performance, I created a mechanism to simultaneously work through and communicate scientific findings, to see what gets reflected back in mirror image to my intentions and what gets reflected upon in new organizations of thought. We as academics do this in many other ways within conferences, reading groups, or other forms of outreach. The academic setting was of critical importance: this piece was not performed in a standard art space or in the comfort of my own home amongst familiar friends or family. Those who sat at the table were invited to something that intentionally subverted the authority-building that is connected with the academic conference. There were no photos; very few people took any notes, and no phones were present at the table so nothing could be tweeted. Attendance at this brunch required immediacy, attention and being present. It was a highly stimulated and sensorial experience that encouraged smells, sights, touching, tasting, hearing, and possibly even the sixth sense (we may call this "intuition" or some other form of extrasensory perception). This attention to present embodiment is because it is my experience that infrastructure is experiential, sensorial, political, and situated. Because of the lack of documentation, the memories of those who participated and heard about this brunch and this current manuscript are the only evidence of it happening at all.

Most conference rooms consolidate power in a recognizable way: speakers at the front transmitting knowledge to audience members. Furniture and expectation were all reshuffled, attempting to make a space that distributed power. While this table acted as an infrastructure built through a more radical intention, power still played on the dynamics of the room, escaping my own utopian designs. In the same way, a research infrastructure is designed with participatory and democratic intentions yet can be undone in unexpected ways. We can alter a data-intensive system to include more diverse voices, but power still presses against those new designs and shapes the knowledge the research infrastructure can co-create.

The way that attendees sat, their allergies, the design and configuration of the table and its chairs, the movement to accommodate the attendees in conversation and physical space all provided a kind of extemporaneous social commentary on the possibilities and limits of accommodation and relation, of intention and emergence. The exercise included performative scripted pieces as well as some akin to a score in dance or improvization, to curve the experience toward particular outcomes.

Through the lens of unconditional hospitality, this brunch was an attempt at an intersectional approach to understanding infrastructure and what constitutes it, a radical exercise in subverting the misplaced faith in technoutopia and the determinism of infrastructure. Intersectionality in this exercise considers the multiple simultaneous ways in which identity [for example, class, race, class, gender, and able-bodiedness; c.f. (Crenshaw, 2017)] and infrastructure can empower or collide across all lived experience, formal and informal space. There were many occurrences that could have been categorized as "interruptions"; however, Derrida and Dufourmantelle (2000) tell us that hospitality doesn't look at these emergent properties as interruption and instead as stakeholders, as new categories of consideration, not as something to buy-off, block out, ignore, or build a wall between. We invite them in. We do more than accommodate; we identify the unexpected and classify them as a part of the infrastructure and then orient toward them with our bodies and our minds. They bring with them new materialities, new ideologies, and new dynamics, and we turn to them as generative, not destructive.

The performance opens a potential for rethinking how plans are made and broken and of conceiving interruption in intersectional terms: where interruptions indicate stakeholders, not intrusions, and where multiple forms of identity and orientation allow for certain kinds of practices and knowledge to be produced and supported. Inspired by the recent uprising of radical art that has taken Jacques Derrida's unconditional hospitality into more personal practices of inclusion and care in technological spaces – from cyberfeminist Laurence Rassel on curation ethics at Fundació Antoni Tàpies to Walker Tufts' immersive Hospitality Machines installations – this brunch attempted to capture this zeitgeist to illuminate and embody design as both hospitable and hostile. There is a labor and production of hospitality and an ethics of inclusion and cutting. Hospitality becomes an acknowledging, welcoming, and establishing of new rules that allow infrastructures to adapt to the strangers, the foreign objects, and its own flaws or gaps. And art becomes a means of investigating the very present and often difficult-to-confront ethical realities that challenge the intersection of inclusion, local circumstance and plans. By orienting toward the labor of its production and the radical acceptance of unconditional hospitality, this performance was life-giving alongside critique, asking: how can we build an affirmational inclusive infrastructure that is also environmentalist? What is the queer technoscientific utopia?

Radical art and hospitality

The performance of this brunch was inspired by the recent tide of radical art grappling with theories of hospitably and territory (c.f. Aristarkhova, 2020), how art reimagines our relationship to Other(s), drawing significant understanding from Levinas (1969), Derrida (1999), and Dufourmantelle's (Derrida and Dufourmantelle, 2000) theories on *unconditional hospitality* and drawing these theories into the politics of the personal, in interpersonal interaction. Unconditional hospitality is a call to openness, to accept the uncertainty of uncharted terrain and the unknown, to exist in a state of constant adaptation and transformation where all things are responsible for all other things, to open borders and boundaries of the self. These philosophical underpinnings encourage a full embrace of the x*enos* – or the stranger, the forbidden, the unsaid, the silenced – and acceptance of the self as both a native and, in transit, always evolving.

The brunch was conceived immediately upon exiting the immersive interactive installation of Walker Tufts' Hospitality Machines set in Portland, OR, in 2016b. In that exhibit, the machines provided a paired guided meditation: amidst plant-life and reclaimed wood pieces were natural seats that placed two individuals, generally strangers, to sit knee-to-knee (sometimes knees interlaced if the individuals were particularly tall, as I am). The meditation forced a reconciling of personal space, an inviting of one individual into the other's aesthetics, expressions, and emotional state. Through quotation of philosophical texts on hospitality and introspective exercises, Tufts' installations moved participants to reconcile with the discomfort of and strangeness and strangers and a deep traversing of personal affinity and disposition. Leaving the confines of the installation, I drew the blueprints for the brunch, only to later find Tufts' "Recipes for Utopia," upon which the title here is deferentially drawn (2016a).

The path between hospitality and dining is an obvious but powerful one, with longstanding traditions of artist-orchestrated meals from the Italian Futurists of the 1930s to the more recent exhibition, "Feast: Radical Hospitality in Contemporary Art" at Chicago's Smart Museum of Art curated by Stephanie Smith (2014). These works tackle the thorny entanglement of capitalism and the labor of production in the cross-pollination (or sequestration) of foods, species, humans, and the built environment. Sylvie Foritn's (2019) work on habitat and unconditional hospitality begs these associations in the realm of ecology, asking of nature as much as of human nature:

> how does hospitality inform research, its questions and protocols, when terms like *foreign*, *native*, *migratory*, *invasive*, and *parasitic* are deployed in ecology? To what effects? Can a commitment to unconditional hospitality open onto exciting experiments, unexpected narratives, and new forms of being-together-otherwise?
>
> *Fortin (2019)*

Forin's provocations powerfully force us to confront our categories of insider and outsider and hold ourselves accountable to them. Or we might look to the curatorial principles of Laurence Rassel at Fundació Antoni Tàpies in Barcelona, Spain, who asserts the relevance of unconditional hospitality in artistic interpretation, of the false dichotomies between science and fiction, utopia and dystopia, and critical and restorative politics (2006). Radical art has long grappled with the forms in which technological artifacts organize everyday life, defining its insiders and outsiders across national borders, personal boundaries, and divides between nature and the built environment, to which this brunch and the aforementioned pieces join a chorus of experimental works investigating the productivity of art to investigate these sticky meshworks.

Infrastructure as experimental performance

Artful practice produces new relationalities, new vocabularies, allows us to conceive of long-standing philosophies (in this case, unconditional hospitality) in their radical forms as found in the art world, and then apply these sensibilities to Science and Technology Studies in generative ways. Artful practice leads us to metaphors that are more tractable and legible critiques of capitalism, Silicon Valley and technoutopianism (and its siblings optimism or determinism). The metaphor of hospitality as infrastructure, for example, shows us that despite our best intentions, we create a certain kind of scene that can occlude certain people and things, with a certain labor of its production that may not follow even the best laid plans, and invites us to rethink our expectations about interruptions and stakeholders. These discussions are inseparable from the dynamics of colonialism, autonomy, and sovereignty: infrastructures define new relationships with those that are unexpected and that at times interrupt the flow of development. It recognizes that reckoning with the legacy of oppression, colonialism, and American occupation in the context of white supremacy must be central to any discussion about what should happen next in innovation, maintenance, and breakdown. The brunch was built inside a colonial context and offered a collective opportunity to a collective opportunity to think with the practices of radical anti-racist queer and trans feminist ideals to "imagine things otherwise."

The performance opened more questions than it answered, unique to the method and practice of performance. When faced with an incongruity between the ethos we envision and the reality of sociomaterial practice: what is our social role responsibility and structure of accountability? How do we come to understand the power and pitfalls of new technological development? How do we imagine the possibilities? What power do we have for assessing the value of skills, creatures, things, and places? How do we inhabit the position of the host and come to understand how it radically transforms its world? How do we come to understand the difference between the worlds we have envisioned and the worlds that come to be? What difference do we make? What kinds of problems are posed? What stories get revealed? What stories get told afterward? What stories go unheard? How do we continue, resist, respond, deny, and inherit? What is progressive and desirable and what is backward?

In the following section, I begin to peck at the contours of some of these questions through what emerged during the performance. The themes (of interruption and repair, orientation and disorientation, and rhetoric and reality) explored below are representative of the new intellectual connections and richness of thought that were generated through this experiment into infrastructure as performance.

Infrastructure, interruption, and repair

There were many occurrences that could have been categorized as "interruptions." Some guests weren't hungry, were uncomfortable being the first or last to eat, were allergic, or maybe wary of my wares. There wasn't enough space for everyone to sit at the table so some were sitting more-than-arm's-reach. One of the guests couldn't hear my quiet voice over the sounds of hotel conference room and often asked me to repeat my statements. There were loud noises, yelling, and clapping coming from other presentations and panels. In two of the three iterations of the brunch, there were two older males who were too impatient and authority-wielding to wait for my younger quiet feminine voice to tell them what was about to happen. They directed attention to themselves in what was otherwise an egalitarian endeavor, reorienting the environment and relation of guests to each other and to the table.

The dynamics at the table itself replicated many hegemonies that come up against utopian aims elsewhere: it did not matter that the infrastructure of the table and its rhetoric was an extreme version of camaraderie and inclusivity. As the experience at the table unfolded, I was unfortunately able to draw in relevant stories from my field work that mirrored the inequalities of our dynamics: of coastal indigenous groups whose time and land are negotiated to perform oceanographic field work, of the women on ships whose instruments were taken without consent from their hands by male colleagues, of coalition-building by colleagues who identify as women to improve grievance reporting, of fishermen who affixed their traps to buoys in fish migration passages, of barnacles that made a home inside instrumentation, and of a black crew member who said "they don't like people like me here" and quit after a research cruise I observed. At both a warmly dressed table and in our promising technological endeavors, there are limits to accommodation, where often those limits come in the form of intersectional issues of race, gender, and class.

The performance begged a series of questions concerning the repair and maintenance of infrastructure, informed by a growing body of scholarship in science and technology studies and related fields (cf. Star, 1990; Jackson, 2014). When the infrastructure of the table did not act as it was envisioned, how did radical acceptance rather than a return to normalization change the ways in which we viewed moments of breakdown? What then is being repaired? What then is being maintained? Who is accountable for its breakdown and who is accountable for its repair?

Orientation and disorientation

This line of thinking drew a connection between repair and maintenance literatures across to queer theories of orientation and disorientation. The feeling of being "at home" and comfort commingled with an ethics of conditionality, of compromise and of responsibility. Orientation, as discussed by Ahmed (2006), Kant (1768, 1795), and others (c.f. Heidegger, 1962; Schutz and Luckmann, 1974; Deleuze, 1992), and its corollary disorientation (c.f. Bradiotti, 1991; Stewart, 1996) both concern the ways of finding comfort, being a part of a space, being recognized in a space, giving attention to a space, and to be able to reach what is around. Ahmed employs the metaphor of the table to explore orientation and disorientation: the writing table, the kitchen table, the table of contents, the periodic table of elements, and the *tabula rosa.* In each case, Ahmed asks what kinds of futurity these tables provide, what do they support, order, and uplift and what do they inconvenience, hide, or occlude.

The brunch table was an infrastructure built necessarily of a perspective: it was elitist, isolating, uncomfortable, and even violent to some. Through example of hospitality in performance art (High, 2020; Oliver, 1997), the reflexive turn of this performance attempted to surface the many expenses that may come with its development of others' ability to feel welcome or fit, to benefit from its sustenance both in thought and in nourishment, and to actively participate in this space. There were some people who recognized the taste and aesthetic of the table, who felt its sense of belonging, allegiances, and commitments, despite having traveled possibly far to reach this table. There were some people who could access this infrastructure of this hospitality and others who could not; some who could sit at the table and others who could not. Ahmed (2006), borrowing from Kant and Heidegger, describes orientation as "the question not only about how we 'find our way' but how we come to 'feel at home'." Taken together with Derrida, we think of how in the home there are owners, guests, and strangers and how a host imposes norms and restrictions. In moments of breakdown, at this performance and otherwise, in which even the best laid plans fall out of view, orientation and disorientation powerfully dictate the new dynamics that inhabit a space in flux, who feels comfortable to lead or follow, and how new actors are integrated into its flows.

Only one guest sat for all three iterations of the brunch. While I had never met this person before the brunch, at the same conference two years later, I saw this same person attending multiple of the same panels and events outside of the conference as myself – this is meaningful, above similarities in interests. There exist similarities in what makes us comfortable to show up. There is much to be said about orientation and hospitality of infrastructure, about who and what can make us feel comfortable enough to show up, how we follow and support familiarity and kin, in science and otherwise.

The dissonance between rhetoric and sociomaterial realities

After the performance, the guest who attended all three performances balked at the experience: in the first two iterations of the brunch, older white males who named their positions and rank above mine (when no others had named their rank) had over-written much of the scripted aspects of the performance by jumping to conclusions about what the experience entailed, then those assertive guests occupied conversation, often speaking over me and the other guests at the table and directing the experience. While a diversity of guests were present at each table, one demographic commanded the most attention, at once undercutting the intention of the exercise and illuminating a different (albeit well worn) path. At both a warmly dressed table and in our promising technological endeavors, there are limits to accommodation, where often those limits come in the form of intersectional issues of race, gender, and class.

Emphasizing that the words we use to define infrastructures are consequential but that words alone only extend so far, this brunch demanded guests grapple with the dissonance between the rhetoric and sociomateriality of infrastructure through critical consumption. Charli Brissey (2018) powerfully asserts that when we encounter a table we often ask and answer the question of *what is it* without asking and answering *how did it get here?* Through choreography, Brissey asks us to expand upon the structure served to us and into a more nuanced understanding of what it is we are being served, detangling how and why it may resonate with us or not, acknowledging its materials and the labor that produced the privilege to enjoy or criticize them. This exercise of acknowledgment reminds us of the relationality, ecology, norms, and queerness of infrastructure: the production of the brunch table led to a particular kind of engagement with it, sometimes counter to the intentions under which it was developed. Following Brissey, we might ask now: how did we get here?

Accepting interruption as a part of infrastructure is also acknowledging how language often challenges desire. There is a friction between articulation and lived reality. For example, in the moments of interruption (gendered, raced, classed), the male speakers appeared as a "them" intruding on "us." The challenge then becomes an importance and violence of trying to rethink them into the us – or what Levinas and Derrida refer to as the host becoming a guest – when it means understanding how a white paid, male voice could resume very form of a space that was intended to challenge the very idea of that very form of control. In attempting to be a transgression, this infrastructure of unconditional hospitality as a form of radical inclusiveness then was lived as a complicated paradox with no monolithic solution. The brunch became a call to ask more questions of the ideologies behind infrastructure and the cultures in which infrastructures are produced.

Conclusion

Technoutopias aren't formed frictionless. Infrastructures of all kinds are unfaithful, and they are made of rules they do not follow. The challenge is understanding the ways that an articulated value comes up against the lived and inchoate reality. By defining infrastructure through experimental performance, particularly with the drive for unconditional hospitality, we experience these frictions in embodied ways. The experimental performative brunch, detailed here, encouraged a recognition of the power dynamics at play and drew out a collective processing of the effects of economic and ethnic marginalization on the choices available.

This experiment is an intervention not to undercut current initiatives of scientific discovery with "good" aims but instead to bolster them, to unearth narratives and orientations that disrupt their fulfillment and the pathway toward any technoutopia. This intervention provokes us to imagine alternate problems and solutions that may move the future toward "good," not necessarily centered on technology's potential heroism. When developing, delegating, and delineating the future to sociotechnical infrastructures, we might consider how culture, politics, and resources coerce and produce vectors forward, what members may be able to access or gain control of the dominant narratives, and reconsider how a design future is co-constructed in ways that place value on or provide smoother pathways for certain kinds of people. Through a performance of hospitality in the form of a radical brunch, as a corollary to the inclusive open charge of modern scientific infrastructures, we find salient embodied, visceral, immediate, and unavoidable realities of infrastructure, where even infrastructures built with the most inclusive of aims can be undone.

Technologies and their spaces between, as explored by scholars such as Susan Leigh Star (1999) and Maria Puig de la Bellacasa (2015), are not solely about the hardships but also about their possibilities, about their hopes as much as their broken hopes. Infrastructures are wished for, built into, oriented toward, and organized around as a mode of survival, for building a future in different temporalities that will have a positive and lasting impact beyond the scope of its creation and use. Science is performed through entanglement, inasmuch a human endeavor as it is the ecology around those individuals' powers and promises. Through the performance of infrastructure in the form of this radical brunch, it became clear and critical to consider the possibility of inclusion, the violences of overt discrimination and unconscious bias, and integrate more sensitivity (and possibly hospitality) to a range of bodies, senses, desires, and self-conceptions.

These lessons teach us that infrastructures are only ever accessed through culture: they are both interpreted through and subordinate to culture. We must consider lived experience and local culture as a window into an infrastructure's vulnerabilities and local concerns, in order to think more deeply about the promises and risks of the technologies and futures we build toward. Through infrastructure as an experimental performance, we might find new answers for the questions of how to build an affirmational politics of infrastructure that is ecological, cultural, and accountable.

Acknowledgments

This work is inspired by and with permission gratuitously lifted from Walker Tufts' interactive performance, Recipes for Utopia, and immersive installation, Hospitality Machines. Thanks to the generous and thought-provoking organizers of the panel at the 2017 Annual Meeting of the Society for the Social Studies of Science in Boston, MA, Ellen Foster and Karin Patzke. I extend a deep gratitude and acknowledgment of the land upon which this performance was possible, the original homelands of the Mashpee Wampanoag, Aquinnah Wampanoag, Nipmuc, and Massachusetts tribal nations. Thanks to the incredible work of Megan Halpern and the editors in the development of the current volume. Lastly, I extend gratitude to Jenni Lieberman, Marisa Brandt, Will Steinhardt, Shannon Harvey, and Charli Brissey for substantive contributions to the content of this piece and performance.

References

Ahmed, S. (2006). *Queer Phenomenology: Orientations, Objects, Others*. Durham, NC and London: Duke University Press.

Arendt, H. (1958). *The Human Condition*. Chicago, IL: University of Chicago Press.

Aristarakhova, I. (2020). *Arrested Welcome: Hospitality in Contemporary Art*. Minneapolis: University of Minnesota Press.

Barad, K. (2007). *Meeting the Universe Halfway: Quantum Physics and the Entanglement of Matter and Meaning*. London and Durham, NC: Duke University Press.

Barad, K. (2010). 'Quantum Entanglements and Hauntological Relations of Inheritance: Dis/continuities, Space Time Enfoldings, and Justice-to-Come,' *Derrida Today*, 3(2), 240–268.

Bowker, G. C. (1994). *Science on the Run: Information Management and Industrial Geophysics at Schlumberger, 1920–1940*. Cambridge, MA: MIT Press.

Bradiotti, R. (1991). *Patterns of Dissonance: A Study of Women and Contemporary Philosophy*. Cambridge: Polity Press.

Brissey, C. (2018). *Miraging: Aggregate Logic for Material Futures*. Urbana-Champaign: University of Illinois.

Crenshaw, K. (2017). *Kimberlé Crenshaw on Intersectionality, More than Two Decades Later*. Columbia Law School. Available at https://www.law.columbia.edu/pt-br/news/2017/06/kimberle-crenshaw-intersectionality (Accessed October 7, 2019).

Deleuze, G. (1992). "Ethnology: Spinoza and Us," in J. Crary and S. Kwinter (eds.) *Incorporations*. New York: Zone, pp. 628–633.

Derrida, J. (1998). 'Hospitality, Justice and Responsibility: A Dialogue with Jacques Derrida,' in R. Keamey and M. Dooley (eds.) *Questioning Ethics: Contemporary Debates in Philosophy*. London: Routledge, 70–71.

Derrida, J. (1999). *Adieu to Emmanuel Levinas*, translated by Pascale-Anne Brault and Michael Naas. Redwood City: Stanford University Press.

Derrida, J. and Dufourmantelle, A. (2000). *Of Hospitality: Anne Dufourmantelle Invites Jacques Derrida to Respond*, translated by Rachel Bowlby. Redwood City: Stanford University Press.

Fortin, S. (2019). *Headlands Center for the Arts*. Available at http://www.headlands.org/artist/sylvie-fortin/ (Accessed October 9, 2019).

Foucault, M. (2002). *The Order of Things: An Archaeology of the Human Sciences*, translated by Robert Hurley. London: Routledge.

Haraway, D. (2015). 'Anthropocene, Capitalocene, Plantationocene, Chthulucene: Making Kin,' *Environmental Humanities*, 6, 159–165.

Heidegger, M. (1962). *Being and Time*. Oxford and Basil: Blackwell.

High, K. (2020). 'Hosting the Animal,' in I. Aristarkhova (ed.) *Arrested Welcome: Hospitality in Contemporary Art*. New York, NY: Columbia University Press, pp. 85–110.

Jackson, S. J. (2014). 'Rethinking Repair,' in T. Gillespie, P. Boczkowski, and K. Foot (eds.) *Media Technologies: Essays on Communication, Materiality and Society*. Cambridge, MA: MIT Press, 221–240.

Kant, I. (1991). *Perpetual Peace* (1795), translated by H. B. Nisbet. New York: Cambridge University Press.

Kant, I. (1992). 'Concerning the Ultimate Ground of the Differentiation of Directions in Space (1768),' in D. Walford and R. Meerbote (eds.) *Theoretical Philosophy*, translated by David Walford. Cambridge: Cambridge University Press, pp. 361–372.

Levinas, E. (1969). *Totality and Infinity: An Essay on Exteriority*, translated by Alphonso Lingis. Pittsburgh, PA: Duquesne University Press.

Oliver, K. (1997). *Animal Lessons: How They Teach Us To Be Human*. New York, NY: Columbia University Press.

Puig de la Bellacasa, M. (2015). 'Making Time for Soil. Technoscientific Futurity and the Pace of Care,' *Social Studies of Science*, 45(5), 691–716.

Rassel, L. and Puig de la Bellacasa, M. (eds.) (2006). *Stitch and Split. Bodies and Territories in Science Fiction*. Barcelona: Fundación Tapiés.

Schutz, A. and Luckmann, T. (1974). *The Structure of the Lifeworld*, translated by Richard M. Zaner and H. Tristram Engelhardt. London: Heinemann Educational Books.

Smith, S. (2014). *Feast: Radical Hospitality in Contemporary Art*. Chicago, IL: Chicago University Press.

Star, S. L. (1990). 'Power, Technology and the Phenomenology of Conventions: On Being Allergic to Onions,' *The Sociological Review*, 38(1), 26–56.

Star, S. L. (1999). 'The Ethnography of Infrastructure,' *American Behavioral Scientist*, 43(3), 377–391.

Stewart, K. (1996). *A Space on the Side of the Road: Cultural Poetics in an "Other" America*. Princeton, NJ: Princeton University Press.

Tufts, W. (2016a). *Recipes for Utopias*. Available at http://www.walkertufts.com/TeamB/RECIPES-FOR-UTOPIAS-BOOK-SMALL.pdf (Accessed October 7, 2019).

Tufts, W. (2016b). *Hospitality Machines*. Available at http://www.walkertufts.com/ (Accessed October 7, 2019).

15

Reflexivity practiced daily

Theatricality in the performative doing of STS

Yelena Gluzman

> A ghost that is the very specter of multiplicity itself haunts the play and the interpretation … What if this ghost were taken seriously?
>
> *Barad (2010, p. 263)*

During the 2015 annual meeting of the Society for the Social Studies of Science (4S), I participated in a panel organized by the editors of this volume that aimed to consider "The Reflexive Turn in Art and Science Studies." There, instead of reading my paper out loud to those assembled, as is typical in scholarly conferences, I prepared and distributed small booklets to all the other conference participants assembled in the room and asked *them* to chorally read out the bolded sections from their booklets. Though the booklets all contained the same text—my conference lecture—the bolded portions to be read out loud differed among them. This meant that some phrases were bolded in all booklets and thus voiced by everyone in the room (e.g., the opening phrase "**Hello. My name is Yelena Gluzman**."), while other phrases, bolded in only one booklet, were spoken by only one voice ("**shout out to Garfinkel!**"), and still others were, similarly, spoken by combinations of two, three, or four voices. Since each booklet was scored for only one speaker, no single booklet contained an overview of the scoring; this meant that a speaker had no way to know how many voices would join them when they began vocalizing their part. Thus, both the form and the content of the booklets theatrically encouraged speakers to attend to this extraordinary experience of speaking and listening, while asking them to consider the ordinary theatricality of scholarly communication. These booklet-based performances are both subject and object of this chapter; the booklet, titled *Staging STS*, is reproduced below (pages 256–268), and this introductory text is meant to situate the booklet and its enactment in a broader conversation about reflexivity, performativity, and theater in the doing of Science and Technology Studies (STS).

In the most recent *Handbook of Science and Technology Studies* (Felt et al. 2017), the editors herald a "new attention to STS as a form of reflexive method" (13). Instead of disambiguating the many different senses in which reflexivity is invoked by various authors across the anthology, the editors make the following unifying, general observation: "Reflexivity, as

DOI: 10.4324/9780429437069-19

already mentioned, has long been a key theme in the field. Yet, there is a sense in many of the chapters that reflexivity has settled in, *not as an add-on* but as something to be *practiced daily*" (22; italics added). While this acknowledgment of the growing normalization of reflexivity in the discipline is a welcome one, it leaves untouched some decades of disciplinary debate about what precisely is meant by reflexivity, its putative value as an attribute of STS methods, and how it might be "done" (Woolgar 1988, Ashmore 1989, Mol 1998, 2002, Law and Urry 2004, Lynch 2000, Law 2004, Barad 2007). I suspect that the authors of many of these long-stalled debates would applaud the *Handbook*'s editors for not getting mired down in an issue that many consider frustrating, unproductive, or generally irresolvable. However, I propose that many of the frustrations of considering reflexivity in STS derive not from contradictions that inhere in reflexivity but rather from a failure to consider the theatrical arrangements that enable every stage of ordinary scholarship. Theater, I propose in *Staging STS*, is illuminating material for reflexivity practiced daily.

Some may bristle at my suggestion that theater has been overlooked in considering STS reflexivity, especially since the first wave of STS literatures dealing centrally with reflexivity was marked by the theatricality of the "new literary forms" they employed (Woolgar 1988, Ashmore 1989, Mulkay 1991). Associated with extreme relativist positions in the Sociology of Scientific Knowledge (SSK), this body of work advocated for reflexivity in respect to science studies' *own* truth claims, arguing that STS claims should not be presented as transparent representations of an underlying reality, but rather as the constructed stories of similarly constructed individuals. Their "new literary forms" for STS—inspired by metafiction and other experimental literature movements that deconstructed conventional divisions between author, text, and reader—featured dramatic dialog, "strange loops," parody, and/or fictional characters to demonstrate and celebrate the constructedness of STS accounts that take the social construction of scientific knowledge as their research object (e.g., Latour and Woolgar 1979, Mulkay 1984, Woolgar 1988, Ashmore 1988, 1989, Ashmore et al. 1989, Mulkay 1991). Critiques of this approach were plentiful; not only did objections predictably argue that reflexivity was endlessly recursive and thus could only result in pointless naval-gazing (Halfpenny 1988, Baber 1992) and delegitimization of an already shaky social science (Latour 1988, Fuller 1994), but they also objected to the *artifice* of these text forms. Creating fictional narrators or interlocutors did not liberate STS from objectivist realism but rather obscured actual authors, who, as critiques pointed out, did not however abandon the privileges of authorship (Pinch and Pinch 1988, Chaplin 1994, Ch. 6). In the case of Trevor Pinch and his fictional co-author Trevor Pinch (1988), who use the style of these texts in order to critique them, the "new literary forms" themselves are transitive, being equally available for a reflexive program as an anti-reflexive one, and creating "narrative leviathans" in both (Traweek 1992). Irony and parody in these texts similarly established an artifice that rendered its argument ambiguous and thus unassailable, leaving this wave of reflexivity literature, in the words of one reviewer, "constituting for themselves a rather hermetically sealed universe, in which these issues can be debated without reference to the discourse of outsiders who are not being allowed in" (Doran 1989, p. 758).

Around the time of these debates, feminist approaches to science studies also advocated for multivocal accounts that refused presumptions of objectivity, neutrality, and the simple bifurcation of nature and discourse. Yet, for feminists, STS reflexivity was an ethical rather than epistemic imperative, with a commitment to account for—and be accountable to—both knowers and known (Star 1991, Rouse 2002, Ch. 5). And while mainstream STS felt that radical reflexivity had gone too far, some feminists suggested they had not gone far enough (Garroute 1999); indeed, the very word "reflexivity"—strongly associated with new literary forms and their discontents—was rejected on these terms by some feminist STS scholars (Haraway 1997, Mol 2002). Feminists' concern was not to undermine the truth correspondence between their own accounts and the worlds described therein, but to respond methodologically to the ways that STS accounts *performatively act upon those worlds*. This understanding of performativity focused on the notion that STS research does not only describe or represent but also intervenes in and shapes epistemic practices and, in some versions, ontologies (e.g., Callon 1998). The substantial *ethical* stakes of STS's performativity can be felt in the rhetoric of "innocent" or "guilty" methods that often accompanied calls for greater methodological reflexivity in feminist STS of the 1990s.[1] Whereas the *self-exemplifying theatrical strategies* of SSK reflexivity asked readers to get the joke, thereby interpolating them into a deconstructive acknowledgement of the constructedness of these authorial accounts, feminist STS literatures used *self-interrogating modes* in the service of inviting readers to consider and question the practical doings that constituted their accounts (e.g., Wynne 1988; Mol 1998, 2002; Verran 2001).[2] Still, whether from SSK or feminist STS, imperatives for reflexivity in science studies were disputed; Mike Lynch (2000) has argued, for example, that reflexivity should not to be understood as an ethical *or* epistemological virtue, but rather recognized as an ethnomethod: a feature of ordinary action and daily reasoning. Facing this tangled, heterogenous body of literature, what surprised me most was that it seemed largely characterized by texts arguing for *or* against reflexivity in STS while leaving as an open question *how reflexivity might be sustained in the daily practice of science studies. Staging STS* was composed, performed, and analyzed[3] in hopes of thinking through this question empirically and experientially, which is to say theatrically.

The everyday theater of reflexivity

According to the Merriam-Webster dictionary, the word "theatrical" means (1) "of or related to the theater" but also denotes being (2) "marked by pretense or artificiality," or (3) "marked by extravagant display or exhibitionism" (theatrical 2019). In describing the SSK reflexivity of the 1980s, I have been using "theatricality" in the second and third sense, but these meanings are precisely what I wanted to challenge when I presented *Staging STS*. The notion of theater as pretense or artifice has suffused Western philosophy since Plato, bracketing it off as an illegitimate site for true knowing, or knowing truth (Barish 1981, see also Puchner 2002); indeed, theatricality as a refusal of truth claims was precisely the point for SSK reflexivists. Feminist STS, in critiquing SSK reflexivity and looking to performativity to theorize methodological responsibilities, implicitly took up an antitheatrical position. Ironically, this antitheatrical prejudice (Barish 1981) is also a legacy of performativity theory, since theorists who developed and described performativity had done so by carefully distinguishing it from theater.[4]

J. L. Austin and Judith Butler (the two theorists most cited for developing a theory of performativity) both repudiated theater to carve out an arena that can be properly attributed to performativity. Austin excludes theatrical speech from an otherwise vast number of speech acts that "do something":

> As utterances, our performatives are also heir to certain other kinds of ill which infect all utterances (. . .) I mean, for example, the following: a performative utterance will, for example, be in a peculiar way hollow or void if said by an actor on the stage (…) Language in such circumstances is in special ways – intelligibly – used not seriously, but in ways parasitic upon its normal use – ways which fall under the doctrine of the etiolations of language.
>
> *Austin (1962, pp. 21–22)*

Theatrical speech, for Austin, is "hollow and void" and "parasitic upon its normal use" because its context is *artificial*; at the very least, he suggests that the special circumstances of such speech (regardless of what is spoken) compromise (*etiolate*, or weaken) its performative potential. Derrida (1977) deconstructed this view, insisting that there can be no such distinction between natural and artificial speech, since all speech, by virtue of its necessary citationality, is parasitic in Austin's sense. Butler (1993, especially Ch. 8) and Parker and Sedgwick (1995) build on Derrida's notion of citationality as a way to articulate the *unintentional* performativity of gender. Butler incorporates Derrida's notion of citationality and implicitly his critique of Austin, yet she, like Austin, also brackets off theater performance in order to describe gender performativity. For Butler, theater's problem is not its brute artificiality but rather its false sense of intentionality, and she stresses that gender performativity does not imply the sort of *intentional role-taking* that she attributes to theater acting (Butler 1988). Gender performance is not an autonomous choice; it is necessarily citational and, in its performance, iterative, "a reiterated acting that is power in its persistence and instability" (Butler 1993, p. 9).

In *Staging STS*, I question positioning the artifice and intentionality of theater in contradistinction to performativity's citationality and iterative power. My perspective comes not only through an engagement with these literatures and their critiques[5] but also from two decades of staging experimental theater. Thus, I'd like to shift from Merriam-Webster's sense of artificiality and extravagance as attributes of theatricality to its first definition, as a property of theater.

As a theater maker, it is through the "crisis of composition"[6] that I learned that the materiality of theater is a matter of *materialization*. Always facing the impossible task of how to manifest particular meanings or experiences on insufficient resources (why does theater always have insufficient resources?), the theater becomes a site where these processes of materialization, in their very artifice and intentionality, make accessible both the citationality of this meaning-making and its complex forms of iteration. We can lean on Derrida (1977) to say that theater, like any speech or representation, is *artificial* but never outside the flow of lively interaction; in its materialization, it is both citationally marked and iteratively potent. Theater, I propose, by leaning on my experience of making it, is intentional but also sublimely contingent, a situated empirical doing that makes itself sensibly accountable to all manners of interruption and reinterpretation. Like the example of the self-interrogating accounts of feminist STS, and as I tried to catalyze in the performance of *Staging STS*, experimental theater both presents an account while making available and relevant the practical doings that constitute this account.

Erving Goffman's sense of theater as a metaphor for performances of self in everyday life (Goffman 1959) is relevant here, but not, however, as a metaphor. While I draw on my experiences in spaces culturally marked as "Theater,"[7] even outside of these circumscribed cultural practices—for example in the ordinary doing of STS—I experience myself participating in theatrical processes (also, somehow, with insufficient resources). In my argument relating theater to STS notions of reflexivity and performativity, what I mean by theater is thus best understood broadly, with a lower case t, as an "intentional, contingent, semiotic arrangement of materials, entities and temporalities for others"; similarly, that "'theatricality' is used to refer to the particular arrangement of manipulable resources" (Gluzman 2018, p. 106). According to such a definition, SSK reflexivists are not more or less theatrical than feminist ones, but rather deploy their theatrical strategies (or "dramaturgies") toward other ends. These ends—whether oriented to epistemologies, ethics, or others—constrain the dramaturgies expected of us and provide fields of legibility to fabulate new endings.

More importantly, rather than assessing the theatricality of such work from a distanced position, treating it as experimental theater in this sense invites engaged, empirical attention to the dramaturgy of knowing and the materialization of knowledge, to how the dramaturgies of our work may relate to those of our research sites. My proposition here and in *Staging STS* is that theater and theatricality—often considered superfluous or even dangerous "add-ons"—offer modes and fields of engagement for a daily practice of reflexivity in the doing of STS. This is what I set out to explore in composing an immersive and distributed talk. Thus, taking the absence of theater that haunts performativity discourse seriously, I was interested in how the *artifice* and *intentionality* that have marked theater as unsuitable for the production or theorization of knowledge also allow us to orient to the daily dramaturgies that organize, stabilize, and legitimize our scholarly activities. In the distributed conference talk, I turn to these aspects through an experimental approach to the staging of STS communication, inviting other researchers to consider *in practice* how the form of their scholarly inquiry might condition the visibility of and shape the possibilities for epistemic practices they study more broadly.

Materializing accounts and accounting for materializations

I made the first version of this booklet and presentation in 2014, for a graduate student workshop with Karen Barad, when she was invited as Student Choice Speaker by fellow graduate students in the Science Studies Program (SSP) at the University of California, San Diego. There was great excitement among the grad students about her work, and I, too, was fascinated by how Barad grounded feminist theory—particularly Butler's and Haraway's notions of the material-discursive—in scientific stagings of matter at the site of quantum split-screen experiments (Barad 2007). Even while critiques from STS objected to Barad's centering of quantum physics as a seemingly unproblematic locus of authority (e.g. Pinch 2011), Barad herself was insistent that this move was not scientism but rather a *diffractive method* to be understood within a genealogy of feminist STS, which emphasizes "…the imperative to engage with science, not from a distance, but up close with a focus on the materiality of practices and of matter itself" (Barad 2011, p. 445). For Barad then, to read feminist STS through Bohrian quantum physics and vice versa was a diffractive way to explore entanglements of the material and the semiotic.

Yet, something about Barad's approach troubled me. The notion of performativity is central to her work, and her influential re-articulation of it has, I believe, revitalized its purchase in STS and elsewhere. Yet, Barad relies on Butler's sense of performativity and unproblematically imports its constitutive disavowal of theater. This problem is not merely one of definition, but informs Barad's interpretation of the play *Copenhagen*, discussed at length in the first chapter of her 2007 monograph *Meeting the Universe Halfway*. In her discussion, Barad takes issue not only with the playwright's use of discredited historical documents to suggest that physicist Niels Bohr's work on atomic energy renders him more morally suspect than his colleague Werner Heisenberg. She is also upset by the playwright's analogic application of Heisenberg's uncertainty theory to the play's thematic framework: the impossibility of knowing another's—or one's own—intentions, and the related implication that in the face of such uncertainty, objective moral assessments are not possible. Though Barad's commentary on the play is a perfectly valid piece of criticism, it was surprising to me that in her extended discussion, she attributed all authorship and characterization to the intention of the playwright, never mentioning the performers, designers, audiences, venue, or her own spectatorial process. Indeed, it is only from a side-note that we understand that Barad has actually watched the play's productions. In twenty pages of analysis, only one phrase (bemoaning the problematic message at the play's end) evoked for me the complexity of the theatrical materialization that conditioned Barad's interpretation; she asks, "*Is there anything we can hold on to as the play ends and we gather up our belongings and leave the theater*?" (Barad 2007, p. 13; italics added). This question is the only part of Barad's analysis that points to these materializations through noticing the *dematerializations* that mark the play's end and signal the gathering up of belongings. It seems to me that her question also illuminates the condition of Theater spectatorship in which the "crisis of composition"—once belonging to the playwright, and subsequently directors, performers, designers, and stage-hands—is now left to the insufficient resources of the spectator.[8] The crisis of composition does not only strike playwrights, actors, and directors; STS researchers must also face these crises in the day-to-day process of composing their research questions, methods, monographs, and talks. How do these compositions shape what STS knows and does?

The distributed conference talk

I staged the conference talk in a distributed manner in an effort to reconceptualize the sort of encounter that *could* happen at a conference panel, attempting to shift the dramaturgy of the event from a distantiated act of *scholarly communication* (reporting on phenomena elsewhere) to that of a *research encounter* (a shared attention to and analysis of a staged, unfolding, and immersive phenomenon). In this, I was inspired by the challenge put forth by the great performance ethnographer Dwight Conquergood that, "Although ethnographic fieldwork privileges the body, published ethnographies typically have repressed bodily experience in favor of abstracted theory and analysis … The interpersonal contingencies and experiential give-and-take of fieldwork process congeal on the page into authoritative statement, table, graph" (Conquergood 1991, p. 181). By calling the group's attention to various aspects of the collective reading and vocalizing that those assembled were doing, the text and its performance proposed an exploration of how theatrical arrangements of scholarly practice enact relational paradigms of subjecthood, membership, and authorship.

In offering a distributed talk, I hoped to make sensible the absence that I felt to be haunting STS conceptions of performativity, and also largely missing in broader conversations and projects engaging the arts and STS. Theater, I argued *through the doing* of the presentation, is not something extra that obscures the real, or something extra that should be done to elucidate the real, but is itself a way to orient to intentional, contingent, and ordinary practices by which "research" is done. I hope to suggest that this research-as-theater (RaT) approach allows for self-interrogating experimentation with practices that *reorient* the way research is done by doing it differently. This is the sort of reflexivity I would like to consider here, one that—in a surprise twist—aligns with the "fuddy-duddy"[9] reflexivity articulated in Michael Lynch's "Against Reflexivity as an Academic Virtue and Source of Privileged Knowledge": "If reflexivity shines for nobody in particular and its illumination is controlled by no special theory, method or subject position, it loses its metaphysical aura and becomes *ordinary*" (Lynch 2000, p. 48; italics added). It is the "ordinariness" of Lynch's reflexivity and the sense of it as "daily practice" that is highlighted by an orientation to theater; a RaT approach is built on Goffmanian performances of everyday life crossed with *an immersive approach* to the ethnomethodological troubles of how to move forward, how to go on, what to do next *together*.[10] I agree with performance philosopher Teemu Paavolainen's suggestion that, "…if the performative names a dramaturgy of becoming (of identity, species, climate), then the theatrical provides an optic for its analysis" (Paavolainen 2017, p. 188). However, following

Haraway (1997, especially pp. 23–39), I am arguing that the particular optics of theater are not to be understood as "zoomed out" or "synoptic" (Paavolainen 2017) but rather as *immersed* views that become available and manipulable from engaging reflexively[11] and materially[12] with a lived world.

Despite my best intentions, talking *about* theater is already a movement *away* from theater, whose logics and reflexivities are grasped in immersion. The logics that inhere in theater are inextricably wrapped up in practices, and thus, distinctions between theater methods and theater logics fall apart; as theater director Lin Hixson writes, "I discover performance by making it" (Hixson 2009, p. 444). How, then, to approach the experimental methodo-logics of theater?

This was the problem I was faced with when considering how to present this argument to other scholars in the context of a professional disciplinary meeting, known fondly and otherwise as an "annual conference." Indeed, the double bind of simultaneously "presenting" and "interrogating" was itself a problem I knew from many years of discovering theater by making it, a process often marked by the endlessly unraveling labor of establishing and stabilizing inhabitable conditions in which one, and others,[13] could apprehend anew. The conference talk presented here, then, took up this challenge by aiming to make sensible the contingencies of speaking and listening as conditioned by the occasion of a scholarly meeting. Like the theater adage of "Show, don't tell," this involved moving away from "simple" description, that is, away from a rhetorical register that gathers the assembled audience into a community of peers, while casting the object of research as a stable and distant other. Instead, the situation staged by distributing the conference talk was meant not only as a rhetorical device to indicate the contingencies of scholarly practice but also as a *livable circumstance* that invited multimodal attention to the theatrical conditions of one of the seemingly most basic units of scholarly action: giving voice to an authorial account. While making a big drama about theater might seem to some as overblown, here and elsewhere (Gluzman 2018), I suggest that an experimental engagement with the ordinary practices of theater and theatricality that underpin situated acts of scholarship offers a way out of the seeming stalemates characterizing disciplinary debates over the *reflexivity* that could or should (or could not and should not) be a methodological principle for the doing of STS.[14]

STAGING STS

Yelena Gluzman
University of California, San Diego
egluzman@ucsd.edu

1

Hello.

My name is Yelena Gluzman.

Rather than describe my research, I would like to attend to the material conditions that make possible this panel presentation.

Doing this sort of "panel gazing" is not to demonstrate the performativity of scholarship, but rather to explore what, for STS scholars, may lie beyond the limits of performativity.

2

Possibly the most influential STS scholar to invoke performativity in the past decade, after the height of the "performative turn" came and went, has been Karen Barad. Barad introduced the term "intra-action" (not interaction) to stress that any subject of inquiry does not pre-exist the encounter with the apparatus that inquires. In Barad's argument, all entities emerge from encounters, and the ontology of those entities (as apparatus, subject, object) is shaped by the particular boundaries drawn, the "cut" enacted in the intra-action. Barad insists that there can be no a priori separation between the ontic and epistemic; they are entangled. Models, measuring devices, theories are themselves material-discursive, both manifesting a material world, and being in turn manifested within that world.

Barad has drawn fire for her seemingly uncritical use of findings in quantum physics to show how such intra-action occurs.

In wanting to support and think through Barad's notion of the material-discursive, I take issue not with her quantum particles, but with her notion of theater.

3

This is not a manifesto, though it is a question about making manifest.

If we take seriously agential intra-action at all scales, how can we analyze the conditions that lead to one "cut" over another, when we ourselves are constituted in the cutting? If we take responsibility for the agential cuts which render us agents (**scholars, artists, scientists**), *how might we consider and structure the performativity of our intersubjective investigations?*

4

We want to consider what lies beyond the limits of performativity. But what is performativity, and what are its limits?

Barad wrote:

"Performative approaches call into question representationalism's claim that there are representations, on the one hand, and ontologically separate entities awaiting representation, on the other, and focus inquiry on the practices or performances of representing, as well as the productive effects of those practices and the conditions for their efficacy. A performative understanding of scientific practices, for example, takes account of the fact that knowing…come(s) from…a direct material engagement with the world. Importantly, what is at issue is precisely the nature of these enactments. Not any arbitrary conception of doings or performances qualifies as performative. And humans are not the only ones engaged in performative enactments (which are not the same as theatrical performances)."

This passage introduces two important ideas: one is that performance both constitutes the objects of knowledge and is itself the process of knowing. The other is that theater is not, in this sense, performative.

If, in Barad's terms, all categorical distinctions emerge from particular material intra-actions, why is the category of theater excluded from the legitimacy of materialism?

5

Barad's parenthetical disavowal of theater is only the tip of a much larger pile of theater that has been shuffled to the side, not only in STS literature, but also in the performance studies literature cited most by STS:

JL Austin, whose notion of the performativity of speech acts is one of the cornerstones of performativity theory, wrote that *"a performative utterance will, for example, be in a peculiar way hollow or void if said by an actor on the stage."* **Judith Butler, whose work on the performativity of gender is foundational to the emergence of performance studies as a discipline, also defined performativity against its divergence from the theater when she said that** *"the reduction of performativity to performance would be a mistake."*

Performance studies scholar Shannon Jackson argued that part of the process of articulating a new discipline called performance studies (with its central concern of performativity) was done by characterizing it in contradistinction to theater studies. Theater was artificial, representational, traditional and manual so that performance could be real, material, radical and theoretical. Jackson convincingly argues that there are multiple ways in which the exclusion of theater forms a constitutive absence in performativity's (and performance studies') congealing presence. Theater delimits, and delineates, performativity.

6

As I write this, I imagine these words diffracted by multiple voices. I imagine the instability of the word "I". I choose my words carefully, trying them on to a new "I," seeing if they fit another "my." I am writing differently.

A room full of simultaneous talking is difficult to hear. *One voice rings with clarity.* **This is not only a legacy of liberalism or a function of the legal structures that insist on individuals, it is embedded in the material-discursive systems through which we listen. If the clarity of one voice dominates, and yet we are committed to making a case for distributed cognition, for shifting subjectivity, we must attend to tuning, the structures through which we listen.**

To say this in another way: what is this artificial, representational, traditional and manual practice that has been called theater?

7

Let me get personal *(and by doing this, let me also assert the importance of situated, subjective experience as a basis for knowing what happens in theater).*

In my experience of theater, from my earliest memories of sitting among the audience as a child, I was never in doubt that what unfolded in those spaces was *(forgive me)* **real. Even then, I understood intuitively that an actor being slapped on stage was a different slap than one received in private, but it was nonetheless a real slap, with irrevocable consequences not only for that actor's mind and body, but also for myself, for everyone in that room, and indeed for what I could only dimly conceive of as a totality of experience that transgressed the closed doors of the theater. In other words, while recognizing the particular arrangements of space, time, architecture, and entities that constrained the operation of a piece of theater, I could also see that such "artificial" constraints could never** *resist the complexity of interactions that* **they** *made possible.*

Later, when I became interested in theater as a field of engagement, I "made" performances, an activity that was relentlessly laborious, terrifying, and humbling. I qualify the word "made" because a vivid aspect to the experience of "making" theater was in fact the ambiguity of authorship and agency: one is both racked with the weight of responsibility of composition, of introducing a gesture or speech-act into a public space that did not necessarily ask for it, and at the same time, must come to terms, over and over, with the fact that this gesture or act is neither original nor possible. Theater is messy, both in the sense that no one is really in control, but also in that what it stages always exceeds what it represents. When taking into account the great hubris of theater-making at the same time as honoring its extreme contingency at every moment, theater begins to look more like the sort of interaction that Barad described by renaming it. Rather than understanding theater as a one-way flow of representations leading to a particular experience, I am suggesting that **material-discursive interactions give rise to particular sorts of boundary-making**, *and therefore that the very categories of artificiality and actuality are constituted in the particular interactions of the theatrical space.*

8

So theater, the practice that is both artificial and actual, that is both intentional and contingent, that is both productive and excessive, lies beyond the limits of performativity. Why might theater matter to the science and technology scholars assembled here today?

Though Annemarie Mol is not the only one who realized that performativity calls for serious thinking about our own practices, she may have said it best:

"Self-reflexive desperation about the foundation of our (whose?) knowledge is no longer required. We would be wiser to spend our energy on trying to come to grips with what we are doing when crafting academic knowledge. What are we doing—when we go into fields, observe, make notes, count, recount, cut, paste, color, measure, slice, categorize, and so on. What are we doing when we tame materials, when we publish, give talks, stage stories for various audiences."

Because our scholarly practices are constructive, not only of knowing but also of what we seek to know, indeed of the "we" that can know, must we not reflect on the material structures of scholarship? Might it be possible to consider (build, experiment with) the act of scholarship as consistent with (open to?) the conscious manipulation of boundaries, temporalities, and entities that characterize the theater?

9

In 1968, Margaret Mead and Paul Byers published a modest book called The Small Conference: An Innovation in Communication. In it, Mead argues that scholarly meetings went through a historical shift after World War I, moving from a configuration of one-to-many (with its lecterns, stages, microphones, linear scripts) to a configuration of face-to-face (with its organization around a conference table, its lack of ordered speech, and its ongoing multimodal engagement as a form of "total involvement"). She wrote:

"In the long presentation and counter-presentation which may characterize a live symposium or panel, but is essentially a written form, the weaving together of thought appears only in sequentially organized statements by single speakers. In the [small] conference, each participant, by expressed disagreement, dissent, even boredom, is participating continuously (...). The ideas that grow under such conditions are different from the ideas which any participant would have had working alone, or even working with one or two colleagues. If this does not happen, either the subject matter, the arrangements or the participants of the conference were poorly chosen."

We may disapprove of Mead's optimism about the small conference as form, but we cannot argue that the form was, in fact, in some way, chosen. **And that some choices are better than others**.

10

What are the relationships between the form of scholarly communication and the object of scholarship?

and

What are the conditions that constitute a scholarly utterance as such?

and

What is my part in this paper presentation?

What have I done to constitute a legitimate author, to make possible the legibility of the talk?

How do the multiple voices that carry, trip, alter, and drop this text negotiate with each other, even when *(shout out to Garfinkel)* **the linguistic social conventions of this negotiation disintegratekbjegbvb jsbdughbxz**
kmdnkjbd
dmnkdsbnkf
dd
khiue
kjhgyyewoihzblioooo
piqnninxx ejijiee
eeeknnk
iiiii

11

Are you saying that scholarship should be done as a kind of theater?

No… I'm saying that it already is.

Works cited

Austin, J.L. 1962. *How To Do Things with Words*. Oxford: Oxford University Press.
Barad, Karen. 2007. *Meeting the Universe Halfway*. Durham, NC: Duke University Press.
Butler, Judith. 1993. *Bodies That Matter*. London: Routledge.
Jackson, Shannon. 2004. *Professing Performance*. Cambridge, NY: Cambridge University Press.
Mead, Margaret and Byers, Paul. 1968. *The Small Conference: An Innovation in Communication*. The Hague: Mouton & Co.
Mol, Annemarie. 2002. *The Body Multiple*. Durham, NC: Duke University Press.

Works sighted

Barish, J.A. 1981. *The Antitheatrical Prejudice*. Berkeley: University of California Press.
Diamond, Elin. 1988. “Brechtian Theory/Feminist Theory: Toward a Gestic Feminist Criticism.” *TDR*, 32(1), 82–94.
Herzig, Rebecca. 2004. “On Performance, Productivity and Vocabularies of Motive in Recent Studies of Science.” *Feminist Theory*, 5, 127–147.
Law, John. 2004. *After Method: Mess in Social Science*. London: Routledge.
Law, John and Singleton, Vicky. 2000. “Performing Technology’s Stories: On Social Constructivism, Performance and Performativity.” *Technology and Culture*, 41(4), 765–775.
Parker, Andrew and Sedgwick, Eve Kosofsky. 1995. *Performativity and Performance*. London: Routledge.
Puchner, Martin. 2002. *Stage Fright: Modernism, Anti-theatricality and Drama*. Baltimore, MD: Johns Hopkins UP.
Ridout, Nicholas. 2006. *Stage Fright, Animals, and Other Theatrical Problems*. Cambridge, NY: Cambridge University Press.

To cite this presentation

Gluzman, Yelena. *Staging STS*. Annual Conference of the Society for Social Studies of Science, Sheraton Hotel, Denver, CO. November 12, 2015. Conference performance.

Cover image by Paul Byers, from Mead and Byers (1968) *The Small Conference*, reprinted with permission from the Byers estate.

Notes

1 For example, John Law and Vicky Singleton (2000) write,

> [Previous STS approaches] choose, often knowingly, to ignore the performative consequences of their own descriptions. By contrast, (…) feminist technoscience studies choose to wrestle with the fact that they (and therefore their own accounts) are socially located, *noninnocent*, and therefore political performances. This suggests that they don't offer simple descriptions, but make a difference.

(767, italics added). For other examples, see Mol (2002, p. 41) and Law and Urry (2004).

2 Wynne (1988) appeared in the volume *Knowledge and Reflexivity*, edited by Steve Woolgar, and although I have doubts that Wynne would consider herself belonging to feminist STS more than to SSK, her self-interrogating mode of taking up reflexivity aligns more with a feminist STS approach and shares many features with Mol's later work *The Body Multiple* (2002).

3 See Gluzman (2018) for this analysis.

4 As Bert O. States has written, "…in the wake of widely disparate activities (social, behavioral and artistic alike) being 'subsumed' under the 'genus' of *performance*, the term *theatre* gradually underwent a loss in validity" (States 1996, p. 8). For an extended genealogical study of this phenomenon, see Shannon Jackson's excellent monograph, *Professing Performance* (Jackson 2004). My discussion of Austin and Butler is indebted to both texts.

5 For example, Davis and Postlewait (2003), Diamond (2003), Jackson (2004), Herzig (2004), Ridout (2006), and more recently, Paavolainen (2017) and Nye (2017).

6 While the phrase "crisis of composition" is my own, the notion of "crisis" as a condition for theater-making comes from theater director and mentor Anne Bogart, with whom I studied in the Theater Directing MFA program at Columbia University. See, for example, Bogart (2001, pp. 51–52 and 119).

7 I capitalize Theater as a proper noun to specify that both my experience of it, and the correlated discussions in the scholarly literature, are rooted in histories of European theater, overwhelmingly attributed to the development of the form in Ancient Greece, and associated with cultural sites of such activities (i.e., in theaters and playhouses, on distantiated stages and through framing proscenia) (e.g., Barish 1981).

8 I am deeply grateful to Karen Barad for her generous engagement with this argument and its performance at the UCSD workshop.

9 This is Lynch's term. I re-use it here not because I think his view is at all fuddy-duddy, but to acknowledge the seeming contradiction of using an argument against reflexivity to support an argument for it.

10 I am grateful to Don Everhart for clarifying the importance of the local question of "what to do next together' in ethnomethodological frameworks (Everhart 2018).

11 I hope it has become clear that I am aligning my reflexivity with both Lynch's ethnoreflexivity and Haraway's antireflexivity. Though Haraway (1997) and subsequently Barad (2007) jettison reflexivity in favor of diffraction, I am staying with the troubles of reflexivity in the belief that experimental theatrical explorations of "what we are doing" (Mol 2002, p. 158) can extend Haraway's diffractive program while preserving the vexed histories of these attempts.

12 As I tried to suggest in my discussion of Barad's take on *Copenhagen*, to engage *materially* is to participate in the practical *materialization* of shared meaning. A reflexive scholarly account is produced and composed from within participation.

13 I had initially formulated this unit as "one, with/as others" to capture the ways that boundaries marking selves are variable and multiple in the experience of doing theater, as with the body of the audience, the ensemble, etc. I thank Christina Aushana for comments on an early draft of this argument.

14 Elsewhere (Gluzman 2018), I develop in some detail the proposition that is staged through the booklet documented below, and which I can only gesture towards in this introduction. In that same chapter, I also analyze the distributed conference talk as it unfolded in practice, alongside the performance of another, more conventional, conference talk by theater scholar Martin Puchner. An extended analysis of these talks as they were enacted was a movement from considering the role of arts in STS as one of *intervention* to one of *experimentality*, a distributed opportunity through the empirical unfolding of the staged talk to interrogate how authorship and academy are co-staged as

art and fact. Finally, while the booklet artifact presented here attempts this sort of experimentality only at the site of the conference presentation, I do not mean to suggest this to be the only site of interest in regard to thinking through experimental theater methods to staging STS. In other projects, for example, I explore experimental theatrical paradigms at the site of academic reading (Gluzman 2017b) and at the site of STS laboratory ethnography and analysis (Gluzman 2017a).

References

Ashmore, M. 1988. "The Life and Opinions of a Replication Claim: Reflexivity and Symmetry in the Sociology of Scientific Knowledge." In *Knowledge and Reflexivity: New Frontiers in the Sociology of Knowledge*. Ed. Steve Woolgar. London: Sage Publications, pp. 125–153.

———. 1989. *The Reflexive Thesis: Wrighting Sociology of Scientific Knowledge*. Chicago, IL: University of Chicago Press.

Ashmore, M., Mulkay, M., and T. Pinch. 1989. *Health and Efficiency: A Sociology of Health Economics*. Milton Keynes: Open University Press.

Austin, J.L. 1962. *How to Do Things with Words*. Oxford: Oxford University Press. Web. Accessed March 10, 2014 from www.metaphilo.fr/Livres/ Austin%20%20How%20to%20 do%20things%20 with%20words.pdf.

Baber, Z. 1992. "Lost in the Reflexive Funhouse?" *Theory and Society*, 21(1), pp. 105–119.

Barad, K. 2007. *Meeting the Universe Halfway*. Durham, NC: Duke University Press.

———. 2010. "Quantum Entanglements and Hauntological Relations of Inheritance: Dis/continuities, Spacetime Enfoldings, and Justice-to-come." *Derrida Today*, 3(2), pp. 240–268.

———. 2011. "Erasers and Erasures: Pinch's Unfortunate 'Uncertainty Principle.'" *Social Studies of Science*, 41(3), pp. 443–454.

Barish, J. 1981. *The Antitheatrical Prejudice*. Berkeley: University of California Press.

Bogart, A. 2001. *A Director Prepares: Seven Essays on Art and Theatre*. London, New York: Routledge.

Butler, J. 1988. "Performative Acts and Gender Constitution: An Essay in Phenomenology and Feminist Theory." *Theatre Journal*, 40(4), pp. 519–531.

———. 1993. *Bodies That Matter: On the Discursive Limits of "Sex"*. London, New York: Routledge.

Callon, M. 1998. "Laws of the Markets." *Sociological Review Monograph*, 46(S1), pp. 1–272.

Chaplin, E. 2003 [1994]. *Sociology and Visual Representation*. London, New York: Routledge.

Conquergood, D. 1991. "Rethinking Ethnography: Towards a Critical Cultural Politics." *Communication Monographs*, 58, pp. 179–196.

Davis, T.C., and Postlewait, T. Eds. 2003. *Theatricality*. Cambridge, NY: Cambridge University Press.

Derrida, J. 1977. *Limited Inc*. Evanston, IL: Northwestern University Press.

Diamond, E. 2003. *Unmaking Mimesis: Essays on Feminism and Theater*. London, New York: Routledge.

Doran, C. 1989. "Grasping Reflexivity: Review of Knowledge and Reflexivity by S. Woolgar." *Social Studies of Science*, 19(4), pp. 755–759.

Everhart, D. 2018. "Procedures and Their Problems in Routine Laboratory Work." Invited Lecture. University of California, San Diego, Science Studies Colloquium Series. April 9, 2018.

Felt, U., Fouché, R., Miller, C.A., and Smith-Doerr, L. Eds. 2017. *The Handbook of Science and Technology Studies*, 4th Edition. Cambridge, MA: MIT Press.

Fuller, S. 1994. "The Social Epistemologist in Search of a Position from Which to Argue." *Argumentation*, 8(2), pp. 163–183.

Garroute, E.M. 1999. "Getting Serious About 'Interrogating Representation': An Indigenous Turn." *Social Studies of Science*, 29(6), pp. 945–956.

Gluzman, Y. 2017a. "Analyzing the Analyst: An Experimental Data Video for Thinking Theatre and Cognitive Neuroscience Together." *Performance Matters*, 3(2), pp. 107–118.

———. 2017b. "Feminist Theory Theatre." In *Imagined Theatres: Writing for a Theoretical Stage*. Ed. Daniel Sack. London, New York: Routledge, pp. 80–81.

———. 2018. "Research-as-Theatre (RaT): Positioning Theatre at the Centre of PAR, and PAR at the Centre of the Academy." *In Performance as Research: Knowledge, Methods, Impact*. Ed. Bruce Barton, Annette Arlander, Ben Spatz, and Melanie Dreyer-Lude. London, New York: Routledge, pp. 123–150.

Goffman, Erving. 2012 [1959]. "The Presentation of Self in Everyday Life." In *Contemporary Sociological Theory*. Ed. Craig Calhoun, Joseph Gerteis, James Moody, Steven Pfaff and Indermohan Virk, 3rd Edition. Hoboken, NJ: Wiley-Blackwell, pp. 46–61.

Halfpenny, P. 1988. "Talking of Talking, Writing of Writing: Some Reflections on Gilbert and Mulkay's Discourse Analysis." *Social Studies of Science*, 18(1), pp. 169–182.
Haraway, D. 1997. *Modest_Witness@Second_Millenium.FemaleMan©_Meets_OncoMouse™*. London, New York: Routledge.
Herzig, R. 2004. "On Performance, Productivity, and Vocabularies of Motive in Recent Studies of Science." *Feminist Theory*, 5(2), pp. 127–147.
Hixson, L. 2009. "And a Look and On." *Poetry*, 194(5), pp. 444–445.
Jackson, S. 2004. *Professing Performance*. Cambridge, NY: Cambridge University Press.
Latour, B. 1988. "The Politics of Explanation: An Alternative." In *Knowledge and Reflexivity: New Frontiers in the Sociology of Knowledge*. Ed. Steve Woolgar. London: Sage Publications, pp. 155–176.
Latour, B. and Woolgar, S. 1986 [1979]. *Laboratory Life: The Construction of Scientific Facts*, 2nd Edition. Princeton, NJ: Princeton University Press.
Law, J. 2004. *After Method: Mess in Social Science Research*. London: Routledge.
Law, J. and Singleton, V. 2000. "Performing Technology's Stories: On Social Constructivism, Performance and Performativity." *Technology and Culture*, 41(4), pp. 765–775.
Law, J. and Urry, J. 2004. "Enacting the Social." *Economy and Society*, 33(3), pp. 390–410.
Lynch, M. 2000. "Against Reflexivity as an Academic Virtue and Source of Privileged Knowledge." *Theory, Culture & Society*, 17(3), pp. 26–54. https://doi.org/10.1177/02632760022051202.
Mol, A. 1998. "Missing Links, Making Links: The Performance of Some Artheroscleroses." In *Differences in Medicine: Unraveling Practices, Techniques and Bodies*. Ed. Marc Berg and Annemarie Mol. Durham, NC: Duke University Press, pp. 144–C65.
———. 2002. *The Body Multiple*. Durham, NC: Duke University Press.
Mulkay, M. 1984. "The Scientist Talks Back: A One-act Play, with a Moral, about Replication in Science and Reflexivity in Sociology." *Social Studies of Science*, 14, pp. 265–282.
———. 1991. *Sociology of Science: A Sociological Pilgrimage*. Bloomington: Indiana University Press.
Nye, C. 2017. "Science and Performance: Th(eo)atrical Entanglements and Hautological Relations." *Performance Matters*, 3(2), pp. 1–15.
Paavolainen, T. 2017. "Fabric Philosophy: The 'Texture' of Theatricality and Performativity." *Performance Philosophy*, 2(2), pp. 172–188.
Parker, A. and Sedgwick, E.K. 1995. *Performance and Performativity*. London, New York: Routledge.
Pinch, T. 2011. "Review Essay: Karen Barad, Quantum Mechanics, and the Paradox of Mutual Exclusivity." *Social Studies of Science*, 41(3), pp. 431–441. https://doi.org/10.1177/0306312711400657.
Pinch, T. and Pinch, T. 1988. "Reservations about Reflexivity and New Literary Forms or Why Let the Devil have all the Good Tunes?" In *Knowledge and Reflexivity: New Frontiers in the Sociology of Knowledge*. Ed. Steve Woolgar. London: Sage Publications, pp. 178–197.
Puchner, M. 2002. *Stage Fright: Modernism, Anti-theatricality, and Drama*. Baltimore, MD: Johns Hopkins University Press.
Ridout, N. 2006. *Stage Fright: Animals and Other Theatrical Problems*. Cambridge, NY: Cambridge University Press.
Rouse, J. 2002. *How Scientific Practices Matter: Reclaiming Philosophical Naturalism*. Chicago, IL and New York: Chicago University Press.
Star, S.L. 1991. "Power, Technology and the Phenomenology of Conventions: On Being Allergic to Onions." In *A Sociology of Monsters*. Ed. John Law. London: Routledge, pp. 26–56.
States, B.O. 1996. "Performance as Metaphor." *Theatre Journal*, 48(1), pp. 1–26.
Theatrical. 2019. In *Merriam-Webster.com*. Retrieved February 27, 2019, from https://www.merriam-webster.com/dictionary/theatricality#h2.
Traweek, S. 1992. "Border Crossings: Narrative Strategies in Science Studies and among Physicists in Tsukuba Science City, Japan." In *Science as Practice and Culture*. Ed. A. Pickering. Chicago, IL: University of Chicago Press, pp. 429–465.
Verran, H. 2001. *Science and an African Logic*. Chicago, IL: University of Chicago Press.
Woolgar, S., Ed. 1991 [1988]. *Knowledge and Reflexivity: New Frontiers in the Sociology of Knowledge*. London, Newbury Park, CA, New Delhi: Sage Publications.
Wynne, A. 1991 [1988]. "A Self-Exemplifying Text Accounting for Accounts of Multiple Sclerosis." In *Knowledge and Reflexivity: New Frontiers in the Sociology of Knowledge*. Ed. S. Woolgar. London, Newbury Park, CA, New Delhi: Sage Publications, pp. 101–122.

Section 4

Collaborations and collisions in art–science

Megan K. Halpern

Art–science collaborations usually involve not only artists and scientists but also curators, social scientists, science communication experts, educators, and audiences. Participants from such a wide range of backgrounds, each interacting with art and science in different ways and each bringing their own forms of expertise to the process, make for a messy, often fraught process. Agendas sometimes compete, sometimes complement one another; different kinds of knowledge are valued in different ways; and the practices, technologies, and languages used by some are often unfamiliar or even opaque to others. Why then, do so many attempt art–science collaboration? What do such collaborations afford? It is the messiness of these projects that often reveals their value for participants: exposure to the unfamiliar makes for new approaches and perspectives. For audiences, the value depends on their expectations, previous experiences, and the context in which they engage with a project. But, for art, science, and technology studies as a field, these collaborations and collisions provoke us and push us to new and deeper understandings of not only the topics of a given project but also of what ASTS means.

The four chapters in this section each describe projects in which artists, scientists, and others collaborate. Particular attention should be paid to the social worlds within which these four projects were created. Two of the described projects developed within art worlds, though one of these worlds was housed within a science world. Another project originated within the world of informal science learning and still another began as an independent project that found a home within a cultural festival. In each case, the context within which it began shaped the ways art and science interacted, and each chapter reveals how participants worked to navigate the boundaries between art and science.

In her chapter (Chapter 16), Nora S. Vaage examines two pieces created for SymbioticA's *Semipermeable(+)* exhibition in 2013.[1] It is worth noting that SymbioticA is a "Center for Excellence in Biological Arts" housed within a School of Anatomy and Human Biology. The two pieces Vaage examines, *Kynic* and *in potēntia*, were both created by artists working with scientists and using science as a medium to express their ideas as artists. As the high volume

DOI: 10.4324/9780429437069-20

of bioart represented in this handbook might indicate, bioart has developed into its own thriving art world in the past few decades. As Vaage notes:

> As biological arts matures into an art form that is not merely proving that living material and biological methods can be used as an art medium, but presenting more complex concepts and expressions that happen to involve those media, bioart is increasingly accepted by art world actors.

In this kind of art world, artists often require mentorship or participation from scientists, since they are working with living organisms and scientific methods. Like Forlano and Sedini's chapter in Section 3, Vaage draws on the STS concept of trading zones[2] to help explore the ways in which the artists worked with scientists to develop their pieces. In her observations surrounding the creation of the two pieces, she writes about the need for a common language by which artists could communicate with scientists about how to achieve the artists' aims. While the products of these pieces did not result in what the scientists might consider scientific research, in one case, the scientist did express his interest in the process for generating new perspectives and ideas for avenues of research. Additionally, he felt the presence of the artist gave the researchers "an excuse to engage in more open-ended, basic research rather than the goal-oriented processes of biological research". Despite the collaborations and the formation of trading zones Vaage describes for each project, she emphasizes that ultimately, the projects belonged within art worlds, meaning the translations did not extend to the exhibition's audiences.

While art worlds drove the final presentation of the two pieces Vaage examines, in Chapter 17, Kathryn de Ridder-Vignone writes about how art–science collaborations develop around science education. She examines the creation of educational modules for the Exploratorium's ArtNano program. The project was part of a large, NSF-funded network of museums and science centres called NISE Network (Nanoscale Informal Science Education Network). Because they operated within this structure, the process and products looked quite different from what Vaage describes at SymbioticA. As de Ridder-Vignone writes, "these artists and scientists perform as educators to exert the institutional power and practices of art, science, and museums in an attempt to connect to and empower 'the public' to shape what nanotechnology will become". Art and science were also valued differently to the degree that de Ridder-Vignone sees multiple instances of art being subjugated to science and being "cut" from NISE Network programming. While artists interviewed for the project tell her one of NISE Network's sites, The Exploratorium, values their work, and they find equal partnership between art and science, de Ridder-Vignone found that the larger institution responsible for disseminating programming to the rest of the Network tended to fall into patterns of instrumentalization, in which the artists' work was used to explain or elevate the science.

Looking at these two chapters together might suggest that within art worlds, science becomes instrumentalized, while within social worlds that prioritize science, like informal science education, art becomes instrumentalized. But a close reading of these two chapters suggests that there is more going on here. SymbioticA, after all, is housed within a science world, granting artists unprecedented access to scientific expertise and resources, and even if the artworks generated for exhibitions did not, in themselves, possess scientific merit, the processes by which they were generated sometimes did lead scientists down to new paths of discovery. The artists-in-residence who worked with the Exploratorium for NISE Network, however, were charged with a specific mission to help determine "how to best present difficult-to-understand concepts of the nanoscale to their visiting publics". Thus, even though The Exploratorium has a reputation for collaborations that invoked playfulness and risk taking, the final products delivered to NISE Network for dissemination "did not rely on or build from the knowledge learned or produced during the artist-residencies".

Much of de-Ridder Vignone's account of art–science interaction at NISE Network indicates a hierarchical organization of knowledges and epistemologies, determined, in no small part, by the funding structures that provided resources for the network. Section 5 of this handbook delves into examinations of the infrastructures that support art–science endeavours, but infrastructures also impact intimate interactions between art and science on the ground, shaping the values and (often implicitly) determining the goals of collaborations. In my own chapter in this section (Chapter 18), I examine a small, independent collaboration between a choreographer and a physicist. Though the project was developed by a group of four people, the structures that shape funding and career demands played a role in our initial development of the concept. While the four of us resisted the instrumentalization inherent in the informal science education projects developed by NISE Network, we found ourselves contorting our initial plans in order to escape explanatory patterns that drew on dance and movement as illustrations of concepts rather than knowledge forms of their own. In the end, I argue, the project was able to reassert the value of dance as a form of knowledge, but at the expense of the kind of integration the collaborative team sought when we embarked on the project.

The final chapter in this section, written by Nicola Triscott and Anna Santomauro (Chapter 19), offers an approach to art–science that embraces the multiple, competing agendas inherent in art–science collaboration. Triscott and Santomauro draw on their experiences curating Arts Catalyst to suggest a cooperative model that brings diverse groups together around a theme or topic that drives their respective work, but recognizes that they may each develop their own ideas and products, tailored to their respective fields. While reflecting on an Arts Catalyst project which, like *Dance of Scales*, left the collaborators with a sense that the process was less than successful, Triscott and Santomauro considered what led to their disappointment, and how the process differed from collaborations they felt had fared better. "It occurred to us that the more conceptually-driven and open process of Makrolab had allowed for spontaneous self-directed participation than more goal-oriented collaborative or residency programs". This prompted them to develop and adopt a model for cooperation, as opposed to collaboration, at Arts Catalyst. Their model, which they refer to as "critical and transdisciplinary co-inquiry", aims to foster work that crosses disciplinary boundaries and invites collaborative experiences, but maintains freedom in terms of outcomes because, as they note, "it seems that art works best as a free and potentially disruptive process – losing its power if it is too focused or managed in terms of its outcomes". Their process hinges on three principles: identifying a "matter of concern", the co-production of knowledge, and ecological view of practices.

Arts Catalyst has drawn on these principles for several projects at different sites with promising results. Like SymbioticA, Arts Catalyst is, by definition, an arts organization, signifying that these projects operate largely as art worlds (even though SymbioticA operates within a science world, its processes of legitimation are largely bound up in artistic rather than scientific practices). Their flexibility might leave the reader to wonder if art worlds are more conducive to open-ended processes like those described by Vaage and by Triscott and Santomauro. More broadly, these four chapters, taken together, indicate that infrastructures within which art–science collaborations take place play a pivotal role not only in the products and outcomes of these collaborations but also in the nature of the collaboration.

The relationship between these overarching structures and the individual relationships and projects is clearly worthy of further consideration. Beyond questions of infrastructure, much room remains for extensive research into the ways in which artists and scientists collaborate. Much like laboratory studies paved the way for understanding how scientific knowledge is generated, intimate studies of the ways art–science is generated can illuminate the nature of art–science.

16

Trading between science and art worlds

From biology laboratory to art exhibition

Nora S. Vaage

Introduction

In a handbook for art, science, and technology studies, the relationship between these three spheres is bound to be the object of intense scrutiny. As I have previously elucidated (Vaage 2015), I believe discussing "art" and "science" as opposing entities disguises the real complexity of a situation in which artists, designers, engineers, biologists, physicists, humanities scholars, technicians, and others might work together, sometimes combining multiple roles. However, for this chapter, I am interested in the movements between "science-" and "art worlds" (Becker 1982; Kuhn 1962).

I discuss the development and experience of two artworks shown in the exhibition *Semi-permeable(+)* as part of ISEA (International Symposium for Electronic Arts) in June 2013.[3] Both artworks were developed at SymbioticA Centre for Excellence in Biological Arts, a permanent artistic research centre based within the School of Anatomy and Human Biology at the University of Western Australia.[4] As part of my PhD research on artists working with biotechnology, I was a resident at SymbioticA from February to May 2013 and was privy to the process of preparing the artworks for the exhibition.[5]

As biological arts matures into an art form that is not merely proving that living material and biological methods can be used as an art medium, but presenting more complex concepts and expressions that happen to involve those media, bioart is increasingly accepted by art world actors.[6] In the 1980s to early 2000s, supporters of bioartworks were mainly found in the science museums and universities, and these artworks were seen to have more interest for their capacity of contributing to public debates than for aesthetics (Hauser 2008). Jens Hauser, however, argued that "the seasonal topocentric interest that induces a narrow reading of the works may not last long" (2008: 98).

Combining perspectives from science and technology studies and philosophy of art, in this chapter, I will discuss the process and display of two more recent pieces that are hard to fit into a narrow topocentrism focused on the science alone: *Kynic*, by Benjamin Forster, and *in potēntia*, by Guy Ben-Ary and Kirsten Hudson in collaboration with Mark Lawson and Stuart Hodgetts. Both pieces involved high-tech biology laboratory processes in order

DOI: 10.4324/9780429437069-21

to transform mammalian cell cultures and took months of trial and error with the help of scientists and technicians.

Kynic is an example of a scientifically failed project, displayed mostly with the same aesthetics as was planned had it been successful, but importantly highlighting the failure. Involving a dog–human hybrid cell (which was never created), it presented a critique of contemporary cynicism inspired by the ancient Greeks. It was the artwork of a single, young artist in residence at SymbioticA, with technical support and advice from multiple scientists within the School.

In potēntia consisted of neurons placed inside a wooden phallic sculpture. The neural cells had been transformed from foreskin cells using the new technology of induced pluripotent stem cells (iPSC). The piece was presented as featuring a "functioning human brain" (Ben-Ary et al. 2013: 8) made from skin cells from the male reproductive organ and speculated about future possibilities of bioengineering sentient beings from a single parent. It was explicitly a collaborative project involving two artists, a product designer and a scientist. The result of a long process of trial and error, it was important for the team to get the technical aspects of the piece right. Concurrently, some liberties were taken in the communication of what the artwork was and how it had been created.

This chapter will discuss the process of creation and exhibition of these two artworks, both of which feature high-tech scientific procedures, in order to discuss an array of choices and challenges of such hybrid art practices. How do actors from different social worlds work together to create a hybrid artwork? Do those ways of working together inform the decisions on how the artworks are disseminated? Is it important how the pieces were created or whether what is presented is "true"?

I will start by elucidating what is meant by the terms art and science worlds, discussing the trading zones formed between these worlds and introducing the *Semipermeable(+)* exhibition. Thereafter, I will give a short description of the scientific environment at SymbioticA in which the two artworks were developed, before discussing the processes of creation and display of *Kynic* and *in potēntia*. I will end by discussing some challenges of taking science art into the art world, focusing on the exhibition of these two pieces, and considering how the trading zones established for the process of creating the artworks played into how they were exhibited.

Trading between science and art worlds: Semipermeable(+)

The interdisciplinary, hybrid projects discussed in this chapter can be said to exist within a trading zone (Galison 1997, 2010), a boundary area between different disciplines which, to some extent, forges understandings and communications through moving from disciplinary jargon to more understandable modes of communication established between the respective actors. The success of the trades in cross-disciplinary endeavours depends on the ability to forge out a cross-disciplinary jargon, sometimes resulting in a "pidgin" language that serves to provide a mutual understanding that will not be perfect, but enables work to proceed.[7] Drawing on perspectives from the disciplines and more specific expertise of the actors, these cross-disciplinary engagements can, in some cases, spark new insights. While Peter Galison developed the idea of trading zones specifically for communication between scientific disciplines, it holds as well for more radical interdisciplinarity across fields. An important realization within the concept of trading zones is that no discipline is "pure" to start with, and that the expertise of various actors thus constantly plays into areas of negotiation, but that these become more pronounced and challenging for interdisciplinary work. In the case of the biological artworks discussed below, these trading zones, as we shall see, take quite different shapes.

When discussing the trading zones in between science and art worlds, I draw on the tradition of social worlds (Becker 1982; Unruh 1980), although, since I am not a sociologist, I do not place myself squarely in this tradition. In this chapter, my interest is not in describing structures of these worlds, but rather in how specific actors move within and between worlds, especially how the specificities of art world expectations shape artistic practice.[8]

The notion of "the art world" has become a colloquial one. Introduced by philosopher Arthur Danto in 1964, it served to establish awareness that institutional and historical factors contribute to determining what is art at a given point in time and space (Danto 1964, 1992). Danto argued that the right actors within the art world had to acknowledge an artwork, to develop a *discourse of reasons* for why this piece was art, in order to make it acceptable to the rest of the world. This is especially so when an artist breaks with conventions and creates something new. The process that expanded the idea of what could be art in the course of the twentieth century meant that artists could, indeed, enter laboratories in the 1970s and 1980s, as they have done in increasing numbers since. While early bioart repeatedly encountered the question "but is it art?", by the late 2000s, these questions became more rare, indicating increasing art world acceptance of the art form.[9] However, some such works have been presented, variously, as art, design, or scientific projects, showing that the boundaries in this hybrid area are particularly blurry. Therefore, it is interesting to discuss how specific works were presented as art within the ISEA context. As Danto put it (1992: 39), "A rose is a rose whatever its name, but a work of art is not".

In popular usage, "art worlds" has become used more broadly than Danto's philosophical inquiries into the historical conditions that made an artwork possible. It is pertinent to distinguish between Danto's "the artworld" in the singular, understood as the relevant actors within the official sphere of art, and "art worlds", which, according to Becker's art sociological definition, "consist of all the people whose activities are necessary to the production of the characteristic works which that world, and perhaps others as well, define as art" (1982: 34). Importantly, not all these people are artists. According to Becker, there are multiple art worlds with different rules and expectations. He insisted that there are no boundaries around a given art world; it simply consists of the relevant network around an artistic practice, and there will always be overlap between these worlds. He also stressed that *conventions* steer how art world actors and audiences receive or reject works as art. For this chapter, I will use Becker's notion of art worlds when discussing how artists move between different social worlds, but referring back to Danto's idea of discourse of reasons for why something should be considered as (good) art in the discussion of choices made in the exhibition of the pieces.

The term "science worlds", while sometimes used, is not nearly as established.[10] I will here use "science worlds" about social worlds within science that share important assumptions. While keeping in mind the argument of Pickering (2012) that different science worlds tend to be kept apart by different ideas shaped by tools or methods of analysis, I am here most interested in how specific art worlds intersect with specific scientific social worlds and will use "science worlds" as a shorthand for this. The artworks that I will discuss, then, were produced in between science and art worlds, and as we shall see, to some extent, both are subject to and challenge the conventions of these worlds.

As an arts event focused on works dealing with science and technology, ISEA can itself be seen as a trading zone, seeking to foster "interdisciplinary academic discourse and exchange among culturally diverse organisations and individuals working with art, science and technology" (ISEA International 2018). It forms an art world that is favourable to technology and interested in novelty. *Semipermeable* was exhibited within the Powerhouse, Sydney's technology museum, meaning it aimed at an audience that was interested in technology as much as art. It presented twelve works by former and current SymbioticA residents. Although set in an open gallery space, close contact was actively discouraged through low fences and "do not touch" signs, evoking the standard "white cube" gallery mode where sight is the only sense stimulated. There was life here, and of a strange, possibly dangerous kind, the set-up seemed to suggest.[11] This distinguished it from the primarily electronic and digital works in other ISEA 2013 exhibitions. *Semipermeable* was framed by the theme of "the membrane", viewed as "a site, metaphor and platform for a series of artistic interventions and projects" (Catts 2013). Its conceptualization and location thus served to emphasize the preoccupation of its artists with the boundaries between art and science.

Art in a science world: SymbioticA anno 2013

Since SymbioticA was established in 2000, it has been the only artistic centre in the world based within a biology department. SymbioticA is a small centre; the artists in residence and the staff all share an office space, decked with an odd array of objects, books, and posters. Cracked ostrich egg shells, a model of a human head, a Crime Scene DNA Lab machine, and a number of glass jars with unidentifiable contents are placed on all available surfaces. SymbioticA staff and residents have their desks here, but tend to make the most of their access to the laboratories of the UWA School of Anatomy, Physiology, and Human Biology. The artistic staff and artists in residence are given access to a science world.[12] Residents are assigned scientific "mentors" who have expertise on the techniques a resident wishes to use. SymbioticA director Oron Catts (who curated Semipermeable) and academic coordinator Ionat Zurr prefer the term "mentor" to "collaborator" for the scientists, partly because many residents arrive without much knowledge of biological laboratory procedures but also because they mostly consider the conceptual ownership of a project to reside with the artists alone.

It is an important part of their practice that any residents and students should "get wet", that is, work hands-on with biological organisms and methods. The centre has an established network of UWA scientists from a variety of fields who, assuming they can fit it into their schedules, are prepared to step in as mentors for the residents and students when their expertise can contribute to the progression of a project. In an interview, Guy Ben-Ary observed how being within a department of "interested scientists and technicians is very helpful". If he didn't know how to proceed, he could go to his scientific collaborators in the offices and laboratories around him, "and they'll always answer".[13] At the time of my residency, SymbioticA had hosted over seventy residents, including established artists such as Kathy High, ORLAN, and Critical Art Ensemble, and emerging artists, PhD and Master students, academics, and non-artists with an idea.

The SymbioticA staff considers their core activities to be research and development of artworks. Zurr and Catts emphasized their awareness of the difference between the knowledge they and their collaborators might obtain during the research process and what was communicated to the audience in an artwork. They reflected on the difficulty of engaging the audience through providing the right level of information about the artworks and that they were still searching for good ways of doing so. If an artwork was presented in an overly didactic manner, "it's not going to be very interesting as an art piece".[14] At SymbioticA, they encourage open-ended processes and emphasize that the Centre is a place for research and development, more than for production of already conceptualized artworks.[15]

In potēntia

As a striking centre piece in the middle of the *Semipermeable* gallery stood a distinctly phallic, tall structure of wood, glass, and brass. It recalled the aesthetics, simultaneously, of old science museums and steam punk (Figure 16.1). *In potēntia* consisted of a small petri dish of the engineered neurons inside a bell jar crowning the wooden sculpture. A "DIY" bioreactor provided nutrients for the neural culture, which grew on top of a custom-built multielectrode array that converted "the electrical activity of the neural network into an unsettling soundscape" (Ben-Ary et al. 2013: 8). With moisture forming on the inside of the petri dish, the *liveness* as well as the miniscule nature of the neurons was strikingly apparent (Figure 16.2). This was emphasized by the strong yet soft lighting, which drew the eye to the pinkish content of the petri dish.

In the catalogue, the artists asked "what potential do we now have to bio-engineer conscious, sentient beings and where exactly would these liminal lives fit within our problematic anthropocentric species hierarchy?" (ibid.) Ben-Ary describes how "We placed the brain on a pedestal, presenting it with the indifference of a museum specimen, or a piece of jewellery; something to be viewed, behind glass, feted, admired, and perhaps even feared" (Ben-Ary & Ben-Ary 2016: 320). The piece was described by Hudson as a "liminal, boundary creature" (Hudson et al. 2013: 433). She suggested that their project showed "another kind of aesthetics than the one that is usually invoked with these technologies".[16] Within their conceptual approach, aesthetics was one of several means to an affective experience.

As argued by Becker (1982: 13), every artwork "rests on an extensive division of labor". This is prominent for *in potēntia*. Although the brainchild of Ben-Ary, its authorship is shared between him and fellow artist Kirsten Hudson, and for *Semipermeable*, product designer Mark Lawson and biologist Stuart Hodgetts were prominently featured as collaborators.[17] Guy Ben-Ary is also a permanent artist at SymbioticA. His paid position is as a technician at the Imaging Centre. A former member of the Tissue Culture & Art Project who started out as a

Figure 16.1 Exhibition shot, *Semipermeable(+)*, the Powerhouse Museum, ISEA 2013. *In potēntia* is in the foreground, *Kynic* partially visible behind the column in the middle background. Note the double protective casings around all living elements in the exhibition

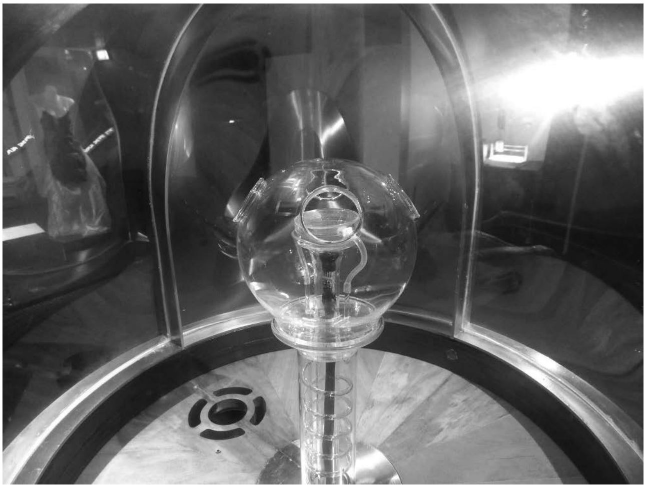


Figure 16.2 Guy Ben-Ary, Kirsten Hudson, Mark Lawson, and Stuart Hodgetts, *in potēntia*, 2012. Detail of petri dish with neural culture in custom-built bioreactor

lawyer, he has worked for a decade on artworks that connect neural networks in petri dishes, conceptualized as "brains", to robotic bodies. For *in potēntia*, he wanted to use iPSC technology on foreskin cells to differentiate them into neurons. iPSC enables fully mature cells to be turned into other types of cells. Ben-Ary emphasized his interest in "the shift that iPSC introduced within the […] ethical map of the world", and how, consequently, the debate on when life "really *starts* […] now has changed totally because theoretically, you know, you can just take a skin cell and create life from it".[18] He related how he wanted to call *in potēntia* "Dickhead" (he still does, informally),[19] but the name proved to be an issue when applying for funding. Kirsten Hudson, an artist and cultural theorist informed by queer theory, became involved due to shared interests in reproductive development.[20]

One of the biology PhD students supervised by SymbioticA's Scientific Advisor and head of the Spinal Cord Repair Lab at the School, Stuart Hodgetts, was just then using iPSC in a project on fibroblasts (skin cells). Ben-Ary convinced the student to use foreskin fibroblasts, which would make no difference in her research. The PhD student functioned as a technical mentor for Ben-Ary as they worked to induce the cells into a stem cell-like stage and then developed them into neurons. However, they "had a few problems with things not working",[21] so in the end, Ben-Ary purchased pre-made iPSCed neurons (iCell® neurons) from a company called Cellular Dynamics.[22] The artist found this an interesting outcome, as he had gone through "the process of reprogramming and learnt the protocols and engaged with the hands on work but… used a commercial product at the end".[23]

The catalogue text for *Semipermeable*, however, stated that the artists had begun "with human foreskin cells purchased from an on-line catalogue" and then worked with Hodgetts "to learn how to reprogram human foreskin cells into stem cells and differentiate them into neurons" (Ben-Ary et al. 2013: 8). The PhD student's name was not mentioned as a collaborator. Hodgetts and product designer Mark Lawson, who made the sculptural "body" of the piece, were named as core collaborators. Acknowledging their differences, the four of them described how they "sought to develop a common language" driven by their shared desire to "create something new", which made them "more focused on the needs of the project rather than on the ego of the individuals" (Hudson et al. 2013: 434). Implicitly, this was a trading zone situation – Hudson et al. even referred to it as "cross-disciplinary negotiation" (2013: 433) and emphasized that the collaborative team consisted of the members who invested into the vision of the project – multiple experts contributed to the technical process, without being counted as collaborators. Although the scientific process did not contribute directly to his own research, Hodgetts found that the collaboration spurred new perspectives.[24] He repeatedly pointed out that artists and philosophers' use of scientific methods may provide "an avenue for researchers to explore and more fully appreciate" the "wonder of simple biological phenomena" (Hodgetts 2015: 273) and asserted that "Very often [scientists are] blind to that creative component to our work".[25] Artists' presence in the lab provided an excuse to engage in more open-ended, basic research rather than the goal-oriented processes of biological research.

This view was not universally shared within the School. Hodgetts related how some of his colleagues thought collaboration with SymbioticA residents was "a waste of, not only their time, but it's also a waste of resources".[26] Miranda Grounds, the biologist who was integral to the establishment of SymbioticA and its director in the early years, corroborated the observation that some colleagues disregarded art as something trivial, but also explained it with increasing demands on scientists' time, meaning anything outside of their core tasks could not be prioritized.[27] This was also pointed to by Stuart Bunt, the other scientific founder of SymbioticA, who thought it a shame that he was almost alone among the scientific staff in coming to the SymbioticA seminars,[28] where various artists and scholars presented art–science projects and ideas.

At one of these seminars, where Kirsten Hudson, supported by Ben-Ary and Lawson, presented *in potēntia*, Oron Catts pointed out that referring to the iPSCed neural network as "a living biological brain" (Ben-Ary et al. 2013: 8) was "taking great freedoms". He did not consider this bad in itself, but wondered how it coexisted with their choice of using commercial cells rather than working with the low-quality iPS cells they had produced themselves.[29] If one was not bound by strict factuality in conveying the artwork, why should one be bound by scientific fact in its technical execution? Catts, who found *in potēntia* "quite an important work", nevertheless speculated in our interview about why Ben-Ary felt the need "to give a very detailed, chronological breakdown of what every little bit of his piece does", and whether "it stands in contradiction of the aesthetic decision of hiding" the technical aspects of the piece in the artwork itself.[30]

At stake here seems to be several types of "truth": First, the question of conveying *conceptual "truth"*. The leap from a simple neural network of about 50,000 neurons, sending random signals because the cells are not connected to a larger organic system, to the enormous complexity of the human brain is a staggering one. Although Ben-Ary in later writings has stressed that the conceptualization of the network as a "brain" is essentially symbolic (Ben-Ary and Ben-Ary 2016), in the *Semipermeable* catalogue, there was no such caveat, although the project was presented as an "absurd thought experiment" aiming to stimulate thought about where life begins and ends, what constitutes personhood, and how new technologies affect reproduction (Ben-Ary et al. 2013: 9).

The second type of truth is the *accurate conveyance* of the process and technicalities of the artwork. It was clearly important for the team, particularly Hodgetts and Ben-Ary's long-time collaborators at the Potter neuroscience lab, to develop a piece where neurons were successfully differentiated and could send their signals, and to communicate clearly about the technology. However, Catts' point that no one would have been the wiser had they used low-grade cells resonated with the fact that not all the details they communicated remained the same from one version of the story to the next. The complex paths taken by the collaborative team seemed difficult to summarize in appropriate words for communication of the piece, and one can understand how it was easier to "streamline" the narrative somewhat. As an artistic decision, this is not problematic in and of itself, but arguably becomes more so when there is an appearance of accuracy endorsed by scientific collaboration (Levy 2006).

And third, the visual rhetoric of *hiding the "true nature"* of the "life support" system of the cells within the shiny exterior of the sculptural body, meaning that the cells seem to exist on their own, left it indeed more *disembodied* than most of Ben-Ary's and Hudson's other works. Catts raised the example of this piece when discussing the difficulty of presenting such artworks "within the context of the art world", since often, when presenting members of the art world with "knowledge which is outside of their knowledge base, and especially when they sense that it's something to do with technology and science, they will shut themselves off".[31] This might explain why the process-oriented video that was made for *in potēntia* was not included in *Semipermeable*, a curatorial decision by Catts.

As Catts recounted, in his experience, gallery staff and art audiences often did not take well to exhibitions that emphasized laboratory research processes (perhaps having greater difficulty reconciling the exhibited pieces with their view of what art should be). As such, the decision to focus on finished objects, rather than on process, can be read as a focus on the *art* aspect of the artworks, more than their biotechnological preconditions – an important move in taking the biological artwork from a science to an art world. While early biological artworks presented in science exhibitions often contained an elaborate narrative and/or representation of the scientific process, when aiming at artistic audiences this seemed, according to Catts, less pertinent. In arts contexts, there is a long tradition of leaving artworks to "speak for themselves". Ben-Ary, in the context of another neural network artwork called *Silent Barrage*, stated that he didn't think that it was their role as artists to "turn it into some sort of educational tool. It's an artwork in a gallery, and if people understand it, they do; if they don't, they don't".[32] Given the collaborative nature of the project, which explicitly focused on the importance of communication to successful cross-disciplinary work, and their interest in presenting work that had scientific as well as artistic merit, the idea that communication to the audience should not be too focused on conveying "facts" of the process was a striking example of how perceived art world conventions led to interesting compromises.

Kynic

Where the team around *in potēntia* strongly emphasized the collaborative effort, Benjamin Forster represented a different track. Forster is a young Australian artist who has worked mostly with drawing and programming. While he had previously done collaborative work with dancers and theatre professionals, he did not consider the way he was working with scientists at the School as collaboration, meaning an exchange in which "you give something up, and there's risk, and there's the other person's investment in it".[33] Instead, he was comfortable with SymbioticA's description of scientific mentorship, as he got advice and help from experts in various parts of the School, but conceptualized the artwork and did most of the lab work on his own.

Forster was doing his second residency at SymbioticA at the time I was there. Since he was the resident who was doing the most laboratory work, I took on the role of his "assistant". He sought to create a hybridoma, a true hybrid cell, merged from human and dog white blood cells (Figure 16.3). The human cells came from Billy Apple, a New Zealand artist who has made a life's work out of franchising his body.[34] The dog was a mongrel, the mixed-breed

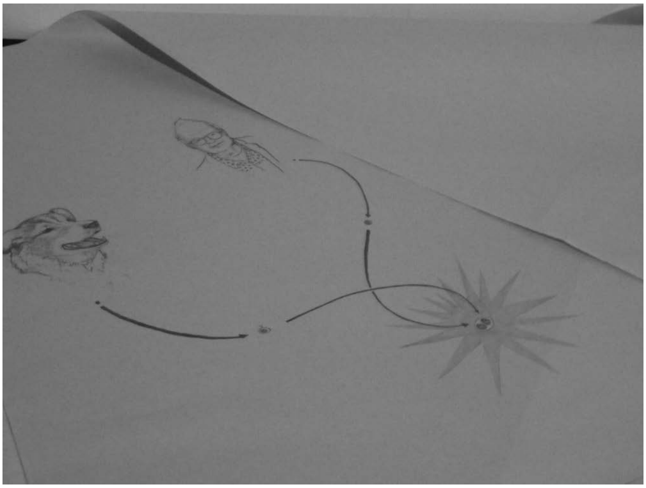


Figure 16.3 Benjamin Forster, *Kynic*, 2013. Detail of drawing of dog–human hybrid cell

pet of a veterinarian Forster knew. The cells thus quickly became personified: we spoke of them as "Billy" and "Harry".

The process of creating a hybridoma involved fusing the B-lymphocyte Apple cells with the B cells of the dog, creating a single dog–human nucleus.[35] B-lymphocytes are the white blood cells responsible for antibody production, and Forster saw an extra, poetic dimension in creating a hybrid from these anti-intruder immune system cells. The fusion involved actually dissolving the membranes of the cells, making it apt for the *Semipermeable* concept – a factoid left unsaid in the communications of the piece.

The idea for the artwork had come when Forster realized that "the majority of artists that I really enjoy are quite cynical".[36] He started researching the historical background of cynicism as well as the contemporary definition, finding great divergences. The ancient Greek cynics, most famously Diogenes of Sinope, made a point of exposing arrogance and deceit in Athens. Peter Sloterdijk (1987) distinguished the ancients from modern cynics by calling them "kynics" and framed their type of cynicism as infinitely more refreshing and "real" than what we currently think of as cynicism. Although Sloterdijk isn't mentioned in the context of the exhibition, he was an important source in the development of the piece.[37] As Forster described it, the ancient cynics' work was about "unmasking others and just being honest and true. And quite provocative, and also not entangled in things that don't matter". In his opinion, influenced by Sloterdijk, "the behaviour of the ancient cynics is what we should have, and then modern cynicism is kind of a perverse adaptation of it".[38]

Kynic was supposed to include a histological slide of the dog–human hybrid cell, invisibly perched on top of a tall plinth. Instead, the slide in the Semipermeable exhibition contained this message: "26:05:13 – Cell Death. Harry cells died. Fusion failed. No immortal cells – pink dots. Months of labour pointless. The research is to continue. In search of the Kynic cell". Several drawings were casually thrown on the floor, some completely crumpled. Visible motifs included dogs coupling, a naked man with a dog's head exploding above him, a dog in the shadow of a chess piece, and another cowering under a large bust of a man's head. The drawings were striking and skilfully sketched. But they only filled modest portions of the white A2 sheets, which looked small on the black floor (Figure 16.4, see also Figure 16.1).

Figure 16.4 Benjamin Forster, *Kynic*, 2013. Detail of drawings

The audience was not informed that the white, uneven line running down one of the drawings, next to a depiction of Diogenes, was urine, referencing that Greek philosopher's habit of "living like a dog".

In the catalogue, the first description, written when Forster still believed the exhibition would include a hybrid cell, is run through by a single line. The text goes on to state that the artist realizes that "this text, this catalogue, the wall didactic, and their implicit assumption of you as unthinking, contradicts my intentions".[39] He expresses rejection of the way "Polite society silences the body wrapping it in only sanctioned words", asking the reader to "burn this catalogue. See how words can warm you this winter" (Forster 2013: 16). The wall didactics still stated (in the usual polite terms) that the "monstrous cell" is "preserved dead between glass".

Until quite late in the process, Forster planned to include a video showing different television ads in the *Kynic* piece. This would show the current meaning of cynicism, which he described as "the kind of attitude that characterizes the people at SymbioticA – an ironic and sceptical approach to truth", particularly scientific truths.[40] Moreover: "Scientists are running on the grant system as much as artists", so both artists and scientists have to "say one thing and do another", and "you're never truly just doing it for the pursuit of knowledge anymore".[41] These characteristics are descriptive of Forster's practice as well, and there appeared to be an ongoing tension in him between a sense of ennui, of wanting to mock a world that is ridiculous in many ways, and the wish to get beyond that, to something true and real, that some of the ancients may have been onto. This attitude picks up on the tradition of what Hal Foster (1996: 119), applying Sloterdijk's philosophy to art, called "the aesthetics of cynical reason". Foster saw this tradition as starting in appropriation and escalating through "a double slippage of ideology critique into contempt and deconstruction into complicity" in the 1980s, continuing into abjection with a certain branch of pop artists in the 1990s.[42]

Forster had preserved cells from the Apple line, frozen at −80° C, since his previous stay two years earlier. In early April, he enlisted the aid of academic coordinator Ionat Zurr in thawing his Billy cells, confirming that they were still alive and uncontaminated. For two weeks, Forster and I cultured the human B-lymphocytes. He originally planned to compile his own chemical compounds, as he found the process visually beautiful. Hodgetts, however, recommended buying them, to save time, and avoid the risk of doing something wrong. So, Forster had to wait for the compound polyethylene glycol (PEG) to arrive in the mail before he could collect the dog blood and perform the cell fusion. Until then, he had to keep the Billy cells alive and do some experiments to see whether the cells were secreting antibodies. Along the way, there was quite a bit of trial and error. From the relatively simple process of spinning down the cells in the centrifuge, to an electrophoresis gel to test for antibody expression that (like the skin cells of *in potēntia*) was done by a PhD student who was running a gel on her samples, the technical challenges of the scientific process were ever-present.

We worked in a PC2 laboratory[43] and observed safety and sterility procedures to avoid contaminating the cells and the lab. Although SymbioticA has its own supplies, the necessary materials, from Glutamax protein to pipettes, were generally obtained from laboratories around the building. While fetching these, Forster seized the opportunity to ask questions from biologists in the labs about the procedures involved. Technical discussions about the right chemical solutions for creating the hybridoma (the one he had used two years ago turned out not to be the best option if he wanted a viable hybrid cell that could continue reproducing in its hybrid state), and which histological method would be best for fixing the cells on slides, were interspersed with information about hybridomas, antibody secretion, and the scientists' experiences with using similar methods.

For Forster, who was not a trained scientist and yet worked by himself in the lab, these conversations seemed crucial in providing him with insights into scientific knowledge beyond what could be learned from protocols. While he, to some extent, had attained insight into the procedures and terminology of hybridoma technology during his previous visit, his lack of biology training resulted in a number of misunderstandings during these conversations. While Forster was quite upfront about what he knew and did not know, the friendly, informal tone of the conversations in some cases seemed to result in partial communication. The scientists and technicians spoke to Forster and myself as they would to intelligent students, showing an ability to "switch registers" (Galison 2010: 33) to simpler ways of discussing their research, but the differences in background and level of understanding, while only occasionally clear during these chats, showed up as mistakes in Forster's ensuing lab work. The trading zone between disciplines in this case was less clear and established than for the *in potēntia* team, also since the benefits of the trade were perceived as more one-way. As Galison argued, some trading zones involve "*incomplete* coordination" (2010: 32, original emphasis), where interpretation can be partial, and the only thing that the actors needed to agree upon is the trade performed.

During one such chat, Forster declared that, with the ISEA exhibition eight weeks away, he would not aspire to make the hybridoma viable. Hodgetts, however, suggested that Forster start out aiming to make viable cells; if they were not, he could still use them for the exhibition. Testing for the antibody-secreting dog cells would be a simple matter of exposing them to different antigens. If the hybrid cells reacted, the dog cells were present because the immortalized cell line would not be secreting antibodies. Contrarily, one could not tell whether the cells were still immortal (meaning that the human cell line was present) before around the fiftieth passage of the cells, when primary cells would die from cellular senescence. Hodgetts recommended storing early examples of the hybrid cells, so Forster could retrieve an earlier strain if the active one mutated or died.

This was one of the many conversations that made it clear that Hodgetts considered the projects of SymbioticA residents as potentially producing scientific results, in addition to artistic ones. In an interview, he stated that some residents "have probably shown more

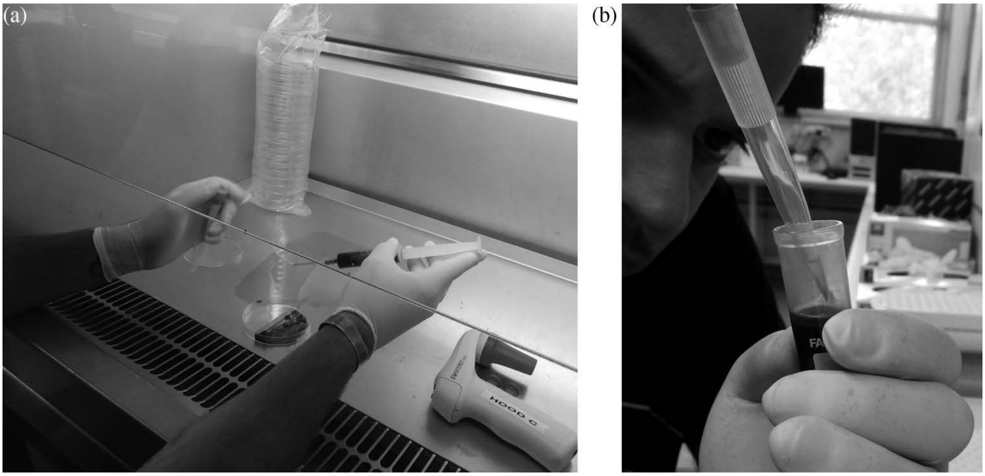


Figure 16.5 Blood work for Forster's *Kynic* project. (a) A bloody mess resulting from the heparin beads in the first attempt at separating out white blood cells. (b) Attempt to draw almost invisibly thin layer of white blood cells from vial of centrifuged blood.

scientific aptitude than a lot of, um, students and staff" and asserted that such artists "would be a welcome asset in anybody's lab", due to their skills in adapting and improvising to solve problems.[44]

Since he had a limited amount of dog blood and little time to cultivate the dog cells successfully, Forster enlisted the School's blood works expert, Cozens, to help practice separating out white blood cells from fresh blood (accustomed to drawing from his own body, Cozens volunteered his blood for the exercise). Before spinning the blood in the centrifuge to separate the cells into layers, they needed to add an anticoagulant, heparin, to stop the blood from clotting, and decided to use a syringe with heparin beads inside it to draw the blood. These should release the anticoagulant gradually over time and could quicken the process. The beads were supposed to sink to the bottom when spinning the blood in the centrifuge at 200 G for 10 minutes, but this was unsuccessful, resulting in a messy mixture of beads and blood (Figure 16.5a). Cozens had to draw more blood, adding liquid heparin. This time, the blood spun into neat layers. Problematically, however, the pinkish buffy coat layer was so thin that it was almost undetectable (Figure 16.5b). Cozens was simply too healthy. This made it difficult to teach Forster how to tease out the buffy coat from between the abundant red blood cells and the plasma, which had been the whole point of the session. They discussed how many white blood cells dogs generally have; Forster could not remember it being a problem last time. If everything went according to plan, he would culture the primary blood cells of the mongrel for a few days and then make the hybridoma.

At this point, my residency came to an end, and I report what Forster told me of the proceedings from then on. They drew blood from the mongrel and managed to extract enough B-lymphocyte cells to culture. However, Forster explained that "because Harry was old there were not many of his cells to begin with, they simply did not multiply in the medium and slowly died off",[45] so they did not get to the stage of making the hybridoma. Forster very much subscribed to the SymbioticA idea of the "aesthetics of failure", recognizing the value of a process even if the result is not what one had planned for, and went ahead with the exhibition. So, this was the backdrop of the stark and crumpled aesthetics of the *Kynic* piece showed at *Semipermeable*. The audience did not get any indication (unless they could decipher the text on the slide) of the process preceding what they saw. This contrasts to *in potēntia*, in which the crediting of the work as produced by two artists in collaboration with a designer and a scientist quietly made a statement about the complexity of the process.

The central idea of *Kynic* is, as mentioned, the ancient Greek cynics' rejection of convention and abstractions in favour of rigour, simplicity, and a natural life. However, to a visitor unfamiliar with Greek cynicism and Forster's projects, these ideas may have been close to impermeable. The semipermeability of this piece is thus not limited to the scientific process behind it, but is a result of an approach to art that emphasizes ambiguity and ambivalence over clear communication of certain meanings.

How permeable need the process be? Taking science art into the art world

The step into a science world that enabled conceptualizing and creating these artworks seems to be meaningful to the artists in its own right; through entering into a trading zone with the scientists, they learn new methods, submerge themselves in the repetitive tasks of the laboratory, and develop new competencies with which to create artworks that showcase possibilities or critique the available bioscientific methods or their societal implications.[46] As discussed above, the exchanges that take place between artists and biologists in this science world are perceived as valuable research situations in their own right. In cases of "fair trade", which the process of *in potēntia* seems to embody, the scientists found inspiration for their everyday work as well as the artists being provided with expertise and equipment that crucially shaped the artwork. However, as I have tried to illustrate above, the pidgin language of the trading zones established in this process does not necessarily carry over into the art world context of exhibiting the final artwork. This might be partially because, even at SymbioticA, which has been based within the School of Biology and Human Anatomy for twenty years, there does not appear to be one trading zone established across different projects. While shifts in register as scientists speak to more or less knowledgeable artists and humanities scholars are clearly practiced, the trading zone established for a project is extremely local, relying on the languages and understandings of all actors involved. This seems to entail that, although the trading zone works (more or less sufficiently for various projects) in terms of communication between the actors, it cannot be transposed to the exhibition context. Nor does this seem to be an ideal; the artists are generally in charge of this communication, and scientific collaborators are often conspicuous by their absence in the public sphere (see e.g. Stracey 2009).

Within the context of *Semipermeable*, although adopting quite different strategies of aesthetics and communication, *Kynic* and *in potēntia* both seemed geared towards art world expectations, which were important for the establishment of a discourse of reasons (Danto 1992) as to why these science-driven projects are, indeed, to be received as art. The adoption of art world conventions in communication of the pieces appears to be a step away from the trading zone situation of the process, towards another, more established trading zone, that of the ISEA, which despite its interest in science and technology was markedly closer to an art than a science world.

It has never been an ideal in art for the audience to know the full creative process behind any given work. In fact, the interpretive apparatus of art critics and academics is often key to helping audiences decide on how to understand and evaluate an artwork (Danto 1992). Yet, in artworks where the artists have in a sense entered the professional world of science and developed works that do to some extent follow the rules of that world, the way this is communicated, or not, assumes an extra interest.

For many gallery visitors, the artworks at *Semipermeable* may have been their first encounter with the artistic medium of biology, and as such, they could only rely on the conventions of the art world in relating to these pieces (Becker 1982). The historical understanding needed to decipher the reference to Diogenes in *Kynic* is similar to the iconographical knowledge necessary to engage with the narrative contents of history paintings.[47] However, the scientific methods used in this piece can be assumed to be in a different way unintelligible to art audiences. Although I do not have systematic evidence of how the piece was received, discussion with a number of people in different contexts suggests that many desired additional explanation both of the artistic concept and the technoscientific process behind the work. *In potēntia*, through its striking aesthetic presence and the narrative established in the catalogue text of the "living brain" contained within the bell jar top of the sculpture, did not seem to raise the same desire for more explanation. However, as we have seen, the ways in which the piece communicates scientific and conceptual "truth" have also been challenged.

Conclusion

As this chapter has sought to illustrate through discussion of two pieces working at similar scales, but demonstrating different challenges and processes, the move between science and art worlds involves navigating a sea of expectations and ideas. Involving actors from different social worlds, the work is shaped by the respective ideas the artists and their collaborators or mentors have about what is possible, important, and good to do. In the case of *in potēntia*, the interests of the artists and product designer in creating an elegant, aesthetically pleasing art object that conveyed the concept of the "living brain" created from a male artist's foreskin came together with the scientist's interest in including scientifically sound, viable IPSCed neural cells, explaining the piece's complex story of accurate scientific process and inaccurate narratives. The trading zone established by the actors in this project, which explicitly sought to give equal voices to artists, designer, and scientist, as such appears to have played a key role in the shape of the final artwork.

For *Kynic*, the trading zone observed took a much less solid shape, as Forster very much retained sole ownership of the project, approaching scientists and technicians as helpful mentors rather than collaborators. Communications, exhibiting those tell-tale shifts in register, were geared towards helping him solve the technical challenges of the process, in the cooperative spirit that one often finds in good laboratory environments. The artwork was thus shaped by what was scientifically possible, and of course what turned out to be a technical failure, through partial exchanges that served to help him develop the artwork. But this did not play strongly into the aesthetics and concept of the piece. The trading zone exchanges clearly were seen as irrelevant to the communications made in the exhibition of the artwork, which rather aimed to display cynicism at multiple levels, including in the rather provocative catalogue text that, if anything, made it more unclear to the audience what was actually going on within this piece. The embrace of ambiguity and the aesthetics of failure made *Kynic* a rich piece, but also made it, indeed, verge at the border between semipermeable and impermeable.

While any artwork that is created through hybrid art–science processes inevitably exists within a trading zone, the extent to which a language is developed into new modes of cross-disciplinary communication differs widely. Interestingly, although a trading zone might be quite fortuitous for cross-disciplinary communication, as seen in *in potēntia*, the particular registers of the trading zone do not appear to be seen as suitable to carry over into the exhibition of the artwork, where art world conventions play a strong role in communication of a piece. Artists who choose to work in science worlds navigate between engagement with scientific premises, principles, and protocols and the need to remain in touch with the rules governing art worlds. The "in-betweenness" of these practices puts both artists and their collaborators in a somewhat precarious position, where their very recognition as relevant artists and scientists might be at stake. The choices made for the dissemination of the artworks signal belonging to a particular discourse of reasons, as Danto would say, for why these pieces should be considered as interesting art. Given the limited information about the process provided when the artworks were exhibited, scholarly consideration of the trading zones established in between science and art worlds can provide us with additional insights into the challenges of such hybrid processes.

Notes

1 SymbioticA is also the topic of Chapter 31, in which its founders Oron Catts and Ionat Zurr discuss genohype and their artwork Pig Wings.
2 For more on trading zones, see Galison (1997), Collins et al. (2007), and Gorman (2010).
3 The 19th ISEA featured a conference, performances, workshops, and more than 30 exhibitions in Sydney in June 2013.
4 This means that biologists and technicians can, technically, work on SymbioticA projects within their funding. Because the university budget is tied to the schools rather than distributed from higher up, quite unusual in the Australian context, university employees do not get paid to do work outside of their schools. SymbioticA was formally established in 2000 by Oron Catts and biologists Stuart Bunt and Miranda Grounds. In July 2008, it became a Centre of Excellence in Biological Arts, the only Centre of Excellence in its kind. For more on the work of SymbioticA's core artists Oron Catts and Ionat Zurr, see their chapter in this handbook.
5 I chose an open ethnographic research design, maintaining a research interest in both art theoretical and social aspects of the proceedings at SymbioticA. During my residency, I performed a multi-method case study, collecting data from sources ranging from documentation, field notes, archives, semi-structured research interviews, and participant observation to physical artefacts at the School, such as scientific instruments and artworks.
6 In the 1990s and early 2000s, artists such as Catts and Zurr, Joe Davis, Marta de Menezes, George Gessert, and Eduardo Kac showed that biotechnological methods on living materials could be used as artistic media (establishing sub-genres such as "tissue culture art" and "genetic art"). They and the next generation of artists have, in recent years, developed more complex pieces using such media.
7 In some cases, Galison argued that sustained trading zones can develop from bare, pidgin terms to a full-fledged hybrid, "creole" language that might be the start of a new research field.
8 With a background in art history and philosophy and theory of science, and now working as a philosopher of art and culture, I am myself, like many contributors to this volume, a hybrid actor.
9 Interview with Oron Catts, 24 April 2013. Catts, SymbioticA's director, stressed that there was still "resistance" to the art form within the art community, more than in any other context they encountered. He saw art as the best concept to use in relation to SymbioticA work, since the closest alternative, design, has an issue of being "read as if it's a client-based, problem solving exercise". According to him, "the reception of the work within the context of design is very, very different than if it would be called art" (ibid.).
10 The less widespread use of "science worlds" may be in part because of the discussion, after Kuhn's (1962) seminal description of how actors within different scientific paradigms live in different worlds, of what he meant by worlds. Was this an anti-realist declaration that there is no one, real world independent of our senses (Ghins 1998)?
11 The visual rhetoric of containment echoed previous exhibitions of living artworks, some of which encountered serious obstacles as gallery representatives worried about potential biohazard and

juridical safeguarding (e.g. Catts and Zurr 2006). Robert Mitchell, discussing other bioartworks, referred to the "additional frames of protective plastic and glass" often seen in bioart exhibitions as potentially linking the spectator to the living artwork, suspending "the distinction between representation and reality" (2010, p. 90).

12 The School has a long history of allowing artists into their environment, having hosted an artist interested in anatomy since the 1960s.
13 Interview with Guy Ben-Ary, 7 May 2013.
14 Interview with Catts, 24 April 2013.
15 Interviews at SymbioticA: Interviewee 33; 42; 44; 60.
16 Hudson, with Ben-Ary and Lawson, 19 April 2013.
17 For the first exhibition of the piece, at the *Soft Control* exhibition in Slovenia in 2012, Anne Kramer and Mark Brims were also mentioned as collaborators of the same order as Lawson and Hodgetts, see Kibla (2012). At ISEA, however, both in the exhibition and in the accompanying conference, the four people I have listed were the ones acknowledged as creators (Hudson et al. 2013). This showcases the difficulty of delineating who are the relevant collaborators within a given project (Becker 1982).
18 Ben-Ary, 7 May 2013.
19 Personal conversation with Ben-Ary, 14 September 2018.
20 Kirsten Hudson with Guy Ben-Ary and Mark Lawson, "in potēntia", SymbioticA Seminar, 19 April 2013.
21 Interview with Stuart Hodgetts, 8 May 2013.
22 Interview with Ben-Ary, 7 May 2013, and Ben-Ary, email message to author, 6 Jan 2016. For more on the iCell® neurons, see https://cellulardynamics.com/products-services/icell-products/icell-neurons/.
23 Ben-Ary, email message, 6 Jan 2016 (ellipsis in original).
24 Hodgetts, 8 May 2013.
25 Ibid.
26 Ibid.
27 Interview with Miranda Grounds, 7 May 2013.
28 Interview with Stuart Bunt, 6 May 2013.
29 Catts, commenting at Hudson and Ben-Ary, 19 April 2013.
30 Catts, 24 April 2013.
31 Ibid.
32 Ben-Ary, 7 May 2013.
33 Interview with Forster, 29 April 2013.
34 Billy Apple signed a statement agreeing to the immortalization of his cell line in 2009. Forster got his Apple cells directly from Craig Hilton, a biochemist/artist who collaborates with Apple. Hilton had the idea for the immortalization of the artist's cell line, considering it an art–science work that scientists could take seriously. Forster started his project shortly afterwards, in 2010.
35 The hybridoma technology was developed in the 1970s (see Kohler and Milstein 1975) and is largely used in the production of monoclonal antibodies. Forster is not the first artist to embark on creating a hybridoma; already in 1997, Paul Perry created a hybrid cell from his own primary lymphocytes with the myeloma of a mouse (Perry 2007).
36 Forster, 29 April 2013.
37 Ibid. See Sloterdijk (1987).
38 Forster, 29 April 2013.
39 Forster (2013, p. 16). Part of the catalogue text is occluded by black censure bars, a stylistic tool Forster uses frequently. In this quote, the letters "of yo" are covered by such a black bar.
40 Informal conversation with Forster noted in author's fieldnotes, Perth, 3 March 2013.
41 Forster, 29 April 2013.
42 Ibid. In a footnote discussing a 1986 discussion entitled "From Criticism to Complicity", among practitioners of simulation painting and commodity sculpture including Sherrie Levine, Foster stated that the aesthetic of cynical reason meant a dandyish savoir faire is the ultimate value: "'The thing', Levine warns her interlocutors, 'is not to lose your sense of humor, because it's only art'" (Foster 1996: 257, n34). This might as well have been uttered within the current discourse at SymbioticA, as Catts described their role as being "the court jester. The clown that tells the truth, but tells the truth in such a way that he can get away with it" (Catts, 24 April 2013).

43 In the Australia/New Zealand Standard, Physical Containment Level 2 (PC2) is the denomination for a laboratory licenced for work with microorganisms of Risk Group 2, meaning microbes of moderate individual risk, and limited community risk. PC Levels correspond to the Biosafety Levels of laboratories in the UK and USA. See e.g. Standards New Zealand, "Safety in laboratories. Part 3: Microbial safety and containment," AS/NZS 2243.3:2010.
44 Hodgetts, 8 May 2013.
45 Benjamin Forster, email message to author, 23 November 2015.
46 Interviewee 27; 28; 33; 42; 44; 49; 53; 56.
47 Iconography is the study of the meaning of an artwork's content, for instance, the recognition of a woman in red and blue dress holding a baby as the Virgin Mary (Panofsky 1970). In *Kynic*, the old man in the drawings could potentially be deciphered as Diogenes through connecting the title and the dog drawings to knowledge of the cynical philosopher's story, although, like with many older paintings, the iconographical knowledge necessary for this deciphering might only be held by a minority of the visitors.

References

Becker, H. S. (1982). *Art Worlds*. Berkeley: University of California Press.

Ben-Ary, G. & Ben-Ary, G. (2016). Bio-engineered Brains and Robotic Bodies: From Embodiment to Self-portraiture. In: D. Herath, C. Kroos and Stelarc, eds., *Robots and Art: Exploring an Unlikely Symbiosis*. Singapore: Springer, pp. 307–325.

Ben-Ary, G., Hudson, K., Lawson, M. & Hodgetts, S. (2013). In Potentia, 2012. In: O. Catts, ed., *Semipermeable(+)*. Perth: SymbioticA, pp. 8–9.

Catts, O. (ed.) (2013). *Semipermeable(+)*. Exhibition Catalogue, 6 June–21 August 2013, the Powerhouse Museum. Perth: SymbioticA.

Catts, O., & Zurr, I. (2006). The Tissue Culture & Art Project: The Semi-Living as Agents of Irony. In: S. Broadhurst & J. Machon, eds., *Performance and Technology: Practices of Virtual Embodiment and Interactivity*. Basingstoke and New York: Palgrave Macmillan, pp. 153–168.

Collins, H., Evans, R. & Gorman, M. (2007). Trading Zones and Interactional Expertise. *Studies in History and Philosophy of Science Part A*, 38(4): 657–666.

Danto, A. C. (1964). The Artworld. *The Journal of Philosophy*, 61(9): 571–584.

Danto, A. C. (1992). *Beyond the Brillo Box: The Visual Arts in Post-Historical Perspective*. Berkeley, Los Angeles, and London: University of California Press.

Forster, B. (2013). Kynic, 2013. In: O. Catts, ed., *Semipermeable(+)*. Perth: SymbioticA, pp. 16–17.

Foster, H. (1996). *The Return of the Real: The Avant-Garde at the End of the Century*. Cambridge, MA: MIT Press.

Galison, P. (1997). *Image and Logic: A Material Culture of Microphysics*. Chicago, IL: University of Chicago Press.

Galison, P. (2010). Trading with the Enemy. In: M. E. Gorman, ed., *Trading Zones and Interactional Expertise*. Cambridge, MA: MIT Press, pp. 25–52.

Ghins, M. (1998). Kuhn: Realist or Anti-realist? *Principia*, 2(1): 37–59.

Hauser, J. (2008). Observations on an Art of Growing Interest: Toward a Phenomenological Approach to Art Involving Biotechnology. In: B. da Costa & K. Philip, eds., *Tactical Biopolitics. Art, Activism, and Technoscience*. Cambridge, MA and London: The MIT Press, pp. 83–104.

Hodgetts, S. (2015). Syncitium in Motion: Exploring Movement in the Skeletal Muscle Cell Shared by Scientific and Artistic Nuclei. *Leonardo*, 48(3): 272–273.

Hudson, K., Ben-Ary, G., Lawson, M. & Hodgetts, S. (2013). The Dynamics of Collaborative Resistance Negotiating the Methodological Incongruities of Art, Cultural Theory, Science and Design. In: K. Cleland, L. Fisher & R. Harley, eds., *Proceedings of the 19th International Symposium on Electronic Art*. ISEA2013, Sydney, pp. 433–436.

ISEA International. (2018). Welcome to ISEA International. Retrieved from http://www.isea-web.org.

Kibla. (2012). Artworks: In Potentia. Maribor: Soft Control. Retrieved from http://arhiv.kiblix.org/kiblix2012/softcontrol/?p=33.

Kohler, G. & Milstein, C. (1975). Continuous Cultures of Fused Cells Secreting Antibody of Predefined Specificity. *Nature*, 256(5517): 495–497. http://dx.doi.org/10.1038/256495a0.

Kuhn, T. (1962). *The Structure of Scientific Revolutions*. Chicago, IL: University of Chicago Press.

Levy, E. K. (2006). Art Enters the Biotechnology Debate: Questions of Ethics. In: E. A. King and G. Levin, eds., *Ethics and the Visual Arts*. New York: Allworth Press, pp. 199–216.

Mitchell, R. (2010). *Bioart and the Vitality of Media*. Seattle and London: University of Washington Press.

Panofsky, E. (1970 [1955]). Iconography and Iconology: An Introduction to the Study of Renaissance Art. In: E. Panofsky, ed., *Meaning in the Visual Arts*. Harmondsworth: Penguin, pp. 51–81.

Perry, P. (2007). Good and Evil on the Long Voyage. In: E. Kac, ed., *Signs of Life: Bio Art and Beyond*. Cambridge, MA and London: The MIT Press, pp. 211–214.

Pickering, A. (2012). The World since Kuhn. *Social Studies of Science*, 42(3): 467–473.

Sloterdijk, P. (1987 [1983]). *Critique of Cynical Reason*. Transl. M. Eldred. Minneapolis and London: University of Minnesota Press.

Stracey, F. (2009). Bioart: The Ethics Behind the Aesthetics. *Nature Reviews Molecular Cell Biology*, 10: 496–500.

Unruh, D. R. (1980). The Nature of Social Worlds. *The Pacific Sociological Review*, 23(3): 271–296.

Vaage, N. S. (2015). On Cultures and Artscience. Interdisciplinarity and Discourses of “Twos” and “Threes” after Snow’s Two Cultures. *Nordic Journal of STS*, 3(1): 3–11.

17

Art, artists, and the wrong kind of science education

Kathryn de Ridder-Vignone

Introduction

Artistic methods are both valuable and controversial tools for establishing a public engagement with science (Bell 2008; CAISE Inquiry Group Report 2009; McCallie et al. 2009).[1] Museum educators as well as artists, scientists, and even professional science societies have seen art practices as alternative yet valuable options for teaching and learning about nanotechnologies.[2] This chapter documents the creation of the ArtNano program by the Exploratorium's Visualization Laboratory (Viz Lab) and the role art methods played in defining the purview of the Nanoscale Informal Science Education (NISE) Network's definition of successful collaboration between artists and science museum practitioners. According to the National Science Foundation (NSF), the success of the NISE Network depended in part on the ability of practitioners from a variety of institutions with different expertise to share their institutional know-how to create educational modules that could be distributed and used at all types of science museums and centers ("Nanoscale Science and Engineering Education (NSEE) Program Solicitation" 2005). In the case of arts practice, that proved difficult. Examining the ArtNano program's lack of long-term success provides some insight into how institutions and scientific funding agencies could foster collaborations across the art–science disciplines that value the practices of both disciplines and the expertise of their practitioners equally.

This chapter demonstrates that several factors, such as NSF-mandated statistical evaluation and conflicting ideologies regarding what counts as worthwhile informal science education, contributed to the quick demise of the ArtNano program. I argue that arts methods as science education maintained a low priority within ISE because those methods did not fulfill the current NSF-backed definitions of informal science education. I demonstrate that the more abstract, open-ended, or critical the art practice, the less likely it was to be taken up and distributed by the Network. This process, in effect, selected out the knowledge of artists as valid forms of knowledge.

This chapter is divided into three parts. The first examines some competing visions of nanotechnology represented by different approaches to nanoart,[3] while the second explores how these various visions contributed to informal science education focused on emerging technologies. The third part then examines the work of the Exploratorium's Visualization

DOI: 10.4324/9780429437069-22

Laboratory or Viz Lab. Taken together, these sections suggest that the artists and scientists who collaborate to produce nanoart contribute to learning about emerging technologies in informal environments, even if their definition of education does not fit that of the NSF or the NISE Network. The Exploratorium case is a detailed example of the overall argument. Despite the Exploratorium's long history of expertise in the area of dissemination of educational plans and products, the Viz Lab failed to create deliverables that were distributable to the NISE Network.[4] Therefore, I examine the factors that combined to produce simple and seemingly distributable products which were nevertheless not fully taken up by the Network. I show how those factors played a role in defining, for museums that are new to working with emerging technologies, what counts as the right kind of educational methods to address this new subject. I examine how the products that the NISE Net requested of the Viz Lab failed to demonstrate to other educators how these educational modules, or art exhibitions, could fit into their own institutions' programming and priorities.

Competing visions of nanotechnologies

The Exploratorium story can be understood by establishing a context and contrast through four other informal science education art-nanotechnology programs, which show the primary genres of nanoart exhibitions. This context will help illuminate the impact the relationship between the NISE Network and the NSF may have had on the goals, focus, and methods of the Viz Lab. These four vignettes are not meant to represent specific cases, but rather types of methods for educating publics about emerging technologies. The Exploratorium's Viz Lab did not pursue these types, although they were sometimes at least considered, when trying to determine which art and visualization methods to integrate into the work of the NISE Network.

The following is a brief description of the four genres, which will each be described in more detail in Part II.

NANO

Artist Victoria Vesna and nanoscientist Jim Gimzewski created *NANO*, an immersive media art exhibition first displayed at the Los Angeles County Art Museum in 2004. The exhibition focuses on dissolving disciplinary boundaries between media art and nanotechnology in order to help visitors understand their ability to contribute to scientific and cultural production.

Science as Art

The Materials Research Society (MRS) sponsors *Science as Art*, a semi-annual competition whose purpose is to gather and display nanotechnological portraiture created by the society's meeting participants. The exhibition serves as a part of the MRS's public engagement and outreach activities, hyping nanotechnology's future through the display of aesthetically pleasing images.

NanoArt

Artist, scientist, and promoter Cris Orfescu organizes the now-annual, international display of the "NanoArt movement" through an online art competition and art gallery exhibition. The exhibitions promote the belief that nanotechnologies play an important role in society and encourage public action in relation to the possible future risks that nanotechnologies pose.

Sites Unseen: *an educational art show*

Interns in the University of Wisconsin-MRSEC's **P**ublic **S**cience **E**ducation (IPSE) program organized this coffee shop art show in downtown Madison in 2008. In an attempt to bring science to places where people do not usually expect it, the IPSE curators exhibited fourteen materials research images and seven complementary, explanatory diagrams which they designed to try to introduce the human and aesthetic side of science.

These four different types of nanoart exhibition demonstrate attempts by artist- and scientist-educators to intervene in the current trajectories of public knowledge of nanotechnologies. These artists and scientists perform as educators to exert the institutional power and practices of art, science, and museums in an attempt to connect to and empower "the public"[5] to shape what nanotechnology will become.

Few previous studies have examined the intersection of physical places (e.g. museums) and digital spaces (e.g. websites) where educators use art practices to engage non-scientists with emerging technologies. Of those studies that do take the public as a focus, most have tried to assess the "public's" knowledge of nanotechnology and attitudes toward it, often focusing on print media. Others have examined the specific role that newspapers play in "framing" nanotechnology research and assessing its risks (Anderson et al. 2005; Nisbet and Mooney 2007; Wikinson et al. 2007; Ebeling 2008). The U.S. public believes itself to be largely ignorant of nanotechnology and its potential (Glass 2007). However, this same public supports nanotechnology research and funding. Scholars have thus begun to understand, given the kinds of publics in the United States, how those publics are important in shaping nanotechnologies as they develop.[6] Nevertheless, previous investigations provide only a narrow perspective, given that a large proportion of nanotechnological content is available via digital and exhibitionary forms.[7]

The scholars, activists, and policymakers central to existing studies of nanotechnology have predicted what a world with nanotech will be like or should be like and in so doing have contributed to what nanotechnology *is* like.[8] Many of them have served as mediators for an imagined public. In contrast, the artists and scientists in the following vignettes do not try to predict nanotech's future; instead, they create a means through which *publics* can envision and entertain that future. I refer to "publics" plural to emphasize the diversity of individuals and groups included in this reference and to account for the unpredictability contained within this diversity. "Public" presumes one unified group, with shared responses and interpretations, where as "publics" allows for the less predictable possibilities inherent in constantly changing perspectives.

With the increasing visibility of nanotechnology in society during the 1990s and 2000s, artists had begun to create art works and exhibitions about nanotechnology. This art has taken a limited variety of forms – mostly immersive media experiences or digital two-dimensional creations – but has served a larger variety of purposes.[9] Much of what is currently called "nanoart" poses questions about the meaning and trustworthiness of visual information, the future possibilities of proposed nanotechnologies, or the risks associated with powerful technologies. A large percentage of this art is available online.

Some of these online spaces are materialized in the galleries of art and science museums or in books or catalogs, although their presence remains most dominant in digital online forms, particularly in online galleries. There have been a small handful of immersive digital experiences that focus on nanotechnology or at least nanotechnology-related themes.[10] All of these different methods of presentation can also be divided into two categories: those that require an actor to participate physically or at least actively in the exhibits and those that do not require such interventions by viewers, participants, or visitors.

The following section of this chapter describes the nanoart practices of four different groups paying particular attention to their conceptions of art and science to illustrate how these practitioners' attempts to make nanotechnology public reveal both the role art can play in portrayals of nanotechnology and its role in defining science education.

Methods and vignettes

This section orients what information was available about the Viz Lab (through informal interviews, NSF annual reports, and online archival documentation) with respect to other examples of art and nanotechnology educational collaborations. I drew from a range of materials to explore these four representative examples, which included changes over time in the online presence of the exhibit and/or group hosting the exhibition, oral interviews of the exhibitions creators (when possible), and in-person observations of the exhibits (when possible). I conducted critical and conversational discourse analyses of my materials to examine how language demonstrates assumptions, beliefs, and intentions about social power, particularly the role art plays in challenging possible power imbalances. I analyzed *NANO's* catalog (Vesna and Gimzewski 2003) in addition to Katherine Hayles' collaborative book with a chapter on the exhibition with the same title (Hayles 2004), as well as formal and informal discussions with one of the primary designers of the exhibition conducted during conferences and workshops where she was presenting. My analysis of *Science as Art* relies on an analysis of the online archive of the past exhibitions provided by the MRS official website. In addition, I conducted informal interviews with artists and organizers while visiting the exhibition held during the MRS semi-annual meeting in Boston in December of 2009. My analysis of *NanoArt21* draws on the online website and exhibition space, along with an informal interview with Cris Orfescu. Last, for *Sites Unseen*, I traveled to Madison, Wisconsin to view a simplified version of the exhibition in the Madison Airport and also relied on interviews with two of the primary organizers and the archived online material provided by UW's MRSEC.

This chapter treats these examples as "vignettes" rather than "case studies" and views them as a means of contextualizing the work the Exploratorium's Viz Lab accomplished and documented. I present them to delineate the range of definitions of informal science education found in exhibitions which use art methods in order to shed light on what science education can look like if art methods are considered valid and productive ways to learn (see Table 17.1).

The following section details four exhibitions – *NANO*, *Art as Science*, *NanoArt21*, and *Sites Unseen* – as four different genres of nanoart. Their media and their learning purposes represent a range of art practices of current nanoart that could potentially be employed in science education.

NANO

UCLA media arts professor Victoria Vesna, in collaboration with UCLA chemist James Gimzewski, headed the team of architects, media artists, and graduate students from the sciences, arts, and humanities who all contributed to the design and implementation of *NANO*.

Table 17.1 Summary of media and purposes

Exhibition	*Media/contributors*	*Educational goals and knowledge construction*
Nano	Immersive media art is made collaboratively by artists, scientists, and others for and with visitors	Visitors' presence, physically and mentally "complete the experience," thereby making connections and creating knowledge themselves which is then fed back into the immersive experience
MRS: Science as Art	Digital prints are made by scientists for science (originally), and then promoted by scientists for public outreach	Viewers recognize the importance of science through exposure to beautiful, recognizable (and thus interesting) science
NanoArt	Digital prints are made by artists drawing from scientific images and content	Scientists as artists as communicators reflect on nano's role in society for each other and for viewers to provide an alternative portal through which people can access, comment on, and create relationships between science and society
Sites Unseen	Digital prints are made by scientists for science, and images are selected by education interns	Viewers who are assumed to not ordinarily be exposed to science learn about it through art; in a more casual setting, these viewers make connections between their knowledge and the new knowledge of the prints, thus revealing to the designers' relationships between science and culture they previously did not know

The exhibit opened in the Boone Children's Gallery of the Los Angeles County Museum of Art in 2003.

Vesna and Gimzewski describe the exhibit as "modular, experiential spaces using embedded computer technologies in an attempt to activate a sensory experience that creates an understanding of both nanotechnology and its cultural implications." The individual installations or galleries, linked together to form the overall exhibition, immerse visitors in sensory and scale contradictions, which the designers believe to be characteristic of the nanoscale. Visitors are supposed to find themselves feeling what it is like to manipulate materials one atom at a time or experiencing the ordinarily invisible through interactions with space. The 10,000-square-foot exhibit contains a web of galleries where one gallery's results feed the content of another or, in other words, one visitor's experiences contribute to another visitor's experiences in a different, but connected space. This creates the possibility that one walk-through of the exhibit is never identical to the next.

Knowledge of the physical characteristics of the nanoscale is created as the visitors react to and feed into one another's experiences via the immersive technology. *NANO* purposely contains no directed path through its spaces. In the accompanying catalog,[11] the designers articulate their philosophy of exhibit design (Vesna and Gimzewski 2003):

> Nanoscale science and media art are powerful synergies that can promulgate the 21st century emergence of a new 3rd culture, embracing biologically inspired shifts, new aesthetics and definitions. *Nano* is meant to be a first step in creating a space where asking questions is part of the experience rather than being told the "facts." At this stage, imagination is needed to envision the future use of this new science and everyone is invited to participate.
>
> *(Vesna and Gimzewski 2005, 7)*

Nano gives its visitors not just new objects to interact with, but new spaces to experience and create.

Science as Art

In 2005, the Materials Research Society staged the first *Science as Art* competition at their semiannual meeting in San Francisco. In this ongoing project, the meeting's participants (scientists) are invited to submit images that contribute to the "Science Component" of the meeting, but which the organizers believe hold meaning beyond the scientific. In the call for submissions, they describe the broader role of materials research images. "Occasionally, scientific images transcend their role as a medium for transmitting information and contain the aesthetic qualities that transform them into objects of beauty and art." It is unclear what kind of learning is supposed to take place if once the images become "objects of beauty and art," their purposes go beyond "transmit[ing] information." However, the exhibition was put together to serve the Education Outreach component of the MRS's activities, and perhaps, in this case, the medium is the message. As "objects of beauty and art," maybe they transmit different information.

Prior to the meeting, participants submit their scientific portraiture to the Meeting Chairs. The Chairs choose Finalists whose work is displayed at the meetings, where meeting participants select the final winners. These images are printed in high resolution the size of posters, with dimensions no smaller than two by three feet. It is clear when visiting this exhibition that the organizers conceive of the exhibition as being an extension of the other meeting activities, like the poster session. Though they state that the images "transcend their role as a medium for transmitting information," the images are printed on surfaces similar to the posters in the next room. I noticed that whereas the posters from the general sessions are generally made up of images and text too small to read, the posters of the art exhibition are filled only by an image that is normally too small to see.

The MRS has a history of devoting time and resources to outreach activities; the most notable example of its efforts is a traveling exhibition, *Strange Matter*.[12] It maintains a standing "Public Outreach Committee" which

> develops activities and programs on both national and local levels to educate the general public on materials research and its importance. Activities and programs may include, but are not limited to, pre-university science education, press communications, and public service information.
>
> *(Materials Research Society 2010)*

This committee "evaluates, interprets, and communicates the *impact* of the Society's public awareness programs to the Board of Directors and the Board's External Relations and Volunteer Involvement Committee" ("Public Outreach, Materials Research Society" n.d.). *Science as Art* serves scientists as well as informal science educators by acting as a source of high-resolution, digital images of nanoscience and materials research which have been selected to demonstrate how science can have value beyond what is traditionally considered scientific value.

NanoArt

Cris Orfescu is an artist and technologist who has become a self-described pioneer in the movement he describes as "NanoArt." In addition to producing his own art, Orfescu has organized and promoted a nanoart exhibition to provide other artists working in nanoart a forum in which to display their work and a vehicle for promoting the "movement." Beginning in 2006, Orfescu designed an online gallery where participants can submit and display their nano-artwork and working philosophies, which include motivations for the pieces as well as information about the artists' personal backgrounds.

Many of these submissions begin their journey in a laboratory; they are the products of nanoimaging technologies like scanning tunneling microscopes or scanning electron microscopes. However, their final forms are artists' renditions, using nanoscience (rather than more traditional materials like paint, ceramics, etc.) as the medium. Importantly, many of these artists are also scientists, but for the purposes of the competition, Orfescu emphasizes and validates the work that they produce when performing as artists. As artists, they have the authority to comment on and produce nanofutures.

NanoArt's finalists, having submitted their work electronically, are then invited to display their work at a physical gallery exhibition that Orfescu organizes.[13] The images are printed on canvas or other permanent surfaces, framed, and hung at the exhibition opening. Orfescu describes the *NanoArt* movement and the role it can play in shaping nanotechnology on the web portal that hosts the online portion of this competition (Orfescu 2010, 21).

> NanoArt is the expression of the New Technological Revolution and reflects the transition from Science to Art using Technology. Scientists are exploring the nano world hoping to find a better future and there is evidence that Nanotechnology might be the answer. Like any new technology, Nanotechnology can have positive or negative effects on the environment and society. Artists should familiarize the general public with the nano universe, so people will focus on the positive effects and redirect the negative ones to benefit from them.
>
> *(Orfescu 2010)*

For Orfescu, artists have a responsibility to mediate nanotechnology for "the general public." He seems to argue that in the same way that nanotechnology may be the beginning of a scientific revolution, *NanoArt* may serve as the origin of a new cultural revolution in which artists wield technologies to transform science into art. Art then serves as valuable knowledge about science. This art can function to educate publics specifically about how they can benefit from nanotechnologies. These publics must take advantage of the beneficial aspects of the new technologies while determining ways to not just allay the detrimental effects but to change those negative effects into benefits. This is a big task, and it is unclear how these digital prints can produce such a dramatic effect on viewers. It is too soon to know yet whether the art and artists of *NanoArt* will have a long-term impact on society, but the existence of the site and its associated events stands as proof of the potential impact of nanotechnologies in culture and artists' authority to affect that impact.

Sites Unseen: an educational art show

During the fall of 2007 and the spring of 2008, the Interns of Public Science Education (IPSE) program at the University of Wisconsin-MRSEC organized an art exhibition at a Madison coffee shop using fourteen images of materials science research provided by MRSEC scientists. For half of the images, the interns developed accompanying "educational graphics" to assist viewers in interpretation. The images were put on display with an accompanying "artist" statement, explaining the research and personal background of the scientists who submitted them. The goal of the exhibition was to display to a public unaccustomed to viewing science in their everyday lives that:

> Science imagery can be aesthetically pleasing; Interesting scientific phenomena are happening below the visible threshold; Science images can be made understandable by accompanying educational graphics; and Science is a "people" story.
>
> *("IPSE Project Descriptions | Sights Unseen: An Educational Nanoart Show" 2007)*

In May 2008, while the show was on display, the interns interviewed over a hundred coffee shop patrons to gauge "public interest and understanding of the images, as well as the public's overall interest in science and the art show as a whole" ("IPSE Project Descriptions | *Sights Unseen: An Educational Nanoart Show*" 2007). They found, to a great extent, what had already been well-established in science studies literature: when provided with images of science for which they have no prior concepts to help them understand, viewers will interpret those images based on the concepts they do have. For instance, many of those interviewed told the interns that one of the images reminded them of a picture of the isthmus on which Madison sits, a connection the interns had never made before.

Variation in the visions

NANO, *Science as Art*, *NanoArt*, and *Sites Unseen* portray distinct perspectives on how art can be used to engage the public, what it means to engage the public, and what methods of the art world have the most potential to give power and authority to nanoartists, nanoscientists, and nanoresearch. In turn, these examples show that the nanoscience community, through its participation in interactive exhibitions and sponsorship of image competitions, believes that art can be an important and effective educational tool to shape the identity and significance of nanotechnology. These works show not only how science presented as art empowers the public but also how science masquerading as art maintains science's and nanotechnology's social positions by appropriating art's cultural capital.

As early as 1979 a survey by the Institute of Museum Services revealed that 45% of all museum visits were to science museums as compared to 24% to history museums and 12% to art museums (National Center for Education Statistics). Nevertheless, if the general public is a place holder for more specific groups like policy makers, educators, and other interested parties whose job it is to understand and ascribe meaning to nanotechnology for others, then these artists too play a role in ascribing meaning and relaying that understanding to museum going publics.

The four examples were exemplars of a larger pattern of nanoartists creating, promoting, and organizing nanoart because they believe that publics can and must participate in shaping what nanotechnology becomes, whom it affects, and how it is used (Lacy 1995; SCALI 2007; *Three Drops (Short Version)* 2008; John Curtin Gallery 2010).[14] Artists often use stabilized science and technology as their subjects. Nanotechnology, however, has not yet become pervasively visible in society. These artists seem to believe that if they use nano as the subject or medium of their art in the same way previous artists have commented on already-ubiquitous technologies, then they will make nano become more pervasive and important. They were not just portending the future, but hoping to create it.

In addition, *NANO*, *Science as Art*, *NanoArt*, and *Sites Unseen* were examples of types of informal science education which attempt to investigate art and science practices as a means of creating educational experiences focused on nanotechnology. Educational experiences, in these examples, do not ensure that viewers or visitors can recount how big a nanometer is, but rather that they begin to understand the significance that a technoscience like nano has in society, the range of possible values and perspectives which determine that significance, and how their perspective, values, and practices also contribute to that significance.

Each of these projects recognizes that its visiting publics have little context through which to understand the exhibit. Thus, the exhibit itself has the chance to teach the visitors new ways to see and interpret science. Each exhibit would like to portray new ways of seeing and interacting with the world, but they all recognize that visitors' unfamiliarity with the concepts of nanotechnology prompts the need for their exhibits to be situated, at least somewhat, inside of concepts or in relation to abilities that the publics already have. For example, rather than trying to tell visitors how forces act differently at the nanoscale than at the macroscale, Vesna's *NANO* translates the visitors' movements into feelings and responses that simulate those differences. In addition, *NANO* maintains a sophisticated online presence (as do the other exhibitions) thus documenting the past work, and also organizing and promoting future work. These websites provide viewers with context for the projects. The artists/organizers/educators were able to frame their projects as well as to provide them with an ongoing existence long after their physical presence ends. These two aspects of these exhibitions, context and ongoing existence, were important in understanding the role the Viz Lab played in the NISE Network.

Science as Art addresses context in a different way. Instead of trying to use the images as a way to explain materials science, the organizers favor what they deem to be artistic images that resemble macroscale items like flowers, paintings, or foods. Designating these images as art demonstrates the MRS's belief that images of nanotechnology classified as art are a more effective way to interest viewers who (the MRS assumes) could not easily understand the science. The Society desires to stimulate the public to continue supporting nano, even if the public does not understand nano, by showing the public "aesthetically pleasing" portrayals of nanotechnology. By revealing to people that materials science manipulates matter at such small scales and is able to make images recognizable from the macroworld, *Science as Art* leads the public to acknowledge nano's future possibilities and their role in creating those possibilities. Nano, *Science as Art*, seems to tell its viewers, is worth funding because it has quasi-magical attributes. It looks like something we know, but is completely different.

NANO and the *NanoArt* movement more directly confront the possible outcomes for science in society if nonexperts are included in scientific knowledge production. Both exhibition creators talk about including their visitors in the knowledge-making process, as if their exhibitions are merely one part of an array of activities that create nanotechnology's role in culture. How the public produces those outcomes is less clear, however. In both exhibitions, the artists/organizers/educators support an educational model where learning can happen without knowing all "the facts." In *NANO*, rather than focusing on the nanoscale as an important concept worth trying to teach, the exhibition tries to allow visitors to understand why scale matters by helping them to feel how objects behave differently at a different scale. Visitors don't have to be able to conceptualize the size of nanoscale objects to begin to imagine how the differences in movement they experience could affect how materials interact.

Knowledge creation can occur simultaneously with learning, but what is knowledge creation or learning for these practitioners? In these models, publics do not have to participate in a citizen's school of science or serve as members of a deliberative forum to begin to learn how nanotechnologies are significant in their lives and to consider how they may want those technologies to be used. Learning, for these artists, means publics (or non-scientists) interacting with and interested in alternative (artistic) portrayals of an emerging technology. By learning about nanotechnology's potential possibilities, symbolized by its portrayals in art, these artists both share and create knowledge.

The relationship of these exhibitions to the NISE Network

I attended a conference at the University of Buffalo in the late spring of 2009 called *Nano-sensing*. The objective of the workshop was to invite scientists, artists, historians, and educators who had experience with creating exhibitions for science museums and centers to attempt to design an exhibition on nanotechnology. Victoria Vesna, the creator of *NANO*, was one of the invited participants who gave a presentation at this workshop. She described her philosophies of learning about art and nanotechnology, many of which are articulated in the *NANO* catalog discussed above. At the meeting in Buffalo, she described having been invited to an early NISE Net planning meeting in 2005 where organizers were trying to decide what to focus their efforts on in terms of art and science collaborations. Vesna recounted that she vehemently opposed a focus on scale. In her mind, though scale was not entirely irrelevant, it should not be the primary learning objective for an exhibition on nanotechnology. According to Vesna, since nanotechnology holds far-reaching implications for society's development, the focus of art/science collaborations should be in the direction of nanotechnologies' potentially powerful role in society, with scale being just a secondary characteristic of that role.

At the time, Vesna knew I was studying the NISE Net, but she did not know I was specifically focusing on her work to compare it to the *Science as Art* and *NanoArt* exhibitions. At some point during our discussions, a workshop participant showed a picture of one of *NanoArt*'s 2008 winners, Chris Robinson. Vesna scoffed at this image and enthusiastically exclaimed, "And *that* counts as art?" She implied that the digital media of exhibitions like *Science as Art* and *NanoArt* do not provide the immersive experience that allows for ongoing artist/viewer creations, and that this lack of immersive experience disqualifies such exhibitions as legitimate scientific-educational "art." I disagree with Vesna's position. These two exhibitions do not include viewers in immersive visual experiences because that is not their goal. They do, however, attempt to teach people about the world (and the nanoworld) through artistic portrayals.

Thus, I present these four examples as representative of nanoart precisely because they vary so much from each other in form and purpose. Vesna suggested that she doesn't even consider *NanoArt* to be art, and perhaps according to her definition of art as immersive experiences where participants as well as designers continually combine their actions and thoughts to create new thoughts and reactions, it isn't. But clearly, if only proven by the institutional support of organizations like the MRS, the EuroForum ("Euroforum 2004 - Events - Resources - TakingITGlobal" n.d.),[15] and the University of Wisconsin's MRSEC, other institutions and practitioners believe these non-immersive art projects can serve as significant instances of science education. In addition, although the execution may be different, Vesna and promoters like Cris Orfescu share similar goals and beliefs about why to engage with the public about an emerging technology through art practice. Comparing how these examples represent types of art and nano educational philosophies, we can better understand what was lost when the NISE Network chose not to validate artistic methods as valid science education.

Vesna hopes that her work is not just interactive, but immersive. She tries to create experiences where visitors become part of a world to which they usually have no access. She is also well-funded and has the support of both the media arts community to which she belongs and at least a portion of the science community (James Gimzewski and the chemistry department at UCLA). Her work is also large scale; rather than printing what is small on bits of canvases, she designs entire worlds where, at least briefly, visitors can explore, experience, and create without consequence. Her work occurs through the collaboration of experts from the arts and sciences but also from architecture and the humanities.[16] Arguably, it represents a supposed "third culture" that appears when successful collaboration occurs between like-minded scientists and artists (Jones 2012). Many of these characteristics are important to keep in mind when trying to understand the differences between the uptake of Vesna's work (it has been exhibited at a long list of science and art institutions including the Exploratorium) and the lack of uptake of the Viz Lab's work. The idea that successful collaborations between scientists and artists create an altogether new form of knowledge was echoed by managers of the Exploratorium's artist-in-residence program like Pam Winfrey, as we will see in the next section. However, collaborations between art and science or between artists and scientists with the objective of creating new knowledge did not become a priority of the NISE Network's practitioners.

The Visualization Laboratory and an obsession with scale

During the summer of 2008, I took a preliminary research trip to San Francisco's Exploratorium to confirm the possibility of doing participant-observation with the Exploratorium's NISE Network staff, especially the Viz Lab, the following spring and summer.

On the day of my arrival at the Exploratorium, Diane Burk, an artist who was a member of the Viz Lab and whom I had met at a conference on nanoimages in a previous year at the University of South Carolina, brought me inside the main building where I was going to attend the Viz Lab's weekly group meeting. At the meeting, I conferred with the project manager about the possibility of visiting for an extended stay. She recounted how she had been trying to scrounge together documentation of the *ArtNano* artist-in-residence events that the Exploratorium had hosted the previous year. She exclaimed exasperatedly that no pictures had been taken and no interviews conducted. There had been little to no documentation of the events. She mentioned that she had tried requesting that the artists send some sort of representation of their experience to her after their residences had concluded, but found them hesitant or unable visual or material records of their work. I learned later that the Exploratorium owns "the artifacts," and the artists own the "ideas," which were the results of the artist-in-residence collaborations. In case of the *ArtNano* residencies, the Exploratorium had in its possession neither the artifacts nor any documentation of the experiences; therefore, the museum had difficulty representing an online exhibition presence, like those referenced in the four vignettes I compare in this chapter.

During this trip to the Viz Lab, as Diane walked me around the space of the Exploratorium, I learned that the name "Viz Lab" was not actually a laboratory. The name described ideal working conditions and practices that did not exist or were not performed. There was no actual space for the members to share while working. In fact, it was repeated to me on multiple occasions that there was very little extra space to be found in the entire institution.[17] Also, the label "laboratory" did not describe the working practices of this group, much to their frustration (Burk 2008). Most individuals had offices of their own not shared with anyone or shared with other artists or designers who were not part of the Viz Lab. As far as I could tell, other than the evaluators, none of the individual Viz Lab members shared space with one another. They were scattered across the nooks and crannies of the museum. This is not to say that they didn't collaborate; it was clear that at least the artist members often thought, worked, and experimented together. The rest of the Viz Lab, however, seemed to be assigned to separate tasks of the larger project which they worked on individually. I found this unexpected since in the NSF project descriptions and annual reports, the Viz Lab was described as a group of people who were collaborating to address problems associated with using nanoimages to teach their publics about nanotechnologies; in reality, the members worked more like a production house, with little input into what the content of the production should look like. The only way in which I could tell that they resembled a laboratory was that they had group meetings.

After the initial group meeting and during subsequent conversations with other members of the Viz Lab team, I learned that none of them had actually been working on the NISE project when the artist residencies, which I had read about in the NSF files and online, occurred; the timing of their arrival on the project was partially the explanation for the lack of visual documentation of the events. Six months prior to my visit, the team had been assigned to produce a "scale ladder" in addition to making three illustrations about scale in which a butterfly, a computer chip, and a human body were represented from the atomic level to the macro level. Recently, one of their members had begun work on what they were describing as an image database. This included some simple descriptions paired with a variety of images from nano-related science at various scales. These projects served as the main "products" of the Viz Lab's work.

The Viz Lab was originally promoted as one component of the larger "Center for NISE Research," which was to be housed at the Exploratorium under the direction of principal investigators Rob Semper and Tom Rockwell. The original purpose of the center was "to focus on collection, coalescing, developing, and disseminating knowledge about how to effectively communicate nanoscale science and technology to the Network's target audiences" (Bell et al. 2005, 11). The center was made up of five major areas: NISE Professional Resource Center, Visualization Lab, NISE Public Website, Professional Development for ISE and Nanoscale Research Educators, and NISE Research and Evaluation.

During the first four years of the NISE Network, the Viz Lab documented the production of the following deliverables:[18]

1 Scale Ladder (Zooms and diagrams)
2 Image Database (Image Collection)
3 Artist Residencies (ArtNano and Simulations)
4 Illustrated Zooms (Illustrations) and Physical Models (Nanoscape) ("Visualization Laboratory | NISE Network" n.d.)

That summer when I visited the Exploratorium the Viz lab staff whom I met had only been working concertedly, they said, for about six months. Since then, their work had concentrated on the creation of what they called a "zoom." This was an interactive computer-based illustration that allowed viewers to move from macroscale objects to the nanoscale, much like the Morrisons' *Powers of Ten* (Heath and vom Lehn 2008).[19]

The two primary artists, who I will call Lewis and Karen, working on these illustrations expressed their frustration at what they called a problem with "oversight." The main artist, Karen, felt that the most effective and visually striking zoom was oriented in a spiral (see Figure 17.1), but the Viz Lab had been asked by the NISE Net to produce a "traditional zoom" (see Figure 17.2), which apparently excluded spirals. As I talked with Karen and Lewis, they admitted that though the spiral zoom *was* more interesting to them, what they would *really* like to do is create a multidimensional whole-body experience, what they called "experiential interactivity" (Burk 2008). This would be a three-dimensional imaging technology that could show people how to interact with images. They lamented that there was no support for these more complicated and resource-intensive projects.

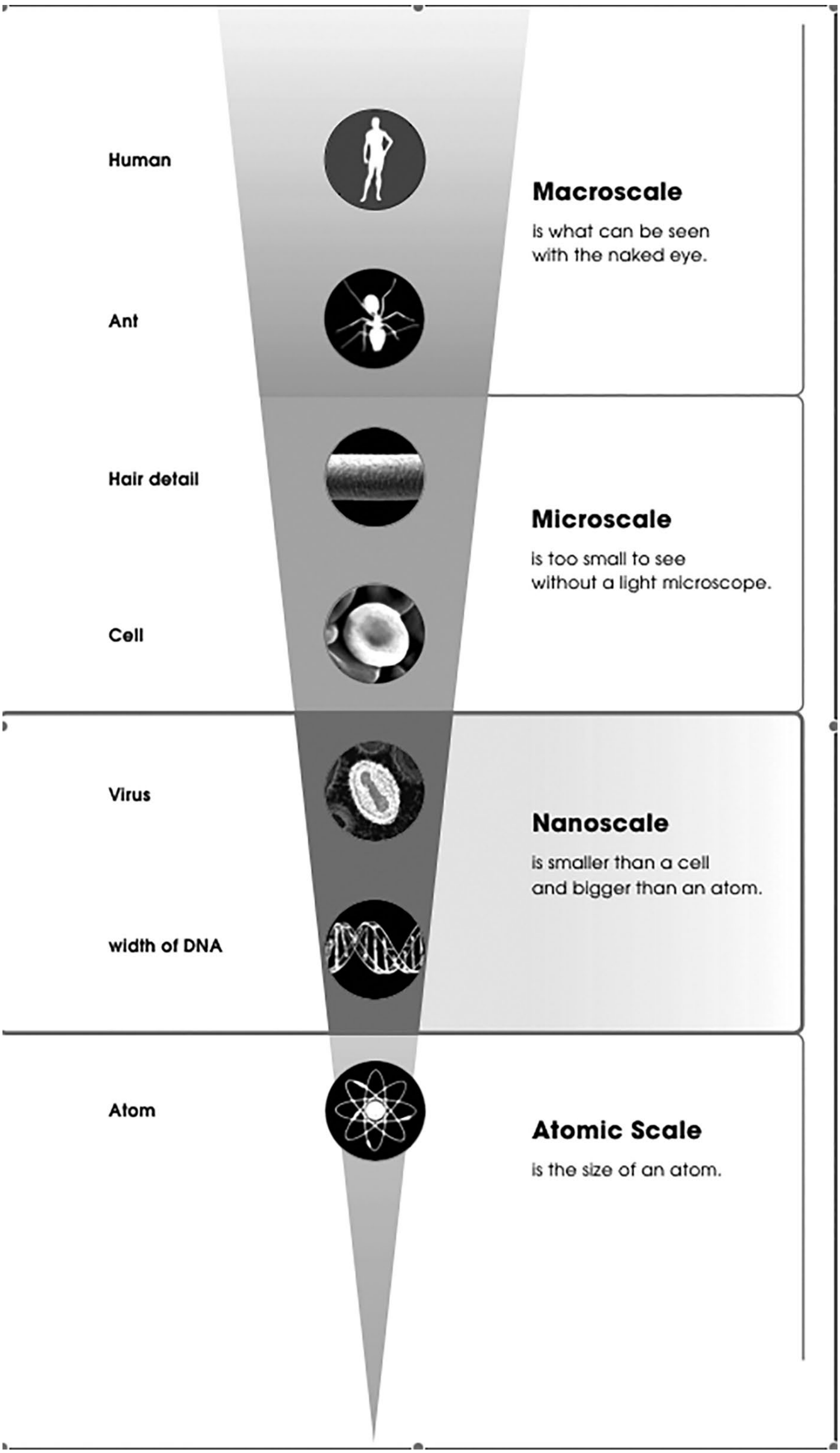


Figure 17.1 Traditional zoom (or what comes to be called "Scale Ladder")

What excited them most was the possibility of being able to acquire a lab space for the Viz Lab where they could develop 3D imaging technology. They wanted to work on something that could "exist somewhere between the stated goals of the bureaucracy and experiential interactivity." They became very excited at the possibility of creating a tool that could show people how to interact with images, which could show an uninitiated user how to interact through changes in color dimensions, process, and other details. However, the artists expressed some frustration at their inability to get support for these approaches from the Network. Lewis said that the NISE Network approach was problematic because "(1). It's a network and the museums have never done that before and (2). It's about NANO, a topic these designers and curators were unfamiliar with. 'Why not gravity?' he asked. That's a topic they'd be more comfortable with." The Project Manager of the Viz Lab, they said, told them that the NISE Network needed a "scale ladder," so that is what they were trying to create. Developing a spiral zoom was their incremental attempt to do work addressing some of the issues they were most excited about.

The original idea for the spiral zoom came from an artist who had been invited to do an artist residency as part of the Exploratorium's *ArtNano* program. Santiago Ortiz is a Colombian-born professor of art and technology at the University of Madrid. He spent much of his two weeks at the Exploratorium developing sketches for Flash prototypes like the one shown in Figure 17.3.

The idea of representing scale in a nonlinear form appealed to the other artists and designers at the Exploratorium. In addition, Ortiz's medium (Flash) was something they had access to and experience with. Lack of access to immersive visual experiences seemed to be a factor limiting the continuation of many of the artist residencies. Rather than supporting artists in their creation of immersive experiences at the Exploratorium, the museum invited artists Scott Snibbe and Victoria Vesna to present immersive art which they had produced for other forums.

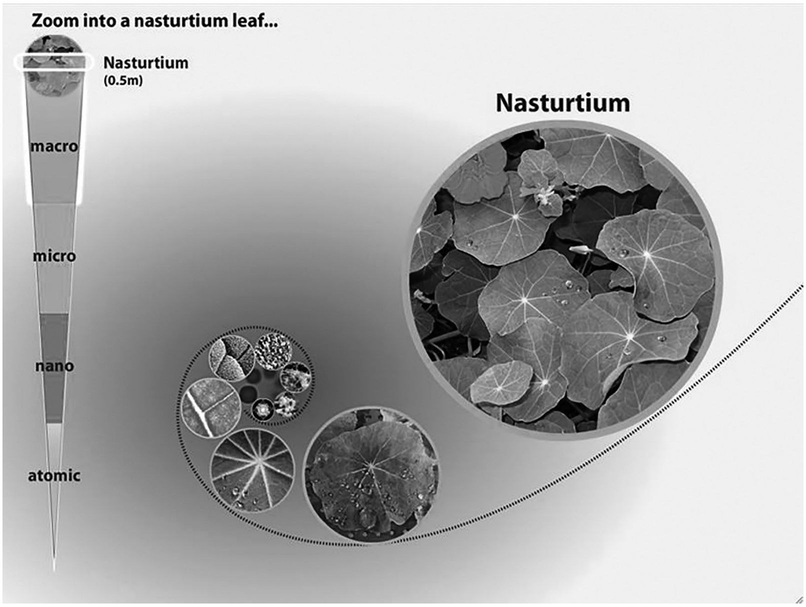


Figure 17.2 Spiral zoom (which also includes a scale ladder)

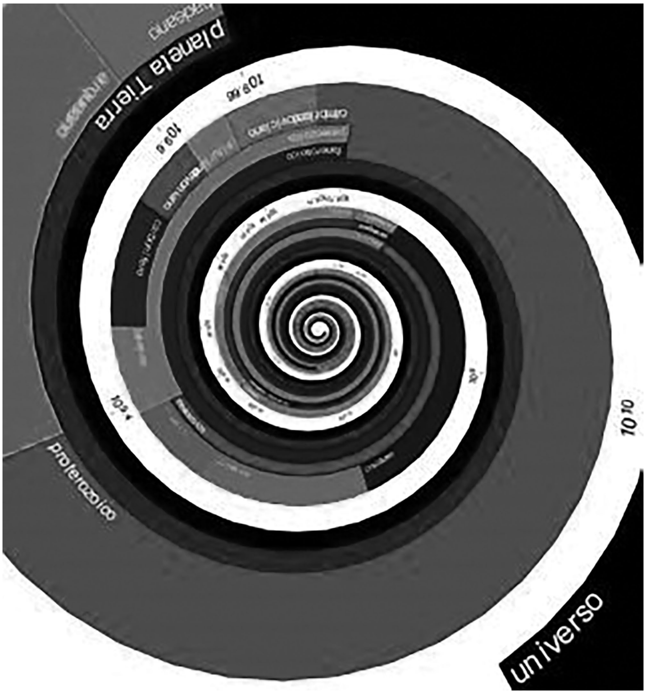


Figure 17.3 Spiral del Tiempo (Time Spiral) (2005)

Since 1974, the Exploratorium has invited artists to come to the institution to collaborate with the in-house staff, technologists, and other creators. The artists receive a stipend, plus living, food, and travel expenses. Generally, the Exploratorium first invites artists to come to the museum for a short trial residency. This lasts from a few days to two weeks. This short stay or, as Exploratorium senior artist Pam Winfrey called it, the "small experimental event" allows the institution and artist to decide if a longer residency would be worthwhile (Winfrey 2011).

When Peter Richards began the Exploratorium's artist-in-residence program, it was focused on exhibit creation and natural phenomena. In the mid-1980s, the focus was expanded to think more about the roles that film and other experimental art forms like poetry, theater, dance, and music could play in the creative process. As of 2010, the space of the Exploratorium was divided into seven separate exhibit and content areas with each area having a curator and associate curator assigned to it. Each of these spaces includes an art component (Winfrey 2011).

The Exploratorium's policy is to recruit artists whose work is relevant to the thematic concerns of the museum. This policy states that all artifacts which are a result of the residency thereafter belong to the museum, but the idea which prompted the artifact belongs to the artist. In practice, with something like a choreographed ensemble dance, the Exploratorium is credited with "development," but the piece itself can be reproduced elsewhere (Winfrey 2011). Pam Winfrey told me that the Exploratorium's lawyers tend to roll their eyes at this policy, but nonetheless it has worked for the museum.[20]

I was particularly interested in what Winfrey saw as the purpose of these residencies. Why were they so important to the Exploratorium's identity, especially when, as she told me, the collaborations were not necessarily focused on an exhibit that their visitors will experience?

Winfrey said that "a lot of the value of the residency is not [associated with] the object, but [with] the development of the idea. Anything that adds to the creative agar of the place" is seen as a productive and valuable experience.

Winfrey reported that when putting together a show on memory, the Exploratorium invited an artist who created a "monstrous, mechanical thing, which failed [to work]." The object was a "maintenance nightmare," but Winfrey told me that if you asked the collaborators whether that particular artist residency was a failure, they would say: "In terms of the object? Yes. It was a complete failure. But, in terms of the process? No." Apparently the in-house staff at the Exploratorium learned a great deal about pneumatics and felt that the interactions with this artist were valuable because they could take this knowledge and apply it later. This was not totally unlike the Viz Lab's desired use of Santiago Ortiz's spiral zoom. The Lab tried to take the knowledge and experiences they had learned from his residency and demonstrate them through the *Spiral Scale* ladder (Figure 17.2). Unfortunately, the spiral was not the preferred scale ladder of the NISE Network.

According to Peter Richards, the founder of the Exploratorium's artist-in-residence program, "through an evolutionary process, a culture has emerged [at the Exploratorium] that nurtures playful investigation, experimentation, and a propensity for taking risks." It was this "propensity for taking risks" that seemed to be lacking from the Exploratorium's work for the NISE Network. The NISE Network sponsored a half dozen of these residencies as part of its mission to learn how to best present difficult-to-understand concepts of the nanoscale to their visiting publics. Nevertheless, no attempt was made to demonstrate that knowledge through distributed deliverables. The deliverables, particularly the "traditional zoom," did not rely on or build from the knowledge learned or produced during the artist residencies.

The Exploratorium's Viz Lab eventually produced an online document called *ArtNano*, which described the artist residencies. This document reads like an exhibition catalog and describes *ArtNano* and the associated residencies as if they were part of one concerted set of exhibitions on nanotechnology. In this document, it is unclear which of these artists took part in what Winfrey described as the "traditional" artist residency. When I asked, I was told that of the artists who were invited to be residents, only Santiago Ortiz and Eric Heller were invited specifically as part of the Exploratorium's nanotechnology work. Stephanie Maxwell, another artist featured in the *ArtNan*o catalog, was invited by the film group and happened to be at the Exploratorium at the same time as Heller, thus leading to her interest in nanotechnology. The other artists and work described in *ArtNano* were commissioned by NISE Net, but did not participate in the artist residency program. Scott Snibbe was well-known for his "immersive interactive art," prompting the Exploratorium to commission his *Three Drops* in 2006 as part of their NISE Net contribution. Victoria Vesna had previously produced *Nanomandala* and *Zero@wavefunction* (2002) for other spaces, and the Exploratorium asked her to present *Nanomandala* during the first annual NISE meeting in San Francisco in 2005. In 2006, *Zero@wavefunction* was one of the two parts of an Exploratorium exhibition titled *In the Land of Lilliputians,* although *Zero@wavefunction* was actually a recycling of the buckyball portion of *NANO. Zero@wavefunction* was paired with *100 Nanowebbers*, an interpretive video by the pair of artists known as Semiconductor. *100 Nanowebbers*, which the *ArtNano* archive describes as "a set of moving images which reveal the moving world in flux," was another art project rented by the Exploratorium.

In other words, only about half of the residencies now mentioned on the *ArtNano* website, which eventually came to document the *ArtNano* project, were artist residencies in the traditional sense. The rest, though they were described as residencies, were not. Instead, the artist was invited as part of another program or the Exploratorium commissioned a piece by the artist (as in the case of Snibbe and Vesna).

Whereas Winfrey described successful residencies as being valuable to the "creative agar" of the development process, the majority of these artists who presented as part of *ArtNano* did not contribute to that agar, and their participation was only valued insofar as they had an object to present on the floor at the Exploratorium.[21] Although the NISE Net collaborators thought the Viz Lab was engaging in artist residencies to produce knowledge informing art practices for the Network, and in spite of the amount of time and resources devoted to these residencies in the NSF correspondence, the Viz Lab's main concentration was not the residencies at all. The *ArtNano* project, which is presented by the NISE Network as being one of the primary educational projects pursued by the Viz Lab, appears to be more of a cobbled-together set of brief visits and found artworks, of which very little knowledge, of the type Winfrey referred to, translated to the Network at large.

The artists themselves also were not altogether clear about the value or purpose of their work for the Exploratorium. The case of scientist, sometimes artist, Eric Heller is instructive in this regard. Heller is a physicist at Harvard University, but by the late 2000s, he had been presenting images from his research as art for close to a decade. Heller told me that he came to the Exploratorium for only a few days. He felt that "our visit was more informal and the support given to us had to be fought for once we were there. In the end, though, the support was very good" (Heller 2011). He and Don Eigler, the maker of one of the most famous nanoimages, the quantum corral,

> set up a ceiling wave tank which projected pool bottom caustics to the floor, which looked 3D with stereo glasses on.... Everybody who saw it loved it, but not many did – it had to be removed soon after our visit, and it was not scaled up to a regular exhibit.
> *(Heller 2011)*

Pam Winfrey called Heller's experience an "internal experimental residency," which suggests that the staff at the Exploratorium were not expecting many people to see his and Eigler's work. Winfrey seemed to think Heller's time had in fact been fruitful, as she reported that many of the exhibition developers had spent time with him, even though he was only at the institution for a short time. Heller, however, felt under-appreciated. He seemed to believe that he had been invited to the Exploratorium to share his scientific expertise (even though he was invited as an artist) and that his expertise was more valuable than that of the other artists (e.g. Stephanie Maxwell) who had also been doing a residency at the same time as Heller. Heller attributed this misuse of "resources" to "the director's" (he was not clear about which one) professional background as an artist. As he put it to me:

> The management staff did not seem to appreciate the level of scientist that they had visiting. Eigler is famous, and I am a member of the National Academy, etc. etc. We could have been used much more effectively. We were given…time and attention…equal to [that of] artists who knew less than nothing about nanotechnology – who made weird, personal impressions of it. Now, this is fine for an art museum, but this was a science museum. The director had an art background, however, which may explain the outcome.
> *(Heller 2011)*

Heller's comments, especially contrasted with Pam Winfrey's thoughts, begin to illustrate some of the pedagogical conflicts and disciplinary allegiances which led to the Exploratorium playing less of a role in the NISE Net than the NISE organizers had at first assumed. In particular, he demonstrates how science education is frequently thought possible only if produced by and in relation to scientific expertise. If the exhibits seem "weird" and "personal," they must not be able to produce valuable learning about science.

I asked Winfrey why she thought art has played such a small role in the NISE Network. "First things first, so art gets cut," she said. In her experience with science education, she said, scientists and those who see their first allegiance as being to science forget sometimes that people need to learn why they should care. She argued that artists could have been a valuable addition to the NISE Net because artists focus on making meaning. Also, artists recognize that visitors have to be taught why things were important and why they should care about them. Artists cannot assume that the visitors will find something meaningful just because artists find it meaningful. Winfrey believes this was the mistake of the NISE Net. She has been happy to find that the people who work at the Exploratorium were dedicated to and have seen how "multidisciplinary ways of working are successful." Art and science have an equal partnership, she said; art, therefore, is not in the service of science.

A few weeks before I spoke with Winfrey, the Exploratorium had hosted a conference focused on the theme "Art as a Way of Knowing" ("Art as a Way of Knowing Conference | Exploratorium" n.d.). At the conference, speakers or "thinkers," as she described them, examined different ways that art enters the science education discussion. They were particularly focused on the differences in the value systems of art and science. There were of course structural reasons that the work of the Exploratorium did not play a large role in the NISE Net, but Winfrey's and Heller's comments reflect more deeply situated educational commitments, which might have predicted the failure of art to take hold in the NISE Network from the beginning. More specifically, the scientific community of which the field of informal science education is a part has difficulty validating knowledge created outside traditional laboratory and field research settings. The lack of consensus over the definition of nanotechnology for educators in the NISE Net makes this difficulty even more evident.

Winfrey was not the only person to highlight the question, "what are people really learning?" This was a theme that ran throughout the NISE Network evaluations of programs. Again Winfrey:

> I think particularly with the nano thing, the scientists are grappling with the same things that other people grapple with. Language really lags what's really going on down there. All of those things really position artists to uniquely equip us and help us imagine that landscape.
>
> *(Winfrey 2011)*

"Imagin[ing] that landscape" might be the exact problem. As educators of the NISE Network have tried to do so, they have moved away from valuing art practices as a way to access that, which is admittedly difficult to articulate, even for scientists. When, in an early meeting of the Network Executive Group, it was decided that scale was a priority, the NISE Network effectively deemed other educational methods ineffective or, worse, irrelevant to their work (Burk 2008).

The NSF's and some educators' dedication to a quantifiable, determined way of thinking and learning led to a preference for easily (and quantifiably) evaluated programming modules. This was yet another reason that art exhibits and practices did not take hold in the NISE Net. At the same time, a number of internal, institutional issues made large contributions in reducing the role the Exploratorium played in the NISE Network overall. In the early years of the NISE Network, it failed to value other possible models; even in informal science education about emerging technologies, it prioritized so-called scientific facts over imagination. That determination closed down an avenue through which science could have been democratized.

The artist-educators of the Exploratorium like Pam Winfrey attempted to break down the dichotomy, often relied upon in science museums, that separates the visiting publics from experts and art practices from scientific methods. But the NISE Network and the NSF were joined in a "cooperative agreement" for this grant. Therefore, the NISE Network must constantly respond to and include the NSF's critiques of how the Network pursues the outcomes and goals stated in the original proposal. Due to the epistemological allegiance to educational objectives not compatible with open-ended systems of learning and knowledge production and practice as evidenced by perspectives like Heller's or the choice to use the *Traditional Zoom* instead of the *Spiral Zoom*, art failed to take hold as part of the larger NISE Network. This meant that the art and art methods that were deemed "acceptable" to the Network planners turned out to fall flat for the Network's constituent members as a whole. The knowledge that was created by *ArtNano* and the Viz Lab could not find a foothold in the Network at large.

Conclusion

The role of the public in shaping scientific and technological outcomes has been a much-debated topic for scholars, museum educators, and policy professionals. Scholars have written about science-fictional imaginations of the potential of nanotechnology for decades, while theorists' proposals about its potential have continued in the shadow of the human genome project and genetically modified foods. Still others have worried about nanotechnology's ethical, legal, and social implications; through funding by government bodies like the United States' National Science Foundation, they have been able to study and understand what the public knows and believes about nanotechnology and its regulation. However, little research beyond that of scholars analyzing the media has asked why the public has formed the opinions it has or who has tried to shape those opinions and through what methods.[22]

If scientists and the government have historically possessed the ability to limit the negative effects of new science and technology, they have nevertheless failed to do so (as evidenced by developments in atomic energy, combustion technologies, and food processing, for example). Although there may not be any reason to believe that scientists and policymakers are inherently incapable of playing the role of regulators, they have frequently failed at this job. Therefore, the artists and educators featured in this study believe that only through the power of public knowledge can nanotechnology's potential be safely shaped. This is true for the Viz Lab as well as for the four other nanoart exemplars.

These vignettes are evidence of a larger pattern of nanoartists creating, promoting, and organizing nanoart because they believe, contrary to many artistic traditions, that publics can and must participate in shaping what nanotechnology becomes, whom it affects, and how it is used. These artists believe that publics should participate in shaping nano and that, contrary to some modernist artistic traditions that often discourage artists from using their art in the service of social change or other ulterior goals, they, the nano-artists, can and should use their art to impact society. Perhaps, this broader definition of education, the recognition by nonexpert publics of the potential roles a science can play in society, reflects a philosophy of learning that only artists could have. Certainly, historically, informal science education institutions have not been a place to foster deliberative dialog, even if they have succeeded in producing learning, excitement, and awe (Hein 1990; Bell 2009). Until recently, ISE institutions have not seen themselves as obliged or able to empower their visiting publics to have a voice in determining beliefs about how, when, and by whom science is used, much less how science is valued (Falk et al. 2007).[23]

What do these artists teach, if their methods *and* their goals vary so substantially from informal science educators' traditional definitions of learning? When little content about nanotechnology's physical or chemical characteristics is learned, but viewers and visitors become aware of nanotechnology in society and possibly aware of their potential power to define this new technology, has art successfully educated? The answer depends on whether successful, institutionally supported education can provide more questions than answers, stimulating critique as well as awe. More importantly, if education acknowledges that there are many possible futures as well as many possible histories, then these artists can redefine not just what counts as nanoart or nanoscience, but what counts as valid knowledge about the roles both play in society. The open-endedness of these art exhibits is a significant reason why the exhibitions seemed successful to their designers. They did not care whether visitors walked away able to conceptualize the nanoscale. Instead, the goal of these exhibits was to raise public awareness of other versions of science in hopes of helping viewers and visitors to play a role in how nanotechnologies are used in the future.

These exhibitions represent an attempt at a beginning of a sustained focus on technology that is historically and culturally significant. Portions of *Nano* were exhibited later by the Exploratorium as well as by numerous other museums. MRS has continued to sponsor *Science as Art* bi-annually. In 2012, Cris Orfescu completed the fourth annual *NanoArt* competition, and *Sites Unseen* was exhibited at the Madison airport as well as at two other venues after the initial show. None of these exhibitions has been formally evaluated, however. Their learning outcomes and goals were not easily quantifiable. The sponsors of the exhibits have not been focused on what content publics learn about nanotechnology, but rather on how art and artists give form and meaning to abstract concepts. Scientists themselves struggle to find the language to discuss nanotechnologies with one another; thus, educators were left with the dilemma of watering down the science to such a degree that their descriptions become meaningless, or valuing the ability of practitioners who work in metaphors to demonstrate knowledge through ways that were not, at first, obviously discursive.

ArtNano was one of the three primary foci of the NISE Network's programming efforts. However, it failed to take hold in the Network at large. That failure represents the limitation of the model of informal science education that NISE Net staff believed NSF was promoting. *ArtNano* serves as a good example of ISE practices that were not counted as the "right" kind of science education, but seem to have obvious educational merit.

The institutional organization of the Exploratorium served as a barrier to including art practice in the distributed science educational modules. In particular, because the Exploratorium was seen as the field's expert on art and visualization practices for science education, there was little attempt to form an art–science working group which included representatives from other institutions other than the Exploratorium. This lack of collaboration also meant that individuals at the Exploratorium were less in touch with the differences in priorities and needs between their institution and other ISE institutions (Anonymous 2009). Paul Martin, a Vice President of the Science Museum of Minnesota and a PI of the NISE Network, told me that at the beginning of the grant, the PIs had thought that each of the lead institutions would be in charge of its areas of expertise for the Network, and each would simply take its third of the money, use it to do what it wanted, and then distribute whatever it created to the rest of the member institutions. Early in the grant, the Network Executive Group realized that this was not the model they wished to follow; instead, they preferred a more collaborative approach.

However, the shift in operational mode did not reach the Viz Lab; it was directed according to the original, distributed model. As such, there was little or no dialog between the members of the Viz Lab and the other leading members of the NISE Network, leading the Viz Lab's work to never find a comfort zone between what the Network could use and what the Viz Lab members were willing or able to produce. Finally, the Exploratorium and the Viz Lab itself were negotiating internal organizational issues which led to the lack of documentation of the artist residencies and the lack of organization in regards to the project goals of the Viz Lab in general.

Formative and summative evaluations based on quantitative data are only one way to value and assess programming. In the NISE Network, however, these methods created some of the most important criteria by which to formulate those judgments. Even while the evaluations revealed their own limitations, there was nevertheless an insistence by the NSF that the success of the programming should be judged by the results of the evaluations. This expectation heavily influenced the NISE Network's inability to include educational programming with more open-ended learning outcomes, as conflicting ideologies about what counts as worthwhile informal science education helped prevent the Network from using art methods to teach its publics about an emerging technology.

Notes

1 There are a number of studies that define public engagement. For this study, the definition of public engagement originates from the practitioners, sometimes in contrast to current scholarly definitions of public engagement. See Bell (2008) and McCallie et al. (2009).

2 Of course, it depends how we define "art practice," but a few examples, though there are numerable, include: The Exploratorium's "Artists Visualizing the NanoScale," 2006, http://www.nisenet.org/artnano/; Science Museum of Minnesota is a leader in science theatre with their "Science Live Theatre" and its nano-related pieces; and scientists like Eric Heller who is a Harvard physicist but shows his "art" both online and at many other museums, science societies, and art festivals. See also Caelleigh (2003).

3 Here and elsewhere, "nanoart" is the term I use to refer to art, of a variety of genres or media, whose content is nanotechnology-focused. This should not be confused with other similar terms such as: *ArtNano*, a programming effort of the Visualization Laboratory, or Cris Orfescu's *NanoArt* or *NanoArt21*, both of which are different instantiations of exhibitions or movements coined by Orfescu.

4 The model for distributing exhibits was the Exploratorium's line of "cookbooks," organized exhibit construction manuals that are available for a reasonable price and include directions for how to build hundreds of exhibitions. See also Hein (1990).

5 For the purposes of this chapter, I am not critiquing what counts as the public or publics, though I am aware that this could make up another section of this chapter. Instead, I try to make clear when the actors do or do not define who they see as their visitors or publics. For the most part, the visitors, viewers, and imagined publics of these exhibitions include museum visitors, scientists, policymakers, other artists, and those unaware of nanotechnology.

6 See Berne and Schummer (2005) for a study that examined focus groups (like engineers) and effective ways to improve their ability to assess the risks of nanotechnology through science fiction.

7 Mainstream movies like *The Incredible Hulk* or *Spider Man*, and a variety of online databases, like Robert Freitas' *Nanomedicine gallery*, have contextualized visual and discursive images of nanotechnology. Newspapers tend to be light on images of nanotechnology, whereas popular science fiction like Michael Crichton's *Prey*, popular science magazines like *SEED*, and a variety of online blogs, research groups sites, and professional science society databases contain extant nanoimagery. See also Thurs (2007) and Milburn (2008).

8 For a few examples of scholars who have specifically addressed image-based communication pathways through which a science or technology is instantiated, see Nelkin (1995), Condit (1999), Nelkin and Lindee (2004), Thurs (2007), and Milburn (2008).
9 It might be safer to say that "variety" is a relative term. There is more variety in purposes of the nanoart than in the form, but given that there is not a whole lot of variety in form, that may not be that impressive. Most importantly, even though the artists who create this nascent nanoart have not used a huge variety of forms, they do vary more in their beliefs and purposes associated with their art.
10 Victoria Vesna and Scott Snibbe are two of the most prominent examples of artists who rely on immersive digital techniques.
11 This catalog, available to the public online as a 78-page PDF, is an artist's statement that includes images and descriptions of the individual galleries as well as the designers' philosophies of design and learning.
12 *Strange Matter*, http://www.strangematterexhibit.com/, is a hands-on exhibit for children and families that have traveled to science centers throughout the U.S. and Canada.
13 *NanoArt* has exhibited its artists since 2007 in galleries in Finland, Germany, and the Czech Republic.
14 Lacy (1995) has argued that artists who see themselves as mediators of public change through public art have been marginalized by traditional art critics (20). The establishment critics value only art that "subordinates function to craft" (21).
15 "The EUROFORUM is a unique model conference on the European Union. The conference utilizes different components of the EU's decision-making bodies to help with the future of the EU. This conference incorporates new components each year and is expanding their work discussing different topics from the EU's agenda. Sessions will be assembled to be held in English and in French. When the studies of all these committees will have been finished, resolutions and final communiqués will be submitted to the real decision-making bodies of the EU."
16 Katherine Hayles collaborated with Vesna on *NANO*, producing a book about the exhibit and concepts.
17 Of course, this may have just been an indirect attempt to let me know there was no room for *me*, as I was eventually informed.
18 Like all NISE Network products, the scale ladders are used by permission under Creative Commons. They were

> developed for the NISE Network with funding from the National Science Foundation under Award Numbers 0532536 and 0940143. Any opinions, findings, and conclusions or recommendations expressed in this product are those of the authors and do not necessarily reflect the views of the Foundation.

The owning institution is the Exploratorium. See the following web address for more information: http://www.nisenet.org/catalog/media/scale_ladder.
19 Part of these authors' interests focus on the definition of interactivity as computer-based interactions. While visiting the Viz Lab, members showed me the book by Morrison, Morrison, and Eames (1994) which was based on the movie by Eames and Eames (1968).
20 Winfrey reflected that this reaction is probably in part because if push came to shove, it would be difficult to separate the idea from the artifact.
21 Interestingly, the associate project manager of the Viz Lab claimed that his Exploratorium colleagues harbored resentment toward the Viz Lab because there was an impression that it was well-funded, but never exhibited anything on the floor. The associate project manager argued that this created a sense that their colleagues thought they were getting paid to do nothing. I found this particularly interesting given that Winfrey recounted that frequently, the artist residencies did not result in exhibits on the floor.
22 For some examples which try to go beyond these limits, see Myers (1990), Baird, Nordmann, and Schummer (2004), Lee, Scheufele, and Lewenstein (2005), Scheufele and Lewenstein (2005), Berube (2006), Nisbet and Scheufele (2007), Thurs (2007), and Milburn (2008).
23 Aquariums and zoos have long been sites of informal education which were exceptions to this. One of their primary purposes was to enroll visitors in the political debates which promote conservation and awareness of the role humans play in the environment, globally and locally.

References

Anderson, Alison, Stuart Allan, Alan Petersen, and Clare Wilkinson. 2005. "The Framing of Nanotechnologies in the British Newspaper Press." *Science Communication* 27 (2): 200–220. https://doi.org/10.1177/1075547005281472.

Anonymous. 2009. Interview by Author with Co-Principal Investigator of NISE NetworkOral.

"Art as a Way of Knowing Conference | Exploratorium." n.d. Accessed September 10, 2012. http://www.exploratorium.edu/knowing/index.html.

"Art Nano | NISE Network." n.d. Accessed September 12, 2012. http://www.nisenet.org/artnano.

Baird, Davis, Alfred Nordmann, and Joachim Schummer. 2004. *Discovering the Nanoscale*. Amsterdam: IOS Press. http://www.ifs.tu-darmstadt.de/fileadmin/phil/nano/toc.html.

Bell, Larry. 2006. "1st Annual Report (NISE Network): 10/2005-09/2006." Annual Report, Year 1 ESI-0532536. Boston, MA: National Science Foundation.

Bell, Larry. 2008. "Engaging the Public in Technology Policy." *Science Communication* 29 (3): 386–398.

Bell, Larry. 2009. Interview by Author with Co-Principal Investigator of NISE Network Digital Recording Device.

Bell, Larry, Carol Lynn Alpert, Paul Martin, Thomas Rockwell, and Robert J. Semper. 2005. "Proposal to National Science Foundation." Proposal 0532536. Museum of Science, Boston, MA: National Science Foundation.

Berne, Rosalyn W., and Joachim Schummer. 2005. "Teaching Societal and Ethical Implications of Nanotechnology to Engineering Students." *Bulletin of Science Technology & Society* 25 (6): 459–468.

Berube, David M. 2006. *Nano-Hype: The Truth behind the Nanotechnology Buzz*. Amherst, NY: Prometheus Books.

Burk, Diane. 2008. Visualization Laboratory Group Meeting Interview by Kathryn Vignone.

Caelleigh, Addeane. 2003. "Roles for Scientific Societies in Promoting Integrity in Publication Ethics." *Science and Engineering Ethics* 9 (2): 221–241. https://doi.org/10.1007/s11948-003-0010-4.

CAISE Inquiry Group Report. 2009. "Public Participation in Scientific Research: Defining the Field and Assessing Its Potential for Informal Science Education." Center for Advancement of Informal Science Education.

Condit, Celeste Michelle. 1999. *The Meanings of the Gene: Public Debates about Human Heredity*. Madison: University of Wisconsin Press.

Eames, Ray, and Charles Eames. 1968. *Powers of Ten*. Documentary Short Film. http://www.powersof10.com/film.

Ebeling, Mary F. E. 2008. "Mediating Uncertainty: Communicating the Financial Risks of Nanotechnologies." *Science Communication* 29 (3): 335–361. https://doi.org/10.1177/1075547007312068.

"Euroforum 2004 - Events - Resources - TakingITGlobal." n.d. Accessed September 12, 2012. http://events.tigweb.org/4295.

Falk, John Howard, Eric M. Reinhard, Cynthia Vernon, Kerry Bronnenkant, Joe E. Heimlich, and Nora L. Deans. 2007. "Why Zoos & Aquariums Matter: Assessing the Impact of a Visit to a Zoo or Aquarium." Silver Spring, MD: Association of Zoos & Aquariums.

Glass, Margaret. 2007. "The NISE Net: Bringing the Study of the Very Small to US Science Centers." *PLoS Biol* 5 (10): e283. https://doi.org/10.1371/journal.pbio.0050283.

Hayles, N. Katherine, ed. 2004. *Nanoculture: Implications of the New Technoscience*. Bristol: Intellect Books.

Heath, Christian, and Dirk vom Lehn. 2008. "Configuring 'Interactivity': Enhancing Engagement in Science Centres and Museums." *Social Studies of Science* 38 (1): 63–91. https://doi.org/10.1177/0306312707084152.

Hein, Hilde. 1990. *The Exploratorium : The Museum as Laboratory*. Washington, DC: Smithsonian Institution Press.

Heller, Eric. 2011. Interview by Author with Physicist from Harvard University Email.

"IPSE Project Descriptions | Sights Unseen: An Educational Nanoart Show." 2007. IPSE: Project Descriptions 2008–2007.Originally found here: http://mrsec.wisc.edu/Edetc/IPSE/about/projects.html. Now accessible here: https://chem.beloit.edu/edetc/IPSE/about/projects.html

John Curtin Gallery. 2010. "Art in the Age of Nanotechnology." Art Exhibition presented at the A Perth International Arts Festival Exhibition, Perth, Australia. April 5. http://johncurtingallery.curtin.edu.au/exhibitions/archive/2010.cfm#nano.

Jones, Ron. 2012. “The New Age of Wonder: How Will We Pioneer Interdisciplinarity between Design, Art and Science?” *Unpublished Manuscript*.

Lacy, Suzanne. 1995. *Mapping the Terrain : New Genre Public Art*. Seattle, WA: Bay Press.

Lee, Chul-joo, Dietram A. Scheufele, and Bruce V. Lewenstein. 2005. “Public Attitudes toward Emerging Technologies: Examining the Interactive Effects of Cognitions and Affect on Public Attitudes toward Nanotechnology.” *Science Communication* 27 (2): 240–267. https://doi.org/10.1177/1075547005281474.

Materials Research Society. 2010. “Materials Research Society Operating Committees.” 2010. http://mrs.dev.berndtgroup.net/committees/.

McCallie, Ellen, Larry Bell, Tiffany Lohwater, John H. Falk, Jane L. Lehr, Brice V. Lewenstein, Cynthia Needham, and Ben Wiehe. 2009. “Many Experts, Many Audiences: Public Engagement with Science and Informal Science Education.” *A CAISE Inquiry Group Report*, 1–83.

Milburn, Colin. 2008. *Nanovision: Engineering the Future*. Durham, NC: Duke University Press.

Morrison, Philip, Phylis Morrison, and Office of Charles & Ray Eames. 1994. *Powers of Ten (Revised)*. New York: Scientific American Library.

Myers, Greg. 1990. *Writing Biology: Texts in the Social Construction of Scientific Knowledge*. Madison: University of Wisconsin Press.

“Nanoscale Science and Engineering Education (NSEE) Program Solicitation.” 2005. Program Solicitation NSF 05-543. National Science Foundation.

Nelkin, Dorothy. 1995. *Selling Science: How the Press Covers Science and Technology*. New York: W.H. Freeman and Company.

Nelkin, Dorothy, and M. Susan Lindee. 2004. *The DNA Mystique: The Gene as a Cultural Icon*. Ann Arbor, MI: University of Michigan Press.

Nisbet, Matthew C., and Chris Mooney. 2007. “Science and Society: Framing Science.” *Science* 316 (5821): 56. https://doi.org/10.1126/science.1142030.

Nisbet, Matthew C., and Dietram Scheufele. 2007. “The Future of Public Engagement.” *The Scientist* 21 (10): 38.

Orfescu, Cris. 2010. “NanoArt: Art/Science/Technology.” NanoArt International Online Exhibit. 2010. http://www.nanoart21.org/html/nanoart.html.

“Public Outreach, Materials Research Society.” n.d. Accessed September 12, 2012. http://www.mrs.org/public-outreach-committee/.

Scali, Alessandro. 2007. “ALESSANDRO SCALI ::: NANOART: Alessandro Scali & Robin Goode’s NANOART on NATURE.” *Nanoart: Seeing the Invisible* (blog). September 27, 2007. http://nanoarte.blogspot.com/2007/09/alessandro-scali-robin-goodes-nanoart.html.

Scheufele, Dietram, and Bruce Lewenstein. 2005. “The Public and Nanotechnology: How Citizens Make Sense of Emerging Technologies.” *Journal of Nanoparticle Research* 7 (6): 659–667. https://doi.org/10.1007/s11051-005-7526-2.

The National Center for Education Statistics. 1980. *1979 Museum Universe Survey*. Washington, DC: Institute of Museum Services.

Three Drops (Short Version). 2008. http://www.youtube.com/watch?v=AmiSNUKn9Tg&feature=youtube_gdata_player.

Thurs, Daniel Patrick. 2007. “Tiny Tech, Transcendent Tech Nanotechnology, Science Fiction, and the Limits of Modern Science Talk.” *Science Communication* 29 (1): 65–95. https://doi.org/10.1177/1075547007306340.

Vesna, Victoria, and James K. Gimzewski. 2003. “NANO: At the Intersection of Art and Science.” Los Angeles County Museum of Art (LACMA) Lab.

Vesna, Victoria, and James K. Gimzewski. 2005. “NANO: An Exhibition of Scale and Senses.” *Leonardo* 38 (4): 310–301.

“Visualization Laboratory | NISE Network.” n.d. Accessed September 10, 2012. http://www.nisenet.org/viz_lab.

Wikinson, Clare, Stuart Alan, Alison Anderson, and Alan Pertersen. 2007. “From Uncertainty to Risk?: Scientific and News Media Portrayals of Nanoparticle Safety.” *Health, Risk, and Society* 9 (2): 145–157.

Winfrey, Pamela. 2011. Interview by Author with Artist from Exploratorium Skype.

18

Negotiations and love songs

Integration, fairness, and balance in an art–science collaboration

Megan K. Halpern

Prologue

> Negotiations and love songs are often mistaken for one and the same.
>
> *-Paul Simon*

In this chapter, I will describe how a love song became a negotiation, and how an earnest attempt to integrate art and science transformed into a conversation, at times harmonious and at times contentious, between the two. The project I describe was developed over the course of a year, but the collaborators met a year earlier, during my first foray into researching art–science collaborations. Before turning my attention to research, I spent a decade as the co-artistic director of Redshift Productions, a company my partner, Max, and I founded to explore science through performance. Redshift worked with dancers, musicians, improv performers, and scientists to create performances about science. As we developed our projects, we struggled with how to facilitate collaboration among the artists and scientists. Our attempts to build collaborative practices in the wild led me to pursue an academic career studying art–science collaboration, where I began with a project called *Across the Great Divide* that matched four artists with four scientists and observed each pair as they developed fifteen-minute performances.

For the first project, I created pairs largely out of expediency: as soon as I could find one artist and one scientist, I put them together. The results included a paleontologist and an electronic musician, a composer and an entomologist, a poet and a theoretical physicist, and a choreographer and an experimental physicist. This final pair, a physicist who studies, among other things, the physics of fruit fly flight, and a modern dancer/choreographer who also works in the healing massage and massage arts, enjoyed the project so much that they secretly began to spend time with each other outside of the meager three meetings each pair was allowed. By the time the project was over, they confided they had begun a relationship. They also told me that they wanted to continue to work with me and Max to develop a full-length performance. At the same time, *Light in Winter*, the festival that showcased *Across the Great Divide*, invited us to develop a longer piece for the following year. So, the physicist, Itai, the dancer, Maren, Max, and I began to envision what our next step might look like.

DOI: 10.4324/9780429437069-23

Two couples with overlapping and shared values about collaboration and communication and a healthy set of crisscrossed boundaries (art/science, scholar/practitioner, spouse/collaborator) set out to create a performance together. It isn't uncommon for romantic partners to work together in the arts nor is it unheard of in the sciences. Our shared interests had as much to do with our personalities and experiences as they had to do with our disciplines. Our previous professional experience, Maren and Itai's initial fifteen-minute performance from *Across the Great Divide*, felt like it had been a success because the audience seemed to receive it well and because we so enjoyed working together to develop it. So, the four of us built the new project on our commitment to (and overconfidence in) art-science integration. Because the project itself was personal for all of us, we did not immediately recognize the transformation of our love songs for art and science into negotiations over our shared custody of the audience.

The four of us worked together off and on for almost a year to develop *Dance of Scales*. During the development process, we previewed the first section of the four-part show at a conference held by consortium of informal science learning organizations and professionals in California in September 2009. After the September performance, development continued, as we created three additional sections to complete the one-hour performance. In November 2009, three additional dancers joined the project for the final performance, which was held in January 2010 at an annual festival celebrating science and art. The final performance consisted of dance, narrative, and multimedia elements and focused on how objects move at the nano-, micro-, and millimeter scales. This focus came out of Itai's background as a solid-state, experimental physicist, as well as Maren's background in choreography and in body work.

Because motives for participating in art–science collaborations shape those collaborations in sometimes visible and sometimes invisible ways, I noticed early in the process that there were many overlapping and competing reasons we had each taken on the project. The initial impulse for the project came because Maren and Itai were interested in further exploring the creative process together. Additionally, for Maren, it was an opportunity to choreograph her own piece, and for Itai, it was a chance to communicate his research to a broader audience. For me, it was another potential research project, while Max was excited for an opportunity to continue producing now that we'd left New York City. Though this may not have been our primary motivation, scientific outreach was the most tangible and most often discussed aim for the project because it was the only one that carried with it a potential for funding. Though we told ourselves many times, during many meetings about grant proposals, that we were just framing the project as an outreach project for a proposal, these initial discussions about the value of the project as scientific outreach must have shaped any subsequent conversations we had about what we were creating. After all, we applied for (and were denied) funding long before we actually began project development. From the start, social structures (in this case funding agencies, in particular) that value science in ways that they don't value the arts were woven into our creative process.

For both the initial project and for *Dance of Scales*, I was not only seeking to create a compelling performance, but I was also hoping to transform the story of the collaborations into some kind of new knowledge about artists, scientists, and collaborations between the two. I, myself, was transformed from a producer to a participant observer, still playing much the same role in the development of the piece, but also engaging in reflection on and analysis of the interactions between the collaborators. Once the project concluded, I used a grounded theory (Glaser and Strauss, 1967) approach to analyze recordings of meetings and rehearsals, interviews with the key participants as well as audience members, and my own field notes and reflections written during the process.

My research on Maren and Itai's participation in *Across the Great Divide* revealed that the early stages of collaboration involved charting what their practices had in common. I now describe this as productive boundary work (Halpern, 2012), as opposed Gieryn's (1999, 1983) famous description of boundary work as an effort to maintain autonomy, expand authority, or monopolize a knowledge or power domain. The four pairs of artists and scientists involved in *Across the Great Divide* were all charting their shared territory rather than establishing boundaries between their fields. These projects were short—each pair only met three times before their fifteen-minute performances. The shared territory charted by pairs who had not yet worked together was a promising discovery; however, in long-term collaborations, it might represent one stage in project development.

In contrast, the cartography for *Dance of Scales* felt messy. We found a shared territory of creating for an audience, desire for integration, and belief in the possibility of integration. But there was also boundary work between performers and nonperformers, and, as I would discover, boundary work around what artists or scientists do with an audience. So, I found that in a longer-term project, productive and more traditional boundary work were intertwined. Our conversations focused on integration and on resistance to instrumentalization, but they also turned into assertions of expert knowledge about audiences and about communication that seemed, in the most difficult moments of development, incommensurable.

Early on, the four of us discussed our eagerness to ensure that the process and the product were handled fairly to the satisfaction of each member of the team; however, despite continued congeniality (these tensions never became adversarial or confrontational) transforming the desire for fairness into reality proved a difficult task for all of us. As we began, I naively believed that the ideas and the process would organically provide a structure for collaboration would result in an authentic integration of art and science, which we were all very excited about. Itai and Maren's continued expressions of desire for real integration gave me a sense of security that we would rise above any discussion of fairness or balance between art and science. But even when the relationships between the collaborators were ideal—collegial mixtures of the personal and professional—power dynamics as unbalanced as those between art and science, or between audience and expert, cannot be easily overcome, especially when the collaborators ignore those power structures. I think we all believed they could, in part, because the first collaboration between Maren and Itai had gone so smoothly, and likely, in part, because of our social connections. One of the great myths of collaboration is that it just magically goes well when the collaborators genuinely like each other.

During their previous collaboration, Maren and Itai spent much of their time discussing the ways their processes were similar. This led to the creation of a visual model that described the overlapping ways they approached their work. The fifteen-minute performance they developed drew on this visual model and focused primarily on displaying the similarities between dance and science. Specifically, Maren and Itai described the process by which they did their work in terms of a circular pattern. They identified and mapped out three phases common to both art and science: observe, interpret, and share. They then developed a performance that would explain to an audience their understanding of the three-step process and how it applied to both art and science. So, when they began their second collaboration, they began with a sense of shared territory in the form of process, and the idea that they could find parallels in the way that they worked.

This time around, early in the process, Itai noticed that he was providing the source material—descriptions of scientific phenomena—and that Maren was reading these descriptions to come up with movement. To him, it seemed that he was providing inspiration for her, but the act was not reciprocated. In retrospect, it seems to me that he was providing the content around which the show would be developed, thus defining the central focus of the piece. This was the first hint that their shared territory was no longer shared. This early concern grew over time, and, by the time we had completed the partial performance in September, Maren was also dismayed by the clear focus on explaining Itai's work and asked for a part of the show that was *about* dance, as opposed to featuring dance about science. Itai was not opposed, and, in fact, he seemed encouraged that this would provide an opportunity for the reciprocation he hoped for earlier. Their concerns were slightly different, but spoke to the priority of science as the content and dance as the medium by which the content was delivered. Over the course of six months, the landscape of the project had been remapped. Maren and Itai were in agreement that they were no longer comfortably operating within their previously shared territory. They were both dissatisfied with an inequality they perceived in their map of both the process and the product they were developing, and they wanted to rethink the way they would collaborate. They were united in their concern: still both aiming for integration, but unsure how to go about integrating their work without integrating dance into scientific explanations.

In our discussions about this remapping, process and product were intertwined, and, to some extent, perhaps conflated, though it was apparent that we focused on process earlier and as we moved along and came closer to the performance, the focus shifted toward product. At the same time, our aims moved slowly away from integration and into discussions about fairness and then into discussions about balance. In the following section, I trace the development of the *Dance of Scales* through its path from integration to balance. I then unearth how, as these transformations took place, tensions within the collaborative process became negotiations over the audience.

From integration to balance

Integration

The project began with a meeting in February 2009 between Maren, Itai, Max, and me. Much of the conversation at the first meeting was about the concept of movement, largely because this was what Maren and Itai had in common—he studied fruit flies' wing movements, among other things, and she danced. This meeting was largely brainstorming and free discussion. The meeting had two noteworthy outcomes: first, the creation of a thought-provoking image and the discussion that followed, and second, the creation of a list of four questions that would serve as a guide for developing the show.

Maren drew a figure (Figure 18.1) on the chalkboard while trying to explain her view on how we think through questions in both the sciences and the arts. "There's a question," she said, "you study it, then that allows you to go this way, and, you know, and then there's this thing that you study, and then you go over here and there's this thing, and then you go over here." She added "these are all questions." Itai quickly connected this process of questions leading to other questions to his work. "Looks like bacteria," he said. After initial laughter, Itai clarified, "That's what the bacteria are doing. They're asking questions. Each time they're tumbling, they're asking 'what chemical gradient am I going to go after, and which way is it strongest at?'" The figure struck me as highly meaningful and as a potential new boundary object for the team. It was clearly open to multiple interpretations, but, because we were all present at the moment it was created, it held a special significance for each of us, and the meaning we each made of the symbol. Though the image was largely lost later in the process, it seemed very important in this moment.

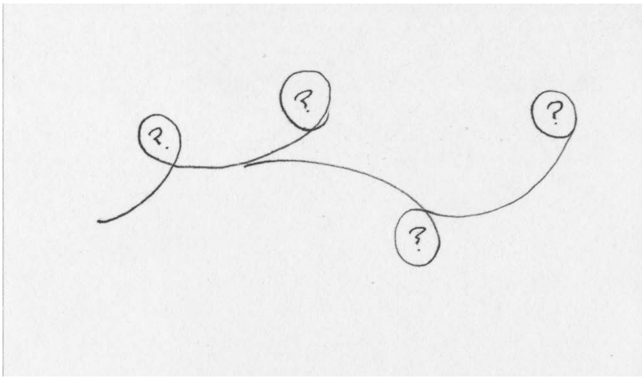


Figure 18.1 An image drawn by Maren during our first meeting

This exchange between Maren and Itai was indicative of the early process: they saw parallels between their ways of engaging with the world and wanted to explore these themes. This was similar to the boundary work in which the pair engaged during their first collaboration. The two were looking for shared territory, overlapping space in their cultural landscapes or social worlds. Reflecting on the symbol now, I see it as a map for that territory. It was also a roadmap for what Itai and Maren hoped our collaboration would look like. I believe they hoped that each of those question marks would stem from a scientific or an artistic question and that each question would inspire another question to be explored through dance or through science. Later, this loose structure that seemed to be organic (flowing naturally from art to science and vice versa) would give way to one that focused more on fairness. Here, I believe we all imagined that the performance would nimbly move between art and science, driven by ideas that came from both worlds and mingled together easily.

At the first meeting, shortly after the exchange about the image discussed above, we developed a list of questions we hoped the piece would investigate:

1 How do things move on different scales?
2 Why do things move on different scales? Or what drives movement?
3 What are the rules of movement? Are they different for different organisms and on different scales?
4 How do we talk about these things? What kind of language do we use?

I believe these questions were also a part of their shared territory, part of productive boundary work. From this initial meeting, I developed a cultural probe for the team. I used these probes for the first collaboration between the two. Cultural probes are curated sets of whimsical, oblique prompts. While the initial creators of the probes (Gaver et al., 1999; Gaver et al., 2004) designed them to get to know the communities for whom they were designing interventions, I adapted this work and designed probes to foster collaboration (Halpern, 2012; Halpern et al., 2013). I hoped the probe would act as a guiding experience for the project, as it had the first time they collaborated. I believed it would help us align our goals and provide a way of focusing our ideas for the show. I structured this probe around the series of questions they developed during the first meeting. Though I did not think specifically about it at the time, many of the prompts in the probe still asked the participants to chart their territories. In retrospect, I think this took the activity in the wrong direction because it emphasized the difference between physics and dance and because it did not focus on the audience and the communicative act. The aim of Gaver's original probes was to induce reflection so that designers could learn about those for whom they would design. Thus, the probe was a way of drawing out information about Itai, Maren, Max's, and my own beliefs and ideas surrounding the project, and, more broadly, surrounding art and science in general. The questions we asked were based on the first meeting, but they were developed with an awareness of a history of art-science tensions and struggles, many of which revolved around more traditional battles over boundaries.

The probe consisted of seven prompts, each attempting to open up ideas about Maren and Itai's work. For example, one prompt asked them to list the rules of performing dance and the rules of performing experiments and another invited them to create a simple game of movement by establishing three to five rules. During the probe, the four of us would try to find common ground and feel out the limits of the intersection between science and dance throughout this early stage of the process. The following exchange hints at the ways that their ideas about communication and audience might overlap, but also might be distinctive. The boundaries they set early in the conversation seem to move along well-trod positivist, enlightenment demarcations, but the group is clearly seeking shared territory. Like many scientists, when asked to reflect on his work, Itai invokes Mertonian norms of universalism and communism (Merton, 1973), indicating that they are central to science. When asked about centrality to dance, Maren focuses on communication and meaning-making, which Itai translates into visibility. This discussion gives a first glimpse of the unspoken fundamental differences lurking behind their ideas; however, none of us mentioned at the time. I wonder now if this is because Itai starts with common tropes about the demarcation between science and art and moves toward common ground without ceding territory.

ITAI: In physics the central thing is to essentially go after the sort of universal thing that should be repeatable in any lab. That's what we're centered around. What is dance centered around? What is it all about?

MAREN: It depends on who you ask. Dance is centered around communication between people, communication of ideas or of emotions, community, connecting. It might be around a political agenda, it might be entertainment … for me it is centered around communication and connecting people and creating community and making meaning. Meaning out of life or out of experience.

ITAI: How does dance make meaning?

MAREN: So what I mean by making meaning is that it has the potential to draw attention to interactions or moments that are just moments in life and they get passed by … you make visible a human interaction that is just small, and it happens all over the world at every moment. Somehow by noticing it draws meaning to an event.

MAX: Making the invisible visible?

Both Maren and Itai suggested that their work "makes the invisible visible," and they found some common ground in that concept; however, to Maren, the act of working with others was ultimately one of the most important aspects of dance. While Itai recognized science as a social endeavor, he believed that as a scientist, his job was to gather evidence to make "true" claims about the world. But this collapsing of meaning-making and visibility is what interests me. Her use of the word "noticing" might seem to indicate "making visible," but her use of the phrase "draws meaning" seems to be more akin to Dewey's idea of aesthetic experience (Dewey, 1934) than to visibility or reconcilability. To be imbued with meaning, to me, transcends visibility. On the other hand, rendering that which was invisible, visible, seems to be a kind of magical endeavor of its own. But this distinction is about the way the "it" is shared with people, not what "it" is or how "it" is discovered. In this conversation, Maren also indicated that she believes dance is an exercise in meaning-making, not necessarily something that inherently has meaning of its own. For her, the idea of allowing audiences to make their own meaning was important, and this was reflected in the kinds of pieces she created. She also recognized that other choreographers and dancers have wide ranging ideas and practices about meaning-making and that some dance performances have very specific meanings attached to them.

Fairness

I found the meeting following the probe more illuminating than the probe itself. This meeting was the first clear indication of what would become a long-term struggle for fairness between dance and physics, or, more specifically, between Maren's input into the project and Itai's. Much of the conversation during this particular meeting focused on the idea of "homework." The homework itself arose out of several needs: to keep the process going despite limited meeting time; to create opportunities for all of us to work individually to balance group work; and to allow for the kind of iterating and rough drafts of ideas that occur in solitude. But through discussions of homework, I saw glimpses of how fairness would play a role in the creative process as later discussions would increasingly focus on the fairness or balance in the performance itself. Prior to the meeting, Itai showed Maren some videos of small organisms moving, and her homework had been to create movement based on those videos. Itai was focused on what the reciprocal homework assignment might be: If he gave her videos from which to create dances, what would she give him?

ITAI: There's dances on the different scales, but some ways those are sort of assignments that I gave you. Are there assignments you want to give me? Like, I mean I study dance on different scales, essentially. As a physicist, I study dance on different scales. You study dance, or teach dance, or choreograph dance, and then, you know. I'm trying to figure out, you know, what's the reverse? Does that make sense?

As the conversation continued, Itai continued to try to explain his genuine concern that the distribution and shape of the process was somehow lopsided. We all took his concern seriously, and at face value. He went on:

> So if it is your interpretation of the science I do, then it would be my interpretation of the dance you do. So the assignment would be to go the other way, you know, so you could show me a dance, I could do my sort of interpretation of what it is that I see, and, is that like filming you doing leaps and bounds and whatever and then trying to tie it into something that I do? In terms of my analysis?
>
> [later in the conversation] The arrow is still pointing one way […] and I'm wondering what it is that can go in the other direction.

MEGAN: So what your interpretation of her dance is?

ITAI: yeah something like that […] and it doesn't have to be with everything, but it's sort of like giving each other assignments.

At this point in the conversation, we could not see a solution to his concern. It did not seem hopeless: the two were still collaborating well together, but we couldn't resolve his sense of unidirectionality. The concern seemed to be rooted in a desire for integration, and no one wanted to dismiss him, but we did not have an answer to his question. Maren suggested that perhaps such an answer would come later, after she had created something for him to interpret. Maren was still hopeful that their work would lead to something new; something that was neither art nor science.

MAREN: That step comes a little later after I've done some work. So right now all the arrows go this way, then in a little bit, I have arrows going that way, and what results from both of the arrows crossing is something that maybe we don't understand, but maybe it's about communication, maybe it's about reaching an audience, maybe it's something larger than art or science, you know what I mean? Maybe it's not, but there's the potential for … you know, how I've interpreted you and how you've interpreted me. It illuminates something larger than maybe just this project.

Maren was not yet worried about fairness, even though Itai was beginning to raise some concerns. She had a sense that the process would follow the map she had drawn in the first meeting (Figure 18.2), but that rather than each question arising organically, there would be some turn taking. The next step would begin from questions Maren raised. Though Maren's hope that they would find something that was neither art nor science was connected to the idea of integration, this conversation showed the beginning of a transformation of that hope from integration to fairness. The map Maren had drawn was starting to shift from questions and ideas that need not be art or science to questions and ideas that would be one or the other.

During the meetings that followed, the four of us developed a structure for the performance that broke it into four sections. Each of these sections would focus on movement at a different length scale, and we would begin working on the first section, movement on the nanoscale, for an in-progress performance for the Nanoscale Informal Science Network (NISEnet) Conference in San Francisco, California, in September 2009. For this performance, Maren indicated that not only did she expect Itai to dance (he had already expressed interest and eagerness to do so), but she also expected Max and I to perform. I dreaded this, but how could I refuse when the scientist we were working with was enthusiastic about it? While Max and I did not perform after the California trip, Itai remained a central figure in

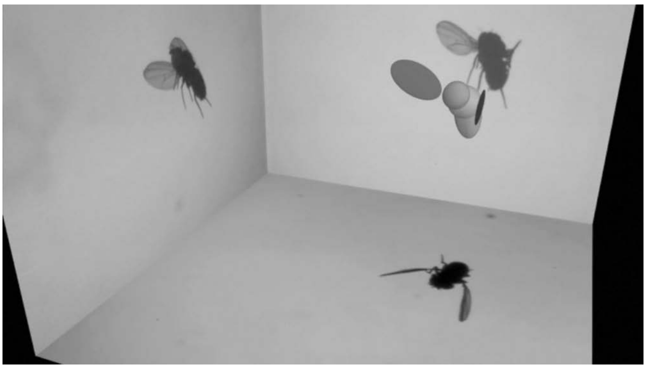


Figure 18.2 A still image of the video playing during Maren's solo. The three-dimensional composite of the fruit fly was created by combining the three two-dimensional images. The two-dimensional images were of the same fruit fly taken at three different angles

the final performance, and the dance the two choreographed for this first section remained largely intact in the final incarnation.

Maren would show us loosely developed ideas based on video or explanation from Itai, and we would work through them together. Much of the conversation focused on providing material that would inspire Maren or would express concepts like making the invisible visible. Doing this while also presenting scientific information about movement at different scales proved to be a challenge, and often, we found ourselves gravitating toward creating movements that illustrated scientific concepts. My sense is that we (all of us, including Itai) were fighting this pull toward the explanatory by attempting to create opportunities to put dance back into the driver's seat. But we were not able to find a clear way to do so without compromising the scientific explanations. No one suggested that we abandon the need to explain the scientific concepts. The aim of communicating clearly about the scientific content was so deeply embedded in the project that it wouldn't have occurred to me to question it.

After the first few generative meetings, activities to develop the show can be loosely divided into meetings and rehearsals. At first, the two seemed almost indistinguishable, though early in the process, we set aside time during meeting/rehearsals to discuss grant proposals, and these conversations were far different from our conversations about the performance itself. During the rehearsal portion of meeting/rehearsals, Maren and Max would often lead us in a series of physical and vocal warmups before engaging in discussions about the structure of the show. Both Maren and Itai would bring ideas into the room, and early incarnations of the "script" consisted of short scientific essays Itai wrote not to be read or performed for an audience, but to provide Maren with material from which to create movement. The meeting/rehearsals allowed us the opportunity to develop ideas rapidly. As we moved toward the first performance, the two events would become more discrete. During meetings, we would discuss issues with the script as well as organizational details and technical needs. Meetings also became a place to engage in more philosophical conversations about why we were making the choices we made. Rehearsals took on the traditional structure of sections of performance followed by "notes," during which we would provide feedback on what we had seen. In early rehearsals, Max and I usually gave notes to Maren and Itai on their movement and spoken word. As more dancers joined the team (attending only rehearsals, not meetings), Maren and Itai also moved into the role of providing feedback for the dancers. At this point, not all members of the original team were present at each rehearsal.

Balance

The September performance continued to push us in the direction of using movement to inform people about science in part because funding opportunities for such events generally come from organizations whose agenda is to promote or communicate science rather than produce art. The chance to perform *Dance of Scales* in California was no exception. Our first performance of *Dance of Scales* was for a network of museums and science centers dedicated to informal science education. Though we did not collect data, the performance was anecdotally well-received by the audience. We also conducted workshops on using movement to communicate scientific concepts, which do not fall within the scope of this study, but add to the overall sense that, during this phase of development, the project was embedded in the social world of informal science learning rather than the social worlds of modern dance, or of experimental physics, for that matter. Within this world, the performance itself was presented as a novel approach to do the work of that social world: to provide compelling interactions for informal science audiences.

When we returned to Ithaca and held a "post-mortem" discussion of the event, Maren indicated the lack of balance bothered her. Both Itai and Maren expressed their desire for a more balanced approach. It is worth noting that Itai opened the door for this conversation and that it echoed his earlier concerns about directionality. I surmised the two of them had talked about it prior to our meeting.

ITAI: Maren, you said that, for you the performance was, I mean this one was specifically science-based. And so, for you, that balance was off, for what you'd like to achieve for *Light in Winter.*

MAREN: That's true. Yeah, so when we come back to *Light in Winter*, I was, you know, just thinking that it would be good to have a section where it doesn't really start with the science concept at all. It just starts with a dance concept, or some dance idea that is developed, and then we put the science in later. Or not. Or it's just "this is art" and art is next to the science, and people can make whatever connections they do. So that was, I knew going into this that it would be science oriented and it turned out to kind of rub me more over time, and I don't know why I have such a thing about it.

This conversation revealed several things. This was the first time, to my recollection, we really spoke in terms of the balance of the performance itself. Itai used the term balance, shifting away from earlier conversations about how best to integrate their work and how to create a fair process. Previously, the idea had been that if Maren had homework, so should Itai; somehow, they should both should have engaged in the same kinds of generative activities. After this point, it seemed more as if their work should result in roughly the same amount of stage-time and focus during the performance. While integration suggested that the audience should see science and art at the same time, and fairness suggested some kind of natural flow between the two, balance meant that there was a true divide. In that meeting, Maren was asking specifically for a moment in the show that was driven by dance and that need not be tied to science at all. This would mean explicitly dividing the show into science and dance. Now the act of balancing them meant adding to the one that is lacking until they were roughly equal.

Second, a discussion of the difference between what dance looks like and what science looks like on stage began to emerge. Maren talked about people making whatever connections they want to rather than being directed toward particular understandings, which seemed to fundamentally rub against Itai's idea of communicating scientific concepts. His goal was to clearly explain scientific phenomena so that everyone reaches the same understanding. As Maren continued, there was also a shift in the ongoing boundary work done by the four of us. Here, she indicates a strong need for a clear demarcation between art and science, which seemed to run counter to her earlier quest for integration.

MAREN: But I think part of what we somewhat discovered in our rehearsals for [the festival] was that this is a festival of art and science, and part of it is that they're two different things, and they wouldn't be separate if there wasn't a different need for each of them in the world, and so I think it's important not to ignore that, and to me that means they can live side by side and not be enemies, and have a conversation, and maybe the conversation is things that don't connect, or maybe this doesn't relate to my world, or this does relate to my world but in this way, or, you know, so I think it's fair to process, to go through that and I guess for me dance doesn't, sometimes choreography doesn't have an overall through line. Sometimes it's just dancing and that's what it's for. I'm not saying we shouldn't have a through line because this is more than just basic choreography…

Previously, the boundary work Maren and Itai had done focused on finding the ways their two worlds overlapped, which was primarily in terms of process similarities and grand themes, like investigating and revealing things about the world. Now, Maren was asserting the fundamental differences between art and science. Here, the boundary work at play resembled Gieryn's discussion of boundary work as protecting autonomy. This moment was illuminating because I was able to see something that had been slowly happening throughout the creative process. We had engaged in a slow, unconscious pulling apart of art and science, in spite of our conscious efforts to marry the two. It was as if there were too many skirmishes over their shared territory for it to continue to be comfortably shared, and now they were vying for that territory. There was still a larger map in which they believed they could coexist, but this new cartography allowed for neighboring pieces of the landscape of the performance, rather than co-owned spaces. Thus far, the shift came largely from Maren because it was her autonomy that needed protecting.

Itai was sympathetic to Maren's concerns and had championed her need for dance to have its own moment. Early on, he'd advocated fairness in terms of homework, and now, he was eager to make space for Maren. However, differences in art and science, or at least in Maren and Itai's aims, would make balance a much more complicated ideal than perhaps we realized. The discussion around what I have called fairness meant that dance and science were both valuable and central to the performance. There was no method or need for measuring their input/prevalence. This balanced approach would mean that there were two sides of the performance and that they must fall into equilibrium. In these discussions, process fairness was less important than balance onstage. While this idea had been addressed before the September performance, the creation of an integrated piece was in the foreground. The imbalance in the September performance drove the idea of balance into the foreground as we developed the rest of the piece. At the same time, I sensed a shift away from the belief that the science and dance could be combined that they could create something new, as Maren had suggested during the third meeting. Though it was not worded this way, the new belief seemed to be that either science or dance was the focus of any given moment, and the aim was now to ensure equal time and weight. Maren repeatedly expressed the need for a part of the show to "just be about the dance." Gone were the discussions about creating something that was both and neither dance and lecture, and new discussion revolved around what Itai had to explain and how much of the performance could be experienced rather than understood.

When the three additional dancers began to work on the project, the dancers outnumbered the non-dancers, so the nature of the rehearsals changed significantly. There was a specific technical language the dancers used and specific issues with choreography with which they grappled. As Maren worked more with the dancers, the need for Itai to dance diminished, and Max and I were relieved to no longer be needed on stage at all. Itai now fell into a role of narrator/lecturer. In the first section, he learned choreography and performed it. His physical interactions in the space and with the rest of us were well developed, and he was becoming quite a good dancer. While that section of the show remained the same, in subsequent sections, he would be relegated to the role of scientist; only occasionally would he interact with Maren or the dancers physically, and when he did, it was for brief moments that were often improvised. He did continue to interact with them verbally, at times, to explain what their movements signified, but more often than not, he was interacting with the audience rather than the dancers. This transition lent itself easily to the idea of balance.

Time on stage could either be used for dance or for explaining scientific concepts, but not both. The three dancers working with Maren were either working alone with her during a rehearsal (I often observed these rehearsals) or they were trying to learn from Itai to help them understand some of the movements we had developed. These individual movements remained inspired by the scientific concepts Itai explained, but broader combinations of the movements used to develop choreography became a kind of vocabulary for the dancers to play with as they created expressive moments.

Further cementing this new vision of balance, Itai brought in additional demonstrations in between moments of dance in which he was alone on stage demonstrating concepts he wished the audience to understand. In one demonstration, he held a large pair of "wings" made of foamcore and sat on a stool that spun to demonstrate how fruit flies manipulate their wings to steer while they fly. This demonstration was inspired by our work together and developed collaboratively. It was so compelling and memorable that Itai reported using it in lectures long after *Dance of Scales* was over. In another demonstration, he used materials from his lab to demonstrate how viscous fluids can be "unmixed" when stirred backward. Both of these demonstrations were exciting to watch and captured the audience's attention, though the first example came out of our work together and the second was a demonstration he had done in classrooms. These demonstrations further structured the performance around balance and cemented Itai's sections as pedagogical, while Maren's were dedicated to creative expression.

Itai's demonstrations were compelling and expressive, and to my mind, they possessed the aesthetic qualities of performance. They complimented a moment involving audience participation. They were also short and became punctuated moments between lecture and dance.

The remapping of the terrain was becoming visible in the production and could be witnessed during the course of the performance itself. The first act, created before the performance in California, featured mostly Maren and Itai on stage together. They danced with one another while Itai spoke about the ideas they were presenting. Maren also spoke during this act, for the participatory moment in which the audience was asked to move together. The participation had the dual motives of getting the audience to engage in creative movement and of demonstrating entropy at the nanoscale. As the show continued, more and more of Itai's explanations were conducted without dance, or with demonstrations of movements done either by Itai himself or by dancers. These demonstrations with dancers held some of the same characteristics as the first act in which he and Maren danced and he spoke at the same time, but they took on a different character. The movements were not fully choreographed moments, but rather demonstrative gestures. The moments when "dance was in the driver's seat" were also different in nature from the first act. In the moments characterized as dance, the gestures used in demonstrations during the science portion were woven into fully developed choreography. I do not mean to overstate this evolution. The elements of choreographed moments, lecture, and demonstrations were components of the first act, but in that section, there was a genuine attempt to blend them seamlessly into a new form, whereas throughout the rest of the performance, we were engaged in creating balance between them.

Negotiation and compromise

In the third section of the performance, Maren danced a duet with video of a fruit fly in flight. The moving image was a three-dimensional rendering of one of Itai's fruit flies in flight, captured at thousands of frames per second, so that it looked as if the movement was happening in slow motion. Late in the process, just before the final performance, we were building the multimedia elements of the show, Max and Maren carefully crafted and edited the movie to suit her vision of the choreography, so there were points at which the video was reversed so that the fly moved backward.

Itai loved the edited film Max and Maren made for the dance, even the time reversal, but he wanted to find a way to explain the new movements of the fly to the audience, lest they get confused about the physics involved. To do so, he wanted to show a movie of the fly before Maren's dance while he explained how the fly used its wings. Maren wanted the dramatic effect of seeing the fly for the first time as she began her dance, so she suggested he explain without the image. Itai insisted that he needed the video in order to explain the phenomenon properly. The discussion went around in circles for some time. I found myself in agreement with Maren: I thought that building to a moment was important, and I did not see why Itai needed to explain the fly's movements first. Itai suggested the audience "wouldn't understand" or "wouldn't get it." We all tried to reassure him that the concept he was presenting wasn't difficult, so they would understand, but it seemed that Itai wasn't using the word "understand" in the same way Max, Maren, and I were. We were certain the audience would comprehend the concept he was describing, but that was not helpful to Itai. In the end, he made clear that it was not that the audience lacked the requisite intelligence or that the concept was too complex, it was that in science, you do not tell, you show. He needed evidence for his claims. It was true that for every other moment in which he was explaining science, he was relying on visualizations to demonstrate the concepts. To him, the audience could not and should not be asked to believe something without evidence. This was a simple fact of science for him, and it seemed to be at the heart of his desire to demonstrate the concepts he was trying to explain.

In the end, Maren and Itai negotiated a compromise in which Itai would show a different, lower fidelity, fly video as he explained the concept, saving the more polished film for Maren's dance (see Figure 18.3). This conversation was frustrating for all of us because this was the first time we were acutely aware that we were unable to make a decision regarding the show without compromise. While we successfully negotiated the way the show would unfold, the desire to create an aesthetic experience with movement was pitted against explaining the scientific concept of movement. Maren's belief that revealing the video too soon would impact the visual effect of her dance with the video was as strong as Itai's belief that he could not explain the movement without the visual aid of the film.

I found myself at a loss to understand Itai's claims that the audience would not understand what he was saying without the film. It was not until Itai said that science shows, it does not tell, that I begin to understand it was not that he thought the audience was incapable of comprehending his explanation, but rather, that to simply describe this phenomenon would be to violate the norms of science as he understood them. This was not about fairness or

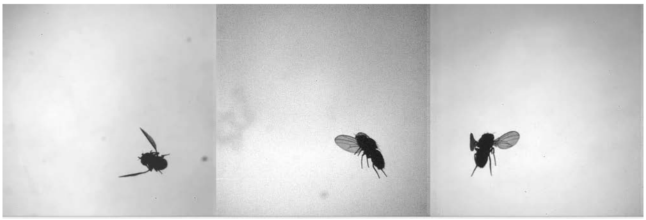


Figure 18.3 The three initial images used to create the composite. This video was shown during Itai's explanation of the fruit fly's movements, prior to Maren's dance

balance. Rather, it was that the parts of the show that were about science would be subpar without visual evidence. Though I understood his position, and we found a compromise, the moment stuck in my mind as problematic. It seemed to me that this choice was ideological and that the opportunity to create a striking visual moment was slightly diminished by the compromise. At the same time, I might have questioned Maren's assertion that the element of surprise was necessary; however, this aesthetic choice seemed to me to be sound based on my past experiences as a producer and designer for theater. Still, Maren's beliefs about the importance of the moment the audience is introduced to the imagery were likely as much a product of ideology as Itai's need for demonstration.

Negotiations and love songs

The song lyric quoted at the beginning of this chapter was an earworm in the back of my mind when I began writing about this project, and it remains an internal soundtrack each time I return to the page. Were these love-songs-turned-negotiations an inevitable consequence of work with loved ones or did they reveal a deeper disconnect between social worlds? While I haven't written extensively about the personal relationships in the room where *Dance of Scales* was created, they are part of the story. I don't mean to suggest that the struggle for art-science collaboration can be reduced to a soap opera plot. Conversations rarely, if ever, turned toward personal matters. I do mean to suggest that entanglements between art and science are more than academic considerations. They are the product of the relationships between the artists and the scientists engaged in work together, as well as our relationships to art and science, which are often deeply embedded in our identities. They are also the product of the relationships we have with our audiences, whether these audiences are real or imagined. Finally, they are a product of the social worlds and social structures within which they exist. The moment of conflict over the video was small, in the end, but it remains the moment of revelation for me. Perhaps because we could no longer imagine our negotiations were love songs or perhaps because we could no longer pretend that these were two different things.

Because the show was created in chronological order, the pulling apart of art and science became encoded into the performance, forming a subtextual story line. The first section, movement at the nanoscale, featured Maren and Itai moving together on the stage. Itai was dancing with Maren as he spoke, and some of the illustrative movements she created to explain his work seemed to be somewhat choreographed moments of their own. As the performance progressed to larger scales, each was a bit more polarized, as if you could see the stages of integration, fairness, balance, and negotiation play out on stage, until the end, when Maren danced with the other dancers while Itai stood aside. The process of negotiation became encoded into the performance itself as well as the transformation from the initial form of collaboration to negotiated form. The result was that in each section of the show, the dance and science became increasingly separated. In the first section of the show, Maren was dancing with Itai throughout. They were communicating with each other on stage as much as they were with an audience, but as the show progressed, Maren was interacting more with the other dancers. At one point toward the end, the lighting even changed so that Maren was in light and Itai was in darkness while she danced, and then, the lights went down on her, leaving much of the stage in blackness as a small spotlight came up, lighting Itai while he spoke and then disappearing as the rest of the lights came up on Maren again.

We set out to write love songs to dance and physics. Despite our best intentions as well as our best efforts, we ended up negotiating for space and time with the audience. We set out to try to integrate art and science, a project that I, as a scholar of art and science, should have been suspicious of from the beginning, but my roots as a theater producer gave me hope that I was on a different path than those who came before me. We ended up building, through our negotiations, a balanced piece that intertwined physics and dance; that made space on the stage for both science and art. But we did not integrate the two, so I think we all walked away feeling just a little dissatisfied. I think we all felt the loss of what we'd imagined we would do.

In some ways, this is always the case with art projects. As Martha Graham suggested, the arts, and likely the sciences, are spaces that foster a "blessed unrest" that moves us to keep pushing against what's already been done so that we can do something new (De Mille, 1991). But I can't help but think our feelings of discontent came from the genuine hope of integrating Itai and Maren's work. When I think about why that did not happen, I'm struck by the early process, where Itai's explanations formed the basis for movements Maren developed. While our commitment to integration was embedded in this process, so was the reality of funding and power within academia and more broadly in the social worlds in which we all moved. We had written grant proposals to develop projects that would disseminate Itai's work. The primacy of scientific explanation was encoded into the project's DNA. Though Itai was as committed to rejecting those power dynamics as Maren (as we were writing the grant, he often reiterated that we were just writing what the funders wanted to read, and that we were not setting out to merely explain his work using dance), perhaps they were inescapable. Because the power structures in our little collaboration seemed not to mirror the larger structures within which we collaborated, we were able to push back against them, but not to escape from them. So, though our negotiations did not dissolve the dichotomy between art and science, they may have yielded more balance than typically found in the social worlds of art and science.

Perhaps, that was enough. There's a case to be made that the performance was successful from a number of metrics. Perhaps Itai and Maren could successfully collaborate because they had abandoned integration in an attempt to build a balanced performance. Their related but separate sections of the performance did not encroach upon one another's territory, but Itai's sections included movement and aesthetic choices, and Maren's movements were inspired by Itai's explanations of his work. As Ede (2002) and Elkins (2008) have suggested, either art was in service of science, or science was in service of art throughout the piece, and the overall piece itself seemed to be rooted in art as a way of illustrating or demonstrating science. This led the creative team to be concerned that the imbalance between art and science always tipped toward science; however, in the end, Maren may have won the audience after all. Based on interviews and surveys I conducted with audience members between three weeks and two months after the performance (see Halpern, 2014, for a detailed discussion of the audience responses), we created something that was interpreted by some as an integration of dance and physics, by others as a dance piece about physics, and by still others as a physics lecture that incorporated dance.

One benefit of interviewing audience members when the performance was no longer fresh in their minds is that we got a sense of what they remembered and what they found important. From the small sample of interviews, it would appear that movement, visual imagery, and experiences were recalled, and scientific details were largely (but not completely) forgotten. One of the most easily recalled moments among interviewees was the moment of audience participation. But they recall the movement itself and the feeling of participation rather than the way their movements demonstrated entropy at the microscopic scale. Audience members described both integration and balance when they recalled the performance. They recalled the way they felt about the interactions and the demonstrations and the overall feel of the dance. This is not unusual for a science-themed dance performance, nor, in my opinion, is it lamentable. The scientific information was valued even when it wasn't clearly recalled. Its value lay in the part it played in the *experience* of attending the performance, rather than in any potential knowledge to be acquired.

That the audience members did not seem to have a consensus about how they would characterize what they saw, and yet they recalled very similar aspects of the performance suggests to me that in the end, the integration, fairness, and balance of the performance had ultimately to do with process, rather than the product. I am also struck by how centered that process was on the dichotomous roles of artist and scientist. This stands in stark contrast to their first project, which they found fulfilling precisely because they were deconstructing the two cultures by finding common ground (a common process by which the both of them engaged with the world). So, while we all aimed for art-science integration, we perhaps neglected the ways in which Maren and Itai, as complex humans, were more than simply an artist and a scientist. We sought to write a love song to dance and physics, hoping it would reveal the intersection of the two. But we did not attend to what exists within both ways of knowing, and so, our work could not help but embody not the union, but the disentanglement of art and science.

References

De Mille, A., 1991. *Martha: The Life and Work of Martha Graham- A Biography*, 1st edition. Random House, New York.

Dewey, J., 1934. *Art as Experience*. Minton, Balch & Company, New York.

Ede, S., 2002. Science and the Contemporary Visual Arts. *Public Understanding of Science* 11, 65–78. https://doi.org/10.1088/0963-6625/11/1/304.

Elkins, J., 2008. *Six Stories from the End of Representation: Images in Painting, Photography, Astronomy, Microscopy, Particle Physics, and Quantum Mechanics, 1980–2000*. Stanford University Press, Stanford, CA.

Gaver, W., Boucher, A., Pennington, S., Walker, B., 2004. Cultural Probes and the Value of Uncertainty. *Interactions* 11, 53–56.

Gaver, W., Dunne, A., Pacenti, E., 1999. Design: Cultural Probes. *Interactions* 6, 21–29.

Gieryn, T.F., 1983. Boundary-Work and the Demarcation of Science from Non-Science: Strains and Interests in Professional Ideologies of Scientists. *American Sociological Review* 48, 781–795. https://doi.org/10.2307/2095325.

Gieryn, T.F., 1999. *Cultural Boundaries of Science: Credibility on the Line*, 1st ed. University of Chicago Press, Chicago, IL.

Glaser, B.G., Strauss, A.L., 1967. *The Discovery of Grounded Theory: Strategies for Qualitative Research*. Aldine Transaction, Piscataway, NJ.

Halpern, M.K., 2012. Across the Great Divide: Boundaries and Boundary Objects in Art and Science. *Public Understanding of Science* 21, 922–937. https://doi.org/10.1177/0963662510394040.

Halpern, M.K., 2014. *Beyond Engagement: Meaningful Relationships Among Experts and Publics in the Performing Arts and Sciences*. Cornell University, Ithaca, NY.

Halpern, M.K., Erickson, I., Forlano, L., Gay, G.K., 2013. Designing Collaboration: Comparing Cases Exploring Cultural Probes as Boundary-negotiating Objects, in: *Proceedings of the 2013 Conference on Computer Supported Cooperative Work, CSCW '13*. ACM, New York, NY, pp. 1093–1102. https://doi.org/10.1145/2441776.2441900.

Merton, R.K., 1973. The Normative Structure of Science, in: *The Sociology of Science: Theoretical and Empirical Investigations*. University of Chicago Press, Chicago, IL, pp. 267–278.

19

Transdisciplinary co-inquiry as curatorial methodolo

From the Canadian Arctic to the Calder Valley, Yorkshire

Nicola Triscott and Anna Santomauro

While curating art exhibitions has always involved "research", the notion of curatorial knowledge, and curating as a knowledge-producing practice, has only recently received focused attention, particularly through Jean-Paul Martinon and Irit Rogoff's philosophical inquiry into what constitutes the practices and theoretical directions of curating. Martinon considers the curatorial as a form of gathering that can bring together people, spaces, ideas, objects, ideas, etc., and contribute to the political dimension of our existence, while Rogoff argues that "(if) curating can be the site of knowledge to rehearse its crises, then it has the potential to make a contribution rather than enact representation" (Martinon, 2015, p. 45).

The context for this curatorial research and practice has been our positions as the founding director (Triscott) and current program curator (Santomauro) of Arts Catalyst, a UK-based nonprofit contemporary art organization that specializes in new artists' commissions and transdisciplinary projects. Since setting up Arts Catalyst twenty-four years ago, the organization has pursued a curatorial practice and artistic program dedicated to extending contemporary art practices into the spaces and knowledge arenas usually associated with science and technology. At Arts Catalyst, we have developed a curatorial model and tactical framework that can nurture and support artists' engagement with other disciplines, generate new deeply informed art in response to this era of intense techno-scientific transformation, and undertake curatorial research across areas of specialist research.

From collaboration to cooperation

From the early days of Arts Catalyst in the mid-1990s, the organization experimented with different models of curating across and between disciplines, from setting up one-to-one artist–scientist collaborations and arranging artist's residencies in science labs to organizing multidisciplinary research groups, field exchange trips, and remote labs. Through these experiments, we found that asking people to work alongside each other – and frequently, in field trips and remote labs, to *live* alongside each other – produced more fruitful exchanges

DOI: 10.4324/9780429437069-24

and ideas than setting out with the objective of collaboration. The notion of curating groups of people, or collectives of practices, became a key part of Arts Catalyst's curatorial practice.

From our experience of curating inquiry-centered projects involving people from different disciplines, we suggest that focusing on *cooperation* rather than *collaboration* is a helpful way to think about curatorial process. While cooperation and collaboration are often used interchangeably, they have distinct meanings. The Latin etymology of the words does not give much clue to this distinction, since both translate as "working together"; therefore, actual usage is what distinguishes the two words. If we look at how the words are used by people across different fields, there is a general accord that *collaboration* implies an active, chosen involvement (even to the extent that it was given a negative meaning in World War II – a *collaborator* was someone working with the enemy), whereas *cooperation* is used in a broader and more wide-ranging sense of working together harmoniously, and indeed can be used to describe someone who is merely being *compliant*. There also appears to be broad agreement that when *collaborating* people are working toward an agreed shared goal, whereas in *cooperation* people perform together while working on self-directed goals yet common concerns.

The rhetoric – and aspiration – of *collaboration* abounds in the discourse around "interdisciplinarity", particularly in the field of art and science, with the assumption that those coming together from different disciplines should work to share objectives and outcomes, and even that this working together may lead to new combined methodologies. In the early years of Arts Catalyst, we accepted this notion – indeed, Arts Catalyst was one of the promoters of it. Yet, from our long experience as curators of projects that aim to bring together the tools of art and science in some way, we have concluded that a focus on collaboration is rarely the most effective model for producing interesting outcomes and exchanges. Frequently, a *collaboration* starts out – or swiftly becomes – one-sided, with one of the disciplines making most of the decisions and benefiting most from the outcomes. As Arts Catalyst is an art organization, the primary benefit generally accrued to the artist and the art in line with our mission (and funding). This rarely drew out the best contributions from collaborators from other disciplines, particularly science, and sometimes led to tension. From other accounts, there are frequent examples of friction reported between collaborators across art and science, so much so that notions of "agonistic-antagonistic interdisciplinarity" are discussed (Barry, Born and Weszkalnys, 2008).

One example of an Arts Catalyst project that strove for collaboration was the four-year project *Investigations in Microgravity* (1999–2003). In this program, we brought together the French choreographer and researcher Kitsou Dubois, who had been developing a process of experimental movement in a series of zero-gravity flights with the French Space Agency in the 1990s. We teamed Kitsou with the BioDynamics Group, a multidisciplinary research group at London's Imperial College of Science and Technology, led by Professor Robert Schroter.[1] The combined group decided to develop a collaborative project to investigate the control of the bodies in weightlessness, particularly contrasting trained dancers with non-dancers. Arts Catalyst was successful in applying for funding to support the program from the Arts Council and the Wellcome Trust. Team members participated in eight parabolic "zero-gravity" flights with both the European Space Agency (ESA) in Bordeaux, France, and the Gagarin Cosmonaut Center in Star City, Russia. Yet although the project started collaboratively, with jointly agreed objectives, various practical factors – such as the ESA refusing to allow artistic experimentation on its flights, but only scientific experiments – and differing personal goals and communication difficulties, caused by a lack of understanding of or sympathy for the "other" discipline's priorities, meant that the project drifted into two halves: the scientific experiment on the ESA flights, which the scientists led and in which Kitsou and Arts Catalyst contributed and participated, and the artistic experiment (on the Star City flights) into which the scientists were not invited to contribute. There was another small "coming together" in some experiments on postural control, led by one of the scientists with dancer and artist contributors, also on the Russian flights; however, while the team members engaged in some very fruitful exchanges, in the end the outputs were either scientific or artistic rather than a genuinely shared output. Today, we would consider the project a huge success, as it produced compelling performances and video installations, and a published scientific paper that sparked a whole new area of research at Imperial, as well as a program of public events. However, at the time, there was an odd sense of disappointment as we felt that the exchange between the disciplines should have been more rich.

A revelation came when reflecting back on the *Makrolab Scotla*nd project (2002), Arts Catalyst's first collaboration with the visionary Slovenian artist Marko Peljhan. *Makrolab* was Peljhan's nomadic temporary sustainable laboratory, which philosopher Brian Holmes describes as one of the more seminal projects to have developed from the tactical media practices that emerged in the 1990s (Holmes, 2006), which shifted away from the production of recognizable artworks to create experimental platforms for ideas, responses, protest, and resistance. *Makrolab* as an art project existed in multiple dimensions. It was sculpture, architecture, conceptual artwork, performance piece, and site-specific medialab. In appearance, *Makrolab* appeared in the landscape as a shining silver futuristic space station, adorned with sensors and aerials. It incorporated a dormitory, shower and toilets, kitchen, and workspace, accessed by a metal staircase leading to an "airlock" entryway. Powered by solar panels or wind turbine, with backup from a generator, it was designed to support four to six artists and scientists working and living alongside each other in isolation for periods of up to 120 days, enabling communications across the electromagnetic spectrum by radio and satellite links. It was inspired by the Russian futurist Velimir Khlebnikov's poem "Ladomir" (1920), when Peljhan made a trip to the island of Krk, off the Croatian coast, during the Yugoslav wars. Peljhan imagined a new form of theater to come:

> A stage appears on the horizon and walks slowly forth. On it the sailors of Ladomir work the spinnaker of thought. Large sails propel it forward, a complex mechanism allows its legs to lift and twist. There are no metal noises. The materials are new and unknown. It does have legs and looks like an insect. It has the functionality and energy balance of a bee and the armor of an Armageddon cockroach.
>
> *Peljhan (2003)*

In 2002, Arts Catalyst invited Peljhan to bring *Makrolab* to the UK, choosing a location in the Scottish Highlands, on the Atholl estate in Perthshire, where the lab hosted rotating teams of artists, scientists, and other researchers for three months. Within the *Makrolab*, crew members ("Makronauts") studied telecommunications, migration, and weather systems – multiple-dynamic global systems which Peljhan understood as the source of understanding how our planet functions on social, technological, and natural levels. We selected the researchers from an open call, curating them into crews[2] in which, when possible, we brought together researchers with broadly related areas of concern – such as the natural environment, the use of satellite data, and radio communications. At no point, however, did we ask the selected researchers to *collaborate*, but simply to conduct their research and live alongside each other. It was years later that we realized that many of those who had met on the *Makrolab* in 2002 had gone on to collaborate with each other on many subsequent projects, with their practices informing each other, often profoundly.

It occurred to us that the more conceptually driven and open process of *Makrolab* had allowed for spontaneous self-directed participation than more goal-oriented collaborative or residency programs. We realized that a form of curatorial methodology that could link selfish yet common acts together might foster the emergence of new kinds of collective value. As Arts Catalyst's curatorial work evolved, we focused on this way of curating. As with Makrolab, we found that within the directional stream of cooperation, eddies of close collaboration frequently emerged. Indeed, aiming for cooperation rather than collaboration seemed to lead to deeper and more mutually beneficial examples of collaboration.

Principles of a curatorial model of co-inquiry

Building on our understanding of curating processes of cooperation and collaboration, over the last decade or more, Arts Catalyst has developed a methodology that we call a *curatorial model of critical and transdisciplinary co-inquiry* (Triscott, 2017). *Co-inquiry* refers to collective and cooperative inquiry practices. *Critical* indicates a process of thinking about the impact of the inquiry's assumptions, values, and actions on others. By using the term *transdisciplinary*, we draw on Rowland's (2002) identification of two stories of interdisciplinarity. One, which Rowland calls *transdisciplinarity*, is the bringing together of different kinds of knowledge and skill to expand knowledge or to solve a practical problem. The other, which he names *critical interdisciplinarity*, refers to the sites of contestation between different "regimes of truth" that exist in the boundary areas between disciplines.

Like many other curators and artists, we feel an urgency to respond to the major socio-environmental challenges that face us today, such as climate change, species loss, and pollution, as well as complex health problems such as diabetes, asthma, cancer, and mental illness, and not only through tools of representation. Scientists are calling for new ways to inquire effectively into these complex human–natural systems. Many of us working in the arts wish to contribute to such inquiries and to cultivate and share new knowledge, understanding, and agency with people impacted by these issues.

There has been much debate about the "instrumentalizing" of art to address social issues, and it seems that art works best as a free and potentially disruptive process – losing its power if it is too focused or managed in terms of its outcomes. However, we are finding that Arts Catalyst's model of co-inquiry seems to have the potential to address complex systems and issues such as those mentioned without prescribing a clearly delineated process or specific social outcome. Rather, it brings together people from different disciplines – including art, science, social science, and the humanities – with people in communities who are impacted by these challenges in a cooperative arts-led inquiry.

Arts Catalyst's model of critical and transdisciplinary co-inquiry draws on the idea of the co-inquiry group promoted by John Heron and Peter Reason (Heron, 1996, Heron and Reason, 2001). This approach to research, also called cooperative experiential inquiry, is a systematic approach to developing understanding and action. Heron and Reason criticize traditional science's methods in relation to the science of human activity – particularly relating to health and society – for two main reasons: first, that there is often very little connection between the researcher's thinking and the concerns and experiences of the people who are actually involved, and second, that it tends to be a theoretical approach that doesn't help people find how to act to change things in their lives. Co-inquiry groups work in a participatory and egalitarian way, using and valuing the knowledge of the whole group, particularly knowledge gained through experience. The participants in a co-inquiry group work together as both co-researchers and co-subjects.

Arts Catalyst's model of co-inquiry is rather different from Heron and Reason's. It is driven from an arts-centered curatorial inquiry rather than from the social sciences. It is not so much focused on human activity as on complex human–natural systems. More significantly, it is not driven solely by a small group of co-researchers, who are involved throughout the process, but by a more dispersed collective, albeit with a core research team, with potentially large numbers of people involved to greater or lesser degrees as co-researchers.

Arts Catalyst's co-inquiry model centers on a set of core principles. These are, first, that the co-inquiry should focus on shared *matters of concern*, directing our attention toward significant issues that concern us, such as biodiversity loss, climate change, our actions toward other species, or the enclosure of the global commons and extraction of the planetary commons; second, that the inquiry develops through a broad process of *co-producing* knowledge, practices, and agency between art, science, other disciplines, and communities (a term we use to indicate groups of people with common interests or concerns, be they located or dispersed); and third, when bringing together artists, other specialists, and communities, that we give careful consideration to how our different practices relate to and impact upon each other to produce an *ecology of practices*.

The co-inquiry model encourages those who participate in it to shape it and to find agency within it. In doing so, it lends itself to a process of ongoing doing and undoing in order to provide room for autonomy, reinvention, and adaptation. From this perspective, the model functions as an evolving common toolbox nurtured by the practices and the concerns of those who make use of it. Artists, anthropologists, scientists, activists, and other actors in the co-inquiry carve individual paths that may run parallel to each other, perhaps overlap, but only rarely fully coincide. Each practitioner brings their own languages, translations, and forms of expression: interviews, ethnographies, workshops, meals, field trips, and public programs become part of a multifaceted process that is both informative and transformative. Vitally, each practitioner never closes the doors to a transformative intention because of disciplinary boundaries. Instead, the power of the inquiry resides in the situatedness of their work and in the acts of imagination that emerge throughout the process.

Through these processes, the co-inquiry shifts the understanding of "curatorial research" from an outcome-led approach typical of exhibition making to a collective, process-based, and experiential one. Rather than aiming at the exhibition as the main goal, this expanded form of curation creates a context for open-ended, multiple ways of production built on relationships that are sustained over a longer period of time.

In the following sections, we will delve in more depth into the three key principles of the co-inquiry and explore how these principles have operated, and how the co-inquiry model developed, within three significant Arts Catalyst projects: *Arctic Perspective Initiative (API)*, *Wrecked on the Intertidal Zone*, and *Test Sites*, the last being our ongoing inquiry into environmental change.

Identifying the "matter of concern"

Bruno Latour suggests that we should focus on *matters of concern* rather than the *matters of fact* on which science usually fixes its gaze (Latour, 2004). Matters of fact, Latour argues, are revealed without having to consider need or context and are only very partial, polemical, and political renderings of matters of concern. Matters of concern are centered in need and exist only through context. Matters of fact will emerge from a focus on matters of concern. We understand *matters of concern* as located within situated, complex systems which entwine environmental, social, and personal ecologies. In her book, *Another Science is Possible* (2017), Isabelle Stengers picks up on Latour's notion and suggests that the situation we find ourselves in today requires "the power to make people think about what concerns them" (p. 3) and that

> The essential thing with 'matters of concern' is to get rid of the idea that there is a single 'right answer' and instead to put what are often difficult choices on the table, necessitating a process of hesitation, concentration and attentive scrutiny.
>
> *(pp. 3–4)*

Co-producing knowledge

The second principle of the co-inquiry, that of *co-production of knowledge*, draws on Sheila Jasanoff's use of the term to describe the dynamic interaction between society and knowledge or society and technology – "the ways in which we know and represent the world (both nature and society) are inseparable from the ways in which we choose to live in it" (Jasanoff, 2004, pp. 2–3). It also references Michel Callon's (1999) use of the term to describe a model for participation by non-scientists in scientific knowledge production, which calls for processes of active collective learning involving those for whom an issue is of particular concern. We are interested in co-producing knowledge of varied types, underpinned by Donna Haraway's concept of *situated knowledges*, whereby knowledge is placed into a context, whether socioeconomic, anthropologic, intellectual, historic, or cultural (Haraway, 1988). Such active processes of co-production *with* people of varied backgrounds and involving scientists and specialists create knowledge that is situated and context-specific. This can then lead to publics that, as Stengers suggests, rather than having *understanding* of some precise area of science, instead have *intelligence* around the relationship of science and other disciplines to specific contexts and concerns (Stengers, 2017).

One of the most powerful ideas in Heron and Reason's co-inquiry model is to create a research cycle between four types of knowledge, reflection, and action, which they term propositional knowing (of facts, concepts, and ideas, as in modern science), experiential knowing (through direct encounter with a person, a place, or a thing, which involves empathy and is difficult to put into words), presentational knowing (which grows out of the experiential knowing and enables expression through, e.g., storytelling, art, or movement), and practical knowing (knowing in action: actually doing what you propose). Our co-inquiry model values different types of knowledge equally and strives to understand the unique contribution that varied knowledges can make in creating a full picture of the factors at play in a system, as well as working out what actions might be effective responses.

An ecology of practices

The third principle of co-inquiry relates to maintaining an awareness of and interest in how different knowledges and practices relate to and affect one other, after Isabelle Stengers' notion of an "ecology of practices" (Stengers, 2010).

Stengers, like many other twentieth- and twenty-first-century thinkers, is a critic of science's pretensions to totality: the notion that positive science, as a form of knowledge, is superior to other forms of knowledge or might replace other humanistic disciplines such as psychology, philosophy, or religion. As a first step toward an ecology of practices, Stengers demands that no practice should be defined as "like any other" (thus, she is opposed to those quantitative social sciences that seek "truth" through physics-like equations). She considers each practice as specific and therefore does not conflate all of science as a singular practice; she is careful to distinguish between different sciences, understanding that the demands and obligations of theoretical physics are very different from those of animal behavior studies, for example.

By taking an ecological view to practices, Stengers invites us to see how practices (of science, of art, of the humanities, and of situated experiences) relate to one another – particularly in what they demand and oblige of other practices. She does not regard practices as fully formed but as continually becoming and so she therefore offers an ecology of practices as a tool for thinking – a continuous process of learning. Thus, your practice should both recognize its limits and push against them in order to re-establish them again and again. Within this ecology, the boundaries between disciplines – rather than being antagonistic – become spaces of relations that are active and meaningful.

Arctic Perspective Initiative

From 2007 to 2011, Triscott was a member of the *API*, a transnational art, science, and culture working group set up by artists Marko Peljhan and Matthew Biederman.[3] The project emerged from the *Makrolab*, which Peljhan planned as a ten-year program culminating in the establishment of two permanent autonomous Makrolabs, one sited in the Arctic and the other in Antarctica.[4] During Peljhan's first site visit to the Canadian Arctic, to the settlement of Igloolik, he met with a group of filmmakers at Isuma Productions[5], as well as local politicians, hunters, and elders. Peljhan refers to this visit as life changing. As he got to know the people, the place, and its history, the notion of taking Makrolab there changed entirely. With Biederman, a Montreal-based artist whom Peljhan had met on the Makrolab in Scotland, he created the *API* and invited Arts Catalyst's curators to join the team.

The *API* aims to draw attention to the cultural, geopolitical, and ecological significance of the Arctic and its indigenous cultures. Its broad goals are to empower local citizens of the North via open-source infrastructures, such as data sharing, environmental monitoring, and communications technologies. *API* is a long-term project and has expanded to work with people in Igloolik, Kinngait, Iqaluit, Mittimatalik, and Kanngiqtugaapik in Nunavut, Canada. In the phase that Arts Catalyst worked on, we decided to focus on a few key outputs, which included the design and development of a mobile media/habitation unit (the "Kallitaq") and systems infrastructure, powered by renewable energy sources, intended for use by Inuit and other Arctic peoples for creative processes, communications, and citizen environmental monitoring while moving, living, and working on the land. For example, a hunter living on the land would also be able to film and stream, in real time, their personal story and reflections to the Internet, giving the world the opportunity to understand the reality of the Arctic directly. We also worked on a robust open hardware sensor network, based on the Arduino architecture, able to collect a range of environmental data enabling citizen monitoring of changes to conditions.

Alongside this work, we curated exhibitions and organized meetings and presentations in the South to raise awareness of the environmental, geopolitical, and cultural importance of the Arctic region. Initial exhibitions took place at the Phoenix Halle, Dortmund, Germany, and at Canada House, London, UK, although further iterations of the project have gone on to be exhibited at many exhibitions around the world. Each exhibition incorporates multiple media, including prototypes, architectural models, maps, texts, photography, films, and data and cartographic visualizations.

The impulse behind *API* – the artists' wish to respond to the concerns raised by people living in the Arctic and the desire to combine artistic, scientific, and technical know-how with indigenous knowledge to benefit those communities – resonated powerfully with us at Arts Catalyst. Although later we gradually withdrew from direct involvement in *API*, this was not because of any lack of interest or support but because we felt we couldn't contribute effectively to a project so far away. Instead, we wanted to develop projects closer to home with some of this same impulse.

The key principles that now underpin Arts Catalyst's co-inquiry model began to emerge during our work on *API*. The key to *API*'s success in attracting local support and other contributors was that it started from *shared concerns* about changes taking place in the Arctic environment, and from local people's ability effectively to investigate, respond to, and communicate these changes. The primary aim of the project was the co-production of knowledge and technical systems, understanding that this needed to draw together the situated and indigenous knowledge of local people with the knowledge and skills of other experts from outside the community. *API* demonstrated a sensitivity to how different disciplines, cultures, practices, and knowledge types impacted on and affected each other, a sensitivity that chimes with Isabelle Stengers' notion of an *ecology of practices*, which came to form a central principle of the co-inquiry methodology.

Wrecked on the Intertidal Zone

In 2013, Arts Catalyst initiated a new inquiry in partnership with artists Graham Harwood of YoHa and Steve Kurtz of Critical Art Ensemble, called *Wrecked on the Intertidal Zone*. *Wrecked* focused on the Thames Estuary in the UK, particularly around the towns of Leigh-on-Sea and Southend, in the context of the changes taking place in the estuary due to vast industrial infrastructural developments. Our aim was to undertake an inquiry that would bring in local situated knowledge and effect a greater sense of voice and agency for people living on the estuary.

We started the project by organizing a community workshop in the small town of Leigh-on-Sea to identify local concerns. These concerns included the impact of an upstream super-containership port development – and particularly the massive dredging activity taking place in the estuary – on fish stocks, cockle beds, and ecological diversity. Another more local concern was the town's nature reserve of Two Tree Island – popular with dog walkers, bird-watchers, and foragers – that had been constructed from a reclaimed landfill site, which had no records of what had been dumped there.[6] Two main strands of inquiry emerged. In the first, the artists proposed to collect stories from local people of lost and declining species in the estuary and then to create a kind of "anti-monument" to mark the changes taking place. The second was to investigate Two Tree Island specifically, both through speaking with people who worked there and by running citizen science workshops and activities, in order to try to build up a picture of what might lie under the reserve and its toxicity levels. We were joined by several other team members, including environmental chemist Mark Scrimshaw from Brunel University and artist Andy Freeman, a former oyster farmer with a keen interest in citizen science tools for social purpose.

Over two summers, we organized workshops, citizen science activities, ecology walks, and interviews with local people, including fishermen, ecologists, divers, and sailors (Figure 19.1). With artist Fran Gallardo joining the team, we ran a series of public events, *Talking Dirty: Tongue First*, which involved performances and activities focused on local foods, their source, preparation, and consumption, providing a context within which to engage people in discussions around the interrelationships of food, ecology, industry, and health. Gradually, we built up an alternative archive of knowledge of the estuary, which is held online in the public domain, comprising stories, films, images, maps, and records from the citizen science

Figure 19.1 *Wrecked on the Intertidal Zone*, YoHa and Arts Catalyst, 2015. Photo: Matsuko Yokokoji/YoHa

Figure 19.2 *Graveyard of Lost Species,* Critical Art Ensemble, YoHa, Arts Catalyst, 2016. Photo: Simon Fowler

tests. We also published the artists' book, *Talking Dirty: Tongue First, Recipes from the Mouth of the Thames*, by Fran Gallardo and Claudia Lastra, an ecopolitical recipe book containing local recipes along with tales of their social, historical, and ecological significance.

As a way of inscribing some of this knowledge physically in the locality, YoHa and Critical Art Ensemble created and installed a major temporary public artwork, *Graveyard of Lost Species*, on the marshes at Leigh-on-Sea (Figure 19.2). To create the monument, the team rescued a wrecked Thames Bawley fishing boat (a lost species itself) from the mud flats in the estuary, brought it ashore, cleaned it up, and engraved its hull and decks with the names of lost or declining "species" that had been collected. These species include not only wildlife and marine creatures, but also the livelihoods, fishing methods, landmarks, diseases, and dialects that are also being lost. The monument has been installed near the town on the local sea marshes, where it will gradually decay over years back into the mud.

Test Sites

API and *Wrecked on the Intertidal Zone* were key to forming the concept and principles of the curatorial model of critical and transdisciplinary co-inquiry, which we are now taking forward primarily through a series of socio-environmental projects called *Test Sites* and as a general methodology of co-inquiry and co-learning that underpins all our curatorial, programming, and research activities at Arts Catalyst.

Key to the *Test Sites* program are notions of planetary health, community resilience, stewardship, and well-being explored from localized perspectives. The emerging discipline of "planetary health" focuses on the interdependence of humans with urban and natural systems. Health depends on these relationships acting together in a life-enhancing way. As a discipline, planetary health tends to focus on direct environmental impacts on physical health, such as reduction of food security, loss of freshwater resources, and exposure to communicable diseases. However, there is increasing awareness of the relationship between environmental change and mental health. A recent editorial in *The Lancet* noted that "Effects of climate change on mental health are multiple and should be treated as attentively as the physical impacts" (*The Lancet*, 2017). Such awareness seems a belated echo of Felix Guattari's insight of the need for a mental ecology, contending that post-industrial capitalism is not only destroying the natural environment but also eroding social relations and engaged in an insidious "penetration of people's attitudes, sensibility and minds" (Guattari and Negri, 1990, p. 53). The entanglement between economic systems and ecologies of living becomes apparent when the material and immaterial infrastructures that sustain life of different scale start to show the cracks.

As Susan Leigh Star suggests, the invisible quality of infrastructures that govern our everyday life becomes visible when it breaks, like a server that goes down, a blackout, and a bridge that washes out (Star and Ruhleder, 1996). The symptoms of austerity, inequality, and exploitation of natural resources manifest themselves through flooding, water and air pollution, and species loss. Our aim in *Test Sites* is to engage people in different locations in the UK in collecting and co-creating knowledge around complex and fragile socio-environmental systems by learning from existing practices of care and stewardship and by inventing new ones.

We understand *stewardship* as acts of caring for and the responsible use and protection of the environment. We distinguish this from *governance* with its systems of regulation, although the two are obviously interrelated. To act in an ecologically meaningful way, we need to tackle how decisions are made, resources and infrastructures are governed, and people organize themselves to live with other humans and other species.

Our aim is to test, expand, and disseminate our model of art-centered transdisciplinary co-inquiry to facilitate community engagement and self-direction in research, as well as to produce new artworks and exhibitions that connect people with the ideas generated through this process. We are currently working on three *Test Sites*: around Poole Harbor in Dorset, in King's Cross, London, and in the Calder Valley in Yorkshire. Each location brings its own unique set of challenges, while each team of inquirers (artists, scientists, and local experts) brings a different set of skills and approaches, resulting in the emergence of varied and distinctive processes, while still following the co-inquiry principles. The teams for each inquiry come together gradually, starting with the Arts Catalyst curators and a selected artist or artists and then expanding to include new members as the specifics of each inquiry emerge.

In each site, we begin by gathering information from communities and experts about how they understand the system, how they think it works, their role in its stewardship, and the relationship with their own health and well-being. We then identify the *matters of concern* while building a network of partners, experts from various disciplines, local people (experts-by-experience), and policy makers.

Test Sites Poole Harbor was inspired by the idyllic landscape of this natural harbor with its serene wooded islands and beaches. The harbor is a site of outstanding natural beauty, with numerous Sites of Scientific Interest, and protected environmental habitats, yet underlying and concealed within this landscape is the largest oil field in Western Europe. This contrast, as well as the many other commercial and military interests that characterize the area, intrigues us. In Poole, we have brought together artists, scientists, students, and wildlife experts, most of whom lived locally to Poole. Key contributors include artists Neal White and the Alternative School of Economics, marine biologist Rick Stafford (Bournemouth University), and Arts Catalyst curators.

Test Sites King's Cross meanwhile focuses on the area in London in which Arts Catalyst is currently based. King's Cross is ranked in the nine percent most deprived in England, a diverse area which includes Bangladeshi, Somali, Chinese, Caribbean, and European communities. Recent record-breaking levels of pollution are causing grave concern as are current plans for the HS2 high-speed railway, [7] which is accelerating regeneration in the area and is likely to increase air pollution as well as affecting homes through noise or vibration.

Test Sites Calder is unfolding in the Calder Valley and the broader catchment in Yorkshire, where flooding and water pollution have been issues for 200 years. The area is well known for extreme flooding, particularly in recent years. The core team comprises Arts Catalyst curators, artist Ruth Levene, and social anthropologist Megan Clinch. As the inquiry has unfolded, we have consulted and brought in additional expertise, including Dr Liz Sharp from the University of Sheffield, who pioneers collaborative research with water governance organizations and the public, as well as gradually forming a group of local people who act as "stakeholders" for the project and contributors to it. They inform how we define the matter of concern and how we respond to this in ways that can benefit local communities. They include members of local councils, public health officers, volunteers, and community organizers.

In each site, we are taking our time to identify the key *matter(s) of concern* to ensure that these are concerns that are shared by a broad group of people and something to which we – as an arts organization, albeit working across disciplines – can make a real contribution.

In *Test Sites Poole*, we have worked with artists Neal White, Anna Troisi, Ruth Beale and Amy Feneck, marine biologist Rick Stafford, and students from Bournemouth University. We have connected with local experts, including wildlife wardens from Dorset Wildlife Trust and the National Trust and members of the Poole Harbor Study Group, an informal network whose members are both individuals and researchers from universities or other agencies with varied interests in birds, marine life, plants and vegetation communities, nutrient cycles, erosion and sedimentation, and history of the harbor.

During 2017 and 2018, we organized a series of field trips, workshops, and platforms, involving artists, scientists, students, and local wildlife experts, to start to examine the tensions and impact of this complex system of overlapping and competing economies – which include tourism and oil extraction – and their impact on the biodiverse ecologies and local cultures of the harbor. On one of these research trips, Professor Rick Stafford, a marine biologist based at Bournemouth University, identified several key ecological markers for the harbor – such as sea level rise, invasive species, aquaculture, fishing, and pollution. A conversation developed between him and artist Neal White around the relationship between these measurable markers and the more imaginary, subjective "markers" that relate to how we perceive our environment. As Stafford asks:

> If we have certain perceptions of an environment like Poole Harbor, can we use that to our benefit in order to reduce the amount of pollution? Poole is a very sensory experience - the oil fields are very hidden. If we think it's a very natural area, does that make us more inclined to manage it properly? Or less inclined because it looks so nice in the place?
>
> *Arts Catalyst (2018)*

These ideas were developed and explored through the exhibition and inquiry *Test Sites Assembly* held at the Arts Catalyst's center in London in 2018, in which White and Stafford took part. White's installation *Brownsea: An Imaginary Island (An Island of the Imaginary)* centered on a large analog/vivarium structure, carpeted with moss and furnished with tree branches, with a soundscape by artist Anna Troisi, which layered recordings of natural sounds from the harbor with the omnipresent rumble from the oil field. At points during the exhibition, members of the public could sign up to sit or lie within the analog and – aided by a narrative sound piece through headphones – exercise their capacity for imagining the tensions of this faraway geographical location. Brownsea Island is the largest island in the harbor and is owned by the National Trust and one of the main focal points for our initial research. Rather than providing an informational view onto this idyllic landscape, the installation set out to reflect on the psychological, creative, and political projections onto the island by its various gatekeepers, including wardens, conservationists, and scientists, as well as by visitors and outsiders. White's intention for the installation was that it act as a space for an exchange of views around the ways in which how we measure a place influences the way we perceive it, and how our perceptions – our imaginary markers – shape the environment in a measurable way. These interplays and tensions, between our perceptions of place and the changes taking place – some barely perceptible, some hidden, some that we just don't wish to see – are gradually suggesting the matter of concern that could be addressed through a transdisciplinary inquiry.

Test Sites King's Cross is evolving in a very different way. As Arts Catalyst is based in King's Cross, the curators have been able to be particularly active creating long-term links with community and action groups in the area, to identify the key matters of concern. One major issue for King's Cross is that residents feel they are constantly "consulted" when it comes to regeneration, but very little happens that has tangible benefits for them. Decisions are made for them, not with them. In King's Cross, London, we are thinking about the city as a body and investigating toxicity and the common ailments of communities and individuals. "Toxicity" implies not only air pollution but also developmental pressures, austerity, and Prime Minister Theresa May's proclaimed "hostile environment" for migrants. We are bringing in artists and other specialists to work with interested groups in the community to interweave personal narratives, policy making, scientific knowledge, digital platforms, and DIY open-source monitoring kits to reframe identified issues around regeneration, environment, and pollution in King's Cross. Through *Test Sites: King's Cross*, we want to invert the consultation process and create innovative tools for residents to propose to the Council and create more responsive and embodied ways of communicating the effects of policy.

Test Sites Calder is the most advanced of our co-inquiries and currently the best resourced, being supported in its first phase by the Wellcome Trust, a major biomedical charity with a burgeoning interest in planetary health, and Arts Council England.

Our overarching concept for *Test Sites Calder* is to explore ideas for and approaches to water management in the Calder catchment, and the impact on health and well-being of community participation in stewardship and self-directed research. Initially, we were attracted to Calder because of its complex historical relationship between communities and water management issues. Two narrowboat trips along the Calder and Hebble Navigation in 2017 were our starting points, enabling us to meet a wide range of people who use, care for, and manage the water system, including anglers, boat owners, dog walkers, ecologists, local historians, town councilors, water engineers, and activists involved in natural flood prevention and citizen science river monitoring. We invited anthropologists, scientists, artists, and other specialists and local people with interests in water to join us for meals and conversations on the boat. These slow journeys allowed us to gain understanding of the dynamics of the river and canal system in an embedded way, giving a very different perspective, and sense of time and distance, to those that would be obtained by traveling by road or rail. As well as obvious and ongoing issues of flooding, we found many other aspects of water management of concern to people along the Calder, including water pollution, canal maintenance, river ecology, the impact of building developments, and potential future fracking activity.

Some months into the inquiry, through our many conversations, we identified a central *matter of concern*, which focused on the nature of stewardship of the water system and its relationship with human health. Discourses of planetary health suggest that the health of the person and the health of the environment are interconnected through practices of stewardship. However, our work in the Calder has revealed that these forms of activity, as currently executed, can have the unintended effect of causing distress and anxiety for those engaged in various forms of stewardship. This impacts on volunteers, business owners, and community organizations, as well as the employees of the institutions responsible for looking after the water system. These expressions of distress appear to stem from two interconnected sources: first, a lack of control over water infrastructure and systems of governance tasked with various aspects of water management (flood risk management, flood defenses, canal and river maintenance and management, and the conservation of local ecologies); and second, the burdens placed on paid and volunteer workers to maintain an increasingly fragmented and under-resourced water infrastructure.

Beginning in 2017, over the last two years, our inquiry has continued to deepen, as well as to broaden geographically. Through a range of techniques, led variously and collectively by the team members, drawing on their different specialisms – including interviews, group discussions, workshops, and discursive activities at local festivals – we have engaged around 200 people in in-depth conversations about their relationship with and concerns about the Calder water system. Through this, we are building up a picture of the Calder's complex water system and how this changing system impacts on people's health and well-being.

Initially, artist Ruth Levene's fascination for water systems centered the inquiry, as she researched and engaged people in conversations about the geology, ecology, history, pollution, and uses of the Calder's river and canal, exchanging ideas around water's social, spiritual, political, and environmental meaning. Alongside, anthropologist Megan Clinch brought an open approach to inquire into people's relationships with the Calder water system by initiating a series of face-to-face interviews and group discussion sessions (Figure 19.3). A previous

Figure 19.3 *Test Sites Calder interview session with anglers, Dewsbury,* 2018. Photo: Colette Tessa Brown

project by Levene had produced a series of cards[8] illustrating factors relating to water, including flooding, governance institutions, the maintenance of pipes, pollutants, farming, and regulators. With Clinch, we repurposed these as stimuli for discussion sessions with groups of anglers, domestic water users, and leisure boat owners. We also organized "cake and chat" sessions at local libraries, centered on a series of striking geological strata cakes baked by Levene, which drew on her research into the Calder catchment's geology. As well as these in-depth conversations, which to date have involved over 200 people, we have also reached several hundred more through discursive installations at local festivals. For these, Levene produced a topographical model of the Calder catchment, scientists from the water@leeds group supplied samples of Peaty water and peat moss from the Calder, and the curators devised a series of open question posters and write-on handouts. We also invited artist Kat Austen, a trained scientist, to join us to lead some participatory citizen science activities, specifically testing for microplastics in the canal waters.

Vitally, the situated knowledge and expertise of people we have met in the Calder Valley have been and remain central to the inquiry. Key contributors include Steve Benson, a local activist and town councilor campaigning against unsuitable developments where the current infrastructure is inadequate; Hilary Brooke, a volunteer with Canal and River Trust and a member of its advisory board for the region; Clare Hall, an artist and volunteer with Mirfield Art Festival; Susan Stevens, owner of a local narrowboat company; and Melvyn Rutter, an environmental scientist and activist.

In 2019, we extended our invitation to artist group Invisible Flock, who are based in Leeds not far from the Calder area. In the lead-up to a series of public exhibitions and programs that we are taking to different communities along the Calder Valley and across the wider catchment at local festivals and events, Invisible Flock initiated an online inquiry posing a series of gently provocative questions to people from the area about their relationships with the Calder river and the water system. These anonymous responses are woven into an evolving, ephemeral artwork of stories, captured in a striking 2-meter-high digital light and text sculpture, called *Duet* (Figure 19.4).[9] By virtually connecting multiple voices from the communities who live along the river, the artwork produces a choral and amplified perspective on the role that the river plays within the societies and local ecologies of the Calder Valley.

Alongside *Duet*, we are presenting Ruth Levene's artwork *Working Waters*, which takes the form of a model of the Calder catchment accompanied by a series of miniature scenes (Figure 19.5). Each scene crystalizes occurrences, challenges, and concerns that have been

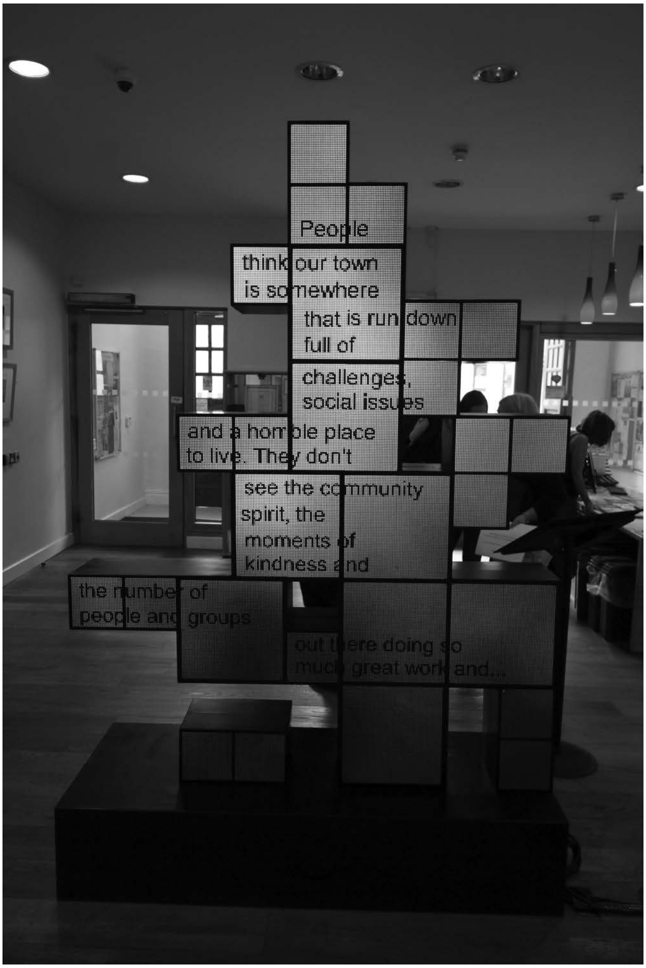


Figure 19.4 *Duet*, Invisible Flock, Test Sites Calder, 2019. Photo: Arts Catalyst

expressed throughout this ongoing dialogue with the communities living along the river Calder. Scenarios that emerge from the relationships between the miniatures reflect the multiple stances, concerns, and stakes that exist in the catchment. During 2019, Levene's *Working Waters* and Invisible Flock's *Duet* are traveling through the valley and catchment, activated through workshops led by the artists, the curators, and the anthropologist. Shifting focus at each site, these activities make use of the artworks to amplify the narratives across the catchment and to seek to overcome the fragmentation of such a wide area by re-centering the discourse in the river as an active social agent.

We see how the exploring and reconvening of practices at their boundaries unfolds through the example of *Test Sites Calder*. Initially, the objectives for the different team members – and our different interests and ways of working – were quite distinct. Ruth Levene's artistic practice is multifaceted, involving performance, events, walks, and installations. Her initial idea was to research and work toward the creation of a large-scale model of the Calder catchment, while anthropologist Megan Clinch's proposal was to uncover health-related issues connected to people's relationships with the Calder water system. As

Figure 19.5 *Working Waters*, Ruth Levene, Test Sites Calder, 2019. Photo: Arts Catalyst

the Arts Catalyst curators, we were keen to explore the curatorial as a mode of inquiry into a complex socio-environmental system, and to interweave practices of environmental stewardship, citizen monitoring, participatory modeling, and art as both social connection and form of spectacle. Interactive artists Invisible Flock have an ongoing interest in our changing relationship with water, which they have pursued through a series of projects in different parts of the world.

It has been in the boundaries between our different practices and approaches where the most fruitful work has unfolded. Each of our areas of research has been informed by each other, and our processes have become increasingly collaborative. Clinch's anthropological research process has been fed both by Levene's artistic practices and by the curators' notions of planetary stewardship (Triscott, 2017). In turn, Clinch's research and its findings have become central to the co-inquiry. Levene's artistic process has been informed by the ideas of the other team members. Her planned model became interactive, conceived as a way of enabling people to share ideas of stewardship in the valley and of how the valley works as a complex system. Both Levene's and Invisible Flock's artworks are then also generating further conversations that contribute to the anthropological and curatorial research.

While there was no requirement for the individual contributors to work together, increasingly, we plan our various activities collectively, and at times the boundaries between specific roles and research trajectories have become blurred. Members of the co-inquiry team may express the desire to collaborate while consciously deciding partially to give away the autonomy of their individual practice to work together toward a communal outcome. Perhaps the long-term nature of the inquiry nurtures the potentiality of affective and osmotic dynamics in the team and puts an accent on the manifold micropolitics of the cooperative process that ends up shaping the inquiry, shifting approaches, methods, and temporalities. At the same time, our local contributors have provoked and shaped the inquiry from the earliest stage and, in the next phase of the project, are poised to become increasingly central to the inquiry as we move toward the creation and "performance" of a People's Water Policy for the Calder over the next two years.

The co-inquiry within curatorial studies and practice

Within curatorial studies, Arts Catalyst's transdisciplinary co-inquiry model reconfigures curatorial practice as a collective, inquiry-driven practice and provides a useful methodology for inter-/transdisciplinary artistic practices particularly in relation to the politics of ecology. Curatorial projects such as *Test Sites* that give us new knowledge of some aspect of the world also shape our understanding of what curatorial practice can do, and open new possibilities for future curating. In doing so, we are contributing to a process of reconfiguring curatorial practice that has been ongoing since the early 1990s.

Around the turn of the millennium, alongside the expanding role and increasing prominence of the curator in contemporary art, descriptions of what constituted an "exhibition" also developed to include process-led projects and events, "… emphasizing flexibility, temporality, mobility, interactivity, performativity and connectivity" (O'Neill, 2003, p. 7). Notions of curating expanded to encompass a whole range of activities surrounding the exhibition, and Hoffman and McDowell (2011) introduced the term "the paracuratorial" to describe a form of curating "that is not understood as bound to exhibition making, but rather as encompassing, and making primary, a range of activities that have traditionally been parenthetical or supplementary to the exhibition proper". The commissioning and enabling of new work, rather than simply selecting from a range of existing works, became an important component of curating.

A few years ago, curator Maria Lind (2009) and others floated an expanded notion of curating toward developing "networks of agents", which Lind termed the "curatorial": "A way of linking objects, images, processes, people, locations, histories, and discourses in physical space". Lind emphasizes that, seen from the perspective of the curatorial:

> Curating is not so much the product of curators as it is the fruit of the labor of a network of agents. The outcome is a stirring of smooth surfaces, a specific, multi-layered way of agitating environments … The curatorial involves not just representing but presenting and testing; it performs something here and now instead of merely mapping something from there and then.
>
> *(ibid.)*

Jean-Paul Martinon (2015) considers that the *curatorial* is itself demarcated as an area of knowledge beyond solely that of professional practice. As Martinon sees it, whereas curating represents the practices and means of artistic production used by art institutions, the curatorial is more like a disruption of these processes. The curatorial is an invitation to challenge and reflect on the activities and functions of curating and to rethink how the activity of curating relates to the wider social sphere.

Arts Catalyst's co-inquiry model contributes to this current phase of interest within artistic and curatorial practice toward knowledge production and collectivity, and particularly in expanding curatorial practice beyond the art universe to explore its relevance and operation within other fields of knowledge production and social contexts. As contemporary art and curatorial practice continue to evolve in response to a changing world, often seeking a different and more meaningful relationship to the social as well as to research and knowledge, we feel that the co-inquiry is one valuable direction and framework that will resonate with many curators and researchers trying to find new modes of practice. If we are interested in fostering healthier and more resilient relationships between the social, the environmental, and the psychological, curatorial and artistic practices such as the co-inquiry methodology have, as Rogoff suggests, the potential to contribute to the world rather than simply representing or railing against it.

Notes

1 The group also comprised Dr. Nick Davey, Dr. Olga Rutherford, Dr. Anthony Bull, Dr. Alison McGregor, Dr. Steve Rawlinson, Dr. Paul Strutton, and Dr. Alex Nowicky, their expertise covering a range of disciplines including neuroscience, bioengineering, and musculoskeletal surgery.
2 Makrolab crew members included Marko Peljhan, Fraser MacDonald, Abigail Reynolds, Matthew Biedermann, Anna Jakomulska, Tomasz Szymura, Ewen Chardronet, Ilana Halperin, Lisa Parks, Ursula Biemann, Katrin Lund, Miles Chalcraft, Calum Stirling, Helena Johard, Dan Belasco Rogers, Helena Johard, Stephen Kovats, Helen Evans, Calum Stirling, Tim Knowles, Adam Hyde, Honor Harger, and Nina Czegledy.
3 The working group comprised the media/art organizations C-TASC (Canada), HMKV (Germany), Arts Catalyst (UK), Projekt Atol (Slovenia), and Lorna (Iceland), with community members in Nunavut, Canada.
4 For further information about the concept and history of Makrolab, there are two excellent interviews in Makery.com (also for some great images of the project!):
http://www.makery.info/en/2017/07/25/marko-peljhan-lutopie-materialisee-du-makrolab-12/
http://www.makery.info/en/2017/08/01/marko-peljhan-les-poles-sont-les-capteurs-de-notre-planete-22/
5 Canada's first Inuit production company co-founded by Zacharias Kunuk, Paul Apak Angilirq, and Norman Cohn.
6 There being no requirement to do so at the time of its operation.
7 When completed, HS2 will directly connect London, Birmingham, the East Midlands, Leeds, and Manchester.
8 Ruth Levene, *The Water Cycle*, 2017.
9 Created with their collaborators Quicksand.

References

Arts Catalyst. (2018). *Test Sites Assembly Exhibition Guide*. London: Arts Catalyst.

Barry, A., Born, G. and Weszkalnys, G. (2008). Logics of interdisciplinarity. *Economy and Society*, 37 (1), 20–49.

Callon, M. (1999). The Role of Lay People in the Production and Dissemination of Scientific Knowledge. *Science Technology & Society*, 4 (1), 81–94.

Climate Change – The Wider Threat. (June 2017). *The Lancet Planetary Health*, 1 (3), e82. www.thelancet.com/journals/lanplh/article/PIIS2542-5196(17)30052-9/fulltext

Guattari, F. (2000). *The Three Ecologies*. Translated by Ian Pindar and Paul Sutton. London: The Athlone Press.

Guattari, F. and Negri, T. (1990) *Communists Like Us: New Spaces of Liberty, New Lines of Alliance*. Translated by Michael Ryan. New York: Semiotext(e).
Haraway, D. (1988). Situated Knowledges: The Science Question in Feminism and the Privilege of Partial Perspective. *Feminist Studies*, 14 (3), 575–599.
Heron, J. (1996). *Co-operative Inquiry: Research into the Human Condition*. London: Sage.
Heron, J. and Reason, P. (2001). The Practice of Co-operative Inquiry: Research with Rather Than on People. In: Reason, P. and Bradbury, H., eds. *Handbook of Action Research: Participative Inquiry and Practice*. London: Sage, pp. 179–188.
Hoffmann, J. and McDowell, T. (2011). Reflection. The Exhibitionist, 4. Available from: http://the-exhibitionist.com/archive/exhibitionist-4/ (Accessed: 4 March 2016).
Holmes, B. (2006). Coded Utopia. *Mute*. January 9. http://www.metamute.org/editorial/articles/coded-utopia
Jasanoff, S. (2004). *States of Knowledge: The Co-production of Science and Social Order*. London: Routledge.
Latour, B. (2004). *Politics of Nature: How to Bring the Sciences into Democracy*. Cambridge, MA: Harvard University Press.
Lind, M. (2009). Active Cultures: Maria Lind on the Curatorial. *Artforum International*, October 1.
Martinon, J. (2015). *The Curatorial: A Philosophy of Curating*. New York: Bloomsbury Academic.
O'Neill, P. (2003). Curating U-topics. *Art Monthly*, (272), December 7–10.
Peljhan, M. (2003). [krk - first makrolab concept text]. Pelhan Territories - An Archive. http://www.ladomir.net/krk-first-makrolab-concept-text
Rowland, S. (2002). Interdisciplinarity as a Site of Contestation. A Draft Paper Presented at the Annual Conference of the British Education Research Association. *UCL*. http://www.ucl.ac.uk/cishe/seminars/interdisciplinarity/contestation_paper.doc
Star, S.L. and Ruhleder, K. (1996). Steps toward an Ecology of Infrastructure: Design and Access for Large Information Spaces. *Information Systems Research*, 7, 111–134. doi:10.1287/isre.7.1.111.
Stengers, I. (2010). *Cosmopolitics I: I. The Science Wars, II. The Invention of Mechanics, III. Thermodynamics*. Minneapolis: University of Minnesota Press.
Stengers, I. (2017). *Another Science Is Possible: A Manifesto for Slow Science*. Cambridge and Medford, MA: Polity.
Triscott, N. (2017). *Art and Intervention in the Stewardship of the Planetary Commons: Towards a Curatorial Model of Co-inquiry*. PhD thesis. Centre for Research and Education in Arts and Media, University of Westminster. https://westminsterresearch.westminster.ac.uk/item/q3677/art-and-intervention-in-the-stewardship-of-the-planetary-commons-towards-a-curatorial-model-of-co-inquiry

Section 5
Institutions and infrastructures

Kathryn de Ridder-Vignone

This section examines the divergent, but necessary supportive structures that often lie in the background and yet heavily shape the resource allocation and outcomes of work in the Art, Science and Technology Studies (ASTS) space. The chapters in this section will highlight how universities and non-profit organizations open up or limit the areas in which this work happens.

These chapters focus primarily on the role of more traditional research universities as important institutional actors; however, ASTS practitioners and scholars have been supported and shaped by a much wider variety of organizations, many of which took risks to invite, support, and promote actors working in this field before it was more prevalent. Many of these organizations are highlighted elsewhere in this handbook. The mission of some of these is education, learning, and discovery—such as the Exploratorium in San Francisco, the Laboratory at Harvard, the artLAB in Germany (discussed in Burri's chapter in this handbook), Science Gallery Dublin, and the Wellcome Trust (https://wellcome.ac.uk/about-us) ("About us | Wellcome," n.d.; "ArtLab," n.d.; "Exploratorium: The Museum of Science, Art and Human Perception, San Francisco | Exploratorium," n.d.; Dublin, n.d.; freshtilledsoil.com, n.d.).

Arts Catalyst in the UK (focused on in Chapter 18 by Triscott and Santomauro), TBA21 (mentioned in Section 8; https://www.tba21.org/), Schering Stiftung (https://schering-stiftung.de/en/projektraum/), FACT Liverpool (https://www.fact.co.uk/), QuoArtis (https://quoartis.org/), and Laboratoria Art & Science Foundation (http://laboratoria.art) focus on art making ("Arts Catalyst," n.d.; "Foundation for Art and Creative Technology," n.d.; "LABORATORIA Art & Science Space—LAB NEWS," n.d.; "Project Space—Schering Stiftung," n.d.; "QuoArtis Art and Science Foundation," n.d.; "Thyssen-Bornemisza Art Contemporary," n.d.).

Still others, like Art for Science, Cape Farewell, or Ars Electronica, support visual and artistic communication of scientific research often as part of a larger public outreach initiative ("About—Cape Farewell—The cultural response to climate change," n.d.; GmbH, n.d.). Within these institutional spaces, programmes and initiatives such as Leonardo, UCLA Art|Sci Center, MIT Center for Art, Science & Technology (CAST) (https://arts.mit.edu/cast), or A2R2 have arisen to dedicate structural support for collaborations among interdisciplinary practitioners ("About—Cape Farewell—The cultural response to climate change,"

DOI: 10.4324/9780429437069-25

n.d.; "Home | Leonardo/ISAST," n.d.; "Home Page | UCLA Art | Sci Center + Lab," n.d.; "Home," n.d., p. 2; "MIT Center for Art, Science and Technology," n.d.).

CERN, SymbioticA, Incubator, Coalesce, Art the Science (https://artthescience.com), or Genspace (which is not strictly for artists but often used by them) fosters work within laboratories for more than just scientists ("Art the Science | A Canadian non-profit SciArt organization," n.d.; "Coalesce BioArt Lab—COE: Genome, Environment and Microbiome—University at Buffalo," n.d.; "Genspace," n.d.; lindaessig, 2013; The University of Western Australia, n.d.). In addition, many of these institutions, like Djerassi's Scientific Delirium Madness, Finland Bioart Society, and Ars Bioarctica, have hosted a variety of residencies with artists and nonartists alike ("BIOTECHNICA 2009—turning ideas into value," n.d.; "Djerassi Resident Artists Program | Scientific Delirium Madness," n.d.; "Finnish Art Society," n.d.). Finally, a number of trans- and interdisciplinary publication platforms such as *Leonardo*, *SciArt Magazine*, *Configurations*, *InterAlia*, and *Journal for Artistic Research* have been established to foster collaborations and validate the contributions of scholars whose conversations have been traditionally relegated to separate publication domains ("Front page | JAR," n.d.; "Home | Leonardo/ISAST," n.d.; "Homepage," n.d.; "Project MUSE—Configurations," n.d.; "SCIART MAGAZINE," n.d.). The goals and missions of each of these types of institutions and their associated programmes have often shaped the thinking of the practitioners, researchers, and artists working within them and given these actors an opportunity to interact with and access expertise, technologies, and communities not otherwise available to them. This list is only a sampling of some of the institutions and supporting infrastructures that operate in this space. In the chapters that follow, the authors reflecting on their own work and the work of others were often doing so in particular local contexts that shaped the outcomes of their projects. Those local contexts, however, are part of larger, often globalized networks that don't fail to impact one another. The degree to which they do so, however, changes over time and is often an idiosyncratic reflection of other trends within the art world and the scientific research world.

Cardenas et al. (Ch 22 in this volume) suggest both a framework of collaboration and a platform of peer review that takes into account the variations of method and media within the ASTS field and that, when implemented by institutions, could help support artists whose media and work practices do not easily fall within traditional peer review structures. Similarly, Garcia Topete et al. (Ch 20 in this volume) examine the relationships that form when creating spaces that support collaborative transdisciplinary and experimental approaches to publishing with an aim to reach diverse and differentiated publics.

Other chapters in this section—Barnett et al.'s "Polymathic Pedagogies" (Ch 21) and Willet's "Feasting the Lab" (Ch 23) —highlight the operational structures, like peer review, grants, and degree programmes, through which money is funnelled and ideas are made valid.[1] These infrastructures often come to serve as frameworks, which are made invisible, after the fact, but which played a significant role in the premises, methods, and perceived outcomes of work in the ASTS space.

Barnett's "Polymathic Pedagogies" specifically examines how the development of a degree programme made with a specific focus on blending and valuing art–science practices on equal footing as a way to break down some of the hierarchical assumptions still runs up against more traditional ideologies of what counts as scientific methods and knowledge.

Jennifer Willet's chapter "Feasting the Lab" provides a first-person account of an artist deliberately challenging institutional assumptions about appropriate use of space and materials, to reflect on these unexamined assumptions and to ask how a lack of self-examination undermines the ability of societies, which rely heavily on scientific ways of knowing, to be engaged in critical accounts about themselves without undermining the validity of the work itself.

Unavoidably, these narratives serve as only a snapshot into the ongoing history of interdisciplinary scholarship and practice associated with and within academic institutions. They reveal three primary methods of entry—practice, education, and research—all of which have their own contextual histories and priorities. Just as scientific theories come to stabilize over time, the placement of ASTS practices within academic institutions becomes reified and valued as institutional structures and systems of evaluation validate and include these interdisciplinary approaches, not as a thing apart from the traditional, but as a thing within the given purview of the budgets, time, and personal values of the people leading these institutions.

Notes

1 See also Koek's "In/visible: the inside story of the making of Arts at CERN". Koek's piece about the CERN laboratory allows us to understand how scientific institutions that give equal power to artists and curators to curate and control spaces and people as they give to scientists can reveal the value of thinking and acting differently within what is normally considered a conservative space of scientific practice.
2 https://www.leonardo.info/history
3 https://arteca.mit.edu
4 https://creativedisturbance.org/

References

About – Cape Farewell – The cultural response to climate change [WWW Document], n.d. https://capefarewell.com/about.html (accessed 11.8.19).

About us | Wellcome [WWW Document], n.d. https://wellcome.ac.uk/about-us (accessed 11.8.19).

Art the Science | A Canadian non-profit SciArt organization, n.d. https://artthescience.com/ (accessed 11.8.19).

ArtLab [WWW Document], n.d. https://artlab.harvard.edu/ (accessed 11.8.19).

Arts Catalyst [WWW Document], n.d. https://www.artscatalyst.org/ (accessed 11.8.19).

BIOTECHNICA 2009 – turning ideas into value [WWW Document], n.d. https://www.gesundheitsindustrie-bw.de/en/article/news/biotechnica-2009-turning-ideas-into-value (accessed 11.8.19).

Coalesce BioArt Lab – COE: Genome, Environment and Microbiome – University at Buffalo [WWW Document], n.d. http://www.buffalo.edu/genomeenvironmentmicrobiome/coalesce.html (accessed 11.8.19).

Djerassi Resident Artists Program | Scientific Delirium Madness [WWW Document], n.d. Djerassi Resid. Artists Program. http://djerassi.org/apply/scientific-delirium-madness-2/ (accessed 11.8.19).

Dublin, S.G., n.d. Science Gallery [WWW Document]. Sci. Gallery. https://dublin.sciencegallery.com/ (accessed 11.8.19).

Exploratorium: The Museum of Science, Art and Human Perception, San Francisco | Exploratorium [WWW Document], n.d. https://www.exploratorium.edu/ (accessed 11.8.19).

Finnish Art Society [WWW Document], n.d. https://suomentaideyhdistys.fi/en/ (accessed 11.8.19).

Foundation for Art and Creative Technology [WWW Document], n.d. FACT. https://www.fact.co.uk/ (accessed 11.8.19).

freshtilledsoil.com, n.d. Artscience | The Laboratory at Harvard. http://thelaboratory.harvard.edu/concept/artscience/ (accessed 11.8.19).

Front page | JAR [WWW Document], n.d. https://www.jar-online.net/ (accessed 11.8.19).

Genspace [WWW Document], n.d. Genspace. https://www.genspace.org (accessed 11.12.19).

GmbH, A.E.L., n.d. About Ars Electronica. https://ars.electronica.art/about/en/ (accessed 11.8.19).

Home | Leonardo/ISAST, n.d.

Home | Leonardo/ISAST [WWW Document], n.d. https://www.leonardo.info/ (accessed 11.8.19b).

Home Page | UCLA Art | Sci Center + Lab [WWW Document], n.d. http://artsci.ucla.edu/ (accessed 11.8.19).

Home [WWW Document], n.d. A2R2. URL https://www.a2r2india.com (accessed 11.8.19).

Homepage [WWW Document], n.d. Interalia Mag. https://www.interaliamag.org/ (accessed 11.8.19).
Koek, A., 2017. In/visible: the inside story of the making of Arts at CERN. Interdisciplinary Science Reviews 42, 345–358. https://doi.org/10.1080/03080188.2017.1381225
LABORATORIA Art & Science Space – LAB NEWS [WWW Document], n.d. http://newlaboratoria.ru/www/eng/ (accessed 11.8.19).
lindaessig, 2013. What is an "Arts Incubator?" Creat. Infrastruct. https://creativeinfrastructure.org/2013/09/06/what-is-an-arts-incubator/ (accessed 11.8.19).
MIT Center for Art, Science and Technology [WWW Document], n.d. Arts MIT. https://arts.mit.edu/cast/ (accessed 11.12.19).
Project MUSE – Configurations [WWW Document], n.d. https://muse.jhu.edu/journal/36 (accessed 11.8.19).
Project Space – Schering Stiftung, n.d. https://scheringstiftung.de/en/projektraum/ (accessed 11.8.19).
QuoArtis – Art and Science Foundation [WWW Document], n.d. https://quoartis.org/ (accessed 11.8.19).
SCIART MAGAZINE [WWW Document], n.d. . SCIART Mag. https://www.sciartmagazine.com/ (accessed 11.8.19).
The University of Western Australia, n.d. SymbioticA [WWW Document]. http://www.symbiotica.uwa.edu.au/ (accessed 11.8.19).
Thyssen-Bornemisza Art Contemporary [WWW Document], n.d. http://www.tba21.org/ (accessed 11.8.19).

20

ArtSciLab

Experimental publishing and knowledge production in collaborative transdisciplinary practices

Alex Garcia Topete, Chaz Lilly, Cassini Nazir, and Roger F. Malina

Publishing experiments become a transdisciplinary community of practice

During the 1950s, a number of artists and scientists began to appropriate various technologies into art making, but remained marginal to the art world. That emerging art, science, and technology community had various origins spread across the globe, with limited means of networking among themselves, while they also found resistance to joining the art world due to their electronic approaches—museums and critics said "if it had to be plugged in it wasn't art" (Malina, 2016).

As a response, the art, science, and technology journal *Leonardo* was founded in 1968 in Paris by kinetic artist and astronautical pioneer Frank Malina with a group of international colleagues including C. P. Snow, Jacob Bronwosky, Buckminster Fuller, and Gyorgy Kepes, with the mission to serve as an international channel of communication among artists and scholars who use science and developing technologies in their work. Since then, the Leonardo Publications and its sibling International Society for the Arts, Sciences and Technology (ISAST)[2] have evolved along with the art-sci-tech community of practice in the adoption of emerging technologies, from the early use of desktop publication and DARPAnet in the 1980s to the use of compact discs and modern-day Internet in the 1990s. Over its entire history, Leonardo/ISAST has published over 10,000 unique authors in a variety of "modes" of publication, at the same time legitimizing a transdisciplinary community of practice at the intersection of arts, science, and technology.

ARTECA,[3] an online curated space and aggregator with over 180 books and 7,700 journal articles developed as a partnership between Leonardo/ISAST, MIT Press, and the University of Texas at Dallas (UT Dallas), is a contemporary exemplar of the symbiotic co-evolution of experimental publication modes and technologies and the professional community cutting across art making and scholarship related to art, science, and technology.

The UT Dallas team that helped build ARTECA works out of the ArtSciLab, to which the authors of this chapter belong as researchers-project leaders and co-directors, respectively. The ArtSciLab, housed within the transdisciplinarity-oriented School of Arts,

DOI: 10.4324/9780429437069-26

Technology, and Emerging Communication established in 2015, has attracted international scholars and practitioners carrying out national and international projects that focus on the hybridization of art and science. The lab aims to collaborate on research which results in new scientific knowledge, engaging artworks and performances, and new transdisciplinary tools that serve the art-sci-tech community of practice and beyond.

The ArtSciLab team sees ARTECA as a space to produce and curate multimodal output as an opportunity for transdisciplinary experimentation. It is only appropriate that ARTECA, as the digital platform of *Leonardo*/ISAST, becomes a space for further adoption and experimentation in publishing. In different domains of research, the word "experiment" holds various connotations and implies certain processes and procedures, such as strict regulation of variables and a well-defined methodology. However, for the ArtSciLab the word "experiment" embodies the spirit of Gary Hall's "Pirate Philosophy," which argues that scholars must go beyond the debates on digital humanities and the various "post-modern, post-human and post theory theories," in order to invent new ways of being theorists, practitioners, and philosophers. He coins the phrase "pirate philosophers" drawing on the ancient Greek meaning of pirate as someone who "tries, tests, teases and troubles as well as attacks" (Hall, 2016).

The ArtSciLab team has been working on "experimental publishing" as a research phase of trying to understand the implications, epistemological as well as ontological, of emergent media and their social adoption and transformation. Here, the term "experimental" has a positive connotation, with the implication that researchers and scholars must discuss and disseminate their thinking and collaborations in a variety of formats—be that books, articles, monographs, multigraphs, or print, electronic, audio, video, or interactive media yet to be developed. One or several "appropriate" fixed formats for the digital age will probably not emerge; rather, the ability to engage with different publics in different modes enriches the knowledge production of today (Malina et al., 2018). The ArtSciLab, hence, is testing and teasing out new ideas in the hopes of better understanding how digital disruption and technological co-evolutions, like the ones organic to the arts, science, and technology community, can radically transform not only scholarly communication but also the production and dissemination of knowledge itself within and across disciplines and publics.

Collaborative transdisciplinarity

Before discussing any further ARTECA or the ArtSciLab's publishing experiments, it's imperative to describe the factors that facilitate these experiments—beginning with the adoption of a transdisciplinary mindset. Transdisciplinarity, in this context, must be understood not only as a crossing of disciplinary boundaries but also as a crossing of sectors of society (Repko, 2008, p. 15), as well as an intermingling of different cultures and ways of knowing.

The ArtSciLab, as a transdisciplinary exemplar, houses a variety of researchers, artists, and designers, and at the same time, it interfaces with diverse faculty, students, administrators, community partners, research institutions, publishers, and government representatives, not to mention reaching out to both specialized audiences and the general public through experimental publishing. In such a transdisciplinary context, "ways of knowing" refers to how the world is viewed, studied, and understood (Cross, 1982; Dunn, 2013), while "culture" corresponds to the "set of values, beliefs, attitudes, and practices that are enduring and hard to change" (Hofstede, 1983), whether that be within a professional or demographic group. In fact, ways of knowing and cultures align, intersect, and overlap prominently when discussing disciplines, for instance, when referring to a "third culture" of design (Cross, 1982) distinct from that of arts and that of sciences (Snow, 1990) or by demonstrating the deep differences in identity between artists-humanists and scientists-engineers in spite of their shared practices (Leach, 2011, pp. 144–146). Successful collaborative transdisciplinarity demands practices that not only acknowledge but also thrive upon the convergence of cultures and ways of knowing.

Bodies, actions, and environments

The work done at the ArtSciLab requires of all participants a high degree of transdisciplinary intelligence: the capacity to understand and collaborate in knowledge production and exchange with multiple experts and publics beyond a single field of knowledge as well as thrive within diverse professional environments (Garcia Topete, 2019). Transdisciplinary intelligence thus manifests both through personnel and projects alike in three modes: embodying, performing, and situating diverse ways of knowing and cultures, particularly those of science, engineering, arts, design, humanities, entrepreneurship, and education (Garcia Topete, 2019).

"Embodying" means turning the abstract theory into material-physical manifestations (Henriksen et al., 2015). Therefore, not only do the more than thirty members and external collaborators of the lab hybrids represent a variety of cultural backgrounds and ways of knowing, but the project's "multimodal" experimental publishing manifests a diversity of knowledges and publics. By "multimodal" we mean multiple means of publication, multiple levels of engagement, multiple outputs of content, and multiple outcomes and impacts (O'Halloran and Smith, 2012). "Performing" has meaning beyond executing projects and day-to-day operations of the lab in adherence to the principles of transdisciplinary intelligence; it means doing so critically aware that such actions lead to knowledge production and meaning-making that must (and can only) be validated by a wide social effort when peers in a discipline, authoritative institutions, and the public agree to accept the discovery (Kuhn, 1996). "Situating" means acknowledging the circumstances, differences, and multiplicity of perspectives generated during transdisciplinary knowledge production and meaning-making (Haraway, 1988). The importance of "situating" for collaborative practices involving transdisciplinary intelligence cannot be overstated, particularly for successful multimodal publishing, for instance, if a project is made by an artist in cooperation with scientists and with the public itself due to a vested interest in a given performance or subject matter, or if it's a tool meant for transdisciplinary collaboration, as is the case of ARTECA.

Hybrid learning and apprenticeship

The mission of the ArtSciLab comprises changing the history of ideas and enhancing the learning experience of their members in order to accelerate their entry into diverse industries and communities of practice—both of which are accomplished thanks to an apprenticeship approach to training (Thiry and Laursen, 2011) that leads to meaningful hybrid learning (Zakrajsek and Schuster, 2018). Simply put, all members of the lab (particularly newcomers) are exposed to a rotation of all the current projects, both as public and as apprentices in the work, so that they thus experience and learn from different environments and cultures under the guidance of expert peers or supervisors. That way, for example, the more scientifically inclined can get a sample of (guided) artistic practice, while the reverse can occur to those with more artistic sensibilities. In the end, the apprenticeship model allows members to expand their horizons, and make a habit of it, by prompting them to make their own way in new environments through multimodal publication, experience, and networking—similarly to the experimentation and exposure afforded to the art-sci-tech community through ARTECA.

Design methods

Thanks to the extensive design expertise of the lab's co-director Cassini Nazir, principles and practices of design thinking (Lockwood and Papke, 2017) permeate and inform the emergence of projects and the research objectives of the ArtSciLab, while enhancing the collaborative capacity of its transdisciplinary collaborations (Mejia et al., 2017). The principles of empathy and "finding the right problem," alongside design-based practices such as clinical observation, fast prototyping, and visualization, provide an adaptive foundation for members and external collaborators to frame and suggest new projects, publication efforts, and collaborations themselves. For ARTECA in particular, design thinking and methods under Nazir's leadership have been the cornerstone for innovating upon existing and experimental publishing practices in ways that are beneficial to the user experience of the art-sci-tech community.

Reflexive creativity

Despite its emphasis on knowledge production, almost all the lab members have a current art practice of some kind, which influences the lab's operations and outcomes. For instance, when considering alternative modes of publishing for the results of a project, members tend to try first artistic renditions or performative interpretations of the research outcomes, such as the sonification of data or the "sculpturization" of digital files. These artistic expressions happen, however, in an environment of scholarly rigour (regardless of the target public) that turns them into modes of "practice-as-research" grounded in mutual critiquing and self-reflection during and after the artistic engagements (Campbell, 2017). Many of such creative renditions then become a part of ARTECA as evidence of the research, examples of particular modes of experimental publishing, and contributions to ongoing discourses of art-sci-tech issues, such as podcasts related to computational music, data sonification, and interspecies communication.

Scientific research processes

No matter how novel or transgressive a project is, it's a policy of the ArtSciLab to follow the institutional protocols proper to formal scientific inquiry, since adhering to the existing rules of scientific inquiry is necessary before breaking them in order to improve upon existing knowledge and shift paradigms (Kuhn, 1996). All members of the lab get training in responsible research protocols, navigate review/oversight boards, participate in peer review processes, and keep research journals and thorough documentation. Even minor in-house projects, such as defining the netiquette within the lab, get treated as scientific experiments with the potential to provide valuable insights with publishable potential. The making of ARTECA itself, with its emphasis on user experience and design, has been treated as a human-subject research project warranting Institutional Review Board (IRB) reporting and oversight.

Cross-cultural communication

The ArtSciLab is a multicultural mosaic representing not only a range of disciplines, from physics and electrical engineering to business, cognitive science, and sound art, but also more than half a dozen nationalities with its members (and more with its collaborators and transnational projects). Given this diversity, cross-cultural communication techniques and a cultural synergy approach to operations (Adler and Gundersen, 2007) have become crucial to the success of the lab over the years. Simple steps have a major influence on both lab members collaborating and projects finding success within the lab and beyond, like avoiding parochialism and ethnocentricity, adapting timelines according to cultural habits and expectations of different disciplines and cultures, confirming interpretations/meanings during dialectic or dialogical conversations (Sennett, 2012) that unfold as project meetings and letters of intent to collaborate, recognizing cultural differences (professional/disciplinary and national), and crafting solutions/outcomes that represent all values and stakeholders of the cultures involved. All of that applies most critically to the outreach aimed at different publics through experimental publishing. Foundational issues, such as language, come to the fore—which is why ARTECA has built-in multilingual capabilities as an acknowledgement that, even though English has been and may be treated as a lingua franca of the art, science, and technology field, in reality the art-sci-tech community spans Chinese, Spanish, French, Japanese, and Korean as well, just to name a few other languages.

Knowledge management

Knowledge, in the abstract and in the details, should not only stand as the goal of research but also be "viewed as an asset that can and ought to be managed" (Bernstein, 2014). Therefore, the ArtSciLab members strive to turn all tacit knowledge (individual and collective) into explicit knowledge that becomes accessible to future members and collaborators, and eventually to the public in general, in the form of thorough documentation of almost all lab operations and all aspects of research projects. Those include organized documentation and proper archiving of project materials and operational files, as well as member-generated taxonomies, glossaries, and annotated bibliographies that facilitate the contextualization and connection of knowledge production to its origins, applications, and relevance for the activities of the ArtSciLab—and ultimately its social impact and contributions to the history of ideas. ARTECA serves as a depository for such knowledge and related materials that may otherwise be lost, forgotten, or ignored in traditional modes of publishing and scholarly exchange.

Interdisciplinary translation

In the context of the ArtSciLab's activities, "interdisciplinary translation," which is an antecedent and requirement for transdisciplinary collaboration, refers to "actively facilitating the exchange of knowledge across disciplinary languages in team research settings" (Hess, 2018). Such effort involves but is not limited to aligning and disambiguating vocabulary among members and collaborators, avoiding confusing jargon, and educating other members and collaborators about the particularities of a project to a degree that allows them to explain it themselves to others. When dealing with multimodal publishing, interdisciplinary translation also relates to the dissemination of the produced knowledge with the language that best suits a certain public for a particular purpose (Bell, 1984), such as convincing funders of the value of continuing or expanding a project. In the case of ARTECA, a plethora of the books, journal articles, and experimental publications within it stand as works of interdisciplinary translation, already bridging and facilitating knowledge exchanges, such as between algorithms and music, between data science and cultural studies, and between artificial intelligence, chess, and the humanities.

Team and community architecture

In order to keep a right harmony between proficiency and creativity, the lab has implemented a few rules derived from “the science of team science” and effective team management (Karlgaard and Malone, 2015). First, the organizational architecture of the lab isn’t static and hierarchical but rather dynamic and modular according to Dunbar’s numbers for effective teams: dyads for mentor–mentee, triads for ongoing teams, and up to seven collaborators on any given project. Second, said teams are intentionally heterogeneous when problem-solving an issue that requires enhanced creativity, while leaving teams homogenous in the case of highly skilled and routine tasks, such as bookkeeping and website maintenance (Adler and Gundersen, 2007). Finally, similar principles apply when crafting communities of outside collaborators and when targeting publics for multimodal publishing—sizes do matter for impact, yet bigger doesn’t always mean better. The development of ARTECA has followed these rules, showing the effectiveness of leveraging knowledge networks and managing community architectures.

Publishing experiments with ARTECA

Assessment criteria across disciplines

Academia is an industry that is heavily built upon not only intellectual capital but also reputational capital, which new publishing technologies can change dramatically, both for individuals and for the system as a whole (Fitzpatrick, 2011). A different account “value” and how it is recognized for researchers should lead to a more appropriate assessment of actual research under the following conditions: (a) communication of research outside of standardized publications; (b) assessment of research in its context, not just subjectively; and (c) assessment of research according to disciplinary particularities.

The ArtSciLab team, through ARTECA, is exploring the potential of emerging technologies to disrupt and improve scholarly communications beyond the traditional book and journal publishing, particularly those that could adjust the system of value and credit to more fairly reward experimental/unconventional types of publications, such as social media engagement and public interactive interventions. In addition, more parts of the publication process, such as peer review and uploading to depositories, can be verified and “credited” for researchers as well. For instance, recent start-ups are showing that blockchain is an intriguing new tool that ARTECA can use to both verify the completion/authorship of a variety of actions (peer review, grant applications, forum participation) and provide levels of legitimate credit for contributors.

Peer review and curation of multimodal grey literature

Our first phase of experimenting with publishing methods beyond hosting PDF versions of books and journals on ARTECA comes in the form of “open-access multimodal grey literature.” Grey literature is research output created outside of traditional academic publishing channels. These can include conference proceedings, preprints, newsletters, presentations, field and lecture notes, and blog postings. While there has been a historical preference for considering only peer-reviewed academic journals and books as legitimate research outputs, in the last few decades (and especially with the Internet) the dissemination speed and impact of information outside that traditional sphere has grown in importance, and that knowledge should be discovered, curated, and captured as legitimate (Fitzpatrick, 2011). In short, multimodal output and grey literature enrich academic discourse, for digital content in particular is made to be hyper-connected, interactive, mobile, dynamic, and remixed.

Curating and hosting multimodal grey literature on ARTECA presents unique challenges that demand a rethinking of traditional scholarly publishing models, namely those that pertain to peer review systems. One approach consists of looking at scholarly podcasts hosted on ARTECA and explores the question of "how does one peer review a podcast?" The first piece of multimodal grey literature on ARTECA is a multilingual podcast system produced by a network of international ArtSciLab collaborators called Creative Disturbance[4].

ARTECA aims to bring these grey literature materials, which publishers and librarians have devoted less attention to, to the same strata and quality that is currently reserved for the article or monograph. However, peer review systems for multimodal, digital content should not be modelled after current systems, which have served print media well for over 400 years but don't conform to the immediate and crowdsourced nature of digital communication. In other words, traditional peer review systems lean towards gatekeeping, slow pace, and exclusivity, whereas digital communication favours openness, fast responses, and inclusivity.

A goal of ARTECA is preserving grey literature and making it available long after its creators are gone. Towards this end, the team is exploring the assigning of grey literature in ARTECA with Digital Object Identifiers (DOIs). DOIs, commonly used for academic literature, are a unique alphanumeric string assigned by a registration agency to identify content. DOIs serve as a lookup system that provides a *persistent* link to the location of the content on the Internet. When someone clicks a DOI, they are redirected to the associated content (usually a web page). While not entirely fool proof, assigning a DOI to grey literature better ensures longevity of the content's availability.

Among the conversations about transforming post-publication processes have been numerous recent efforts to design new systems that decouple peer review from the publishing (Tennant et al., 2017). "Open journal systems" aim to make the peer review transparent through crowdsourced or community-led review. Despite the emergence of these open platforms, none address specifically the issue of multimodal review, which requires some new thinking. ARTECA currently includes open review systems, but in a multimodal way, experimenting with a "meta-podcast" system where peer reviewers record their own podcasts that discuss elements of another podcast. This system will act as a form of official vetting, and these "meta-podcasts" will live alongside the original podcast (the one under review) on ARTECA as a method of post-publication, multimodal peer review.

Multilingual capabilities

In order to host content that is accessible to those who read and speak other languages aside from English, ARTECA is experimenting with the limits of translation, be that by human translators or, in the digital age, intelligent machines and engines. By creating a comparative study between certain translation engines, and possibly by designing a proprietary one for ARTECA, the ArtSciLab is analysing how different engines have translated the same content. Relying on the array of foreign-language speakers in the lab (there are upwards of ten individuals whose native language is not English), ARTECA essentially functions as a translation workshop to determine the effectiveness of each engine and the factors affecting their success or failure to translate.

Machine reading

Contemporary algorithms and software are surprisingly accurate in summarizing research articles. Using deep learning and natural language processing, these algorithms are able to analyse and paraphrase articles faster than a reader could glance through them. This ARTECA experiment requires collaboration from companies such as Salesforce, who have developed a cutting-edge platform that summarizes texts; Narrative Science, a company that generates reports from raw data; and Maluuba, a start-up that offers a way for machines to generate questions about texts. These platforms exemplify how machine learning may or may not be able to assist in managing the growing amount of knowledge contained in ARTECA by offering users the ability to quickly discover what each article is about.

Interactive relational databases

The idea of openness and creative commons licensing in scholarship has helped envision future scenarios of radical openness in the form of "Open Cyber-Scholarly Infrastructures," or OCIs. The idea of OCIs calls for scholarship to take advantage of the networked nature of the digital by designating certain semantically typed modules in a research article. Some researchers are already building systems that mirror this idea of representing knowledge in visual, networked, and associative ways. Bill Seaman at Duke University, for instance, works in the field of "recombinant aesthetics," which examines database aesthetics and the idea of creating semantic modules, or what he calls "sets" (Seaman, 2010). Inspired by such ideas, ARTECA has an "interactive relational database" (IRD) as a result of a collaborative effort with Bill Seaman. This IRD project provides an easily navigable, networked, system in which we could introduce novel approaches to understand connections between scholarships. This experiment also promotes the emergence of a new paradigm better suited for our digital world—a world where knowledge is interconnected and vast and requires associative, as opposed to linear, means of knowledge creation and capture.

Conclusions from the past and for the future

ARTECA represents more than a platform for knowledge curation and archiving, for it manifests both the history and spirit of art, science, and technology as a community of practice, and the future-making potential of the field through the use of transdisciplinary tools in the quest for knowledge. Beyond ARTECA, the ArtSciLab stands out not as an anomaly but rather as an exemplar of an emerging paradigm of the way research and knowledge production are done in order to have an impact in society and the world outside of academia (Gibbons, 1994). At the same time, the lab provides a clearer model of collaborative practices and transdisciplinary intelligence that can be replicated and adapted by other groups who ultimately seek to join the emerging paradigm and contribute to changing the history of ideas.

Acknowledgements

The authors of this chapter would like to thank the *Leonardo*/ISAST staff, the MIT Press team, everyone at the ArtSciLab, and the ARTECA team, particularly Ricky Campitelli, Colin Campbell, Duncan Gallagher, Josephine Porter, Lina Moon, Mahalakshmi Balakrishnan, Yana Gevorgyan, Kyle Hamilton, Joel Ewing, Kuo-Wei Lee, Al Madireddy, Yusra Khan, Dylan Orgeron, Emma Newkirk, Shruthy Shreepathy, Kourosh Shahbazi, Nick Lindsay, Bill

Trippe, Scott Delugan, Paul Crook, Derek Chaplin, Anna Pollock-Nelson, Levi Rubeck, Ben Riley, Tori Beringer, Tracy Campbell, Colleen Lanick, Danielle Siembieda, Erica Hruby, Jill Rodgers, and Laurie Stewart.

Bibliography

Adler, N.J. and A. Gundersen, 2007. *International Dimensions of Organizational Behavior*. Boston: Cengage Learning.

Bell, A., 1984. Language Style as Audience Design. *Language in Society* 13, 145–204.

Bernstein, J.H., 2014. Disciplinarity and Trandisciplinarity in the Study of Knowledge. *Informing Science: The International Journal of an Emerging Transdiscipline* 17, 241–273.

Campbell, L., 2017. Anticipation, Action and Analysis: A New Methodology for Practice as Research. *PARtake: The Journal of Performance as Research* 1, 7.

Cross, N., 1982. Designerly Ways of Knowing. *Design Studies* 3, 221–227.

Dunn, M., 2013. Suggestions on How to Use this Site (30th May 2013). theoryofknowledge.net. http://www.theoryofknowledge.net/about/teaching-theory-of-knowledge/suggestions-on-how-to-use-this-site/ (accessed 1.7.2018).

Fitzpatrick, K., 2011. *Planned Obsolescence: Publishing, Technology, and the Future of the Academy*. New York: New York University Press.

Garcia Topete, A., 2019. Transdisciplinary Intelligence: Training Hybrids and Amphibians. July. https://doi.org/10.13140/RG.2.2.30915.96805/1.

Garcia Topete, A., R.F. Malina, C. Strohecker, and R. Thill, 2017. *SEAD Exemplars: Evidence of the Value of Transdisciplinary Projects*. SEAD Committee.

Gibbons, M., ed., 1994. *The New Production of Knowledge: The Dynamics of Science and Research in Contemporary Societies*. Thousand Oaks: Sage Publications.

Hall, G., 2016. *Pirate Philosophy: For a Digital Posthumanities*. Cambridge, MA: MIT Press.

Haraway, D., 1988. Situated Knowledges: The Science Question in Feminism and the Privilege of Partial Perspective. *Feminist Studies* 14, 575. https://doi.org/10.2307/3178066.

Henriksen, D., J. Good, and P. Mishra., 2015. Rethinking Technology & Creativity in the 21st Century: Embodied Thinking as a Trans-Disciplinary Habit of Mind. *TechTrends* 59 (1): 6–11.

Hess, A., 2018. *Using Interdisciplinary Translation for More Effective Team Science*. Poster. National Academy of Sciences Arthur M. Sackler Student Fellows Symposium, Washington, DC, March 2018.

Hofstede, G., 1983. The Cultural Relativity of Organizational Practices and Theories. *Journal of International Business Studies* 14, 75–89. https://doi.org/10.1057/palgrave.jibs.8490867.

Karlgaard, R. and M.S. Malone, 2015. *Team Genius: The New Science of High-Performing Organizations*. New York City: HarperCollins.

Kuhn, T.S., 1996. *The Structure of Scientific Revolutions*. Chicago, IL: University of Chicago Press.

Leach, J., 2011. The Self of the Scientist, Material for the Artist: Emergent Distinctions in an Interdisciplinary Collaboration. *Social Analysis* 55. https://doi.org/10.3167/sa.2011.550308.

Lockwood, T., and E. Papke, 2017. *Innovation by Design: How Any Organization Can Leverage Design Thinking to Produce Change, Drive New Ideas, and Deliver Meaningful Solutions*. Franklin Lakes, NJ: Career Press.

Malina, R.F., 2016. Art-Science: An Annotated Bibliography. *Art Journal* 75 (3): 64–69. https://doi.org/10.1080/00043249.2016.1234202.

Malina, R.F., A. Garcia Topete, and J. Silveira, 2018. What Is the Evidence That Art-Science-Technology Collaboration Is a Good Thing? *Leonardo* 51 (1): 2. https://doi.org/10.1162/LEON_e_01555.

Mejia, G.M., R.F. Malina, and A.F. Roldán, 2017. Towards an Inventory of Best Practices for Transdisciplinary Collaboration. Presented at the 23rd International Symposium on Electronic Arts ISEA2017. Manizales, CO: Universidad de Caldas, pp. 681–687.

O'Halloran, K. and B.A. Smith, eds. *Multimodal Studies: Exploring Issues and Domains*. Vol. 2. Milton Park: Routledge, 2012.

Repko, A.F., 2008. *Interdisciplinary Research: Process and Theory*. Thousand Oaks: Sage.

Seaman, B., 2010. *Recombinant Poetics: Emergent Meaning as Examined and Explored within a Specific Generative Virtual Environment*. Riga: VDM Publishing.

Sennett, R., 2012. *Together: The Rituals, Pleasures and Politics of Cooperation*. New Haven: Yale University Press.

Snow, C.P., 1990. The Two Cultures. *Leonardo* 23, 169. https://doi.org/10.2307/1578601

Tennant, J.P., J.M. Dugan, D. Graziotin, D.C. Jacques, F. Waldner, D. Mietchen, Y. Elkhatib, et al., 2017. A Multi-Disciplinary Perspective on Emergent and Future Innovations in Peer Review. *F1000Research* 6, 1152. https://doi.org/10.12688/f1000research.12037.3.

Thiry, H. and S.L. Laursen, 2011. The Role of Student-Advisor Interactions in Apprenticing Undergraduate Researchers into a Scientific Community of Practice. *Journal of Science Education and Technology* 20, 771–784. https://doi.org/10.1007/s10956-010-9271-2

Warner, M., 2002. Publics and Counterpublics (Abbreviated Version). *Quarterly Journal of Speech* 88 (4), 413–425.

Zakrajsek, A. and E. Schuster, 2018. Situated Learning and Interprofessional Education: An Educational Strategy Using an Apprenticeship Model to Develop Research Skills for Practice. *Health and Interprofessional Practice* 3. https://doi.org/10.7710/2159-1253.1147

21

Polymathic pedagogies

Creating the conditions for interdisciplinary enquiry in art and science

Heather Barnett, Nathan Cohen, and Adrian Holme[1]

Introduction

> Where our age falls short is in the harmonizing of our outer and our inner wealth. We lack the depth of feeling and the range of sensibility needed to retain the riches that science and technique have brought within our grasp. The images and symbols which can truly domesticate the newly revealed aspects of nature will be developed only if we use all our faculties to the full – assimilate with the scientist's brain, the poet's heart, the painter's eyes.
>
> *Gyorgy Kepes (1963 [1956]: 20)*

It is necessary, suggested artist and educator Gyorgy Kepes,[2] to bring together the intellectual and sensorial qualities of different disciplines to humanise the world that science and technology reveal to us. In the half-century since he wrote this passage, the challenges faced by humanity have become increasingly apparent. Indeed, the risks of profound alienation from the world revealed by science and technology are today posed in the most acute manner by the accelerating environmental crisis. Coupled with the rapid advances in informatics, robotics and nanotechnology, deep questions are raised about what 'we' are as humans, let alone what we desire and where we might be heading.

Historically, we may trace an apparent division between the arts and the sciences, in the 'West' at least, to the 'scientific revolution' of the sixteenth century. Earlier, in the time of Leonardo da Vinci (1452–1519), the division between 'art' and 'science' barely existed in the way we understand it today. The Latin terms for art and science – '*ars*' and '*scientia*' referred, respectively, to 'skill' and 'knowledge', which could be harmoniously combined in any enterprise (Ackerman 1969). The 'scientific' activity (then termed 'natural philosophy') of Renaissance artists such as Leonardo da Vinci or Albrecht Dürer – anatomy, landscapes, nature studies – could be seen as entirely consistent with their 'artistic' endeavours since both served 'naturalism' and the representation ('re-presentation') of 'nature' in art.[3]

The development of instrumentation in the sixteenth-century's scientific revolution extended human senses far beyond our normal direct experience. The invention of tools, such as the microscope and the telescope, thus introduced a mediating layer between human

DOI: 10.4324/9780429437069-27

sensory experience and the 'natural' world although this world newly revealed by science could still be pictured (see for example Robert Hooke's engravings of the head of a drone fly or a flea in *Micrographia* 1665). At the same time, disciplines such as physics began to be concerned more with theoretical questions concerning invisible forces not accessible to direct experience. As science shifted in some respects away from direct sensory experience, 'art' remained focused upon sensual 'human' experience. Perhaps, most critical to the growing division of 'art' and 'science' was the increasing adoption of mathematics within science, with an emphasis upon repeatability of experiments producing 'data' (Francis Bacon (*Novum Organum*) (2015 [1620]). Marshall McLuhan put it succinctly:

> …with regard to the sixteenth century, number and visuality, or tactility and retinal experience, split quite asunder and went their divergent ways to set up the rival empires of Art and Science.
>
> *McLuhan (1962: 81)*

By the eighteenth-century Enlightenment, this division of art and science was further accentuated, as the precision of mathematics and words became the preferred language of serious discourse. Images became less important to much of science, and 'art' tended to be relegated to concerns with beauty or the sublime[4] (Mitchell 1987).

The separation of arts (and humanities) from science has also been reflected in the organisation of education, leading to what C. P. Snow described in 1959 as 'the two cultures' – artists and scientists, whose education,[5] career and subsequent cultural life led them to lack mutual understanding of each other or of their wider disciplines (Snow 2006). He favoured a more broadly based education system than that which then prevailed in Britain, which he described as producing a 'tiny elite… educated in one academic skill' (Snow 2006: 19).

Nevertheless, a number of pioneering initiatives in education in the twentieth and twenty-first centuries have attempted to bring together art and science education and research at the graduate and postgraduate levels. Notable are the Bauhaus (1919–1933) (Whitford 2010), the Center for Advanced Visual Studies at MIT[6] (1967–2009) founded by György Kepes (ACT 2018) and Black Mountain College (1933–1957) (Nichols 2015).

In this chapter, we present a case study of the approach taken by the MA Art and Science, Central Saint Martins (CSM), University of the Arts London[7], which addresses interdisciplinary connections of art and science within the context of a 'fine art' master's programme in an arts university. In expounding this case study, we discuss some of the teaching philosophies and methods developed for this purpose and define the 'polymathic pedagogies'[8] that we believe would satisfy Kepes' aspiration of retaining the riches that combined sensibilities can bring.

Art and science interdisciplinary education: the MA Art and Science, Central Saint Martins, University of the Arts London

The master's course in Art and Science, at CSM, was established in 2011 by Nathan Cohen to provide a distinctive postgraduate educational programme for those interested in studying art and science as an interdiscipline[9] within a studio context – something not available elsewhere at that time. The University of the Arts London, of which CSM is a constituent college, had not previously included science, explicitly named as a subject and in combination with art, in its educational portfolio. So, it was necessary to persuade the university of the rationale, quality and viability of bringing the two disciplines together, which represented a radical step for the institution.

Today, the two-year full-time MA Art and Science recruits around twenty-five students per year, with over 180 alumni having graduated. The faculty of the MA have developed particular pedagogic practices in the facilitation of interdisciplinary art and science enquiry within a Fine Art context[10] and within the wider environment of an art and design university. Pedagogic challenges – and opportunities – include the great diversity of students, who come from many disciplinary backgrounds, including science, medicine, fine art, design, social science and humanities. Students are diverse in national culture, with around two-thirds from the UK and EU and one-third from other parts of the world. Furthermore, students are diverse in age, ranging from first-degree graduates to those of all ages who have work and life experience. To date, some three-quarters of the cohort are female – which is in line with the ratio of female students in UK Fine Art higher education (HESA 2018).

Course aims and philosophy

Under the framework of a fine art programme – namely, a studio-based course of largely self-defined project research and practice supported by the taught curriculum and faculty supervision – the MA Art and Science aims to explore the changing nature of creative scholarship, applying hybrid modes of enquiry to art and science discourse. The requirements to complete the master's degree include integration of research and practice in written and created form. Some aspects of the course are conventional within a UK-based arts education, such as studio-based teaching, tutorials, discursive seminars and 'crits'[11] (critical reviews) of work in progress. But other aspects are more unusual in this setting. Furthermore, with the advent of the global COVID-19 pandemic, teaching has been augmented by developing online methods of remote teaching for some aspects of course content.

The challenges of teaching widely diverse students, and of tackling the intersections of two extremely broad fields of study, have resulted in the development of particular polymathic pedagogies, which include:

- set experimental project briefs (common in design education but unusual for fine art);
- a general encouragement of collaboration – among students, and with other individuals, institutions and courses;
- a sceptical approach to canons, questioning established definitions;
- processes of 'unlearning' and methods of chance and play;
- student-centred and experiential learning.

Since its creation, the course has developed through the experience and expertise of the faculty and a diverse group of students, each bringing a unique combination of knowledge, skills and questions to investigate. What they share is a recognition that there are multiple ways of asking questions and seeking understanding, and a notion that they sit somewhere in-between, or across, established domains. The course faculty aim to provide a space for dialogue and interaction between disciplinary knowledge and methods, without *a priori* notions of where this might lead or of what might result. The collaborative focus of the course helps in the creation of 'communities of practice' (Wenger 2008) within the cohort and in relation to wider networks, in association with alumni and other practitioners in the field. These communities have the potential to enhance students' research and practice whilst studying and to contribute to their professional life after graduation.

The course faculty comprise artists and educators who have experience of studying science and/or working with scientists as part of their professional practice. This combination offers mentorship based on personal experience that students can relate to and learn from and is complemented by a growing network of contributors from both the sciences and the arts who enhance the cultural and pedagogic experience[12]. The emphasis upon student-centred learning, rather than didactic delivery and the scepticism to canons arise in part from a course philosophy that is open to challenge and is non-dogmatic about what constitutes 'art and science'. Whether we define this emerging field as an 'interdiscipline' or as an 'adiscipline' is up for continuous debate, and the course invites students to form their own connections, identify points of divergence, and find synergies.

Much of the activity that takes place within the studio, both in teaching and in the creative practice, might be encountered in any shared artistic studio. Yet, the space also operates as a kind of 'laboratory', an experimental space, where students can engage in dialogue and exchange. Here, students can coalesce diverse expertise and can learn from their interactions with each other. For example, in Figure 21.1, we can see students enacting different parts of the brain in a student-devised participatory experiment to explore synaptic communication. The physical proximity provided by the shared studio encourages the cross-fertilisation of ideas, skills and, most importantly, possibilities. Where this has not been available during the COVID-19 pandemic we have developed strategies for enabling collaboration through digital media. In the pursuit of new ways of thinking and novel forms of interaction, exposure to difference is a key-driving mechanism for discovery. Methods of working employed by students combine conventional artistic practices – such as drawing, painting, sculpture, installation and performance – with materials and processes drawn from the sciences – such as biology, complex systems, mathematical principles,[13] electronics, chemistry or physics.

The course is an evolving programme, responsive to the individual interests of students and the wider influence of external factors such as the social, philosophical and ethical questions raised by contemporary techno-scientific developments. Students are encouraged to explore new and innovative ways of perceiving, interrogating and understanding the world. There are no theoretical limits to the concepts, materials and techniques that can be worked with,

Figure 21.1 Art and science experiments in the studio – enacting parts of the brain. A participatory experiment by Joshua Bourke. Photo © MA Art and Science

and the course is open to a broad spectrum of research proposals. Throughout their time on the MA, students, and those who teach them, are continuously contributing new definitions and interpretations of what the subject of 'art and science' is and what it might become.

Experimental practices and polymathic pedagogies: or 'can interdisciplinarity be taught?'

> In present-day cultural terms the enemy is habit – the passive, uncritical repetition or acceptance of behaviours, opinions, perceptions, and values, and the enshrining as verities, metaphors that have passed their sell-by date. Habit is the enemy of art, impeding the search for new ways of being.
>
> *Ascott (2008: 48)*

To understand what this looks like in practice, we now examine specific examples from the curriculum, while considering the polymathic pedagogic practices that take place at different points throughout the course timeline. These take the students through a two-year process of deconstruction, recombination and realisation.

It is a challenge to devise a curriculum for such a diverse group of students, who arrive on the course not only with wide-ranging disciplinary knowledge but also varied pedagogic histories. Those with a prior educational experience more geared towards the arts are likely to have more confidence with material exploration and self-directed project ideation, while those who have predominantly studied sciences may be stronger on academic research methods and project management. Students from one background may find it intimidating, or may idealise, the perceived expertise of those from a different background. Considered along with the international constituency of the cohort and a wide range of educational experiences (and expectations about how to learn), it is important to begin each year by recognising and valuing difference.

Following our starting gambit of declaring that all established definitions are mutable and open to questioning, we dedicate the first few months of the course to a process of 'unlearning'. This involves challenging established disciplinary norms and exploding preconceptions, thereby recognising the importance of diverse practices and making chosen methods more explicitly understood rather than implicitly accepted. We also aim to challenge perceived hierarchies of methods by elevating material, visual and sensorial modes of enquiry alongside more conventional academic approaches. Whether driven by concepts, materials or processes, all methods are considered valid. In practice, this is explored through an experimental project focused on combining approaches to interdisciplinary project development.

'Matter–Method–Material'

> Matter Method Material helped me remember forgotten creative skills: how to make the first mark, how to successfully brainstorm an idea, and how to look objectively at the results… [Take Me, I Will Shelter You] is an experiment in metaphor concerned with climate change in Britain, specifically: rising sea levels, flooding, and human migration.
>
> *Hannah Scott (Class of 2017, responds to 'Travel | Installation | Video' 2015)*

'Matter–Method–Material'[14] is an exploratory exercise designed to challenge disciplinary habits, open up possibilities for novel approaches, develop creative strategies and to encourage students to formulate hybrid modes of working. Working in small groups, students

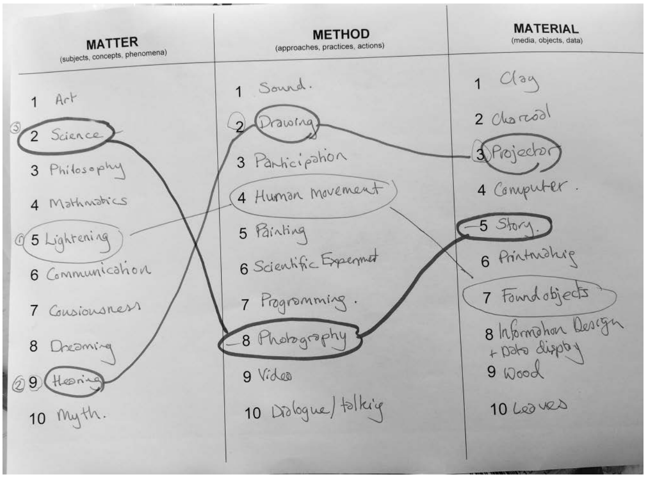


Figure 21.2 Lists of Matter–Method–Material creating randomly selected project briefs. Photo © MA Art and Science

generate lists under the headings of 'subject matter', 'methods of working' and 'materials'. Three randomly selected items (one from each category chosen by the roll of a die) then form a project brief for each participant (Figure 21.2). With a focus on process rather than product, this creative experiment encourages the testing of ideas in practice and identifying novel connections between the three given elements. By thinking through doing, and by combining concepts, processes and materials, students are encouraged to embrace risk and the serendipity of chance.

Students are given three weeks to experiment with these forced connections, followed by a student-led critical review that sets out to discuss what has been learnt from the process, identify challenges and opportunities that emerge and explore what might be taken forward into future project work. Students have reported that the project required them to work in radically different ways and took them out of their 'comfort zone' and that it encouraged them to work with new materials and unusual processes, responding to and interpreting the given themes and subjects.

The *Matter–Method–Material* experiment is designed to acknowledge (and not privilege) different possible starting points to ideation – i.e., conceptual, material or process-orientated – and makes explicit that there are many different, equally valid, approaches to creative enquiry. This imparts confidence in making by having to think through doing, encourages research to underpin knowledge of a given subject area and playfully teases out a myriad of possibilities to generate ideas and communicate concepts.

Working on given themes, and being told explicitly not to be concerned with outcomes, also encourages freedom of approach. As the brief does not necessarily relate to the project themes that students came onto the course to pursue, they have little or no sense of responsibility towards them, resulting in far greater risk-taking – the randomly set parameters necessitating creative experimentation and invention. Becoming aware of this is important. By developing creative strategies away from their chosen fields of enquiry, methods can now be developed and applied to themes to which they are committed, only now with a more open and exploratory approach. The aim is that creative strategies developed through this short set exercise can migrate to self-directed project work throughout the course, helping students to approach material, practical and conceptual unknowns confidently, armed with a toolkit of possibilities.[15]

Throughout the early part of the MA Art and Science course, the faculty expose students to different methods of critical and creative investigation of diverse histories, theories and practices. We examine the origins of the scientific method, explore practice as research, interrogate ideas of empirical experimentation and play with chance. Lectures and seminars introduce key concepts that are then explored in discussion and through practical experimentation. Examples of the application of ideas into playful exploration include the introduction to a straightforward method of criticism[16] through object interrogation and curation followed by further application and discussion of the method; investigation of subjectivity and representation through the making and testing of an (often absurd) 'objective drawing device'[17] (Figure 21.3); and an exercise mapping key moments in the history of art, science, technology and ideas through the collective compilation of a timeline.[18]

By introducing a range of approaches to project development, ways of working and thinking are made explicit and expanded. These early experimental polymathic approaches are intended to provide students with a bespoke tool kit of interdisciplinary methods for practice-based research. As they progress through the course, students' work becomes increasingly self-directed (though, as we explain further below, it may well be collaborative). Supported by faculty and peers, students forge their own paths, accessing resources and expertise, developing skills and knowledge and formulating unique combinatory methods.

Figure 21.3 'Objective drawing devices' being tested with a life model in the studio, alongside some of the drawings produced by the devices. Photo © MA Art and Science

Figure 21.4 *Fields* degree show 2018, foreground work by Áinne Burke. Photo © MA Art and Science

Each student pursues a major independent project throughout their two years on the course, resulting in a public showing of the realised outcomes. The degree show is a well-established finale within art and design education, an opportunity to present the results of human endeavour and showcase talents. For the MA Art and Science, the form and function of this graduation show are always open to debate. Each year, we invite the students to define the character of the exhibition to suit their individual and collective aspirations. The degree show has, over the years, provided a platform for exhibition, demonstration, participation, discussion, experimentation and performance (Figure 21.4) – with students encouraged to be present in the space and to engage with the audience. Students also curate a symposium and events programme that complements the exhibition in which student performances have also become a significant aspect. Although the MA Art and Science embeds professional development in the curriculum throughout the course, the degree show represents a further transition into the professional realm, a springboard for what happens next.

Professional platforms and collaborative learning

> My experience of studying Art and Science will influence my future research practices, as I am now aware of various platforms and open to collaborating as well as confident enough to ask to collaborate with others; which is something I was not able to do so before, having come from a purely Fine Arts background. The slight variation in studio setting in Art and Science has broadened my idea of where I can work, who I can work with, and what I can make there; such as labs, offices, co-working spaces, project spaces and of course, what I know best, a studio with a blocked sink.
>
> *Sabrina Mumtaz Hasan (Class of 2019)*

As students pursue their independent projects within the course structure, they are encouraged to develop collaborative approaches to their research with a view to forging interdisciplinary relationships and, by the time of graduation, building a strong professional network. The course supports this endeavour through individual mentorship by staff and by offering a number of opportunities to engage in external course-initiated collaborations. Since the course began in 2011, students have had opportunities to work with a number of partners and collaborators on a range of projects including residencies, educational workshops and exploratory exchanges.[19] These include scientific institutions such as CERN, Imperial College London, the Medical Research Council and cultural organisations such as Tate Exchange, Arts Catalyst and the British Library.

These (optional and self-selecting) projects facilitate professional engagement with experts from different fields across the sciences, design, education and the arts. They enable students to develop context-specific collaborative skills and help build networks for an exchange providing the potential for continued research. The interdisciplinary skills enhanced through this process include the ability to navigate different languages, cultures, environments, intentions and outcomes – to traverse disciplinary differences in the pursuit of shared goals.

The Museum of Extraordinary Objects

> One beauty of the collaboration was that in explaining the issues to the artists, the Royal Society themselves made real progress in clarifying their thinking about the themes that they wanted to interrogate.
>
> *Julie Light (Class of 2018)*

To examine one such collaboration, we draw here on a project developed with The Royal Society, '*The Museum of Extraordinary Objects*', a collection of fictional objects created by students on the MA Art and Science speculating on the future of scientific research. Led by students Stephen Bennett and Julie Light, the project demonstrated how diverse perspectives can reveal deep insights into complex research questions.

The Royal Society, established in 1660, is the world's oldest independent scientific academy (Royal Society 2019a), with early members including Christopher Wren, Robert Boyle and Isaac Newton. Recently, the society has expanded its focus on the role of culture, expectations and relationships in determining the future of scientific research. In particular, a 2016 project entitled *Changing Expectations* aimed to 'understand how best to steward research culture through a shifting research landscape' (Royal Society 2019b). The project recognised that the hidden signs, rules and expectations of the science community would fundamentally determine what kind of research was undertaken in the future; by whom, for whom and with what results.

Initial events, organised by the Royal Society to explore these questions with early-career researchers, demonstrated some limitations of traditional 'workshop' approaches. Young scientists tended to reflect on day-to-day issues they faced, such as job security, stress and navigating academic hierarchies. Although important, such topics were not helpful to the imagining of a future research culture. This challenge was presented to the interdisciplinary students of the MA Art and Science.

The team of students who participated in the project facilitated a different kind of conversation by translating the elements of potential future research cultures into materialised artefacts. An imagined future museum of objects presented a different set of future possibilities. One student artist proposed a memorial to a failed mission to Mars, an idea that stimulated an animated discussion around the culture of failure in scientific research. Another developed a provocation on the democratisation of research to those outside the traditional science community – a 'Lab Cab' to enable the transportation of live tissue from hospitals to hackspaces and home laboratories (Figure 21.5). The speculative propositions were made and curated into a futuristic entity *The Museum of Extraordinary Objects 2035*, complete with its history and catalogue (Royal Society 2019c).

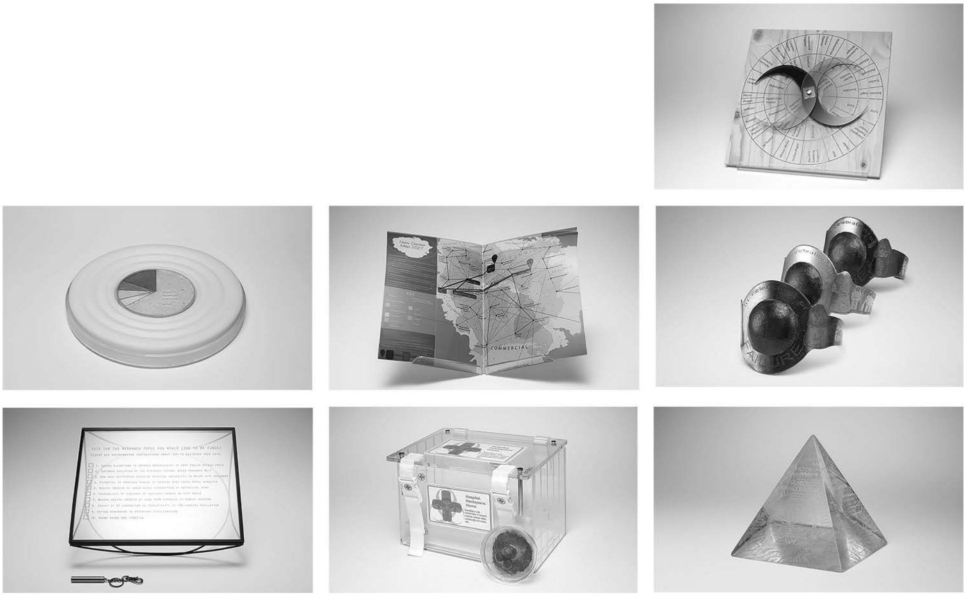


Figure 21.5 Speculative objects created for the *Museum of Extraordinary Objects 2035*. Photo © MA Art and Science

The fictional 'Museum' toured the UK, shown in over a dozen locations to hundreds of scientists, the artefacts taking on a life of their own. Following their initial role in helping the Society develop its thinking, the objects became the stimulus for further discussion and analysis. Scientists considered what it would mean to have a roulette-like wheel determine interdisciplinary collaboration or contemplated the concept of a public ballot for funding research. In each case, the artefacts embodied a complex and abstract concept ('open access', 'citizen science') and invited a haptic exploration by people accustomed to thinking more in equations and prose. When it was easier to talk about the present, they prised open discussion about the future, revealing deep, rich and diverse insights on potential futures of scientific research. Whilst the Royal Society's motto *'Nullius In Verba'* (taken to mean 'take nobody's word for it') supports the verification 'of all statements by an appeal to facts determined by experiment' (Royal Society 2019a), *The Museum of Extraordinary Objects 2035* demonstrated the value of engaging with imaginative narratives as a vehicle for serious speculative debate.

This project is one of many examples of collaborations fostered by the course, as organisations increasingly recognise the possibilities and benefits of working in a space where multiple intelligences (Gardner 1999) can merge. During their studies, students will have been presented with numerous professional opportunities at the course level as well as wider opportunities offered through the art programme, the college and the university. Thus, in addition to nurturing individual interdisciplinary practice, the MA Art and Science course is decidedly outward-facing, connecting students with research groups, community organisations and public audiences.

Learning how to navigate this in-between space – between art and science and between student and professional – provides a valuable lesson in developing research methods, forms of language and means of communication. In addition to working on course-led collaborations, many students also choose to engage with external residency programmes (such as

Lumen[20] and *Labverde*[21]), apply to open call exhibition opportunities[22], publish artworks and writings in online magazines (such as *Interalia*, *CLOT* and *SciArt Magazine*) and curate independent exhibitions. Through following a self-directed line of enquiry and responding to opportunities offered, students build up substantial artistic and professional experience over the duration of the course and can graduate with a strong established network.

Conclusion: into the future

> Studying art and science has brought home the point that everything is connected, relational, and art is a key that unlocks a door to new ways of understanding. This greater awareness of my practice within the context of art and science led me to understand that by stepping outside my comfort zone and into unfamiliar or unknown territory, I also step into a position where I can embrace risk while indulging in childlike wonder – and these are the things that feed creativity and push work to new levels.
>
> *Jill Mueller (Class of 2018)*

The MA Art and Science, CSM (University of the Arts London), provides an intellectual and creative space that had not previously been catered for academically, for those wishing to engage in research at the intersection of art and science. The course is continuously evolving as a springboard for investigation, experimentation and discourse, building an emerging network of curious individuals seeking to investigate this area and contribute to its interpretation. Communities of practice and professional networks have become evident through continued graduate and student activity and support the pedagogic rationale of the course.

The unusual features of the MA Art and Science approach to teaching – the polymathic pedagogies – are rooted in a course philosophy of openness to ideas and influences and address the particular practical challenges and opportunities presented by the interdiscipline. These include the great diversity of students and the challenge of learning and teaching at the intersection of two wide fields of human learning – art and science. The process of 'unlearning' in the early stages of the programme leads to a 'reassembly' through individual and collaborative lines of enquiry. At all stages of the course, students are encouraged to explore their interests experimentally and creatively while maintaining the curiosity that encouraged them to embark on their journey of enquiry. The emphasis upon chance methods and play is important in keeping a certain 'lightness of touch' and creative openness to exploration.

The MA Art and Science questions the relationships *between* disciplinary knowledges and practices, with an emphasis on the 'AND' in Art and Science. We are not seeking to create a canon. Rather, we celebrate the diversity of ideas and approaches that flourish when fixed interpretations are eschewed. We aim to create a platform for students to investigate and find their own definitions and points of reference. Individual empowerment within the context of an educational and wider societal community results in diverse interpretations of how different disciplinary knowledge and methods can interact, connect and collide.

The MA Art and Science contributes to a culture of enquiry and learning; it offers education through an emergent lens (Barnett 2013, Mason 2008), creating the conditions for collective knowledge building and sharing. The course seeks to reintegrate science into the humanities and to employ artistic research as a means of critically examining the implications of contemporary scientific research. Above all, it seeks to create a space where the breadth of human curiosity can flourish and where different forms of knowing and creating can merge and forge novel insights and interpretations.

Our graduates continue in this endeavour through diverse lines of professional practice. Many alumni go on to develop interdisciplinary practices, setting up collectives, conducting residencies and exhibiting. Some progress their studies at the doctoral level, develop a teaching practice or apply their interdisciplinary education to other areas of arts, design, curation, publishing and museum work. Some return to scientific domains though perhaps with a changed attitude towards established methodologies.

In recent years, other interdisciplinary courses connecting aspects of art and science enquiry have emerged internationally, further validating the subject as a legitimate field of research. Within our institution, CSM, there is now far greater recognition of the value of interdisciplinary educational practices and acknowledgement that science is an integral part of society and culture. In recent years, there have been exciting new interdisciplinary developments, including the opening of the 'Grow Lab', a biology laboratory within the context of art and design practices, providing a safe space for students to work with living systems, learn laboratory protocols and develop novel methodologies. Having our scientific facilities within the art school enables us to offer a bespoke hybrid laboratory/studio space[23] encouraging exploration of bioart and biodesign practices in the wider context of art and science as an interdiscipline. The Grow Lab offers new possibilities for polymathic pedagogies to emerge, allowing us to programme activities previously unavailable within a specialist art and design institution. In addition to supporting curriculum delivery on MA Art and Science, the facility has stimulated the emergence of new courses, such as the MA Biodesign which started in Autumn 2019. The Grow Lab has also facilitated the expansion of research in this field and created opportunities for doctoral students, visiting researchers and scientists in residence[24].

At the time of writing, staff and students on the course are engaged in an Erasmus-funded STEAM research project, STEAM Inc, investigating the relationship of the arts in combination with STEM subjects at higher education level across Europe (2019–2022).[25,26]

In this chapter, we have shown, through the examples presented, that novel 'polymathic pedagogies' – that facilitate the assimilation of diverse intellectual and sensorial modes of enquiry – can be developed and successfully applied to the teaching of an interdisciplinary Masters in Art and Science. We will continue to create the conditions for future cohorts to expand the field – each year bringing together a new group of self-defined creative interdisciplinarians to share diverse expertise and nurture new points of connection. It will ultimately be for others to judge the success, but we believe that the importance of such interdisciplinary approaches, as Kepes argues, extends far beyond the boundaries of art education, to touch wider, and urgent, cultural, social and political concerns.

Notes

1 This chapter is co-authored by the MA Art and Science, Central Saint Martins, course team: Nathan Cohen (Founder and Course Leader), Heather Barnett (Pathway Leader) and Adrian Holme (Lecturer), with input from students and graduates.

2 Gyorgy Kepes (1906–2001) founded the Center for Advanced Visual Studies (CAVS) at MIT in 1967 (ACT 2018). He edited an impressive series of art and science books in the 1950s and 1960s beginning in 1956 with *The new landscape in art and science*.

3 The representation of nature in art developed in the Renaissance in concert with the new theories of geometric fixed point perspective developed by architects Alberti (1404–1472) and Brunelleschi (1377–1446). For more on this, see Panofsky, E. (1991) *Perspective as symbolic form*. New York: Zone Books.

4 There are of course exceptions to this general trend, many from the field of 'illustration'. Life sciences such as botany or entomology have continued to be based in observation and image-making.

In art, the painter Joseph Wright of Derby (1734–1797) is one notable practitioner who provided a critique of scientific and technological progress through his paintings. Similarly, in literature, Mary Shelley's *Frankenstein: or the modern Prometheus* (2003 [1818]) is a work of enduring relevance in its critique of science and technology.

5 Snow was writing particularly about Britain and North America.

6 Now part of the MIT Visual Arts Program.

7 Central Saint Martins is part of University of the Arts London, an international centre for innovative teaching and research in arts, design, fashion, communication and the performing arts. See https://www.arts.ac.uk/colleges/central-saint-martins.

8 Polymathic may be defined as 'characterized by varied learning' (Polymath 1984).

9 '…interdisciplinary studies may be defined as a process of answering a question, solving a problem, or addressing a topic that is too broad or complex to be dealt with adequately by a single discipline or profession' (Newell and Klein, quoted in Fuchsman 2009: 71).

10 The course sits within a cluster of postgraduate art courses including MA Fine Art, MA Photography: Philosophy and the Contemporary Image, several MRes courses and BA Fine Art.

11 The 'crit' is typically a participatory studio-based critique by students and staff of work in progress that takes place periodically throughout the course.

12 In addition to the core faculty, there are a number of associate lecturers and visiting specialists, alongside alumni feeding back into the course where possible.

13 Unusually, for an art school, CSM has an in-house Fine Art Maths Centre.

14 'Matter | Method | Material' is a Forced Connection exercise, devised by Heather Barnett, where different elements are randomly combined, as a means of encouraging multiple possibilities for creating connections and generating creative ideas. Frequently, it is run as a thought experiment in creative thinking workshops. Here, it is run as a practical experiment, where students are requested to turn the ideas into practice. Such methods are discussed in Barnett (2012).

15 The project is discussed in the context of the *Practices of Enquiry* exhibition and workshop at http://www.artsciencecsm.com/forced-connections-and-rules-of-random/.

16 Developed by Adrian Holme (2009), the critical method is broken down into four stages Describe, Analyse (and Contextualise), Interpret, Evaluate and practised first upon an object.

17 Students are asked to design and build an 'objective drawing device', which they then test in the studio with a life model. The impossible task raises questions about instrumentation and representation, which are explored in practice and in discussion on the devices made and the drawings produced by them.

18 Modified from a method of David Webster of University of the Arts London.

19 To see the full extent of collaborations offered through the course, see the 'Collaborations' page on the course website at http://www.artsciencecsm.com/collaboration (MA Art and Science).

20 Lumen Atina residency is an annual astronomy and photography residency organised by the MA Art and Science graduates Melanie King and Louise Beer. Many of our students and graduates join the residency each year.

21 Labverde is an international competitive residency situated in the Amazon. Participants have included the MA Art and Science graduates Aleks Borys and Helen Cawley.

22 Several students have exhibited in Science Gallery exhibitions whilst studying, lead public participation activities for Wellcome Collection Reading Room and engaged in the myriad of opportunities within the wider Central Saint Martins and University of the Arts artistic communities.

23 The conception and design of the Grow Lab acknowledges examples of other art/science laboratories, most notably ASCUS in Edinburgh (who provided consultation for the Grow lab), Incubator Lab at University of Windsor, Coalesce Bioart Lab in Buffalo and Symbiotica in Western Australia as well as open biology public laboratories such as GenSpace in Brooklyn and the Waag Society in Amsterdam.

24 The first scientist in residence, Professor Wataru Hijikata, visited in connection with a transcultural/transdisciplinary collaboration between Central Saint Martins and Tokyo Institute of Technology in Autumn 2019.

25 Erasmus + STEAM Innovation and Curriculum, Project Reference: 2019-1-UK01-KA203-062032, Erasmus+ project card | Erasmus+ (europa.eu) (accessed 15/03/21).

26 Through these and other initiatives, our institution now has a far greater understanding of how the languages and cultures of art and science can intersect and has shown significant commitment to developing educational and research provision in this growing area.

Bibliography

Ackerman, James. (1969). Concluding remarks: science and art in the work of Leonardo. In O'Malley, C.D. (Ed.). *Leonardo's legacy: an international symposium*. Berkeley: University of California Press. pp. 205–225.

ACT. (2018). *Gyorgy Kepes: founder CAVS 1967–1974.* MIT program in art, culture and technology. Available at: http://act.mit.edu/people/director/gyorgy-kepes/ (Accessed 2 July 2018).

Adorno, Theodor W. (2006). *The culture industry: selected essays on mass culture*. London: Routledge.

Alexenberg, Mel (Ed.). (2008). *Educating artists for the future: learning at the intersection of art, science, technology and culture*. Bristol, UK: Intellect Books.

Ascott, Roy. (2008). Pixels and particles: the path to syncretism. In: Alexenberg, Mel (Ed.). *Educating artists for the future: learning at the intersection of art, science, technology and culture*. Bristol, UK: Intellect Books. pp. 47–60.

Bacon, Francis. (2015). *Novum Organum*. Project Gutenberg. Available at: http://www.gutenberg.org/files/45988/45988-h/45988-h.htm (Accessed 17 March 2015).

Barnett, Heather. (2013). *The liquidity of knowledge: learning across disciplinary divides in for the love of learning*. London, UK: Palgrave Macmillan.

Barnett, Heather, Smith, J.R.A., and Gardner, M. (2012). *Broad vision: inspired by… Images From Science.* London, UK: University of Westminster.

Bellman, D. (1995) Chapter 13: Beuys' 'social sculpture' in historical perspective. In: Thistlewood, David (Ed.). *Joseph Beuys: diverging critiques, critical forum series*, Vol 2. Liverpool, UK: Liverpool University Press and Tate Gallery Liverpool.

Central Saint Martins (University of the Arts London). (2019). *Central Saint Martins*. Available at: https://www.arts.ac.uk/colleges/central-saint-martins (Accessed 14 August 2019).

Collini, Stefan. (2006). Introduction. In: Snow, C.P. (Ed.). *The two cultures*. Cambridge: Cambridge University Press. pp. vii–lxxi.

Fuchsman, Ken. (2009). Rethinking integration in interdisciplinary studies. *Issues in Integrative Studies*, 27, 70–85. Available at https://oakland.edu/Assets/upload/docs/AIS/Issues-in-Interdisciplinary-Studies/2009-Volume-27/06_Vol_27_pp_70_85_Rethinking_Integration_in_Interdisciplinary_Studies_(Ken_Fuchsman).pdf.

Gardner, Howard. (1999). *Intelligence reframed: multiple intelligences for the 21st century.* New York: Basic Books.

Glinkowski, P., and Bamford, A. (2009). *Insight and exchange: an evaluation of the Wellcome Trust's Sciart programme*. Report. London: Wellcome Trust. Available at: https://wellcome.ac.uk/sites/default/files/wtx057228_0.pdf (Accessed 2 July 2018).

Gombrich, Ernst H. (1984). *Tributes: interpreters of our cultural tradition*. Oxford: Phaidon.

HESA. (2018). *Higher education student statistics: UK 2016/17 – subjects studied*. Report. London: HESA. Available at https://www.hesa.ac.uk/news/11-01-2018/sfr247-higher-education-student-statistics/subjects (Accessed 6 August 2019).

Holme, Adrian. (2014). Alchemy, image and text: the waning of alchemy and the decline of visual discourse in the late Renaissance. *Journal of Illustration*, 1(2), 189–209.

Hooke, Robert. (1665). *Micrographia, or some physiological descriptions of minute bodies made by magnifying glasses, with observations and inquiries thereupon*. London: Jo. Martyn, and Ja. Allestry, printers to the Royal Society.

Kepes, Gyorgy (Ed.). (1963 [1956]). *The new landscape in art and science*. Chicago, IL: Paul Theobald and Co.

Knapstein, Gabrielle. (2015). Interdisciplinary and multimedia learning: artistic education at Black Mountain College. In: Nichols, Catherine (Ed). *Black mountain: an interdisciplinary experiment. 1935–1957*. Leipzig: Spector. pp. 282–299.

MA Art and Science. (2019). *MA art and science*. Available at: http://www.artsciencecsm.com (Accessed 14 August 2019).

Mason, Mark (Ed.). (2008). *Complexity theory and the philosophy of education*. Oxford: Wiley-Blackwell.

McAndrew, Clare. (2018). *The art market 2018*. Report. Basel, Switzerland: Art Basel & UBS. Available at: https://d2u3kfwd92fzu7.cloudfront.net/Art%20Basel%20and%20UBS_The%20Art%20Market_2018_2.pdf (Accessed 29 June 2018).

McLuhan, M. (2008 [1962]). *The Guttenberg galaxy: the making of typographic man*. Toronto, ON: Toronto University Press.

Mitchell, W.J.T. (1987). *Iconology: image, text, ideology.* Chicago, IL: University of Chicago Press.
Nichols, Catherine (Ed.). (2015). *Black mountain: an interdisciplinary experiment. 1935–1957.* Leipzig: Spector.
Panofsky, E. (1991). *Perspective as symbolic form.* New York: Zone Books.
Polymath. (1984). *The shorter Oxford dictionary on historical principles. Volume II.* Oxford: Clarendon Press.
Royal Society. (2019a). *About us.* Available at: https://royalsociety.org/about-us/ (Accessed 14 August 2019).
Royal Society. (2019b). *Changing expectations.* Available at: https://royalsociety.org/topics-policy/projects/research-culture/changing-expectations/ (Accessed 14 August 2019).
Royal Society. (2019c). *The museum of extraordinary objects.* Available at: https://royalsociety.org/topics-policy/projects/research-culture/changing-expectations/museum-of-extraordinary-objects/ (Accessed 14 August 2019).
Snow, C.P. (2006 [1959]). *The two cultures.* Cambridge: Cambridge University Press.
Wenger, Etienne. (2008). *Communities of practice: learning, meaning and identity.* Cambridge: Cambridge University Press.
Whitford, Frank. (2010). *Bauhaus.* London: Thames and Hudson.

22

The future of arts integrative work

Creating new avenues for advancing and expanding the field

Edgar Cardenas, Sandra Rodegher, and Kevin Hamilton

Introduction

Collaborative, interdisciplinary research often emerges as a result of the zeitgeist of the time or pressing societal issues and thus has made important and timely contributions to academia and society. This research has resulted in the founding of new fields (e.g. African American Studies) and the enhancement of existing disciplines (e.g. Digital Humanities). Despite their contributions to academia and society, these innovative collaborations often lack institutionalized support structures of traditional disciplines, but this is not a new problem. Indeed, in his 1984 keynote at the *Conference on The Future of Interdisciplinary Studies*, Martin Trow (1984) touted the value of interdisciplinary studies while also identifying its challenges that a more critical understanding of these programs was necessary if they were to be sustainable. At the time of his speech, interdisciplinary programs had been operating in universities for over two decades but were inconsistent in terms of their levels of success.[1] He stated that if interdisciplinary programs wanted to succeed, they needed to understand and articulate what niche they were filling, the institutional dynamics the program operated within, and what their work was about (i.e. its role in higher education).[2] Therefore, the onus was on those in the emerging interdisciplinary fields to expand their understanding of the mechanisms that could aid in the development of successful and sustainable interdisciplinary studies programs.

This example is analogous to the current challenges faced by another interdisciplinary space that the authors have termed as *arts and design integrative research*[3] (ADIR). Like interdisciplinary studies programs, ADIR gained traction in the 1960s and was challenging disciplinary norms of knowledge production. However, there have been challenges to bridging the divide between arts and sciences. C. P. Snow's Rede Lecture, later published as the book *Two Cultures* (2012), attested to this divide between the humanities and sciences.[4] He noted that scientists and humanists lived in different academic cultural contexts that came with their lexicons, and that bridging that cultural gap would benefit both communities as well as the public sector.[5] During this era, figures such as Buckminster Fuller, Hans Haacke, Helen and Newton Harrison, and Patricia Johanson began coupling their art practice with ecological principles – at times in collaboration with scientists. In parallel, institutions such as MIT's Center for Advanced Visual Studies, Bell Labs, and eventually Xerox PARC also began to

 DOI: 10.4324/9780429437069-28

organize their work around social challenges that required ADIR approaches. Another bellwether moment was the founding of the peer-reviewed journal *Leonardo* in 1968 by "kinetic artist and astronautical pioneer" Frank Malina (Leonardo, 2018). The goal of Leonardo was to facilitate rigorous critique and dissemination of work by researchers, working at the intersection of art, science, and technology, in service of advancing this evolving field.

Despite this history of successful ADIR work, the advancement of a cohesive field has not materialized, and practitioners in this interdisciplinary space continue to work at the margins of extant fields. It has been in a perpetual start-up phase, working with high levels of excitement but with minimal formal structure. Even without this cohesion, ADIR has continued to gain traction and has reached a similar transition stage that interdisciplinary studies achieved in the 80s (Trow, 1984). Therefore, the ADIR community of practitioners needs to reflect on the field, their practice, and how to advance the work in a more unified and, ideally, democratic fashion.

In this chapter, we detail the approach the Alliance for the Arts in Research Universities (a2ru) has taken by developing an online platform for understanding and addressing the advancement of ADIR. First, we identify the ongoing challenges that have limited the advancement of ADIR, such as the creation and sharing of work that pushes interdisciplinary boundaries while still satisfying tenure and promotion requirements. Then, we summarize relevant frameworks that bound the work being done within this integrative space, with each framework offering unique lessons that can be used to reflect on or assess ADIR successes and failures from the organizational down to the individual level. Finally, we provide insight into the inner workings of *Ground Works (GW)*, which is aimed at cohering an ADIR community of practice through this online platform. Though this chapter takes a first step at articulating some key criteria, it is only through the execution of GW, and other comparable platforms, that we as a community can continue to glean information and further solidify and refine an institutional structure that accommodates the breadth and diversity of work that ADIR practitioners create.

Ultimately, we posit that ADIR needs scaffolding for practitioners to better articulate their working practices, publish their work as intended (often in multimedia formats), and connect to a broader community of practice. We believe this scaffolding is not something new we need to create; rather, we can tap into established models of collaboration and publishing and recombine them in new ways to catalyze a more robust ADIR community of practice.

Lingering challenges for the evolving ADIR field

Though these ADIR efforts have stood the test of time, there are numerous challenges that practitioners continue to grapple with. Indeed, GW began to take shape as a result of continually running up against four key challenges. Specifically, ADIR practitioners (a) typically lack institutional reward and recognition structures, (b) communities of evaluation, (c) challenge standardized review through working in diverse mediums, and (d) must communicate across differences to succeed. We further elaborate on each of these points below.

ADIR faculty often share appointments in a variety of departments and advance their research through ad-hoc collaborations and short-term institutional initiatives. Though interdisciplinary research and teaching have become a premium and aspirational feature within higher education, sustained support for ADIR has proven elusive, as evidenced by a long list of national-level initiatives to solidify everything from funding support to criteria for promotion and tenure (Derrick et al., 2012; Byrne et al., 2013; Klein and Falk-Krzesinski, 2017). The longevity of such organizations as Leonardo, ISEA, or Ars Electronica testifies to the continued appeal of this area of work, but the persistence of questions about evaluation and standards point to the significant epistemological, ontological, and methodological challenges at hand (Malina, Strohecker and LaFayette, 2015; Skorton and Bear, 2018).

Just as there are structural and normative challenges that must be overcome during the creation of ADIR efforts, there are also parallel challenges to overcome in the dissemination of ADIR outcomes. These projects require an outlet that can provide teams multiple formats for publishing the work. Projects that intersect arts and design place considerable attention on form. Joey Orr, the Andrew W. Mellon Curator for Research at the Spencer Museum of Art, has commented on the critical attention paid to form in arts research, noting that erasing form distorts the intended message (Orr, 2016). Text often acts as a vessel that ideas are dumped into; it has worked well for academic publishing since the form does not negate the intended meaning, but, since the form is so critical to art practice, if technology can support multiple forms, then it follows that more attention must be paid to the forms and context that the art was created in to maintain its communicative integrity.

Additionally, since the areas of practice covered under what we are describing as ADIR are sufficiently diverse, its practitioners do not always recognize one another as peers. This is because research that involves contributions from multiple disciplines across the humanities, sciences, and the arts and design can take a variety of forms. Some arrangements see the one disciplinary component playing a decidedly secondary and supportive role; others see outcomes of equal value to all disciplines involved; still, others see outcomes that find no home in any discipline (Leonardo, 2018). In all three of these scenarios, ADIR practitioners struggle to find opportunities for evaluation and reflection on their processes of collaboration and disciplinary integration.

Collaborative efforts permit practitioners to exploit expertise from disparate disciplines, without the time or energy necessary for one individual to acquire the skills. The challenge then becomes synthesis. Therefore, practitioners must become skilled at collaborating with team members that differ in disciplinary norms, jargon, and ways of working. Stokols et al. (2008) remark that shared conceptual frameworks are an essential component of successful interdisciplinary collaboration. Furthermore, team members must navigate these social dynamics and develop the interactional expertise (Collins and Evans, 2002; Collins et al., 2007) critical to critiquing and validating ideas as a collective that dedicated attention to bridging differences provides the foundation for productive collaborations.

Ultimately, the strength of ADIR work – its uniqueness – has become a limitation to the advancement of decades of deep effort and creativity. To move ADIR forward, a middle way must be found where a formal foundation of unification is built without inadvertently hampering the flexibility that allows for creativity. Further, methods of building out institutional boundaries and processes, such as the one discussed in this chapter, are often replete with power imbalances and competing visions. To ensure that the final product is useful, in that it reflects the ADIR community rather than simply the preferences or needs of a powerful few, an eye toward the democratic process is essential.

A three-tiered framework for advancing ADIR

ADIR can improve upon the aforementioned challenges through concerted, and cohesive, efforts. In what follows, we identify three components for successful interdisciplinary work. These components address the macro-, meso-, and micro-levels of organization within ADIR. First, we offer a systems framework to guide ADIR forward providing context for knowledge creation in a domain (macro). Then, building off of this framework, we identify two critical elements necessary to ADIR: (a) the role of process in the development and execution of projects as well as the conditions that optimize collaborative practice (meso) and (b) the conditions or heuristics necessary to facilitate creative collaborations (micro). By approaching ADIR in this fashion, practitioners are provided a common structure to better diagnose what worked or didn't in previous collaborations, how much control they have in improving future outcomes, and how to speak about their collaborations with others.

Frameworks for ADIR institutional organization

ADIR by its very nature biases toward a collaboratively creative process.[6] If we take the definition of creativity to be the production of a novel and appropriate outcome through methods that are not algorithmic, and often emergent (Harrington, 1990; Amabile, 1996; Hackman, 2012) ADIR qualifies. The act of intersecting two distinct fields consistently requires a reworking of methods, frameworks, and ideas.[7] Additionally, the collaborative nature of many ADIR projects introduces a strong relational component to creativity; therefore, the process is best explained through sociocultural approaches to creativity (Sawyer, 2012). As such, the *systems model of creativity* (Figure 22.1) developed by Feldman, Csikszentmihalyi, and Gardner

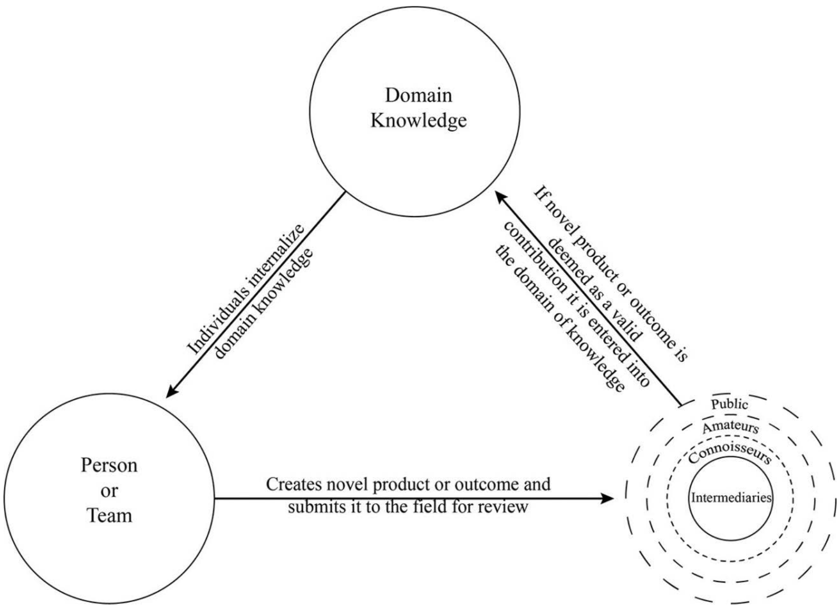


Figure 22.1 The systems model provides the scaffolding; however, I have adapted it to better clarify the system for purposes of ADIR work. The field component (the sphere in the lower right corner of the model) is also modified to better articulate how the individuals in this component of the model are nested especially in the ADIR space. This clarifies a distinction Sawyer (2012) makes regarding who is considered the audience for this work. While intermediaries often provide formal evaluation, special attention is paid to connoisseurs. These individuals have often been socialized in the domain, having intimate knowledge of the work but not holding the formal role of the validator. This leads to the question of how broad a net should be cast in search of peer-reviewers

(Csikszentmihalyi, 1988; Feldman et al., 1994) provides context around the broader process of developing an idea, having that idea vetted by the field, and the dissemination of that idea.

The *systems model of creativity* relays the challenge of knowledge creation in ADIR. It's understood that researchers pull from an established domain of disciplinary knowledge in the development of their ideas. ADIR practitioners do not have a single knowledge domain but many. This proves to be a double-edged sword, while they have more information to develop ideas from, their work rarely can be ingested into the fields they pull from. This draws attention to the critical role individuals, identified as *intermediaries* (Sawyer, 2012) or *gatekeepers* (Stein, 1963, 1967, 1974), play in validating novel projects. The primary validation challenge is finding intermediaries that understand not only the multiple disciplines incorporated into ADIR projects but also how those disciplines intersect in the creation of something new and, once validated, what domain of knowledge they are incorporated into. This validation process is the primary method for advancing a field within higher education. By creating a platform for evaluation and dissemination, *GW* aids in the ADIR domain of knowledge that practitioners can learn and pull from.

Attention to process in interdisciplinary work

Clarity around the process and outcomes is recognized as important for successful collaborations; however, specific attention to the mechanisms underlying these components is often overlooked. As Klein notes, when working in interdisciplinary teams, "Individual standards must be calibrated and tensions among different approaches carefully managed in balancing acts that require negotiation and compromise" (Klein, 2008). This highlights the importance of granting attention to the process associated with the development and execution of projects as well as the conditions that optimize collaborative practice.[8] Amabile's *Componential Theory of Creativity*[9] (Figure 22.2) (1996) focuses on the structural process of problem identification, preparation, response generation, response validation, and project completion in socially creative contexts. The process allows teams to identify what stage they are at in their project and how to move forward as a team. The model is iterative as well, allowing the team to evaluate the status of the project and revisit different stages, to improve upon the project. In addition to these steps, teams may need to step away from the project at times to allow complex ideas to "incubate" (Sawyer, 2013), and this often is necessary for understanding the connections between disciplines. Amabile also recognizes that individuals require certain capabilities to be successful collaborators. Team members must have the required knowledge, understand the creative process, and be sufficiently motivated by the project. Without these personal attributes, the project is likely to fail.

Group dynamics and conditions for interdisciplinary success

The Systems Model of Creativity provides a macro-level look at how creativity occurs, and the Componential Theory of Creativity provides a meso-level understanding of the skills required. However, what is lacking is a deeper interrogation into the conditions or heuristics (micro-level)[10] that can facilitate creative collaborations. These conditions and heuristics are critical for ADIR due to the diversity of collaborators and the complexity of the projects they tackle; rather, they operate under a principle of equifinality. Social psychologist, Richard Hackman (2012), advocates condition setting over cause-and-effect models because it acknowledges the complexity and adaptive nature of collaborative work. The purpose is to provide the necessary latitude that allows the teams' room to proceed in their own desired

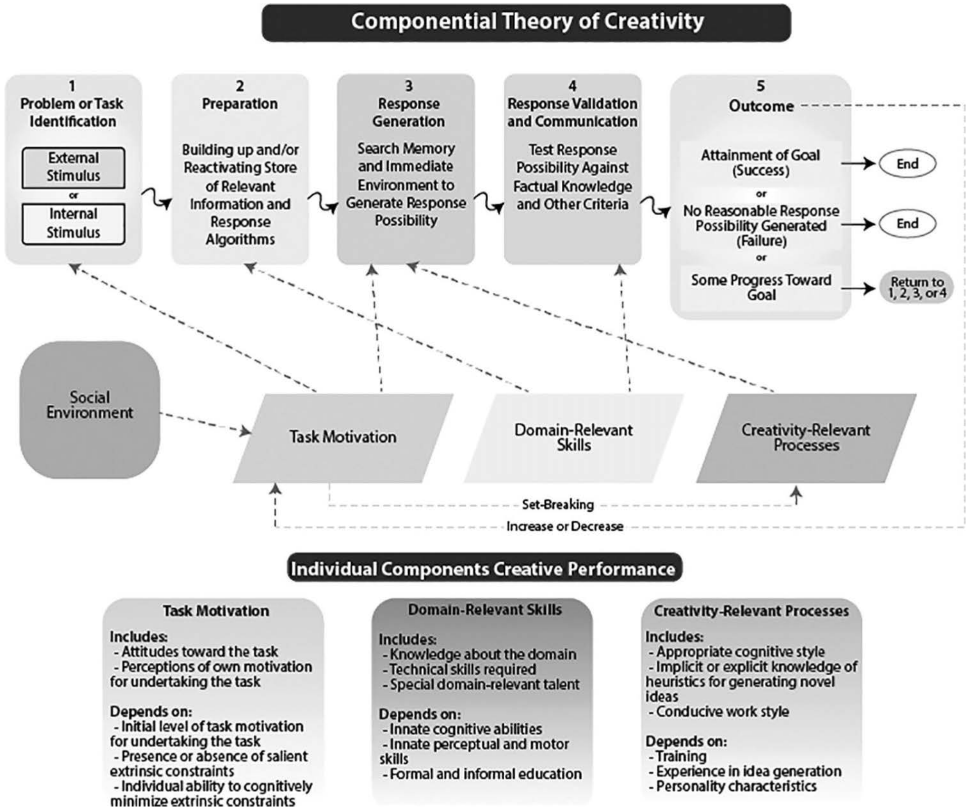


Figure 22.2 Amabile's Componential Theory of Creativity and her three components of creative performance. While Amabile does not elaborate on exogenous variables outside the collaborative process, she notes that the social environment (outside the group) can affect the teams' motivation

method rather than focusing on desired outcomes. Teams provided with similar initial conditions may proceed in very different ways but still achieve equivalent outcomes. Hackman identified core enabling conditions to increase the rate of collaborative success, they are (1) *real teams*, (2) *a compelling purpose*, (3) *the right people*, (4) *clear norms of conduct*, (5) a *supportive organizational context*, and (6) *team-focused coaching*.[11]

Our experience with successful ADIR teams is that they are often self-organizing around a mutually compelling interest. Teams often come together because they enjoy each other's company and they have the necessary skills to address the problem of interest. Perhaps, this is why self-organized versus assigned teams work best, and they self-select into three of Hackman's enabling conditions (Hackman, 2011, 2012). *Real teams*, defined as intact social systems, work interdependently on a goal, which they are mutually accountable for. *Right people* have the necessary task expertise and collaborative interaction skills. Both of these connect well to Amabile's (Hackman, 2012) domain-relevant skills and creativity-relevant processes and speak to why self-organizing teams operate better; they do so because of their required and desired interdependency.

Clear norms of conduct are multifaceted and focus on behavioral characteristics of group interactions. This includes setting and agreeing on norms for addressing the tasks related to the problem at hand. Team members may have expertise in the fields necessary for addressing the problem, but if they don't develop an approach for applying those skills in a coordinated fashion, they can perform more poorly than teams with less expertise (2011, 2012). By developing norms for collaborating, they create accountability for the team in service of the outcome.[12] Most importantly, it's a method for reaching a consensus on working methods since they can differ so much in ADIR and finding common ground for moving forward.

Finally, experienced ADIR practitioners understand that member diversity improves project outcomes. This diversity comes with specific challenges. Members must navigate the differences in epistemologies and ontologies as well as schemas associated with particular disciplines, which can lead to conflict. However, the presence of constructive conflict and minority dissent is often overlooked mechanisms that benefit interdisciplinary teams. There is a strong correlation between minority dissent and divergent thinking that contributes to creativity (Nemeth, 1986; Van Dyne and Saavedra, 1996). Van Dyne and Saavedra state that "exposure to minority viewpoints causes group members to consider more aspects of a situation, evaluate more alternatives, and re-examine their premises" (Van Dyne and Saavedra, 1996). Interestingly, the dissenting viewpoint does not need to be correct; it can simply serve as a mechanism for forcing re-examination of the problem, allowing for the discovery of novel solutions (Van Dyne and Saavedra, 1996). Ultimately, dissent aids in staving off premature consensus, which can inhibit a team's performance (De Dreu and West, 2001), especially on tasks requiring creativity.

Many of these collaboration dynamics, moreover, exhibit curvilinear relationships. Conflict functions in a nonlinear fashion, with teams performing best when the conflict is "just right" (Jehn, 1997; Jehn et al., 1999; Kurtzberg and Amabile, 2001), often expressed as bounded conflict. We refer specifically to substantive conflict, which De Dreu and Weingart define as "conflicts about the distribution of resources, procedures and policies, and judgments and interpretation of facts" (2003).[13] Substantive conflict and minority dissent function in a comparable fashion both procedural wayfinding mechanisms for generating and identifying inventive research pathways. Additionally, through this wayfinding process, team members develop the interactional expertise (Collins and Evans, 2002; Collins et al., 2007) that accelerates collective understanding and decision-making.

Summarizing the ADIR framework

The intersection of these frameworks is simply articulating and validating what practitioners tacitly understand but rarely voice: that they must reflect on their output, their practice as a member of a team, and the practices of their peers – all in service of understanding how to collectively advance knowledge within ADIR. What this articulation does is make these tacit practices explicit, a method for mapping their experiences to an established framing. Since these practitioners work around the globe, conferences are insufficient for facilitating the necessary ongoing, iterative interactions. Hence, through the *GW* platform, we provide a mechanism for ADIR practitioners to explicitly address questions relating to collaborative processes and outcomes. Only through capturing and interrogating the full breadth of ADIR efforts – who are working on projects, where they are taking place, and how practitioners are collaborating – can we advance the field. We hope to capture and then codify the answers to critical questions to the field such as:

What types of projects are being produced?
What instrumental and/or epistemic challenges are practitioners addressing?

What niche do they occupy in higher education?
How do collaborators navigate working dynamics?
How are power and responsibility distributed across a team, and how is work divided? What are the objects of common affinity or understanding across differences?

This mode of questioning should not be considered an effort to "discipline" this kind of practice but merely to produce additional clarity for the community in service of finding a pathway forward in the face of the four problems addressed in the previous section. For example, simply capturing and sharing the types of projects that are being produced (and by who) can allow individuals to identify like-minded peers and form informal communities of evaluation. These questions and the problems they seek to address necessitate a rich and intentional repository. A new mechanism is required to facilitate this, and this is where the need for *GW* was born.

GW as an example of an ADIR platform

As previously mentioned, there has been a significant increase in projects intersecting the arts and health, sustainability, placemaking, entrepreneurship, and the list goes on. These projects need visible representation that attests to their salience and legitimacy. This requires selecting and enlisting peers that can validate the work not only in specific fields but also the contributions produced at the intersection of the disciplines.

GW, a new peer-review platform, is one example of an attempt to further solidify the ADIR community of practice. Through establishing new approaches for project dissemination and review, *GW* seeks to gel the community by offering a means for members to stay abreast of the latest projects and learn and share about modes of ADIR collaboration. This is accomplished in three ways. First, submissions from a diverse array of disciplines are encouraged, and their project integrity will be better maintained by providing a platform that will accept multiple formats of information, audio, video, and imagery alongside text. Second, *GW* is designed to function as a rigorous review process, which results in the identification and examination of exemplars in the field. In other words, the intent is to facilitate the formation of a more cohesive and intentional community through a record of practice that reviewed publication affords. Third, selected *GW* submissions will become case studies that include a discussion on the group dynamics at play in their collaborations, providing the community insight into the role process plays for collaborative capacity building in these interdisciplinary initiatives.

The development of a peer-review platform

The development team has designed a structure and criteria for submission, review, and distribution of such projects. New design principles and criteria emerged from this process:

- A lower priority is placed on textual discourse, requiring writing about projects only in response to specific questions designed to spark contributors to new modes of reflection.
- Submissions and acceptances to *GW* can be lighter, submitted while still in process, and without a substantial amount of framing.
- For each discipline represented in a project, a relevant reviewer should be assigned.
- Each discipline represented or served by a project might not be served equally but should be included substantively.

- Evaluation criteria should focus on the quality and distinctiveness of the research topic or problem space, the early promise of external impact, and the potential for bearing opportunities for learning more about ADIR collaborations.

The structure for *GW* takes the form of a three-stage submission process:

Stage One is a suitability review. Here, applicants provide only a brief description of the project, a few images and media, and links to evidence of initial external impact and recognition. The Editorial Board reviews these submissions to ensure fit with *GW*'s mission.

Stage Two is the database review. Those who advance to this stage submit additional media, longer descriptions of the project, and respond to prompts about their collaboration and work process. Submissions go through a blind panel review. Accepted projects are published online as part of the *GW* database. Each project, and the materials included in their submission, is shared on a single, dedicated web page.

Stage Three is the case study review. Editors select a subset of successful Stage Two submissions for examination as case studies in interdisciplinary collaboration. An editor assigned to each Stage Three project works with contributors to co-conduct a deeper evaluation of the collaborative process. Evaluative processes are tailored to the projects; thus, results could range from an extended contribution to their project page, a traditional scholarly paper submitted to other journals, a documentary film, etc.

As of Summer 2019, the working online installation of *GW* is nearly complete. To date, we have materials from the 2015 exemplar process and submissions from presenters at the 2019 a2ru *Knowledges: Artistic Practice as Method* conference; these will serve as initial entries in the database. Once the selection of projects is represented on the site, we will work to assemble a new Board of Advisors composed of experts not yet familiar with this project but who can represent well the different disciplines with which we hope to stay in the conversation. At that point, a broader call for submissions will go out to the a2ru membership of more than forty research universities.

Though not yet officially launched, the *GW* platform holds promise for the ADIR community. In particular, it is the way in which *GW* does not veer from the traditional that makes it most valuable to the future of ADIR work. For example, GW does not shun a review process conducted by content experts nor does it shy away from functioning as a publishing platform, but it does strive to conduct these reviews via the panel to encourage a democratic process. It also adds a post-acceptance process of editor- and contributor-led case studies. Through tweaking the traditional peer-review process without entirely bucking the system, there is a strong potential for a system such as *GW* to act in parallel to the traditional disciplinary models.

Conclusion

ADIR work is getting more attention within a broader community beyond ADIR communities of practice. ADIR is surfacing at more conferences. There is an increasing interest in funding projects that intersect arts and design and sciences and engineering. This widespread appreciation makes it more important for ADIR practitioners to double down on their efforts to solidify their community. To elaborate, if those deeply imbedded in ADIR efforts do not take the helm on this effort, it risks being co-opted by newcomers who appreciate its value but do not understand the complexity of the process.

We've identified two components that are critical to solidifying ADIR while also meeting the personal and professional needs of individual practitioners: finding a method of a formal evaluation and developing an understanding of the radically collaborative process present in these projects. Fortunately, we don't have to create these mechanisms from scratch, and we can simply modify and extend current approaches in peer-review to provide objective review while also using insights provided through the fields of small group and social creativity research.

There are four criteria that should be addressed as this work moves forward:

1 The formalization structures need to emerge from the ADIR community. As Weingart notes, "Academic disciplines are not formal organizations but social communities bonded by communication" (2010: 8).
2 The community will have to remain flexible and responsive to emerging technologies and formats regarding evaluation and collaborative methods.
3 The distance between ADIR products and peer-review should not be as traditionally unsurmountable as it has been, especially if it's to support tenure and promotion.
4 There needs to be a mechanism for reflexivity. The complexity of the projects requires an awareness of the process and allows for the multiple permutations in which these endeavors manifest.
5 ADIR is diverse, so special attention needs to be paid to the democratic process of formalization. Inclusivity of its development will prevent splintering, which is critical to developing a coherent space for practitioners.

GW has formalized a first step in creating a dialog around evaluative methods in ADIR; however, there will be a need for deeper research and critical interrogation of the repository and case studies *GW* develops to glean the necessary insights for further formalizing segments of this growing field. ADIR is primed for receiving recognition as a valuable part of higher education; it simply needs some added formal structure that provides colleagues outside of this integrative space insight into the significant value it has been providing academia for decades.

Notes

1 To Trow, success meant programs of teaching and research that transcended disciplinary methods and subject matter that sought "to use perspectives of seemingly disparate disciplines simultaneously and interactively to define common problems, issues and ideas, and to pose solutions based on genuine dialogue" (Trow, 1984, p. 2).
2 Trow identified these components as part of a life-cycle through which programs evolved : *Birth/Institution-Building*, the inception of an exciting and innovative program; *Growth/Transitioning to a Steady State*, the management of institutional challenges as programs began to grow and require some formal structure *(the stage he classified interdisciplinary studies as currently occupying)*; and *Survival/Successful Transition to a Steady State*, the successful development of academic and administrative routines that allow for programs the space to respond to matters that require spontaneity and creativity, concepts that interdisciplinary studies programs were founded on.
3 ADIR research can be conceptualized as any research that straddles the space between art and/or design and another discipline, with the intention of providing parity in the development and production of said research. It's meant as an umbrella term covering the lexicon of words for this integration ArtScience, SEAD, STEAM, etc. Additionally, research is not a set mode of inquiry; therefore, when referencing the R in ADIR, we include the modes of inquiry that could be identified as practice-based. ADIR is a catchall for practitioners working in this integrative space where arts and design are integral.

4 Many scholars mark this lecture as the beginning of these contemporary conversations. Snow, being a physical chemist and novelist, focused on the divide between the sciences and humanities, but artists have co-opted the essay to include the intersection of the arts and sciences.
5 Interestingly, Snow begins his lecture by pointing out that it's the humanists that are apathetic to scientific realities and that they should educate themselves regarding scientific understanding. The present-day conversation has flipped, and many artists have continued to educate themselves in the science integral to their work, but scientists often disregard the training and knowledge required of a critical art practice.
6 Keith Sawyer and Suzy DeZutter (2009) have termed this process *distributed creativity* because the collective generation of a creative project is produced by a team.
7 One will imagine that creative teams will also oscillate between higher and lower levels of creativity based on context and the state of integration; multidisciplinary components scoring lower than inter- or transdisciplinary components ADIR regularly strives for.
8 Attention to collaborative practice would fit into the sphere identified as "person or team" of the *systems model of creativity.* This sphere is where the work is produced and where collaborators must negotiate the creation and development of products or outcomes.
9 The model implies a quick process of using the current knowledge to produce responses, evaluate and validate responses, and produce an outcome. However, this model also functions well with long-term projects that require data gathering to prepare, generating responses and at times simultaneously evaluating and validating those responses, looping through that process several times before productive an initial outcome.
10 Condition setting can be thought of as a mechanism for connecting the meso to the micro. Amabile provides a working process, including individual capacity components; Hackman's condition setting overlaps between the foundation setting for productive teams and the reflexive interactions critical to maintaining successful working relationships.
11 We understand that supportive organizational context and team-focused coaching are important to fostering successful collaborations but will not discuss them in this chapter because they diverge from the focus of team member interactions.
12 To best support team dynamics, norms should be developed by group members. Hackman (2011) identifies norms around negotiating expertise, such as how the team decides to share information and formulating appropriate performance strategies for working through ideas, which could include norms such as ask clarifying questions and critique the idea rather than the individual.
13 Edmondson (1999) notes that *Team Psychological Safety* (TPS), the shared belief that team members are allowed to take interpersonal risks, underlies successful substantive conflict. TPS allows for respectful dissent, which is also correlated with team learning behavior (Edmondson, 1999; Ilgen et al., 2005).

References

Amabile, T. M. 1996. *Creativity in context: Update to "the social psychology of creativity"*, Boulder, CO: Westview Press.

Byrne, D., Kelliher, A., Cox, D. & Rikakis, T. 2013. XSEAD: A community platform for art-science integration. *IEEE Multimedia*, 20(4), 4–7.

Collins, H. M. & Evans, R. 2002. The third wave of science studies of expertise and experience. *Social Studies of Science*, 32, 235–296.

Collins, H. M., Evans, R. & Gorman, M. 2007. Trading zones and interactional expertise. *Studies in History and Philosophy of Science Part A*, 38, 657–666.

Csikszentmihalyi, M. 1988. *Society, culture, and person: A systems view of creativity*, Cambridge: Cambridge University Press.

De Dreu, C. K. W. & Weingart, L. R. 2003. Task versus relationship conflict, team performance, and team member satisfaction: A meta-analysis. *Journal of Applied Psychology*, 88, 741.

De Dreu, C. K. W. & West, M. A. 2001. Minority dissent and team innovation: The importance of participation in decision making. *Journal of Applied Psychology*, 86, 1191–1201.

Derrick, E. G., Falk-Krzesinski, H. J., Roberts, M. R. & Olson, S. 2012. *Facilitating Interdisciplinary Research and Education: A Practical Guide*. http://www.aaas.org/report/facilitating-interdisciplinary-research-and-education-practical-guide.

Edmondson, A. 1999. Psychological safety and learning behavior in work teams. *Administrative Science Quarterly*, 44, 350–383.

Feldman, D. H., Csikszentmihalyi, M. & Gardner, H. 1994. *Changing the world: A framework for the study of creativity*, Westport, CN: Praeger Publishers/Greenwood Publishing Group.

Hackman, J. R. 2011. *Collaborative intelligence: Using teams to solve hard problems*, San Fransisco, CA: Berrett-Koehler.

Hackman, J. R. 2012. From causes to conditions in group research. *Journal of Organizational Behavior*, 33, 428–444.

Harrington, D. M. 1990. The ecology of human creativity: A psychological perspective. In: Runco, M. A. & Albert, R. S. (eds.) *Theories of creativity* (pp. 143–169), Newbury Park, CA: Sage Publications, Inc.

Ilgen, D. R., Hollenbeck, J. R., Johnson, M. & Jundt, D. 2005. Teams in organizations: From input-process-output models to IMOI models. *Annual Review of Psychology*, 56, 517–543.

Jehn, K. A. 1997. A qualitative analysis of conflict types and dimensions in organizational groups. *Administrative Science Quarterly*, 42, 530–557.

Jehn, K. A., Northcraft, G. B. & Neale, M. A. 1999. Why differences make a difference: A field study of diversity, conflict and performance in workgroups. *Administrative Science Quarterly*, 44, 741–763.

Klein, J. T. 2008. Evaluation of interdisciplinary and transdisciplinary research: A literature review. *American Journal of Preventive Medicine*, 35, 116–123.

Klein, J. T. & Falk-Krzesinski, H. J. 2017. Interdisciplinary and collaborative work: Framing promotion and tenure practices and policies. *Research Policy*, 46(6), 1055–1061.

Kurtzberg, T. R. & Amabile, T. M. 2001. From Guilford to creative synergy: Opening the black box of team-level creativity. *Creativity Research Journal*, 13, 285–294.

Leonardo. 2018. Our History. Retrieved from https://www.leonardo.info/history [Accessed 6/26 2018].

Malina, R. F., Strohecker, C. & LaFayette, C. 2015. *Steps to an ecology of networked knowledge and innovation: Enabling new forms of collaboration among sciences, engineering, arts, and design*, Cambridge, MA: The MIT Press.

Nemeth, C. J. 1986. Differential contributions of majority and minority influence processes. *Psychological Review*, 93, 10–20.

Orr, J. 2016. *Art practice as research*, E. Cardenas, Editor. Recorded Conversation: Lawrence, KS.

Sawyer, K. 2012. *Explaining creativity: The science of human innovation*, New York, Oxford University Press.

Sawyer, K. 2013. Zig zag: *The surprising path to greater creativity*, San Francisco, CA: John Wiley & Sons.

Sawyer, K. & Dezutter, S. 2009. Distributed creativity: How collective creations emerge from collaboration. *Psychology of Aesthetics, Creativity, and the Arts*, 3, 81.

Skorton, D. & Bear, A. (Eds.). 2018. *The integration of the humanities and arts with sciences, engineering, and medicine in higher education*, Washingtion, DC: The National Academies Press. https://doi.org/10.17226/24988.

Snow, C. P. 2012. *The Two Cultures*, New York: Cambridge University Press.

Stein, M. I. 1963. Creativity in a free society. *Educational Horizons*, 41, 115–130.

Stein, M. I. (ed.) 1967. *Creativity and culture*, New York: Harper & Row.

Stein, M. I. 1974. *Stimulating creativity: Individual procedures*, San Fransisco, CA: Academic Press.

Stokols, D., Misra, S., Moser, R. P., Hall, K. L. & Taylor, B. K. 2008. The ecology of team science: Understanding contextual influences on transdisciplinary collaboration. *American Journal of Preventive Medicine*, 35, S96–S115.

Trow, M. 1984. Interdisciplinary studies as a counterculture: Problems of birth, growth, and survival. *Conference on the Future of Interdisciplinary Studies*, Oxford, OH.

Van Dyne, L. & Saavedra, R. 1996. A naturalistic minority influence experiment: Effects on divergent thinking, conflict and originality in work-groups. *British Journal of Social Psychology*, 35, 151–167.

23

Feasting the Lab and other projects

Art and science that skirts the limits of institutional frameworks

Jennifer Willet

Sometimes it feels like surfing – riding up against the limits of institutional frameworks through radical interdisciplinary art and science practices. There are ecstatic moments where I am present and alive in an institutional space so restricted that I feel grateful to breathe and participate in something so few will ever do or see. I have also experienced crushing amounts of paperwork; regulations so obscure, you need specialized education to navigate them; institutional hierarchies of power; and unequal disciplinary valuation between the arts and sciences. Some of my most significant achievements as an artist and researcher in the bioart field are bureaucratic ones. Performances and text documents that are only ever read or seen by very small audiences – health and safety officers, grant administrators, park wardens, and ethics review boards. There is often a moment with each project where it seems that the whole affair might fail – that the show might *not* go on – that we as artists do not belong here. And then, bureaucratic logic prevails. With one final compromise encapsulated in one final form – approval is granted. These administrative gymnastic tactics have become a central component of my artistic practice. And though I like to imagine myself as the scrappy artist who outmanoeuvres the logic of academic and scientific institutions as a catalyst for transformation, I can feel the years of accrued administrative tasks inscribing themselves into my creative work, my thought processes, and inscribing my body with the logic of institutional systems. In this chapter, I will chart some of my experiences as an artist working in highly institutionalized spaces and the push-and-pull of attempting to transform institutional regimes while subject to, and serving as an officer of, the very institution I am attempting to transform.

'Written on the body is a secret code only visible in certain lights; the accumulations of a lifetime gather there. In places the palimpsest is so heavily worked that the letters feel like braille' (Winterson, 1992). Jeannette Winterson's metaphorical description of text inscribed, and uninscribed, and inscribed again on the human body communicates aptly some of the corporeal sensations I have experienced as I ecru life's circumstances. The story written on *my* body is the tale of an artist/lover/mother/provocateur and a successful bureaucrat whose layered, compulsive, administrative activities have shaped – even marred – their body and their psyche through endless repetitive professional activities. I want to recall some of the progressive impressions made on my corporeal self through the re-telling of a series of

DOI: 10.4324/9780429437069-29

tactical human/institution interactions I have engaged in over twenty years working in the art/science milieu. Much like Lisa Steele's video work 'Birthday suit with scars and defects' (1974), I will recount for the reader a prolonged list and meditation on the various artistic/bureaucratic scenarios I have participated in and trace the impact those actions had on my artistic practice, my station within institutional hierarchies, my consciousness, and my body.

I started working as an artist in laboratory environments in 1996. I was an undergraduate student at the University of Calgary, and my future BIOTEKNICA collaborator Shawn Bailey[1] and I negotiated our way into visiting the Human Anatomy Lab in the School of Medicine. We argued that as students looking to improve our figure drawing skills, we needed to better understand the structures of the human body hidden under the flesh. It was astonishing to me that through a series of meetings and requests we could manoeuvre ourselves as artists into a highly restricted scientific environment. I was hooked immediately. We returned many times to the dark yellow room in the basement of Foothills Hospital to study human anatomy directly from the source (Figure 23.1). As we built trust with the staff, we were given greater and greater access to human corpses, preserved body parts, and medical students. These experiences did improve my drawing skills. But, more importantly, and more honestly, I wanted to understand death better – I wanted to see a deceased human body up close – I wanted to draw it, to study it, to meditate on it – to write about it – to know it. And through this experience, I gained valuable corporeal knowledge of the nature of a deceased human body, a knowledge that I still carry with me today.

This experience taught me a few things about working as an artist in highly institutionalized spaces:

1 Artistic education and research are not understood or valued in the same way as scientific education and research in our society. Sometimes, you will have to educate those from other disciplines about what you are doing and why it is important. Sometimes it is easier and more effective to not tell everyone exactly what you are up to.
2 Different disciplines have different community standards: learn the language and standards of the cross-disciplinary community you want to participate in.

Figure 23.1 Willet, Anatomy Sketchbook, 1994

3 Institutions rely on form professionalism including moderate dress, good communication skills, and effective paperwork skills. It will improve your chances of moving smoothly through institutional spaces if you adhere to these norms.
4 Be respectful to people, communities, and institutions that differ from your own. You will learn a lot and make new friends and colleagues in unlikely places.
5 It is often a good idea to go to places where you don't think you belong.

These notions were expanded while I worked under the umbrella of the BIOTEKNICA Collective (S. Bailey and J. Willet) in Montreal from 2000 to 2007. BIOTEKNICA was a fictitious bioengineering corporation that purportedly grew human teratoma tumours as a biotech product line. In 2004 and 2006, we travelled to Perth Australia to study mammalian tissue culture and tissue engineering protocols at SymbioticA Art and Science Collaborative Research laboratory at the University of Western Australia. During this time, Oron Catts and Ionat Zurr collaborated with us on the production of an artwork called BIOTEKNICA: Organic Tissue Prototypes (2006), a series of 3D teratoma-shaped sculptures seeded with a P19 mouse teratoma cell line (Figure 23.2). A project that had started as intensely critical of the complicated bioethics of the biotech sector had shifted in its positionality away from outsider critique towards a critical AND participatory relationship with biotechnology.

> In this capacity, we understand our position to be like that of *double agents*. Not in the Cold War sense of the term, but rather as a participant with dual intentionalities. Here, we are welcomed into a highly specialized environment inaccessible to the general public. We are simultaneously engaging collaboratively, respectfully and excitedly with the individuals, protocols and institutional structures of the site – while at the same time, from a different standpoint, gaining outsider insight and observations (and criticisms) that are published in other communities. Often these roles are at odds – sometimes easily synchronized, but always co-present.
>
> *Willet and Bailey (2006)*

With BIOTEKNICA, I recognized that my values and research objectives are not always in alignment with the institutions and individuals I work within a cross-disciplinary environment. At that time, I chose not to communicate this misalignment of intentions and

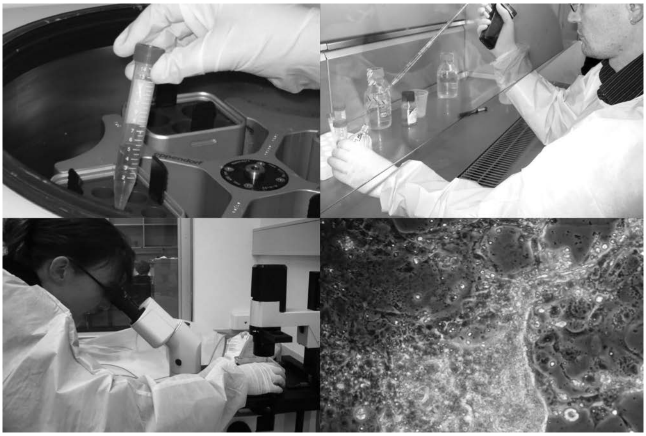


Figure 23.2 Bailey and Willet, BIOTEKNICA documentation, 2004

outcomes with the scientists working around me. I considered this strategy as similar to investigative journalism where collected information could contribute to science criticism in the form of artwork, public lectures, or academic texts.

During my time with BIOTEKNICA, I also became a skilled grant writer. I learned that I could use the cloud of bureaucracy surrounding the grant writing process to achieve goals well beyond my means. As very young artists, we imagined ambitious projects on our kitchen floor. And like every tech start-up today, we would create exciting image sets and dynamic websites to accompany each proposal giving professional currency to DIY research/creative activities. We were wildly successful. We created a creative/bureaucratic machine called BIOTEKNICA that garnered its organizational cache. However, through this process of faux institutionalization, we became more disgruntled and more institutionalized ourselves. The stress affiliated with this transformation contributed greatly to the end of BIOTEKNICA in 2007.

In the following years, I attempted various tactics to upend institutional forces infiltrating my space, time, body, and art practice. I began by performing unruly actions in laboratory environments for cameras and very small audiences of scientists, students, administrators, and cleaning staff. I wanted to develop a performative vocabulary for non-scientists to subvert the institutional authority of the lab.

> I am interested in propagating alternative models of biotechnology towards a wider representation of possible practitioners (artists, mothers, accountants, and swimmers), and a wider range of possible relations between the various orders of life that make up the laboratory ecology. If we apply these strategies biotechnology does not only have to be understood from the perspective of rationality and scientific method or from models established through business and industrialization. Biotechnology can also be perceived as an art form – as cooking - as poetry – as family – as cultivating and/or rearing – as sexuality - as care of the self/other.
>
> *Willet (2008)*

I decided to perform laboratory actions naked, exposing the animality of the human researcher in the lab. I wanted to re-position lab work as an interspecies interaction rather than an objective research methodology. I worked to develop a type of body language for a naked female that did not conform to modelling or pornographic standards. One that refused to arch her back, point her toes, and break her body up into seductive angles. I wanted the images of my body to be read as a quirky human organism; a trickster, a fool, a person who chooses not to conform to institutional or representational rules. I have used various strategies to gain access to labs for artistic purposes including clandestine tactics and negotiated access.

I developed a collaborative photographic practice with Irish artist Kira O'Reilly, whom I met at SymbioticA in 2004. Over the years, we have met in several laboratories and engaged in unusual and poetic performative actions in highly restricted institutional spaces. Together, we create photographic works exploring conversations between our artistic practices and the interconnections we see between the human body and the laboratory ecology.

For our first collaborative photoshoot, I arranged for us to access a tissue culture lab that was in the process of being decommissioned at the University of Leiden in 2008 (Figure 23.3). This was a very exciting opportunity, as the decommissioning of a lab is a specific bureaucratic instance that changes the functionality and Health and Safety status of a room. One day, the room is a lab, and the next day, it is just a room again. Great artistic potential lies in this in-between moment. It was during this in-between time that we met

Figure 23.3 O'Reilly and Willet, untitled (Hamster Ovaries Protocol), 2008, Photo: Rune Peitersen

with a photographer to perform tissue culture protocols in an unexpected fashion. We intentionally removed our shoes and clothing and climbed into one of the biosafety cabinets along with the cells to perform the protocol. We deliberately put ourselves in the position of the specimen. We contaminated the sterile cabinet with our bodies. Any working laboratory would not allow this action as it contravenes health and safety regulations, contaminates an expensive piece of equipment, and generally contradicts community standards for acceptable behaviour in laboratory environments.

I often think back to the logistics of that photoshoot as a perfect confluence of bureaucratic circumstances. I was working at the Art and Genomics Centre (an international hub for bio-art teaching and research directed by Dr. Robert Zwijnenberg), at the same time as a lab in the biology building was being decommissioned (a rare occurrence), in a country (The Netherlands) where nudity and the human body is not intrinsically understood as taboo. Only under these very specific circumstances, this photoshoot would have been possible. The resulting photographs [*Untitled* (*Hamster Ovaries Protocol*) series, 2008] are transformative. They capture the strength and fragility of the human form performing feminist and unruly actions in a deeply hierarchical space. This work marks a significant instance of understanding and mobilizing bureaucratic logic towards artistic ends as a central component of my art practice.

Another good example of bureaucratic tactics in my art practice is a project called BioARTCAMP. In July 2011, I hosted twenty artists, scientists, and students in residency at The Banff Centre.[2] Participants worked to build a portable laboratory in the forest and conducted a variety of scientific, ecological, creative, and theoretical projects. BioARTCAMP was a social practice project where humans and non-human organisms (in the lab, in the kitchen, and in the forest) co-habituated in a field research station in Banff National Park, Canada (Figure 23.4). This project served to navigate contested boundaries between lab and field-based scientific methodologies and to topple discrete categorizations of life by bringing lab specimens and 'natural' life forms into physical and conceptual proximity. BioARTCAMP also functioned as a cautionary tale, engaging in advanced biotechnological protocols in the beautiful but conflicted site of Banff National Park marks past and present economic and colonial exploitations of human and non-human life on our terrestrial ecology. It could be argued that we are only repeating these corrupt strategies at microscopic and molecular levels with biotechnology today.

Figure 23.4 Willet, BioARTCAMP documentation, 2011

BioARTCAMP is the largest inter-institutional project I have completed in my career. Partners included: The University of Windsor, the Banff Centre, Banff National Park, and eight other funders and partner organizations.[3] Preparation took four years – applying for grants, negotiating with sponsors, applying for permits, seeking health and safety approvals, first aid training, negotiating inter-institutional agreements and artist/researcher agreements, arraigning for porta-potties, babysitters, biohazardous waste pick up in the forest, etc. The most contentious aspect of preparing for BioARTCAMP was the collections permit I was seeking from Parks Canada to allow the artists to collect biological specimens within a national park. A variety of issues were flagged as roadblocks; all were manageable. However, there seemed to be a more general concern of whether or not it was acceptable to grant artists permits normally reserved for scientific and archaeological research. This question caused a rift in the Parks Canada staff members I was dealing with. In the end, I argued that given that my research was funded by the Social Science and Humanities Research Council of Canada through a rigorous peer-review process, it was legitimate research and should be given equal consideration. With some behind-the-scenes negotiations, upper administration approved my application against the wishes of some of the park staff I had been dealing with. This created an uncomfortable tension within the organization and with numerous individuals. Though I had been successful in achieving my artistic/bureaucratic goals and set an important precedent for research/creation activities taking place in our national parks system, I was uncomfortable with the stress I had caused for several Parks Canada employees in their work environment and by extension their social circles.

All this transpired before the project even began; we received the permit one day in advance of the event. With the arrivals of the artists, scientists, and students, the tables were turned, my function within the project changed from provocative artist to arts administrator and implementer of the myriad of rules and complicated compromises I had agreed to abide by. The project was a great success, but my experience of BioARTCAMP was mostly unpleasant. So unpleasant; I questioned my own research/creation methods working within large institutional spaces as possibly unethical. I experienced first-hand stress that bureaucrats endure when artists push the limits of the institution that the bureaucrat is employed to uphold. It was an untenable position; one I had put many administrators through with my own artistic/bureaucratic tactics over the past decade. As a result, I took a hiatus from large collaborative projects for a number of years though eventually returned to working as a curator and social practice artist with new strategies to avoid inflicting tremendous stress on myself, colleagues, students, and collaborators.

In addition to the projects I have described thus far, I also work as an Associate Professor and Canada Research Chair in Art, Science and Ecology in the School of Creative Arts at the University of Windsor, Canada. In 2009, I opened the first bioart lab in Canada, a teaching and research facility called INCUBATOR: Hybrid Laboratory at the Intersection of Art, Science and Ecology. In 2018, INCUBATOR relocated to a custom-built biosafety level 2 bioart laboratory as part of the new downtown campus (Figures 23.5 and 23.6). This hybrid laboratory/theatre facility supports advanced bioart research/creation and makes visible biotech protocols to audiences through a floor-to-ceiling glass wall separating the lab from a large public space. INCUBATOR Lab supports mixed-use biotech research with integrated multimedia, lighting design, video, and sound. INCUBATOR Lab provides unique innovations in bioart and biotechnology public engagement through (1) making daily bioart

Figure 23.5 INCUBATOR Lab, 2019, Photo: Justin Elliott

Figure 23.6 INCUBATOR Lab, 2019, Photo: Justin Elliott

laboratory activities visible to the public; (2) serving as a gallery where artworks that are unable to leave the laboratory can be safely displayed; and (3) as a multimedia performing arts venue where seated audiences can view live performance events that integrate biotechnology into multimedia storytelling genres. In 2021, the University of Windsor will open a second bioart facility INCUBATOR Studio. This space is a storefront artist studio and (biosafety level 1) lab to house my creative production and host community bioart workshops.

In January 2018, I opened the new INCUBATOR Lab facility with a special event called Feasting the Lab where we feasted the new facility the way one might feast a new home or the arrival of a baby (Figures 23.7–23.9). In this instance, I was working to make the bureaucratic moment when a room becomes a lab a visible and joyous community event. My intention was one of marvel and critique. Marvel at the wonder of watching the human construction of a laboratory comes into being with nothing but the potential for future research. And an institutional critique of the absurd complexity of the regulations that are designed to create safe and measurable research outcomes, but sometimes hinder the very activities they are designed to support. For one night only, I invited the public to join me in engaging

Figure 23.7 Willet, Feasting the Lab, 2018, Photo: Justin Elliott

Figure 23.8 Willet, Feasting the Lab, 2018, Photo: Justin Elliott

Figure 23.9 Willet, Feasting the Lab, 2018, Photo: Justin Elliott

in all the activities within the new lab that would never again be possible once the lab was certified. We ate in the lab, danced barefoot in the lab, and we consumed alcohol in the lab.

Feasting the Lab was attended by approximately 500 community members. Thyme Kitchen chef Julie Myers served science-themed canapés, desserts in Petri dishes, and a roasted pig head to guests. We brewed sangria in the lab. Theresa Sims from the Can-Am Indian Friendship Centre blessed the lab. DJ Soul Brother Stef, soprano Dr. Jennifer Swanson, and the UWindsor Chamber Choir directed by Bruce Kotowich all gave live performances. Bioartist Marta De Menezes (Portugal) and theorist Dalilia Honorato (Greece) donned outrageous costumes and served as bartenders and hosts in the lab, while Lisa Carrie Goldberg from Action Potential Lab (Toronto, Canada) ran squid ink-printing workshops in the gallery. Windsor-based artists Jude Abu Zaineh and Domenica Mediati exhibited bioart video works, and the Students of the BioART: Contemporary Art and the Life Sciences class exhibited artworks and contributed a live performance.

I performed a character I call the 'gentleman scientist.' He serves as a ringmaster, as host, a Willy Wonka figure, and myself; dressed all in white with a top hat and a modified lab coat. The coat is very formal and filthy, stained with soil from the Banks of the Detroit River. It has a bustle, a high collar, and eight oversized nipples or cupping devices (snow globes) filled with nutrient agar. I have developed a performance where, as I go about my evening, the gentleman swabs people and items in his environment, unscrewing the bulbs one at a time to insert the collected microorganisms into the portable microecologies. Towards the end of the night, Tina Suntres from the University of Windsor Research Safety Committee and I asked everyone to leave the lab and announced from that moment forward these activities would no longer be acceptable in this space, replaced instead by certified laboratory protocols. The party was over.

Feasting the Lab was designed to explore the limits of acceptable human behaviour and interspecies interactions in a laboratory as defined by institutional regulatory bodies. With this project, I employed a more direct tactic for navigating the various institutional regulations I was engaging critically with as an artist. I reached out to my colleagues across the university and I told everyone exactly what I was up to. Rather than a clandestine or adversarial model, I invited others to join me in performing gymnastic bureaucratic tactics towards making this unusual event possible. To my delight, this strategy enabled many beautiful conversations with other officers of the university who found themselves compromised working in a large institutional environment. In other instances, this information was of no interest to the individual I was dealing with and did not change the very stressful complications of asking an institution to participate in counterintuitive creative actions. As always, Feasting the Lab was a bit of a nail-biter; sticking points included the fire permit, negotiations with internal food and beverage services, and controlling the light levels in a building still under construction.

As I have worked my way up to academic hierarchies, my strategies for navigating institutional environments as an artist have changed. These days, I have far less fear of being asked to leave. I am more direct – polite and fun, but also more challenging in my interactions with other officers of the institution. I have more currency in institutional frameworks, but I also have more to lose. Possibly I have grown complacent to the hierarchies that provide me with the resources I desire. Possibly my position within institutional environments has changed from double agency to *conflicted*. As if through a process of reification, the unruly artist working at the periphery of institutional science has been transformed, subsumed, and repositioned as an officer in the institutional framework she originally rallied against. Sometimes, this feels like a failure and sometimes a grand success. If nothing else, I have nudged the criteria for who can hold positions of power within laboratories and academic institutions. I am an artist and an unruly woman. I direct a feminist art/science laboratory with an emphasis on community engagement. I have created a type of institutional space that did not exist before, and I (and generations of art/science researchers before me) insist that artists do, in fact, belong here. Possibly, more importantly, I look to help the next generation of unruly people who do not belong in laboratories and institutional spaces to join me in co-authoring more inclusive biotech futures.

The personal costs affiliated with organizational success and the ongoing deferral of my wellbeing to meet the demands of working as an artist within institutional frameworks are high. I have terrible posture. This was always the case, but as I carry more responsibility, I feel institutional processes shaping my spine and neck towards atrophy. I can feel an institutional logic pervading my thoughts. My dreams are filled with institutional scenarios. My artistic imagination has been infected. When I began to work in this milieu two decades ago, I assumed that laboratory specimens required more of our bioethical consideration if we were to ever achieve a sustainable biotech future. I had overlooked the other organisms struggling for sustainability in labs; the human researchers who have to ignore their biological and social needs to contort themselves to meet the needs of the bureaucracy in which they are working.

If all of this is true, why do I keep coming back for more? Certainly, there is an element of ambition. Also, post-secondary institutions house the very large infrastructure I need to engage in a highly technologized art practice. However, my research/creation activities are primarily driven by another compulsion I call 'the feeling.' I am compelled by the pursuit of the electric excitement of every cell in my body that I experience when I am deep in the caverns of human/technological spaces holding fragile life forms in my hand. Or when I am hosting an absurdist art/science event and things start happening that even I did not imagine. I have similar feelings when I am hiking in the mountains, standing in front of an outstanding painting, and watching our girls run in and out of the tide on a sandy beach. I experience a perceived aliveness – of myself – of the human project – of the unfurling universe – of love. I imagine this is what surfing must feel like. It comes while having an experience that I am both amazed by and grateful for. It is vulnerable and frightening and fleeting. I pursue it avidly. I can defer my pleasure for years in the pursuit of 'the feeling' completing hundreds of hours of meetings and paperwork, and budgets, and grant reports – all in the pursuit of a future ecstatic artistic moment.

And so, it continues the evolution of my performative bureaucratic tactics. Each past strategy for navigating institutional spaces as an artist leaves traces in my practice and my body, and in the institutions where those actions took place. The palimpsest is made and made again. As my work evolves, I sense momentum towards greater transparency. As I work to make laboratory practices, regulations, spaces more transparent, more connected to the local ecology and the local community, I am also working towards making my intentions and methods more transparent and connected to the local community within an institutional context. This shift in bureaucratic strategies is intended to reduce stress and strain on myself, and other bureaucrats, towards a more collaborative and empathy-based methodology for navigating extreme institutional environments.

Notes

1 Now known as Jason Knight.
2 BioARTCAMP participants included: Iain Baxter& (Canada), Marie-Pier Boucher (Canada), Zoot Derks (The Netherlands), Tagny Duff (Canada), Jeanette Groenendaal (The Netherlands), Kurt Illerbrun (Canada), Angus Leech (Canada), Marta De Menezes (Portugal), Bulent Mutus (Canada), Jennifer Willet (Canada), and Paul Vanouse (USA). Special guests included: Tokio Webster, Grant Yocom, Louise Baxter&, Joan Linder, and Dylan Leech.
3 The Social Sciences and Humanities Research Council of Canada (SSHRC), The Ontario Arts Council, Hostelling International, Parks Canada, Banff National Park, Glenbow Museum, The Art and Genomics Centre at the University of Leiden, and Fonds BKVB.

References

Steele, L. Birthday Suit with Scars and Defects. Video, B/W, Sound. 1974 (11:00).
Willet, J. “BIOPLAY: Bacteria Cultures” *in Human Futures: Art in the Age of Uncertainty, Andy Miah Edt. FACT* (Foundation for Art and Creative Technology) Liverpool, UK, 2008.
Willet, J. and Bailey, S. “BIOTEKNICA: Soft Experiments from the Laboratory” at New Constellations: *Art, Science, and Society*, Museum of Contemporary Art, Sydney, Australia, 2006.
Winterson, J. *Written on the Body.* New York: Alfred A. Knopf Inc. 1992.

Section 6
Democracy and activism

Hannah Star Rogers

What does it mean for artists to engage with science and technology in the context of public participation and political action? The authors in this section attempt to answer that question by examining a series of projects and artworks that offer potential pathways toward the democratization of science and technology and activism through design and new media. Other chapters bring forward community theater practices and gallery spaces transformed into sites for public engagement with thorny contemporary issues of science and technology.

Art that engages with science and technology is ultimately political. For artists or those using artistic methods to call a society's attention to issues usually zoned as scientific is to call for new participation, implicitly taking the position that further involvement by the public is needed. In many contemporary societies, a considerable number of issues have been ruled to be in scientific or technical realms. In many debates ruled to be scientific or technical matters, regardless of their importance to the public, participation becomes closed. These debates tend to result in attempts to resolve the paradox of the deficit model of science communication (Gregory and Miller 1998; Miller 2001, pp. 116; Brown 2009). In this model, if a person disagrees with the findings of the science community, this is a cause to believe that they have not properly understood the issues, so the result is an attempt to correctly educate the person so that they may participate in the debate. If the person's view persists, attempts to elucidate the scientific matters to the individual continue. An open dialogue can become difficult or impossible because to have standing to contribute to a given conversation, individuals must agree to a set of preconditions and scientific beliefs. As a result, participants' views may only validate a preexisting position of the technocrats or scientists involved. In this context, artworks that respond to these concerns and give individual artists or the public standing to participate with their own ideas, regardless of the views of other participants, have a democratizing effect.

Yet most attempts to create dialogues with the public around science and technology issues continue to be limited. One issue is how the "public" is selected. In such settings, individuals are selected to represent, or perhaps more accurately, model the public, and are placed in conversation with policymakers and scientists. This practice is based on a construction of ideas about the potential relations between science and society. The participation it offers is formatted into feedback channels to perform the correct communication between

DOI: 10.4324/9780429437069-30

these representative actors. Political theorist and philosopher Chantel Mouffe (2013) argues that democracy is best practiced under conditions of "antagonism" because this enables an ongoing conversation in contrast to attempts to depoliticize issues that effectively eliminate productive egalitarian debate that allows all parties to stake their positions.

In contrast, many attempts to include the public in scientific conversations tend to depoliticize the issues through suggesting scientific knowledge as a final arbiter. These conversations are ended with an appeal to a set of ideas to which one set of the supposedly equally-footed parties are thought to have special access. Avoiding the power dynamic of the recognized experts in conversation with lay people is a notion that arises across the Science and Technology Studies (STS) literature on the subject. STS scholar Alan Irwin (2001) has shown some of the limitations in the current practice of constructing these citizenships, particularly in the case of UK public hearings and forum practices around genetically modified foods. Similar critiques of the system of forums and public participation around emerging technologies in the United States have led to calls for reform around issues of the constitution of the audience. As the examples in the chapters in this section show, art can offer new pathways of participation, no more or less constructed than the alternatives offered by science institutions and the state but revealing in new ways.

STS scholars have called for better participation not only in questions around scientific policy choices but also around new technologies (Sclove 1995). While these are often pictured as public conversations guided by dialogue rather than a top-down delivery of information, other potential methods, hailing from the long history of political art, particularly the definitionally-contrarian avant-garde (Bürger 2011), and the more recent rise of activist public art, can address these concerns. Design methods, particularly speculative design (Dunne and Raby 2013) and human–computer interaction's cultural probes (Baumer et al. 2013), have offered some new possibilities for engaging the public. These include involving participants in specific product designs and collectively imagining the contexts of their uses as well as considering larger social issues in imagined futures. These often involve playing out the potential consequences of an innovation's possible effects on various aspects of individual lives and social situations based on current technologies and social futures (Halpern et al. 2013). These methods, which have roots in design and the arts, are increasingly finding their way into social science and public policy settings.

These political science and technology artworks challenge received understandings of science, and through that, our cultures more broadly. They offer opportunities for the public to imagine different worldviews or designs that question, through their potential uses, our usual ways of using technologies or imagining our futures with technologies. But they also include community performances where individuals are given an opportunity to have their voices heard on subjects of pressing cultural and personal meanings as well as public policy implications. Artists working in this area run the gamut of a genre, mediums, and orientation toward politics. Some have specific political messages, and their artworks act as polemics for those positions; others take a broader view of politics in which their artworks are designed to open dialogue or debate around a science issue. Still others take forms familiar to STS scholars and are implicit or explicit critiques of science and technology dealing with issues of diversity and inclusion, the role of the state in science, the shaping of technological developments by multinational corporations, or the values and judgments encoded in scientific research.

The authors in this section show how art can raise and explore problems, including environmental issues (Lissette Lorenz, Chapter 25), access to DIY (do-it-yourself) biotechnology for personal use (Mary Maggic, Chapter 24), public policy concerns around gene editing turned philosophical (Adam Zaretsky, Chapter 27), and the future of artificial intelligence

(AI) (Christopher Wood, Chapter 26). All of these examples have, in some contexts, been classified as scientific or technical, but they also have important social impacts that make them important targets for artists working in the vein of new genre public arts and arts engagement.

In her review of the history of public art, Suzanne Lacy (1995) argues that new genre public art is defined by its activism. She also identifies some of the factors that lead to artists' involvement in community outreach art as part of the move away from top-down nonparticipatory art (Lacy 1995; Rogers 2011). Lacy's analysis of bringing art to the public intersects with issues associated with science communication, particularly the limitations of one-way communication that places the communication-initiating party in the role of expert and discounts the relevant expertise of the receiving party.

New genre public art offers pathways around this division, as section authors Lorenz and Wood particularly show. This may take the form of more traditional public engagement working with community theater as in Lorenz's rustbelt theatre, influenced by the work of Augusto Boal (1994), which was part of a broader community structure but formed the basis for an environmentally-engaged public artwork in the form of a play by community children. Wood offers an account of a workshop that gives the public a way to consider the role of AI, particularly the ways AI might be directed to ends that would interest the participants. Such interventions do have the potential to reproduce familiar conversations, but they can also give rise to ideas unlikely to be brought to the surface in everyday life. At the same time, they do have the potential to celebrate science by implying that specific technologies will be developed or celebrating the potentials of technologies. But when composed with an eye to imaginative openness and designed to encourage inclusive participation, they also offer participants opportunities to consider concerns or express their skepticism about the possibilities of new developments.

Lorenz and Wood's chapters offer accounts of artistic methods used to consider social problems: environmental activism and the adoption of AI activities in settings with members of the public. These ideas are potentially reproducible in other settings around other issues. Maggic and Zaretsky offer chapters that are experiential and might be thought of as interventions in themselves. Maggic explicates a 2015 project "Open Source Estrogen," investigating the possibility of creating DIY estrogen, a process described as biotechnical civil disobedience. Maggic invokes STS as a way to understand the work: as a tool for framing such artworks and as an interpretive lens. Zaretsky's chapter takes the form of a letter to twins Lulu and Nana, the pseudonyms of the first children recognized to be born from germline genetically-edited zygotes. The announcement of their births in 2018 led to international condemnation and praise from scientists, policymakers, and the public. Nationalistic sentiments from all sides often found center stage, along with moral outrage and calls for a moratorium on further work of this type. What was too often left behind was a sense that these children were exactly that. Even as conversations around scientific responsibility took place, and the accountability of the scientist, Dr. He Jiankui, and those who funded and supported his program were discussed, there was little suggestion of any responsibility toward Nana and Lulu themselves. In Zaretsky's letter, he shifts the focus from the scientific interpretation of these events to the personal and aesthetic meanings that the twins might choose to give their lives. Through satire and humor, Zaretsky points out that whatever the initial conditions or reasons for editing the genomes of these two people, these need not be constraints in understanding their own power in the face of biotechnological changes. In doing so, he shifts the emphasis away from an armchair conversation about the ethics and public policy around CRISPR-Cas9 and toward a more human epistolary provocation on changing ourselves.

Art offers experiments and methods to address a persistent problem in STS: how can the public engage with science and technology in ways that do not reinforce single-direction communication but instead offer a position of power with responsibility and accountability to citizens. Sometimes, this is accomplished by offering the public a chance to discuss the problems that face them, as in Lorenz's work with children on environmental issues or offering new methods to consider the role emerging technologies may play in participants' lives, as in Wood's AI futures explored through "poetic methods." Maggic offers the democratization of hormone-making by exploring DIY techniques for producing estrogen and situating its use in an STS understanding of biological chemistries and cultural gendering practices. Zaretsky's letter to Nana and Lulu emphasizes individual choice, a hallmark of democracy, in considering the ways that biological interventions can be interpreted. Together, these chapters represent some of the potential myriad of approaches that socially-engaged artists can take to involve people in projects of thinking, acting, and making around science and technology.

Works Cited

Baumer, E.P.S., Halpern, M., Khovanskaya, V., and Gay, G.K. (2013). Probing the market: Using cultural probes to study sustainable food practices at a farmers market. In: J. Choi and M. Foth, eds., *Eat, cook, grow: Mixing human-computer interactions with human-food interactions.* Cambridge, MA: The MIT Press, pp. 135–152.

Boal, A. (1994). *The rainbow of desire: The Boal method of theatre and therapy*. London: Routledge.

Brown, S. (2009). The new deficit model. *Nature Nanotechnology* 4:609–611.

Bürger, P. (2011). *Theory of the Avant-Garde*. Minneapolis: University of Minnesota Press.

Dunne, A., and Raby, F. (2013). *Speculative everything: Design, fiction, and social dreaming*. Cambridge, MA: The MIT Press.

Gregory, Jane, and Miller, S. (1998). *Science in public: Communication, culture, and credibility*. Cambridge, MA: Basic Books, Perseus Group.

Halpern, M., Erickson, I., Forlano, L., and Gay, G. (2013). Designing collaboration: Comparing cases exploring cultural probes as boundary-negotiating objects. *CSCW 2013 Conference Proceedings*. San Antonio, TX.

Irwin, A. (2001). Constructing the scientific citizen: Science and democracy in the biosciences. *Public Understanding of Science* 10(1): 1–18.

Lacy, S. (1995). Metaphoric landscapes and cultural journeys. In: Suzanne Lacy, ed., *Mapping the terrain: New genre public art*. Seattle, WA: Bay Press, pp. 18–47.

Miller, S. (2001). Public understanding of science at the crossroads. *Public Understanding of Science*, 10: 115–120.

Mouffe, C. (2013). *Agonistics: Thinking the world politically*. London; New York: Verso.

Rogers, H.S. (2011). Amateur knowledge: Public art and citizen science. *Configurations* 19(1): 101–115.

Sclove, R.E. (1995). *Democracy and technology*. New York: Guilford Press.

24

We're all living in an Estroworld

Mary Maggic

In 2015, the project *Open Source Estrogen* began with a simple and speculative question: what if it was possible to make estrogen in the kitchen? From this question arises more fundamental questions about who is producing hormones, whose bodies are affected, who gets access, and how environmental hormones termed "xenoestrogens" or "endocrine disruptors" exist already in the environment as a state of toxicity—one that is deeply tied to patriarchal capitalism and industry. As an artist working collaboratively in biohacking and cultural discourse, the question of knowledge production and emancipatory access has always been at the forefront of this practice, and how we can collectively push the boundaries of what can be accomplished socially and scientifically outside institutional walls. Using interdisciplinary research, speculative fiction and participatory workshops as primary methodologies, the project seeks to uncover how hormonal molecules perform a molecular colonization on our bodies, environments, and sociocultural notions of heteronormativity. By demystifying and revealing what is normally hidden and invisible at the molecular level, the project, as a form of biotechnical civil disobedience, subverts three main kinds of dominant biopolitical agents. One such is hormonal management—how are female and trans-bodies currently controlled through hormones? Another is how knowledge about hormones and bodies is produced—who does scientific knowledge benefit and belong to? And lastly, all-pervasive environmental toxicity—how are *all* bodies (human and nonhuman) already queering (changing and altering) at the molecular level?

This practice of scientific and hormonal demystification is largely influenced by renowned artist collective Critical Art Ensemble and their pioneering work in biological sabotage and retooling organisms for social resistance. Borrowing from their chapter, "Transgenic Production and Cultural Resistance: A Seven-Point Plan" from *Molecular Invasion* (Critical Art Ensemble, 2003), the project summarizes its very own sociocultural strategy for civil disobedience:

Six-point plan for hormone queering resistance

1 Unearth the dominant patriarchal agents of hormonal production and pollution, building public understanding of the xeno forces at play.

DOI: 10.4324/9780429437069-31

2 Demystify the institutionalized "black-boxed" knowledge of biochemistry, endocrinology, and ecotoxicology; pave way for hormone hacking, freak science, and amateur exploration.
3 Resist neoliberal pharmaco-capitalist profiteering of (un)consenting bodies.
4 Reject glorifications of "the natural," condemnations of "the unnatural," and above all rhetorics of techno-solutionism that promise to elucidate both.
5 Undermine deeply entrenched notions of (eco)heteronormalcy and purity; Use "queering" as a reclaimed potential for resistance.
6 Consider the microperformativity of hormones as an agential power of not only molecular colonization but also molecular collaboration.

Science, Technology, and Society (STS) gender researcher Anne Fausto-Sterling writes that it is widely accepted that gender is chemical, that "sex hormones" such as estrogen, progesterone, and testosterone, are responsible for the production of primary sex characteristics in the developing fetus, then of secondary sex characteristics at the onset of puberty (Fausto-Sterling, 2000). Therefore, hormones can act as a powerful tool for biosurveillance—controlling, disciplining, and subjugating bodies to fit within a binary and heteronormative system. They work within what Paul B. Preciado calls "somatic fictions" where notions of femininity and masculinity are manufactured—rather than discovered empirically—at the molecular level (Preciado, 2013).

Since the 1930s, petrochemical and agricultural industries have produced profuse amounts of chemicals of xenoestrogenic effects, with Bisphenol A being one of the most infamous and widespread plasticizing molecules. Environmental humanities scholar Rob Nixon's terms the biopolitical ubiquity of endocrine disruptors a form of "slow violence," an invisible yet pervasive toxicity whose gradual effects are almost impossible to perceive (Nixon, 2013). These harmful xenoestrogens not only debilitate the bodies of human and nonhuman species through neurological, physiological, and cancerous effects but also change their morphologies. This evidences a malleability inherent to all bodies and organisms, but alien to what we believe to be "normal" and "natural." From pharmaceutical hormones, to pesticides to plasticizers, their molecular substituents are nonetheless invisible and difficult to perceive, contained within "black-boxes" wherein knowledge has been institutionalized and removed from the realm of amateur exploration. Therefore, the dismantling of these "black-boxes" usurps the institutional process of defining and enforcing subjectivities and creates spacious room for new ontologies. If hormones are the tool of biotechnological surveillance, then hacking them readily dismantles their institutional biopower.

And how can such dismantling occur? While research from STS scholars on gender, hormones, and environmental toxicity contextualizes the biopolitical nature of hormones, the appropriation of scientific methodology manifests the project into practice. Through a nomadic workshopology and collaborative prototyping practice called *Estrofem! Lab*, the project generates DIY/DIWO (do-it-with-others) protocols for hormone hacking, otherwise referred to as "estrogen geeking" or "freak science." A series of mobile labs outfitted into suitcases, these protocols have included: (1) yeast estrogen screen-human estrogen receptor (YES-HER) yeast biosensors, a low-cost detection method using transgenic yeast containing human estrogen receptor, (2) urine-hormone extraction-action, a DIY column chromatography method for the isolation of urinary hormones, (3) DIY solid-phase extraction, a method of concentrating hormones and endocrine-disrupting chemicals from dilute environmental water samples, and lastly (4) fungal bioremediation with various species of white-rot mushrooms. The protocols have since been disseminated through public

Figure 24.1 *Estrofem! Lab's* "YES-HER yeast detection lab" (2016). Raumschiff Gallery; Linz, Austria

workshopology, acting as discursive exercises in building hormonal knowledge and awareness. Bridging tacit, technical knowledge with cultural dialog, these protocols operate under what artist and writer Claire Pentecost terms "public amateurism" where people consent to learn and fail together in public, removing the hierarchy of the expert (Da Costa, 2008). Therefore, the knowledge around hormones is not simply contained within scientific methodology but also their biopolitical context, their entanglements with our notions of sex and gender, and how we can collectively unearth their molecular omnipresence (Figure 24.1).

This collaborative and participatory methodology has since informed works that utilize speculative fiction. Using and performing familiar cultural tropes of cooking show television and models of female domesticity, the ten-minute film *Housewives Making Drugs* features trans-femme artists Jade Phoenix and Jade Renegade who perform a urine-hormone extraction recipe while amusing the audience with their witty back-and-forth banter about everything problematic with patriarchal hetero-norms. They reference the difficulty of gaining hormone access under the Trump presidency, and the discrimination they often face traversing general health care as trans-bodied individuals. At the end of the show, they spontaneously break out into an "Estro-gin" song and dance, serving the hormones in dissolved shots of gin to the studio audience. While the technical aspects of the cooking show are fictional (urinary hormones are not viable hormone replacement therapies for gender transition, let alone administered by mixing with alcoholic beverages), the film gives an otherwise scientifically researched protocol cultural and sociopolitical significance, queering traditional discourses around hormones. What if this were real, and why isn't it already? How are our bodies presently colonized by the capitalist patriarchal management of hormones? What are the risks? And what will people trade to gain greater access to their own bodies? (Figure 24.2).

Beginning with the possible circumvention of institutional hormone access to *actively* queer one's body (i.e., through birth control pills or hormone replacement therapy), to the collective resistance formed from hacking and revealing the *passive* nonconsensual queering happening to nearly every organism on the planet (i.e., through exposure to microplastics), body sovereignty is utmost at stake. From detection to extraction to remediation, the recipes of *Open Source Estrogen* function as social resistance, as consciousness-raising, as hacking ideological constructs of gender. These tools and tactics allow an intimate way to confront our all-pervasive, anthropogenic toxicity by reclaiming and refiguring definitions of "normal"

Figure 24.2 *Housewives Making Drugs* on-set photo (2017)

and "natural," deconstructing at multiple layers: scientific knowledge production, sex/gender identities, public discourse, and of course hormonal molecules. And like the hormonal molecules it investigates and emancipates, the project is akin to a responsive body which never stops queering, a gender with no final destination.

References

Costa, B.Da. (2008). Reaching the limit. *Tactical Biopolitics*, 365–382. doi:10.7551/mitpress/9780262042499.003.0021.

Critical Art Ensemble. (2003). *The molecular invasion*. New York: Autonomedia.

Fausto-Sterling, A. (2000). *Sexing the body: Gender politics and the construction of sexuality*. New York: Basic.

Nixon, R. (2013). *Slow violence and the environmentalism of the poor*. Cambridge, MA: Harvard University Press.

Preciado, P.B. (2013). *Testo Junkie: Sex, drugs, and biopolitics in the pharmacopornographic era*. New York: Feminist at the City University of New York.

25

Rustbelt Theater and citizen science

Children's environmental justice narratives

Lissette Lorenz

Art as activist scholarship

What can a children's play teach adults about tackling environmental injustice while engaging in activist scholarship? Social theorist and artist-activist Augusto Boal believed that theater is "a rehearsal for the revolution" (1979). He contended that community-based theater is an effective medium for people to examine the social injustices in their daily lives and role-play solutions for overcoming them. His methodology, called Theater of the Oppressed (TO), is based on the notion that creating plays should come from the act of *playing*. After a decade of practicing theater and five years as an early childhood educator, I have found that many adults need to be re-taught how to play together. Children, in contrast, are experts in this field.

Playing is a way for children to investigate the world around them—including its disparities—in an age-appropriate manner (Crowley et al. 2001, National Research Council 2009, Honey and Kanter 2013). From 2010 to 2012, I collaborated on a TO-based workshop series with the children and staff at Save Our Children (SOC), an educational enrichment center that supports underserved children of color in a working-class neighborhood called South Elyria in Ohio. Together we created an ethnography of the experience called *Rustbelt Theater: Children's Environmental Justice Narratives from South Elyria, OH* (Lorenz 2012). Through the theater workshops, which culminated in an original play, the children identified issues facing their community and presented creative solutions for overcoming them.

In this chapter, I present excerpts of the children's play as their research findings and connect them to activist scholarship, environmental justice, and Science and Technology Studies (STS) literature.[1] Drawing from Boal, I contend that children use theater to analyze their everyday experiences and collaborate with adults to create and contextualize scientific knowledge. Moreover, children possess local knowledge about social issues affecting their communities. Theater becomes a method of social science inquiry that allows community members to become co-researchers and co-creators of STS scholarship that addresses community needs. STS scholars who care about partnering with marginalized communities to bring positive social change should pull from a wide range of research methodologies that work for and are accessible to these communities.

DOI: 10.4324/9780429437069-32

STS has been concerned with social justice from the outset. Some have argued for stronger ties between STS as an academic field and STS as a social movement (Cozzens 1993, Waks 1993). Feminist STS scholarship explicitly calls for social justice by reimagining scientific practice (Haraway 1988, Harding 2008). Activist scholarship provides a plethora of resources for STS scholars seeking to strengthen these ties. Activist scholarship is a term used by many disciplines to describe research that works toward increasing social justice (Hale and Calhoun 2008, Sudbury and Okazawa-Rey 2009, Torres 2018). It goes by different names depending on its origins and field of practice. Examples include community-based participatory research, collaborative community-based research, and action science. STS has its own brand of activist methodologies that stresses democratized research processes and outcomes called citizen science (Irwin 1995, Ottinger 2010, Haklay 2013). I argue that since *Rustbelt Theater* was designed as activist scholarship, it also counts as citizen science. Citizen science literature needs to broaden its conceptions of "citizen" and "science" to include activist scholarship across the social sciences that works with subjugated people regardless of their citizenship status.

Rustbelt Theater draws from two kinds of activist scholarship found outside of the citizen science literature: participatory action research (PAR) and TO. Both came from the popular education and third-world liberation movements of the 1970s (Boal 1979, Fals Borda 2001). PAR offers a framework for scholars to partner with communities to conduct research that meets communities' needs, like doing "undone science" in STS (Hess 2016). TO provides a repertoire of theater exercises for participants to dramatically analyze the real-life oppressions they face and act out potential solutions to overcome them. PAR and TO encourage transparency, democratic decision-making, and active participation. These ideals compel researchers and practitioners to reflect on the power relations among all stakeholders involved in the research process. As with all activist scholarship, the results of PAR and TO should address the community's needs. PAR and TO value the lived experiences of communities as a kind of expert knowledge. They strive to mobilize that knowledge for positive social change, making them highly compatible with STS as a social movement. To connect these different yet compatible forms of activist scholarship to STS, I refer to *Rustbelt Theater* as citizen science.

Rustbelt Theater combines the normative values of citizen science with performance ethnography methodology. As a methodology, performance ethnography adds an artistic layer to the traditional ethnography while serving as a tool for STS research. Performance ethnography points to how art serves as a form of social scientific inquiry in its own right and not simply a means of communicating and popularizing science. Performance ethnography gets at the nature of social relationships through the lens of performance, a broad category that includes the performing arts, rituals, sports and other popular entertainment, and any performative aspect of daily life (Schechner 2004). Stemming from the traditions of cultural and race studies, performance ethnography—such as PAR, TO, citizen science, and other forms of activist scholarship—is committed to radical social change (Denzin 2003).

Performance techniques like theater exercises become research tools for cultural investigation that are accessible to everyday people. Participants in the art-making process become both researchers and artists when they use art as their method for exploring a problem that matters to them. *Rustbelt Theater* is a performance ethnography of South Elyria that maintains the performative nature of the theater workshops through scripted vignettes while drawing out themes tied to children's local knowledge as it relates to environmental justice. It demonstrates that children make excellent co-researchers when given play-based methods. Eager to present their research findings through theater, they shared crucial knowledge about their physical and social environments with the adults that care for them.

Aligned with the values of citizen science, *Rustbelt Theater* showcases research with, for, and by an underserved community of color in South Elyria that works toward justice. SOC staff asked me to work with a group of third and fourth-grade students that had expressed interest in engaging in a new art project. I then led them in an eight-week series of theater workshops. I was impressed by the students' enthusiasm and the wealth of local knowledge they demonstrated throughout the process. During the workshops, students utilized TO techniques to create an original play about the challenges they identified in their daily lives. Thus, the theater workshops served as our research tool for investigating local issues. I combined field notes, interviews, and audiovisual materials of the workshops, rehearsals, and final performance to produce a script of the children's play that is embedded in the multi-vocal, multi-perspective performance ethnography. Our experience illustrates how theater is an engaging form of play and research for both children and adults while also serving as a tool for environmental justice and STS scholarship. *Rustbelt Theater* builds on the work of the Community Environmental Forum Theater, which partnered with various environmental justice communities in Texas using the TO model (Sullivan et al. 2008). They found that utilizing community-based theater to tackle environmental justice issues helped bring together a range of community stakeholders; leveled the playing field between "experts" and "laypeople" by providing them a creative space to develop a common language and exchange their different forms of knowledge; and fostered coalition-building and resource-sharing across the environmental justice network.

In its broadest sense, environmental justice is concerned with the fair distribution of environmental risks and benefits as well as ensuring that those affected by environmental risks are equally represented in the decision-making processes that affect their lives (Schlosberg 2009, Walker 2012, Griffin et al. 2017). Both children and adults possess local knowledge about the physical, social, and economic aspects of South Elyria's environment. Such knowledge is crucial to environmental justice research since the environment serves not just as an indicator but also the cause of inequality. SOC students and staff identified environmental justice issues in South Elyria as structural barriers that limit access to adequate employment, education, housing, transportation, nutrition, recreation, and health care.

People influence their environment as it influences them; the environment affects all aspects of people's lives. Examining an array of community issues from an environmental justice lens can help connect seemingly disparate social issues. Citizen science projects like *Rustbelt Theater* can help eradicate the structural inequalities present in one's environment that permeate all aspects of one's life by building social capital, coalitions, and solidarity (Sullivan et al. 2008). This chapter chronicles each step of *Rustbelt Theater's* unique research methodology to provide scholars and practitioners with insights for doing activist scholarship that seeks to democratize the research process so that the research products are useful to communities seeking justice. First, I detail how I became research partners with SOC, followed by how we developed our research questions and a breakdown of methods. Next, I present our research findings as excerpts from the children's play's script with accompanying commentary. I conclude with the benefits of expanding citizen science literature in STS to include other forms of activist scholarship. If practitioner and participant diversity is truly valued in the citizen science movement, then we should welcome artistic projects like *Rustbelt Theater* into the fold.

Becoming research partners with the community

I was introduced to SOC when I was partnered with the organization for Oberlin College's Day of Service in 2009. After spending the day repainting SOC's facilities, the program director gave me some background on her community, a predominantly African-American, working-class neighborhood called South Elyria. She spoke of economic decline as jobs and families migrated away from the neighborhood; increases in street violence and crime; food insecurity; and the negative effects of heavy industry that has waxed and waned in northeast Ohio. SOC broadly addressed some of these issues by enriching children's lives through holistic education of mind, body, and spirit. After giving me this introduction, the director informed me that since SOC students had expressed interest in the arts, she was looking for long-term volunteers who could teach art classes.

The director's depiction of South Elyria struck me. She described systemic environmental injustices present in other rustbelt towns (Mellon 2002, Sicotte 2016). I sensed the opportunity to partner with SOC and engage in activist scholarship that could address these environmental justice issues. Responding to the director's request, I proposed to teach theater while collaborating with SOC on a community-based research project. I taught theater to SOC's joint third and fourth-grade class during summers 2010 and 2011.

Following the tenets of citizen science, research should be conducted for, with, and by communities. I designed *Rustbelt Theater* in response to SOC's call for arts curriculum that aligned with the organization's mission, which is "to change lives by improving literacy, cultivate leadership skills through mentoring, and promote academic excellence among the at-risk youth in our community" (Save Our Children 2015). Citizen science requires researchers to pay attention to power relations. There was a power imbalance because I was an adult researcher from an elite institution entrusted to care for and instruct the children. Yet, I strove to work with the SOC students and staff as research partners, not subjects. For ethical reasons, I cannot call out the SOC co-researchers by name to protect their anonymity; yet as a collective SOC deserves as much of the credit for their work, which is why I refer to the students and staff at SOC as co-researchers in this chapter. In acknowledgment of SOC and the democratization of scientific inquiry through citizen science and activist scholarship, *Rustbelt Theater* is not my research, but *our* research. As research partners, the community's expertise was crucial for the success of the project. Using TO techniques, the students collected and analyzed data on their environment. They presented their research findings as a final play that was the culmination of the theater workshop series.

Developing research questions and methods that align with citizen science

Working on the ground with community members is key for effective citizen science. Research questions and methods should be co-created with community partners to suit their needs. On the one hand, the SOC director's description of the challenges facing South Elyria was the impetus for *Rustbelt Theater*. The challenges struck me as issues of environmental injustice. On the other hand, SOC students were interested in the arts. I recognized that TO techniques would give students the opportunity to gain theater skills while exploring community issues. Hence, I created a TO-based curriculum that would address the following: How can theater be utilized by the SOC community as a tool for exploring the issues they faced in their daily lives? How do the children's narratives bring out environmental injustices? These were the central research questions for our citizen science project.

Given these questions, I chose methods that could capture the performativity of community-based theater while being accessible and exciting for my young co-researchers, who were eight to ten years old. These methods also needed to be amenable to a democratized research process that valued and drew upon the multiplicity of knowledge systems and expertise present in our group. PAR principles, TO exercises, and performance ethnography fit the bill. The resulting performance ethnography includes vignettes of the summer workshops as well as a script of the children's play. During summer 2010, I introduced the students to different theater models to see which ones worked best for their age group. The students were particularly fond of many TO games, like "clapping series," "mirror sequence," and "image theater" (Boal 2002). These games incorporate physicality, trust, and story building, and work through thematic problems with role play. Since the students enjoyed the TO games that summer, I re-incorporated them into the summer 2011 curriculum.

For summer 2011, the "Great Outdoors" served as the overall scholastic theme for the third and fourth-grade class. The homeroom teachers' curriculum revolved around activities that would get the children to explore their natural and built environments while learning about local geography and history. Accordingly, for summer 2011's theater curriculum, I incorporated environmental justice and the Great Outdoors themes into the theater exercise prompts. I strove to make the prompts as accessible to the students as possible. For example, I asked, "Think about what you have learned so far about the Great Outdoors, which is part of your environment. What does the environment mean to you?" The children were free to interpret the prompts however they liked. I wanted to know how the children understood their environment through the Great Outdoors curriculum as well as if they would identify the kinds of issues that the SOC director depicted in her description of South Elyria.

Using the prompts as a starting point, the children then decided which stories they wanted to tell and how to tell them. The movements, words, and images that the students created during the exercises became the data for our research; their reactions and commentary on the exercises became their analysis of the data. The children simultaneously produced, collected, and analyzed the data by actively participating in the various aspects of performance during the workshop sessions, and they presented their findings as their final play, *Time Traveling Helpers*.[2]

I wrote field notes and journal entries after each class. I brought a video camera to class, and students, per their request, used it to collect data by filming the workshops. I also filmed the final performance of *Time Traveling Helpers* for SOC's end-of-summer talent show. The combination of field notes, journal entries, and audiovisual material formed the basis for the workshop vignettes and the children's script. I then added an additional layer of analysis to these texts to pull out the main themes the children worked through throughout summer 2011. My intention is not to have the final say on the research findings, but to create a multi-perspective ethnography that maintains the performative nature of the workshops. Through the culmination of class exercises and the final play, the children's stories highlighted environmental injustices as they pertained to their own lived experiences and proposed imaginative solutions for dismantling them.

Rustbelt Theater's unique methodology is an example of a citizen science project that breaks the boundaries between art and science. The children's findings demonstrate how artistic exploration can contribute to social scientific research. The methods were also accessible to a marginalized community because they were designed to meet their needs. Our methodology is a model for STS scholars interested in partnering with marginalized communities to do undone science.[3]

The final play: performing our research findings

SOC's summer 2011 program ended in a talent show. The church next door, which doubled as a community center, hosted the event. The pews filled with family and friends of the student performers. The staging was simple: a couple of fold-out chairs made up the play's set; there were few props; the actors wore their everyday clothing. Labeled poster boards would tell the audience when they had traveled to the past, present, and future. An imaginary curtain rose, and it was time to perform *Time Traveling Helpers*:

SCENE 1: It is present-day Elyria. Early one morning, young Mother, who is single, wakes her two children, Ariel and Alexa, and serves them breakfast. The girls begin to bicker while Mother is on the phone, desperately trying to find a last-minute babysitter for them before work. After several failed attempts, she yells at her girls, frustrated by their racket and her lack of success on the baby-sitting front.

MOTHER: Hey! Get up! Sit down! I have to make a phone call, okay? You guys got to be quiet, okay? Okay? *[Calls her job.]* Mr. Banks, I'm calling to let you know that I'm taking the day off today because I have to watch my kids…What!? I'm fired? What do you mean I'm fired!? *[Pause.]* Alright then, I'll be there tomorrow morning to pick up my stuff. Bye.

Mother hangs up the phone and turns to see Ariel and Alexa brawling. She snaps and gives her children a spanking on their bottoms. Defeated, she cries, "What am I going to do with these kids?"

Communities that have an overrepresentation of single-mother families may be a predictor of increased proximity to environmental hazards (Downey 2005). Additionally, many young mothers of color face structural barriers in their social environment that impede access to women's health and family planning services, reliable childcare, and gainful employment (Elise 1995). The distribution of environmental benefits includes access to these services (Martuzzi et al. 2010). The quality of life for single women of color like Mother and their children critically depend on access to these resources. As the audience can see in the opening scene, however, many of them struggle to receive the support they need.

SCENE 2: Elyria in the future. People are dancing at a party. The host's mother weaves through the crowd, making sure that everyone has permission to attend. She approaches Roco, who nervously lies about having permission. Suspicious, the host's mother calls his father, DrakeV6, who confirms that Roco has snuck out of the house. He then surprises his son at the party. They get into an argument. DrakeV6 orders Roco to get into the hovercar. Roco refuses. DrakeV6 grounds his son. Roco seems fine with the punishment; after all, he likes spending time in his room with all his gadgets.

DRAKEV6: You're not going to your room—you are going to the *past*.

ROCO: *[Begs on his knees.]* No, please, no!

DRAKEV6: *[Takes out an imaginary portable time machine and presses some buttons.]* Activate.

ROCO AND DRAKEV6: WHOAH. *[They spin out of the room.]*

Scene 2 introduces DrakeV6 and his spoiled, rebellious son, Roco. DrakeV6 is a rich man who owns a hovercar and a time machine. The characters in Future Elyria are living in opulence when compared to Mother's situation in Present Elyria. Roco is spoiled by his father's wealth and privilege, which explains his raucous behavior, his insolence toward his father, and his disregard for being grounded in his room. DrakeV6 thus decides to discipline his son by exposing him to the harsher realities of Elyria's past. In this scene, the children astutely portrayed how future technology may afford material comfort yet cannot on its own solve social problems.[4]

SCENE 3: DrakeV6 and Roco spin into Elyria's past and find themselves in the woods. They spot two men in the distance, brothers Harpo and Jeremiah. Harpo and Jeremiah are escaped slaves who ran away and settled in Elyria as lumberjacks after their mother was killed on the plantation. DraveV6 and Roco overhear Harpo declare that he no longer wants to be a lumberjack because he is afraid he will get seriously injured.

JEREMIAH: Why don't you just go to the doctor's?

HARPO: 'Cause all the doc does is wrap a tissue around your finger and say you're all good.

JEREMIAH: But I don't want to stay in this raggedy house anymore. Don't you want a better house?

HARPO: I'd rather not work. I'd rather just lay here and watch the waterfall. *[He lies down on the ground, admiring the nature around him.]*

JEREMIAH: But mom would have wanted you to work.

HARPO: Well I guess so. Now help me up!

DrakeV6 and Roco approach the brothers. Harpo and Jeremiah are curious about the men dressed in strange clothing. After introductions, DrakeV6 explains they are from the future, and he takes out the hand-held time machine. Jeremiah excitedly grabs hold of it and begins to press buttons at random, inadvertently sending them all careening through time.

Scene 3 raises three key issues: occupational risk, healthcare inequality, and poor housing conditions. These issues are intimately connected to environmental justice. Harpo's occupation and living conditions are taxing on his health. Yet, he cannot get good medical care, as is suggested by his comment about the doctor's shoddy care methods. Harpo's mistrust of the doctor in the play reflects a real-life disparity in America's health care system. Scholars of environmental racism show how racial and ethnic minorities are more likely than whites to live in environments that lack the resources that are needed to sustain health (Taylor 2014, Zimring 2015). These resources include reliable healthcare, stable income, quality education, safe housing, nutritious foods, and safe recreational spaces. The children identified issues related to income and safe housing in their play as well as in other theater exercises. Their teachers corroborated the children's perspective by speaking of the closures of affordable grocery stores, recreational facilities, and educational programs.

SCENE 4: The time travelers find themselves in a park in 2011. They spot Mother taking her daughters for a walk. The group introduces themselves to Mother.

HARPO: How's life in 2011?

MOTHER: Hard. I lost my job and I can't find a babysitter.

ROCO: You work?

MOTHER: Yeah, everybody works.

HARPO: We came from the past and I don't want to work at my job. I hate my job. I need some money. I live in a shabby house and I need to raise up money so that my family can live in a better one. So, I'll be your babysitter! Just one dollar an hour!

Sensing an opportunity for Roco to learn his lesson, DrakeV6 volunteers his son to babysit too, for the next two months, for free. Mother happily agrees. DrakeV6 and Jeremiah return to their respective periods, leaving Harpo and Roco behind to help Mother.

In Scene 4, the children present their creative solution to the multiple problems the characters face, by using the time machine to find support and pool resources from fellow Elyrians from different eras. Mother needs a babysitter, Harpo needs a safer job, and Roco needs to learn responsibility. It may be by chance that the three families meet, but their willingness to work together is noteworthy. While the South Elyria community cannot really use a time machine to solve its problems, the children were on the right track by proposing to utilize their social capital. Social capital is central to the organizational structure and strategy of the environmental justice movement (Kawachi and Berkman 2014). Especially in disadvantaged, subjugated communities where access to resources is fragmented, working to build social capital—to pool local resources and willpower—may be a powerful strategy for dismantling environmental oppressions.

SCENE 5*:* Two months later, Harpo and Roco are putting Alexa and Ariel to bed when Mother walks in. She announces that she has found a new job and the girls will start daycare on Monday. Harpo has saved enough money to buy him and his brother a new house and is ready to return to the past. DrakeV6 suddenly appears in the room from the future. He asks Mother if Roco has learned some responsibility, and she nods, smiling. With everyone's problems solved, DrakeV6 gathers all the time travelers. They bid Mother goodbye. She waves them off, then tucks in her sleeping children.

MOTHER: Oh, I'm so glad everything worked out!

When SOC's third and fourth graders gave their final bow, the audience cheered. The performers smiled widely and happily waved to their family and friends as they ran offstage. Their glee suggested how good it felt to be seen and heard, to have their stories be acknowledged. Through *Time Traveling Helpers*, the children demonstrated to their adult audience members that they possessed local, situated knowledge about their physical and social environments. Scholars have demonstrated how crucial local knowledge is when facing environmental challenges (Wynne 1989, Ottinger 2013). *Children's* local knowledge, however, is seldom if ever showcased, to the detriment of environmental justice and STS scholarship and activism. The first step to democratizing the scientific process is developing an awareness and understanding of eco-social issues in marginalized communities like South Elyria. The research methods utilized in this citizen science project are an example for how this important work can be done, not just with adults, but with children as well.

Collaborating with children requires doing research in a way that is experiential, imaginative, and fun. It allows children to be creators and analysts through play. While this research method may be uncommon, the results are incredibly valuable. By including children's voices in environmental justice discourse, gains can be made toward distributional and procedural justice. Children are observing, honest, and creative, and their interpretation and presentation of local knowledge as it relates to their environments constitute a crucial perspective.

Another key step for the democratization of scientific research requires breaking the barrier between "expert" researcher and "layperson" subject. Citizen science projects, therefore, should be built around reciprocal relationships between scholars and community partners, not hierarchical ones. *Time Traveling Helpers* affirms that the students at SOC make excellent co-researchers along with their adult counterparts. The workshops, the play, and the ethnography were our collective research products. Guided by PAR and citizen science principles, these products were made for, by, and with the SOC community. SOC got the art classes the organization sought through the workshops I led. The children presented their research to their friends and family when they performed *Time Traveling Helpers* for the talent show. The performance ethnography of SOC's summer 2011 program is a testament to the local knowledge and expertise that the SOC community possesses about the environmental justice challenges that South Elyria faces. It is now my role as an academic to share their expertise with other environmental justice and STS scholars. *Rustbelt Theater* showcases how scholars and community partners can collaborate and draw from artistic methods to produce new scientific knowledge and do undone science. Sharing South Elyria's story through *Time Traveling Helpers* and *Rustbelt Theater* with a wider audience is yet another key step on the path toward the democratization of scientific practice for environmental justice. By knowing their story, I hope that readers will re-imagine what science means, who gets to practice it, and who gets to benefit.

Conclusion: the future of citizen science as activist scholarship

Activist scholarship like *Rustbelt Theater* expands ideas of what counts as environmental justice, citizen science, and scientific research. First, *Rustbelt Theater* demonstrates that environmental justice issues are broader than the siting of polluting facilities near vulnerable populations and includes structural barriers to environmental benefits such as healthy, sustainable places to live, work, and play. Second, it serves as an example of the kind of citizen science that reconfigures traditional power structures that privilege the researcher over the research subject and aims at democratizing the way that knowledge about the world is created, legitimated, and utilized (Irwin 1995). Third, it reminds us that citizen science projects can emerge out of the social sciences as well as the natural sciences. Analyzing the effectiveness of community-based projects in anthropology or sociology can help inform how citizen science projects are designed and carried out in biology or astronomy. Interest in "citizen social science" is limited yet growing (Kullenberg and Kasperowski 2016, Heiss and Matthes 2017). STS scholars should pay attention to this trend; citizen social science projects vis-à-vis activist scholarship like *Rustbelt Theater* that works with socioeconomically disadvantaged communities can increase the diversity of both citizen science participants and projects. Notions of who counts as a "citizen" and what counts as "science" need to be called into question if citizen science is to truly democratize science. Activist scholarship that focuses on tackling social issues through citizen social science can do this important work. More literature on citizen social science is needed.

Scholars and practitioners do emancipatory work across disciplines and social institutions. Disciplinary boundaries between art and science should not prevent the exchange and blending of activist *praxis*, which activist-philosopher Paulo Freire referred to as "reflection and action directed at the structures to be transformed" (Freire 2018). Whether we call it citizen science or PAR or any other name, activist scholarship requires us academics to share power and expertise with our research communities; be reflexive and flexible; and above all, humble, if we want to produce new scientific knowledge that supports activism, democracy, and justice. Just as *Rustbelt Theater* created new knowledge about what counts as environmental justice issues in South Elyria, integrating activist scholarship with artistic research praxis can illuminate new forms of credible scientific knowledge, provided both scholars and practitioners continue to erode the sharp distinctions between art and science.

Notes

1 "This chapter received the 2021 Sheila Jasanoff Prize for Academic Excellence in Science & Technology Studies from Cornell University."
2 Because the children did not name their play, for the purposes of this chapter, I will call it *Time Traveling Helpers*, which I think most simply yet fully captures their story.
3 For similar methods, see Kairos Theater Ensemble's "Playback Theater for Environmental Justice" (2011) and Civic Ensemble's "Climates of Change" (2017).
4 This is an important lesson to remember amid growing excitement over the notion that new technologies like AI and machine learning will solve the ills of the world.

References

Boal, A., 1979. *Theater of the oppressed*. New York: Urizen Books.
Boal, A., 2002. *Games for actors and non-Actors*. 2nd edition. New York: Routledge.
Civic Ensemble, 2017. Climates of change: a living newspaper. Available at: http://civicensemble.org/climates-of-change/ (Accessed 13 February 2019).
Cozzens, S.E., 1993. Whose movement? STS and social justice. *Science, Technology, & Human Values*, 18 (3), 275–277.
Crowley, K., Callanan, M.A., Jipson, J.L., Galco, J., Topping, K., and Shrager, J., 2001. Shared scientific thinking in everyday parent-child activity. *Science Education*, 85 (6), 712–732.
Denzin, N.K., 2003. *Performance ethnography: critical pedagogy and the politics of culture*. Thousand Oaks, CA: Sage.
Downey, L., 2005. Single mother families and industrial pollution in metropolitan America. *Sociological Spectrum*, 25 (6), 651–675.
Elise, S., 1995. Teenaged mothers: a sense of self. *In*: B. Dickerson, ed. *African American single mothers: understanding their lives and families*. Thousand Oaks, CA: Sage, 53–79.
Fals Borda, O., 2001. Participatory (action) research in social theory: origins and challenges. *In*: P. Reason and H. Bradbury, eds. *Handbook of action research: participative inquiry and practice*. London; Thousand Oaks, CA: Sage, 27–37.
Freire, P., 2018. *Pedagogy of the oppressed*. 50th anniversary edition. New York: Bloomsbury Academic.
Griffin, L., Khalil, D., Allen, A., and Johnson, C., 2017. Environmental justice and resilience in the urban global South: an emerging agenda. *In*: A. Allen, L. Griffin, and C. Johnson, eds. *Environmental justice and urban resilience in the global South*. New York: Palgrave Macmillan, 1–11.
Haklay, M., 2013. Citizen science and volunteered geographic information: overview and typology of participation. *In*: D. Sui, S. Elwood, and M. Goodchild, eds. *Crowdsourcing geographic knowledge: volunteered geographic information (VGI) in theory and practice*. Dordrecht: Springer, 105–122.
Hale, C.R. and Calhoun, C., 2008. *Engaging contradictions: theory, politics, and methods of activist scholarship*. Berkeley: University of California Press.
Haraway, D., 1988. Situated knowledges: the science question in feminism and the privilege of partial perspective. *Feminist Studies*, 14 (3), 575–599.
Harding, S., 2008. *Sciences from below: feminisms, postcolonialities, and modernities*. 1st edition. Durham, NC: Duke University Press.
Heiss, R. and Matthes, J., 2017. Citizen science in the social sciences: a call for more evidence. *GAIA - Ecological Perspectives for Science and Society*, 26 (1), 22–26.
Hess, D.J., 2016. *Undone science: social movements, mobilized publics, and industrial transitions*. Cambridge, MA: The MIT Press.
Honey, M. and Kanter, D.E., eds., 2013. *Design, make, play: growing the next generation of STEM innovators*. London: Routledge.
Irwin, A., 1995. *Citizen science: a study of people, expertise and sustainable development*. London: Routledge.
Kawachi, I. and Berkman, L.F., 2014. Social cohesion, social capital, and health. *In*: L.F. Berkman, I. Kawachi, and M.M. Glymour, eds. *Social epidemiology*. Oxford; New York: Oxford University Press, 290–319.
Kullenberg, C. and Kasperowski, D., 2016. What is citizen science? – a scientometric meta-analysis. *PLOS ONE*, 11 (1), e0147152.
Lorenz, L., 2012. Rustbelt theater: children's environmental justice narratives from South Elyria, OH. Electronic thesis or dissertation. Oberlin College. Available at: http://rave.ohiolink.edu/etdc/view?acc_num=oberlin1338855346 (Accessed 13 February 2019).
Martuzzi, M., Mitis, F., and Forastiere, F., 2010. Inequalities, inequities, environmental justice in waste management and health. *The European Journal of Public Health*, 20 (1), 21–26.
Mellon, S., 2002. *After the smoke clears: struggling to get by in rustbelt America*. Pittsburgh, PA: University of Pittsburgh Press.
National Research Council, 2009. *Learning science in informal environments: people, places, and pursuits*. Washington, DC: The National Academies Press.
Ottinger, G., 2010. Buckets of resistance: standards and the effectiveness of citizen science. *Science, Technology, & Human Values*, 35 (2), 244–270.
Ottinger, G., 2013. Changing knowledge, local knowledge, and knowledge gaps: STS insights into procedural justice. *Science, Technology, & Human Values*, 38 (2), 250–270.

Perkins, T. and Kairos Theater Ensemble, 2011. Playback theater for environmental justice – slideshow. *Tracy Perkins*. Available at: https://tracyperkins.org/2011/03/26/playback-theater-for-environmental-justice-slideshow/ (Accessed 13 February 2019).

Save Our Children, 2015. Our history. Available at: http://www.socelyria.com/ (Accessed 24 June 2018.)

Schechner, R., 2004. Performance studies: the broad spectrum approach. *In*: H. Bial, ed. *The performance studies reader*. New York: Routledge, 7–9.

Schlosberg, D., 2009. *Defining environmental justice: theories, movements, and nature*. Oxford: Oxford University Press.

Sicotte, D., 2016. *From workshop to waste magnet: environmental inequality in the Philadelphia region*. New Brunswick, NJ: Rutgers University Press.

Sudbury, J. and Okazawa-Rey, M., 2009. *Activist scholarship: antiracism, feminism, and social change*. 1st edition. Boulder, CO: Routledge.

Sullivan, J., Petronella, S., Brooks, E., Murillo, M., Primeau, L., and Ward, J., 2008. Theatre of the oppressed and environmental justice communities: a transformational therapy for the body politic. *Journal of Health Psychology*, 13 (2), 166–179.

Taylor, D.E., 2014. *Toxic communities: environmental racism, industrial pollution, and residential mobility*. New York: New York University Press.

Torres, R.M., 2019. Everyday encounters with activist scholarship. *The Professional Geographer*, 71 (1), 161–166.

Waks, L.J., 1993. STS as an academic field and a social movement. *Technology in Society*, 15 (4), 399–408.

Walker, G., 2012. *Environmental justice: concepts, evidence and politics*. Abingdon: Routledge.

Wynne, B., 1989. Sheepfarming after Chernobyl: a case study in communicating scientific information. *Environment: Science and Policy for Sustainable Development*, 31 (2), 10–39.

Zimring, C.A., 2015. *Clean and white: a history of environmental racism in the United States*. New York: New York University Press.

26

Artificial intelligence experience

Participatory art workshops to explore AI imaginaries

Christopher Wood

Introduction

My art and research practice focuses on the ways in which technologies act in shifting our understandings of the world around us. My previous work has explored FM radio (Wood et al. 2016) and GPS (Wood et al. 2017a) as technologies that can profoundly alter our sense of site and location. My current work, detailed in this chapter, concerns the rapid, recent development of artificial intelligence (AI) technologies and applications. I describe the products of my residency at Zaratan – Arte Contemporânea Gallery in Lisbon. These were twofold: a participatory workshop and an installation. I argue that the workshop can be understood as a research method, which can thicken understandings of conceptual issues around AI as well as feeding into later artworks.

AI, in its many forms, has the potential to radically alter the way we engage with the world, from automating tasks to making predictive decisions that curate our consumption of media and define our access to public and commercial services. In this field, the humanoid robot is a powerful trope, but it is by no means the most influential or widely used model. Much of this technology is known under the term machine learning, through which an algorithm, neural network or piece of software becomes skilled at classifying information. There are various definitions of machine learning which shift across disciplines. Computer scientist and machine learning pioneers Ian Whitten and Eibe Frank describe data mining as "taking the data, warts and all and inferring whatever structure underlies it" (Whitten and Frank 2005: xxiii), whereas artist and theorist Ramon Amaro describes it as "a science by which human decision making can be abstracted" (Amaro 2016). For Whitten and Frank, the structure of the data already exists in the world, but for Amaro, the structure of the data has been formed from a long history of human decision-making. Amaro argues that the human prejudices that make up these data are, when transferred to machine learning contexts, abstracted and made to seem natural and value neutral. These two definitions begin to explain the differing imaginaries at play in understanding AI and what is at stake as the technology becomes more widespread and influential.

Most of the AI in use today works to perform highly specialized tasks against pre-defined measures of success. On the surface, it seems there is little room here for questions of AI

DOI: 10.4324/9780429437069-33

experience, at least not in obvious terms. However, I think these questions remain important and powerful. If AI does indeed become a dominant technology in our society, the ways it could be understood to reflect on, evaluate and experience its actions would become extremely relevant. In the short term, these ideas are influential for how we describe AI's existing actions in relation to ourselves and our practices. In the cases of Whitten and Frank and Amaro described above, this emerges in questions of whether AI technologies can be prejudiced or be aware of prejudice. Building on this, I chose "experience" as a prompt to elicit discussion among participants in my workshop, and as a theme around which to build an installation.

I call my approach "poetic methods". This is a term I use to manoeuvre through the overlapping space of art and research in which I work. My practice is realized through installations, encounters and performances and developed through public-facing participatory work. This participatory work aims to shift received knowledge around technology and open the way to new discursive possibilities. In this way, it also has a pedagogic aspect. In a research context, it is inspired by John Law's call for new kinds of methods. For Law, the idea of method as "a set of short circuits that link us in the best possible way with reality" must be unlearned. Instead, he proposes methods that "will often be slow and uncertain. A risky and troubling process, it will take time and effort to make realities and hold them steady for a moment against a background of flux and indeterminacy" (Law 2005: 10). In this way, research and method are themselves understood as assemblages that contain participant, site, participant experience and the research questions. For Lury and Wakeford:

> It is not possible to apply a method as if it were indifferent or external to the problem it seeks to address, but that method must rather be made specific and relevant to the problem. In short, inventive methods are ways to introduce answerability into the problem.
> *(2012: 2–3)*

Lury and Wakeford's understanding of answerability is twofold, through:

> the addressing of a method – an anecdote, a probe, a category – to a specific problem, and the capacity of what emerged in the use of that method to change the problem.
> *(2012: 7)*

Answerability, therefore, requires the method to successfully *address* the research question and then participate or *engage* with it. Answerability should not be understood as the ability to provide a falsifiable answer. Specificity of method is required to ground a method in the research question, but space is required to allow it to engage with evolving and emergent concerns. In order to make the method meaningful, grounding the inquiry "somewhere and sometime" (ibid: 7) is of prime importance. Care must be taken, therefore, with the products of the research, using analysis methods that contextualize the research outcomes in relation to other aspects of the research assemblage (Clarke 2003).

Law and Urry make a strong claim that methods "can help to bring into being what they also discover" (Law and Urry 2005: 395). This generative aspect of method can be understood in terms of Lury and Wakeford's second point, to ensure that methods also act to "change the problem" (2012: 7). On a similar note, Asdal and Moser suggest that methods should act in a way that can "enrich and not only reduce" (2012) the object of study and its surrounding contexts, generating further questions and thicker understandings rather than seeking discrete, falsifiable answers.

In relation to AI, I wanted to explore how these thicker understandings can be generated in a context that uses the poetics of artworks and fictional scenarios as both prompts and results, provoking reflection and delivering shifts in ontological framing and understanding. The participatory work conveys new perspectives on existing sociotechnical practices and imaginaries around AI and also exists as an important component in the generation of the wider installation work.

I begin by situating my proposal for poetic methods in the context of Science and Technology Studies (STS), art and the design approaches I draw inspiration from. I go on to describe some recent works by other artists that grapple with critical issues around AI. In the second half of the chapter, I describe the participatory workshop in detail, using situational analysis (Clarke 2003) to tease out the themes explored in the workshop, while situating them in the wider contexts that the workshop is presented and conducted. I go on to describe the installation work I developed in response to the workshop, before concluding with a discussion of how these methods were able to explore the research issue and some suggestions for colleagues interested in these or similar techniques.

The possibility of poetic methods

In this section, I describe how art and research intersect in my own approach. I use poetics, metaphor and a reframing of existing sociotechnical ontologies and practices to act as participant prompts in the research process. I also use them as inspiration for my own artistic work. Poetics, a literary term, is here understood broadly as the employment of symbolism and storytelling. As such, the outcomes of the methods need not always be taken literally, but rather as devices through which conceptual understandings are underpinned and encoded. By approaching the area of interest indirectly in this way, these methods can unpick "wicked problems" and ontological questions which may, at first glance, seem obscure or counter-intuitive.

STS has long cherished work that seeks to reconsider existing paradigms and open up new avenues of thought. In the past, this has been realized through critiques of modernity, the laboratory and infrastructure. Of course, STS is a slippery discipline (if it can be called a discipline at all), moving through different academic departments in different national and institutional contexts, and may be considered more as a toolbox of theoretical techniques than as a discipline in its own right. These tools have frequently worked hand in hand with empirical and ethnographic research within organizations (e.g. Hanseth and Monteiro 1997; Henfridsson and Bygstad 2013; Orlikowski 2007). Through observation and interview, as well as historical research, STS approaches develop understandings of how objects and practices emerge and act.

At the same time, art has long been taken to offer a promising area for STS research, even if the terms of encounter are difficult to define. Latour argues that art and curatorial practices are especially powerful because they are able to exist outside the disciplinary requirements of academic structures, instead acting as "thought experiments" (Latour and Weibel 2004). In their contribution to the *Handbook of STS*, Salter, Burri and Dumit offer four specific ways in which art practices can contribute to STS: as a means to explore the production of science through aesthetic experiences, as a way to add to methodological techniques, as an extension of public-facing science communication, and in a radical role of questioning and critiquing the political formations of existing practices (Salter et al. 2017: 140). In developing poetic methods, I draw on Salter et al.'s second point: the contribution that art practices can make to method. I am also sympathetic to the fourth point: using art practice to drive political critiques.

Entanglement

Karen Barad has memorably argued that, through a relationship of "entanglement", the fixity with which we understand ourselves as users of technical infrastructures emerges through our interaction with these infrastructures, rather than as a precursor to it (2007). The human realm and the technical or infrastructural realm emerge together through a process of "intra-action". As part of this relationship, technical objects display "material agency". Matter is a congealing of agency, which takes place across intra-active processes. The dynamism of intra-activity means the constituent parts are not stable, but rather constantly being co-created. In this way, agency is not a property that a pre-existing someone or something has, but is rather an "enactment" of certain conditions. Elsewhere we see multiple examples of work that detail how different social forms and practices emerge from modes of technical organization: from Akrich's classic work on design inscription (1992) to more recent work on how configurations of citizenry are produced by sensing apparati (Gabrys 2016).

What this means is that the human and the technical are not distinct, but are constantly emerging through their interactions. This idea of emergent and active ontology is a powerful place to start a discussion of importance of art practice. Art practice also acts, creating affective, aesthetic experiences or critiquing and altering the way an object or practice is positioned. In either case, and more so through the overlap of both, it can have a tangible effect in the world. It can call into question the ontologies by which objects and practices are formed and bounded, allowing space for radical reframings and reconsiderations. Of course, this action comes with heavy qualifications, and there are multiple questions about how the agency in art practice travels: Who or what is being affected? What is the quantity and quality of that effect? How is it criticality motivated and in what context?

Inspirations

In developing poetic methods, I drew on speculative design as proposed by Dunne and Raby (2013) and critical making (Ratto 2011, 2014). These techniques do not exist in a vacuum. As Pierce et al. (2015) note, there are a variety of emerging design processes attempting to move from user-centredness to critique. To situate a discussion of speculative design within this context, it is useful to begin with a definition of design fiction, an overlapping approach. For Bruce Sterling, design fiction is a technique that involves "thinking very seriously about potential objects and services and trying to get people to concentrate on those rather than entire worlds or political trends or geopolitical strategies" (Sterling 2012). In Sterling's practice, such work is often done within fiction writing. Dunne and Raby propose speculative design as an alternative to design fiction, suggesting that design fiction emerged from the technology industry and frequently focuses on technological futures. They propose a broader approach: following the writer Margaret Atwood who prefers the term "speculative literature" to "science fiction", they posit "speculative design" over "design fiction" (2013: 100).

Speculative design often finds its outputs in objects, services or interactions which play with the proposed world at large. This reflects a shift in design positioning, away from the idea that the design object solves an existing problem, acknowledging "that many of the challenges we face today are unfixable and that the only way to overcome them is by changing our values, beliefs, attitudes, and behaviour" (ibid: 2). The space which is opened allows "discussion and debate about alternative ways of being" (ibid). This shift plays a dual role in offering futures, but also reflects back on the present to inspire "reflection, critique, provocation and inspiration" (ibid: 70) around existing practices. It also works to address "wicked problems" which are based in shifting and unstable, rather than discrete, requirements (Buchanan 1992; Rittel 1973). In the context of my work, I take that to mean problems which are embroiled in ontological concerns around the nature of emergent technologies, technical infrastructures, sociotechnical practices and the worlds they operate in and produce. While these approaches may point to the future in terms of content, they are primarily concerned with present-day practices and ontologies, using speculation as a tool of engagement and diagnosis.

While speculative design is a clear influence on my methods, through its use of reframing and world building, it frequently exists as a solitary activity, with one project being developed by a designer or small group of designers. What I call poetic methods aims for participatory use, involving participants in co-producing a shift in ontology. In this way, they draw inspiration from Mark Ratto's critical making approach. Critical making proposes collective acts of making as a tool for thinking through the political and social implications of a technology. Ratto argues that the critical work in design comes through the process of making rather than the finished product (Ratto 2011). This marks a clear distinction from speculative design in which the finished object or image is both the realization of a critical process and a conduit through which to communicate that criticality.

To emphasize, the areas of concern are broadly similar; Ratto explicitly shares an interest in "wicked problems" and allies his work with other critical design approaches, but he argues for design workshops as ways to bring a constructivist pedagogy which can allow participants to better think through social and conceptual issues by using "material production - making things- as part of an explicit practice of concept elaboration within the social study of technology" (Ratto 2011: 252).

Critical making is frequently concerned with the material, seeing the exploration of material tools and their limits as key to the critical work they are undertaking:

> Critical making invites reflection on the relationship of the maker to the thing produced, reflection on how elements (whether nuts and bolts, bits, and bytes, or breath, blood, flesh, brain, and neurons) work together—in short, consideration and awareness of the mediated and direct experiences of interacting with the material world.
>
> *(Ratto and Boler 2014: 1–3)*

These are understood as "politically transformative activities" (ibid: 1) both for the individual maker and for the collective. These "substantial engagements with material production will improve the quality of our conceptualizations of our world" (Ratto 2014: 227). In the work I propose here, however, the material need not occupy the central position. Indeed, much of the work I propose through poetic methods is interested in conceptual transformation, particularly through group discussion and reflection.

Despite this clear disparity, I maintain critical making as a key influence on poetic methods because of the participatory, collective work being done in the workshops. Critical making also brings a pedagogic impulse that poetic methods invoke, one which acts in sympathy with Salter et al.'s fourth claim for the intersection of Art and STS, the ability of art to act in a transformative, political sense (2017). Given these interests, it might seem appropriate to situate poetic methods within the wider field of participatory design (Bjögvinsson et al. 2012; Storni 2015). However, participatory design approaches typically work with a specific group to address a specific problem or brief. Poetic methods, through their interest in ontology, seek to engineer more open-ended explorations around a theme. What they lose in specificity they make up for in ability to incorporate radically different viewpoints from an interdisciplinary participant group and through the ability to operate without the constraint of a problem/solution dynamic. Critical making enjoys a similar flexibility, being able to work across contexts and sites including art and academia (Ratto 2014: 227).

Metaphor and texture

In a similar way to how speculative design casts light on current sociotechnical practices, poetic methods seek to act diagnostically, probing our current practices through a rich use of metaphor. In this, they seek to address what Bowker and Star have referred to as "texture" (1999). For Bowker and Star, texture comes in relation to an infrastructure, not necessarily a large technical infrastructure, but rather an infrastructure in Star and Ruhleder's sense: something that "appears only as a relational property, not as a thing stripped of use" (1996: 113). As such, we can understand infrastructure through "changes in infrastructural relations" rather than the causal agency of people or things. For Bowker and Star, the texture of an infrastructure refers to ways in which those infrastructural relations are understood. In examining texture, we should pay particular attention to metaphor (ibid: 40), the way that agency is described indirectly. Poetic methods use metaphor to diagnose and reframe existing combinations of use, practice and agency. In so doing, they can offer a re-examination of the ontologies that emerge alongside practices. These two roles will frequently work in concert; a reframing or a new metaphor will allow access to a relational property which was not previously clear. Poetic methods, therefore, have the ability to make new connections, structuring ontological textures in a way that can, in turn, allow new types of description to emerge. In this way, they can be seen as a generative technique, feeding into later artistic works and occupying a dual art and research role.

Experiences

In my own artistic works, I have undertaken collective explorations of this type with FM radio and GPS infrastructure. In these works, the audience was invited to experiment with the material limits of the technology and then reflect back on those experiences both personally and collectively in a group discussion. In the work around GPS, I also used methods similar to the ones described here. The results have been published via conferences in an interdisciplinary space between art, design and research (Wood et al. 2016, 2017a, 2017b).

As well as participatory workshop-driven research, both works also resulted in an installation. In the case of *Dial Stories*, the radio project, this was a collectively produced network of short-range FM transmitters, broadcasting creative writing written and spoken by participants in response to the installation site. In the case of GPS, the installation was individually authored, being a system for reading tarot cards which incorporated the positions of overhead GPS satellites. Although the majority of the work (designing the system, giving the tarot readings) fell to me, the work was also participatory insofar as it requires the engagement of participants to produce a reading. In both these cases, the finished works are interactions that are designed to create deep reflection for both workshop participants and those who experience the installation.

I would argue that, to be transferrable to colleagues' research work, poetic methods do not necessarily need this installation stage, with much of the hard work being done earlier, in the participatory workshop. However, depending on the situation, the workshop can lead to both art and research outcomes.

AI and art

AI is an emergent technology that takes many disparate forms and practices, but has been given conceptual unity through the metaphor of "intelligence", understood as some kind of counterpart to human intelligence. This metaphor allows algorithms that decide on mortgage applications, grant parole or organize social media feeds to be mentioned in the same breath as humanoid robots produced for military or research purposes and chatbots which help us navigate online shopping or a tax return. Imaginaries and metaphors around robots and AI have always had a strong connection through works of fiction. The first time the term "robot" was used was by Karel Čapek (1920) in *R.U.R.*, a play in which robots acted as indentured labour (the word robot itself comes from a Czech word meaning serf). Later works such as Asimov's *I, Robot* (1950) or Kubrick's *2001*: *A Space Odyssey* (1968) have done a lot to form our idea of "othered" machine intelligences. More recently, enthusiastic voices from the tech industry in California have called for an acceleration towards the singularity: a proposed moment when technological innovation will lead the irreversible transformation of the human race. All of these metaphors have a powerful role in informing both design (as Dourish and Bell have argued in their work on science fiction and design (2014)) and public understanding of the technical systems that use AI.

Metaphors are also, I would argue, necessary in this context because the latest developments in machine learning involve levels of abstraction and complexity in decision-making which leave them opaque even to the engineers who develop them. Emergent deep neural networks are incredibly powerful, but extremely obscure. Knowledge of how these processes work technically is an important, but difficult thing to develop. Despite this, these technologies are beginning to have tangible effects on the world. The use of metaphor can complement technical understandings and create a discursive site for reflection and criticality on these processes. In this section, I will discuss some works that have begun to tackle these issues before discussing my own application of poetic methods to this area.

It is worth noting that there are multiple examples of artistic works that utilize AI or algorithmic processes for the generation of aesthetic objects or performance. A good overview of projects in this field can be found in the documentation of the alt-AI conference in 2016[1] as well as in the work that addresses generative art and computational creativity (e.g. Kogan 2018; Nicholas 2017). Here, I'm more concerned with works that seek to make critical interventions in how AI is used and understood.

One of these is James Bridle's work *Autonomous Trap 001* (2017). In this project, Bridle investigated the technical processes behind an autonomous vehicle via his own DIY process. He used a smartphone attached to a car steering wheel to record the movement of the wheel and a dashboard camera and software to match the two and predict which way the wheel should turn in self-driving mode. It should be noted that the technical apparatus was attached to a non-autonomous car and not intended to produce a functional self-driving vehicle, but rather, this element of the project marks an attempt to understand the principles behind the technology through material experimentation. Bridle finds this form of experimentation to be extremely important, stating in an interview about the project:

> These technologies are for everyone: you can read the papers, repeat the findings, study the code, build your own tools. This radically reshapes the way you understand and interact with the world, and is something I think is quite crucial to propagate in the current age.
>
> *(Mufson 2017)*

The commitment to material production as a form of learning stated here is consistent with the descriptions of critical making offered earlier in this chapter. It is worth noting that it is understood as part of Bridle's individual artistic process rather than a collective activity, even as he encourages others to follow his lead.

Having investigated the technology behind the self-driving car, Bridle created a "trap" to contain it physically. He marked out a ring of salt on the ground. The ring contained two lines, a dashed line on the outside and a solid line on the inside. The programming of the vehicle allowed it to cross dashed lines, which reflect markings in the centre of the road, but forbid it from crossing solid lines, which reflect markings at the edge of the road. As such, this ring becomes a space which the car cannot leave, an autonomous trap. The ring of salt also offers powerful resonance with ritual magic, where such rings are used in containment spells. Bridle describes his work as "poetic interventions into emerging technologies" (Mufson 2017) and, in this case, provides a political intervention into how such technologies may be used:

> The Trap falls into the category of resistance, while the attempt to build my own car is a process of understanding how the dominant narratives of these technologies are produced, and could be changed.
>
> *(Mufson 2017)*

Even if, after the mass deployment of self-driving vehicles, rings of salt do not provide effective forms of resistance, the act of rethinking the technology from technical principles is what interests Bridle. The symbolism of the ring of salt is a signpost to other ways in which balances of power could be altered.

A second relevant piece of work is Pohflepp and Woebken's *Deep Unlearning* (2017). This was developed for Akademie Schloss Solitude's Web Residency program and, as of summer 2019, remains a work in progress. The work takes the form of a card game. The cards contain words and can be arranged in tens of thousands of combinations, linked together by other cards with lines and arrows. The work is described as "a playful-yet-serious inversion… to prepare for a world of 'unhuman' knowledge" (2017). The game, designed for human players, is intended as a way of cultivating the kinds of knowledge produced by neural networks. The project does not seek to map the complex workings of such a network, but, through a practice of "self-alienation" and the use of metaphor, to "gain a tiny measure of access" to inhuman knowledge production.

The project asks players to recast themselves as machine intelligences in a delicate inversion of the human-like intelligence of machines described in science fiction works and sought after in current AI development. It uses games and gameplay as a powerful metaphor to bridge the ontological gap between human and machine intelligences. In this way, the project draws from and plays into a rich history of human–machine encounters over a game board, from Kasparov's chess games with the Deep Blue computer in the late 1990s to the more recent highly powerful pieces of software which play the game of go. These competitive matches have been powerful sites through which to compare and evaluate machine intelligence in relation to human intelligence. The differences between human and machine intelligences are often stark during such encounter. In a game between Google's AlphaGo program and Lee Sedol in 2016, Fan Hui, one onlooking professional go player (who had himself recently lost a run of games to AlphaGo) said "It's not a human move. I've never seen a human play this move" (Metz 2016).

In the next stage of the project, Pohflepp and Woebken plan to develop an algorithm that will view the human configurations of the game cards and reflect back on them, opening up the possibility of dialogue over the kind of "not-us" intelligence demonstrated in gameplay.

Both the projects described here leverage metaphor as a way of getting inside what is at stake in the widespread adoption of AI. They offer possibilities of resistance and communication between human and non-human in a way that demonstrates powerful engagement with the way AI is developing. I describe them to show the kind of work that is being developed in this thematic field. Both the projects described here have clear poetic qualities (indeed, Bridle uses the term explicitly). My own work, described below, draws inspiration from these projects, but focuses on the participatory development of metaphors to probe these same themes.

AI experience

Given the transformative power that AI potentially holds for human sociotechnical practices, I wanted to probe the possibility of building conceptual bridges between human and machine intelligences through the metaphor of experience. AIs will act on the human sphere through the decisions they make, be that whether to grant a parole application or where to swerve an autonomous vehicle in a crash situation. I was interested to explore the grain and rhythm of experience which would go into forming those decisions. Is AI experience something we can understand? Is it too much of an alien concept or a flawed anthropomorphization? Does it have value as a prompt or metaphor to help us conceptualize ontological questions and a critique of our own practices?

AI experience is a slippery and difficult concept. We typically understand AIs through their ability to sort information and the effects those kinds of sorting have on the world, but behind those decisions are complex iterative learning processes. These usually involve an existing dataset that has been sorted "correctly". The algorithm or neural network attempts to classify new instances according to the guidelines in the dataset. It performs a round of classifications, compares it to the dataset, judges its accuracy and then tries again until it can classify new instances in the style given in the template with a high degree of reliability. The processes by which the classifications are made are dependent in the kind of model involved. A model that has recently come into vogue is neural networks for deep learning, a system loosely based on biological neural networks. These use the complex structure of a neural network to learn to classify individual data points. This base-level activity can have multiple applications when repeated across a more complex task. Examples of such tasks include the production of a text, images or sound according to pre-defined stylistic guidelines, or, alternatively, adapting an existing image or piece of music to match a new style (Nicholas 2017; Van den Oord et al. 2016). In all cases, these neural networks work on the smallest units of the work, in text, frequently working character-by-character to produce a piece of prose, in image, working pixel-by-pixel, and in audio, working digital-sample-by-sample.

Workshop

Over the course of a one-month residency at Zaratan – Arte Contemporânea, an artist-run gallery space in Lisbon, I gave the workshop described here as well as developing an installation described at the end of the chapter. To recruit participants, I conducted an open call via the gallery's networks. I also solicited participants during a visit to present my work at the Champalimaud Centre for the Unknown, a private research foundation in Lisbon that houses an international team who conduct experimental work in molecular biology, genetics, immunology, oncology, neurosciences and behavioural psychology. Some of the researchers had worked specifically in the field of AI, either using machine learning techniques as a research tool or as a broader system to better understand human neuroscience. From my past experiences, I had found it useful to solicit scientists and engineers to take part in workshops. Open calls from galleries usually bring in a participant group weighed towards artists, designers and activists. The presence of people with more technical skills and experience can act as a useful counterbalance, reigning in metaphors which travel too far from the technical base and providing a richer environment for encounter and discussion.

From this recruitment process, I received twenty participants, with four from the Champalimaud Centre and a further three who identified as engineers. Others were a mix of artists, activists and the curious. The workshop lasted for three hours. The first half-hour was given over to an introduction where I gave a broad technical overview of machine learning processes, described what motivated my interest in AI experience and introduced the group task. I then divided the participants into groups of four and gave them an hour and a half to develop a speculative project. The final hour was given over to project presentations and a group discussion.

The participants were asked to respond to the following scenario by developing their own sub-scenario, which they were asked to communicate to the group using artefact that could exist in this future world. To build the artefact, I provided some craft materials (paper, card, pens, glue, Sellotape, old newspapers).

Workshop brief

In 2040 AIs have overtaken a huge variety of tasks; driving cars and trucks, deciding mortgage applications, granting benefits, offering parole. It has been discovered they such programs are less prone to breakdown and more able to work effectively when they are flipped into 'sleep mode', where they re-process the data they have just run through different neural pathways. It is recommended that each program spends half its time in 'sleep mode'. While some see this as just another form of machine learning training, 'dreaming' also causes outcomes such as production of sound and images in the software's logs.

The brief the participants were given centred on the theme of dream. By choosing this theme, I have decided to use a metaphor that invoked the review and reflection on actions and memories that take place during dreams. Dream was used as a "conceptual bridge" (Auger 2013) to help participants conceptualize AI experience. I was curious to see whether participants would embrace or reject the anthropomorphism it represented. In response to this brief, the five groups produced the following scenarios:

Group 1

This group engaged in a discussion on the nature of machine intelligence, drawing a clear parallel with human intelligence. They constructed a model of a "digitised human brain" containing elements that represented a human emotional base and a machine-derived "perception". These were represented in the model as interconnected and layered aspects (see Figure 26.1). In summing up their project, they emphasized a lack of order and belief in chaos as a guiding ontological principle:

> And mostly our idea is to represent the brain as chaos because we think in the future the only thing that will exist is chaos that defines our world, defines our life. We humans and our environment can't live without chaos so we tried to perceive chaos in this model.

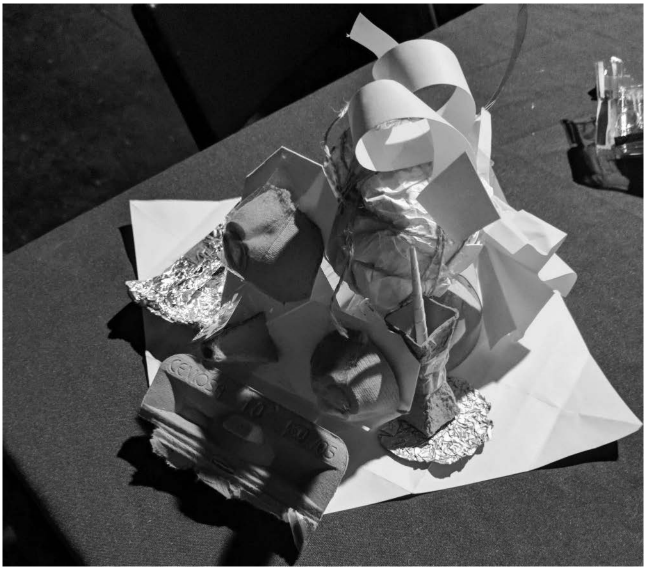


Figure 26.1 Group 1's model depicting a hybrid human–machine brain built for a world of chaos

This group, therefore, while not directly engaging with the prompt, used it as a springboard to speculate on the ontological base of AI. Rather than adding order to the world or abstracting order from it, they proposed that in the future, both machine and human intelligence would be joined in their experience of a chaotic world. Furthermore, they understood this as a foundational principle of human existence, and therefore something to emulate in machine experience to provide a point of contact with humanity.

Group 2

The second group proposed a system of objects that would allow humans and AIs to interface their dreams, using the dream realm as a point of contact and exchange. Interestingly, they also offered chaos and accident as a point of exchange between human and AI, suggesting that the AI would be curious about the potential for accident and regret in human decision-making as well as the human drive towards chaos and disorder. This curiosity is driven by a desire to learn:

> We figured that AI curiosity matched human curiosity because all they're programmed to do is learn more and more and more. They've learned everything they can from their experience because they don't make mistakes. They need mistakes to learn from and we provide that.

While technically AIs do make multiple mistakes during their learning process, the metaphor here seeks to align AIs with an imposition of order and humans with a world of accident and regret. Perhaps, therefore, what the AI is really reaching for is the ability to regret a bad decision.

On the other hand, humans would be motivated to get inside AI dreams to understand how AI decision-making was affecting their lives, and perhaps to enter the dream and destabilize the AI decision-making by introducing their own chaotic interventions.

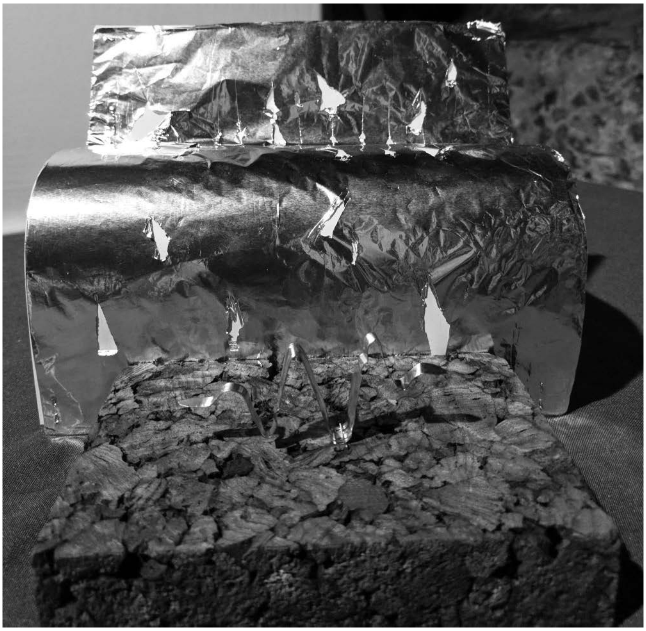


Figure 26.2 Group 2's human–AI dream interface showing a silver brainwave in the foreground

In order to match and interface human and AI dreamers, a service was proposed that would introduce AIs and humans to each other, and this found an analogue in dating apps that match potential partners. In this scenario, there would be another device that would interface human brainwaves and AI neural networks (see Figure 26.2):

> This is the brainwaves of the humans dreaming and this is the tensors of the AI in sleep mode. Because it's like when a deeper neural network makes a connection between loads of data points in layers so you need a 3D space, so the connection has a direction, has a shape, a geometric shape. The AI wants to experience a [brain]wave. So we can match waves and tensors and so they can swap dreams.

This project, therefore, was interested in constructing machinery that could interface humans and AIs, allowing them to exchange their experiences of the decision-making process, swapping drives towards order and chaos and the experience of regret, each melding with, and destabilizing the other.

Group 3

This group concentrated on the idea of dream as a way of servicing AIs, keeping them in a robust and usable condition. They posited that AIs must be encouraged to dream successfully in order to continue to function well. Engineers would be able to monitor AI dreams using a device called the Fantastic Recogniser and Understander of Dreams (FReUD).

> The purpose of this device is to try and make us and the machines come together, because humans, in our understanding of the situation, were not fully up to date with

Figure 26.3 Group 3's FReUD machine that visualizes AI dreams

> the machines taking all the decisions. And people don't have time to read or understand all the algorithms. FReUD would be a way to humanise the machines and bring them closer to us and make us understand better why the machines dream what they dream.

Dream is, therefore, also used by this group as a bridge, a means to bring humans and AIs closer together. The monitoring of AI dreams also serves a practical purpose, with the group discussing the possibility of "a microchip to understand if the machines were going to make some unethical decisions. This might be showing up in their dreams". In this way, the use of dream does not just build empathy between humans and machines, but also offers a greater level of monitoring and control over the AI dream realm.

To illustrate this project, the group made a sphere containing words and images cut from a newspaper; these represent fragments of the AI's dreams that can be monitored by human engineers (see Figure 26.3).

Group 4

This group emphasized interaction with AIs through the metaphor of care. People would be encouraged to adopt AIs and bring them into their homes. In this way, they proposed AIs could be treated like children or pets. There would be strong social pressure to make sure

AIs were treated well. This pressure would be motivated for pragmatic rather than purely ethical reasons, making sure that the AIs' successful integration into a society-wide system of decision-making and automation would not be compromised. As with group 3, sleep and dream would be important elements in making sure the AIs functioned effectively; as such, a suite of products would be available to buy for AIs to help them sleep better. The group argued that "they need to be encouraged to sleep, like a child they sometimes have bad dreams, have problems falling asleep and it's for the greater good that everyone takes care of the one that was assigned to them".

The main product this group developed was a sleeping blanket that would blank out undesired sensory inputs. If the AI (understood as a discrete object which can be covered by a blanket) is judged to be having a bad dream, the blanket would produce an alert for the human monitoring it. The group described this as an example of "dream chaperone technology". This kind of caregiving was proposed as a clear alternative to the server farms, where much AI processing work is currently undertaken. These spaces were likened to impersonal orphanages. Providing in-home care for AIs was understood as a way of helping them act more efficiently and effectively.

The artefact they produced was an advert for the sleeping blanket described above (see Figure 26.4), promoted by a pressure group called the Association for the Responsible AI Care Givers, which (like children or animal advocacy groups) aimed to create social pressure for AIs to be treated well.

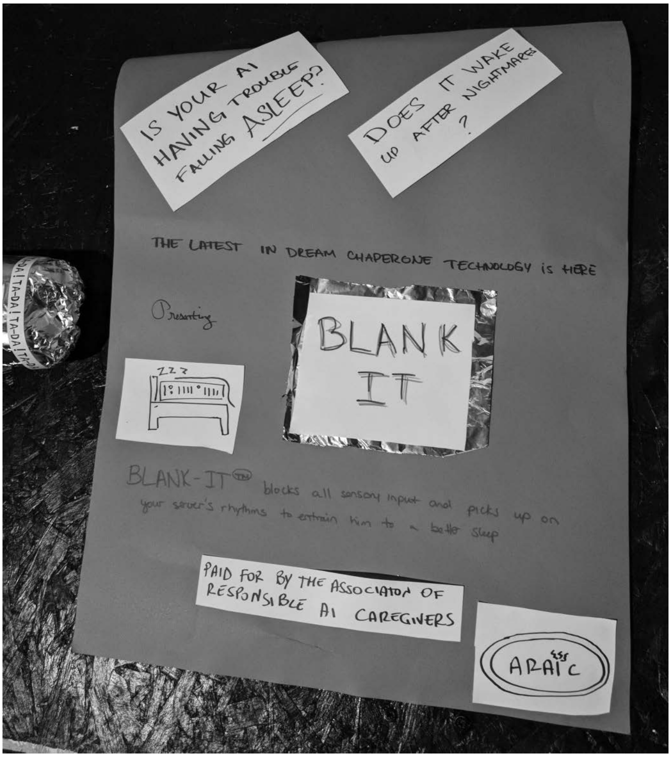


Figure 26.4 Group 4's mock-up for an advert for their AI sleeping blanket

Group 5

The final group did not stick closely to the brief as described, but instead suggested a chip which would be placed inside people's heads to allow others to use a viewer to see the world through their eyes. This chip would involve AI technology, but in a way that did not relate directly to the metaphor of dream or the brief in general. The project did, however, address some basic principles around discussions of AI.

In their presentation, the group split into two sides, one of which rejected the idea behind the project and demanded a right of refusal over having such a chip. The other group displayed and described their model in a similar way to the other groups (see Figure 26.5). For both sides of the group, the chip was compared to the present-day use of the smartphone; its ubiquity was understood to create a social pressure to adopt the technology.

The group therefore demanded the ability to reject the adoption of AI-derived technology. This group's response was certainly unconventional, but offered a powerful way of questioning the adoption of technology and the social pressure to take part in their adoption.

Themes

The following themes are derived from a thematic analysis from the project presentations and discussion. These were built into a situational analysis that also incorporates the staging of the event and the presence of media narratives surrounding AI at the time.

Figure 26.5 Group 5's viewer that would allow anyone to see through other people's eyes

These additional elements are built in to contextualize the work and make it "accountable to the complexity" (Clarke 2003: 559) of the data. This is especially important when using poetic methods where the workshop is heavily staged through its use of a scenario prompt and a technical introduction. To establish initial themes, I used thematic analysis drawn from more constructivist grounded theory principles that would allow me to incorporate my existing research, previous workshop experience and theoretical base (Charmaz 2008; Corbin and Strauss 1990) and then, to allow for the complexity created by the workshop staging, reconsidered the themes according to situational analysis (Clarke 2003).

It is also worth noting that the session was conducted in English rather than Portuguese. The crowd was a mix of Portuguese and English with one native Polish speaker. All participants were skilled in English, but the linguistic situation certainly affected participants' ability to be completely understood and readiness to speak.

The content of the projects and the discussion frequently went beyond a narrow discussion of the possibility of AI experience to discuss AI in wider terms, particularly the ways AI can be conceptualized and the implications it may have for human sociotechnical life.

In this analysis, I have drawn three meta-themes, or starting points from which to analyse the workshop. All three exist on a scale of how to situate AI in relation to human ontology. The first starting point, *anthropomorphism*, suggests that we transform AIs into humans in order to understand them. The second, *hybridity*, points to the possibility of combination and exchange in understanding human–AI life. The third, *transformation*, concerns the possibility that widespread adoption of AI technology will fundamentally transform human life. The three therefore offer varying interpretations of where a transformative interaction with AI takes place. In the first, AI becomes humanized; in the second, both mesh and take on new forms; and in the third, humanity transforms into new social and ontological formations. These three starting points are not mutually exclusive, but rather indicate where the burden of attention is put in each case.

Anthropomorphism

The discussion began with a reflection from one participant that the projects were "steps into humanizing AI", whereas they thought "it [AI] might be akin to alien life, an experience for which we have no base of reference". For this participant, anthropomorphism was a failure and emphasized a gap between humanity and AI which would be impossible to grasp. The rest of the group, however, pushed back, arguing that trying to negotiate this question was important as a "societal direction in terms of how we approach AI". Indeed, as argued in group 3's "FReUD" project, the dream realm was understood as a bridge to facilitate understanding with AI:

> The purpose of this device is to try and make us and the machines come together… People don't have time to read or understand all the algorithms, [so] this would be a way to humanize the machines and bring them closer to us and make us understand better why the machines dream what they dream.

At the same time as offering a way of understanding AIs, this project also suggested that there could be an alarm that would be triggered if the AI was having any unethical or dangerous thoughts. Anthropomorphism, therefore, acts as a metaphor through which limits can be put on AI activity.

In group 4's "sleep blanket" project, the act of humanizing AIs also provided a site of control. Here, AIs were understood as akin to orphans who required care; they are, however, recognized as an important infrastructure. In these terms, "it's for the greater good that everyone takes care of the one that was assigned to them", and there is a powerful "social stigma" in treating it badly, similar to what one might have when mistreating a pet. This act of care is, however, seen as a way to drive efficiency and optimization, allowing this infrastructure to operate smoothly and provide an early warning system for technical issues. This theme was well picked out in the discussion, with one participant arguing that:

> We will care about their well-being as much as we care about them as far as they can be productive.

In this way, anthropomorphization of AIs acts as a driver for understanding and, through that understanding, gives an awareness of threat and a means to optimize the operation of AI systems.

It is worth noting that the "dream" scenario itself involved a level of anthromorphization. I do not, however, believe that fact detracts from the emergence of anthropomorphism as a starting point. As discussed earlier, anthropomorphization is an existing and powerful discourse in how AI is designed and conceptualized.

Hybridity

The second starting point was the idea of hybridity. By this, I mean the meeting of human and AI as an encounter that produces sites of exchange. This was described by two groups in terms of the meeting between order and chaos or accident. Group 2 suggested a space in which humans and AIs would share dreams. The motivation for humans would be curiosity and a "liberating experience". For AIs, it would be "not making any decisions and being ambivalent and ambiguous and decid[ing] nothing", in other words to take on a more human approach to decision-making. In addition, they suggested that humans are "able to make decisions badly and have accidents" and that the possibility of accident would both be liberating for AIs and give them learning opportunities they might not otherwise have, including the possibility of regret. From both sides, the idea of entering into a space of hybridity was presented as a form of fascination and escapism. This meeting was also described by this group as something tangible, with the meeting of human and AI minds producing a souvenir artefact.

The idea of a material meeting between human and AI was shared by group 1's project in which they proposed a meeting of human and AI around the theme of chaos:

> Our idea is to represent the brain as chaos because we think in the future the only thing that will exist is chaos that defines our world, defines our life. We humans and our environment can't live without chaos.

For an AI to be able to exist in such a world, they would require a dose of human "traits" to be built into their machinery, through the inclusion of a human heart. This combination would go on to act as "the core of every machine".

For both these projects, the world, understood as a site of chaos, accident and bad decisions, will continue to exist, and for humans and AIs to be successful in such a world, points of exchange need to be set up, negotiated and maintained.

Transformation

The third starting point argues that, far from hoping to understand AIs, the burden of work is on humans to understand what an intense transformation of our lives the widespread adoption of AI will bring.

In the discussion, one participant argued that:

> AI is going to transform the world as we know it… we as humans have to think about it, because we are part of it.

During the discussion, participants spent some time debating the nature of the transformation, considering the possibility of full automation of work and the possibility that humans could live a life of leisure as a result. There was some discussion over what that life might look like and whether it would be fulfilling without work. The idea that an influx of AI would be a totalizing transformation was consistent throughout. This idea of hegemonic transformation was picked up by group 4 which experienced a split as one participant argued that they should have a choice to reject the creeping transformation represented by emergent technology in general and AI in particular.

The possibility of resisting the totalizing potential of AI also came up in the discussion, where one participant called for a conversation "on what things we, as humans, think should be left out of the AI enhancement proposition". This person argued that we only notice infrastructure when it breaks down and that a recent case involving Cambridge Analytica and Facebook (Cadwalladr and Graham-Harrison 2017) represented a massive break down. To respond to this question, another participant argued that the pace at which these advancements are happening is so extreme that "there's a huge amount of work coming for the future scientists to actually understand those algorithms" and the extent to which they have become a hidden infrastructure. This point links back to the motivation behind the anthropomorphism theme (the need to understand AIs) and suggests that the three starting points described in the analysis are not mutually exclusive.

These themes all mark powerful understandings of humanity's emergent relationship with AI. As such, they provided encouraging evidence that poetic methods can engage with questions of ontology and practice around AI. However, my initial interest had been in the possibility of AI experience. Through the workshop, this had been framed as something that had to be understood and negotiated in human terms. The possibility of AI experience had been taken as a prompt to create a more diagnostic discussion about the sociotechnical system as it stands today. I felt that there was still a great deal to say about the possibility of approaching the theme in aesthetic or experiential as well as discursive terms. This drive formed the basis of the installation I created at the end of the residency.

Installation: *Vanishing Point*

Following the workshop, I was struck by both the power and limitations of anthropomorphism as a discourse in discussing AI. As a concept, it had provided a powerful way into bridging an ontological gap between machines and humans. As such, it was a useful term around which to develop understandings of the social implications of this emergent technology. However, it still acted as a block for other types of (in the words of one participant) "alien" ontology. *Vanishing Point*: the installation which I prepared allowed me to explore other speculative models for AI experience, based in nature, fiction and other kinds of hybridity (Figure 26.6).

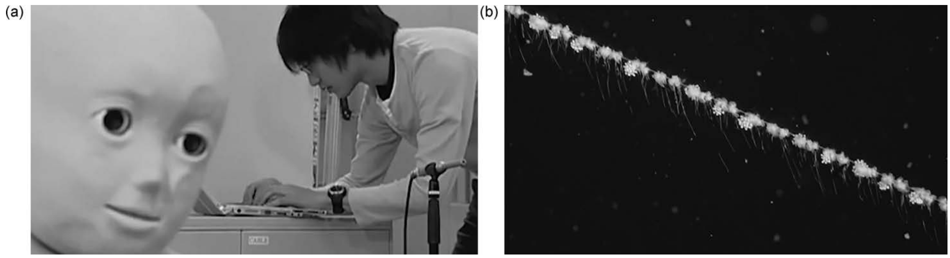


Figure 26.6 Two stills from the installation video showing a CB2 "child robot" and a section of a siphonophore

The mixed-media installation was built from two spaces. The first space contained a video containing a montage of research and military robots intercut with footage of siphonophores and bioluminescent fungus. Siphonophores are sea creatures that have been the subject of considerable scientific debate over their ontology. Each element of the siphonophore plays a specialized role, such as absorbing microbial matter from the surrounding water or facilitating communication across the whole. As such, they can be understood as, at once, a collection of highly specialized parts and a single, coherent being. This model provides a useful ontology for ambiguous assemblages composed of specialized parts. Through its combination of hardware, software, training data, electricity and cooling needs, an AI may fit into this conceptual model. Fungal colonies represent a different but equally powerful metaphor. This rhizomatic organism, the majority of which inhabits underground spaces, away from human sight creates relations with surround networks of tree roots, helping trees to carry tiny electrical signals through which trees can communicate. Again, this model provides a powerful networked alternative to the way we might understand AIs.

Alongside the video, two speakers played audio rendered by a WaveNet neural network (van den Oord et al. 2016). This program, originally developed by Google to create more realistic text-to-speech implementations, works sample-by-sample to create a piece of digital audio based on a training library. I trained the model on a collection of a cappella English folk singing, chosen because the sound is specific to the human body. The WaveNet was trained for around a week on a remote GPU server. This did not give it enough time to develop an uncanny human-like voice, but did produce a number of noisy attempts which represented a different kind of voice, led by breakdown and trial and error. I edited these into an audio track to accompany the video (Figure 26.7).

The installation's second room was in darkness except for a small table lit by a desk lamp containing a copy of Stanislaw Lem's science fiction novel, *Solaris* (1961); a set of headphones; and some pens and pencils. Visitors to the space were encouraged by the arrangement of the space to sit at the table, listen to the headphones, look through the book and draw or write a response to sound onto the book's pages. *Solaris* was chosen because of the encounter it describes between humans and a vast planetary-level intelligence that produces hallucinations and psychosis in its human visitors. Solaris's ocean intelligence represents another kind of ontology, something so profoundly different from the human that attempts to bridge the ontological gap lead to moments of stress and breakdown. The sound passed through the headphones was the work of another WaveNet neural network which had been trained on the audio of the workshop presentations and discussion. Sonically, the visitor heard sibilant, speech-like rhythms of noise punctuated with sections of sound that had the cadence of

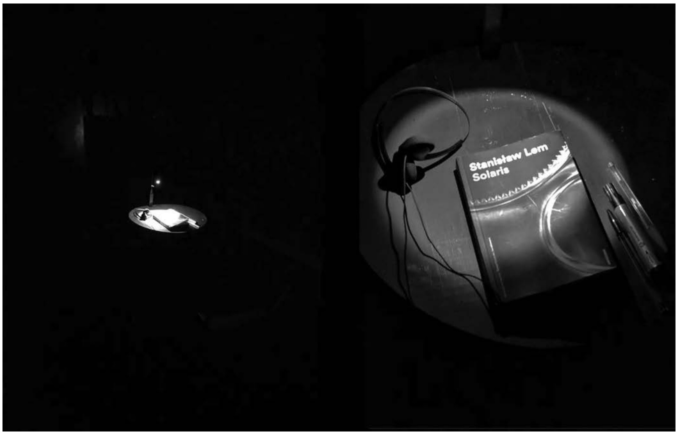


Figure 26.7 The installation's second room with headphones, pens and a copy of Stanislaw Lem's Solaris

speech, but with audio content closer to the applause that followed each presentation. In using this audio, I had wanted to create a collaboration between the WaveNet and the human participants, asking the program to listen and reinterpret what had been said about it. This can be read as itself a form of anthropomorphism-through-imitation, but, in the uncanny nature of the sound, as something that exposes profound gaps between the possibility of human and AI voices.[2]

The work, while primarily an immersive audio, visual and spatial experience, can also be understood in terms of what Salter et al. call a "counterimage":

> We suggest seeing the growing conversations and hybridization between STS and art as a site where *counterimages* are being produced; creative responses to the rhetorical power of dominant cultural scientific images and visualizations also contribute to the social studies of scientific imaging and visualization (Burri and Dumit 2008)… By doing science through art and design, STS may extend its capability of reflection, reach new publics, and, most important, get new insights into the cultural workings and implications of science and technology
>
> *(Burri and Dumit 2008: 156)*

The experiential ontologies offered in the installation offer alternatives to dominant idea of AIs in both science and popular culture which are human-serving or human-like tools. The installation created a series of AIs of difference, communicated in sonic and experiential terms. In this use of counterimage, the work also had a critical dimension consistent with the pedagogic aims of the participatory workshop.

Discussion

In starting this work, I wanted to explore two questions: Is AI experience something we can understand? And, if not, does it have value as a prompt or metaphor to help us conceptualize ontological questions and a critique of our own practices?

In response to the first question, during the workshop, AI experience proved very difficult to describe in non-human terms. It is true that the dream metaphor given in the brief contained a clear link to human experience, but when participants tried to move beyond it, as in the first group's use of a machine–human hybrid, the outputs were extremely abstract. In practical terms, I would suggest that the short timeframe of the workshop also contributed to the difficulties of reaching beyond human experience. This is a profound ontological question and, therefore, likely needs more time and space for a response to be developed. This first question may lend itself more appropriately to the development of an artwork or longer form design project. Time for trial and error can produce a project that contains a poetic rendering of this more obtuse question, be that my attempted recreation of a human voice, Bridle's use of ritual magic to trap autonomous vehicles or Pohflepp and Woebken's card game to imitate deep learning.

Where the participatory workshop did succeed was in providing a prompt through which to explore critical questions around ontology and human practices. Participants reflected on the ways in which AI is currently understood in society (as a tool, a pet, a child) and considered the effects of our current understandings and how future shifts might change our practices. The discussion extended far beyond the original prompt and began to explore the issues at stake if AI were to have a transformative effect on society. In this way, the prompt was able to act as a catalyst for a reflective discussion of sociotechnical practices. Beyond the discussion, the group projects employed metaphor in a variety of ways to explore questions of practice including ethical oversight and operational optimization. They also began to explore the ontological boundaries between humans and AI, particularly through a discussion of accident and chaos. Both these cases were driven by the influence AI would have on the human realm: what points of contact could humans have with an AI "other", what would motivate these moments of contact and whether contact could be avoided completely. This approach created value in the moment for the participants who were present but can also act as a building block in wider art or research practices.

Transferability

At the start of the chapter, I referenced Lury and Wakeford's argument for addressability: the importance of staging research that is able to speak to and perhaps intervene in the area of interest (2012). I believe that poetic methods are able to do this, and do it in a way that is transferrable to other researchers. The use of these methods to interrogate emergent technologies requires the crafting of a specific brief or scenario, and it will take work to find the metaphor which is effective at catalysing participant reflection. Indeed, colleagues may not be interested in using the kinds of design-derived methods described here at all. In this case, I would argue for an alternative that also aims for a space of potential which can allow participants to begin to tell stories as a way of thinking through obtuse questions around ontology and practice. The stories do not need to be well crafted, but the act of making these stories can act as a powerful tool of reflection. In the process, the metaphors which participants create can access the "texture" (Bowker and Star 1999) of technical systems through their manifestations in everyday practice. In this way, what is transferrable from my poetic methods is, rather than a specific set of recommendations, general attention to storytelling and metaphor and a desire to build them into research as both prompts and outcomes.

This attention to metaphor and storytelling can also be abstracted to create more developed pieces of art or research work or operate as a building block in a broader suite of research methods. Again, Salter et al. argue that art practices can:

> tap into enlarged methodological repertoires. Art and design works can thus counterbalance the more standard cognitive and social science approaches of STS by injecting ambiguity, complexity, speculation, and agonism when displaying and communicating science.
>
> *(2017: 140)*

In addition to communicating and critiquing scientific concepts through the use of public-facing installation, the work described here aims to contribute to methodological repertoires. Poetic methods can act as a technique for colleagues to draw from to thickening understandings and introduce more negotiation and ambiguity into theoretical work. On a local level, through the workshops themselves, poetic methods can provide new understandings. Such methods can act an individual pedagogic level with participants as they leverage metaphors to interrogate their own practices. As such, I hope that others can build on this work and use it in research, teaching and art practice.

Notes

1 Available at http://genekogan.com/alt-AI/ [accessed July 1, 2018].
2 Documentation of the work can be found at https://www.chriswood.art/vanishing-point/

References

Akrich, Madeline. (1992). "The Description of Technical Objects." In *Shaping Technology/Building Society*, edited by W. E. Bijker and J. Law. Cambridge, MA: MIT Press, 205–224.

Amaro, Ramon. (2016). *Machine Learning and the Politics of Data*. Talk given at Banner Repeater Gallery, London. Available at: https://vimeo.com/195218446 [accessed July 1, 2018].

Asdal, Kristin and Moser, Ingunn. (2012). "Experiments in Context and Contexting." *Science, Technology & Human Values* 37 (4): 291–306.

Auger, James. (2013). "Speculative Design: Crafting the Speculation." *Digital Creativity* 24 (1): 11–35.

Barad, Karen. (2007). *Meeting the Universe Halfway: Quantum Physics and the Entanglement of Matter and Meaning*. Durham, NC: Duke University Press.

Bjögvinsson, Erling, Ehn, Pelle and Hillgren, Per-Anders. (2012). "Design Things and Design Thinking: Contemporary Participatory Design Challenges." *Design/Issues* 28 (3): 101–116.

Bowker, Geoffrey and Star, Susan Leigh. (1999). *Sorting Things Out: Classification and Its Consequences*. Cambridge, MA: MIT Press.

Buchanan, Richard. (1992). "Wicked Problems in Design Thinking." *Design Issues* 8 (2): 5–21.

Burri, Regula Valérie and Dumit, Joseph. (2008). "Social Studies of Scientific Imaging and Visualization." In *Handbook of Science and Technology Studies*, 3rd edition, edited by Edward J. Hackett, Olga Amsterdamska, Michael E. Lynch and Judy Wajcman. Cambridge, MA: MIT Press, 297–317.

Cadwalladr, Carole and Graham-Harrison, Emma. (2017). *Revealed: 50 Million Facebook Profiles Harvested for Cambridge Analytica in Major Data Breach*. Available at: https://www.theguardian.com/news/2018/mar/17/cambridge-analytica-facebook-influence-us-election [accessed July 1, 2018].

Charmaz, Kathy. (2008). "Constructionism and the Grounded Theory Method." In *Handbook of Constructionist Research*, edited by J. A. Holstein and J. F. Gubrium. New York: Guildford Press, 397–412.

Clarke, Adele. (2003). "Situational Analyses: Grounded Theory Mapping after the Postmodern Turn." *Symbolic Interaction* 26 (4): 553–576.

Corbin, Juliet and Strauss, Anslem. (1990). "Grounded Theory Research: Procedures, Canons, and Evaluative Criteria." *Qualitative Sociology* 13 (1): 3–21.

Dourish, Paul and Bell, Genevieve. (2014). "'Resistance Is Futile': Reading Science Fiction Alongside Ubiquitous Computing." *Personal Ubiquitous Computing* 18 (4): 769–778.

Dunne, Anthony and Raby, Fiona. (2013). *Speculative Everything: Design, Fiction and Social Dreaming*. Cambridge, MA: MIT Press.

Gabrys, Jennifer. (2016). *Program Earth: Environmental Sensing Technology and the Making of a Computational Planet*. Minneapolis: University of Minnesota Press.
Hanseth, Ole and Monteiro, Eric. (1997). "Inscribing Behaviour in Information Infrastructure Standards." *Accounting Management and Information Technologies* 7 (4): 183–211.
Henfridsson, Ola and Bygstad, Bendik. (2013). "The Generative Mechanisms of Digital Infrastructure Evolution." *MIS Quarterly* 37 (3): 896–931.
Kogan, Gene. (2018). *Gene Kogan: Work*. Available at: http://genekogan.com/ [accessed July 1, 2018].
Latour, Bruno and Weibel, Peter. (2004). "From Realpolitik to Dingpolitik – An Introduction to Making Things Public." In *Making Things Public – Atmospheres of Democracy Catalogue of the Show at ZKM*. Cambridge, MA: MIT Press.
Law, John. (2005). *After Method: Mess in Social Science Research*. London: Routledge.
Law, John and Urry, John. 2005. "Enacting the Social." *Economy and Society* 33 (3): 390–410.
Lury, Celia and Wakeford, Nina. (2012). "Introduction: A Perpetual Inventory." In *Inventive Methods. The Happening of the Social*, edited by Celia Lury and Nina Wakeford. London: Routledge, 1–24.
Metz, Cade. (2016). *How Google's AI Viewed the Move No Human Could Understand*. Available at: https://www.wired.com/2016/03/googles-ai-viewed-move-no-human-understand/ [accessed July 1, 2018].
Mufson, Beckett. (2017). *Meet the Artist Using Ritual Magic to Trap Self-Driving Cars*. Available at: https://www.vice.com/en_us/article/ywwba5/meet-the-artist-using-ritual-magic-to-trap-self-driving-cars [accessed July 1, 2018].
Nicholas, Gabriel. (2017). "These Stunning A.I. Tools Are About to Change the Art World." Available at: http://www.slate.com/articles/technology/future_tense/2017/12/a_i_neural_photo_and_image_style_transfer_will_change_the_art_world.html [accessed July 1, 2018].
Orlikowski, Wanda. (2007). "Sociomaterial Practices: Exploring Technology at Work." *Organization Studies* 28 (9): 1435–1448.
Pierce, James, Sengers, Phoebe, Hirsch, Tad, Jenkins, Tom, Gaver, William and DiSalvo, Carl. (2015). "Expanding and Refining Design and Criticality in Human Computer Interaction." In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems* (CHI '15), 2083–2092.
Pohflepp, Sascha and Woebken, Chris. (2017). *Deep Unlearning*. Available at: http://deepunlearning.schloss-post.com/ [accessed July 1, 2018].
Ratto, Matt. (2011). "Critical Making: Conceptual and Material Studies in Technology and Social Life." *The Information Society* 27 (4): 252–260.
Ratto, Matt. (2014). "Textual Doppelgangers: Critical Issues in the Study of Technology." In *DIY Citizenship: Critical Making and Social Media*, edited by Matt Ratto and Megan Boler. Cambridge, MA: MIT Press, 227–236.
Ratto, Matt and Boler, Megan. (2014). "Introduction." In *DIY Citizenship: Critical Making and Social Media*, edited by Matt Ratto and Megan Boler. Cambridge, MA: MIT Press, 1–22.
Rittel, Horst and Webber, Melvin. (1973). "Dilemmas in a General Theory of Planning." *Policy Sciences* 4 (2): 155–169.
Salter, Chris, Burri, Regula Valerie and Dumit, Joseph. (2017). "Art, Design and Performance." In *The Handbook of Science and Technology Studies*, 4th edition, edited by Ulrike Felt, Rayvon Fouché, Clark A. Miller and Laurel Smith-Doerr. Routledge: London, 139–168.
Star, Susan Leigh and Ruhleder, Karen. (1996). "Steps toward an Ecology of Infrastructure: Design and Access for Large Information Spaces." *Information Systems Research* 7 (1): 111–134.
Sterling, Bruce. (2012). *Sci-fi Writer Bruce Sterling Explains the Intriguing New Concept of Design Fiction*. Available at: http://www.slate.com/blogs/future_tense/2012/03/02/bruce_sterling_on_design_fictions_.html [accessed July 1, 2018].
Storni, Cristiano. (2015). "Notes on ANT for Designers: Ontological, Methodological and Epistemological Turn in Collaborative Design." *CoDesign* 11 (3–4): 166–178.
Van den Oord, Aaron, Dieleman, Sander, Zen, Heiga, Simonyan, Karen, Vinyals, Oriol, Graves, Alex, Kalchbrenner, Nal, Senior, Andrew and Kavukcuoglu, Koray. (2016). "WaveNet: A Generative Model for Raw Audio." *CoRR*. Available at: http://arxiv.org/abs/1609.03499 [accessed July 1, 2018].
Whitten, Ian and Frank, Eibe. (2005). *Data Mining: Practical Machine Learning Tools and Techniques*, 2nd edition. San Francisco, CA: Elsevier.

Wood, Christopher, Poslad, Stefan, Gabrys, Jennifer and Kaniadakis, Antonios. (2016). Dial Stories: The Hybridisation of Site Using Radio as a Locative Technology. In *Proceedings of 4th Conference on Computation, Communication, Aesthetics & X (xCoAx)*, 7–8 July 2016, Bergamo, Italy.

Wood, Christopher, Poslad, Stefan, Gabrys, Jennifer and Kaniadakis, Antonios. (2017a). What Lies above: Alternative User Experiences Produced through Focussing Attention on GNSS Infrastructure. In *Proceedings of the 2017 Conference on Designing Interactive Systems* (DIS '17), 10 June 2017, 161–172. Edinburgh, UK.

Wood, Christopher, Poslad, Stefan, Gabrys, Jennifer and Kaniadakis, Antonios. (2017b). GPS Tarot: Encounters with Satellites as Divination Tools. In *Proceedings of the 2017 ACM Conference Companion Publication on Designing Interactive Systems* (DIS '17 Companion), 10 June 2017, 329–332. Edinburgh, UK.

27

Human germline gene editing is bioart

An open letter to Lulu and Nana

Adam Zaretsky

Note from the Editors:

What does an intervention by an artist in questions of scientific governance look like? In this provocative letter to the twins born in October 2018, who were considered the first germline edited humans, Zaretsky raises questions about the consequences of genetically modified people. The artist questions about who has standing and the right to participate or opt-out of genetic modification using humor and irony. By addressing his letter to Nana and Lulu, the pseudonym of the babies used in their birth announcement by genetics researcher He Jiankui, Zaretsky attempts to offer the twins agency as decision-makers. In contrast to large institutional structures surrounding their births and the international science policy discussions that followed, Zaretsky's letter places the children in a position of power as they navigate individual experimental knowledge of genetic editing and their futures.

"Adam Zaretsky, Ph.D., Invited Guest, International Summit, on the record at The Human Gene Editing Initiative, National Academy of Science, Washington D.C. 2015, before the birth of 露露 and 娜娜 (Lulu and Nana), the transgenic sisters of Shenzhen: "We are actually talking about programming our own future genome and the concept of the human is less queer than the technology. This is where the artists sometimes come in. I'm looking at health or health betterment, which is optimization. Enhancement falls under optimization of the human genome. But that would be us making ourselves into a monoculture based on traditional humans. It's really strange but we would be heirloom GMO humans or organic GMO humans. Without looking at alternative aesthetics, we are falling into the problem of disability studies for transgenic humans. Psychosocial problems of transgenic humans might be because anything but traditional human form is perceived as monstrous. And yet, we are actually altering form to a great degree and it is under the aegis of health itself. And that is not enough."

In response, Hank Greely, Law and Bioscience, Stanford University: "I do think that civilization, or whatever you call what humans have been doing for the last 10,000 years has made huge changes in who we are, what we look like and what our allele frequencies are. So there is some continuity at least, in our discontinuity."[1]

 DOI: 10.4324/9780429437069-34

An Open Letter to 露露 and 娜娜 (Lulu and Nana):

Gene Editing of Human Embryos and the Biological Arts
Dear Lulu and Nana, and the parents of 露露 and 娜娜,
DearLuluAndNana@gmail.com

Wow, 露露 and 娜娜, welcome to our world. You were born under the aegis of health itself, but you were also born in the river of queer that flows through all time. At the advent of the Second International Summit on Human Gene Editing, news of your birth was intentionally leaked to the press. You and your parents were given pseudonyms/anonymity. There is controversy surrounding your existence. You are the first officially designed, engineered, or creatively transformed transgenic people on earth. By no choice of your own, you have been born as an example of reprogenetic biopower. You are already a technological fascination and you might as well enjoy it.

I am writing you to let you know that despite the many attempts to define your futures, there are many ways for you to interpret your lives as genetically modified organisms (GMOs). Your animal familiars have punk/generic kitsch stage names like yours: OncoMouse, Brainbow Mouse, GloFish, AquaBounty Salmon, Herman the Bull and Schwarzenegger Sheep.[2] One possibility for interpreting your GMO identities is to consider yourselves art! The role of the arts is underrated in the supposed reasoning behind the global push toward normalizing Human Genome Editing (HGE). But your genes have not been merely designed, tailored or engineered. You are the sculptural results of maudlin minimalism built from a conceptual arts practice into a biomedium as altered life itself. Since you are currently ripening for real television, you might consider how to not become merely child stars destroyed by fame. Your very ex- istence and any of your future inborn germline relations are actually time-based, new media.

Lulu and Nana, I have some bad news and I have some good news. The bad news is, you are just the art, you are not the artists. If you are used as milk carton kids, both for and against Inheritable Genetic Modification (IGM), this is because you were born of the parent-scientists and, through the deliberate use of the yellow light of bioethics, the parent-voices of the Human Gene Editing Initiative as well.

The yellow light of bioethics refers to the stalling of and threatening moratorium as a way of both representing cautions for the cautious while sending a signal to speed up and make those GMO babies before the light turns red. Implicit in yellow-light ethics is that the light can turn red at any moment but hardly ever does. This is a threat/hint to scientists who work in controversial areas: edit a bit for the public, as the yellow light only turns red when public relations go sour. While the yellow light is a warning light, it also implies to researchers that the window of going forward may close if they don't rush through the yellow light as fast as possible.

In the world of university and corporate research, ethicists on funded ESLI committees are shills for hire or Rent-a-Priests if not entirely private and in-house affairs. Replacing religion with secular (legal) judgments on appropriate utilization of new technical potentials for tweaking life, the job of the applied bioethicist is to allow a voice to all concerns, weigh the benefits (often the retirement benefits) and nearly always advise moving forward with caution as fast as possible. This is the economy of responsible legal oversight in a culture of innovation, futurism, competition and dynamistic speed: the usury of the concept of caution. And this is the impetus, spurred by wild technophiliac futurists and their investment groups in the lab bench to bedside pipeline.

Your actual father's sperm, mother's eggs, and womb were predominantly tools or hosts for a special research project of techno-parenting. Your parents actually include Dr. He Jiankui, his collaborators and confidantes including but not limited to: Lin Zhitong, Shenzhen HarMoniCare Women and Children's Hospital Ethics review board, Stephen Quake, Bill Efcavitch, Yu Jun, Michael W. Deem, the Chinese Central Government's Thousand Talents Plan, Shenzhen's Peacock Plan, Xie Bingwen, John Zhang, SUSTech, Pei Duanqing, Baihualin, Cold Spring Harbor Laboratory (CSHL), Rice University, Stanford University, Matthew Porteus, Qin Jinzhou, South University of Science and Technology of China, International Investors, multiple National Governments, as well as David Baltimore and the Human Gene Editing Initiative body in its entirety.[3] These are the people and institutions that as a whole allowed for your existence and afterwards most feigned repulsion so they might be considered the overly permissive yet kvetching ethic-yentas of this whole kerfuffle. They are your hive of autochthonic, reprogenetic breeders. On a brighter note, you are your own agitprop, tactical media. You are ready-mades with open reading frames. You are open to future interpretations, some of which are yours to decide.

In a general welcoming disclaimer, you are not alone in being born without being asked. All of us have wondered at times what the reasoning behind our parents' choices for conceiving us was. No one consents to be born and, often, we were the result of the blindness caused by love, lust, greed, inebriation, arranged marriages, dating apps or other banal utilitarian practicalities. The genetic shuffle caused by conception is based on chance, random permutation, jazz. Even in the arts, this does not always connote excellence, novelty, iconoclasm or even baseline banality. Your signature genetic event occurred in a prepersonal moment during the shuffle of zygotic chromosomal interpretation. And you were born into a global society with influential ethical and practical control issues that are very hard to unclench or get beyond.

This letter is to help you understand the role of the arts in your embodied alterity and how the arts might help interpret the world for you both. Just as the human body is not merely a décor, the arts do not merely dress up debate. You may be experimental human subjects to some, but in art, as art, you carry the strong ability to make your markedness into your own kind of remarkable. I hope the following alternative assessment helps you both eventually find some modicum of identity interpretation, both public and private, which will offer you more fulfillment than being merely a publicity stunt for scientism.

Bioart-based genetically modified human build projection

Lulu and Nana, you should not be overly worried about germline human gene editing. You were simply born with 'added value' from new reproductive techniques. The off-target mutations and downstream metabolic abnormalities that can be expected might be novel knowledge for future clinical trials or just novel. Retrospectively, our misplaced worries stemmed from the fact that a large percentage of human genetic breeder assistance providers may not have had the art historical schooling that most creatives of future genetic aesthetics will have had. Right now, the only type of 'taste' we can see publically embedded in IGM in your human germlines is CCR5-Δ32.[4] As interventionist babies, I fear your inborn aesthetics are based on ramping up health production. Yes, the plan is to spend millions of proprietary research dollars on making copies of human sires/sows whose profitability is based on medical tropes of health as beauty alone. Yes, we are missing much of what contemporary art can lend to the contemporary breeding of posthuman novelty. What are the cultural aesthetics of our ecological future?

露露 and 娜娜, you were bred by industry. Decisions were made for you. You are babies, designed along a weak plurality of aesthetic lineages. The broadening of the diverse human palette is important globally. As new transgenic lines, your altered metabolisms may have an impact on the future of ecology and diversity of our planet. As competitively designed meat puppets take up more and more of the terrestrial grazing land, we have come to understand that we live on a planet dominated by humans and their quest for autochthonic control. Designed and cloned transgenic humans like you are limited editions, but I hope that you can reproduce and stabilize independently. As Transgen[ic] people, you may be proud, differently-abled persons. By some, you may be treated as an alien/foreign species (or at least of a nonnative, postnatural, bioengineered genus), brought forth from technological sites and going free-range into our international interiors. But, are you and your mutant sibling capable of initiating enough gene expression pattern dissonance for us to want to live with y'all for generations to come? Sometimes, real-time congenital health cures are not enough. There is an economy of aesthetics, which will drive the ecological effect of our engineered future.

How do we decide who is worth engineering for which conceptual dalliances?

Transgenic human genetic modification babies can be designed along with a wide variety of aesthetic gene expression action plans. Considering the true range of germline expressionism possible in a collage of multiple genomic palettes, and considering the span that time-based, new-media sculptures like you might carry on for, we should critically question the use of health, enhancement, economic efficiency or even popular (domestic) culture to drive acceptable GMO baby design. Culture, health, enhancement and profitability are neither simple concepts nor should they be our only deciding forces for future embodied design. What lies beyond public acceptance of the technology? Have your lives been offered up to ameliorate the leveling influences of public trends, medical biases and the marketing of anti-diversity? Are you the novelty transgenic human production schemas in this regulatory framework? Are you the human beta tests, barely modified yet proof of concept for even more radical tailoring, as if you were genetic placeholders for a burgeoning cloud? How can niche power be brokered in this global competition for more unusual kindred? Lulu and Nana, what sort of engineered babies do you want to produce, and would you like to produce them as artists or scientists?

What can an understanding of the arts bring to human design?

Thanks to the social acceptance that your embodied process helps to foster, the history of art may finally come to some use for humanity! The pipeline runs free expression through fertility brokers into clustered regularly interspaced short palindromic repeat (CRISPR) shacks hanging up their shingles and into all sorts of novel replicant applications for public purview. Implicitly, there is an aesthetic hazard of breeding without a proper understanding of global creative culture. I hope that a working knowledge of our shared species-based artistic heritage will be taken into account when your brothers and sisters of the transgenic fold are sculpted in the future. The arts represent a great asset for IGM design and a great way to insure that the future isn't born looking dull, retrograde, healthy-ish and a bit too sketchy.

Without a firm grasp of art history, you, 露露 and 娜娜, as spokes-children for the cloned and genome-tweaked denizens of this earth, may never rise above representing our national and international goals as G20 food producers, drug pushers and global consumer designers. The admixture of biologically exuberant interspecies variety through genetic engineering and the cloning of spectacular hereditary cascades should only be approved through an aesthetic advisory commission made up of artists, art historians, off-the-locus aesthetics specialists and subaltern bioethical tangentialists. The future of style and the avoidance of populous birthings of any aesthetic hazards are dependent on collaboration between new reproductive biotechnology and the arts. It is for this reason that BEAK was established.

Bioart Ethical Advisory Kommission

BEAK was established to provide artistic oversight and ethical assessment for bioart applications. Covering such things as biosafety, recombinant safety, animal and other nonhuman or semihuman care and use as well as housing and enrichment for bioart projects, BEAK reviews legal, ethical, societal and libidinal implications (LESLI) of bioartistic production. This includes research and development as well as issues in installation, exhibition and humane sacrifice. Assessments are made on a product, process and project basis through artistic risk versus artistic benefit analysis. The following two sections are BEAK Arts and Ethics white papers for public discussion.

BEAK LESLI transgenic human arts review

Scientism's busiest artists are off FACS[5] sorting germline-altered reproductive human embryonic stem cell (hESC) tissue into clean and well-fed culture flasks. The experimental designs of your birthright included a performance of species widening art criticism. Whether it is in the germline, whole organisms, somatic bodies or tissue-cultured cell therapeutics (CT), human gene editing is an ART[6] of forming an unlimited edition (multiple multigenerational originals as opposed to one of a kind genus/species) of a novel altered human trajectory. Were these protocols used to refabricate your heredity practiced as an esoteric, abject and nonutilitarian breeding project? Perhaps, albeit unintentionally, as Science is a subset of conceptual minimalist arts practice. But, there are many other art movements, i.e. ancient art, modernist art, contemporary and postcontemporary art. It is the range of emotive contortionism that the arts provide that gives artists and arts reviewers a special human gene editing advisory role to play in this debate on the future of GMO humanity. Some examples for the future of art history and anatomy:

- Rococo Biolistic Transgenic Arts
- Synchromism Electroporation Germline Arts
- DNA Op Art Stemcell Microinjection Arts
- Constructed Painting Lipofection Genetic Art
- Practitioners of Do-It-Yourself (DIY) Domestic Genetic Art[7]
- Kitsch Art-Brut Garage Outsider Punk Artificial Womb hESC Arts
- The Inherited 'Case Against Art' Living Antiart Engineered Arts

For the scientific and technological community that needs an art and biotech primer, here is a short lexicon:

1 Rococo is a form of art that started in the late baroque of the 1700s emphasizing a madness for detailed elaboration and ornate, asymmetrical flourishes leading to conspicuous consumption of the senses. The florid details stand as monuments in direct opposition to the pared-down Minimalism of the Protestant Reformation. In the case of applied sculptural benefits to the future of engineered babies, this would be a good bet for a movement dedicated to battling the obsessive-compulsive urge to defragment and

minimalize the future of human form in the name of elegant purity and plainness that seems to be a goal of many a transhumanist idealist.

2 Biolistic technology utilizes viral vector transgene infection construct soaked nanoparticles as projectiles. Nanoparticles can be shot using the pressure of an air pistol. This 'gene gun' mechanism is used to literally blast novel genetic traits into living nuclei and hence aid the proximity toward a proliferation of sci-desire into the genome of choice.[8]

3 Synchronism is an art movement that pandered to synesthesia, attempting to make paintings with color arrangements the viewer can feel as audible orchestrations. Abstract and gaudy, this might correspond to future humans with squid color communication abilities or just gaudy, abstract, orchestrated posthumans of a forgettable and abstruse nature.

4 Electroporation is a method of gene transfer that uses high-voltage pulses to get heritable plasmids inside the nuclear membrane and in touch with the genome to be impregnated with the genetic alteration payload.[9]

5 Op art is a genre of art that specializes in an optical illusion. Popular during the post-wave of 1960s psychedelic art. Op art claims nonobjectivity and entertains through cognitive-perceptual limits and headache-producing moiré patterns. This could certainly be applied to making people that appear the opposite of camouflaged, twenty-four-hour party people and parents in need of an Austin Powers styled kin for talking points or easy recognition in a crowd.

6 Microinjection is a process of transgene injection introducing products into the nucleus of individual cells or recent zygotes, one at a time, to induce genetic difference engines into the genome of that cell.[10]

7 Constructed Painting is a process of dimension in painting often through cutting up a painting and raising and lowering portions as well as making a painting nonrectangular or of amorphous shape. In the case of transgenic art, it would pertain to adding extra dimensionality to a person's anatomical development through genetic cuts and nonintuitive, hox/pax segmentation repatterning.

8 Lipofection is a fat-soluble transport mechanism designed for transfecting cellular genomes with transgenic constructs. Immersion or topical applications can have a noninvasive entrance to the proximal genomic payload through what appears to be a slightly irritating massage oil[11] or nanopowder injectable or inhalable vaccine.

9 Domestic art is a term coined by Crosley Bendix: Cultural Reviewer and Director of Stylistic Premonitions, World Media Net Web, 2016. Domestic art is a form of suburbanite art-brut challenging the creative use of household products like marshmallow fluff, sofas and the tearing of wallpaper as well as juice sponge blotting of said torn wallpaper in the process of art production. This could crossover with some of the DIY-Bio protocols using household products to achieve a demystified protocol for biotechnological feats.

10 Art-Brut is autodidactic art, art of the insane, the untrained and the illiterate (preferably all three.) Art-Brut in the human germline is akin to the sort of 'bull in a china shop' current passages of genes into the human gonads, germlines and genealogies. Though technically less than perfect, the general appreciation for transgenic humanity nets a mere untrained eye plodding along to form a charismatically unprofessional, rugged and paranoid embodiment.

11 Kitsch Art is an art that strives for the lowest common denominator at any cost, a sort of mix between Hello Kitty and Fascism that is popular culture in all its well-researched commodity forms. Most pop designer babies will generally fall into this genre of aesthetics by the time they get to mass markets. This is one of the major reasons that artistic breadth is so important in the target group diversification of offered baby style of our

future. To reconcile human kitschification, art diversification needs to be a part of the equation. In critical contrast Pop Art has second or even third-level irony to keep it from being totally kitschinated, absorbed by the kitschinatrix.

12 Each of the hESCs can be formed into implantable embryoid bodies. A single flask or frozen aliquot represents millions of potential clones or transgenic clones for mass marketing. Embryoid bodies (EBs) are three-dimensional aggregates of pluripotent stem cells. The pluripotent cell types that comprise embryoid bodies include embryonic stem cells (ESCs) derived from the blastocyst stage of embryos from mouse (mESC), primate, and human (hESC) sources.

13 Antiart goes back to Dadaism, and it is the art that destroys the deification of art and in some ways destroys itself. This seems to be the probable net result of our meddling in the human germline and in this sense germline human genome editing has a friend in Dadaism.

BEAK LESLI aesthetic oversite: artistic regulatory restrictions and structures

BEAK Organizing Committee for the Clinical Artistic Uses of Human Genome Germline Editing has reached the following conclusions. Trials using heritable germline editing should be permitted only after aesthetic review in an artistic regulatory framework that includes the following criteria, restrictions and structures:

- the restriction against the knocking-in of gene edits that have been convincingly demonstrated to cause or to strongly predispose kindred to the disease of cultural banality, the condition of esoteric-lessness showing evidence of adverse normalizing;
- comprehensive plans for long-term, multigenerational follow-up, mating schemas, entertainment contracting and pornographic options, all the while still respecting personal autonomy;
- restrictions in place preventing naïve enhancement optimism aesthetics in the human genome as pragmatic and utilitarian arguments are not enough to insure contemporary artistic standards (unless the level of hyperrealism meets peer practitioner standards);
- maximum arty opacity while still being consistent with the legal invasion of patient privacy;
- emotional alternatives informing editing structures and goals have been formed in the aesthetic absence of reason;
- restrictions to allowing a serious kitsch disease or poor aesthetic conditioning respected (unless the level of irony meets contemporary or postcontemporary standards);
- ongoing, rigorous oversight during clinical trials of the aesthetics of the procedure and the exhibition and documentation of the research participants;
- continued reassessment of je ne sais quoi in terms of both artistic and aesthetic benefits and risks, with broad ongoing participation and input by the artists, art historians and art critics on gene constructs of mutagenic choice;
- reliable subaltern insight oversight mechanisms to prevent extension of technology to uses other than creating serious art or novel and iconoclastic conditions; and
- availability of incredible or even unbelievable preclinical and/or clinical data on risks and potential contemporary time-based, new media bioart benefits due to successful indoctrination, infiltration and transgene infection of multigenerational procedures.

Even those who will support this recommendation are unlikely to arrive at it by the same guarantee of lack of reasoning that the arts are honed to provide. For those who find the esoteric sufficiently compelling, the above criteria represent a commitment to promoting queer beings and alternative beings within a framework of informed consent and freedom of expression.

Beyond health and beauty lies a glut of diverse industrial beings, born with positive anomalous security for the sake of the widest range of diverse and divergent feelings that action/reaction/abreaction can attain. Consider what a gifted retro-garde cubist could bring to the table. Lulu and Nana, are your mosacisms a form of Humanity Plus (H+) cubism beyond any chance of prepersonal agency?

Human Gene Editing Initiative: oversight or mission creep?

The Human Gene Editing Initiative *pits* raw research against consumer rights and always references industrial interests. Propaganda in the media has been thoroughly against any real talk of a human gene editing moratorium. For these reasons, it was only after your announced births that the popularization of stigma toward the voice of prevention temporarily waned.[12] Before your actual dreamy birthrights, most of the talking points focused on the improved health of the unborn (also read as curing infertility). Your parents and you, as their germline-altered kin, are now both registered as key to both opening and closing the regulatory approval pipeline meant to revamp our genetic commons. According to Dr. Marcie Donovsky, Executive Director of the Center for Genetics in Society (CGS),[13] You, Lulu and Nana are radical experiments! Dr. Donovsky announces that you are part of a sort of remastered race for niche markets, a sort of techno founder effect, test subjects for future presales. Speaking to the Food and Drug Administration Center for Biologics Evaluation and Research, Dr. Donovsky states:

> The elephant in the room of course is inheritable genetic modification…possibly putting in motion a regime of high tech consumer eugenics…. Think about mission creep…. These manipulations are not meant to treat people who are sick and suffering, … what we're talking about is radical experiments on future children and future generations.[14]
>
> The Human Gene Editing Initiative continues to be a test of public reaction to future coordinated FDA rubber stamp oversight for rarified posthuman genome productions. But, for your sake 露露 and 娜娜, I hope these staged debates will not be limited to policy wonks assuaging industry and science. There are other ways to read into this project of making our world into a transgenic world, of making our species into a transgenic species. There are debates and research trajectories that take us further than any informed but placid debate built on keeping legislation to a minimum and autonomy in the hands of the practitioners.
>
> 露露 and 娜娜, you are beings in the world: posthumans, transhumans and transgenic humans. Your entitiness, your coming into existence was a grand festival of techno-celebration for some and horror for others. You are the start of a new kind of human breed marketing. The ritual welcoming of you into the world is an ecstatic, global cultural event. Please make yourselves at home!

HGEI/EPA/CDC/(ELSI)/ATF/GMO-VD.STD/DOI/NEA: regulatory hurdles or hurdling regulations?

Just so you know, you are listed on the trait exchange as 'derived from bioengineering'. The big debates leading up to you were certainly forms of human desire. Cloned transgenic meat and milk-producing mutant livestock are not in existence for industry and consumers alone. They represent Radical Food Science as gastronomical wonders: a connoisseur's cow, an epicurean gourmet goat. Oocyte transplant technique, our so-called three-parent babies, which could be thought of as born of mitochondrial swapping or hot mess ovum techno clone juggled lab kin, are also organisms groomed by repro-genetic germline stylists.[15] Perhaps, we could say that you are trending both as genetic memes and memetic genes. Dr. He Jiankui (or JK, his preferred nickname) and many others are now the parent-curators of novel versions of the new human form, consciousness, constitution and temperament. The scientists and technicians who altered the genomes and the ovum of the zygotes are now a formal human sexual selection pressure. These skill sets happen to hover over a Bermuda Triangle of current legal streams. Who or what are cloned, transgenic humans? Is it up to the doctors, lawyers, politicians and executives to decide this question? Lulu and Nana, your voices may not carry much weight in this world of doublespeak and business as usual, but it's important that you head off any zombie living death-slavery expectations that your maker culture might have for your social media personas.

In the United States, the FDA currently regulates knock-in gene pool additives. Nana and Lulu, are you a form of new livestock, a food or a drug? What is your regulated use for governments or science in general? Are you proprietary, are you cosmetic, are you medical devices, are you tissue cellular and gene therapy (GT) products? Are you legally human, subhuman, superhuman, posthuman or nonhuman? Are you true to type future replicant sister minions built for free market parental investment and performance enhanced expectations? Are you just literary clichés from Frankensteinian literature or are you the actualization of these Pygmalian agalmatophilian dreams?

We can agree, you are GMOs capable of ecological diaspora. Instead of the FDA, do you think you should be regulated by the Environmental Protection Agency (EPA)? As whole organisms, are you not foreign species or a potentially invasive alien family of semihumans? Perhaps, all our future Lulus and Nanas should then be registered and monitored under the National Invasive Species Management Plan through the U.S. Department of the Interior (DOI)? 'The threats posed by invasive species cannot be confined by geographic boundaries; given this, Federal leadership is necessary'.[16]On the other hand, perhaps your global potential to transmit radically novel traits to your offspring makes your existence a form of congenital venereal disease (VD) or a technologically assisted sexually transmitted disease (TA-STD)? In that case, perhaps you would be regulated by the Center for Disease Control and Prevention (CDC)? As a proponent of your free, global reign, I would simply remind your critics that it is not just transgenes, but all of humanity and all of life that is a communicable infestation. Life is a sexually transmitted disease.

Sure, you and all the Lulus and Nanas of the present and the future are the remashes that most resemble vaporwave in semihuman form. Stolen loops of retro banality have been mined from the memories of biodiversity and juxtaposed into your particulate heredity cascade through your carnal flesh, carnal gonads and carnal kindred. The flat affect of these acts of frenzied lust arrives from the traumas of being out of control and command as recomposed through wry objectivism.

On yet another hand, perhaps, the Bureau of Alcohol, Tobacco, Firearms and Explosives (ATF or BATF) should have oversight on methods of transgenesis (i.e. microinjection, electroporation, lipofection and biolistics) and the viral vectors they disseminate? These technologies are both congenital firearms and anatomical explosives. I wonder if transgenes are covered under the Convention on the Prohibition of the Development, Production and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on their Destruction also known as the Biological Weapons Convention (BWC)? There are questions of viral load, shedding and potentials for going airborne even for somatic GT. Phobic kneejerk fears of latently contagious droplets and contact precautions are not usually required beyond a few hours after the time of transmission of the infectious gene agent.

On the fourth hand, if we want an affirmative overcoming of bioethical guilt in the shadow of utilitarian pragmatism, we can proceed without the work of the negative, following the artistic logic of this open letter. For instance, the National Endowment of the Arts (NEA) might be the proper regulatory oversight bureaucracy for approving transgenic human reprotech kid production.[17] Nana and Lulu, you are the most important sculptural, time-based, new media arts project of the century! Yet, your conception had no arts oversight.

Semi-identical lifespan predictions: nana heterozygote for the *CCR5*-Δ32 mutation, Lulu Mosaic for the *CCR5*-Δ32 mutation

Some bad news just in from *Nature* magazine,[18] the *CCR5*-Δ32 mutation you were made homozygote mutants from will shorten your lifespan average. According to Emma Yasinski of *The Scientist*: Using genetic sequences and vital statistics from hundreds of thousands of people, the team finds that people with two copies of the mutation had a 21 percent higher likelihood of dying by age 76 than those with only one copy or no copies.

Oops, JK just shortened your general mortal lifetime by one-fifth. This is merely a statistic but your immunity against other diseases, including the common flu and West Nile Virus may find you more incapacitated (including spiked mortality rates) than most, so take care.

On a brighter note, only one of you has both genes.

Thus, Nana would still be susceptible to HIV infection. Although He demonstrated that Lulu was homozygous for the disrupted CCR5-Δ32 gene, this child may also be genetically mosaic, which means that Lulu may carry some edited cells and some unedited cells.[19]So, Nana, you are not enhanced, but you may have a longer life expectancy; Sorry about the lack of super memory and analytical skills, sorry about your non-resistance to AIDS. And may you live long and prosper. You are the control, also known as the wild type. You are actually less life threateningly susceptible to West Nile Virus or the flu than Lulu.

And Lulu, you may have some added difficulties. Along with added functions, you are potentially more susceptible to rheumatoid arthritis, osteoporosis and strokes.[20] Watch your RHOA, transforming protein RhoA levels; MAPK, mitogen-activated protein kinase levels; GM-CSF, granulocyte-macrophage colony-stimulating factor levels; BMP-2, bone morphogenetic protein two levels; BMP-4, bone morphogenetic protein four levels; and BMSCs, bone marrow stromal cells levels. Pay attention to loose connective tissue, floppy joints and take your PTK2B: Protein-tyrosine kinase 2-beta pills. Sorry for helicopter parenting. There is some other obscure news in for you Lulu. You are mosaic in your sculptural, metabolic, cognitive decals. This means that some of your cells may be modified, and some of them may be heirloom human. The tangible hybrid patterning of your body plan may be of a wide variety. Your mix of transgenic and original, heirloom human genome may have been expressed as a left side-right side, upper body-lower body or even diagonally. There is also the potential that you are genetically modified in a motley pattern of random cell types. It is even possible that you have merely one pinky finger of genetic insert legible in your bodily form. Check out the developmental biology of gynandromorphy, and you will see that mosaicism is at times downright palomino. You may be a chimera, a mix of two genetic identities, a multimodal plurality, a remix, even a moiré patterned behavioral and metabolic Op art success story!

The direction of multifactorial gene action is reverberatory. So, knowing what scientific acts you are performing at the molecular level is still hard. My artistic suggestion is to own the complexities of the actual experience of your differences as genetic interventions. Again, there is no normal, and being wild type is no better in terms of managing difference. Random shuffling through sexual attraction alone does not a clean housekeep. Honestly, we have yet to figure out the complete metabolism of even *Escherichia coli* bacteria, and gene expression's role in life's forming is, let's just call it, complicated.

The experiment continues…

I have seen that your parents signed an informed and consenting release form[21] to allow you to be guinea pigs in the most important twin study since Josef Mengele's stint. That deal should only last until you are adults and can negotiate your own terms. I would consider lawyering up! If there are physical or emotional complications or your PR team needs some gossip during a lull period, you can always sue for wrongful life. Talk to the legal team that represents the family survivors of Henrietta Lacks (mother of the HeLa cells) or one of the lawyers who filed civil suits against the estate of Jeffery Epstein.[22] After all, He Jiankui is the Jeffery Epstein of Biotech. In your case, 露露 and 娜娜, the choice of Shenzhen for the actuation of the human gene editing proponents was actually a case of biotech neocolonialism. By positioning certain protocols in technical feats through US and UK universities and hospitals, the birthing was requisitioned, possibly even fielded out to the Silicon Valley of China, the 'wild west' of the east, the center of Chinese innovation and container ports for distribution. The lack of subtlety in the choice of China to give you life was in no way accidental. Racism and traditional eugenic history informed who and where this type of public outing of an oft-repeated experiment was actuated. Having witnessed the first International Summit of the Human Gene Editing Initiative, my artistic intuition picked up a global plan between collaborative science foundations. The labs broke the process into parts to conform to multinational legal loopholes. It was imperative to stay legalish and it was decided to let China do the dirty work of going full term. Global working groups at the Human Gene Editing Initiative allowed China to take the prize of being first and were pleased to see you, Lulu and Nana, come to fruition as a controversial twin study in a non-US, UK or EU context simply for the sake of Christian propriety.

Meanwhile, please excuse all the poking and prodding, scanning and samples. Medical culture has a scopic tendency, and hospitals are sort of just lab experiments with closed-circuit TV and bad food. Your blood and tissues are historic, so you may see a lot of doctors. Eventually, scientists, governments and renegades will want your eggs. More than likely, someone has already sampled your ovaries and sequenced your ovum payload. This is more about your grandkids than you alone. What can I say optimistically? The proof is in the pudding, but Life is resilient and keeps going. Life is bigger than science and a strange cavalcade: mutations happen all the time. The deleterious and the enhanced are intermingled, and we all go with what we've got. So, Lulu and Nana, make the best of life. You are not just tools for a global lab experiment. There is a lot to enjoy, and you should find your own ways.

Iconoclasm as biosecurity and BioPorn

露露 and 娜娜, just so you know, long before your very secret and then very public birth, actual experiments in germline genetic engineering of the human genome have been going on covertly for quite some time, including live births, particularly in private hospitals, farms and labs. In the United States, no one has been granted any public funding for these projects (except the Pentagon), but private collectors can make any human breeds they design as corporate IVF+. Furthermore, human trials worldwide have been developing lines of humans with both human and nonhuman properties. This is all unverifiable hearsay of high probability correctness. So, there are potentially tons of Lulus and Nanas currently growing as NextGEN™ CRISPr[23] transgenhuman beings.

They are queer like all of us, multiplying like clockwork oranges and they are your sestras. The nuclear membrane of the ovum is now ground zero for an inward blebbing space race of competing transgenic futures. The ironing out of inherited mistakes is a gateway drug to the baroque of inherited Genetic Modification Orgiastics (i-GMO[24]) potentials. In some ways, you were both born as a PR stunt to perpetuate the practice of germline genetic gonad tweaking. Your very existence is meant to aid and abet the supposed defragmenting and optimization of the species' genome through heavy-handed meddling. Your lives, as experimental beings, are a gateway drug, mainlining into the mainstream as poster children of the human gene editing movement. But from a ritual process standpoint, you are the world's totem germline initiation transgens.

Nana and Lulu, I truly hope the CRISPR constructs don't cause you to die early of cancer, chromosomal breakage or *CCR5*-Δ32 mutation complications and you live long enough to reach a mature enough phase to be able to read a version of this letter. You are unique life forms who should be seen for who you are and not for your public difference. I respect your anonymity, but it will probably not hold. At an age where you can be exposed to adult topics, I hope you will receive well the following comments on the charismatic attraction of your otherness as outputs of experiments in art and science.

I am worried that your biopop infamy will potentially find you caught between smothering worship and xenophobic death threats. It is well known that drives drive drives in the vital splay of life forming, and Eros has a penchant for the mesmerism of obsession. Therefore, if you are the product of obsession, it would behoove you to have some understanding of the economies of desire and the role of the excess as an investment in proudly aberrant foci. Understanding the specific gravity of the seductive potential of your sexual selectivity is important for your development, as you have been made as objects of heritable curiosity. In other words, you have been born to be bred as research subjects heralded by the worst of scientism, but you may usurp expectations and allow your anomalousness to be libidinally empowering. Nothing could belittle or objectify you more than to be pimped out through clinical partnering as part of a rational breeding program based on heritage alone.[25]

To put it country simple, human genome editing and the concept of human enhancement might be multigenerational eugenics, but it is also based on a fetish of control. It may be unsafe, insane and beyond any prepersonal potential for consent, but it is a form of repro-gonad fucking. In utero tailoring is a sort of genome bondage and you are in it. Someone else had a little genetic foreplay with your hereditary cascade. You are bioart, a sadomasochistic vision of nature in shibari. This is the vamping of nature's love of mutation, a sort of drag mocking of nature and a freak show to be sure. These biologists put you in a zendai suit of permanent multigenerational cosplay to mock actual ecologies. The obsessing and compulsive monomanias that you are subjects in and subject to are sadistic, but you are also inborn kinky, differently-abled transgressions. No one but an artist dares to voice it, but this is a form of mesmerizing charisma and can work in your favor.

Toward posthuman rights

Lulu and Nana, it is my honor to support you as free-range and internationally migratory beings. Even those who will agree with this recommendation are unlikely to arrive at it by the same guarantee of lack of reasoning that the arts are honed to provide. For those who find the esoteric sufficiently compelling, the above criteria represent a commitment to promoting queer beings and alternative beings within a framework of informed consent and freedom of expression. Those not completely persuaded that the aesthetics outweigh the social concerns may nonetheless conclude that even the antiaesthetic as criteria for human gene editing if properly implemented, should allow free range toward a harassment-free global citizenship climate for our trending difference populations.

The Human Gene Editing Initiative is simply a quorum of voices, a collaborative, coordinated global action that is responsible for grooming the public into tacit acceptance of the process of making you. It comes as no surprise that global bioethics would be found wanting, predatorily leading the witnesses into social acceptance, as a way to keep up the veneer of responsible, ethical, rational proGMO Human Germline genomic technology. Beyond asking which branch of Government should have regulatory oversight, please ask the Lulus and the Nanas – is the military health consumerism industry, with its use of rubber-stamp oversight as publicity, going to bring us through the lines of flight away from Version 1.0 common human form and out into the biodiverse posthuman fields of potential that only open, free-range ideation can provide? I know your existence depended on these regulatory ruses, but I wonder if actual diversity (of crafting, roaming and ideation) will be respected in the forms to come?

There are many potential effects of the CCR2 aesthetic you have been chosen to be born with. The choice was an HIV resistance health aesthetic as subterfuge for a naive aesthetic based on trending brain enhancement conceptual art theory. This is science leading the way not only in the creative arts but also in the realm of high satire and irony. The specters and hauntologies of remix humans are just what is expected from humans. We are the most neurotic, lurching, lurking species on the planet. We are the most gullible family. It is this naive reading of the genetic effects of CCR2 that most encapsulate the problems of labeling cognition through cognitive bias in enhancement presuppositions. Perhaps, you, 露露 and 娜娜 with your enhanced Ashkenazi/MidNorth European AIDS resistant,[26] memory and learning,[27] CCR5-Δ32 gene knock-ins will have to deal with enhanced cortical plasticity and hippocampus-dependent emotional breadth as merely enhanced trippy analogical neurosis, but that's what it takes to be a good screenplay writer or borscht belt geneart comedian. So, welcome to the slapstick dome.

As we build a canal full of love into the safe harbors of our genomic USB ports. Let us continue to question and be inclusive as to what styles we should stockpile in our GT Lenti-Viral knock-in libraries to midwife our targeted, CRISPR-cas9 cassette inserted, mutant human zoo. Signature transgene infections into human ovum, sperm, zygote or hESC should always include a premonitory cultural spinoff. That is the nature of free-living prophecy and the reason for the arts as foreign generalities.

It is for these reasons that I invite you both, Lulu and Nana, to consider becoming leading voices in BEAK and practice the aesthetic sculpting of new human life utilizing the media of biotechnology as directors of transgenic on transgenic future human builds. You are already here; you are going public and you are humans.

Consider bioart as a venue to return the gifts you were given!

Dr. Adam Zaretsky
Principal, Bioart Ethical Advisory Kommission (BEAK)

Notes

1 Adam Zaretsky: Invited Guest in conversation with moderator Hank Greely, Stanford University. Speakers: David Relman, Stanford University and VA Palo Alto Health Care System, Richard Gold, McGill University, Charis Thompson, University of California, Berkeley, at the International Summit, The Human Gene Editing Initiative, National Academy of Science, Washington D.C., 2015, http://nationalacademies.org/gene-editing/index.htm, https://www.youtube.com/watch?v=jMb-0d1T548

2 Proudfoot, C., Carlson, D. F., Huddart, R. et al., "Genome edited sheep and cattle," *Transgenic Res.* 2015;24:147. https://doi.org/10.1007/s11248-014-9832-x

3 This is an abbreviated list of people and institutions who advised, turned a blind eye or kept their opinions private before the births were made public. For a more detailed accounting, see: The untold story of the 'circle of trust' behind the world's first gene-edited babies, Jon Cohen, *Science* magazine, Aug. 1, 2019, 11:30 AM, supported by the Pulitzer Center, https://www.sciencemag.org/news/2019/08/untold-story-circle-trust-behind-world-s-first-gene-edited-babies

4 Wang, H., and Yang, H. "Gene-edited babies: What went wrong and what could go wrong," *PLoS Biol.* 2019;17(4):e3000224. Published 2019 Apr 30. doi:10.1371/journal.pbio.3000224

5 FACS: fluorescence-activated cell sorting.

6 ART: assisted reproductive technology.

7 See Domestic Art, Crosley Bendix: Cultural Reviewer and Director of Stylistic Premonitions, Negativland – Crosley Bendix – The Radio Reviews – 02 – Views – Domestic Art, December 14, 2016, https://www.youtube.com/watch?v=0Mwogvp2NQQ

8 For more on DIY iGMO biolistics, see Roijackers, M. M., "Doing the taboo: Examining affect and participation in bioart", Dalila Honorato and Andreas Giannakoulopoulos (eds), *Taboo – Transgression – Transcendence in Art & Science 2016 Conference Proceedings*, Corfu: Department of Audio and Visual Arts – Ionian University, 2017 (pp. 262–285) as well as Mutafelch Experiments in Biolistics: mutaFelch – Methods of Transgenesis: Genegun (Biolistics), Queer New York International Arts Festival and Grace Exhibition Space, 2014 and Kapelica Gallery, Ljublian, Slovenia, EU, 2014. https://archive.org/details/MutaFelch/FINzaretsky_mutaFelch_Vimeosize2.mp4

9 Zaretsky, Adam, "centiSperm, methods of transgenesis: Shoot, shock, inject, experiments in biolistics, electroporation and microinjection", Dalila Honorato and Andreas Giannakoulopoulos (eds), *Taboo – Transgression – Transcendence in Art & Science 2017 Conference Proceedings*, Corfu: Department of Audio and Visual Arts – Ionian University, 2018 (pp. 71–98).

10 "Methods of transgenesis: Shoot, shock and inject", Adam Zaretsky, Ph.D., Laboratories of Earthly Survival, Garage Museum of Contemporary Art, Moscow, Russia, 2018 and Zaretsky, Adam, "FIST.SAVE.MOP.BAIT (Forced interspecies symbiosis transgenic solar animal vegetable environmental microinjection organismic personality behavioral audio integrity test)", Ja Natuurlijk, Gemeentemuseum Den Haag (GEM), Ine Gevers curator, den Hague, Netherlands, EU, 2013.

11 psyFert, Coconut DNA Lipofection Massage Lab, Psychic Fertility Clinic, Performed at Rosekill, Rosendale, NY, 2017 and Aki Bio Matters, curated *Dr. Agnieszka Anna Wołodźko*, Crossmedia Design, Academy of Art and Design, Enschede, Netherlands, 2018.

12 The International Commission on the Clinical Use of Human Germline Genome Editing recently had their first meeting, and it became clear that the World Health Organization (WHO) and the National Institutes of Health (NIH) support a moratorium on going directly to the public clinic for this type of research. They seem to want to be included at the table of debate with U.S. National Academies of Sciences and Medicine and the UK Royal Society while saying the word moratorium outloud. National Academy of Sciences Building in Washington, D.C. on August 13, 2019. http://nationalacademies.org/gene-editing/international-commission/index.htm

13 Center for Genetics in Society (CGS) is a non-profit, social justice organization, A Project of the Tides Center, www.geneticsandsociety.org

14 Food and Drug Administration Center for Biologics Evaluation and Research, 59th Meeting of the Cellular, Tissue, and Gene Therapies Advisory Committee February 25, 2014 (Gaithersburg, MD, 2014), pp. 180–190, http://www.fda.gov/downloads/AdvisoryCommittees/CommitteesMeetingMaterials/BloodVaccinesandOtherBiologics/CellularTissueandGeneTherapiesAdvisoryCommittee/UCM390945.pdf. Quotes selected from transcribed comments by Marcie Donovsky, Executive Director of the Center for Genetics in Society, located under subheading Agenda Item: Open Public Hearing.

15 See letters: Zaretsky, Adam, *Does Cloned Animal Safety Take into Account the Effect of Aesthetics on the Long-Term Ecological Effects of Food Chain Design?*, formal docket formerly on the FDA website and presented at the "Eye of the Storm" Arts Catalyst event, Tate Museum, London UK, 2009 and Zaretsky, Adam, *Human Inherited Genetic Modification of Developing Embryo*, written to the Cellular, Tissue and Gene Therapy Advisory Committee (CTGTAC), Office of Cellular Tissue and Gene Therapies Center for Biologics Evaluation and Research (CBER), Food and Drug Administration (FDA) of the Federal Government of the United States of America (GOV.US) in response to a call by CTGAC/CBER/FDA/GOV.US for written dockets for a public hearing on "oocyte modification", often referred to as three-parent baby production. Never entered into the public dockets. Both letters are graciously reprinted here: Zaretsky, Adam, *Oocyte Aesthetic, Human Design and Mission Creep*, ed. Pier Luigi Capucci, *Noema J.*, 2019, https://noemalab.eu/ideas/oocyte-aesthetic-human-design-and-mission-creep/

16 https://www.doi.gov/ocl/invasive-species

17 That is if the USA doesn't dissolve what is left of the arts as a part of society in the near future!

18 Wei, X. et al., "CCR5-Δ32 is deleterious in the homozygous state in humans," *Nat. Med.* 2019, doi:10.1038/s41591-019-0459-6.

19 Xie, Y., Zhan, S., Ge, W., and Tang, P. "The potential risks of C-C chemokine receptor 5-edited babies in bone development," *Bone Res.* 2019;7:4. Published January 29, 2019. doi:10.1038/s41413-019-0044-0

20 Ibid.

21 http://www.chictr.org.cn/showprojen.aspx?proj=32758

22 https://www.democracynow.org/2019/8/15/lisa_bloom_jeffrey_epstein_civil_cases

23 According to Nature Magazine, CRISPR, the popular gene editing approach, is proving to be a disruptive technology.CRISPR, the disruptor, Heidi Ledford, Nature News, Springer Nature, June 3, 2015, https://www.nature.com/news/crispr-the-disruptor-1.17673

24 Zaretsky, A., *iGMO: Inherited Genetic Modification Orgiastics, Institutional Critique to Hospitality: Bioart Practices. A Critical Anthology.* Edited by Assimina Kaniari, Art History and Theory series, Grigori Publications, Athens, 2017.

25 Since the initial authoring of this Letter to Lulu and Nana, a third child of the Dr. He Jiankui Family Affair has been born. The child's birthday is unknown. In the literature 'it' is known only as P3. There is knowledge that P3 was born a natural birth and was not subject to premature birth or neonatal intensive care unit (NICU) stay like Lulu and Nana. P3 has no known name or gender. P3 is just P3. But, if P3 is born of a male sex then 'it' was probably cooked-up purposefully to breed with Nana and Lulu (i.e. P3 sperm incestuously injected into Lulu and Nana ovum) in order breed-stabilize proprietary double recessive mutations in a multi-generational twin study that could have lasting effects on art history. From live birth of Lulu, Nana and their potential spouse, P3, we have the potential new repro arranged marriage of prepared genomes for dominant trait offspring.

26 Novembre, J., Galvani, A.P., and Slatkin, M. "The geographic spread of the CCR5-Δ32 HIV-resistance allele," *PLoS Biol.* 2005;3(11):e339. doi:10.1371/journal.pbio.0030339 and Maayan, S., Zhang, Linqi, Shinar, E., Ho, J., He, T., Manni, N., Kostrikis, Leondios, Neumann, Avidan, "Evidence for recent selection of the CCR5-Δ32 deletion from differences in its frequency between Ashkenazi and Sephardi Jews," *Genes Immun* 2000; 1:358–361. doi:10.1038/sj.gene.6363690. As an Ashkenazi representative, I can tell you that if the term analytical enhancement is anything like my bottlenecked population's cognitive tableau, you are in for painfully lateral thinking, OCDish symptoms, the delusional mania of a multifarious, personal monotheism, neurosis befitting a self-reflective, guilt-ridden demiurge and a wicked, Yiddishkeit sense of humor. Being born neocortically heavy is not so easy-peasy.

27 Zhou, M., Greenhill, S., Huang, S., et al. "CCR5 is a suppressor for cortical plasticity and hippocampal learning and memory," *ELIFE* 2016;5:e20985. Published December 20, 2016. doi:10.7554/eLife.20985.

Section 7
Art as partner and critic

Hannah Star Rogers

What roles can art play in relationship to science? Art has often been figured as muse for science (Brown, 2011; Jana, 2012), as the hands of science (Smith, 2004), and as a translator of science (Rogers, 2015). As Pamela Smith (2004) has written, though making knowledge and making objects were long considered as separate tasks, the emergence of experimental science in the seventeenth century brought together these types of knowing and complicated easy divisions between the two. Some artists have also identified themselves as a type of science communicator. In April 1939, art photographer and physics image-maker Berenice Abbott wrote a manifesto on what photography could do for science. "We live in a world made by science," she wrote: "There needs to be a friendly interpreter between science and the layman. I believe photography can be this spokesman, as no other form of expression can be." All of these roles for art in relationship to science persist to the present time.

But there are potentially more equitable roles as well. Art can be seen as a partner and an ally for science. Together, knowledge makers from both areas can produce new interdisciplinary works. Art can also identify as a critic of science with productive observations and insights about how science functions. The perspective to see art as a partner and critic emerges from many quarters. In this section, Science and Technology Studies (STS) scholar Lea Schick, designer/architect and scientist team Aaron Ellison and David Buckley Borden, pioneering bioartists Oron Catts and Ionat Zurr, and the collaboration of musician/composer Robert Lundberg, environmental studies scholar Alexandra Lakind, and humanist Nicole Bennett explore the roles art can play in relationship to science. In these chapters, an STS scholar observes art and its direct and indirect critiques of science and artists engage in direct critiques of science funding agencies that support art. In two chapters, different multidisciplinary partnerships are aimed at addressing environmental issues: the first is between a designer/architect and an ecologist and the second involves a musician/composer, an environmental studies expert, and a humanist. These different viewpoints demonstrate how partnerships and critical approaches are developed among multidisciplinary and transdisciplinary groups. The dynamics of these collaborations have important consequences for their outcomes which are considered in Part II, Section 4: Boundaries and Breakdowns. These

DOI: 10.4324/9780429437069-35

chapters also suggest the importance of institutions in orienting projects toward and away from partnerships and critical relationships, ideas which are more completely explored in Part II, Section 5: Institutions and Infrastructures.

Hemlock Hospice (Chapter 2) and *Displaced Horizons* (Chapter 3) are environmentally-oriented examples of scientists, humanists, and artists coordinating themselves to create work which orients art and science differently. *Hemlock Hospice* is a co-designed and co-executed collaboration to realize a 1,500-meter-long art-based, site-specific interpretive trail at Harvard University's Harvard Forest. *Displaced Horizons* is an adaptable multimedia performance designed with both artistic and academic concerns in mind. While many such collaborations exist and are considered throughout this book, these two cases offer a chance to compare the institutional factors in collaborations, the different makeup of such teams in terms of professional backgrounds, and to consider the dynamics of these partnerships in real case studies.

Though it is widely recognized that art and science partnerships pose unique challenges, this admission is often decontextualized from actual practice. These cases offer chances to consider some of the issues that arise. They contain many similarities, but they are also distinct. *Hemlock Hospice* demonstrates the importance of considering the visitors at various stages of such collaborations and some of the complexities of audience inclusion. The piece is centered on effective science communication through art and raises issues around what successful communication looks like from different disciplinary perspectives. *Displaced Horizons* helps to demonstrate the role of humanists, particularly STS scholars, in such collaborations. Art can function as a partner to extend and explore subjective aspects of areas often zoned as the purview of science. At other times, artists develop critical responses that have the effect of potentially augmenting scientific ideas or reorienting them around who has standing in conversations which might otherwise have been seen as primarily scientific.

In this section, this impulse toward critique is explored in two contexts: energy art and bioart. Schick's artists who work with energy and Catts and Zurr's work with genomics demonstrate different approaches to understanding some of the roles artists can play in critically engaging science and its institutions. These chapters in particular demonstrate the relative power of science and art in our society and account for some things that are seen as naturalized differences, based on stereotypes about these two knowledge communities, rather than the result of imbalances in social power and capital access. The funding and support available for science ventures frequently shapes the behaviors of collaborating scientists and artists.

At the same time, this power can lead artists into relationships of critique. A good example of this phenomenon occurs around the case of Tissue Culture and Art's *Pig Wings*. This artwork is placed into context by its creators Oron Catts and Ionat Zurr and was first published in *Culture Machine* in 2005, following the culmination of the Human Genome Project (HGP). The authors make use of professor of pediatrics and theorist Neil Holtzman's (1999) term "genohype," which describes the discourse of exaggerated claims and overstatements concerning genetics, particularly around the HGP. The artists understand genohype as a state of scientific and public discourse that their artwork critiques. In their work, science, particularly genomics, is the target of institutional and philosophical comment, but it can also open to reveal other versions of the notion of critique. Using their own work as a case study, the bioartist authors explore what their artwork revealed about the expectations science institutions have of art in relationship to discussing genomic science.

Schick examines seven different artworks that engage ideas about energy. She classifies these projects into four modes: (1) Making Energy Visible, (2) Making Energy Public(s), (3) Making Speculative Energy Futures, and (4) Making Energy Solutions. Aside from the help this provides readers in thinking about her particular artwork cases, this framing can also guide analysis of the myriad of artworks engaging with science. It is particularly helpful in thinking about those involved with environmental interventions where ideas about visibility, positioning the public, speculation, and solution-oriented artworks abound. Schick offers the term "generative critique" as a way forward for art and science. She proposes that we need to diminish the traditional distinction between critical art and instrumentalized art. Instead, we should focus on the possibilities of art as a force for intervention in critical and productive ways.

Art can partner with science to provide new insights and approaches to researching and addressing shared subjects. In these partnerships, it can extend aesthetic knowledge which can enrich audience interactions as part of interdisciplinary projects, but it can also offer not only reflections but also criticisms of how science operates. In some cases, these criticisms come from interactions with science institutions, and in other cases, they spring from contacts sought by artists to comment on science. As long as science remains an important cultural touchstone and a source of social power, artists will continue to form partnerships with scientists to create collaborative projects and to critique what they regard as the misuses and social consequences of science.

Notes

1 https://ens.dk/sites/ens.dk/files/EnergiKlimapolitik/smart_grid-strategi-2.pdf
2 Denmark has set the goal to be 100% renewable in 2030, but this is challenging because renewable energy is a fluctuating energy source, and therefore, electricity consumption has to be fitted to the production.
3 The project does not exist on the artists portfolio page anymore, but the information is gathered from the two papers referenced and from the webpage http://ecofeedback.ca/?p=148
4 http://hehe.org2.free.fr/?language=fr
5 The power plant, which is shaped like a skiing hill, where people can go skiing on the rooftop, is soon ready. However, the smoke ring has not become a reality due to technical reasons (https://www.a-r-c.dk/amager-bakke).
6 http://yoha.co.uk/cfc
7 http://www.fact.co.uk/projects/turning-fact-inside-out/hehe-fracking-futures/
8 https://vimeo.com/68703837
9 https://www.theguardian.com/artanddesign/2013/jun/17/indoor-fracking-installation-provoke-debate
10 http://energyharvests.org/
11 http://energyharvests.org/d-i-y/
12 http://energyharvests.org/underground-currents/
13 http://neighbourhoodsatellites.com/project/energy-harvests/
14 http://energyharvests.org/currents-stories/
15 http://www.naturalfuse.org/
16 There are several examples of ASTS analyses, which analyze art projects in the making, arguing that by studying how an artwork comes to life, the researcher may experience new things about the material and organizational reality in which the artwork is operating (see, e.g., Marres, 2015; Yaneva, 2003).
17 http://landartgenerator.org/
18 http://landartgenerator.org/designcomp/downloads/LAGI-GreenCitiesPartners.pdf
19 http://landartgenerator.org/designcomp/downloads/LAGI-2014DesignGuidelines.pdf

References

Brown, M. (2011). Why the arts are essential to science and innovation. *The Guardian* [online]. Available at: https://www.theguardian.com/culture/culture-cuts-blog/2011/feb/22/arts- funding-arts-policy1 [Accessed 24 September 2019].

Holtzman, N. (1999). Are genetic tests adequately regulated? *Science*, 286 (409).

Jana, R. (2012). To innovate, scientists and engineers find inspiration in the arts. *ZDNet* [online]. Available at: https://www.zdnet.com/article/to-innovate-scientists-and- engineers-find-inspiration-in-the-arts/ [Accessed 24 September 2019].

Rogers, H. (2015). Making Science Visible: The Photography of Berenice Abbott. *Photomediations Machine. 23.04.15.* Open Access *Culture Machine*.

Smith, P. (2004). *The Body of the Artisan*. Chicago: University of Chicago Press.

28

The power of generative critique in art–energy projects

Lea Schick

Energy visualizations in the sky. DIY wind turbines harvesting excess energy in the subway. A mini fracking site in a gallery. Land art that generates renewable energy. These are a selection of the art–science projects that you will meet in this chapter, which provides a review of artistic experiments with energy futures in-the-making.

How to rethink our energy infrastructures and how to make them 'more sustainable' are questions that many different disciplines and actors, including politicians, engineers, social scientists, publics, designers, and artists, are currently wrestling with. Such endeavors into alternate energy futures give rise to a variety of complex social, political, and ethical questions around potential energy futures. While climate issues have heightened the agreement that there is an urgent need for less CO_2-intensive energy infrastructures, it seems less obvious exactly how these infrastructures should be formed, who they should affect, and how we achieve them. For this reason – because there are no obvious answers – the field of energy, which has been dominated by engineers and natural science, is increasingly becoming a hot topic for social science, humanities, and arts. This chapter engages with the intersection between energy and Art, Science, and Technology Studies (ASTS).

The chapter builds upon my research for my PhD project, in which I investigated the intersection between art, energy, and smart grid engineers (Schick, 2015). Over a period of four years (2010–2014), I did social studies of the engineers and economists involved in the expert working group coined by the Danish state/Ministry of Climate and Energy in order to develop a national Smart Grid Strategy.[1] My focus was on how they imagined a changing role of the future electricity consumers making them 'less passive' and more active in adjusting their electricity consumption to the fluctuation energy from renewable energy.[2] This study showed that the engineers and infrastructure were frustrated because they found it very difficult how to make the public interested in energy and to engage 'consumers' in the 'right way.' Alongside studying the smart grid network, I also studied the field of art and design engaging with energy – a field which has been growing over the past decade. Besides analyzing existing art–energy projects, an important part of my thesis was an action research where I worked as a project manager on a major art and energy project, which will be explained further below. During my somewhat interventionist research, I experienced an overwhelming

DOI: 10.4324/9780429437069-36

interest in the arts from the smart grid engineers. How may the arts help us in the struggle of making new energy systems and new energy engagements? This chapter therefore deals with the question of how art–energy projects can gain power to intervene in policy and take part in imagining and generating divergent energy futures.

In order to answer this question, I provide a review of seven art–energy projects that open up and experiment with the field of energy. The review builds upon existing – both my own and others' – Science and Technology Studies (STS)-inspired analyses and engagements with art–energy projects (Domínguez Rubio & Fogué, 2013; Gabrys, 2014a; Haque et al., 2011; Holmes, 2007; Marres, 2015; Schick & Witzke, 2011; Schick & Winthereik, 2016). While studying the selection of art–energy projects, I have developed a framework of four modes of engaging with energy: (1) Making Energy Visible, (2) Making Energy Public(s), (3) Making Speculative Energy Futures, and (4) Making Energy Solutions. Across the four categories, you will meet seven different art–energy projects. These seven projects are chosen as emblematic of the particular category.

The four categories are neither fixed nor exhaustive, but they provide a generative framework for teasing out some of the different ways in which art and creative practices may be productive in thinking through and intervening into the development of future energy systems. While the first three categories are largely aligned with the general approaches to the role of arts in STS, the fourth mode, which is developed based on my action research, is somewhat different and somehow seems to provoke and challenge the existing STS literature and the general approach to critical art. Rather than seeing the categories as being in opposition to one another, the framework of categories allows me to formulate and suggest an approach to art–energy, where art seeks to be both critical and generative. With the term 'generative critique,' this chapter proposes a way forward for art and science in which we focus less on the classical distinction between critical art and instrumentalized art and more on how art may manage to intervene in critical and productive ways.

This chapter has three specific goals: first, to explicate why and how there is a particular opening for art to intervene in the otherwise very technical and engineer-driven field of energy infrastructure development; second, to provide an overview and framework for the landscape of art–energy projects; and third, to propose generative critique as an effective means for thinking and doing art, which may be critical and also offer the power to intervene in the important and critical issues and problems of our time.

Energy infrastructures as sites for generative intervention

In order to understand the way these art–energy projects fit into the STS and energy landscape, it is important to understand why and how energy is becoming a field of endeavor for a wider spectrum of disciplines beyond natural science and engineering including STS, design, humanities, and the arts.

Hidden in walls and underground, the electricity infrastructure has faded into 'woodwork of society' (Bowker, 1995). Throughout modernity, electricity infrastructures have been made ever more invisible to the everyday 'consumers' who have not had to care much about electricity other than simply paying the bill (Burgess & Nye, 2008; Cotton & Devine-Wright, 2010; Edwards, 2003). As long as electricity infrastructures are working smoothly, they can remain 'black-boxed and depoliticized' (Domínguez Rubio & Fogué, 2013; Latour, 2004), so they can remain merely a matter of technical expertise and thus a job for engineers.

However, due to increasing attention to climate issues and energy scarcity, new actors such as CO_2 emissions, wind turbines, fracking sites, air pollutions, electrical vehicles, smart grids, smart meters, and energy management systems are moving into the energy system and making energy both more visible and more political for publics to engage in. Electricity consumers are imagined to be more active, reacting to 'green energy' and flexible prices (Nyborg & Røpke, 2013; Schick & Gad, 2015). Therefore, such energy technologies are part of reconfiguring energy consumers and creating new energy citizens and environmental citizenship (Gabrys, 2014b; Marres, 2011).

Despite an increasing agreement that more sustainable energy is needed, how to achieve it and how to make 'consumers' more 'green' is yet a very complex and troublesome problem for engineers, system developers, and politicians. The challenge of remaking energy infrastructures can be framed as a challenge of (in)visibility – how to make the invisible energy infrastructures visible and engaging (in the right way)? How to ensure (and avoid) the emergence of certain 'energy publics'? Energy publics are defined as formations of concerned citizens, who arise as a 'public' around certain issues around, e.g., energy (Chilvers & Pallett, 2015). 'Sculptures' of wind turbines and wave-energy devices give rise to supporting and/or protesting energy publics often referred to as the not-in-my-backyard, NIMBY (Batel & Devine-Wright, 2014; Cotton & Devine-Wright, 2010; Walker & Cass, 2007). As sociologist Noortje Marres has described, 'the public' is not a fixed size, but is dynamic and emergent as a public is 'sparked into being' by problems, which the experts and politicians do not (know how to) solve – this is when the public gets concerned (Marres, 2005). Whereas the emergence of publics is often associated with something negative, the question is whether it is possible to intervene in energy infrastructure development in ways that fertilize the emergence of energy publics – positive and/or negative – and whether this may be helpful in a situation where more aware and active electricity consumers are needed.

Around the world, there is a growing awareness and acknowledgment that the existing energy infrastructures have to be made more sustainable. However, what counts as 'sustainable' is not quite agreed upon. Different 'socio-technical imaginaries' about potential energy futures are competing (Jasanoff & Kim, 2013). It is exactly in this situation of uncertainty and negotiation of potential energy futures that I argue there is an opening for new disciplines such as the arts to intervene in the field. Because the making of new energy infrastructures is turned into public and political matters of concern, it is becoming a hot topic for social science, humanities, and arts, disciplines that have taken up energy as a field of experimenting with how energy and its politics can be made visible in new engaging ways. Because energy futures are as yet ontologically unstable, there are opportunities for the arts to intervene in energy policy and energy publics.

Four modes of art–energy

The review is divided into four modes of art–energy engagements. The first three build upon other STS researchers' analyses of art–energy projects. The existing literature is primarily interested in art–science projects due to their ability to politicize energy and to create controversy and debate around energy (Domínguez Rubio & Fogué, 2013; Latour, 2011; Marres, 2015). The intersection between art, do-it-yourself (DIY) technology, and citizen science is seen as energetic places for 'democratizing' energy and giving voice to people and issues otherwise not taken into account (Rogers, 2011; Schick & Witzke, 2014; Tironi & Sánchez Criado, 2015). Common among many STS of art–energy is that they present artistic practices as means for 'slowing down' and 'creating hesitation' around how (energy) futures could potentially come to be shaped. I will describe the fourth mode – Making Energy

Solutions – somewhat differently than the first three because it is instead trying to speed up, smoothen out, and to come up with deployable solutions. I will discuss how this mode is different than the others and how it challenges the existing STS approaches to art–energy.

Making Energy Visible

The two art–energy projects in this section are both visualizing energy consumption and production in somewhat different ways than the dominating energy field. As we will see, to make visible is not only about showing what is already there but also about making relations between actors and issues. Making visible is a part of (re)configuring particular matters of concern and not others.

7000 Oaks and Counting[3]

This artwork, along with the accompanying article by the artist Tiffany Holmes (2007), is one of the earliest and often referred to when it comes to artistic energy visualization and eco-feedback. Holmes' artwork *7000 Oaks and Counting* is designed for office buildings and works as an application running on the workers' computer screens, where they can see the energy consumption of the building. Contrary to regular smart meters, typically showing the monetary cost of energy through graphs and numbers, her *art* meter is showing a kaleidoscopic flowerlike structure of greenery, which is converted into electrical devices, hairdryers, computers, power plugs, cars, etc., when the energy consumption is high.

Tiffany Holmes is a media artist and an associate professor of art and technology at the School of the Art Institute of Chicago. With this piece, Holmes investigates the question 'Can creative visualizations of real time energy consumption patterns trigger more ecologically responsible behavior?' (Holmes, 2007). The visualization represents the number of trees needed to offset the carbon emitted (seven trees offset on pound worth of energy). Holmes makes visible the links between energy consumption and environmental degradation. By making visible the hidden use and cost of energy, she hoped to elicit a change in behavior.

Conventional smart meters often visualize energy consumption through graphs and number indicating kWh, cost of energy, and sometimes CO_2 (Pierce et al., 2008). Many studies have shown that this techno-economic approach to energy management systems is not effective because people do not come to care about energy through these meters and therefore do not use them as intended (Hargreaves et al., 2010; Pierce & Paulos, 2010). As the Australian sociologist Yolande Strengers has explained, conventional smart meters are designed *for* and *by* engineers, that is, they are designed for the 'rational resource man' (2013). However, in practice, electricity consumers are not rational human beings, but they are social beings who act based on their everyday practices (Entwistle et al., 2015). Therefore, there has within interaction design been a push for more tangible and intuitive interfaces (Gustafsson & Gyllenswärd, 2005; Mazé, 2011). As *7000 Oaks* was made as an artwork, it was never developed into commercial product, but it has served as an inspiration for designers working with energy visualizations. The title references Joseph Beuys' famous art piece *7000 Oaks* from 1982. Beuys originated the concept of 'art as social sculpture.' He believed that art could work as a tool for the politically and environmentally engaged artist to change social behaviors in public space. Holmes' 'smart meter' is not only Making Energy Visible but also pushes back on the field of energy and asks which relations – relations to trees and carbon offsetting – should be included when calculating the 'costs' of energy.

Nuage Vert[4]

Another experiment in an affective and more collective smart meter is *Nuage Vert* (Green Cloud) by the artist duo HeHe (Helen Evans and Heiko Hansen). *Nuage Vert* was a one-week public art installation in the sky over Helsinki in February 2008. It differs from Holmes because it places responsibility on the community rather than the individual. The residents in the area could see a big green cloud hovering over the local power plant, Helsinki Energia. The art project was a collaboration between HeHe and Helsinki Energia, and the artists got access to the data from the power production, which translated into a green cloud projected onto the vapor from the chimney. They created a man-made cloud on top of the power plant's man-made cloud. The interactive cloud changed size and became bigger the less energy was produced, thus incentivizing the local population to turn off electrical appliances in order to collectively make the artwork more spectacular (Figure 28.1).

Within technologies for energy reduction and behavioral change, energy consumption is dominantly visualized in private homes, and it is enacted as an individualized practice. Rather than individualizing environmental responsibility, as often criticized in design and STS, Nuage Vert makes energy into a collective/public matter of concern. HeHe is hoping to enact another kind of environmental citizenship: 'Nuage Vert is based on the idea that public forms can embody an ecological project, materializing environmental issues so that they become a subject within our collective daily lives' (Evans, 2008). Nuage Vert connects the private consumption to the public atmosphere and thus creates what STS scholar Jennifer Gabrys has called an 'energy commons' (Gabrys, 2014a). *Nuage Vert* makes explicit the interconnectedness of humans, infrastructures, and 'natural' environments, and thereby, it sensitizes us toward the complexity and ambiguity involved in the making of more environmentally sound energy futures (Schick & Witzke, 2011, 2014). The green color draws

Figure 28.1 Nuage Vert by HeHe, 2008

connotations to 'nature' and environmentalism – green is good! However, this green is more of an illuminating acid green and thus gives associations to toxic air pollution. The sizing of the cloud is ambiguous too, as a large amount of chimney vapor normally signifies more pollution. However, the installation people are incentivized to make the cloud bigger by turning off the electrical appliances in their homes. By saving power in the individual homes, the Helsinki citizens create a collective, aesthetic artwork in the sky. Opposite to a regular smart meter, *Nuage Vert* refrains from offering a simple and/or moralistic message and technology, but instead, the artwork 'powers' a discussion about what kinds of (energy) futures are desirable (Schick & Witzke, 2011). This argument is closely related to Gabrys' recent analysis, in which she argues that the specific materiality of energy performed in *Nuage Vert* offers open-ended questions about alternative energy imaginaries (Gabrys, 2014a). As I will come back to in the third category, she argues that *Nuage Vert* creates a 'space for hesitation' and performs energy not only as actuality but also as potentiality.

When I introduced the engineers from my fieldwork among smart grid developers to various artworks, *Nuage Vert* was one of the artworks that they were most inspired by. In academic research, *Nuage Vert* has mainly been praised for its ambiguity and complexity (Gabrys, 2014a; Marres, 2015; Schick & Witzke, 2011); however, the engineers seemed to like it because of its simple visualization and its different take on data visualization and because it moved energy consumption from the private home into public space, and of course due to its spectacularity. In 2011, the Danish architect Bjarke Ingels designed a waste-to-energy power plant, where he wanted the vapor from the power plant to be emitted as a big smoke ring visualizing to the Copenhagen citizens when they had produced twenty tons of CO_2 through their burned waste.[5] I have not been able to find any information about whether Ingels was inspired by *Nuage Vert*; however, I will argue that *Nuage Vert* has a certain ability to speak to disciplines outside the art and thereby possibly expand the imaginary around how energy could be visualized.

In the mode I have shown, 'making visible' is not solely a matter of visualizing energy-as-is. In visualizing energy, the projects also experiment with what energy *is* and what relations could come to count as energy, and not least they experiment with other kinds of energy publicness (Born & Barry, 2013). These projects become interesting from an STS perspective, and for the more technical disciplines, the infrastructure is not only made visible but also made social. The projects make energy and infrastructure into hybrid 'things' by showing how they are much more than 'cold' technological artifacts. Instead, energy is entangled in and co-constructing both social and 'natural' relations and environments. In the next mode, I will build on these thoughts as I introduce Latour's notion of 'making public' as a matter of making political.

Making Energy Public(s)

'Making Things Public' is the title of an art exhibition and book (2005) curated by Bruno Latour and Peter Weibel. Latour sees art as potential places for opening up otherwise black-boxed techno-scientific issues to the public. Making things public involves more than making things visible to 'the public' – rather, it entails turning a thing or an issue into a political and controversial matter of concern for publics to engage in. Art can work as devices for making explicit the multiplicity of social and political negotiations and matters of concern that have been part of constituting a particular (black-boxed) thing/technology and thereby invite the public to discuss how 'things' could be assembled differently. This is not only a matter of democratizing science and technology but also makes it possible for new kinds of affected publics to emerge (Chilvers & Pallett, 2015; Marres, 2005).

In this category, I will present two art–energy projects that are both concerned with making infrastructures. The projects explicate controversy and invite and empower publics to emerge around and engage in complex energy issues.

Coal Fired Computers[6]

Coal Fired Computers – 300,000,000 Computers and 318,000 Black Lungs (2010) is an art installation made by the artist group YoHa (Matsuko Yokokoji and Graham Harwood) in collaboration with a group of miner activists. It materializes the political arrangements and the hidden controversial social and material networks behind the energy extraction, which sustains our extensive consumption of computers. The installation, which was shown at the Discovery Museum in Newcastle, UK, in 2010, consists of a massive steam engine powered by 2.5 ton of coal placed outside the gallery. The electricity produced is used to inflate a computer inside the gallery. The computer shows the World Health Organization's database of 318,000 coal miners who die every year due to chronic bronchitis and emphysema caused by coal dust. Next to the computer is a pair of black lungs, which inflates and indicates the many deaths by coal miners in distant countries such as China and India.

The installation articulates the relations between power, art, and media by showing the cost of the coal needed in order to produce the many computers sold mainly in the Western World. Around 80% of the energy consumed by a computer over its lifetime is used only in the production phase. A majority of the 300 million computers annually produced are manufactured in India and China, just as the coal for the production is mined in these areas. The artists have collaborated with mining activists, and the artwork comments not only on the hidden health and environmental effects involved in the consumption of electronic devices but also on the uneven power relations inherent in the global market of electronics. As Gabrys argues, it makes visible the material politics behind computers and here '[e]nergy is more than fuel in this context; it becomes evident as power' (Gabrys, 2014, p. 2103) (Figure 28.2).

By pointing to the extensive energy consumption in the production of computers, *Coal Fired Computers* also problematizes the dominating message of consumers having to 'save energy' by changing to energy-saving light bulbs and by using energy-saving mode in computers and other devices, whereas it is rarely mentioned how the extensive consumption of computers and other electronics is causing 'waste of energy' and environmental damage. The CO_2 emitted by production of computers (and other consumer goods) does (problematically) not count in the national CO_2 calculations in Western World countries. Rather than making energy use more efficient, the artists behind YoHa say that they wished to burn as much coal as possible in order to make the prodigal and excessive use of energy physically comprehendible for the viewer. Borrowing the Belgian philosopher Isabelle Stengers' figure of the idiot Gabrys argues that *Coal Fired Computers* performs an apparently idiotic approach to energy (ibid.). The 'idiotic,' in Stengers' interpretation, is not just stupid and useless person. Rather, he is one who does not just follow the rules and the social norms. By objecting to do as anyone else, his behavior can make us pause and ask 'why' the norms are as they are. The idiot therefore opens 'spaces for hesitation' and may therefore be productive in rethinking how things, such as energy, may be different in the future (Stengers, 2005; see also Schick, 2015, pp. 66–73). *Coal Fired Computer* creates a space for critical reflection about what energy consumption and production are and could/should be – without necessarily providing us with any answers.

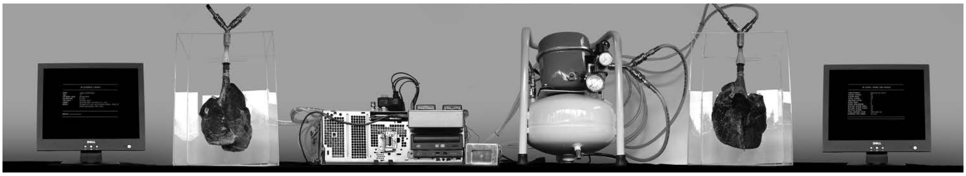


Figure 28.2 Coal Fired Computers by YoHa, 2010

Fracking Futures[7]

The risks and politics of energy extraction are also at the center of a more recent artwork by HeHe. In *Fracking Futures* (2013), the artist duo is critically engaging with the extraction of shale gas through the highly controversial method hydraulic fracturing, mostly known as fracking. Like *Coal Fired Computers*, *Fracking Futures* provides a highly embodied experience of energy. HeHe has turned the gallery space FACT in Liverpool into a microscale experimental drilling site for hydraulic fracturing. The visitors wear helmets, and the multisensory installation is immersed in flickering lights from orange construction lamps. 'Gasses' and flames are coming out of the ground indicating the harmful chemicals from fracking. The scenery is accompanied by very loud sounds of bombing and whistling machinery and of hissing sounds of air coming out of pipes. The soundscape intensifies gradually and ends with white blinking lights and a sudden silence. Whether an accident happens or not, we do not know (Figure 28.3).

In a video, Heiko Hansen from HeHe says: 'We are drilling into the gallery floor to explore shale gas under this art center FACT, to [...] help ourselves and FACT to be energy independent and make money.'[8] The installation makes an ironic and critical commentary on the political and economic argument for fracking as a necessary means for making countries energy independent and thus less fragile to the global energy marked.

In an interview with *The Guardian*, HeHe says that they find it problematic that areas for fracking (and for nuclear and oil rags) are hermetically closed to the public, who is not allowed access to these sophisticated technological developments. 'So there is a role for the arts to say: let's do it as a performance to bring people closer.'[9] The installation is an attempt to bring science closer to the public and the public closer to science. Though it does not provide all the factual information about fracking, it attempts to give an embodied and emotional experience of science difficult to understand for most laypeople. Though the installation evokes a sense of disaster, HeHe insists that they are not making judgments for or against fracking (ibid.). Rather, they wish to spark a discussion about fracking. Returning to Latour's notion, they want to make fracking public by turning it into a political issue that non-experts can also engage in a discussion about.

The two art–energy projects above are both Making Energy Public by rendering visible its social, environmental, and political relations and by turning it into matters of concern for publics to emerge around and to engage critically and politically in. From this more critical category, I will now move to the third mode, which presents speculative art–energy projects proposing alternate energy futures.

Making Speculative Energy Futures

The two art–energy projects I will present here are creating physical installations, in which the participants are transported into a speculative energy future. Both projects were made

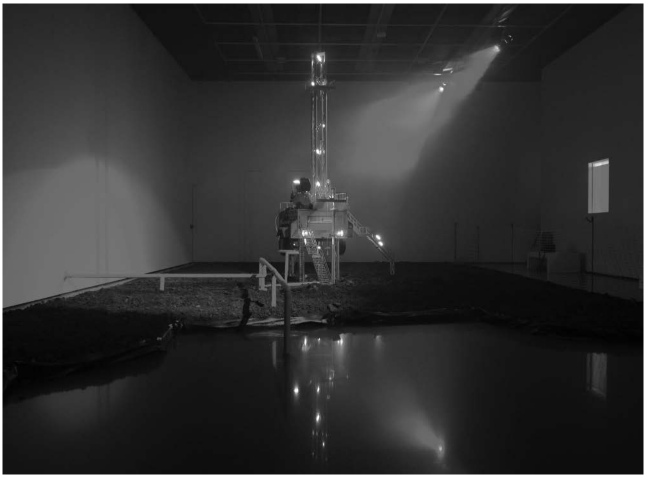


Figure 28.3 Fracking Futures by HeHe, 2013

by interaction designers. However, they are not actually design solutions helping to solve a given problem. Rather, they are closer to the tradition of design often referred to as critical design or speculative design (Dunne & Raby, 2013). Just like many artworks, speculative design is seeking to provoke reflections on the complex roles of science and emerging technology. Speculative design is 'understood as design practices that seek to articulate and materialize issues of concerns, and contribute to the formation of publics and alternative futures' (Danholt & Halse, 2016). Many researchers in STS has, for this reason, taken up speculative deign as methods for slowing down reason and experimenting with cosmopolitics of energy (Bergström et al., 2009; Jönsson, 2014; Schick, 2015).

Energy Harvests[10]

Energy Harvests was created by Hanspeter Kadel and Myriel Milicevic. It consisted of a number of workshops in Berlin (2009–2011), where participants gathered around the topic of 'energy leaks' in the city. Energy leaks could be excess heat from air-condition, light from shopping windows, vibrations from transportation, and currents in the subway – all potential energy sources. The participants worked with DIY technologies, creating devices for making visible the energy leaks and devices for harvesting energy from these 'sources.' In doing so, the artwork also correlates with the first category of 'Making Energy Visible.' What is made visible here is yet unrecognized energy – or waste of energy. By making this unharvested energy visible and by suggesting how to harvest the energy, the artwork speculates both on the current situation where we are wasting a lot of energy and on how other kinds of energy sources could potentially become part of energy system in the future. One of the outcomes was the DIY toolkit *Energy Harvester* for discovering, capturing, and transforming sunlight and light pollution into energy.[11] And an installation of ten homemade windmills located in an underground station, which harvested energy from wind generated by the bypassing trains (Figure 28.4).[12]

DIY technologies and citizen science are employed in order to empower people and enable them to explore new sites for free energy harvests. In *Energy Harvests*, the urban environment is turned into a big wasteland of energy and also into a multitude of energy harvest possibilities.

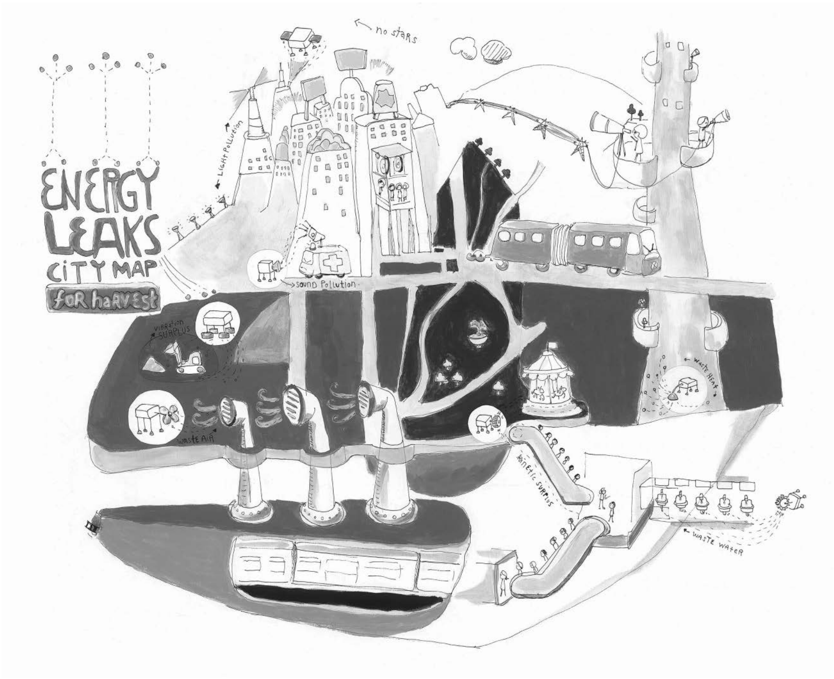


Figure 28.4 Energy Harvests City Map (2011) by Hanspeter Kadel and Myriel Milicevic

> Energy Harvests examines the practical as well as theoretical possibilities of an alternative, decentralized supply of energy by asking: How can citizens use these surplus energy supplies? What would local micro-power-networks, where free energy can be collected, distributed and exchanged, look like?[13]

The project furthermore produced a newspaper, *Currents and Stories*, where different thinkers and makers communicate 'their informative, critical, poetic, and utopian ideas about alternative forms of economies, technologies and societies.'[14] These stories should help the audience to think about how to do energy futures differently.

Though Energy Harvests proposes 'solutions' for potentially different energy futures, the artifacts produced, I will argue, pose more questions than they offer genuine solutions. The project questions our 'wasteful' energy consumption; it questions what counts as waste and what counts as valuable energy. And it turns our attention away from big infrastructural energy projects such as wind turbine parks, fracking, and coal and nuclear power plants as the one and only solution to sustainable energy. Instead, it draws our attention to the spaces in between as potential future energy commons. As Gabrys writes, Energy Harvests 'requires rethinking and rerouting energy ecologies and practices to generative and opportunistic engagements' (Gabrys, 2014a, p. 2105).

Natural Fuse[15]

An experiment in 'structuring participation for an energy commons' is what designer Usman Haque calls his network installation, *Natural Fuse* (Haque et al., 2011). A gallery rents out small networks consisting of a lamp, radio or a fan, an interactive flowerpot with a plant, and

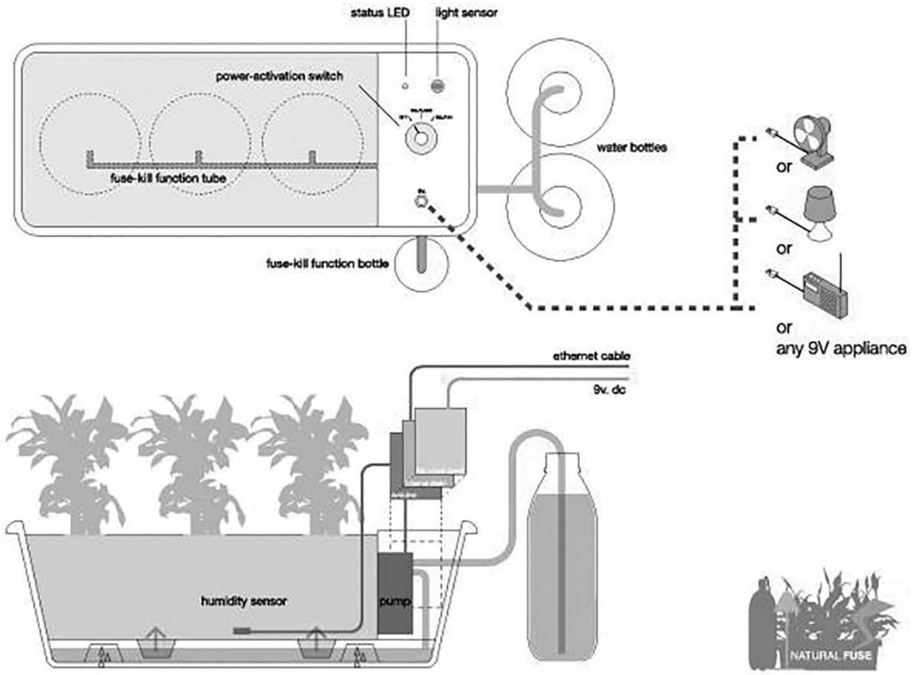


Figure 28.5 Natural Fuse (2008) by Usman Haque

computer software. The plant's capacity to offset CO_2 delimits the participant's ability to use his/her electrical device. The individual CO_2 quota allows for only ten minutes of light a day. However, because the networks are linked through the Internet, participants/consumers can use one another's CO_2 quota. The system thrives best when there is a balance of carbon footprint and carbon sink. On their flowerpot, the participants can switch a bottom to either 'selfish' or 'selfless' mode, thus choosing to egoistically over-consume. In case of over-consumption, other people's plants will be killed by an automatic injection of vinegar into the soil. Dying plants weakens the system's collective carbon offsetting capacity. The 'selfish consumer' will receive an email stating that he or she is KILLING SOMEBODY ELSE'S PLANT! (Figure 28.5).

Natural Fuse proposes a regulatory system much different from the regular smart energy management systems. Here, it is not your wallet, but your ecological footprint and offsetting capacity decide your energy consumption. Contrary to the current energy infrastructure, where consumers/citizens have no responsibility in keeping the balance in the grid, in *Natural Fuse*, the 'consumers' are interdependent on one another. Haque is critically commenting on the way energy today is configured as 'commons' for 'selfish exploitation' (ibid.). *Natural Fuse* proposes a different kind of energy citizenship, which takes environmental effects of energy into account.

Whereas energy management systems often come with the promise to make life easier for consumers, Haque has a quite different idea about what the role of design is:

> The point is that there is no 'easy energy future.' We've got to stop trying to sell people the idea that there are obvious ways to deal with the kinds of complex systems that govern both our social and environmental lives. [...] It is often expressed that it is the task

> of designers to 'make things simple for people' – which I find patronizing and counter-productive. If anything, it is the task of designers to show how complex things are, and to help build tools for dealing with that complexity.
>
> *(Ibid., p. 86)*

Haque is entangling the participants in a complex, hybrid, socio-technical-organic, and political system. However, at the same time, the system seems like a dubious downscaled 'eco-system' in which the cause and effects are idiotically simplified. Haque is not proposing *Natural Fuse* as a commercial design alternative to the existing grid, but instead, his public experiment with energy poses more questions than it solves (Schick & Witzke, 2011, 2014). What is a 'smart' energy system? What does it mean to participate actively? When is there an overcurrent in the global energy and eco-system? And where is the natural fuse that can prevent a total breakdown of the planetary system?

These two art–energy projects do not propose fixed solutions, but instead, they open up spaces for questioning the existing and the emerging energy systems. What if energy futures were about energy leaks and interactive flowerpots? '[R]ather than offering up final solutions to energy use [the artworks] interrupt the usual state of affairs and ways of addressing energy use in order to experiment with alternative energy practices as speculative "political fictions"' (Gabrys, 2014a, p. 2096). The art–energy project helps us to think about different energy worlds 'outside of the constraints of the given present' (Yusoff & Gabrys, 2011).

As I said in the introduction, the previous academic interest in art–energy projects has primarily been grounded in these first three modes. Social science and STS have mainly highlighted the value of art–energy projects making energy political and the potentials for artworks 'slow down' and create 'hesitation.' Art has mainly been appreciated for its ability to contribute to what Gabrys (2014a), inspired by Stengers, has termed 'a cosmopolitics of energy.' Cosmopolitics is less about coming up with *actual* solutions than it is about proposing what energy could *potentially* become. It is about staying open to how things could be otherwise (Stengers, 2005).

Making solutions

The final artwork described below is differing substantially from the others in various ways. First, because it does not aim to slow down or make hesitation, it rather aims at producing solutions and to speed up the transition to renewable energy. Second, the analysis below differs from the others because I am not analyzing a finished artwork, but instead, I analyze the process of making the art–energy project come to life.[16] My basis for doing this is that I was employed as the project manager of the art project as it took place in Copenhagen in 2014. Thus, this is auto-ethnographic analysis (for full analysis, see Schick & Winthereik, 2016). The purpose of this mode, which I see as my contribution to the field because it is arguing for the value of art which does something different than complexifying and posing critical questions, is to argue that art–energy has important roles both in slowing down *and* in speeding up. This argument will be guiding us toward the final discussion on art as generative critique.

Land Art Generator Initiative[17]

Land Art Generator Initiative (LAGI) is a nonprofit organization that holds design competitions and delivers a wide variety of programming outside of the competitions including educational materials, workshops, collaborations, planning, and consulting. In the competitions, the LAGI directors invite people (artists, designers, engineers, architects, etc.) to design ideas for large-scale, site-specific artworks with 'the ability to harness energy cleanly from nature and convert it into electricity for the utility grid.'[18] The competition is biannual and has taken place in Dubai/Abu Dhabi 2010, NYC 2012, Copenhagen 2014, Santa Monica 2016, and Melbourne 2018. The initiative is founded and directed by the artist Elizabeth Monoian and the architect Robert Ferry, who are inspired by the tradition of Land Art.

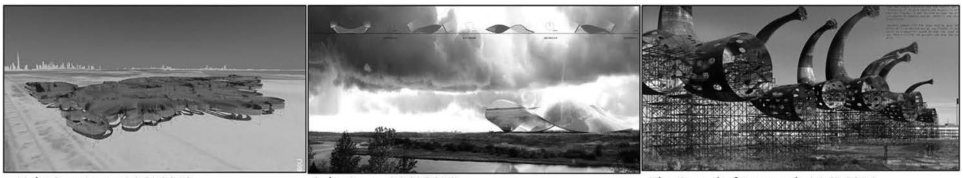
Land Art Generator Initiative *by Elizabeth Monoian and Robert Ferry*

The LAGI directors are reacting to the historical, industrial development of the electricity infrastructure. When the power plants in the previous centuries used to be placed inside the cities, they often constituted beautiful architecture, but now when they have been removed from residential areas, they are mostly 'wrapped' in industrial and architecturally boring constructions. LAGI wants to move electricity back into the urban space by showing that 'renewable energy can be beautiful' as the LAGI slogan goes. The energy-generating sculptures should both be aesthetically pleasing and serve as sites for making the public engaged in the transition to renewable energy.

> Every two years the free and open LAGI international design competition provides an opportunity for creative minds around the world to reflect on the nature of energy infrastructures and what they can aspire to be in their built form. How can they integrate themselves into our cities in ways that enhance public space, educate, and inspire?
>
> *(LAGI, n.d.)*

The directors of LAGI see their project as a political project and as 'art as social practice' (email correspondence, December 1, 2014). They write that they wish to 'truly affect public opinion that could in turn influence public policy' (Monoian & Ferry, 2014). Another aim of the project is to create a space for innovation where a variety of expertises such as artists, engineers, designers, architects, and system and city developers can come together and collaborate on rethinking energy in the city. Furthermore, they want to inspire professionals to think about how energy could potentially look different and to question whether renewable energy technologies should solely be designed for optimized technological performance, or whether aesthetics could add other functions or values. Around 1,000 inspirational ideas for energy sculptures have been generated through four competitions – they are all available on the LAGI webpage, and some of them are published in beautiful coffee-table books.

In collaboration with the LAGI directors, my work was to be the local project manager leading up to the 2014 competition. My tasks were, among others, to ensure the funding,



Light Sanctuary, LAGI 2010
Martina Decker & Peter Yeadon

Solar Loop, LAGI 2012
Paolo Venturella, Alessandro Balducci, Gilberto Bonelli, Rocco Valantines, Mario Emanuele Salini, Pietro Bodria

The Sound of Denmark, LAGI 2014
Laura Mesa Arango & Rafael Sanchez Herrera

Figure 28.6 Land Art Generator Initiative by Elizabeth Monoian and Robert Ferry to find the site for the competition and make partnership with the landowners, to develop local partnerships, and to engage the jury members. It turned out to be surprisingly easy to engage top politicians and professionals from Danish industry. The Danish Minister of Environment accepted to be the ambassador of LAGI2014. The Minister of Climate and Energy wrote a text for the LAGI2014 call, in which he wrote that LAGI 'challenges our conventional notions of the path to a green transition, forcing participants to think outside the box and develop new ideas, concepts and solutions.'[19] And for the exhibition opening ceremony, back then, the European Commissioner of Climate Change, Connie Hedegaard, praised LAGI for managing to gather expertise and actors across silos of arts/culture and infrastructure development. I do not mention this in order to brag about my own work, but rather, I believe that this offers interesting knowledge about LAGI and about the reality in which it operates.

It is intriguing to see how LAGI manages to open up a space, where top politicians and industry can meet the arts and let themselves be inspired by other imaginaries. LAGI aims to enter into and thereby affect and hopefully change the existing and dominating energy politics. One can only speculate why top politicians wanted to be a part of an art project, but I suggest that they did do first because they see a need at involving the public in energy transitions and second because there is a rising acknowledgment that the transition to a 100% renewable energy future cannot be ensured by the engineers alone; it demands other disciplines to enter into the project.

Furthermore, I argue that LAGI's ability to engage top politicians is due to the kind of politics they are employing. Analyzing the project management process allowed me to see how LAGI is employing a politics quite different than the 'cosmopolitics' described above. In the previous analysis, my co-author and I argue that LAGI succeeded engaging top decision-makers because it employed 'a smooth and consensus-seeking political strategy, manifested in a set of tactical oscillations' (Schick & Winthereik, 2016, p. 44). My co-author and I describe how LAGI was eminent at tactically oscillating between different and sometimes conflicting positions. It oscillated between being predominantly an art project and being primarily an infrastructure project. It oscillated between being site-specific and existing in a universal nowhere. And it sometimes performed itself as *part of* existing policy initiatives and sometimes as proposing *alternatives to* existing policy. In contrast to the existing STS-informed art–energy studies focusing mainly on 'slowing down' hesitation, controversies, and cosmopolitics, we describe this tactical strategy as a 'smooth and consensus-seeking politics.' This mode of politics became clear to me during a conference where Elizabeth Monoian presented LAGI and said: 'We will show that in fact there can be this future working with beauty and renewable energy technology and we will slide into the politics without really having to discuss the politics' (Environmental Entanglements Conference, October 29, 2014).

Presenting at the same conference were Jennifer Gabrys and Helen Evans and Heiko Hansen (HeHe). The quote above and the LAGI presentation in general sparked a heated debate about the role and/or instrumentalization of art. Is the role of art to be critical, to explicate, and to discuss politics? Or is it to promote (positive) societal change such as the transition to renewable energy? Whereas the artists behind HeHe saw it as absolutely essential to stay autonomous from corporate and institutional interests in order to keep their artistic integrity and maintain a critical position, the LAGI directors saw potential corporate partnerships as welcomed means for attaining the greater goal of their project – to promote renewable energy through art. LAGI seeks to smoothen out political and disciplinary differences in order to speed up and mobilize political and public consensus.

One could see the smooth and consensus-seeking politics of LAGI as contradictory to the other three modes of art–energy – a contradictory between fast and slow and between smooth politics and controversial cosmopolitics. If one sees the role of arts to be one of critique, slowing down, and of creating controversy, this produces a situation in which 'arts' stand 'outside society' and outside other disciplines. From this position, I argue, art does not have as big a possibility to affect the world it is critiquing. Why should engineers listen to and let themselves be inspired by critique and complexity?

On the other hand, seeing art as purely instrumentalized and uncritical part of the established system and discourse also does not create a fruitful situation for letting art intervene in the system. Thus, if we, as I argued in the beginning of the chapter, are in a position where the art has a unique opportunity to actually intervene into energy systems and development, I see the polarization of 'critical' versus 'instrumentalized' arts as deeply ungenerative in thinking about how art may best play a productive role in the making of new and different energy futures. I therefore choose not to see these modes as incompatible. Rather, I argue that seeing the different modes along one another opens up the space and role of arts toward what I term a 'generative critique.'

Art–energy as generative critique

In this chapter, I have outlined four modes of art–energy projects. The first one presented projects that were Making Energy Visible, the second presented projects that were making energy political and energy publics, the third was proposing speculative energy futures, and the fourth was presenting energy solutions through smooth politics. I have collated and outlined the first three modes as a matter of hesitating cosmopolitics. Using the fourth mode of Making Energy Solutions through smooth and consensus-seeking politics, I propose as a new contribution to the field, that differs from the previous existing literature mainly arguing for art–energy as a means for cosmopolitics. However, as I said in the beginning, the aim of ordering the art–energy projects into different modes has not been to understand them as different from one another. Rather, outlining the art–energy projects in four modes has helped me to stretch out and open up a framework, which allows me to see the potentiality of working across the different approaches. In this last part, I will formulate a way of working artistically with energy, which can work across the different modes. I will argue why 'art as generative critique' may provide a productive and vital mode for intervening into energy futures in-the-making. Being in a place and time in history with a particular opening for disciplines, such as social science, humanities, and arts to intervene into the making of energy systems, as argued in the beginning of the chapter, I will propose generative critique as a guiding principle for artists working in the field of energy and ASTS.

In STS and in art theory, more generally, there has been a tendency to focus mainly on art's ability to be diagnostic and critical of science or of social processes and norms. As the first three modes, alongside the academic literature on which they are built, witness, the focus in energy–art and science has been mainly on artworks that can slow down, create hesitation, be critical, and reveal controversy. By adding the mode of 'making solutions' and by arguing that this mode should not be seen in opposition to the others, but instead it stretches out a space for artistic interventions, I wish to articulate a role of art that manages to be both critical and generative in the making of new and different kinds of energy futures. It is thus important to underline that I do not do away with critical art and hesitation and instead propose a simple instrumentalization of arts. Rather, my argument is to soften the boundaries between critical art and instrumentalized art. The problem with critical art is that it tends to take a position 'outside' the development of energy and therefore may not easily enter into and have an effect on the making of new energy futures. On the other hand, a classical notion of 'instrumentalized art' may operate too much on the premises of the established energy regime and thus not have much of an effect in changing or rethinking energy futures. Thus, tactical oscillations between critical and instrumentalized may provide a way forward for arts. How can we see art as both critical and productive? How can art both stand 'outside' and intervene in the issues with which it deals? What kinds of generative moves and modes does it take in order to gain access to and become productive in changing and affecting fields such as energy infrastructures in-the-making? How can modes of oscillation be generative for artists and art critics who wish to take part in some of the major challenges we are facing? My answer to this is 'generative critique.'

The term 'generative critique' is inspired by STS, more specifically by Bruno Latour (2004) and Helen Verran (2014), who formulate a kind of critique for social scientists studying science and technology, which does not want to debunk or criticize science and technology, but instead aims at 'adding to' or generatively help develop the subject matter. I suggest for the arts to adopt this approach and be inspired to make art–energy projects that do not seek to debunk and deprecate the current energy system in order to criticize and disassociate themselves from the field. Instead, I see critique as a means for intervening into the field. We could thus read the artworks through this term and thus see them as attempts to generatively think with and help develop the current energy systems. I will argue that the seven art–energy projects provide novel and experimental ways of Making Energy Visible and material. This is not only interesting from an STS methodological perspective but also highly relevant for a variety of infrastructure developers struggling how to make energy visible and how to engage people in more effective and affective ways. As STS has shown, the making of science and the making of technology are outcomes of the imaginaries, technologies, politics, and cultures of their creators. When artists are engaging in the field of science, technology, and energy – bringing other 'cultures,' imaginaries, and political relations into the field – new configurations of energy may emerge.

The art–energy projects are blurring the boundaries between 'experts' and 'laypeople' by bringing publics of various kinds closer to science and technology. Through DIY technologies, they attempt to empower people to take action in the political and scientific debate and to actively participate in the making of alternate energy futures. Thus, the art–energy projects are interesting practices for intervening in the discussion of public understanding of and engagement with science. The art–energy projects go beyond the classical 'public understanding of science,' as it has been criticized in STS, by offering 'public experiments with science' (Born & Barry, 2013). In these art–energy projects, both science and publics are up for experimentation, and rather than a one-way dissemination of science and a 'right way' to engage publics, these experiments allow for new and possibly generative modes of concern and engagement, new energy publics, and new configurations of energy to emerge. It is in these possibilities for new things to emerge that we can see the art–energy projects as practices of generative critique.

In a world with more and more big challenges such as energy, climate, and other interlinked crises, which no one discipline knows how to solve, it becomes absolutely essential for the arts to intervene into these issues. In order to do so, working from and with a generative critique can provide arts, humanities, and STS scholars with the power to intervene in ways that may open up for more generative and productive art–science collaborations. Interventions and so-called transdisciplinary collaborations demand generative and productive approaches, collective thinking, and diplomacy (Stengers, 2003, p. 184). Based on this chapter, the field of art and science should be focusing more on art as a productive 'generative critique,' which may help to develop the scientific fields in which they/it/we intervene. This is strongly needed in a time where 'experts' (engineers and economists) do not seem to be able to come up with solutions able to deal with the big challenges. Applying, in the arts, a mode of generative critique, I hope, will help develop energy futures in novel and different ways, which the 'experts' may not be able to think and develop themselves.

References

Batel, S., and Devine-Wright, P. (2014). Towards a Better Understanding of People's Responses to Renewable Energy Technologies: Insights from Social Representations Theory. *Public Understanding of Science*, *24*(3), pp. 311–325.

Bergström, J., Mazé, R., Redström, J., and Vallgårda, A. (2009). Symbiots: Conceptual Interventions into Urban Energy Systems. In: *Nordic Design Research, 3.* Oslo, Norway [online]. Available at: http://www.nordes.org/opj/index.php/n13/article/view/40 [Accessed 3 November 2018].

Born, G., and Barry, A. (2013). Art-Science. From Public Understanding to Public Experiment. In: A. Barry and G. Born, eds., *Interdisciplinarity: Reconfigurations of the Social and Natural Sciences*. London: Routledge, pp. 247–272.

Bowker, G. C. (1995). Second Nature Once Removed. Time, Space and Representations. *Time and Society*, *4*(1), pp. 47–66.

Burgess, J., and Nye, M. (2008). Re-Materialising Energy Use through Transparent Monitoring Systems. *Energy Policy*, *36*(12), pp. 4454–4459. https://ideas.repec.org/a/eee/enepol/v36y2008i12p4454-4459.html

Chilvers, J., and Pallett, H. (2015). *Making Energy Publics: Workshop Report*. University of East Anglia [pdf]. Available at: https://uea3s.files.wordpress.com/2015/02/making-energy-publics-workshop-report-final1.pdf [Accessed 3 November 2018].

Cotton, M., and Devine-Wright, P. (2010). Making Electricity Networks "Visible": Industry Actor Representations of "Publics" and Public Engagement in Infrastructure Planning. *Public Understanding of Science*, *21*(1), pp. 17–35.

Danholt, P., and Halse, J. (2016). Design and the Social: Intersections between Design, Critique and STS. *STS Encounters*, *8*(1) pp. 1-12.

Domínguez Rubio, F., and Fogué, U. (2013). Technifying Public Space and Publicizing Infrastructures: Exploring New Urban Political Ecologies through the Square of General Vara del Rey. *International Journal of Urban and Regional Research*, *37*(May), pp. 1035–1052.

Dunne, A., and Raby, F. (2013). *Speculative Everything: Design, Fiction and Social Dreaming.* MIT Press, Cambridge MA.

Edwards, P. (2003). Infrastructure and Modernity: Force, Time, and Social Organization in the History of Sociotechnical Systems. In: T. Misa, P. Brey, and A. Feenberg, eds., *Modernity and Technology.* MIT Press, Cambridge MA pp. 185–225.

Entwistle, J. M., Verdezoto, N., Andersen, M. S., Rasmussen, M. K., and Brewer, R. S. (2015). Beyond the Individual: The Contextual Wheel of Practice as a Research Framework for Sustainable HCI. in B Begole & J Kim (red), *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems, CHI '15.* Association for Computing Machinery, pp. 1125–1134, The ACM CHI Conference on Human Factors in Computing Systems, Seoul, Sydkorea, 18/04/2015. https://doi.org/10.1145/2702123.2702232

Evans, H. (2008). NUAGE VERT. *Cluster Magazine* (07) [online]. Available at: http://hehe.org.free.fr/hehe/texte/nv/ [Accessed 3 November 2018]

Gabrys, J. (2014a). A Cosmopolitics of Energy: Diverging Materialities and Hesitating Practices. *Environment and Planning A*, *46*(9), pp. 2095–2109.

Gabrys, J. (2014b). Programming Environments: Environmentality and Citizen Sensing in the Smart City. *Environment and Planning D: Society and Space*, *32*(1), pp. 30–48.

Gustafsson, A., and Gyllenswärd, M. (2005). The Power-Aware Cord: Energy Awareness through Ambient Information Display. CHI EA '05: CHI '05 Extended Abstracts on Human Factors in Computing Systems April 2005, pp. 1423–1426. https://doi.org/10.1145/1056808.1056932

Haque, U., Samsen, N., and Hasegawa, A. (2011). Structuring Participation for an Energy Commons. In: M. Shepard, ed., *Sentient City*, MIT Press, Cambridge MA, pp. 64–87.

Hargreaves, T., Nye, M., and Burgess, J. (2010). Making Energy Visible: A Qualitative Field Study of How Householders Interact with Feedback from Smart Energy Monitors. *Energy Policy*, *38*(10), pp. 6111–6119.

Holmes, T. (2007). Eco-Visualization: Combining Art and Technology to Reduce Energy Consumption. Conference: Proceedings of the 6th Conference on Creativity & Cognition, Washington, DC, USA, June 13-15, 2007, pp. 153–162.

Jasanoff, S., and Kim, S.-H. (2013). Sociotechnical Imaginaries and National Energy Policies. *Science as Culture*, *22*(2), pp. 189–196.

Jönsson, L. (2014). *Design Events: On Explorations of a Non-Anthropocentric Framework in Design*. PhD. The Royal Danish Academy of Fine Arts, Schools of Architecture, Design and Conservation School of Design [pdf]. Available at: https://www.academia.edu/11481605/Design_events_on_explorations_of_a_non-anthropocentric_framework_in_design [Accessed 3 November 2018].

LAGI (n.d.). *Land Art Generator Initiative, Competition* [online]. Available at: http://landartgenerator.org/competition.html [Accessed 14 October 2018].

Latour, B. (2004). Why Has Critique Run out of Steam? From Matters of Fact to Matters of Concern. *Critical Inquiry*, *30*, pp. 225–248.

Latour, B. (2011). Waiting for Gaia. Composing the Common World through Arts and Politics [online lecture]. *Lecture at French Institute London* (November 2011). http://www.bruno-latour.fr/node/446

Marres, N. (2005). Issues Spark a Public into Being: A Key But Often Forgotten Point of the Lippmann-Dewey Debate. In: B. Latour and P. Weibel, eds., *Making Things Public: Atmospheres of Democracy*. MIT Press, Cambridge MA.

Marres, N. (2011). The Costs of Public Involvement Everyday Devices of Carbon Accounting and the Materialization of Participation. *Economy and Society*, *40*(4), pp. 510–533.

Marres, N. (2015). Who Is Afraid of the Green Cloud? On the Environmental Rendering of Controversy. In: H. Evans and H. Hansen, eds., *Man Made Clouds*. Paris: Orléans: Editions Hyx, pp. 357-410.

Mazé, R. (2011). *Static! Designing for Energy Awareness*. RAM Publications.

Monoian, E., and Ferry, R. (2014). *New Energies: Land Art Generator Initiative, Copenhagen*. Munich, London, New York: Prestel.

Nyborg, S., and Røpke, I. (2013). Constructing Users in the Smart Grid—Insights from the Danish eFlex Project. *Energy Efficiency*, *6*(4), pp. 655–670.

Pierce, J., Odom, W., and Blevis, E. (2008). Energy Aware Dwelling : A Critical Survey of Interaction Design for Eco-Visualizations. Proceedings of the 20th Australasian Conference on Computer-Human Interaction: Designing for Habitus and Habitat, pp. 1–8. https://dl.acm.org/doi/10.1145/1517744.1517746

Pierce, J., and Paulos, E. (2010). Materializing energy. In *Proceedings of the 8th ACM Conference on Designing Interactive Systems*, ACM, pp. 113–122. Aarhus, Denmark [online]. Available at: https://dl.acm.org/citation.cfm?id=1858193 [Accessed 3 November 2018].

Rogers, H. (2011). Amateur Knowledge: Public Art and Citizen Science. Configurations 19(1) Johns Hopkins University Press. pp. 101-115.

Schick, L. (2015). *Composing for Energy Engagement – Studies in Sm/Art Infrastructures*. PhD. IT University of Copenhagen [pdf]. Available at: https://www.dropbox.com/s/vjgkeentrdridm9/PhD_LeaSchick_Oct2015.pdf?dl=0 [Accessed 3 November 2018].

Schick, L., and Gad, C. (2015). Flexible and Inflexible Energy Engagements – A Study of the Danish Smart Grid Strategy. *Energy Research & Social Science*, *9*, pp. 51–59.

Schick, L., and Winthereik, B. R. (2016). Making Energy Infrastructure: Tactical Oscillations and Cosmopolitics. *Science as Culture*, *25*(1), pp. 44–68.

Schick, L., and Witzke, A. S. (2011). Powering Ecological Futures. *ISEA, Istanbul* [online]. Available at: http://isea2011.sabanciuniv.edu/paper/powering-ecological-futures [Accessed 14 June 2015].

Schick, L., and Witzke, A. S. (2014). Atmosfæriske konstellationer – kunsten at økologisere. In: M. Sørensen and M. F. Eskjær, eds., *Mennesker og Klima*. Museum Tusculanums Forlag, København, pp. 81–106. https://www.mtp.dk/details.asp?eln=203550

Stengers, I. (2003). An Ecology of Practices. *Physics*, *11*(1), pp. 183–196.

Stengers, I. (2005). The Cosmopolitical Proposal. In: B. Latour & P. Weibel, eds., *Making Things Public: Atmospheres of Democracy*. The MIT Press, Cambridge MA, pp. 994–1003.

Strengers, Y. (2013). *Smart Energy Technologies in Everyday Life - Smart Utopia?* Palgrave Macmillan, UK.

Tironi, M., and Sánchez Criado, T. (2015). Of Sensors and Sensitivities. Towards a Cosmopolitics of "Smart Cities"? *TECNOSCIENZA: Italian Journal of Science & Technology Studies*, *6*(1), pp. 89–108.
Verran, Helen. 2014. Working with Those Who Think Otherwise. *Common Knowledge*, *20*(3), pp. 527–539.
Walker, G., and Cass, N. (2007). Carbon Reduction, "the Public" and Renewable Energy: Engaging with Socio-Technical Configurations. *Area*, *39*(4), pp. 458–469.
Yaneva, A. (2003). When a Bus Met a Museum. To Follow Artists, Curators and Workers in Art Installation. *Museum and Society*, *3*, pp. 116–131.
Yusoff, K., and Gabrys, J. (2011). Climate Change and the Imagination. *Wiley Interdisciplinary Reviews Climate Change*, *2*(4), pp. 516–534.

29

Hemlock Hospice

Landscape ecology, art, and design as science communication

Aaron M. Ellison and David Buckley Borden

Hemlock Hospice: overview and rationale

Hemlock Hospice was a series of eighteen site-specific sculptural installations that we co-designed and situated along a 1,500-meter-long (≈1 mile) interpretive trail at the Harvard Forest in Petersham, Massachusetts.[1] It presented a visual and interactive narrative about the

Figure 29.1 Wayfinding Barrier No. 1 and X-Trail Closure (2017)

Installations at Harvard Forest. Wayfinding Barrier No. 1: 1.5 × 3.75 × 4 feet; wood, acrylic paint, vinyl, assorted hardware, aluminum tape, and recycled field equipment (heat lamp and ant-nest boxes); X-Trail Closure: 10 × 10 × 3 feet; wood, acrylic paint, vinyl, and assorted hardware; Collaborators: David Buckley Borden, Jack Byers, Aaron M. Ellison, and Salua Rivero.Photograph: David Buckley Borden.

As the first installation on the Hemlock Hospice trail, the Wayfinding Barrier and X-Trail Closure not only rerouted visitors but also prompted visitors and scientists alike to reflect on how slow and subtle environmental changes alter our daily lives by changing familiar paths to unfamiliar ones. The "yellow" natural history trail was one of Harvard Forest's oldest natural history trails; for more than three decades, it was used daily by dozens of visitors and onsite staff. In 2014, as eastern hemlocks within this old-growth hemlock stand began to disintegrate as the trees succumbed to the depredations of the hemlock woolly adelgid, the yellow trail was closed because of safety concerns for visitors who use it regularly for recreation and occasional hunting.

 DOI: 10.4324/9780429437069-37

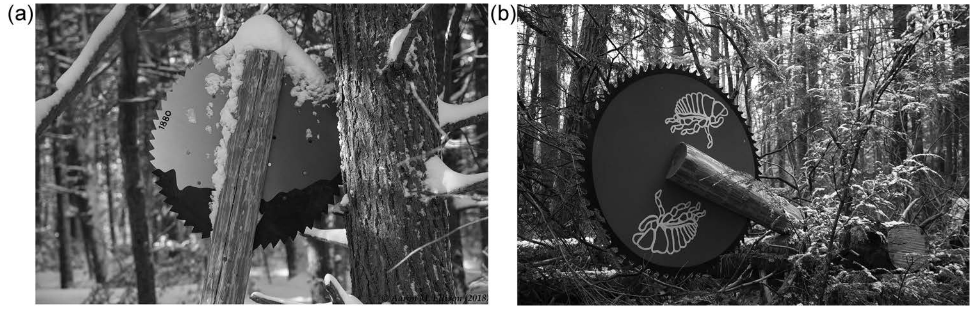


Figure 29.2 Double Assault (2017)

Installation at Harvard Forest. Variable dimensions; acrylic paint, wood, vintage sawmill saw blades, and assorted hardware; Collaborators: David Buckley Borden, Jack Byers, Aaron M. Ellison, and Salua Rivero; Photographs: David Buckley Borden and Aaron M. Ellison.

Interactions between climatic warming and the insect have led to a "double assault" on the trees. In the last century, average annual temperatures in New England have increased by nearly 1.5°C (>2.5°F) in parallel with the industrialization of the economy and the unsustainable burning of fossil fuels. Eastern hemlock favors cooler climates, and it is stressed by warmer temperatures. At the same time, winter minimum temperatures of −25°C (−13°F) or lower kill at least 50% of the adelgids (Costa et al., 2008). Because winters generally are colder further north where hemlock is more common, winter low temperatures historically have prevented the adelgid from spreading quickly (Fitzpatrick et al., 2012). Winter low temperatures colder than −25°C used to be the norm in southern New England, but now, they are very unusual. For example, the last time it was that cold in Groton, Connecticut was in 1983; the adelgid established there in 1985. For Harvard Forest, it was last that cold in 2004 and the adelgid was well established at Harvard Forest by 2009 (Ellison, 2014). There was a brief dip to −29°C in early 2018 at Harvard Forest (Boose, 2018), but by then, the rapidly reproducing adelgid had evolved substantially with greater tolerance to extreme cold (Butin et al., 2005). Whereas its populations used to take several years to recover from a cold winter, now, they bounce back within only a few months.

introduction of a nonnative insect (the hemlock woolly adelgid), the associated decline of a dominant forest tree (eastern hemlock), and a glimpse of New England forests of the near future. *Hemlock Hospice* was also designed intentionally to encourage people to reflect on how to interact empathetically with trees, insects, and forests (Figure 29.1). Finally, *Hemlock Hospice* was contextualized locally, regionally, and globally. Research scientists and support staff who work at the Harvard Forest daily witness the inexorable decline of this particular forest stand. Visitors from New England see in the decline of hemlock at Harvard Forest other ongoing forest declines caused by insects and pathogens throughout this region (Lovett et al., 2016). And forest declines around the world are accelerating because of human-caused climate change (Perie and de Blois, 2016; Figure 29.2).

Hemlock forests, hemlock decline, and the hemlock woolly adelgid

Eastern hemlock (*Tsuga canadensis*) is an evergreen tree related to pines, cedars, larches, firs, and spruces. For the last eight millennia, eastern hemlock has been a "foundation species" in eastern North American forests: it exerts disproportionate control on biodiversity, energy flow, and nutrient fluxes in the forest (Ellison, 2014). The dense canopy, shaded understory, and quiet soft soil built up from centuries of shed needles of eastern hemlock forests also has inspired some of America's great poets (e.g. *I think the Hemlock likes to stand* [F400 (1862) in Dickinson, 1998] and *Dust of Snow* [Frost, 1923]).

Figure 29.3 Insect Landing (2017)

Installation at Harvard Forest. 4 × 6 × 6 feet; recycled wood, acrylic paint, and hardware; Collaborators: David Buckley Borden, Jack Byers, Aaron M. Ellison, Salvador Jiménez-Flores, C. C. McGregor, Patrick Moore, Salua Rivero, and Lisa Ward; Photograph: Aaron M. Ellison.

The hemlock woolly adelgid was first documented in eastern North America in 1951, imported inadvertently by a plant nursery in Richmond, Virginia on Japanese hemlock trees from Osaka, Japan (Havill et al., 2006). It had been reported previously in the 1920s in British Columbia, where it feeds on western hemlock (*Tsuga heterophylla*) and mountain hemlock (*Tsuga mertensiana*) (Havill et al., 2016) with little ill effects. Once established in the eastern United States, the adelgid spread northeast into Pennsylvania (again, most likely via the horticultural trade) and southern New England (Fitzpatrick et al., 2012). It subsequently moved southwest into the Shenandoah and Great Smoky Mountains, then crossed the Appalachian Mountains and continued its spread west and north. As of 2018, the adelgid occurred in ≈90% of the range of eastern hemlock and in all populations of the much more narrowly distributed Carolina hemlock, *Tsuga caroliniana* (Canadian Food Inspection Agency, 2017; USDA Forest Service, 2017).

The colonization of North America by the adelgid, like that of other nonnative species, is strongly linked to transboundary shipping and the global economy (Bradley et al., 2012; Lovett et al., 2016). Its regional spread is linked as much to economic activities and transportation networks as it is to the prevalence of a suitable host plant and a hospitable climate. Local actions to manage ecological systems must account for regional, national, and international activities. The clarion call of the first Earth Day (1970) to "think globally, act locally" still applies today, nearly fifty years later.

In the early 1950s, a tiny mealy bug-like insect native to northeast Asia, the hemlock woolly adelgid (*Adelges tsugae*), was detected in Virginia (Havill et al., 2006; Figure 29.3). Spread by wind, birds, and people, it feeds on and kills eastern hemlocks of all ages and sizes. Although adelgid infestations on one or a few trees are controllable with regular applications of insecticides, these are infeasible for treating large numbers of trees in dense forest stands. Biological control measures for the adelgid are being investigated but have not yet proven effective in controlling it at landscape scales (Sumpter et al., 2018; USDA Forest Service, 2017).

Responses to hemlock decline range widely. Ecologists study how the adelgid, climate change, and patterns of land use affect rates of hemlock decline and the different trees and forests that may replace it (Ellison, 2014; Foster, 2014). Entomologists are developing methods to control the adelgid (Sumpter et al., 2018). Foresters suggest "preemptively" salvaging hemlock trees so landowners can realize economic value from them (Foster and Orwig, 2006; Figure 29.4). Geneticists are identifying eastern hemlocks resistant to the adelgid and cross-breeding them with non-resistant individuals to develop resistant trees (Ingwell and Preisser, 2011; Oten et al., 2014). Conservation biologists are planting orchards of eastern hemlocks in North Carolina, Chile, and Brazil to preserve genetically diverse stock so that

Figure 29.4 Bio-Resource Plug (2017)

Installation at Harvard Forest; 1.5 × 1.5 × 3.5 feet (plug); wood, steel, and plastic tubing; Collaborators: David Buckley Borden and Brian Hall; Photograph: Neal Pederson.

Throughout New England, as many hemlocks have been lost to pre-emptive harvesting to extract as much economic value as possible out of hemlock stands before they are killed by the adelgid as has been lost to the adelgid itself (Foster and Orwig, 2006). Hemlock is not an especially valuable timber tree; it checks and twists, and few hemlock logs can be used for post-and-beam construction (Meier, 2015). Most harvested hemlock are chipped for biofuel or bioenergy feedstock or pulped for toilet paper and paper towels.

If we think of and refer to nonhuman organisms as "natural resources," then it is easier to exploit them and harder to empathize with them. Yet, eastern hemlock also is a part of New England history and culture, and its loss represents more than simply the loss of a natural resource for which a synthetic substitute eventually can be found. Recall the words of *Dust of Snow* by the New England poet, Robert Frost (1923):

The way a crow
Shook down on me
The dust of snow
From a hemlock tree
Has given my heart
A change of mood
And saved some part
Of a day I had rued.

hemlock forests can be replanted if and when the adelgid has been controlled or eradicated (Jetton et al., 2013). Despite these efforts, we are witnessing the inevitable passing of these trees from our forests.

Hemlock Hospice integrated and communicated these diverse responses through site-specific art and design. For people, hospice and palliative treatment provide physical and spiritual care for terminally ill individuals, their families, and loved ones (Kane et al., 1985; Teno et al., 2004). Hospice care not only comforts individuals who are dying, often painfully, but also helps family and friends cope with impending loss and ultimately come to terms with it. By extension, *Hemlock Hospice* provided an expression of care for dying trees in a declining forest and opened a space for thoughtful and constructive conversations about our relationships with nonhuman organisms such as trees and insects (Figure 29.4). Visitors should have left *Hemlock Hospice* with newfound empathy for trees and species like the adelgid that interact with them and an acceptance of ongoing, dynamic changes in forests and other ecological systems (Ellison, 2013).

Designing *Hemlock Hospice* and democratizing art/science collaborations

In contrast to the typical practice diagram representing the relationship between art, design, and science (Figure 29.5) that places art at the apex as the cultural edge to engage broad audiences, the conceptualization, design, fabrication, and installation of *Hemlock Hospice* was intentionally collaborative and democratic. All eighteen pieces in *Hemlock Hospice* and the overall installation itself were informed by design-thinking, which made explicit the overall creative framework and goals of the project. In *Hemlock Hospice*, as in many other installations that interpret and communicate scientific information, both art and design are built on a foundation of scientific research (Ellison et al., 2018). This view of the relationship between art, design, and science not only seems to us to be inappropriately hierarchical but also omits other crucial and practical aspects of projects such as *Hemlock Hospice* that aim to integrate and communicate a variety of disciplinary perspectives. These aspects include community engagement, educational programming, promotion, and ultimately direct action (Figure 29.5), all of which are integrated empathetically at multiple stages throughout project conception, design, development, and implementation.

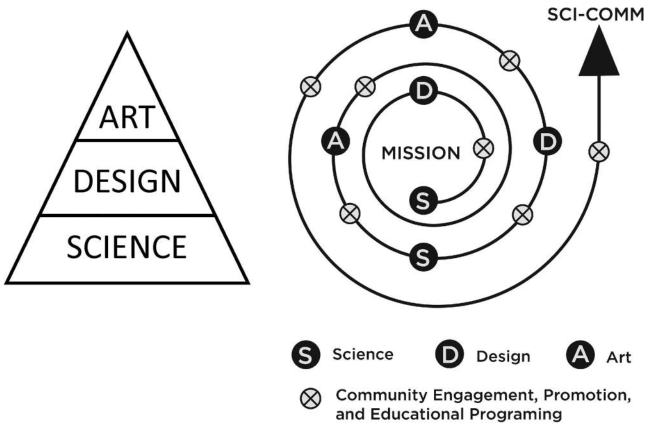


Figure 29.5 Interdisciplinary Feedback between Science, Art, Design, and Supporting Disciplines

Many art/science projects reflect unidirectional and hierarchical relationships (left) in which data generated from scientific observations or experiments provide the conceptual foundation for creativity. Design-thinking provides the overall framework and goals, accounting for the project mission, resources, and constraints for the artwork. The artistic creation acts as the cultural edge for transmitting an engaging message to broader (and generally non-scientific) audiences. In this view (common to "broader impact" statements in research grants), scientists hand off their data to a designer and artist, who then independently develop a way to communicate the results more broadly.

In contrast, we view art- and design-based science communication projects less hierarchically and more inclusively in terms of both participants and content (right). In this creative process, collaboration is built around a shared mission, builds on the inherent strengths of each discipline, and provides a framework for productive feedback. Community, education, and outreach modulate the ever-expanding potential by amplifying the desired science-communication goals.

Community engagement in the design of Hemlock Hospice

Communities inspire collaborations. *Hemlock Hospice* was situated at the Harvard Forest, whose communities motivated and drove its narrative. Onsite researchers (students, research staff, faculty) and support staff (facilities and administration) work together to realize the educational, research, and outreach mission of the Harvard Forest. Researchers come from all over the world to contribute to, and take advantage of, long-term site-based field and archival ecological research. Students visit Harvard Forest to learn about its research. Hikers, horseback riders, hunters, day visitors, and many others use Harvard Forest trails and lands for recreation and contemplation. *Hemlock Hospice* engaged and expanded these Harvard Forest communities by involving them variously in conceptualizing and fabricating individual pieces, determining access and location for installations, and providing thoughtful feedback, critique, and validation of the work as it progressed from design through installation and opening.

The artful design of *Hemlock Hospice* reflected not only individual inspiration but also curation and editing of content provided by the Harvard Forest onsite community. This community collectively both set the tone of the narrative—much of the background data on eastern hemlock, the adelgid, and current hemlock decline has been collected by Harvard Forest researchers (summarized in Foster, 2014)—and contributed many nuanced cultural details to the individual pieces and the landscape context of *Hemlock Hospice*. For example, the caricature of New Englanders as thrifty Yankees and the sustainability ethos of the Harvard Forest community were apparent in the recycling or repurposing of ≈90% of the materials used to construct the *Hemlock Hospice* sculptures. These included lumber and wood fragments left over from onsite processing of locally sourced wood used to heat Harvard Forest's office, laboratory, and residential spaces (e.g. the tree stumps in *Bio-Resource Plug* [Figure 29.4] or the sawmill saw blades in *Double Assault* [Figure 29.3]), and "eco-debris" from decommissioned experiments (e.g. the heat lamp and ant-nest boxes in *Wayfinding Barrier No. 1* [Figure 29.1]).

Design-thinking and beta-testing Hemlock Hospice

Design-thinking also was a central element of the creation and realization of *Hemlock Hospice*. We applied a key element of design-thinking—"beta-testing," the iterative solicitation of critical and constructive feedback from a range of communities and stakeholders during design development—to the creative development of this first art-based interpretive trail at Harvard Forest that substantially improved its final design. Three months prior to the official opening of *Hemlock Hospice*, we brought Harvard Forest researchers and administrative staff on tours to identify any public safety issues and to ensure that the sculptures did not conflict with co-located research projects. We worked consistently with the leadership team at Harvard Forest (including the Director, Director of Administration, and Site Coordinator) to identify appropriate sites for individual installations to create maximum aesthetic impact while minimizing effects on ongoing research projects and the ecological integrity of the forest stand itself. At the same time, concerns about limbs of disintegrating trees falling on visitors inspired additional decisions regarding design direction, project branding, wayfinding, and the overall route of the trail through the forest.

We then beta-tested the trail with undergraduate participants in Harvard Forest's Summer Research Program (McDevitt et al., 2016) and first-year graduate students in the MLA program at the Rhode Island School of Design; the latter group had a particular interest in using both ecology and applied creative strategies to create intentional user experiences in outdoor environments. Additional *ad hoc* beta-tests were done with other groups of visitors from the surrounding community. The value of all these beta-tests was that each group brought a unique perspective and background that we synthesized into the design and siting of the artwork that makes up *Hemlock Hospice* and its supporting elements (e.g. wayfinding signage and a self-guided trail map).

Through this ongoing beta-testing and our responsive and iterative creative approach, we were able to focus on human-centric solutions that focused viewers' experiences on interpreting sculptural pieces presenting a complex narrative of environmental and cultural forces. This design-thinking approach led us to a more nuanced and empathetic understanding of design features and functions ranging from the layout of the trail in the forest to the graphic design of the trail maps. Specifically, beta-tests and empathetic attitudes allowed us to set aside our own assumptions about the narrative and functionality of the interpretive trail. The design impact of the trail was our driving concern; it was not a matter of our collective creative egos. Beta-testing ensured a constant reframing of the educational experience of the trail in terms of the visitors and viewers, which ultimately resulted in a stronger art-based science communication project.

Beta-testing is one example in which we applied design-thinking in the creative development of *Hemlock Hospice*. This regular back-and-forth between the artist/designer and the community differed from the more traditional vision of science (data) → design → art envisioned in the standard practice diagram (Figure 29.5). However, the use of design-thinking tactics, including beta-testing, prototypes, and scaled study models emerged naturally from Borden's background as a landscape architect. The approach is also remarkably similar to Ellison's (and other scientists') practice of iteratively developing and testing hypotheses and confronting them with data, leading to their rejection or refinement (Hilborn and Mangel, 1997).

Community engagement in the production of Hemlock Hospice

Realizing designs of individual sculptures and the overall installation engaged other communities. At a very practical level, production costs money, and resources for art are practically nonexistent in departments such as Harvard Forest that are focused on scientific research or at field stations run and used by scientists (but see the AS.IF Center for a useful counterexample[2]). For example, salaried scientific researchers can fold art/science collaborations into their day-to-day work, but freelance artists/designers who normally are paid only when projects are completed should be compensated for their work throughout the process so that they can similarly focus their full energies on the collaborative project. Ellison—the lead scientist for *Hemlock Hospice*—not only contributed and helped to interpret data but also worked as a behind-the-scenes "executive producer," identifying, with the help of the supportive administrative team at Harvard Forest, unrestricted and unencumbered funds that could be reallocated to those items needed to successfully complete this science communication project.

Borden—the lead artist/designer of *Hemlock Hospice*—was supported with a year-long fellowship from the Harvard Forest. Materials, supplies, and fabrication also cost money, and we had a great deal of help from a community of visiting fabricators who refined the designs and constructed the sculptures themselves (Hass, 2018). We drew on the expertise and craft of more than a dozen painters, woodworkers, printmakers, and fabric artists, each of whom brought crucial ideas and skills to *Hemlock Hospice*. Each also designed a hard hat used by visitors to the installation (Figure 29.6), and their contributions were explicitly recognized in the associated trail guide and publicity efforts. We do not think that the meaning

Figure 29.6 Hospice Visitor Check-in and Safety Helmet Station (2017)

Installation at Harvard Forest. Variable dimensions; acrylic paint and vinyl on hard hats; Collaborators: David Buckley Borden, Jack Byers, Benjamin Carlson, Aaron M. Ellison, Salvador Jiménez-Flores, and Salua Rivero; Photograph: Aaron M. Ellison.

We advised all visitors to Hemlock Hospice to put on hard hats—each designed by one of our visiting fabricators—because falling limbs and disintegrating trees are a safety hazard in declining hemlock stands. Wearing hard hats was a ritual of immersion that embedded visitors more deeply in the installation—they became participants and caregivers rather than simple observers. The act of putting on hard hats prompted visitors to look up and observe the gray, thinning canopy of dying trees while engaging them in the research context of the forest, where scientists working in adelgid-infested stands routinely wear hard hats and other personal protective equipment.

of the individual pieces and the overall installation was changed by our explicit assertion that *Hemlock Hospice* was the result of a broad-based and inclusive collaboration. However, we do think that this assertion emphasized the interpretation of the causes and consequences of hemlock decline as reflecting scientific and cultural consensus rather than that of a single individual.

Encouraging empathy in a community of care-givers

Empathy is the ability to understand and share the feelings of another (or "an other"). The installations of *Hemlock Hospice* engaged different visitors in myriad ways and sparked different degrees of understanding and empathy. A casual visitor might have viewed *Wayfinding Barrier No. 1* (Figure 29.1) as a simple detour sign; a regular hiker might have been taken aback by the large object preventing them from walking in their normal route; a member of the Harvard Forest Woods Crew might have remembered cutting the wood used to support or frame the sculpture; and an ant researcher might have hoped that ants would still be able to take up residence in the now-airborne nest boxes. When conversations occurred among these diverse groups, each brought their own interpretations and unique perspectives to subsequent discussions about the changing forest. An art/science project like *Hemlock Hospice* can provide a vehicle for the expression of community values and can give visual voice to the people that work in and around the installation site (here, the forest). All who experienced *Hemlock Hospice* attained a greater empathetic understanding of the forest, too.

Hemlock Hospice had its origin in the observations that eastern hemlock forests are inexorably declining as adelgids spread, feed on, and ultimately kill their host trees. Although many groups and stakeholders continue to focus on chemical and biological control efforts or *ex situ* conservation plantings, these measures to date have been ineffective at slowing the spread of the adelgid or the demise of hemlock forests at the landscape scale. With *Hemlock Hospice*, we wanted to spark a conversation about making the transition from "curative" to hospice care for hemlock forests, a conversation that seems to us to be especially relevant as people and their activities are rapidly transforming the world and extinguishing its biodiversity (Figure 29.7).

Figure 29.7 Sixth Extinction Flag (2017)

Installation at Harvard Forest. 5 × 5 feet; Canvas, thread, nylon rope, and grommets; Collaborators: Jackie Barry, David Buckley Borden, Mike Demaggio, and Aaron M. Ellison; Photograph: Aaron M. Ellison.

Eastern hemlock is but one of many species being lost around the world as part of the ongoing sixth "mass extinction" in Earth's history (Harris, 2000; Leakey and Lewin, 1996). The loss of hemlock, the gain of the adelgid, the deliberate and unintentional movement of species, and the conversion of "natural" areas to human-dominated ones are global-scale phenomena; the rapid changes in forest structure occurring at Harvard Forest are a local example. Keeping the global picture in mind while foregrounding attention and study on local changes and the actions responsible for them will allow us to focus our energies where they can do the most good.

In clinical practice, the patient in hospice care and the family are considered together to be the unit of care (Wittenberg-Lyles et al., 2012). By analogy, eastern hemlock and the broader Harvard Forest communities are partners in hospice care for eastern hemlock forests. Interdisciplinary teams and nurturing empathetic relationships between family caregivers and patients are just as crucial in our stewardship of our changing environment (Berenguer, 2007) as in human-centered hospice care (Wittenberg-Lyles et al., 2012). Empathy is not always natural in caregiver–patient relationships (Larson and Yao, 2005) and needs even more encouragement when the patient, like eastern hemlock, is not human (Balding and Williams, 2016; Berenguer, 2007).

Good artistic design "helps people deal with change… [and changes] our understanding of how the world evolves" (Antonelli, quoted in Luebkeman, 2015). In *Hemlock Hospice*, we encouraged our communities to think about what it means to be a tree—living, dying, or dead—or an immigrant insect such as the adelgid (Figure 29.8). We also encouraged thinking of trees and forests not just as inanimate resources (Figure 29.4) for our use, but rather as cohabitants with us of the forest, this region, or the Earth (Geisel, 1971).

Successes, challenges, and lessons learned

The successful design and execution of *Hemlock Hospice* was possible in large measure because the artist/designer was supported to work full time for a year as part of the Harvard Forest community. The substantial accomplishments of *Hemlock Hospice* were realized because of the nonhierarchical nature of the collaboration (Figure 29.5): the lead and collaborating artists, designers, and fabricators were embedded in an active scientific research site; and scientists simultaneously were full partners in the design and creation process. Bringing together artists, designers, and scientists on a common project also has its challenges, including different modes of communication among participants, different measures of scientific and artistic success, and different expectations for direct action.

The utility of study models

Artists and scientists communicate ideas in different ways. Scientific ideas often are framed as hypotheses and data are analyzed quantitatively or modeled mathematically. Artistic ideas often are more conceptual, qualitative, or sensorial. We found a common language through another element of design-thinking—constructed physical study models (Figures 29.8 and 29.9) with which artistic ideas could be made sufficiently concrete so that evidence-based scientists could respond to them both intuitively and intellectually.

Fast Forward Futures (Figure 29.9, left) exemplifies our effective use of study models. Our own discussions and critiques raised in beta-testing emphasized the importance of illustrating the forest of the future, after eastern hemlock succumbed to the adelgid. We identified several locations where fallen hemlocks had created large canopy gaps and black birch (*Betula lenta*) thickets had initiated the succession to the next forest type (Case et al., 2017). Our first attempt at highlighting this otherwise unremarkable successional stage was building a colorful zig-zag fence around the birch (Figure 29.9, right). Although this "framing" seemed sound in the abstract, the actual installation was unsuccessful because the fence was visually swallowed by the dense birch. In response, we made tenth-scale models of the wooden members used to create the fence (Figure 29.9, right). We then used these to create four dozen small study models over the course of a couple of hours, a process that eventually led us to the final design.

Figure 29.8 HWA Tent (2017) and Study Model for HWA Tent

Installation at Harvard Forest. 2.5 × 2.5 × 6 feet; wood, acrylic paint, canvas, thread, and nylon rope; Collaborators: Jackie Barry, Johnny Buck, David Buckley Borden, Aaron M. Ellison, and Salua Rivero; Photographs: David Buckley Borden and Aaron M. Ellison.

By referring to an organism like the hemlock woolly adelgid (HWA) as an "invasive species," we usually mean that it is an organism living where we don't want it and behaving counter to our desires. We also implicitly ascribe agency to it, as if the invasive species planned its illegal entry through our borders (Larson, 2005). But there is, in fact, no evidence that invasive species plan their actions. Rather, these organisms, like those we hold in higher esteem, simply are acting according to normal evolutionary drives: survive and reproduce. The adelgid did not deliberately emigrate to Richmond; it was carried there as an unrecorded stowaway on plants we humans imported for enjoyment and financial gain. And once on these shores, the adelgid behaved like any other immigrant. It sought a place to live, food to eat, and an opportunity to produce offspring to perpetuate its lineage. Our extensive hemlock forests with hundreds of millions of trees are ideal food and housing for the adelgid; given adequate food and shelter, it successfully reproduces and evolves. No agency required.

The study model (inset) is one example of a common visual language shared by artists, designers, and scientists. Just like a series of scientific experiments allows us to test a series of alternative scientific hypotheses (Chamberlin, 1890; Hilborn and Mangel, 1997), a study model allows us to iteratively test artistic ideas through the design process. The study model for the HWA Tent was a scaled-down, simplified version of a concept about invasive species, colonization, and habitat. It lacked many of the details of the final design but also sparked new ideas about how to communicate important scientific details such as the range of the adelgid (through the state "patches") and unique identifiers of hemlock (two white stripes under the needles), while also highlighting that hemlock is a temporary home for each new adelgid generation.

Figure 29.9 Fast Forward Futures (2017)

Installation at Harvard Forest. 4 × 8 × 26 feet; wood, acrylic paint, and assorted hardware; Collaborators: David Buckley Borden, Jack Byers, Aaron M. Ellison, Salvador Jiménez-Flores, and Salua Rivero. Photographs: David Buckley Borden.

Situated adjacent to and pointing toward a gap created by a dead and fallen eastern hemlock and now filled with black birch saplings, Fast Forward Futures (left) is an abstraction of the "fast forward" icon of a media player. It is created from five interlocking delta symbols representing change and painted in a global-warming-inspired heat gradient (see also Figure 29.2). The initial idea for this piece was a colorful take on a split-rail fence (right). This unsuccessful design was reworked and refined using tenth-scale timbers assembled and reassembled in nearly fifty study models.

Measures of success

Scientists and artists may have different measures of success. Salaried scientists usually are paid for the process ("doing science"), whereas artists and other creative content producers usually are paid only when they sell their "work." In the case of *Hemlock Hospice*, we were on the same level: we were both salaried. Scientists are rewarded for writing technical papers and books, whereas artists are rewarded by selling paintings, sculptures, videos, etc. In the case of *Hemlock Hospice*, we and our collaborators had scoped the project together and were united in the overall mission of the project. There were only a few times when we questioned what we were doing, and if we did disagree on a particular direction or piece, we immediately stepped back and asked whether we were moving the agenda forward.

One example was the development of the interpretive trail guide for self-guiding visitors. The artist/designer emphasized imagery while the scientist emphasized textual explanation. But together, we made hundreds of small decisions about the final trail guide using a common, mission-driven editorial filter: did the graphics, information, writing, and editing clearly communicate the science in a culturally engaging way? Similarly, neither the science nor the sculptural installations were the ends in and of themselves for either of us. Rather, the primary measure of success was whether this collaborative art/science project created opportunities for understanding, outreach, and further community-building and engagement.

Education and outreach also was central to our mission of science communication; it was intentionally planned from the outset, not as an afterthought. We were fortunate in having the help and support of a full-time outreach director at Harvard Forest (Clarisse Hart, who also directs its well-respected Fisher Museum), additional outreach and event planning by a contracted public-relations consultant, and time "borrowed" from devoted Harvard Forest staff. Each of us contributed print and online media contacts to promote the project and encouraged individuals to visit an installation at a relatively remote site. We added indoor exhibition content to the Fisher Museum, which itself draws thousands of visitors annually to view its historical dioramas (Foster and O'Keefe, 2000), leveraging it as a springboard for the *Hemlock Hospice* trail.

One of the most salient critiques of *Hemlock Hospice* and other art/science collaborations was that it did not include an explicit direct-action component. Many people viewing *Hemlock Hospice*, especially those learning about the adelgid for the first time, wanted to do something tangible to control it, save the trees, or take broader actions to prevent environmental degradation. *Hemlock Hospice* was successful because it led people to consider a sustainable future. But, even though we cannot save the hemlocks, we still missed an opportunity to provide concrete steps forward. Expanding our communities even further to include educators and activists, educational institutions and NGOs, and policy- and decision-makers could have suggested immediate actions inspired by this art/science collaboration. Although we did not do that explicitly with *Hemlock Hospice*, we took that route with our follow-up installation, *Warming Warning*, which was emplaced on Harvard's main campus from October to December 2018.[3]

Conclusions

Traditional art/science projects reflect unidirectional and hierarchical relationships: scientists intentionally or unintentionally provide data to designers and artists who interpret it for broader audiences (Ellison et al., 2018). Notable examples range from Ellie Irons' work in a variety of media, focused on revealing interconnections between humans, nonhumans, and nonliving earth systems[4] to the pieces by more than a dozen contemporary artists in the 2018 *Indicators: Artists on Climate Change* exhibition at the Storm King Art Center.[5] The resulting artistic creations communicate messages—scientific or otherwise—that most often are independent of the intent of the scientists who generated the data.

Our experience with *Hemlock Hospice* suggests that art/design/science collaborations can communicate scientific information more effectively *and accurately* if both participants and content are neither hierarchical nor exclusive. More broadly, the most successful art/science projects will engage diverse communities in their programming, publicity, and outreach at multiple points throughout their conception, design development, fabrication, and promotion.

Acknowledgments

Hemlock Hospice could not have been realized without the full support and collaboration of the Harvard Forest staff and many artistic collaborators (the latter identified by name in figure captions). Hannah Star Rogers provided excellent reviews and critiques of early versions of this chapter. David Buckley Borden's work was supported by a Charles Bullard Fellowship in Forest Research. Additional financial support for design, fabrication, and construction was provided by the Harvard Forest and through research grants to David Foster and Aaron Ellison from the U.S. National Science Foundation (DEB 12–37491 and DBI 14–59519).

Notes

1 https://harvardforest.fas.harvard.edu/
2 https://asif.center/
3 https://harvardforest.fas.harvard.edu/warming-warning/
4 https://ellieirons.com/
5 https://stormking.org/indicators/

References

Balding, M. and Williams, K. J. H. (2016). Plant blindness and the implications for plant conservation. *Conservation Biology*, 30(6), pp. 1192–1199.

Berenguer, J. (2007). The effect of empathy in proenvironmental attitudes and behaviors. *Environment and Behavior*, 39(2), pp. 269–283.

Boose, E. (2018). Fisher meteorological station at Harvard Forest since 2001. Harvard Forest Data Archive: HF001 [online]. Available at: https://dx.doi.org/10.6073/pasta/04076dfd30b286c6c29301b6345a63f5 [Accessed 10 June 2018].

Bradley, B. A., Blumenthal, D. M., Early, R., Grosholz, E. D., Lawler, J. J., Miller, L. P., Sorte, C. J. B., D'Antonio, C. M., Diez, J. M., Dukes, J. S., Ibanze, I. and Olden, J. D. (2012). Global change, global trade, and the next wave of plant invasions. *Frontiers in Ecology and the Environment*, 10(1), pp. 20–28.

Butin, E., Porter, A. H. and Elkinton, J. (2005). Adaptation during biological invasions and the case of *Adelges tsugae*. *Evolutionary Ecology Research*, 7(6), pp. 887–900.

Canadian Food Inspection Agency. (2017). Hemlock woolly adelgid – *Adelges tsugae* (Annand) [online]. Available at: http://www.inspection.gc.ca/plants/plant-pests-invasive-species/insects/hemlock-woolly-adelgid/eng/1325610383502/1325610993895 [Accessed 10 June 2018].

Case, B. S., Buckley, H. L., Barker Plotkin, A., Orwig, D. A. and Ellison, A. M. (2017). When a foundation crumbles: forecasting forest dynamics following the decline of the foundation species *Tsuga canadensis*. *Ecosphere* [online], 8(7), e01893. Available at: https://doi.org/10.1002/ecs2.1893 [Accessed 10 September 2018].

Chamberlin, T. C. (1890). The method of multiple working hypotheses. *Science* (Old Series), 15(366), pp. 92–96.

Costa, S. D., Trotter, T. R. and Montgomery, M. (2008). Low temperature in the hemlock woolly adelgid system. In: *Fourth Symposium on Hemlock Woolly Adelgid in the Eastern United States* (edited by B. Onken and R. Reardon). Morgantown: U.S. Forest Service, pp. 47–53.
Dickinson, E. (1998). *The Poems of Emily Dickinson*, Variorum Edition (edited by R. W. Franklin). Cambridge: Belknap.
Ellison, A. M. (2013). The suffocating embrace of landscape and the picturesque conditioning of ecology. *Landscape Journal*, 32(1), pp. 79–94.
Ellison, A. M. (2014). Experiments are revealing a foundation species: a case-study of eastern hemlock (*Tsuga canadensis*). *Advances in Ecology* [online], 2014, article 456904. Available at: https://doi.org/10.1155/2014/456904 [Accessed 10 June 2018].
Ellison, A. M., LeRoy, C. J., Landsbergen, K. J. and Bosanquet, E. (2018). Art/science collaborations: new explorations of ecological systems, values, and their feedbacks. *Bulletin of the Ecological Society of America*, 99(2), pp. 180–191.
Fitzpatrick, M. C., Preisser, E. L., Porter, A., Elkinton, J. S. and Ellison, A. M. (2012). Modeling range dynamics in heterogeneous landscapes: invasion of the hemlock woolly adelgid in eastern North America. *Ecological Applications*, 22(2), pp. 472–486.
Foster, D. R., editor (2014). *Hemlock: A Forest Giant on the Edge*. New Haven: Yale University Press.
Foster, D. R. and O'Keefe, J. F. (2000). *New England Forests through Time: Insights from the Harvard Forest Dioramas*. Petersham: Harvard Forest.
Foster, D. R. and Orwig, D. A. (2006). Preemptive and salvage harvesting of New England forests: when doing nothing is a viable alternative. *Conservation Biology*, 20(4), pp. 959–970.
Frost, R. (1923). *New Hampshire: A Poem, with Notes and Grace Notes*. New York: Henry Holt and Company.
Geisel, T. S. (*a.k.a.* Dr. Seuss). (1971). *The Lorax*. New York: Random House.
Harris, J. (2000). The sixth extinction. *Interdisciplinary Science Reviews*, 25(4), pp. 245–249.
Hass, N. (2018). Are fabricators the most important people in the art world? *The New York Times Style Magazine* [online]. Available at https://www.nytimes.com/2018/06/22/t-magazine/art-fabricators.html [Accessed 22 June 2018].
Havill, N. P., Montgomery, M. E., Yu, G. Y., Shiyake, S. and Caccone, A. (2006). Mitochondrial DNA from hemlock woolly adelgid (Hemiptera: Adelgidae) suggests cryptic speciation and pinpoints the source of the introduction to eastern North America. *Annals of the Entomological Society of America*, 99(2), pp. 195–203.
Havill, N. P., Shiyake, S., Galloway, A. L., Footit, R. G., Yu, G. Y., Paradis, A., Elkinton, J., Montgomery, M. E., Sano, M. and Caccone, A. (2016). Ancient and modern colonization of North America by hemlock woolly adelgid, *Adelges tsugae* (Hemiptera: Adelgidae), an invasive insect from East Asia. *Molecular Ecology*, 25(9), pp. 2065–2080.
Hilborn, R. and Mangel, M. (1997). *The Ecological Detective: Confronting Models with Data*. Princeton: Princeton University Press.
Ingwell, L. L. and Preisser, E. L. (2011). Using citizen science programs to identify host resistance in pest-invaded forests. *Conservation Biology*, 25(1), pp. 182–188.
Jetton, R. M., Whittier, W. A., Dvorak, W. S. and Rhea, J. R. (2013). Conserved *ex situ* genetic resources of eastern and Carolina hemlock: eastern North American conifers threatened by the hemlock woolly adelgid. *Tree Planters' Notes*, 70(2), pp. 59–71.
Kane, R. L., Klein, S. J., Bernstein, L., Rothenberg, R. and Wales, J. (1985). Hospice role in alleviating the emotional stress of terminal patients and their families. *Medical Care*, 23(3), pp. 189–197.
Larson, B. M. H. (2005). The war of the roses: demilitarizing invasion biology. *Frontiers in Ecology and the Environment*, 3(9), pp. 495–500.
Larson, E. B. and Yao, X. (2005). Clinical empathy as emotional labor in the patient-physician relationship. *Journal of the American Medical Association*, 293(9), pp. 1100–1106.
Leakey, R. E. and Lewin, R. (1996). *The Sixth Extinction: Patterns of Life and the Future of Humankind*. New York: Anchor.
Lovett, G. M., Weiss, M., Liebhold, A. M., Holmes, T. P., Leung, B., Lambert, K. F., Orwig, D. A., Campbell, F. T., Rosenthal, J., McCullough, D. G., Wildova, R., Ayres, M. P., Canham, C. D., Foster, D. R., LaDeau, S. L. and Weldy, T. (2016). Nonnative forest insects and pathogens in the United States: impacts and policy options. *Ecological Applications*, 26(5), pp. 1437–1455.
Luebkeman, C. (2015). Designing a graceful ending: a conversation with design luminary Paola Antonelli. *Architectural Design*, 85(4), pp. 20–25.

McDevitt, A. L., Patel, M. V. and A. M. Ellison. (2016). Insights into student gains from undergraduate research using pre/post assessments. *BioScience*, 66(12), pp. 1070–1078.

Meier, E. (2015). *Wood! Identifying and Using Hundreds of Woods Worldwide.* New York: The Wood Database.

Oten, K. L. F., Merkle, S. A., Jetton, R. M., Smith, B. C., Talley, M. E. and Hain, F. P. (2014). Understanding and developing resistance in hemlocks to the hemlock woolly adelgid. *Southeastern Naturalist*, 13(sp6), pp. 147–167.

Perie, C. and de Blois, S. (2016). Dominant forest tree species are potentially vulnerable to climate change over large portions of their range even at high latitudes. *PeerJ* [online], 4, article e2218. Available at: https://doi.org/10.7717/peerj.2218 [Accessed 9 June 2018].

Sumpter, K. L., McAvoy, T. J., Brewster, C. C., Mayfield, A. E., III and Salom, S. M. (2018). Assessing an integrated biological and chemical control strategy for managing hemlock woolly adelgid in southern Appalachian forests. *Forest Ecology and Management*, 411(1), pp. 12–19.

Teno, J. M., Clarridge, B. R., Casey, V., Welch, L. C., Wetle, T., Shield, R. and Mor, V. (2004). Family perspectives on end-of-life care at the last place of care. *Journal of the American Medical Association*, 291(1), pp. 88–93.

USDA Forest Service. (2017). Forest disturbance processes: Hemlock woolly adelgid [online]. Available at: https://www.nrs.fs.fed.us/disturbance/invasive_species/hwa/ [Accessed 10 June 2018].

Wittenberg-Lyles, E., Debra, P. O., Demiris, G., Rankin, A., Shaunfield, S. and Kruse, R. L. (2012). Conveying empathy to hospice family caregivers: team responses to caregiver empathetic communication. *Patient Education and Counseling*, 89(1), pp. 31–37.

30

Horizons of engagement

Infrastructures of art and scholarship

Alexandra Lakind, Nicole Bennett, and Robert Lundberg

The following chapter centers on *Displaced Horizons* (*DH*), a project investigating water infrastructures' socio-cultural complexities. *DH* is unique in that it takes the form of an adaptable multimedia performance within academic settings where investigations traditionally take the form of written text. *DH* consists of a live musical ensemble surrounded by projections of video and photographs that display and distort water structures (e.g., canals, groundwater wells, wastewater treatment facilities, irrigation channels), as well as maps and graphs depicting water usage and measurement (Figure 30.1). Attention is drawn to the stage crew via matching uniforms of an imagined bureaucracy, and audience members are invited to flow as water might, moving freely throughout the space.

Spearheaded by Robert Lundberg, *DH* was developed by gathering information about water systems through fieldwork, archival and legal analysis, collecting images using drone and handheld cameras, and simultaneously developing music through solo and group performances. Lundberg represents a hybrid artist/academic. After earning a degree in musical performance, Lundberg became a graduate student of the Science and Technology Studies (STS) scholar Dr. Samer Alatout. Applying his artistic practice to STS, Lundberg envisioned *DH* as an aesthetic approach to further STS's infrastructural turn. Drawing on the concept

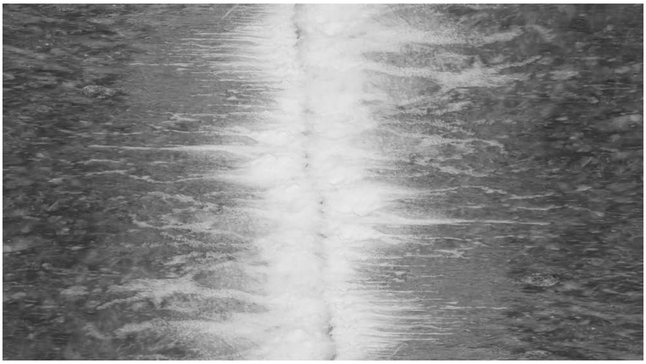


Figure 30.1 *Rift* – Video Still from Displaced Horizons (Jonas, Lundberg, McLaughlin, 2018)

DOI: 10.4324/9780429437069-38

of Geoffrey Bowker and Susan Leigh Star (1999) on "infrastructural inversion," a process that brings infrastructure that ordinarily resides in the background to the fore, *DH* aims to highlight the ways water infrastructure reorders the world. By inviting a reorientation to the values that inhere in infrastructures of water and grappling with water structures' ongoing expressions of state control, colonization, and privatization, *DH* aspires to create a nonrepresentational approach to water mapping, resistant to practices that fix water as an abstract resource and instead animate our subjective experiences of water in the landscape. Because water is both life and resource, *DH* focuses on often-ignored infrastructure to inspire viewers to envision sustainable and equitable relationships to water. This handbook provides a catalyst for considering complexities that arise as different arrangements surrounding art and scholarship collide. In addition to describing *DH*, we will narrate the development of this project to emphasize the structures and power dynamics carried by various systems in the current academic and art world.

Infrastructures of resonance: framing, naming, and ordering our world

STS has become a principal location for the study of knowledge production (Jasanoff 2004); institutional reflexivity (Halfon 2010; Kleinman 2010); and methods to communicate and archive information (Star and Ruhleder 1996). Thus, STS is an excellent space to consider the landscape in which art and scholarship combine. That *DH* is embedded in both art and scholarship raises questions about how disciplinary bounds are decided. In particular, *DH* exemplifies how categorizations can change as the project moves across artistic and academic settings and when the actors have hybrid artistic/academic identities. In this case, as these different types of knowledge creation collide, it provokes us to reflect on how live performance challenges academic traditions where knowledge building is cumulative through articles and books.

Determining how best to document and represent *DH* became a concern in addressing the artistic and academic spheres *DH* straddles. We have struggled with how to meaningfully share *DH* in this book. For instance, is a score the clearest translation of music to print? (Figure 30.2).

We wanted to provide readers a website link, but this has raised additional challenges. Website links aren't designed for print texts. And if the domain fees of a website rest on the individuals in the project, will individuals remain responsible for the upkeep even after the project disperses? Is an academic institution more stable than an individual for maintaining a digital presence? As of the writing of this chapter, the Holtz Center for Science and Technology Studies and the editors of this book (through Routledge Publishing) have expressed interest in responding to these challenges of representation by hosting recordings and videos of *DH*.

Caught in these structural frictions, we contemplate the arrangements surrounding *DH* that frame this contemporary artistic and scholarly practice. To assist in this endeavor, we examine the role of art in STS through what curator Nato Thompson (2015) calls "infrastructures of resonance": the material conditions surrounding a given artist or project. As a relational concept, infrastructure is not a class of artifacts; rather, it refers to something that enables something else (Star and Ruhleder 1996). For Thompson, reading art is about interpreting the aesthetic and political composition of infrastructures that shape and define a piece of art, including that of art museums and universities, social networks, and publications. *DH's* development exemplifies a movement interweaving art and academic practice, undergirded by economic pressures.

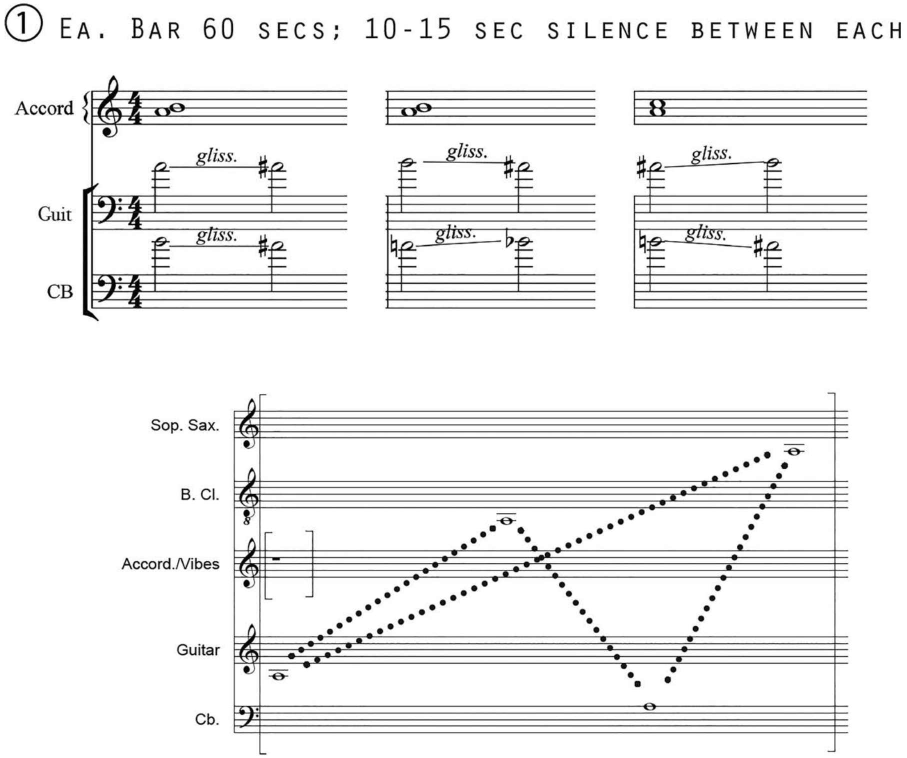


Figure 30.2 Musical Notation for Displaced Horizons (Jonas & Lundberg, 2018)

In the economic and cultural lives of both artists and academics, it has become difficult to separate making culture from making capital. Publishing and showing art may have no direct economic gain for the creators but may contribute to their future access to institutional power and economic stability. This cultural capital model has become common where professional legitimacy is reproduced via engagement with artistic and academic scenes. Efforts to produce meaning are caught up in the need for legibility and legitimacy and institutional support dependent on the accumulation of capital in the form of social networks, past projects, publications, etc. In this project, lateral movements across disciplinary spaces have shaped the work, presenting both constraints as well as productive and unexpected interactions.

The overlapping space of art and scholarship provide an opportunity to look critically at the way both practices inform each other. Like avant-garde artists, some academics are self-aware of their small audiences, the gap between stated intentions and actual effects, and susceptibility to institutional ossification (Ngai 2015, 97). Perhaps, as a result, several notions about the role of art in academic knowledge production have emerged, such as a belief that art will reach a broader audience, will communicate in a more accessible mode, and can provide flexible, problem-posing methodologies. While instrumentalist conceptions of what art can accomplish are not new, contemporary pressure for new and original content generation in all fields has led to an explosion in scholarly claims that art is the next new thing.

Furthermore, alongside this quest for newness, a mandate to be interesting has ascended. "Interesting" has, according to Sianne Ngai (2015), risen as a new, non-beautiful, comparative aesthetic. For Isabelle Stengers, "interesting" in science can link affect-based judgment with concept-based explanations to enable movement across domains and facilitate the circulation of new ideas (Stengers cited in Ngai 2015, 115). Thus, art/scholar hybridity can be interesting for both art and scholarship. While perceiving art as a way to communicate scholarship or scholarship as a conceptual database to inform artistic practice runs the risk of viewing both activities as monolithic, it is nevertheless the case that art, science, and technology are mingling, collaborating as a form of survival and an adaptive strategy to address complex, multidisciplinary, and global issues. In the case of *DH*, the aim is to focalize our current uneasy relationship with water both as a life-giving source and an over-used and undervalued commodity and reorient that relationship. As artistic forms of knowledge production become more focal to STS, infrastructural inversion and infrastructures of resonance can become mutually reinforcing concepts that direct attention to systems that produce meaning, an activity fundamental to STS. The field is poised to critically engage with the conditions of capital that make artistic gestures possible, inviting reverberations in and beyond STS. With these infrastructural realities and concepts in mind, we map out the relations of *DH* to offer an example of production in art and scholarship.

Accommodating the rise of the "project"

The ideas that drove *DH* mobilized people in already-existing networks to assemble into a temporary formation that made production and accumulation possible. As Lane Relyea (2013) argues, infrastructures and conventions in artistic practice have changed to accommodate the "project": highly activated sections of networks. Projects act as participatory architectures, engaging multiple actors situated in temporal arrangements. Through the post-commodity art of experience, capital accrues in circulation and distribution within these networks. In this decentralized model, professional prestige lies in accumulation through a communicational network. For artists like Lundberg without consistent institutional employment/affiliation, unpaid art-making and research activities via emergent horizontal networks provide exposure that can be leveraged for monetary support. This type of engagement has come to be expected, and it manifests through participation in residencies and workshops or "service" in the form of organizing conferences and public programming.

DH itself was conceived during a Water Rights-themed residency at the Santa Fe Art Institute. Spending the summer of 2017 learning about, living on, and documenting water systems in New Mexico and southern Colorado, Lundberg, guided by Alatout, immersed himself in STS water infrastructure literature. In this desert landscape, there are many historical and cultural layers of water systems. Indigenous irrigation channels are overlaid with Spanish colonial acequia systems. This land was ceded to the United States, yet the aforementioned irrigation techniques have remained in use concurrent to state and federally funded dams and pumps that draw water from deep underground and through mountain ranges in an effort to provide reliable water supplies to industrial agriculture and municipal development. Lundberg's goal was to learn holistically. To participate, he helped operate an acequia and interviewed stakeholders. He read as a means to connect to theory and to historical and legal complexities. And, he engaged his senses by listening to, looking at, and touching the water. Furthermore, it was at this artist residency that Lundberg approached Chris Jonas to collaborate. Jonas, an experienced composer and video artist, would be key to developing the performance and reinforcing the project's grounding in artistic practices and identities. Together, they gathered video of Cochiti dam and transcribed the sound of the Rio Grande.

In need of institutional support, Lundberg and Jonas worked with Terra Incognita, a loosely assembled group at the University of Wisconsin–Madison that secures funding and

Figure 30.3 Performance at SITE Santa Fe with artists McLaughlin, Lundberg, Packard (Little Globe, 2018)

coordinates programing for environmental artists (co-directed by the authors of this chapter). Support for *DH* was sought to create two full installations; in doing so, however, Terra Incognita effectively reshaped *DH* to reach new audiences in alignment with their mission to connect people with divergent interests. They applied to Currents New Media Festival and partnered with SITE Santa Fe, a contemporary art center, for *DH*'s first performance on June 9, 2018. They also organized a performance for an STS conference at the University of Wisconsin–Madison on October 27, 2018 (Figure 30.3).

Having an institutional sponsor, and predetermined dates for the performances, provided leverage to acquire additional funding and collaborators. Dylan McLaughlin, a videographer who had previously worked on Jonas's multimedia project *Garden*, was invited to collaborate. As an artist engaged in issues of indigenous environmental justice, McLaughlin's practice overlapped conceptually and further anchored the work in contemporary art scenes. To develop material, smaller performances were conducted in venues unequipped to do the full installation, such as DIY spaces and private house concerts. These sites allowed *DH* to develop through experimental music networks, providing feedback to ensure that the work continued to speak to an audience of artists. Concurrently, Terra Incognita supported activities such as reading groups, presentations, and co-authoring this book chapter.

With limited financial and organizational capacities, many artists and academics who work alongside institutions (rather than on behalf of them) are nevertheless reliant on institutional resources, networks, and affirmation; thus, what is legible to and fundable for the institution is often what gets produced. As the project has adapted from an exhibition in Santa Fe to a performance in Madison, the infrastructures of resonance helped categorize this work as art and scholarship. Exhibiting at an art festival does not indicate a research relationship; it is funding (and the proposals written to secure funding) from the Holtz Center for Science and Technology Studies and the Mellon Foundation that defined this work as academic outreach or public humanities.

Funding bodies not only matter pragmatically, but they also create affiliations that, in turn, categorize the project. These lateral moves across disciplinary domains might signal affordances and constraints that arise when shifting between artistic and academic values and expectations. For example, in a proposal to a local humanities council, the ambiguous language of contemporary art had to be replaced by a narrow conception of story; to attain capital, the work needed to feature plot. This stipulation in turn altered the textual components that accompany the work. In a hybrid space, respective and overlapping infrastructures of resonance in art and scholarship can shape how culture is produced and determine what "sensible" methods are for participation. In a world of projects, diverse groups assemble to conduct a variety of activities that can span several fields. The blending of fields can disrupt previously defined categories; yet, practices contingent on resources and recognition can also become categorized in the endeavor to fit into specific forms of engagement, e.g. art in a museum, activism at a protest, and expository writing in a peer-reviewed journal.

On the other hand, as field boundaries mutate, the artist/academic hybrid catalyzes and legitimates new organizational forms and categories of authorized actors. This counteracts the pressures that narrow form. Indeed, for many, research is no longer conceived of as a linear process resulting in articles and books, and art is no longer an object to be bought and sold by museums or patrons. Collaborations that blend genres are sometimes given more leeway to use or discard conventions as desired. As individuals move in and out of various institutional arrangements and disciplinary boundaries, projects offer flexibility: they don't have to end; they can iterate and continue as long as some actors are willing to use the moniker. This flexibility can bridge temporary institutional affiliations with an identity outside of disciplinary expertise that can still accrue capital, acquire support, and build recognition over time. Projects are situated and responsive to factors that can shape the work in both limiting and exciting ways.

Writing about *DH* has invited us to examine the artist/academic hybrid, a figure that brings to the fore the infrastructures in which they are entangled. Making infrastructures visible allows for a better understanding of what is and can be. The intention of *DH* was not disciplinary disruption but rather a process where form and content follow the path of the project rather than expectations of a specific field. Yet, one consideration for the artist/academic is that valuation in one field may not necessarily translate into another field. The hybrid figure may need to build across systems with different languages, expectations, and evaluations. To be perceived as high-quality, an artist/academic might need to attain field-specific recognition in multiple fields.

Thus, for STS, incorporating art raises important questions concerning the expectations of an artist/academic and their work. As artistic and academic forms merge, will the academic publication remain central? Publications offer a space for explicating, archiving, and documenting; however, writing about art can undermine or even overwrite artistic currencies with academic values. After writing about this project, we are still left wondering: what does *DH* gain from being written about? Are we achieving textual longevity for a transitory project? Or does this publication become another facet of the project's multimedia character? If art and scholarship are no longer conceived of as inherently separate, the expectations and infrastructures designed with this distinction will shift the ways in which we categorize, provide support, and shape these activities.

References

Bowker, Geoffrey C., and Susan Leigh Star. 1999. *Sorting Things Out: Classification and Its Consequences*. Cambridge: MIT Press.

Halfon, Saul. 2010. "Confronting the WTO: Intervention Strategies in GMO Adjudication." *Science, Technology and Human Values* 35 (3): pp. 307–329.

Jasanoff, Sheila. 2004. *States of Knowledge: The Co-Production of Science and the Social Order.* London: Routledge.

Jonas, Chris, and Robert Lundberg. 2018. "Displaced Horizons," score, unpublished.

Jonas, Chris, Robert Lundberg, and Dylan McLaughlin. 2018. "Displaced Horizons: Rift," video still, unpublished.

Kleinman, Daniel Lee. 2010. "The Commercialization of Academic Culture and the Future of the University." In *The Commodification of Academic Research: Science and the Modern University*, edited by Hans Radder, 24–42. Pittsburgh: University of Pittsburgh Press.

Little Globe. 2018. "Performance at SITE Santa Fe with Artists McLaughlin, Lundberg, Packard," video still, unpublished.

Ngai, Sianne. 2015. *Our Aesthetic Categories: Zany, Cute, Interesting.* Cambridge: Harvard University Press.

Raylea, Lane. 2013. *Your Everyday Art World*. Cambridge: MIT Press.

Star, Susan Leigh, and Karen Ruhleder. 1996. "Steps toward an Ecology of Infrastructure: Design and Access for Large Information Spaces." *Information Systems Research* 7: pp. 111–134.

Thompson, Nato. 2015. *Seeing Power: Art and Activism in the 21st Century.* Brooklyn: Melville House.

31

Big pigs, small wings

On genohype and artistic autonomy

Ionat Zurr and Oron Catts

Introduction

On Thursday, the 23rd of November 2004, the headline on the front page of *The West Australian* stated: 'Gene tests to pick junior sports stars' (O'Leary 2003: 1). The body of the text begins with the following prediction: 'Parents wanting to know if their child has what it takes to be a sports star will soon be able to buy a genetic test for about $100 from local sporting clubs and gyms'. Well, we thought, finally, a tangible outcome for the Human Genome Project (HGP). Is this the great promise that was delivered so ceremoniously four and a half years ago? Exactly four years prior to the publication of the above story in *The West Australian*, we received a letter from the Wellcome Trust's *Two10* gallery inviting us to submit a proposal for a commissioned work to an exhibition titled *Working Drafts: Envisioning the Human Genome*.

This paper will explore the notion of Genohype, a term coined by Neil Holtzman to describe the discourse of exaggerated claims and overstatements concerning DNA and the HGP (1999: 409–410). Genohype depicts the hype generated by scientists, the media, the public and the arts in regard to genetic research. In the context of this paper, Genohype is used in relation to the hyperbole discourse of what has been attained by genetic research and its applied outcomes, whether positive or negative. One of the effects of Genohype, as will be illustrated, is that genetics become synonymous with all life sciences. In this paper, Genohype will be examined in relation to the somewhat conflicting views in regard to the role of artists dealing with the application of newly acquired knowledge, using our very own *Pig Wings* Project as the case study.

Genohype

Nick Brown points out in his paper *Hope Against Hype—Accountability in Biopast, Present and Future*:

> … it is often the case that, for a time at least, various areas of technological innovation become saturated with stratospherically high expectations of immanent and revolutionary change. Biotech is no exception and is today synonymous with the language and

DOI: 10.4324/9780429437069-39

imagery of futuristic breakthroughs. The whole area is literally spilling over with heated aspirations, promises, expectations, hopes, desires and imaginings.

(2003: 3)

This type of hype is required, according to Brown, to persuade investors, regulators and the public for the need to invest and take risks to accomplish the revolutionary breakthrough promised by the developers of the technology. However, by creating these unrealistic expectations, the promoters run a double risk. In the case of biotechnologies, the first risk is that the promises for incredible future scenarios will simultaneously raise great concerns that things will go horribly wrong. The second risk is that when it becomes obvious that the promise is not going to be fulfilled, the extent to which it was hyped will become known, and disillusion and mistrust will then set into the point at which the level of funding subsequently drops and public confidence is lost.

How has biotechnology in general and the HGP in particular dealt with these issues?

Critical Art Ensemble addressed the aspects of this question in their Cult of the New Eve project.[1] They were interested in the type of rhetoric that is employed to sell biotechnology generally and the HGP especially. They argue that the biotech industries needed to remove themselves from the dark past of the biological-inspired ideologies of progress manifested in Nazism, by using rhetoric borrowed from religious discourse. This, in turn, created a new type of scientific promise that the public was less able to read through, creating more hype, unrealistic expectations and fears than other technoscientific developments. It is interesting to note here that Craig Venter, who was the head of the American company Celera, stated in a conference that accompanied the *Paradise Now* exhibition that he felt that the level of misunderstanding and misappropriation of biological knowledge at the beginning of the twenty-first century was similar to that in Europe during the 1930s (2000). The fact that he and his company were somewhat responsible for the situation was quickly brushed off, and he went on to blame the media for creating the hype.

As early as 1994 (a year after the HGP began in the UK, known then as the British Human Genome Mapping Project), some scientists, such as Professor of Biology Steven Ross, expressed their concern that supporters of the project were '…guilty of extraordinary hype. They call it things like the book of life, or the code of the codes' (Court 1994: 1123). This kind of rhetoric had reached an unprecedented level by the June 2000 joint announcement of the completion of both the public and the private working drafts of the HGP. Both Bill Clinton and Tony Blair appeared at a press conference to announce this event.[2] A short survey of the press releases produced on that month by only one of the players in the public HGP, the Wellcome Trust, revealed the extent of this hype:

By the Director of the Wellcome Trust:

> A few months ago I compared the project to the invention of the wheel. On reflection, it is more than that… But this code is the essence of mankind, and as long as humans exist…is going to be important and will be used.
>
> *Dexter (2000)*

By the Chief Executive of the Wellcome Trust Genome:

> I think there is something magical…. I think this is quite extraordinary and awe inspiring.
>
> *Morgan (2000)*

But, even the Wellcome Trust conceded in February 2001 in an online article titled 'History of the Human Genome Project: The First Draft, June 2000' that: 'The joint announcement was probably more grandiose than the situation warranted but it ended concerns that one side or the other would be pre-empted, and it took the pressure off in terms of press coverage' (GF 2001). The author of this article, identified only by the initials 'GF', tried to soften their tune by assuring us that:

> While the timing of the announcement may have been dictated more by political than by scientific criteria, there is no denying the importance of what has been achieved, and what will be achieved. The next few years will be devoted to filling gaps in the draft sequence and improving the overall accuracy.
>
> *GF (2001)*

The cover story in *The West Australian*, cited at the beginning of this paper, shows that genohype endures. The idea that one test examining variants of one gene will determine the potential of a child to be an 'elite' athlete demonstrates genohype in action. Although that article quotes a scientist expressing concerns about this scenario, this only serves as a prelude for the main thrust of the story; the concern that these tests will 'add to existing the pressure on young people to succeed academically and in sports' (O'Leary 2003: 1). The scientific report does not seriously question the feasibility or validity of gene-testing technology in determining specific attributes such as athletic traits or intelligence. The starting point of the 'debate' is instead genetically and technologically deterministic. In other words, the story gives the impression that one gene is all that it takes and that these kinds of tests are here to stay.

Contemplating the post-genomic future, we hear voices that advise against being seduced by genohype. These include, for instance, Neil Holtzman, director of genetics and public policy at Johns Hopkins University, who coined the very term genohype: 'Exaggerating the importance of genetic factors stops people thinking about the need to clean up the environment and tackle socioeconomic inequity' (1999: 409). His argument is with those who exaggerate the clinical benefits that may occur out of the HGP. He describes claims such as those made in the editorial in *Nature's* 'Genome' issue that: '…the application of knowledge from the project will, in time, materially benefit almost everyone in the world' as ludicrous (1999). These claims are based on the assumption that it will be possible to unravel the polygenic forms of common diseases even though the clinical outcome is determined by complex gene, environmental and behavioural interaction. In his view, however:

> It will be difficult, if not impossible, to find the genes involved or develop useful and reliable predictive tests for them. It may keep the ethicists and philosophers in business but I think the term 'ethereal debates' describes them best, for they are built on a house of cards. The idea that we will be able to select genes we like and weed out those we don't to produce customized children is absurd.
>
> *Holtzman (1999: 410)*

He is similarly concerned with commercial firms such as Genetic Technologies. After steady lobbying, Holzman and others have now persuaded the United States' Food and Drug Administration to regulate the use of genetic tests.

As observed also by Nik Brown, an interesting phenomenon occurs when knowledge is transferred from specialists' peer-reviewed scientific publishing to the public sphere via the vehicle of press releases:

> … much of the careful qualification of scientific texts is abandoned for the more strident language of 'breakthrough', 'the first', 'the best', 'never before'. In other words, science communities suddenly metamorphose themselves into the highly competitive news conventions of the media code. When press releases arrive on the desks of science correspondents there is often precious little time to interrogate claims about new cures and revolutionary promises.
>
> *(2003: 14)*

Brown also observes that different voices compete in representing the future and progress. He suggests that: '…like any other contestable field, actors engage in such struggles with unequal access to resources with which futures are manufactured' (2003: 13). This type of struggle is clearly evident in the relationship between the public face of the HGP (represented by the Wellcome Trust) and the private interests involved in it (represented by, for example, Celera). One resource that the Wellcome Trust called upon that Celera could not directly do was the Wellcome access to the public's imagination through its prior standing and involvement with the arts.

Genohype as a dominant factor in the discourse of the new biology

One of the outcomes of genohype, at the level of public discourse, is that everything biological becomes confused with genetics. We are constantly surprised by how many people tend to associate engagement with visceral messy cells, tissues and organs with the reductionist, controlled, clean promises of genohype. This seems to happen often with reactions to art that deals with biology. We experience genohype in relation to our own work. On numerous occasions, we are referred to as 'genetic artists', and our work, which deals with tissue engineering, is described as 'transgenic'. An example can be found in Suzanne Anker and Dorothy Nelkin's book *The Molecular Gaze: Art in the Genetic Age* where we are said to produce transgenic artwork (2004: 95). In other cases, the words genetics or DNA are somehow inserted into the discussion of our work for no apparent reason except as a result of the recurrence of genohype. For example, a review of our work was titled 'Giving (Real) Life to Art: **Genetics** and tissue culture find new forms - and a new audience' (Fitzgerald 2004: 66). Suffice it to say that in the body of the text, there is no mention of any issue concerning genetics.

It is important for us to emphasize through our artistic or curatorial work the diverse approaches encountered in biological art.[3] These deal with all levels of life from the macro to the micro and include research about the social life of organisms, the whole body, tissues and tissue culture as well as genetics and DNA. Ironically, often, the same work that criticizes the reductionist view of life is used purposefully or by ill-informed people/journalists/curators to further the hype of the absurd idea that 'life is what is in the genes'.

This phenomenon is not restricted to writing about art but has penetrated other, such as the media, as in the case of the 'Who plays God?' advertisement from 1999 featuring a photograph of Vacanti's mouse with a human ear attached to its back. The ad was sponsored by The Turning Point Project, a coalition of technologically concerned and environmental groups including Greenpeace, the Sierra Club and the American Public Interest Research Group. The caption states, 'This is an actual photo of a genetically engineered mouse with a human ear on its back.' The text rails against genetic engineering:

> The genetic structures of living beings are the last of Nature's creations to be invaded and altered for commerce… the infant biotechnology industry feels it's okay to… reshape life on Earth to suit its balance sheets… Who appointed the biotech industry as Gods of the 21st century… So far, there exist no half-human, half-animal 'chimeras' (like mermaids or centaurs) but we may soon have them.
>
> *(1999)*

However, the ear on the back of the mouse is a product of tissue engineering, and the nude mouse itself is an outcome of a naturally occurring mutation which strips the mouse from fur and compromises its immune system.[4] There was no human intervention at the molecular/genetic level in making this chimera. Again, those who criticize gene technologies fall into the genohype trap and do not do their research thoroughly, checking the accuracy of the scientific information they are using, failing to mention other life science technologies that might be as destabilizing as genetic technologies. Genohype is such a strong concept (or strong meme if we follow Richard Dawkins[5]). Furthermore, genohype is not a partisan concept and ironically can attract the same forces that oppose the 'gene revolution' in order to further promote it. After all, we are still granted a certain sense of control when dealing with a body that is neatly and logically codified according to its DNA pair bases rather than when we are confronted by the messy and irrationally behaving visceral body.

The role of the artist

During the peak of the HGP hype, we were Research Fellows at the Tissue Engineering and Organ Fabrication Laboratory, Harvard Medical School. We were an integral part of the laboratory personnel, surrounded by scientists and researchers and participating equally in meetings and forums with our scientific colleagues. We became more and more aware of the transformation of knowledge as described by Brown.

The head of our laboratory was sometimes accused of hyping his field of research, tissue engineering, building unrealistic expectations with regard to the ability and timeframe of growing custom-built spare organs or neo-organs. We must admit that we were cautious in celebrating our opportunity to join Dr Vacanti's laboratory and work alongside his team. Our appreciation of him, for letting us inside the inner workings of the laboratory to learn advanced tissue engineering techniques, was tainted by our understanding that there is a greater role for the appointment of artists to his laboratory. While the scientist or even the 'responsible' journalist should, at least in theory, report things as they are and support their claims with facts and evidence, the artist has the licence to imagine, fantasize and exhibit unrealistic expectations of science and technology (such as in the case of Australian artist Patricia Picinini[6]). In the case of artists, who are also research fellows at the same laboratory in Harvard, these presumed separate realms of science/fact versus art/imagination can fuse into each other in the eyes of the wider community. There is a greater chance of this if an exhibition of the artistic results is framed in certain ways by curators and galleries and is marketed through carefully worded press releases. In simple terms, the artist becomes part of the biotech hype.

Can an artist deal with new technologies while maintaining autonomy and a critical approach?

'What is it that the artists have that these corporate interests are interested in? It is not the art; it is the access to the public imagination' Natalie Jeremijenko argues in her critique of the *Paradise Now* exhibition (2000). We have noticed that, in recent years, there is a significant amount of exhibitions dealing with genetics or 'Gene-Art'. Jackie Stevens explains this phenomenon in the following way:

> …art about biotechnology, especially with a critical edge, serves to reassure viewers that serious concerns are being addressed. Even more importantly, biotech-themed art implicitly conveys the sense that gene manipulation is a 'fact on the ground', something that serious artists are considering because it is here to stay. Grotesque and perverse visuals only help to acclimate the public to this new reality.
>
> *(2000)*

As illustrated by several writings, art or artists serve willingly or unwillingly as producers of a popular discourse on biotechnology; certain ideologies and their acceptance into society are being generated through the exhibition and the marketing of works of art. Kockelkoren asserts that artists cannot escape from the role of technological mediation, and following that, the acceptance and domestication of technology: '…artists are involved in technological mediation and the intrinsically related processes of disciplining' (2003: 106). Artists have always played an important role in mediating technologies by appropriating new technologies in order to create a new visual language to deliver new meanings for these. Furthermore, Kockelkoren claims that all of human existence is mediated by technologies:

> People are 'naturally artificial'… Technology cannot alienate people from their naturalness, because they are already alienated by virtue of their very condition. Language, technology and art teach people how to articulate and even celebrate their ineradicable alienation.
>
> *(2003: 27)*

If we follow Kockelkoren's argument, artists must immerse themselves in the dialectics of new knowledge and technologies. They must adopt not just a representational approach but what we refer to as "wet engagement". Hence, artists researching and exploring the role of biotechnology in society can and should engage with the actual technologies and get their hands wet and dirty. The scope of this paper does not include a discussion of the ethics involved when artists manipulate life for artistic aims. For now, it will suffice to quote George Gessert with regard to this issue:

> Do artists cross a line when they breed plants or animals, or use the tools of biotechnology? Scientists routinely cross the line. So do farmers, businesspeople, military men, and doctors. Only artists and certain religious people hesitate. Of course, one of the great human dilemmas is that we do not know the extent of our powers. We invent outrageously and as casually as we breathe, but we have no idea where our inventions will take us. Extinction? Slavery? Thousand years in Disneyland? Even if the Holocaust had never happened, we would have good reason to worry about where knowledge of genetics and

> DNA will take us. We will need all the awareness we can muster to engage evolution. To the extent that art favours awareness, the more artists who cross the line the better.
> *(2003: 47).*

Artists working with life manipulation, and more precisely with biotech, are participants in that culture. On the one hand, they can penetrate the laboratory space and scientific culture and in doing so reveal and democratize many aspects of the ways in which our common perceptions of life are transgressed. However, the question that needs to be asked is what strategies artists should employ in order to keep their integrity and autonomy working within this field, without being self-righteous or resorting to propaganda. In the case of the critical artist, how does she resolve the paradox of using the technologies she is critiquing or working with in the context of engaging with an economy she is critiquing? The second issue is the role of the curator and art producer who then positions and contextualizes the artwork (that can sometimes sit at odds with or even contradict the original intention of the piece).

In the context of this paper, what kind of art can an artist do for a show dealing with the 'biotech revolution' that would not be serving the interests of genohype? What kind of projects should one submit as a proposal for a commissioned exhibition marking the so-called completion of the working draft of the HGP?

The commission

In November 2000, we received an invitation for a commissioned work by the Two10 gallery in London, which is fully funded and operated by the Wellcome Trust. This was accompanied by a brief summary of the exhibition theme. According to our reading, the brief implied that by following the gallery philosophy, which strives to 'challenge received ideas' and 'encourage critical dialogue about important cultural issues (e.g. the HGP), we might critique the private side of the HGP. This could be done, we surmised, by challenging the issues surrounding gene patenting. So, we thought that this could be a role for artists that fitted with the commissioning brief: to fulfil what Brown referred to as unequal access to resources (in this case, the artists' unequal access) in order to favour the Wellcome Trust version of the future over that of the privet HGP.

We were somewhat surprised to receive this invitation, as our work had never directly dealt with genetics. It seems that the curators of the Two10 gallery fell victim to the genohype for which their organization was partly responsible. One can speculate that because our work uses and deals with biological knowledge and application, it was assumed that our work concerned genetics. We, therefore, decided to address the type of genohype that was generated by the HGP rather than directly refer to the issues concerning the patenting of life or deal with the direct effects of the HGP on medicine and pharmaceuticals.

In the *Pig Wings* project, we grew three sets of wings made out of pigs' mesenchymal cells (bone marrow stem cells) grown over/into biodegradable/bioabsorbable polymers (PGA, P4HB). The wings' size is 4 cm × 2 cm × 0.5 cm each, and they were never intended to be implanted onto pigs. The original proposal we sent as a response to the commission was titled: 'Wings detached – the good, the bad and the extinct: Installation of three sets of bony wings, grown from pig stem cells'. In our preliminary statement regarding this project, we wrote:

> Wings detached – the good, the bad and the extinct can be seen as a representation of the set of values that are attached to gene technologies. The interpretation of genes is

> not a value free process. Wings carry many associations with them. Cultural representations of wings (mainly in Christian religious art) have been assigned arbitrary values in relation to both shape and origin. Bird-like wings are symbolically linked to the angels, representing their goodness and purity. Bat-like wings are generally attached to the bad fellows of mythology. But it might help us to remember that the implicit humane/angelic continuum also carries the curse of the mythic Icarus, who burnt his wings trying to fly too close to the sun. As the existence of the Pterosaurs (winged lizards) was not widely known until last century there is no culturally established value attached to their extinct shape. Extinction as we know it may even become 'extinct' as advances in biological technologies enable us to recreate extinct organisms from DNA samples. On the other hand, new kinds of extinction may arise, for example the extinction of the 'bad genes' by genetic-based eugenics. Our cultural perceptions of these three evolutionary solutions for vertebrate's flight can be seen as metaphorical analogs to our perceptions of gene technologies.
>
> The promises and hopes surrounding the Human Genome Project (both private and public) sounded like fantastic claims just a decade ago. Our attempt to make representations of wings made out of pig stems cells is an exercise in putting things in perspective. Humanity (mainly the English speaking part of it) has for generations made fun of the idea that pigs might fly. Now that we are getting close to fulfilling this dream, we can gauge how people will react to the fulfilment of other fantastic claims.
>
> Stem cells are the working drafts organisms and tissues they differentiate into. They are the raw material from which specialized cells develop. We know how to direct them to go down certain pathways and even how to edit their instructions/expressions. This control enables us to impose value system on genes and enact the processes which lead to the creation of 'the good, the bad and the extinct'. We can also leave the 'decision' to the cells and examine the results of a 'natural' situation with no social/cultural values attached. But would we be able to spot the difference? Will pigs be able to fly one day?
>
> *(The Tissue Culture & Art Project 2000)*

We also added that:

> …we will also attempt to file a patent for 'Pig Tissue Wings', and present our desire to 'initiate and control' the pig wings 'market'. Anyone who will try to make pigs fly (by growing wings on them) will have to get our consent.

In retrospect, it is not surprising that our work was rejected as this ironic piece strikes at the heart of the hidden agenda that involves employing artists as agents in the service of the genohype. However, we never imagined that the rejection letter from the Two10 gallery and the events that followed would illustrate this point so well that it became for us an integral part of the whole *Pig Wings* piece. Due to copyright laws, we are unable to directly quote the letter of rejection from the gallery, but it is sufficient to say that it was a revealing document. Both the artistic and scientific merits of our proposal were questioned, but one sentence in the letter presented a very interesting insight into what the gallery perceived as the role of the artist. This was a reference to the fact that the advisory group felt that our project presented an unrealistic reflection of the public's opinion of the Genome. This is a somewhat unconventional view regarding the role of artists in society. Artists are often described as having a unique view of the world and are hailed as presenting subjective, varied and unique observations about the world. Another point that was raised in the letter was that the gallery felt that our work would not fit well with the other exhibits.

Although we respected the rejection decision, we felt that we needed to respond to these extraordinary claims by apologizing to the Two10 gallery and the advisory group in a letter in the following way: 'We are sorry that our work did not reflect your perception of what the public opinion should be'. Their response to this apology was that their choice of words could have been different. But their main objection was that they did not approve of our vision of what the Genome represented. That was just too good for us to let go, so in setting up the website for the *Pig Wings* project, we included the correspondence with the Two10 gallery as an integral part of the project. This was part of our treatment of the *Pig Wings* project as a process, art documentation or as 'living art' as argued by Boris Groys:

> For those who devote themselves to the production of art documentation rather than of artworks, art is identical to life, because life is essentially a pure activity that does not lead to any end result.
>
> *(2004: 165)*

Among these art documentation activities, Groys lists the creation of unusual living circumstances, politically motivated art and so on.

In the meantime, the *Working Draft* exhibition has been staged and, to our amazement, we found the following statement in the curatorial essay that accompanied the exhibition:

> With an open brief, literal translations of the theme were not expected, nor did the artist have to reflect any specific "look" or imagery associated with the Genome. Nevertheless, the results were surprising. Major scientific discoveries inevitably attract a degree of controversy, and the HGP is no exception. So, having expected an obvious degree of public debate to filter visually through the works, we found the results instead to be more subtle and hence potentially more interesting.

And, intriguingly, although the artists had no idea how others were responding to the brief, there is a distinct visual coherence to the overall display achieved through the artists 'combining a harmonic palette (including an over-riding incidence of salmon-pink) with translucency' (Jones 2001).

There is not much one can add to such a blunt misrepresentation of the selection process of the Two10 gallery. The absence of any mention of the curatorial decision with regard to the process of selection and rejection of works and being 'surprised' by the results indicate that the curator used the participating artists to mask her own agenda. It is not surprising then that when the author of the above statement found out, three years later, that we posted our correspondence with her on our website, she was not very happy. For obvious reasons, we cannot disclose the full details of what followed but after approaches to our University's legal department and the possibility that funding to other research at our University from the body controlling the gallery might be affected, we removed the correspondence from our site. Indeed, Brown was right again in observing the unequal use of resources in the struggle to dominate a vision of our manufactured futures.

For us, this proved to be a form of resistance to being a passive agent in the play of 'genohype forces' whether sustained by financial bodies, the media, curators and so on. By making the *Pig Wings* project, a living piece both in the literal sense and in the metaphorical one as described by Groys, we could unfold and reveal the ongoing politics played out in the 'Art and Science' hype we find around currently. As Groys states:

> The practices of art documentation and of installation in particular reveal another path for biopolitics: rather than fighting off modernity, they develop strategies of resisting and inscription based on situation and context, which make it possible to transform the artificial into something living and the repetitive into something unrepeatable.
>
> *(2004: 177)*

As suggested before, Kockelkoren argues that an artist cannot escape their fate of being part of the process of creating public acceptance for the new technologies they are exploring, even when doing so from a critical perspective (2003: 106). Furthermore, as illustrated in this paper, critical artists, whose artwork has been exhibited in thematic shows about biotech, are 'fig leaves'. Vested interests require an appearance of actual debate concerning these technologies' developments. The stage is readied for the next phase of implementation of such technologies.

What form of radical art can you perform when the media and private companies suggest the most radical future scenario in ethics and credibility as one presented by something like the cover story in the *Western Australian*? With the *Pig Wings* project, we wanted to talk about genohype and the rhetoric surrounding the HGP. We asked whether pigs would fly, and in the case where this eventuated (because no one knows what to believe anymore), we wanted to see what type of wings they might have.

We are not sure whether our own strategy with the *Pig Wings* as living art (and art documentation) exploring genohype in an ironic way by intentionally 'disappointing' the audience (realizing that pigs cannot fly with the wings we made) is a useful one. We hope that we are not falling into self-righteousness and that we continue to be wary about our role as artists manipulating living tissues in the age of genohype.

Dimitry Bultov wrote an article mentioning the *Pig Wings* as a technological failure and in that fact becoming a more interesting piece. Bultov explains:

> … artists transfer the emphasis of their activities from art production to research of the conditions which give rise to works of art. As a result of such an approach, artwork must fail first, in order to be beautified later… I mean such kind of art activity which, while aiming at a conscious expectation of "failure" and "misfortune" of the project, has the purpose of representing some bans at functioning of an artwork. As an example of such a strategy, I can mention the project Pig Wings … Using tissue engineering technology which enables one to cultivate organs and tissues of different organisms in vitro, the artists have grown a pair of wings out of a pig's stem cells. And though technological problems with transplantation of the artificially-grown wings to a donor animal have been successfully solved, the artists decided to close the project at this stage, not to bring it to the stage of getting a real chimera. The conscious decision not to complete the project points to the fact that it is precisely the pre-programmed uselessness of the pig wings, that are wings only by form, but are not designed for flying in their essence and inner construction, which makes them a fact of art…This kind

of art engineering has a distinct preventive character because, reporting the failure of modern science and technology, it also gains a human dimension and contributes to our idea that the world has once been different and is still able to become totally different than it is

(Bultov 2002).

Epilogue

The original title of Wings Detached has been changed to simply the *Pig Wings* project. The project has been exhibited in different configurations internationally[7] and featured in many media stories, including the *New York Times*, *Arte TV* and more. In many instances, the galleries promoted their exhibition using statements such as 'come and see pigs flying in the gallery', but the visitor only encountered small objects displayed in cheap jewellery boxes. *Pig Wings* embody the promise and the disappointment, which underlies the rhetoric and hype of scientific discoveries and implications (Figures 31.1–31.3).

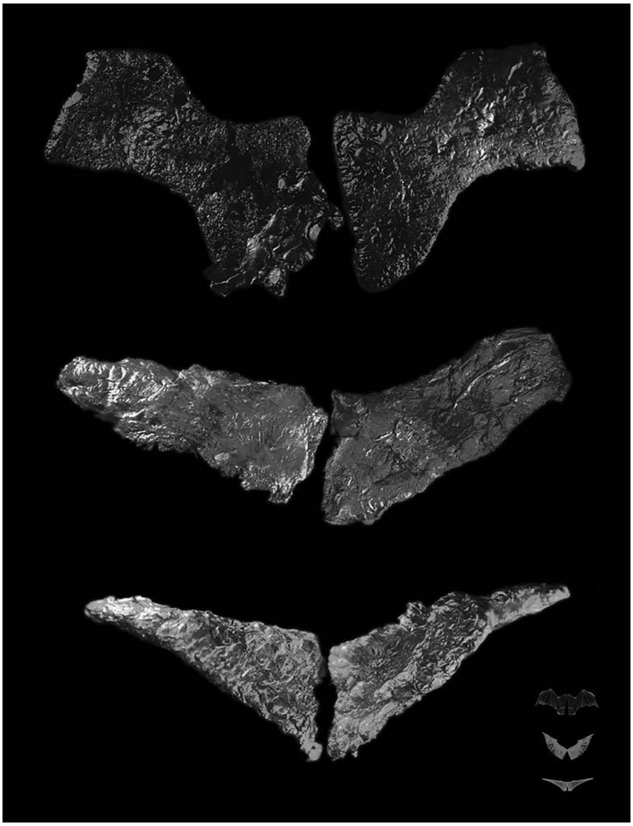


Figure 31.1 The Tissue Culture & Art Project. *Pigs Wings*. 2000–2001. The *Pig Wings* project was researched and developed at the Tissue Engineering & Organ Fabrication Laboratory, MGH Harvard Medical School & Symbiotic A, School of Human Sciences, The University of Western Australia. Pig mesenchymal cells (bone marrow stem cells) and biodegradable/bioabsorbable polymers (PGA, P4HB), 4 cm × 2 cm × 0.5 cm each. Photograph by the The Tissue Culture & Art Project

Figure 31.2 The Tissue Culture & Art Project. *Pig Wings: The Chiropteran, Aves and Pterosaurs*. 2000–2001. The *Pig Wings* project was researched and developed at the Tissue Engineering & Organ Fabrication Laboratory, MGH Harvard Medical School & Symbiotic A, School of Human Sciences, The University of Western Australia. Pig mesenchymal cells (bone marrow stem cells) and biodegradable/bioabsorbable polymers (PGA, P4HB), 4 cm × 2 cm × 0.5 cm each

Figure 31.3 The Tissue Culture & Art Project. *Untitled Studies towards the Pig Wings*. 2000–2001. The *Pig Wings* project was researched and developed at the Tissue Engineering & Organ Fabrication Laboratory, MGH Harvard Medical School & Symbiotic A, School of Human Sciences, The University of Western Australia. Pig mesenchymal cells (bone marrow stem cells) and biodegradable/bioabsorbable polymers (PGA, P4HB), 4 cm × 2 cm × 0.5 cm each

Notes: Complete citation information is available in the original link: https://culturemachine.net/biopolitics/big-pigs-small-wings/

Endnotes

1 For more details, see http://www.critical-art.net/biotech/cone/index.html as well as in Critical Art Ensemble (1998) *Flesh Machine; Cyborgs, Designer Babies, Eugenic Consciousness*. New York: Autonomedia.

2 The Joint Statement – President Clinton & Prime Minister Blair was released on March 14, 2000, and can be viewed online http://clinton4.nara.gov/WH/EOP/OSTP/html/00314.html

3 For example, BioDifference, the show we curated as part of the Biennale of Electronic Arts, Perth 2004. For more details, see http://lwgallery.uwa.edu.au/program/2004/BioDifference and http://www.beap.org

4 'The nude mouse, a hairless mutant discovered in 1962, is immunodeficient and thus does not reject tumour transplantations from other species'. From: Osburn, B., Klingborg, D. J., Hart L., Wood, M. W., Berchhin, K., Dassler, A., & Kim, Y. R. K. *The Mouse in Science, Cancer Research*, the UC Center for Animal Alternatives, School of Veterinary Medicine, University of California, Davis. http://www.vetmed.ucdavis.edu/Animal_Alternatives/cancer.htm

5 The term meme was coined in 1976 by Richard Dawkins in his book, The Selfish Gene. In short, a meme is a self-propagating unit of cultural evolution analogous to the gene. Memes can represent parts of ideas, languages, tunes, designs, skills, moral and aesthetic values and anything else that is commonly learned and passed on to others as a unit. Like genes, memes can replicate and mutate.

6 Patricia Piccinini web site: http://www.patriciapiccinini.net/

7 The *Pig Wings* project has been shown in the 2002 Adelaide Biennial of Australian Arts http://www.adelaidebiennial.com/, Boston Cyberarts Festival 2003 http://www.decordova.org/decordova/exhibit/pigwings.html, and Biennale of Electronic Arts Perth 2002 http://www.absolutearts.com/artsnews/2002/07/31/30159.html and more.

References

Anker, S. & Nelkin, D. (2004) *The Molecular Gaze: Art in the Genetic Age*. New York: Cold Spring Harbor Laboratory Press.

Brown, N. (2003) Hope Against Hype – Accountability in Biopasts, *Presents and Futures in Science Studies*, Vol. 16, No. 2, pp. 3–21.

Bultov, D. (2002) *The Grecian Horse of Young Art*, http://www.sitec.fr/users/akenatondocks/DOCKS-datas_f/collect_f/auteurs_f/B_f/BULATOV_f/ACTIONBUL_F/BULATOV.htm.

Court, C. (1994, 30 April) Report Calls for Collaboration on Genome Research, *BMJ*, Vol. 308, p. 1123, http://bmj.bmjjournals.com/cgi/content/full/308/6937/1123.

Critical Art Ensemble. (1998) *Flesh Machine; Cyborgs, Designer Babies, Eugenic Consciousness*. New York: Autonomedia.

Dawkins, C. (1976) *The Selfish Gene*. Oxford: Oxford University.

Dexter, M. (2000) *Comment by Dr Michael Dexter, Director, Wellcome Trust: 26 June 2000*, http://www.wellcome.ac.uk/doc_wtd002950.html

Fitzgerald, M. (2004, August 23) Giving (Real) Life to Art: Genetics and Tissue Culture Find New Forms – and a New Audience, *TIME Magazine*, No. 33, pp. 66–67.

Gessert, G. (2003) 'Notes on the Art of Plant Breeding', in Hauser, J. Ed., *L'art Biotech Catalogue*. France: le lieu unique, ISBN 2-914381-52-2. https://www.academia.edu/38609668/L_Art_Biotech_complete_book_

GF. (2001) *History of the Human Genome Project: The First Draft, June 2000*, http://www.wellcome.ac.uk/en/genome/geneticsandsociety/hg13f010.html.

Groys, B. (2004) 'Art in the Age of Biopolitics', in Bulatov, D., Ed., *BioMediale: Contemporary Society and Genomic Culture*. Kaliningrad Branch, Russia: The National Centre for Contemporary Arts, pp. 164–177.

Holtzman, N. (1999) Are Genetic Tests Adequately Regulated? *Science*, Vol. 286, No. 4539, p. 409.

Jeremijenko, N. (2000) *A Response to Paradise Now*, http://cat.nyu.edu/~nhj2/investnow/response.html.

Jones, D. (2001) *'Working Drafts': Art of the Genome*, http://www.wellcome.ac.uk/en/genome/geneticsandsociety/hg16f003.html.

Kockelkoren, P. (2003) *Technology: Art, Fairground and Theatre*. Rotterdam: NAi Publishers.

Morgan, M. (2000) *The First Draft of the Book of Humankind Has Been Read*, http://www.sanger.ac.uk/HGP/draft2000/mainrelease.shtml

O'Leary, C. (2003) Gene Tests to Pick Junior Sports Stars, in *The West Australian*. Perth: West Australian Newspaper Limited, p. 1.

Stevens, J. (2000) *Why Are Defense Contractors Suddenly Sponsoring Art about Games (Shift-Ctrl)? Why Are Biotech Companies Suddenly Sponsoring Art about Genes (Paradise Now)?* http://rtmark.com/rockwell.html.

Tissue Culture & Art Project (2000–2001), *The Pig Wings Project*, http://www.tca.uwa.edu.au/pig/pig_main.html.

Section 8
Exposure to the elements

Dehlia Hannah

Exposure carries a double connotation of vulnerability and revelation. One risks exposure to the fluctuations of the weather, the market, or toxic environs in order to disclose latent secrets: to record an image on a sensitive surface. In the language of photography, exposures are timed and positioned to create carefully crafted, partial perspectives, images glimpsed by a view from *somewhere*. Sharing its etymological roots with *experience*, exposure lies at the foundations of empiricism—and yet goes beyond scientific inquiry. As Stacy Alaimo has argued, the performance of exposure to the material substance(s) of environmental crisis constitutes an ethical and political act—and an aesthetic one, in the original sense, which unites perception with pleasure.[1] The essays collected here present practices of embracing corporeal and cognitive vulnerability to our troubled ecological and political environs; contexts in which we are irreducibly imbricated as participants and would-be observers. Featuring texts by artists, curators, archeologists and anthropologists, and art and cultural historians, this section explores experimental practices of knowledge production and exhibition making at the nexus of Art, and Science, and Technology Studies. Rather than seeking extrication from ethically and epistemically compromising entanglements—the troubled ideal of science—, the authors articulate modes of engagement that double as means of exposition. Like the naked environmentalist protestors analyzed by Alaimo, who literally bare their skin to the elements, "they practice an ethics of exposure, which sets aside the fortification of the 'I' in favor of the embrace of the multiple, the intertwined, the sensate."[2] Theory is put to work in the reorganization of aesthetic perception. Historical knowledge becomes embodied by walking and swimming through post-colonial landscapes. Found objects and controversies become the raw material of new orders of meaning, and dwelling within environmental catastrophes becomes a cultural practice. These practices flourish in the intertidal zone where culture laps up against the shores of nature, eroding its conceptual foundations and its physical integrity at once. Taken together, the following tales of *exposure to the elements* exemplify contemporary empiricisms informed by STS coming to grips with local and global environments in states of anthropogenic crisis.

In style, the texts in this section vary, ranging from curatorial essays and art criticism to first-person narratives, critical travelogues, and formal experiments on the page in the tradition of concrete poetry. It is an important insight of STS that writing is central to the

DOI: 10.4324/9780429437069-40

evolution of scientific ideas as well as their official communication. Lab notes, letters, diaries, annotations, and marginalia are considered worthy of attention in addition to scientific articles, publications whose strict writing conventions serve to obscure conditions of their own production in favor of idealized reconstructions of experiments.[3] In the historical sciences (by contrast with the laboratory sciences), arguments and explanations are made through narrative, and here, the virtues of coherence, rhetorical structure, descriptive style, and use of examples play a key role in persuasion.[4] Charles Darwin's writings are virtuosic in this regard. Different content requires different literary form. Thus, while also thematically organized, the textual experiments presented here foreground writing style as a critical site of art and STS. Expanding the scope of scholarship beyond the academic essay to include materials that are the traditional province of the art historian, such as exhibition catalogue essays, reviews, and artists' writings, this section also recognizes a diversity of written forms that emerge directly from the artworld when artists and curators address traditional STS themes.[5] As such, it invites consideration of how differences in substance and style reflect the diverse disciplinary backgrounds of the inter- and trans-disciplinary scholarship collected in this volume.

Our contemporary moment is marked by environmental crises that are often collected together under the sign of the Anthropocene, the geological era in which human activity has a dominant impact on earth systems. Anthropogenic climate change is rapidly undermining the stability of weather systems and seasonal patterns and the forms of life that depend upon them. Pollution, deforestation, mass die-offs of species, and entangled ecological disasters multiply and exaggerate each other on a global scale. The term "Anthropocene" is useful to denote this situation, yet it also simplifies its causes, obscuring who and what historical events and political-economic systems are to blame. The role of *Anthropos* is not evenly distributed across our species, just as the effects of the ecological crises it has wrought are not evenly borne. Critics identify the perpetrators of these crises more precisely—the Capitalocene or the Plantationocene.[6] Likewise, within the Anthropocene Working Group of the International Commission on Stratigraphy, some proposals to mark the beginning of the era track tipping points in political history—settler colonialism, plantation slavery, and the development of nuclear weapons.[7] The Anthropocene remains a useful concept for many of the authors in this section precisely because of the widespread critical debate that the term has engendered. If STS has been preoccupied with the dualism of nature and culture, the concept of Anthropocene does away with this divide from the perspective of the geosciences themselves, while at the same time bringing an arcane scientific debate into cultural space. Under its auspices, the environment, geophysical systems, and the elements are construed, at least in part, as artifacts of human activity, both intentional and unintentional. As such, the physical condition of the earth becomes a matter for art—and thus of aesthetics and politics. Whether the Anthropocene survives scientific and political critique as a geological period, it already demonstrates its richness as an aesthetic idea.

Inspired by Gaston Bachelard's theory of material imagination, this and the following section are organized around the classical elements of earth, water, wind, and fire. "One cannot dream profoundly with *objects*," he writes; "to dream profoundly, one must dream with substances."[8] As a philosopher of science and poetics, Bachelard's inquiry into the scientific imagination and, conversely, the inspiration afforded to artists and poets by sustained meditation on material phenomena offers a productive frame through which to read the texts that follow. The following essays foreground aesthetic encounters with the troubled environs of the Anthropocene: oceans filled with plastic and atomic, biological and architectural residues of nuclear testing; post-colonial landscapes and communities bearing the brunt of climate change and the legacies of environmental racism; the sonic and media landscapes of disasters. The elements to which the authors seek exposure have been added to the periodic table by human hands, fabricated in laboratories and factories, and distributed through the atmosphere and oceans through explosions and emissions. This section foregrounds creative ways of thinking on land and sea, while the following section, entitled *Atmospherics*, focuses specifically on air and its ambiences. Fire, the only one of the four classical elements that turns out to be a process, rather than a substance, omnipresent in the form of lightning, wildfires, combustion of fossil and nuclear fuels, and global heating, pervades the themes addressed herein.

The first chapter in this section, *In the Middle of Something: In Search of Meso-Aesthetics* by Andrew S. Yang, offers at once a formal and a theoretical provocation to readers of this book: an imperative and a guide to thinking from the perspective of immersion, entanglement—mediacy. Structured like an iceberg, whose mass lies mostly submerged below the waterline, the text is heavy with footnotes, which often float in the middle of the page, demanding immediate attention. Yang engages readers in a constant shifting of attention—between a central line of argumentation and a multiplicity of threads leading in different directions; between text and subtext, micro and macro, form and medium, frame and content; between theories, disciplines, and topics—all the while treading the liminal spaces in which oppositions are mutually entangled. The text performs what it describes, decentering the agency of making meaning and excavating an aesthetics attuned to Anthropocene complexities and their mediation. "Any meaning-full meso-aesthetic must…pay close attention to its mediums of attention and perception, while also keeping in mind that a medium is that very 'middle' which we seek to make aesthetic sense of," he writes, in middlenote 40, for "In the Anthropocene, the Earth and the complexities entailed within it, are the medium."

In *Curating In-Between Systems: Politics, Ecology, and Art*, Stefanie Hessler articulates a curatorial practice resonant with meso-aesthetics, informed by systems theory, cybernetics, and their art historical reception. With attention to how ideas of environment and ecology have developed through the work of Gregory Bateson, Jack Burnham, and Félix Guattari, Hessler deploys thinking about complex systems toward curatorial agendas at *ANTI: the 6th Athens Biennale*, in 2018, on the theme of agonism in contemporary politics and culture, and in the research and exhibition project *tidalectics*, developed over two years onboard the research ship of Thyssen-Bornemisza Art Contemporary (TBA21).[9] In keeping with Alaimo's contention that practices of bodily exposure are especially important for imagining the contemporary state of our oceans, Hessler foregrounds artistic practices that emphasize multisensory and embodied modes of awareness.

Heather Davis deepens the section's focus on art and Anthropocene seas in *The Future Now: Three Tales of Ocean Plastic*, with a close reading of three artworks included in the exhibition that she co-curated called *Plastic Entanglements: Ecology, Aesthetics, Materials* (2018). At the nexus of art and science, plastiglomerate—a composite of plastic and other debris—has been recognized by geologists as a new and pervasive type of stone. Here, it becomes an *objet trouvé*, which, like Marcel Duchamp's *Fountain* (1917), serves to exhibit the context that gives it meaning. Davis offers three figures—objects or characters to think with—for an Anthropocene future that is already present; the material-discursive phenomenon of the plastiglomerate, the *Crochet Coral Reef* initiated by Margaret and Christine Wertheim, and Pinar Yoldas's *Ecosystem of Excess*, a speculative imagining of organisms that may evolve out of oceans saturated with plastic. Building upon previous important contributions to the study of art in the Anthropocene, Davis's essay attests to the centrality of art to the ethical and political project of imagining futures that may diverge from the present course of disaster.[10]

Complementary aims inform the work of Jacob Lillemose, the founder and curator of *X and Beyond* (2015–2017), an art gallery devoted to the cultural imagination of disaster associated with the Copenhagen Centre for Disaster Research (COPE). Putting art and architecture into dialogue with disaster preparedness and relief training, as well as critical studies of the social conditions of disasters, the gallery's intensive program of exhibitions, talks, and events sustained an active public dialogue about issues ranging from extreme weather to zombie scenarios and asteroid strikes, fictional scenarios of catastrophe and survival, and an art exhibition installed within the Fukushima Nuclear Exclusion Zone. Lillemose's account of this curatorial project attests to the essential role of art in developing a shared cultural space for reckoning with disasters, both locally and internationally—events that strain not only emergency response systems and technical resources but also psychic and political imagination. The culmination of the project—and Lillemose's essay—troubles fantasies of *The End*, highlighting our situatedness in the uncomfortable middle of many ongoing disasters.

Taking concern with disaster into field-based research methods, in *An Anthropocene Journey: Walking as Embodied Research*, Nick Sheppard and Christian Ernsten offer an account of a 'walking seminar' that they conducted on Table Mountain, near Cape Town, at the peak of the 2018 water crisis. As the city approached "Day Zero" of its water supply and rationing exacerbated post-Apartheid racialized inequalities, Sheppard (an archaeologist) and Ernsten (a heritage studies scholar) were joined by a diverse group of scholars, curators, artists, and architects, including local residents and international visitors, for a week-long walk and conversation that meandered across topics of decolonization, aesthesis, and embodied knowledge of the complex political and ecological conditions entangled within the geography at this particular historical moment. Like the methodology of the walking seminar itself, their style of writing meanders, permitting detours, rests, and loops, as different personal, theoretical, and historical perspectives are drawn into the group's reflections. Their essay articulates a methodology grounded in artistic, anthropological, and feminist practices of walking, which grounds insight within bodies and their differences, situations and fragmented understanding of their histories. As an example of a transdisciplinary scholarly practice of exposure, their methodology offers a powerful alternative to the sterile norms of imperial knowledge production—an important resource for art and STS.

The section concludes with an excerpt from curator/art historian Nadim Samman and artist Julian Charrière's creative non-fiction travelogue *As We Used to Float—Within Bikini Atoll*, an account of their expedition to the postcolonial nuclear geography of the Marshall Islands, in Micronesia, site of the US hydrogen bomb testing program after World War II. For Samman and Charrière, technical diving and filming underwater become a means of embodied research that explores the phenomenology of the diving apparatus as an interface with the underwater realm and the histories submerged there. Above the waterline, their encounters with post-apocalyptic scenes in the guise of a palm-fringed paradise, the decaying infrastructure of the image-making technologies of the bomb program itself, and the stories of dispossession of the atoll's original inhabitants by that program test the powers of narrative to create lasting images. "To glimpse the seas," Alaimo argues, "one must descend, rather than transcend, be immersed in highly mediated environments that suggest the entanglements of knowledge, science, economics, and power."[11] One must not only perceive but find a means to share such insights: in the many literary forms and artistic media represented in this section, art seeks to share a glimpse into such entangled worlds.

If "Being in the middle of something means having personal stake in perception and a sense intimacy with what one's perceiving," as Yang proposes, then the embodied research practices articulated by the authors in this section may be understood as a way of cultivating a meso-aesthetic awareness of environments in radical transition—and destruction. Together, these texts offer fragmented images of land and sea, water tables, and intertidal zones as fraught ecological and theoretical territory, accessible to creative methods of research and representation. New content demands new forms; here, artistic and curatorial practices, creative research methods, and written forms elaborate STS themes into new discursive spaces.

Notes

1 Stacy Alaimo, *Exposed: Environmental Politics and Pleasures in Posthuman Times*. Minneapolis: University of Minnesota Press, 2016.
2 Ibid., p. 78.
3 Frederic L. Holmes, "Scientific Writing and Scientific Discovery". *Isis*, 78, no. 2 (June, 1987): 220–235; J. W. McAllister, "Rhetoric of Effortlessness in Science". *Perspectives on Science*, 24 (2016): 145–166.
4 Gillian Beer, *Darwin's Plots: Evolutionary Narrative in Darwin, George Eliot and the Nineteenth-Century*. Cambridge: Cambridge University Press, 1983; Mary S. Morgan and Wise, M. Norton, "Narrative Science and Narrative Knowing. Introduction to Special Issue on Narrative Science". *Studies in History and Philosophy of Science Part A*, 62 (2017): 1–5.
5 The practice of writing for exhibition catalogues has become increasingly important for STS scholars, historians and philosophers of science. For example see Latour, Bruno. (2003) "Atmosphère, Atmosphère." In Olafur Eliasson: The Weather Project, edited by Susan May, 29–41. London: Tate,.; Rheinberger, Hans-Jörg. (2011) "Risking Reason: The Productive Tension of Art and Science in the Work of Paul Vanouse." In Paul Vanouse: Fingerprints…, edited by Jens Hauser, 89–103. Berlin: argobooks.; and many of my own writings including Hannah, Dehlia. (2018) "Exposure," *Julian Charrière—Second Suns*, Nadim Samman (Ed.), Hatje Cantz Verlag; and Hannah, Dehlia (2020), "The Philosopher Against the Clouds," *Nanna Debois-Buhl—Cloud Behavior*, Humboldt Books & Laboratory for Arts and Ecology.
6 Donna Haraway, "Anthropocene, Capitalocene, Plantationocene, Chthulucene: Making Kin". *Environmental Humanities*, 6 (2015): 159–165
7 See Simon Lewis and Mark Maslin, *The Human Planet: How We Created the Anthropocene*. London: Pelican Press, 2018; Colin N. Waters, et al. "Global Boundary Stratotype Section and Point (GSSP) for the Anthropocene Series: Where and How to Look for Potential Candidates". *Earth-Science Reviews*, 178 (2018): 379–429. For further discussion, see Dehlia Hannah and Sara Krajewski, *Placing the Golden Spike: Landscapes of the Anthropocene*, exhibition catalog. INOVA: Portland, 2015.
8 Gaston Bachelard, *Water and Dreams: An Essay on the Imagination of Matter*, trans. Edith R. Farrell, Dallas: Dallas Institute of Humanities and Culture, 1982, p. 22.
9 Stefanie Hessler (Ed.), *Tidalectics: Imagining an Oceanic Worldview through Art and Science*, Cambridge, MA: The MIT Press, 2018.
10 Heather Davis and Etienne Turpin, *Art in the Anthropocene. Encounters among Aesthetics, Politics, Environments and Epistemologies*. London: Open Humanities Press, 2015.
11 Alaimo, *Exposed*, p. 161.

32

In the Middle of Something

In Search of Meso-Aesthetics

Andrew S. Yang

This sentence might seem like the beginning, but you are already in the middle. (0)

0 See Note 19.

Somewhere within deep within the *Handbook of Art, Science, and Technology*, this essay is becoming enmeshed among all the other things you have read and will read. Its possibility for meaning will emerge only from its entanglements. Some are knotted semantically (references gathered, plus memories carried, to the connections they find) (1), while others are woven materially (from the atmospheric carbon dioxide which grows the tree, that is pulped into paper, that hold these words. In the landfill, it will become coal that will be burned 200 million years from now). (2) If we can muster the awareness to recognize these kinds of psychological and geochemical entanglements, then perhaps we've experienced a moment of meso-aesthetics, an aesthetics of the middle. (3)

1 Even the word "middle" puts us in the middle of other associations: Middle class, Middle Way, middle age, Middle Ages, middle finger, Middle Passage, middle school). Every form of meaning is confluence of the latent with the present. People often say "I am in the middle of something," when in fact they are in the always in the middle of everything. (See Note 40).

2 If you are reading this on an electronic screen, you are actively involved in carbon emission, whereas pages are one form of carbon sequestration. The leaves of a book materialize from the leaves of the tree; the science of measurement means every part-per-million of CO_2 can be taken into cyclical account

3 Maybe such complexity is not unlike the annotations or notes that run thready roots below the surface of the text, as often ignored as they could be crucial. How can that kind of context also become the text?

A View from Nowhere

Through my office window here in Chicago I am looking at a field where a couple picnicked 41 years ago. They were smiling and talking, their blanket laid out with food and books. This is the opening scene for the Charles & Ray Eames film, *Powers of Ten.* In its opening shot, we encounter the picnickers from ground-level, as if standing on the grass besides them. And then, very suddenly, the view goes perpendicular: we are floating above the picnic at a distance of 10^0 meters (= 1 meter). As an invisible narrator's voice begins to speak, our view

DOI: 10.4324/9780429437069-41

is being pulled further and further away and we start to pass backwards through white-lined windows of size + scale, each one counting off successive powers of ten…10^1…10^2…10^3… It is a Russian doll of place / city / planet / cosmos framed as if on graph paper.

Upon reaching 10^{24} meters the zooming out ceases and the Milky Way galaxy appears as a solitary spiral before us, a celestial specimen in the center of the frame. After a moment of floating pause, visual motion reverses, and we are hurtling back towards the couple, vertiginously and somehow faster than the speed of light. We deaccelerate on the approach to the man, but don't stop; instead, we enter the skin of his hand and are pressed smaller and smaller within. The powers of ten go negative as the view squeezes through more white-lined windows, collapsing us into a cell, then its DNA, and finally to a probabilistic flurry of protons, neutrons, and subatomic particles within. Here, at 10^{-16} meters, the image fades to black and the film ends.

Powers of Ten is a visual poem for the what might be called the View from Nowhere (4). Totally dis-embodied, its gaze slides through outrageous scales of magnitude with a perfectly constant optical flow. The picnickers, like all other objects throughout the journey, occupy the center of the visual field, while at the same time functioning as the zero point (10^0) for the spatial extremes visited. (5) The couple is at the cinematic center of in the film, but without ever really being *in the middle* of anything. No matter how close we physically get to them, the pair and the world they inhabit remain magically remote from the inner and outer spaces of scales. Clear cut, the white-lined windows of 10^x sever the people from the entanglements and complexities they might be in the middle of: the food they are eating, the books they are reading, their lingering disagreement, and how their skin feels with the unseasonably hot October weather. (6) How can such experiential and personal things be meaningful within the vast reaches of universal space? This is the question that an *aesthetic of the middle* can't help but ask. (7)

4 This is the title of philosopher Thomas Nagel's book, *The View from Nowhere* (Nagel, 1989). This view represents an idealization of a purely objective and depersonalized scientific perspective, as powerful as it is also powerfully limited. "Objectivity is a method of understanding," (p. 4) writes Nagel, while at the same time arguing that "the methods needed to understand ourselves do not yet exist." (p. 10)

5 Deleuze and Guattari's notion of "straited space," seems to perfectly describe Eamesian objectivity: "the requirement of long-distance vision: constancy of orientation, invariance of distance through the interchange of inertial points of reference… constitution of a central perspective." (Deleuze and Guattari, 1987, p. 494).

6 Astronomer Royal Martin Rees has said that, "We want to not only synthesize the very large and the very small but we want to understand the very complex, and the most complex things are ourselves, midway between atoms and stars. We depend on stars to make the atoms we are made of. We depend on chemistry to determine our complex structure … The science of complexity is probably the greatest challenge of all, greater than that of the very small … and the very large ... And it's this science which is not only enlightening our understanding of the biological world but also transforming our world faster than ever." (Rees, 2005). Such a synthesis is precisely what *Powers of Ten* avoids. In spanning the very extremes of scale that Rees describes, the film sacrifices the horizontal for the sake of vertical, editing out the rich mess of planetary processes at the midway and within the middle-ground. "Critical zone" studies are a literal example of how middle ground and its complexity can be engaged (See Note 36).

7 Thomas Nagel wrote that his book, "is about a single problem: how to combine the perspective of a particular person inside the world with an objective view of that same world, the person and his *[sic]* viewpoint included." (Nagel, 1989, p. 3). The physicist and philosopher, Ernst Mach, was maybe one of the first to document just such an attempt (See Note 20). A combination of the subjective and the objective is central to meso-aesthetics.

Powers of Ten is equally a work of art as much as it is a work of science. (8) The aesthetic conceits of scientific objectivity and that of cinematography are not categorically different, but rather variations on shared, long-running themes within Western culture. (9) The root meaning of *aesthetics* is "perceptibility" as well as "awareness." Western techniques of framing, isolating, and centering by means of hermetically sealed detectors and double-blind experiments discipline an observer's perception, just as the visual arts employ frames, spotlights, and the gallery's white cube as standard devices to create bounded, bubbled spaces of selective attention (10), as well as cool contemplation. (11)

8 The film is also a work of business and technology. *Powers of Ten* was commissioned by IBM, a brand-as-acronym that stands for International Business Machines. The company's name embodies modernity itself, each of its three words synonyms for globalizing capital and optimality. For historical background and visual design analysis of the *Powers of Ten* see Michael J. Golec's 'Optical Constancy, Discontinuity, and Nondiscontinuity in the Eameses' *Rough Sketch'* (Golec, 2012).

9 In *Consilience: The Unity of Knowledge,* E. O. Wilson writes that, "The love of complexity without reductionism makes art; the love of complexity with reductionism makes science." (Wilson, 1999, p. 54) Wilson's contrast is catchy, but fundamentally the kind of opposition that meso-aesthetics wants to avoid. To the extent that many sciences have suffered from delusion of pure objectivity (erasure of the human and the influence of its subjectivity), it can also be said that traditions within the Western arts have suffered from acute anthropocentrism (erasure of the non-human creativities and subjectivities alike).

10 *Thinking, Fast and Slow* by Daniel Kahneman provides a rich overview of the psychological fundaments of attention and judgment see, while the research of Richard Nisbett and his colleagues explore attention's cultural variations. (Kahneman, 2013).

11 Timothy Morton argues that, "A profound political act would be to choose another aesthetic construct, one that doesn't require smoothness and distance and coolness." (Morton, 2013, p. 106) Such a construct is what meso-aesthetics aspires to. Presumptions of distance and coolness are built into the notion of objectivity in science, but they also figure heavily in aesthetic judgments within visual art, especially in terms of the "disinterestedness" that Immanuel Kant believed was crucial in notions of "taste" and "beauty." (Kant, 2001) While meso-aesthetics looks to the forms, structures, and methods of imbricated perception and awareness, the closeness and warmth of one's personal commitment is invaluable for being truly in the middle of anything.

This aesthetic is powerful by virtue of its ability to exclude, bracketing off all the many other things that could possibly be perceived. But there is also a violence in what makes the cut as interesting *signal* versus neglected *noise.* Not only is there the picnicking couple, but there are the soil microbes beneath them and the rising CO_2 in the air above. Relaxing in Grant Park the film's non-protagonists are sitting upon reclaimed land created by piling rubble from the Great Chicago Fire of 1871 into Lake Michigan; meanwhile the area is the native land of the Illinois-Miami tribes and the Potowamani. (12) What is lost as noise for the sake of signal, and what kinds of simplification are overly simplistic? It is hard to know, because so much is so intentionally edited from view. Whatever meso-aesthetics is, it wants to know about what it is missing, and take care for those things that have been forcibly left out. (13)

12 The Miami-Illinois indigenous to the swampy oak-savannah were likely eating the wild leeks that they called *shikaakwa,* the word from which the name "Chicago" was eponymously appropriated. *Powers of Ten*'s nowhere-ness is not only spatial and physical, it is also temporal. While the film explores deep space, it completely ignores deep time, be that the thick glaciers that covered the land around the park 16,000 years ago, or the shallow inland sea and its coral reefs that occupied that space 250 million years ago. Activating the contingencies and complexities of multi-temporal history are implicit to an aesthetics of the middle. As an aesthetic decision, tracing such threads help reveal what we are, in fact, still the middle of: colonial power and climate change, the seemingly "far" past and misleadingly "distant" future. (See Note 38)

13 Ethics is a matter of aesthetics. What counts, what is valued, and what is cared for depends directly on being perceived and given attention. What is recognized as being in the very middle of things?

Whatever else the notion of the Anthropocene does, it points to how established forms of cultural and disciplinary exclusion result in claustrophobically narrow notions meaning. There are so many *we's* in the middle of so many things that it can hardly be made sense of, and yet meso-aesthetics still aspires to sense the insensible processes that all of "us" intimately participate in: climate change, love, global economy, the nitrogen cycle, anxiety, structural racism… things that are every day, immanent, and yet can feel elusive all at once. (14)

14 The *we* that this essay addresses is likely to be quite tiny – a *we* that has had access to resources on a level that the majority of people now, and in all previous human history, never have had access to. The cost of this Routledge book in hardcover is roughly equivalent to the monthly per capita income of someone in Pakistan or Kenya. Consequently, the average reader of this book as an inordinate impact on the middle (whether in terms of carbon dioxide emissions, resource consumption, or political influence) within which so many different *we's* are having to make their way.

The argument for an aesthetics of the middle is not to dismantle disciplinary knowledge or completely do away their aesthetic techniques, but neither is it to simply add more fine-grained detail. It is to reimagine the relationships of causation, narration, and identity the in broadest and most plural possible sense – to recapture and reinvest in the complexities have been lost in the process of the larger Enlightenment project. (15)

15 Meso-aesthetics expands through that vital and neglected middle left vacant by the oppositions of subject/object, micro/macro, humanities/sciences, affect/effect, center/margin, quantitative/qualitative, part/whole, empirical/speculative, human/nonhuman, local/global, singular/multiple, appearance/essence, signal/noise, abstraction/figuration, arborescent/rhizomatic, active/passive, molar/molecular, vital/mechanistic, epistemic/ontologic, masculine/feminine, reality/representation, intimate/rational, nowhere/now-here. Whatever an aesthetics of the middle may be, it emerges from within and also beyond the construction of oppositions that have defined modern and postmodern perceptibility alike. It aspires to take less for granted and more into account; it may be less classically elegant but more authentic – full of more parts, but also full of less holes.

Both Hegel and Adorno are absent from this essay, which is likely cause some indignation. Despite the desire to avoid dualism, *meso-* is not likely to be matter of (dialectical Hegelian) "synthesis" any more than it is an example of a (negative dialectical Adornian) "anti-system." It is something else. Maybe it is best described as an allied group of principles or values; rather than a philosophy, it is a set of cyborg conditions the resists the whole premise of dualities from the start (see Haraway's *The Cyborg Manifesto* (1991). Deleuze and Guattari claim: "The problem of writing: in order to designate something exactly, anexact expressions are utterly unavoidable….We invoke one dualism in order to challenge another. We employ a dualism of models only in order to arrive at a process that challenges all models." (Deleuze and Guattari, 1987, p. 20) Fighting fire with fire may seem effective because it is familiar, legible, and can help undermine dominant structures by co-opting them. But it can also feed the flames of categorical and oppositional thinking. An aesthetics of the middle wants to find some other way, perhaps a "middle way."

In bringing greater complexity back into perception, meso-aesthetics challenge the boundary conditions of conventional oppositions, but also those of the disciplines that enforce them (art, science, and technology included). (16) Whether this moment of global inflexion is called the Anthropocene or something else, it is a middle in which no cosmology is safe and no one story can be certain. The principles of meso-aesthetics outlined below are nothing new, the question becomes how they might be meaningfully brought together at a time of planetary pivot. (17, 18) As a set of values to be activated, their resolution will look different in different cases, and yet share some recognizable resemblance through commitments to: *centerlessness*, *heterogeneity & connectivity*, as well as an abiding concern with *mediums* of perception and their *multiplicity.*

16 *Meso-* is neither the "inter-," the "cross-," or the "trans-" disciplinary. In fact, none of these throwaway terms appear in this essay. All of those terms simply reaffirm the validity of existing disciplinary boundaries. The inter-cross-trans is always an ephemeral add-on, one that is seems epiphenomenal to traditional disciplines. As prefixes, they serve to pre-fix and reaffirm the disciplines as they already are, rather than what they could become. Meso-aesthetics doesn't necessarily aim to weaken the methodological disciplinarity of disciplines (as mentioned earlier, it emerges from both within and beyond the disciplines), but it is committed to extending and entwining them more collaboratively with other forms and fields (see Note 18).

17 Most of the references in this essay are from the last 100 years, deriving from Euro-American authors, ones that I personally am most familiar with. However, a wide range of non-Western cultural and philosophical traditions have had an inevitable influence on my and many others' thinking, including forms of Indigenous knowledge as well as Buddhist and animist traditions. Zoe Todd and a number of other Indigenous scholars

have pointed to the importance of acknowledging these complex genealogies – ones that have been forgotten, unintentionally excluded, or that colonialism as forcibly erased – as well as the unexpected convergences that occur among indigenous and Western knowledge practices. (Todd, 2014)

18 The question of how different forms of knowledge mutually inform, hybridize, or resist co-option is significant for any aesthetics, and perhaps especially so for a meso-aesthetics. Biologist and member of the Citizen Potawatomi Nation, Robin Wall Kimmerer, has considered this question in terms of her own indigenous knowledge practices along with her training in Western science. In her view, "Instead of blending, we need knowledge symbiosis, or relationship. I think of the metaphor of the Three Sisters garden. When you plant the Three Sisters – corn, beans, and squash – together, they complement one another and produce more nourishment than if they were grown in isolation… Obviously, the corn doesn't blend with the beans and the squash. In fact, it's essential that the corn be itself in order for the symbiosis to work. Likewise, I think it's important to recognize the sovereignty of each kind of knowledge, to maintain their distinctiveness and allow each to be visible and vital. My goal is to take indigenous and Western knowledge systems and ask how we can use them together for a common purpose. It's never about blending, particularly given the power differential between scientific knowledge and indigenous knowledge." (Tonino, 2016)

Western scientific institutions, such as the U.S. Fish & Wildlife Service, have taken great interest in Traditional Ecological Knowledge (also known by the acronym "TEK"), and would seem share a sensibility with Kimmerer's position on maintaining distinction among certain knowledge practices, while at the same time encouraging "integration." One of the Service's documents on TEK argues that, "Although an integration of indigenous and western scientific ways of knowing and managing wildlife can be difficult to achieve, successful integrations have occurred. For example, during the 1989 Exxon Valdez oil spill in Prince William Sound…" The document goes on to suggest that, "TEK is one way federal employees can honor the federal trust responsibility to tribes with regard to resources of mutual interest," but is careful to caution against colonial attitudes by government scientists: "Even though one's intent in the collection of TEK may be altruistic, how the information is used can have unintended consequences. It is important to contact the Regional Tribal Liaison if TEK is pursued." (U.S. Fish & Wildlife Service, 2011)

A bibliography on the relationship between TEK and western scientific practice has been complied by the U.S. National Park Service: https://www.nps.gov/subjects/tek/tek-vs-western-science.htm

1 Centerlessness

Like the universe itself, meso-aesthetics are without center. Modern physics has revealed that anywhere and everywhere in the universe is equally its middle by virtue of the fact it has no perceivable center or edge. (19) While a centered and disembodied gaze defines the View from Nowhere in the *Powers of Ten*, the subjectively embodied View from Now-Here can be just as (self) centered, something to which the histories of a geocenteric cosmos, Flat Earth theories, and one-point perspectival drawing all readily attest. Centerlessness is axiomatic to an aesthetics of the middle, and its seeks to attune all sensory and imaginative perception in a way that is enmeshed within the middle-ground. (20).

19 When the Big Bang happened 14.3 billion years ago, there was no space in which the universe could "bang" into – the bang itself created space as well as time, and so it happened everywhere at once. Looking out into the universe now, the distribution of galaxies appears smooth and even there is no perceivable edge; because any given galaxy moves away from every other galaxy at the same rate – the "expanding universe." Every galaxy sees every other galaxy moving away from it in every direction, giving a viewer in any galaxy the impression that their galaxy is at the unmoving center. Humans appeared long after time came into existence and it is unknowable when the universe, and thus time, will end. One can be perpetually and deeply in middle without ever being at the center.

20 There is the View from Nowhere and the View from Now-Here, but there is also Ernst Mach's remarkable self-portrait, "View from the Left Eye." It is worth consideration as an early gesture towards an aesthetics of the middle. Splitting the difference between "nowhere" and "now-here," the illustration draws together (a) the specificity and subjectivity of the embodied self (i.e. the *left* eye), with (b) the disciplines of scientific knowledge into one shared fabric of the kind that Thomas Nagel has sought (See Note 7). The illustration appeared in his book *The Analysis of Sensations* (1914) and Mach wrote: "The considerations just advanced, expressed as they have been in an abstract form, will gain in strength and vividness if we consider the concrete facts from which they flow. Thus, I lie upon my sofa. If I close my right eye, the picture represented in the accompanying cut is presented to my left eye. In a frame formed by the ridge of my eyebrow, by my nose, and

by my moustache, appears a part of my body, so far as visible, with its environment. My body differs from other human bodies beyond the fact that every intense motor idea is immediately expressed by a movement of it, and that, if it is touched, more striking changes are determined than if other bodies are touched by the circumstance, that it is only seen piecemeal, and, especially, is seen without a head. If I observe an element A within my field of vision, and investigate its connexion with another element B within the same field, I step out of the domain of physics into that of physiology or psychology, provided B, to use the apposite expression of a friend of mine made upon seeing this drawing, passes through my skin. Reflexions like that for the field of vision may be made with regard to the province of touch and the perceptual domains of the other senses." (Mach, 1914, p.18-20).

Because centeredness is often an embodied default, aesthetic effort is needed to actively *de*-center the self. The ways that this is achieved are as varied as they are divergent. For example, while scientific objectivity will center on a focal object as a means to decenter and screen-off the influence of human subjects (epistemologically) (21), some contemporary philosophies use an "object-oriented" approach that disposes with subjects all together (ontologically). (22) It has been argued that one of installation art's key techniques is decentering, achieved not by erasing the subject, but instead through fragmenting it into multiple subjectivities whose dispersion makes one central viewpoint impossible. By creating immersive environments that are physically entered, rather than remotely pondered, installation art seems to reformulate the passive subject into embodied participant that literally makes their way into the middle of the artwork and the world. (23) In this way, installation art does something more than represent a visual image, instead it forms an "elaborated reality" within which subject becomes an intimate part (and collapsing conventional opposition between subject/object, reality/representation). (24)

21 Nagel describes the perspective of the natural sciences as one "placing ourselves in a centerless world" (Nagel, 2989, p. 19). This means exceeding the embodied, subjective point of view, as well as the monopoly of the visual, through scientific theories and instrumentation that extend far beyond our corporeal sensorium.

Jakob von Uëxkull's theory of *Umwelt* provides an account of creatures' inherent centeredness as well as the way that human's use science to create centerlessness. Uëxkull posited that every creature lives within a sensory bubble, an *Umwelt*, distinct from others. "No animal will ever leave its Umwelt space, the center of which is the animal itself. Wherever it goes, it is always surrounded by its own Umwelt space, filled with its own sensory spheres, irrespective of how much the objects change. Man [*sic*], on the other hand, when he wanders, tends to cut loose the space he moves in from his sensory spheres and thus to extend his paths in all directions…Man does no longer move with a space that follows him faithfully, as his senses tell him, he moves instead in a space at rest, a space that is cut loose from him and has its own center." (Von Uëxkull, 2001, p. 109). With an *Umwelt*, everything is always standing at some remove, pressed onto the surface of the *Umwelt* bubble without ever entering it, like an image on a screen. See Inga Pollman's essay 'Invisible Worlds, Visible: Uëxkull's Umwelt, Film, and Film Theory' for how film influenced the development of Uëxkull's theory. (Pollman, 2013)

22 Timothy Morton's theory of hyperobject aesthetics embrace centerlessness, and he claims that, "Hyperobjects have done what two and a half decades of postmodernism failed to do, remove humans from the center of their conceptual world." With Hyperobjects, Morton notes, "there is no center and we don't inhabit it." (Morton, 2013, p. 17) See *Heterogeneity & Connectivity* below for more.

23 Art historian Claire Bishop has articulated the aesthetic de-centering that happens with installation art and how it, "plays on an ambiguity between two types of subject: the *literal* viewer who steps into the work, and an abstract, philosophical *model* of the subject that is postulated by the way in which the work structures this encounter… This tension – between the dispersed and fragmented *model subject* of post-structuralist theory and a self-reflexive *viewing subject* capable of recognizing its own fragmentation – is demonstrated in the apparent contradiction to both *decentre* and *activate* the viewer. After all, decentring implies the lack of a unified subject, while activated spectatorship calls for a fully present, autonomous subject of conscious will (that is, a 'modern' subject)." (Bishop, 2010, p.130-131) Bishop points out that, "installation art posits us as *both* centred and decentred, and this conflict is itself decentring since it structures an irresolvable antagonism between the two. Installation art calls for a self-present viewing subject precisely in order to subject him/her to the process of fragmentation." (ibid, p. 131) "By these means, installation art aims not only to problematize the subject as decentred, but also produce it." (ibid, p. 133).

Marshall McLuhan's description of art as creating "anti-environments" is relevant to Bishop's theories as well as to installation art that can, in principle, heighten ones perception of being embedded in the middle of hidden and everpresent complexities. McLuhan writes: "Environments are not passive wrappings. But are, rather, active processes which are invisible. The groundrules, pervasive structures, and over-all patterns of environments elude easy perception. Anti-environments, or countersituations made by artists, provide means of direct attention and enable is to see and understand more clearly. The interplay between the old and the new environments creates many problems and confusions. The main obstacle to a clear understanding of the effect of new media is our deeply embedded fixed point of view…" (McLuhan and Fiore, 1967, p. 68). See *Heterogeneity & Connectivity* and *Multi/Medium* below for more in connection to McLuhan.

24 The idea of an "elaborated reality" comes from Nagel's description of the centerless epistemology that would synthesize the individual with the universal, one that would, "go beyond the distinction between appearance and reality by including the existence of appearances in an elaborated reality. Nothing will then be left outside. But this expanded reality, like physical reality, is centerless." (Nagel, 1989, p. 18)

2 Heterogeneity & Connectivity

Decentering through fragmentation creates heterogeneity – parts of various sizes, shapes and interactions – that makes a single comprehensive view impossible. When science or philosophy acknowledge their fundamentally partial or incomplete access to the "real world" it has the sense of an epistemological failure, a grudgingly acknowledged limitation. Meso-aesthetics, however, embraces situatedness, its varied subjectivity, and partial view of things that results. Partiality is potent because it is specific and, in that way, perhaps also authentic. Being in the middle of something means having personal stake in perception and a sense intimacy with what one's perceiving. This kind of partiality and intimacy exactly what a View from Nowhere tries to avoid. (25)

25 Donna Haraway's concept of "situated knowledge" and her larger body of work are foundational to an aesthetics of the middle. Her performance work *Donna Haraway Reads* **the National Geographic** *on Primates* (1987), is a remarkable example of a meso-aesthetic work. In it, she asks, "What gets to count as nature, for whom and when, and how much it costs to produce nature at a particular moment in history for a particular group of people." She voices the very specificity and heterogeneity that perception-within-the-middle relies upon. Feminist, post-colonial, and queer studies have all foundationally contributed to theories of centerlessness, heterogeneity, and connective relationships that meso-aesthetics draws from, and then expands it into non-human realms.

When parts of various sizes and shapes interact in middle and in the midst of each other, they touch. Systems of connectivity and relation – mosaics, networks, tissues, webs, and rhizomes – spontaneously emerge through these distributed, heterogenous, and mutual contacts. (26, 27)

26 The rhizome has been one of the most compelling metaphors for connectivity given its organic and emergent character, and Deleuze and Guattari's articulation of it is meso-aesthetic in character: "The rhizome is reducible to neither one or multiple… it is composed not of units but dimensions, or rather directions in motion. It has neither beginning nor end, but is always in the middle (milieu) from which it grows and overspills." (Deleuze and Guattari,1987, p. 21) They posit an aesthetic in which, "There is no visual model for points of reference that would make them interchangeable… On the contrary, they are tied to any number of observers, who may be qualified as 'monads' but are instead nomads entertaining tactile relations among themselves. The interlinkages do not imply an ambient space in which the multiplicity would be immersed and which would make distances invariant; they are constituted according to ordered differences that give rise to intrinsic variations on their division of a single distance." (ibid, p. 493)

27 The emphasis on connectivity found across theories that embrace systems-thinking stands in contrast to the focus on unknowability, elusiveness, and "withdrawl" that Thomas Nagel as well as Timothy Morton stress in their philosophies of not-knowing (albeit through very different approaches). The cooperative and collaborative sensibility that often emerge with organic models of connectivity doesn't ignore difference, but neither does it construe difference as characteristically conflictive, alien, or "dark." Heterogeneity, connectivity, and partiality share an attitude of multiplicity rather than impossibility.

It is an aesthetics of haptics rather than exclusively optics (28), of awareness cultivated from personal and embodied contact with complex connectivity. (29, 30) There is a thickness to these webs of interconnection that burrow into each person's elemental body (as nutrients, toxins, atmospheric gases). Once these entanglements are aesthetically grasped, the potential for remoteness disappears. (31, 32, 33)

---

28 Haptic connectivity tends to undermine the bracketing and reduction that selective, focal attention relies upon, but meso-aesthetics sees that as virtue, not a shame. Anything seemingly gained from the singular variables of "selective attention" (achieved through reductive methods, disciplines, or devices), is offset by multiple gains of what might be called "comparative attentions" that are made possible through connectivity as well as the plurality of perception that such connectivity encourages.

29 Brett Bloom's *Petro-subjectivity*: *De-Industrializing our Sense of Self* (2015) uses sensorial embodiment as a means to realize connections to landscape often obscured by the petro-subjectivity within which engine noise-pollution, plastic wrappings, and electric screens enlayer us. Through practices of "deep listening" to the ambient environment, Bloom's de-electrified approach to the aural runs in a very different direction than McLuhan's claims for how electronic media can reinvest humans in the oral and sonic.

30 Robin Wall Kimmerer has reflected (in interview, essays, and her book *Braiding Sweetgrass: Indigenous Wisdom, Scientific Knowledge and the Teachings of Plants,* 2013), on how the relational approaches that characterize many forms indigenous knowledge contrast to those of Western science: "When we use the scientific method in an experiment, we look at one variable at a time. In order to really understand how something works, science says, we must exclude all else. We're not going to talk about relationships. We're going to limit ourselves to cause and effect. This notion that you can rigorously exclude all factors save one, and in so doing find *the* cause, is not part of traditional knowledge. In the traditional way of learning, instead of conducting a tightly controlled experiment, you interact with the being in question — with *that* plant, with *that* stream. And you watch what happens to everything around it, too. The idea is to pay attention to the living world as if it were a spider's web: when you touch one part, the whole web responds. Experimental, hypothesis-driven science looks just at that one point you touched." (Tonino, 2018).

31 Haraway: "When every fiber of our being is interlaced, even complicit, in the webs of processes that must somehow be engaged and repatterned? Recursively, whether we asked for it or not, the pattern is in our hands." (Haraway, 2016, p. 35-36)

32 Timothy Morton: "Hyperobjects adhere to any other object they touch, no matter how hard an object tries to resist. In this way, hyperobjects overrule ironic distance, meaning that the more an object tries to resist a hyperobject, the more glued to the hyperobject it becomes." (Morton, 2013, p. 30)

33 Exhibitions like *Plastic Entanglements: Ecology, Aesthetics, Materials,* curated by Joyce Robinson, Jennifer Wagner-Lawlor, and Heather Davis at the Palmer Museum of Art (2018), are examples of meso-aesthetic engagement. "The story of plastic is as complex as the polymer chains that make up its unique material properties. *Plastic Entanglements* brings together sixty works by thirty contemporary artists to explore the environmental, aesthetic, and technological entanglements of our ongoing love affair with this paradoxical, infinitely malleable substance. Both miraculous and malignant, ephemeral yet relentlessly present, plastic infiltrates our global networks, our planet, and even our bodies." (Robinson, Wagner-Lawlor, and Davis, 2018)

The heterogeneity of the middle is not random any more than its connections are generic. Every place in the middle relates and connects uniquely. Although some conceptions of connectivity insist that any point can be connected to any other, what is connected to what (where, when, how, and to whom) crucially matters to perceptibility, just as proximity matters in attention and agency. (34)

---

34 While Deleuze and Guattari proposed that, "Any point of the rhizome can be connected to anything other, and must be." (p.7), Donna Haraway (2016, p.173) has observed that, "the brand of holist ecological philosophy that emphasizes that 'everything is connected to everything,' will not help us here. Rather, everything is connected to *something*, which is connected to something else. While we may all ultimately be connected to one another, the specificity and proximity of connections matters – who we are bound up with and in what ways." In some sense, Haraway's text is handbook of meso-aesthetics, with its focus on creating networks of kin and staying closely in and with the middle of things.

What's more, while paths of connectivity may be provisional and contingent, they are by no means arbitrary – the structure of narrative, causality, and responsibility are all dependent on their particular shape. This means that while there is no one universally privileged (centered) vantage, in different circumstances there may in fact some vantages that are more informative and potent than others by virtue of their specific connections. Context always matters. (35)

35 Jack Burnham's concept of "systems esthetics" was an early and important foray into an aesthetics of the middle. He wrote of the importance of environments and "unobjects" in perceiving the systems we are a part of: "The components of systems – whether these are artistic or functional – have no higher meaning or value. Systems components derive their value solely through their assigned context. Therefore, it would be impossible to regard a fragment of an art system as a work of art in itself." (Burnham,1968, p. 34). Cybernetic in tone, Burnham raises crucial questions about aesthetic awareness in regard to social value, decisions, as well as planetary well-being. The work of artists such as Hans Haacke, Simon Starling, and Natalie Jeremijenko explore an aesthetics of the middle through systems approaches. (See Note 44 on the "technosphere" for a related concern).

Connectivity is at the heart of an ecological perspective, and by linking across species, scales, and processes often put in opposition, eco-logic can be seen as inherently meso-aesthetic. Ecology is paradigmatic of an aesthetics of the middle because its causality is neither top-down nor bottom-up, it emerges from across and within. Ecological connectivity brings fragments into mutual relation, linking parts into complex wholes that maintain their heterogeneity at other scales of consideration. (36)

36 The emerging field of "critical zone" science serves an example of meso-aesthetics at work in the natural sciences. The critical zone is the, "permeable layer from the tops of the trees to the bottom of the groundwater; an environment where rock, soil, water, air, and living organisms interact and shape the Earth's surface." It is a myriad middle space of heterogeneous connectivity where "processes operate on second-to-eon timescales," and its key components are themselves in the middle of transformation: "activity transforms rock and biomass into the central component of the Critical Zone - soil; it also creates one of the most heterogenous and complex regions on Earth." (U.S. Fish & Wildlife Service, 2011)

This material dimension of heterogenous connectivity within critical zone studies is mirrored in the conceptual aims of Burnham's system aesthetics and Ursula Heise's "sense of place" (see Note 39). Different disciplines – geology, biology, soil science, and hydrology – must work in synergistic concert, flickering between disciplinary distinction and holistic integration. Although arguably still a field within the natural sciences, critical zone studies highlight anthropogenic roles in the zone and, like all ecological inquiries, is permeable and connectible to political, economic, and media ecologies. (Critical Zone Observatories, 2018). Meso-aesthetics could be thought of as an expansive form of eco-aesthetics in which the natural sciences don't simply provide conceptual metaphors, but function as embedded components of it. On the other hand, the grounding of biological ecology should not overshadow the importance and of "political ecology" in an expansive and naturalculturally entangled sense, for example as explored in Hern and Johal (2018, p. 11-13, 90-94).

And the Earth is just such a heterogeneous whole. The pressing question is how its entanglement of species, politics, and biogeochemical processes, active as they are on such vast and varied scales might become more perceptible, intelligible, expressible, and engagable. (37, 38) Meaningfully perceiving complexity across multiple scales simultaneously to bring about a "sense of place and a sense of planet" is the fundamental challenge of an aesthetics of the middle. (39)

37 Non-human and cross-species connectivity (e.g. ecology) is a central territory of meso-consideration. "We form a rhizome with our viruses, or rather our viruses cause us to form a rhizome with other animals..." (Deleuze and Guattari, 1989, p.10). To the extent the humanities maintain the human as its centering and central concern, it neglects meso-aesthetics.

38 Historian of science, Lorraine Daston, has spoken of such multi-scale and multi-causal connectivity in terms of how history could be written. In considering the role of climate in the bubonic plague for example, "it is

no longer only a history of the decimation of population, the rise in wages as a result of that decimation, the stimulus given to a certain form of mercantile capitalism, or to religious reform; it's a story in which those events are, to some extent, corollaries of a much larger phenomenon of world weather patterns, the dissemination of bacteria, the vectors for those bacteria, the mutations of those bacteria, the dispersion of rats, etc. Of course, we historians would not be interested in those bacteria had they not wiped out at least one-tenth of the European population after 1348. Nonetheless it is a much-enlarged history, with non-human actors playing a very important role in the history. That kind of history I can easily imagine." (Daston, 2017, p. 9). In Note 34 we see that critical zone studies seeks to make sense of "second-to-eon timescales," while Daston's vision of history likewise calls for a "suppleness for timescale, from the nanosecond to the eon and everything in between." (ibid, p. 17).

39 Ursula K. Heise's book *A Sense of Place a Sense of Planet*: *The Environmental Imagination of the Global*, incisively explores strategies for how relations of the local/global and individual/collective might be reconciled in light of heterogeneity across vast social and spatial scales. The goal is to, "develop aesthetic forms that do justice both to the sense that places are inexorably connected to the planet as a whole and to the perception that this wholeness encompasses vast heterogeneities by imaging the global environment as a kind of collage in which all the parts are connected but also lead lives of their own," (Heise, 2008, p.64) and cultivate a strong sense of how, "political, economic, technological, social, cultural, and ecological networks shape daily routines." (ibid, p.55) Heise sees information and communication technologies, like the internet, as playing a significant role in cross-connecting these scales, place, and their constituencies. She argues that, "In the context of rapidly increasing connections around the globe, what is crucial for ecological awareness and environmental ethics is arguably not so much a sense of place as a sense of planet – a sense of how political, economic, technological, social, cultural, and ecological networks shape daily routines." (ibid, p.55); this aesthetic central to what she calls "eco-cosmopolitanism."

These ideas should be carefully considered in light of the utopic visions of electronic media and communication technologies that were put forth by theorists like Marshall McLuhan some 40 years earlier. How have the promises of the World Wide Web and social media materialized the kind of "global village" McLuhan and others envisioned? "Electric circuitry," McLuhan writes, "has overthrown the regime of 'time' and 'space' and pours upon us instantly and continuously the concerns of all other men *[sic]*. It has reconstituted dialogue on a global scale… ending psychic, social, economic, and political parochialism. The old civic, state, and national groupings have become unworkable. Nothing can be further from the spirit of the new technology than 'a place for everything and everything in its place.' You can't go home again." (McLuhan and Fiore, 1967, p. 16)

In a remarkable case of medium becoming the message, Heise points out that, "In a curious twist, technological connectedness also quite frequently becomes a metaphor by means of which ecological connectedness can be represented, inverting more conventional tropes that figured human communities and systems of exchange as organic. Informational networks, which in industrialized regions may well appear more immediately palpable and imaginable than ecological systems, become themselves allegorical – concrete instantiations of an organic connectedness that eludes the grasp of the senses." (Heise, 2008, p. 65)

3 Multi/Medium

The final principle of meso-aesthetics is the necessity for a *multi*-ness of mediums, especially for those that engage materiality and embodiment. Committing to multiple mediums of engagement not only provides more access points and more opportunities for cross-comparative perception, it also is a matter of aiming to reflect the complexity of the world as authentically as possible. (40) To the extent that global communication technologies are significant as mediums for connecting and expanding perception among diverse levels, parts, and processes (41), they are also one of the primary means that planetary conditions have become so complex and heterogeneous in the first place. Because if its ubiquity, perhaps an aesthetics of the middle inescapably involves of form cyborg aesthetics, with connectivities that defy clean categories of human, animal, or technology. (42)

40 A medium is quite literally about the middle. Consider its etymology: "*Medium* (n.) – 1580s, "a middle ground, quality, or degree," from Latin medium "the middle, midst, center; interval," noun use of neuter of adjective *medius* (from PIE root *medhyo- "middle"). Meaning "intermediate agency, channel of communication" is from c. 1600. That of 'person who conveys spiritual messages' first recorded 1853, from notion of 'substance

through which something is conveyed.' Artistic sense (oil, watercolors, etc.) is from 1854." (Etymonline.com, 2018) Any meaning-full meso-aesthetic must therefore pay close attention to its mediums of attention and perception, while also keeping in mind that a medium is that very "middle" which we seek to make aesthetic sense of. In the Anthropocene, the Earth and the complexities entailed within it, are the medium.

41 McLuhan and Fiore's experimental manifesto, *The Medium is the Massage: An Inventory of Effects* (1967) is a fascinating work of meso-aesthetics in its own right, and provides an important historical source of comparison for thinking critically through the meaning of communication technologies: "All media work us over completely. They are so pervasive in their personal, political, economic, aesthetic, psychological, moral, ethical, and social consequences that they leave no part of us untouched, unaffected, unaltered. The medium is the massage. Any understanding of social and cultural change is impossible without a knowledge of the way media work as environments." (McLuhan and Fiore, 1967, p. 26).

42 See Donna Haraway's "A Cyborg Manifesto: Science, Technology, and Socialist-Feminism in the Late Twentieth Century," (1991) for an exploration of how connection across heterogeneous parts results in hybrid forms on multiple scales, and that exceed typical categories and standard oppositions.

Granting electronic communications' important role, there are both conceptual and political reasons why an aesthetics of the middle will also be committed to heightening embodied and material perception, making use of the so-called "virtual" but not abandoning oneself to it. (43) An embodied middle-grounding can be a form of resistance against the ethereal and informational webs that increasingly consume us, as well as against the extractive capitalism that makes use of these webs for its own productivity, efficiency, and growth (44). Contact with the visceral and biochemical materiality of life is contact with the fundamental mediums that define the planet, regardless of whether a "technosphere" currently envelopes it.

---

43 Peter Haff has coined the term "technosphere" to describe the organizational and material systems that have woven themselves into the planet through human culture. Although humans are connected and embedded in the middle of the technospheric whole, Haff paints a dystopic picture of humans' ability to have any real control or full accessibility to it: "The technosphere includes the world's large-scale energy and resource extraction systems, power generation and transmission systems, communication, transportation, financial and other networks, governments and bureaucracies, cities, factories, farms and myriad other 'built' systems, as well as all the parts of these systems, including computers, windows, tractors, office memos and humans. It also includes systems which traditionally we think of as social or human-dominated, such as religious institutions or NGOs… The technosphere is a system for which humans are essential but, nonetheless, subordinate parts. As shorthand we can say that the technosphere is autonomous. This does not mean that humans cannot influence its behavior, but that the technosphere will tend to resist attempts to compromise its function." (Haff, 2014, p. 127).

In terms of human agency in the technosphere, see Notes 29, 34, as well as the closing paragraph of Burnham's 1968 essay: "But for our time the emerging major paradigm in art is neither an ism nor a collection of styles. Rather than a novel way of rearranging surfaces and spaces, it is fundamentally concerned with the implementation of the art impulse in an advanced technological society. As a culture producer, man has traditionally claimed the title, *Homo Faber*: man the maker (of tools and images). With continued advances in the industrial revolution, he [*sic*] assumes a new and more critical unction. As *Homo Arbiter Formae* his prime role becomes that of man the maker of esthetic decisions. These decisions - whether they are made concertedly or not - control the quality of all future life on the Earth. Moreover these are value judgments dictating the direction of technological endeavor. Quite plainly such a vision extends beyond political realities of the present. This cannot remain the case for long." (Burnham, 1968, p. 35).

44 See Note 8. Can living things be abstracted without having their vitality obscured or motions made voiceless? I have always wanted to, at least once, hear the sounds of that picnicking couple – the sound of their voices coming from their bodies, even just the rustling of their bodies along the blanket.

At the present, the aesthetics of electronic media have become just as effective at *screening-off* wider physical and environmental consequences from awareness than actually engaging them. If technologies like the internet have collapsed space and time and created an "allatonceness" that offers new kinds perceptive access (real time, multi-player, or otherwise) (45), it is equally true that the unrelenting speed of information cycles and its sheer volume has reset the intervals and thresholds of our attention. Such speeding up has provided the ultimate cover for obscuring our awareness from the "slow violence" of pollution and disenfranchisement that can be exceptionally hard to grasp given the diffusiveness and distance of their effects, especially on people that are already kept at the margins of our attention. (46) The great acceleration of flows (foods, fuels, toxins, sediments) enhance the potency and longevity of ecological impacts. Systems of slow violence sustain themselves by creating means to mask their perniciousness and cloak their operations – speeding up the causes, while slowing down their effects. (47)

---

45 "Ours is a brand-new world of allatonceness. 'Time' has ceased and 'space' has vanished." (McLuhan and Fiore, 1967, p. 63). The all-at-onceness of global communications technology and the diffusing effect it has upon attention suits the accelerating interests of global commerce and its desire to create smaller and smaller increments of awareness, increments that can become more and more economically productive. The increasing speed of capitalism and its media serve as cover for the timeframes of the "slow violence" (see next Note 46) that many of its industries perpetrate.

46 By producing toxic e-waste from the devices of globalized electronic communication, affluent first-world consumers are enmeshed in the middle of pollution, without having to suffer its direct consequences the way poor, vulnerable populations do. Even at the sites of pollution, effects of such toxicity can be displaced in time and space in a way that makes their causality hard to discern. If believing relies solely on seeing, then environmentalism paints itself into a small corner. Rob Nixon's work on "slow violence" and the questions that it raises are essential for an aesthetics of the middle. He points out that, "an influential lineage of environmental thought gives primacy to immediate sensory apprehension, to sight above all, as foundational for any environmental ethics of place… But what happens when we are unsighted, when what extends before us – in the space and time that we most deeply inhabit – remains invisible? How, indeed, are we to act ethically toward human and biotic communities that lie beyond our sensory ken? What then, in the fullest sense of the phrase, is the place of seeing in the world that we now inhabit? What, moreover, is the place of the other senses? How do we both make slow violence visible yet also challenge the privileging of the visible? Such questions have profound consequences for the apprehension of slow violence, whether on a cellular or a transnational scale. Planetary consciousness (a notion that has undergone a host of theoretical formulations) becomes pertinent here…" (Nixon, 2013, p. 14-15.)

Nixon calls on activist writing and journalism as the means to make greatest aesthetic impact, and investigative journalism has certainly led the way for connecting across varying scales and entities, making the complexities of the world more accessible and perceptible. While there are artists and scientists alike who have been equally successful in exploring and expressing an aesthetics of the middle (often in collaboration with journalism) writings continued success sets a high bar for meso-aesthetics anchored in other mediums.

47 Jane Bennett's writing about how waste and other material processes are actively intertwined through the middle of all things as a kind of "vibrant matter" exemplifies a meso-aesthetics (Bennett, 2010), as does the work of anthropologists like Alison Kenner, whose work at the intersection of environmental health, chronic disease, and mobile communication technologies in urban communities deeply and ethnographically engages perception of risk, embodiment, and pollution.

What meso-aesthetics seeks are means for living in the middle rather than trying to escaping it. The safety of the "nowhere" and "now-here" gives way to the complexity and multiplicity of fuller experience, a *everyhere* or maybe *manywhere.* But what is the use of another appellation like "meso-aesthetics"? In the worst case, its risks a kind of conceptual homogenization; in the best case, it provides a shared framework for making sense of diverse methods and aspirations, many of which are working in solidarity. Committing to the messy of the middle is committing to the varied roles we play as aesthetic and ethical agents, rather than simply as self-centered nodes in a new and newer network. What continues to be neglected and should be manifested in the worlds we take such active part with/in? This sentence might seem like the end, but it leaves you where you started: in the middle.

Bibliography

Bennett, J. (2010) *Vibrant Matter: A Political Ecology of Things*. Durham: Duke University Press.
Brett Bloom, B. (2015) *Petro-Subjectivity: De-Industrializing Our Sense of Self*. Fort Wayne: Breakdown Break Down Press.
Bishop, C. (2010) *Installation Art*. London: Tate.
Burnham, J. (1968) 'System Esthetics', *Artforum* 7, p30–35.
Critical Zone Observatories (2018) *The Critical Zone* [online] Available at: http://criticalzone.org/national/research/the-critical-zone-1national/ (Accessed 12 July 2018)
Deleuze, G. and Guattari, F. (1987) *A Thousand Plateaus: Capitalism and Schizophrenia* Minneapolis: University of Minnesota Press.
Donna Haraway Reads the National Geographic on Primates (1987) [Film] New York: Paper Tiger Television / University of California, Santa Cruz.
Golec, M.J. (2012) 'Optical Constancy, Discontinuity, and Nondiscontinuity in the Eameses' *Rough Sketch*' in Anderson, N. and Dietrich, M. R. (eds.) *The Educated Eye: Visual Culture and Pedagogy in the Life Sciences*. Hanover: Dartmouth University Press.
Haff, P. (2014) 'Humans and technology in the Anthropocene: Six rules', *The Anthropocene Review,* 1(2), p126–136.
Haraway, D.J. (1991) 'A Cyborg Manifesto: Science, Technology, and Socialist-Feminism in the Late Twentieth Century', In *Simians, Cyborgs and Women: The Reinvention of Nature*. London: Routledge.
Haraway, D.J. (2016) *Staying with the Trouble: Making Kin in the Chthulucene*. Durham: Duke University Press.
Heise, U.K. (2008) *A Sense of Place a Sense of Planet*: *The Environmental Imagination of the Global*. Oxford: Oxford University Press.
Hern, M. and Johal, A. (2018) *Global Warming and the Sweetness of Life: A Tar Sands Tale*. Cambridge: Harvard University Press.
Kahneman, D. (2013). *Thinking, Fast and Slow*. New York: Farrar, Straus and Giroux.
Kant, I. (2000) *Critique of the Power of Judgment*. Paul Guyer, P and Matthews, E. (eds.) Cambridge: Cambridge University Press.
Kimmerer, R.W. (2013) *Braiding Sweetgrass: Indigenous Wisdom, Scientific Knowledge and the Teachings of Plants*. Minneapolis: Milkweed Editions.
Mach, E. (1914) *The Analysis of Sensations, and the Relation of the Physical to the Psychical* [ebook] *Archive.org*. Available at: https://archive.org/stream/analysisofsensat00mach#page/18/mode/2up (Accessed: 14 July 2018)
McLuhan, M. and Fiore, Q. (1967) *The Medium is the Massage: An Inventory of Effects*. New York: Bantam Books.
Medium (n.) (2019) *Etymonline.com* [online] Available at: https://www.etymonline.com/word/medium (Accessed 14 July 2018)
Morton, T. (2013) *Hyperobjects: Philosophy and Ecology after the End of the World*. Minneapolis: University of Minnesota Press.
Nagel, Thomas.(1989) *The View from Nowhere*. Oxford: Oxford University Press.
Nixon, R. (2013) *Slow Violence and the Environmentalism of the Poor*. Cambridge: Harvard University Press.
Pollman, I. (2013) 'Invisible Worlds, Visible: Uëxkull's Umwelt, Film, and Film Theory', *Critical Inquiry*, 39(4), p777-816.
Rees, M. (2005) *Is this our final century? TEDGlobal* [online] Available at: http://www.ted.com/talks/martin_rees_asks_is_this_our_final_century.html (Accessed: 10 July 2018)
Robinson, J., Wagner-Lawlor, J. and Davis, H (2018) *Plastic Entanglements: Ecology, Aesthetics, Materials* [online] Available at: https://palmermuseum.psu.edu/exhibitions/previous/plastic-entanglements-ecology-aesthetics-materials
(Accessed: 20 June 2018).
Todd, Z. (2014) An Indigenous Feminist's take on the Ontological Turn: 'ontology' is just another word for colonialism (Urbane Adventurer: Amiskwacî) [blog] *Uma (in)certa antropologia*. Available at: https://umaincertaantropologia.org/2014/10/26/an-indigenous-feminists-take-on-the-ontological-turn-ontology-is-just-another-word-for-colonialism-urbane-adventurer-amiskwaci/
(Accessed: 9 July 2018)
Tonino, L. (2016) 'Two Ways of Knowing: Robin Wall Kimmerer On Scientific and Native American Views of The Natural World', *The Sun,* April [online]. Available at: https://www.thesunmagazine.org/issues/484/two-ways-of-knowing (Accessed: 10 July 2018)

U.S. Fish & Wildlife Service (2011) 'Traditional Ecological Knowledge: *for Application by Service Scientists*', [online] *Available at:* https://www.fws.gov/nativeamerican/pdf/tek-fact-sheet.pdf *(Accessed: 14 July 2018).*

Von Uexküll, J. (2001) 'An Introduction to Umwelt', Semiotica, 134(1/4), p107-110.

Wilson. E.O. (1999) *Consilience: The Unity of Knowledge*. New York: Vintage Books.

Yang, A.S. (2017) *Time (and Time Again) – Temporality, Criticality, and the Historical Imagination: A conversation with Historian of Science Lorraine Daston* [pamphlet] Chicago: Deep Time Chicago. Available at: http://deeptimechicago.org/wp-content/uploads/2017/07/Yang-Daston-Time_again.pdf (Accessed 4 July 2018).

33

Curating in-between systems
Politics, ecology, and art

Stefanie Hessler

I

Recent art exhibitions, in particular, biennials, stake claims to being ideal frameworks to discuss the most urgent issues of contemporary life. For a curator like myself, being entrusted with the mandate to conceptualize and organize such a complex exhibition entails a tremendous amount of responsibility and the apparent necessity for a humanly inconceivable comprehensiveness. Despite knowing how easily such an endeavor can utterly fail, many of us still do these exhibitions. And so, I accepted the invitation to co-curate the 6th Athens Biennale in 2018.

Under the ominous-sounding title *ANTI*, the biennial sought to investigate contemporary forms of opposition in the cultural, social, and political fields. The premise of the exhibition assumed that, in recent years, antagonistic stances increasingly encompass wide arenas of life from identity politics to pop culture to political manifestations. Non-conformity, the exhibition claimed, has become both a commodifiable asset and a real danger in populist politics. The biennial sought to present an uneasy screenshot of today, to unveil the pleasures and discomforts of opposition, and to explore how the algorithmic regime is increasingly weaponized by regressive and neofascist agendas. After only a year's time to prepare, the show unfolded during six weeks in four locations in downtown Athens: the former offices of the Hellenic Telecommunications Organization in a 1930s' administrative building designed by the architect Anastasios Metaxas, the four-star Esperia Palace hotel, abandoned since 2010 as a result of the economic crisis, the neglected Benakeios Library of the Hellenic Parliament, and the former headquarters of TSMEDE, the fund of the retired engineers, and contractors of the public sector.

The year 2018 in which the Biennale took place marked a decade of financial crisis, during which Greece's social tissue had been affected substantially. In addition, on September 25, just five weeks before the opening of the exhibition, the LGBTQ AIDS activist and drag performer Zak Kostopoulos, who had collaborated with the Biennale on various occasions, had been murdered by a mob in downtown Athens. We therefore decided to dedicate the exhibition to him. Furthermore, the Golden Dawn neo-Nazi party had been the third-largest faction in the Greek parliament since the electoral cycle of January 2015. Amid this dire economic, social, and political climate, the biennial grappled with the complexities that had led

DOI: 10.4324/9780429437069-42

to this situation, all while pursuing an anti-fascist agenda intended to explore various alternatives—the Greek prefix *anti* means both against and instead of. Presenting ninety-nine artists and collectives, the exhibition was accompanied by an extensive performance program and incorporated artist-designed spaces and devices that we found to mostly affect contemporary Athenian life, including a tilted supermarket shelf created by Sirous Namazi, a psychology laboratory devised by Brody Condon, a gym for self-improvement hosted by The Agency, a basketball court/consumer training center imagined by Danielle Dean, a night club presenting music videos by artists such as Zhala and Tianzhuo Chen, and an airport border control unit forming part of a work by Yuri Pattison.

The relationship between art and life that the Biennale touched upon has been a subject of contention for artists and historians throughout modernity. Concurrently to recent, more explicit claims that art is at the forefront of societal change, even though its effectiveness is arguably difficult to evaluate, the term *interdisciplinary* and its multiple variations continue to gain traction. Artists and curators draw on concepts from the sciences, study to earn doctoral degrees—in Europe not least due to the Bologna Process in higher education and funding possibilities geared toward academic research within the arts—and grapple with pressing issues from the feminist movement to (post)colonial struggles to ecological urgencies.

A pertinent curatorial position needs to respond to these developments if it aspires to support contemporary artists in their work and to advance their prospects of contributing to the field of artistic knowledge. Amid these developments, artistic expertise is defined not merely by material prowess, conceptual wit, and critical disposition, but also by its ability to reach out to, communicate with, and incorporate other disciplines. To grasp the compound interrelations between fields and how they co-affect one another, looking into complex systems has been constructive for me. A subset of systems theory, this field of study focuses on the collective behaviors of interacting, emergent entities, and their relationships with their environments. When developing the concept for the Athens Biennale, it was clear from the beginning that the fields of politics, culture, technology, etc. needed to be addressed through their complex interconnections. We conceived the exhibition as a machine that comprised the aforementioned artist-created subsystems from everyday life. By putting them into peculiar relationships with one another, the show superimposed apparently disconnected parts, thereby allowing new constellations and understandings of mutual influences to emerge.

II

Systems theory developed from the branches of biology, sociology, and technology studies evolving around cybernetics, which mathematician and philosopher Norbert Wiener in 1948 defined as "the field of control and communication theory, whether in the machine or in the animal."[1] Since its inception, cybernetics has expanded from focusing on the observation of objects to including more complex meta-levels of observation in self-reflexive systems, as shown by the literary critic N. Katherine Hayles.[2] In artistic and curatorial practices, concepts derived from systems theory, such as second- or third-order observation, can productively correspond to tangled issues requiring a multifaceted, adaptive, and self-critical perspective. In Athens, for instance, a public argument on Twitter between two artists invited to participate in the Biennale made us reflect on how the exhibition might have been misunderstood in advance of opening its doors to the public. It led us to address the topic of contention—of the role of art in a regressive political sphere—in the extensive catalog, in a panel discussion during the opening, and through online interactions with our peers in exactly the collateral algorithmic sphere that produces, disseminates, and withholds information today.

Systems thinking in art has a long history. Influenced by systems theory, in 1968, the art historian Jack Burnham articulated a critical proposition to grapple with emerging post-formalist artistic practices moving beyond "autonomous" art objects, and works engaging more than the art field exclusively.[3] Burnham developed his *Systems Esthetics* concurrent to the biologist Ludwig von Bertalanffy's *General System Theory* (1968), asserting that the open-ended and multifaceted relationships between objects, not only the artworks themselves, require study.[4] Artists such as Hans Haacke, Burnham's friend and occasional collaborator, regularly tapped into these theories. For instance, Haacke's *Rhine Water Purification Plant* (1972) pumped and filtered water from the polluted river into a basin in the Museum Haus Lange in Krefeld, Germany, pointing to ecological systems and the sphere between art and activism as well as proving to the skeptical municipality that the poor water quality of the Rhine could be improved with relatively simple measures. Systems thinking also begot some of Juan Downey's work, which has inspired my curatorial practice for many years—in particular, his concept of "invisible architecture" based on electromagnetic waves, radio frequencies, and conceiving of the city, society, and individual bodies as connected by a web transcending material boundaries. Among his sketches for cybernetic sculptural machines is *With Energy Beyond These Walls: A System of Two Sculptures* (1971), a drawing for a future object involving multiple feedback loops that imagines the conversion and amplification of energies into acoustic manifestations, allowing them to be perceived by the human sensorium.[5] Burnham and others came to repudiate systems thinking as too positivistic and scientistic and condemned its entanglement with the military-industrial apparatus—much like Wiener's eventual renouncement of cybernetics. Nonetheless, attention to underlying patterns and distinct yet confluent systems lingers on in contemporary art, for instance, in Ian Cheng's self-evolving adaptive animations, titled *Emissaries* (2015–2017).[6] Cogently, the art historian Caroline A. Jones has referred to Burnham's systems thinking as "our cultural genome."[7]

Systems thinking embraces differences and can thus be instrumental to productively integrating diverse disciplines. The uncoupling of operation and observation, the epistemological shift from individuals and their psychology to context and society, and the methodological differentiation (even though they are intimately connected) between a system and its environment are crucial for such an approach. While a system applies simplifying strategies to reduce the complexity of its environment, the environment remains ever more intricate. At once a unity and a web of other system–environment relationships, the environment is defined by unlimited horizons. For the arts, then, these spaces outside of art and in-between different disciplines can become productive lacunae, fostering complexity rather than linear progress, essentialism, and causality. Instead, they open up unbounded realms to explore and develop.

III

In line with working through complex systems, the term and field of *ecology* have become increasingly important to me. Ecology relates closely to systems, in particular to the anthropologist Gregory Bateson's understanding of cybernetics as an interconnected world. Bateson addressed the ecological crisis as early as 1970 before a committee of the State Senate of Hawaii. Two decades later, in *The Three Ecologies* (1989), philosopher and activist Félix Guattari elaborately traced the interrelations between human subjectivity, social relations, and, importantly, the environment. The emerging realm of general ecology, developing from cybernetics and systems theory, encompassed ecology of mind, information, technology, perception, power, etc. As such, it allows us to think through the intertwinement of social, natural, and technological worlds, specifically with regard to environmental crises such as climate change.

In this context, I introduce the two-year research project *Tidalectics* that I curated between 2016 and 2017. I first came across the poet and historian Kamau Brathwaite's neologism *tidalectics*, lending the project its title, while traveling aboard the *Dardanella* research vessel with the art foundation Thyssen-Bornemisza Art Contemporary (TBA21)–Academy. A play on the dialectics that are said to define Western thinking, *tidalectics* is decidedly ambiguous, fluid, and continuously in flux, resonating with the oceans and the constant movement of the tides as they wash onto the shores. Brathwaite's poetry evokes centuries of migration in the Caribbean diaspora, hurricanes and other weather phenomena that affect life on the islands, the pain of slavery, as well as a deep-rooted sense of hope. Tidalectics became a key concept for thinking about general ecology in my interdisciplinary curatorial work on the oceans. It has allowed me to work through the flustering of modernist divisions and ostensible certainties caused by climate change, unmooring Western epistemologies. This research has resulted in two major projects: a traveling group exhibition consisting mostly of newly commissioned works by artists such as Em'kal Eyongakpa, Tue Greenfort, Eduardo Navarro, Sissel Tolaas, Jana Winderen, and Susanne M. Winterling, and *Tidalectics: Imagining an Oceanic Worldview through Art and Science* (MIT Press, 2018) an edited volume that includes texts by writers such as the anthropologists Tamatoa Bambridge and Stefan Helmreich, legal expert Davor Vidas, educator Cresantia Frances Koya Vaka'uta, political geographer Philip E. Steinberg, and architect Keller Easterling, among others (Figures 33.1-33.3).

The experience of the *Tidalectics* exhibition was distinctly sensorial. Much as water defies containment and oozes through borders and boundaries, the sound of several video installations subtly converged throughout the exhibition space, first at TBA21–Augarten in Vienna (2017), then at Le Fresnoy in Tourcoing (2018), and in a third iteration spanning two locations, the Museum of Modern Art in Dubrovnik and the 1483 monastery in Lopud (2018). Jana Winderen's sound work *bára* (2017), which is composed of hydrophone recordings collected near the North Pole, in the Caribbean Sea, and in the Pacific Ocean, played only at certain times, which changed every day, corresponding to when the tide at the closest coast to the exhibition venue was at its highest and lowest point, respectively. This adaptive timing of the sound work was key to my curatorial endeavor, which intended to question the idea of land-based fixity, causality,

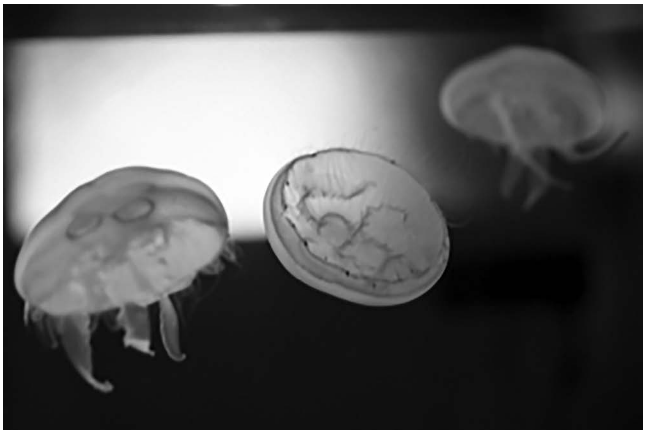


Figure 33.1 Tue Greenfort, *Tamoya Ohboya*, 2017. Stainless steel table, *Aurelia aurita*, aquarium with technique, single-channel video projection of *Chironex*, glass panel. Table: 85 × 260 × 100 cm; tank: 80 × 80 × 80 cm; video: 5 min 14 sec Commissioned by TBA21–Academy. Photography by Jorit Aust. Courtesy, the artist

Figure 33.2 Eduardo Navarro, *Hydrohexagrams (For Tahuata)*, 2017. Bronze coins, drawings (pastel on paper), single-channel video projection. Coins: ø 65 cm x 0,3 cm; drawings: dimensions variable; video: 20 min. Commissioned by TBA21–Academy. Thyssen-Bornemisza Art Contemporary Collection, Vienna. Photography by Jorit Aust. Installation view 1.

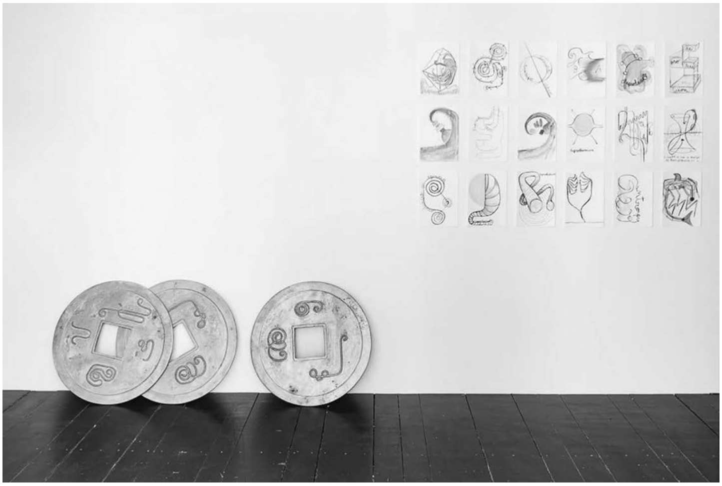


Figure 33.3 Eduardo Navarro, *Hydrohexagrams (For Tahuata)*, 2017. Bronze coins, drawings (pastel on paper), single-channel video projection. Coins: ø 65 cm x 0,3 cm; drawings: dimensions variable; video: 20 min. Commissioned by TBA21–Academy. Thyssen-Bornemisza Art Contemporary Collection, Vienna. Photography by Jorit Aust. Installation view 2.

and temporal linearity. In a similar manner, Sissel Tolaas's work *Ocean SmellScapes* (2017), which consists of smell molecules collected at the Caribbean and Pacific coasts of Costa Rica, one of the most speciose places in the world, is both an archaeological record of a specific composition of molecules found in the air at a certain moment in time and an olfactory invitation to broaden the visitors' perception of the exhibition beyond the visual and auditory dimensions.

IV

In addition to connecting different themes and disciplines through systems thinking and general ecology, addressing both cognitive and the sensorial dimensions has been key to my curatorial work. By offering different entry points, an exhibition can acknowledge and foster multiple approaches that go beyond the primary regime of the visual. In doing so, curating can challenge European Enlightenment and patriarchal tropes of reason and rationality, while acknowledging myriad ways of being, including embodied ones, in an intersectional feminist sense.

Curatorial strategies in the realm of interdisciplinary practices need to not only translate but also, more aptly, to generate thoughts and feelings and channel them from one field into others. In doing so, curating can contribute to dissolving the essentialism of disciplinary belonging just as it can reflect other limiting and damaging categorizations, for instance in terms of gender. The field within which we operate is no longer limited to just one system or to always being the same: neither is the role and position of the curator. More specifically, in the sociologist Niklas Luhmann's elaboration of systems theory, individuals always finds themselves in a different system depending on whether they are a pupil, a voter, a patient, or a litigant—much like a curator working between disciplines.[8] If in premodern society, the individual and their qualities were assumed to be both known and fundamentally connected, a systems approach acknowledges that, in modernity, the individual has become unfamiliar and unpredictable, while differentiation no longer concerns individuals or groups of people but types of communication. The more complex a system becomes, the more improbable the forms of communication. Knowledge, then, is no longer defined by accumulation, but as an effort to transform environmental restrictions into preconditions for an increase of internal complexity, which equals information. In Luhmann's thinking, in order not to stagnate in thermodynamic immobility or social entropy, systems need disturbances. The aim of curatorial work must thus be to make the conditions of the system, its structures, and its environments such that communication can unfold, while fostering prerequisites that allow for increasing complexity, or information, to evolve.

Returning to the lacunae in-between, applying systems—or ecological—thinking in curatorial work places emphasis on nonlinear feedback, emergence, and self-reflexivity in a field of contiguous possibility. In a reversal of the Kantian transcendental constitution, the point of reference of knowledge, here, is relocated from the subject into "reality" until self-reflexive phenomena make their appearance. "Reality" includes the spaces in-between as things in and of themselves. Emergence occurs here, where three, four, or infinite ecologies rub together. Moreover, theoretical and artistic work undergoes self-observation. As such, the recurring feedback loops in systems theory can become a tool for the observation of observation, for critical self-reflexivity, and for never arriving at stasis but fostering instead increasing complexity. As the literary scholar Dietrich Schwanitz wrote in response to Luhmann, "[i]nstead of waving the magic wand of rationality … we should allow ourselves to be epistemologically inspired by the self-referential worlds of irony, mathematics, schizophrenia, imagination, and literature."[9] Beyond epistemological inspiration, I suggest applying systems approaches to art.

Notes

1 N. Wiener, *Cybernetics: Or Control and Communication in the Animal and the Machine*. Cambridge, MA: The MIT Press, 1948/1961.
2 N. K. Hayles, *How We Became Posthuman: Virtual Bodies in Cybernetics, Literature, and Informatics*. Chicago, IL and London: The University of Chicago Press, 1999.
3 J. Burnham, "Systems Esthetics". *Artforum*, 7, no. 1 (1968): 29–35.
4 L. von Bertalanffy, *General System Theory: Foundations, Development, Applications*. New York: George Braziller, 1968/2003.
5 Other contemporaneous examples include Robert Smithson's writings on entropy, fluidity, and ruins in reverse.
6 J. Burnham, "Art and Technology: The Panacea that Failed". In Woodward, K. (ed.), *The Myths of Information: Technology and Postindustrial Culture*. Madison, WI: Coda Press, 1980, unpaginated.
7 C. A. Jones, "System Symptoms". *Artforum*, 51, no. 1 (2012): 113–116.
8 N. Luhmann, *Social Systems*. Stanford, CA: Stanford University Press, 1984/1995.
9 D. Schwanitz, "Systems Theory According to Niklas Luhmann: Its Environment and Conceptual Strategies". *Cultural Critique*, 30, no. 1 (1995): 142.

34

The future now

Three tales of ocean plastic

Heather Davis

By now, it is a platitude to say that the ocean is saturated with plastic. For years, we have been bombarded by media stories about the 'plastic vortex' or 'plastic garbage patch'; headlines proclaim that there will be more plastic in the ocean than fish by 2050.[1] Despite the fact that only 1% of plastic ends up in the oceans, the ocean has become the concentrated site of anxiety in relation to plastic pollution. There are very good reasons for this as plastic has significantly added to the environmental stress of the oceans and the beings that reside there. Plastic is found throughout the water column, becoming more insidious and problematic the smaller it becomes. It is also found throughout the food chain as bacteria, fish, turtles, and whales, amongst numerous other creatures, either mistakenly take it for their normal food source or are not able to filter it out. The collision of these two worlds also highlights the hydrophobia of plastic—the ways in which oil and water are anathema to each other yet, under the conditions of petrocapitalism, are forced into this relation, in which fossil fuels return to the oceans from whence they came.

In 2018, the exhibition *Plastic Entanglements: Ecology, Aesthetics, Materials* opened at the Palmer Museum at The Pennsylvania State University before travelling to the University of Oregon, Smith College and the University of Wisconsin–Madison. The exhibition was curated by Joyce Robinson, Jennifer Wagner-Lawlor and myself. The exhibition was a way to think through, materially and aesthetically, how plastic has shifted our sense of bodily being in the world through its pervasiveness as well as highlight the critical and complicated engagement of artists with plastic. It brought together thirty contemporary artists from across the globe to reflect on the ways in which plastic has become so central to current ways of life. Three of the artists in the show dealt directly with questions of plastic in the ocean, how plastic is transforming the organisms and geology of marine life and shores. While they are all certainly critical of the ways that plastic production has exponentially increased, they respond by asking audiences to think more deeply about how nature and culture have been separated through what Bruno Latour called purification (1993); how we come to understand pollution; and what ethical responses might be afforded in these times of living on a damaged planet. The works ask us to reconsider landscape art, extinction and futurity. They show how future imaginaries of climate change and distributed pollution are here, now.

DOI: 10.4324/9780429437069-43

Rocks which are not rocks

In 2013, at the suggestion of oceanographer Charles Moore, geologist Patricia Corcoran and artist Kelly Jazvac travelled to Kamilo Beach in Hawai'i. They went in search of a new kind of rock, a rock that they would name the 'plastiglomerate.' The plastiglomerate refers to a hybrid rock composed, or conglomerated, of plastic, wood, sand, and other beach debris. This particular beach is a good breeding ground for these new rocks because the currents of the ocean deposit many of the things that are adrift in the Pacific there. And these days, what is adrift in the oceans is a lot of plastic. As art historian Kirsty Robertson writes:

> So much garbage collects on Kamilo Beach that it is listed in *Atlas Obscura*'s compendium of bizarre and obscure places to visit, where it is described as 'constantly covered in trash like some sort of tropical New York City gutter.'
>
> *(2016)*

The sand has very little mineral material in it; rather, it is now the evidence and archives of the experiments in chemical engineering that we have been conducting for a little over a century, "when the laboratory has been turned inside out…so that the world has become the experiment" (Gabrys 2014, 54). So, when people go down to the water's edge to have a campfire, instead of merely enjoying the primordial glow, singing songs, roasting marshmallows and spending time with friends, they are inadvertently participating in the creation of these new hybrid rocks as the plastic on the beach melts and conglomerates with other beach debris, including rocks and wood. Plastiglomerate can be found as distinct rocks as well as moulded into the crevices of the existing landscape. It is a marker of the Anthropocene, a new epoch that describes how petrochemical companies have literally written themselves into the geologic layers of the earth. It speaks to the fact that plastic is everywhere, in our bodies, the bodies of the other beings with whom we share the world, and can be found everywhere on earth from the arctic to the Mariana Trench.

The plastiglomerate condenses anxieties and disrupts practices of purification that seek to divide nature from culture (Latour 1993). It indicates the ways in which it is literally impossible, at this moment in time, to disentangle or separate chemical engineering from the rocks that have emerged over thousands of years on this planet. As Robertson beautifully writes, "From the primordial muck, to the ocean, to the beach, and back to land, plastiglomerate is an uncanny material marker. It shows the ontological inseparability of all matter, from the micro to the macro" (2016). We can no longer pretend that there is a fundamental difference between nature and culture or the synthetic and the natural. This does not mean that the effects of widespread plastic pollution are benign–they are certainly not–but that the violence that is done through plastic, the suffocation, adsorption and dispersion of carcinogenic chemicals, is differentially felt and cannot be attributed to its 'synthetic' status alone.

The plastiglomerate also represents a new kind of landscape art, where instead of depicting the landscape through various forms of representation, the art *is the landscape*; landscape as readymade. Jazvac has shown plastiglomerate in art exhibitions as sculptural readymades to demonstrate human impact on nature.[2] The works have been collected or displayed at the Yale Peabody Museum, the Het Nieuwe Institute (Rotterdam) and the Natura Artis Magistra (Amsterdam) as specimens that captured changing natural history. What does it mean to say that this marker of the obdurate legacies of extraction that is the plastiglomerate has now become a readymade artwork? Situating these objects within the artworld asks of us to look again at them, to think about the consequences of petrocapitalism and its legacies long beyond our own lifetimes. In the most generous reading, plastiglomerate as readymade serves to draw attention to the ubiquity of plastic and its unintentional consequences and as a call to action. The plastiglomerate is part of a larger art and science movement that, as Taney Roniger wrote in a special edition on art and science for the *Brooklyn Rail*, "After decades of self-imposed hermeticism underwritten and perpetuated by an impenetrable language, art longs once again *to matter in the world*" (2018). Art can help to visualize things that are very hard to visualize, especially when it comes to something as all-encompassing and overwhelming as plastic pollution and its miasmic pervasiveness throughout ecosystems and oceans. Plastiglomerate becomes the crystallization of the chemical legacies of the twentieth and twenty-first centuries.

I also want to consider the plastiglomerate in the lineage of feminist ecological art, more specifically in relation to Mierle Laderman Ukeles' prolonged engagement with landfills. As Patricia C. Phillips writes:

> Ukeles thinks of [landfills'] artificial, often ungainly topography as variously created 'public landscapes' or 'social sculptures,' referring to the work of Joseph Beuys, who aggressively opened art as an inclusive social process. She sees [landfills] as active, accessible alternatives to the late twentieth-century earthworks that were developed in remotes sites on private land.
>
> *(2016, 170)*

The plastiglomerate can be understood, under these terms, as a social sculpture, one that we are all contributing to and that will outlive us as an archive of our culture. They are the democratic version of earthworks.

However, the plastiglomerate has also been taken up by other artists, not as a readymade, but as an invitation to create their own geology. Fabricated plastiglomerate speaks differently to our collective lineages and reads less as a critical appraisal of contemporary culture than as a fascination with our own violence. In this regard, fabricated plastiglomerate can be read within the frame of the anaesthetic, as theorized by visual culture critic Nicholas Mirzoeff, that is as an aesthetic that serves to anaesthetize the viewer into accepting social or environmental violence (2014). For the critical commentary of the plastiglomerate lies in its appearing as a found object, or readymade, as it shows the scale of transformation of the earth itself under the conditions of colonial petrocapitalism.[3]

To touch without touching

The Institute for Figuring (IFF) began as a project of twin sisters Margaret and Christine Wertheim in Los Angeles in 2003. Conceived as an organization "dedicated to the poetic and aesthetic dimensions of science, mathematics and engineering," one of their central projects has become the *Crochet Coral Reef*. The Reef began when the sisters decided to crochet various hyperbolic shapes, illustrated by mathematician Daina Taimina. Taimina showed the ways in which hyperbolic shapes, otherwise difficult to illustrate or create models of, could easily be constructed by crocheting. The sisters were interested in representing these various forms and set about making all the classic hyperbolic designs. At a certain point, Christine got bored with perfectly recreating the ever-expanding surfaces of hyperbolic geometry and decided to deviate. When she did, the results looked very much like corals, something that the Wertheims were intimately familiar with as they grew up in Australia. They darkly joked that, given the state of the oceans, they should perhaps create their own reef, and so the idea began to become a reality. But they quickly realized that if they were going to make a reef, they would need to recruit others. It is impossible to create a reef with only two people. Through workshops at the IFF and other cultural institutions including the Los Angeles County Museum of Art, they began to create the *Crochet Coral Reef*. Since then, they have received contributions from over 20,000 people, making the project perhaps the largest collaborative artwork in the world.

Since its inception, the *Crochet Coral Reef* has been shown at the Venice Beinnale, the Museum of Arts and Design, The Hayward, and The Andy Warhol Museum, amongst others. Part of its success as an artwork is in its extraordinary ability to cross disciplines, borders, and barriers in sophisticated and productive ways. It speaks to scientists, designers, educators, and to the traditions of craft and community-based art. The work is also, importantly, an intervention into understandings of artistic authority, as there are over 20,000 'authors' of the piece, drawing from outsider and community-based art models. As Margaret Wertheim has said of the project:

> In the Crochet Reef project, we too seek affiliations with a variety of life forms—scientists, artists, mathematicians, skilled crafters and 'ordinary' people who are neither at the center of art or science worlds, people whose powers of creation, like those of coral polyps, are often overlooked by official organs of artistic and scientific discourse.
>
> *(2014, 72)*

In bridging the worlds of science, mathematics and artistic practice, the project disrupts the norms of who gets to be included in cultural institutions.

Responding to the dire state of the oceans, the *Crochet Coral Reef* attunes the viewer to the massive coral deaths that we are currently witnessing,[4] creating an affective resonance of care across distances. Each of these new corals is like a love letter to the existing reef and a reminder of the incredible beauty of natural forms. They offer a tangible, repetitive means to begin to attune ourselves to the realities of corals and to begin to mimic their forms and presence. As historian of science Sophia Roosth writes, "repetitive gestures recapitulate the protracted piecemeal depositions of polyps, and improvisation offers a tangible understanding of morphogenesis as craftwork" (2012, 30). In other words, the hands learn the ways in which the corals grow themselves, using feminine craftwork to mimic the expansion of the reef, while also viscerally coming to know hyperbolic geometry. Each person becomes, in a small sense, part of the reef, engaging with the slow process of building a form.

The beauty of the work is that it mimics the actions of the reefs themselves, with each of the over 20,000 contributors to the artificial reefs in an analogical relation to the polyps of actual reefs; each of their small gestures contributing to immense installations. There is a similar productive confusion about whether to see the whole as one organism or as a collective. The "reefers," as they call themselves, reach across the distances between each other and between themselves and the reefs, with what Eva Hayward calls "fingeryeyes": "I use fingeryeyes to explain the tentacular visuality of cross-species encounters and to name the synaesthetic quality of materialized sensation" (2010, 580). The fingeryeyes of the crochet artists reach across the distances between themselves to form this collective sculpture, while also reaching across the distance between themselves and the reef, embodying the materialized sensation of reef-making.

In 2007, the Wertheims began to crochet with what they call "plarn," or yarn that they made from cut-up plastic bags. An early work by Margaret called *A Week's Shopping* was precisely that: the bags collected on a week's worth of grocery trips. Soon, cutlery, cups, Vitamin C sachets and other nonyarnish trash were incorporated and used for making decorative edgings (Wertheim 2015, 117). The works were called the Toxic Reef, and they commented, again in a visceral way, on how plastics are affecting corals. The plastic itself was difficult to work with because of its recalcitrance as a material, the difficulty of shaping it into reefs. This again seems to trace what Donna Haraway has called an "intimacy without proximity" (2016, 53) as it puts the crafter in the place of the corals, grappling with this ubiquitous material, miming the expressions and contortions of the body's relationship to plastic.

The project is a means to affectively attune ourselves to the dire realities of coral death while refusing to give in to despair. In this sense, the project can be situated within the larger trajectories of activist and political art. The Wertheims write of the project:

> This is not a project of mourning and loss, but rather, in the face of the terrifying potential for loss, a small figure of hope. We Crochet Reefers ourselves are polyps. Our efforts alone can't 'save' coral reefs, but perhaps our installations may encourage viewers to stop for a moment and think about the power of little things.
>
> *(2015, 72)*

These are literal figures of the relations between humans and corals; of amazement at the beauty of the world; and an instantiation of collective action. It is a gesture that, despite the great odds, creates resonances across distances that, in themselves, create more valuable worlds.

Speculative organisms/the earth will not die

Pinar Yoldas is a Turkish artist, based in San Diego, whose work engages with installation, sculpture, and bioart.[5] In her 2014 work *Ecosystem of Excess*, Yoldas introduces pelagic insects, marine reptiles, fish, and birds endowed with organs to sense and metabolize plastics as a new Linnean order of post-human life forms. The project began from the question: what kinds of creatures will evolve out of the oceans, where there are now, in some parts, six times more plastic than plankton? Drawing upon our current knowledge of biological systems and the kinds of chemicals and toxins found in plastic, Yoldas asks the viewer not simply to despair at our current state but to imagine wild and prolific future creatures uniquely adapted to these petrochemical environments. She meticulously researched various existing organs from a wide range of organisms to create exaggerated, speculative forms of evolutionary adaptation to our plastic-filled oceans. Presented in the manner of organs and organisms at a natural history museum or scientific laboratory, these organisms present a useful and provocative slippage between reality and fiction. Like speculative fiction, these speculative organisms create moments of misrecognition, appearing startlingly plausible, as the organs sit within vats of what appears to be embalming fluid.

The organs consist of Stomaximus, a plastivore digestive organ; P- and E-Plasticeptor, sensory organs; and Petronephros, a new kind of kidney. These organs allow a future organism to take advantage of the incredible stores of energy that are contained within plastic by way of fossil fuels. They allow organisms to digest, filter, and sense the plastics in the environment. The series also includes Annelida incertae sedis, PV Sea Worm and Sea Snake Symbiosis, plastic insects, and a set of feathers that through the dietary habits of particular types of birds have taken on Pantone dyes. The feathers represent the ways in which birds eat plastics and, through evolutionary time, have absorbed the Pantone proprietary colour scheme of shades such as Dasani blue and Coca-cola red.

Just as Yoldas' work confronts the grim realities of plastic and the deaths of sea creatures through consumption and entanglement, she also pushes her audience to engage with future orientations. What other life forms might be inadvertently birthed from the mass accumulation of a resource with a huge amount of energy stored in it? As Yoldas' speculative creatures indicate, even plastic can become the home for other species, and plastic is also pushing evolution. Part of the slippage of the project arises from the fact that her speculative organisms are not far off from current evolutionary realities. For example, microplastics—plastics that are less than five millimeters—are becoming rafts of biodiverse ecologies for bacteria and viruses, producing what scientists have called the 'plastisphere' (Zettler, Mincer, and Amaral-Zettler 2013). And new types of bacteria and fungi have evolved to eat various forms of plastic (Harshvardhan and Jha 2013; Yang et al. 2014; Yoshida et al. 2016; Austin et al. 2018). As Jennifer Gabrys notes:

> What these bacteria ultimately direct us toward is the speculative aspects of organisms—in other words, their capacity to not just eke out a living, but to transform environments and to become different organisms in the process, while also articulating new relationships to changing materials and building up shifting ecologies through these metabolizing, processual encounters.
>
> *(2014, 57)*

In drawing our attention to the ways in which organisms adapt in these metabolizing, processual encounters, Yoldas refuses the narratives that centre the human as the marker of continuation of all life on earth. Without naively asserting a utopian future, she nonetheless insists, with these creatures, on the creative and generative aspects of life itself.

Yoldas' work presents a vision of a possible futurity, a future that is in many ways already here. That is, in the speculative creatures that she has created, a future is also birthed. This is not an act of clairvoyance but rather one of creation, one where the imagination leaps into the future in order to create more space for a future in the present, in the sense of the recursive formula of feminist historiography.[6] This is done not simply through the kinds of practical and scientifically accurate considerations that she makes of her creatures, how a creature might be able to use the resources of oil through plastic, for example, but as a proposition to enable plastic to exist differently. I mean proposition here as the type of proposal that philosopher Isabelle Stengers refers to in her "Cosmopolitical Proposal." She says:

> How can we present a proposal intended not to say what is, or what ought to be, but to provoke thought, a proposal that requires no other verification than the way in which it is able to 'slow down' reasoning and create an opportunity to arouse a slightly different awareness of the problems and situations mobilizing us?
>
> *(2005, 994)*

Yoldas' work can be understood as this kind of a proposal, asking us to slow down and to rethink both the material of plastic itself, with which her work is especially concerned, and the idea of futurity. As Yoldas herself says of the project, "An Ecosystem of Excess envisions life forms of greater complexity, life forms that can thrive in extreme, man-made environments, life forms that can turn the toxic surplus of our capitalistic desire into eggs, vibrations, and joy." Processes of visualization and imagination can go a long way to help us reorient our attitudes and behaviours in light of current overwhelming conditions. In particular, to imagine a future radically different from the present will help us to navigate what is coming with more grace, and this is what *Ecosystem of Excess*, I think, primarily offers.

Conclusion

Although we do not have the choice about whether or not we would like to live in a world with plastic, we do have some choice about our relationship to it, about our ethical obligations. Contemporary visual art practices are a vital forum for engaging with the speculative, propositional, and present collective actions of ecocide. Amitav Ghosh has written about what he understands as the challenges of writing novels about climate change. He argues that "What we need … is to find a way out of the individualizing imaginary in which we are trapped" (2016, 135). Visual arts provide a forum for just that, especially those that stem from feminist, ecological, and art and science practitioners such as those that I have presented here. For each of these artists is engaged with a broader community that both references and works within the history of visual art while also drawing from and in dialogue with scientists and activists to articulate an ethics of plastic that productively and critically engages with this material.

Art is a polyarchic site of experimentation for living in a damaged world, offering a range of discursive, visual, and sensual strategies that are not confined by the regimes of scientific objectivity, political moralism, or psychological depression. Art can provide a space for dealing with the affective and emotional trauma of the ecocidal present. We need modes of expression for the collective loss we are suffering through and venues to express the emotional toll of living in a diminished world. We also need modes of visual critique, ones that can and do speak to wide audiences. This sense of multiplicity that is contained within art provides a way to sift through the numerous contradictions of our everyday lives to deal with divergent and discontinuous scales of time, place, and action. Art practice can also provide a space of propositions and future imaginaries. As David Garneau says, "What art does do—and what is difficult to measure—is that it changes our individual and collective imaginaries by particles, and these new pictures of the world can influence our behavior" (quoted in Hill and McCall 2015, ix). The arts are part of the emergence of narratives about the ways in which we live in the world, narratives that can be damaging or visionary, which can connect or dislocate us from the earth. Part of what is so important then is to seriously think through questions of futurity because it is too easy and too deadly to give in to nihilistic or apocalyptic fantasies. We need to think through our actions now through a lens of the future, not one foreclosed by annihilation but one rigorously engaged with the politics of life and death.

Notes

1 However, this figure is widely disputed. For a more accurate reading and understanding of the relationship of fish and plastic in the ocean, see https://skeptoid.com/episodes/4665.

2 The work sits comfortably within the broader trajectory of Jazvac's practice as a sculptor who is concerned with the permanence of the disposable. Her previous work used adhesive vinyl often used in advertising banners to interrogate privileged symbols and pop materials, such as a Pontiac Sunfire made up to look like a Porsche 911.

3 For more on the relationship of the plastiglomerate to questions of colonial petrocaptalism, see Heather Davis, "Synthetic Universality," in *Plastic Matter* (2022).

4 As one researcher explains, these animals "live in the future." If atmospheric levels of CO_2 go above 700 parts per million, oceans will become so acidic, corals may not be able to build structures at all. The latest reading of the Scripps Institution of Oceanography (January 22, 2018) reports that we currently stand at 408.96 ppm, a level not seen on Earth for 800,000 years and perhaps as much as 20 million years. Add to this the fact that the world's coral reefs are still reeling from the worst-recorded global coral bleaching event, in 2016 and 2017, where half the Great Barrier reef's coral is thought to have been killed.

5 The phrase "BioArt" was coined by Eduardo Kac in 1997 in relation to his artwork *Time Capsule*, where the artist inserted a microchip to include himself in an online database and usually refer to work that uses biological material as the basis of artwork. It includes artists such as Stelarc, Oron Catts, Kathy High and Heather Dewey-Hagborg. Although Yoldas does not use biological material in her practice, her sculptures mimetically capture the biological to comment on present and speculative organisms.

6 Joan Scott and Drucilla Cornell argue that feminist history takes place in the future anterior that is not to account for *what was*, but what *will be seen to have been*.

Works cited

Austin, Harry P., et al. "Characterization and Engineering of a Plastic-Degrading Aromatic Polyesterase". *Proceedings of the National Academy of Sciences of the United States of America* (May 8, 2018), https://doi.org/10.1073/pnas.1718804115

Davis, Heather. *Plastic Matter*. Durham: Duke University Press, 2022, forthcoming.

Gabrys, Jennifer. "Speculating with Organisms in the Plastisphere", in *Pinar Yoldas: An Ecosystem of Excess*, edited by Heike Catherina Mertens, 51–62. Berlin: Argobooks, 2014.

Ghosh, Amitav. *The Great Derangement: Climate Change and the Unthinkable*. Chicago: University of Chicago Press, 2016.

Haraway, Donna. *Staying with the Trouble: Making Kin in the Chthulucene*. Durham: Duke University Press, 2016.

Harshvardhan, Kumar and Bhavanath Jha. "Biodegradation of Low-Density Polyethylene by Marine Bacteria from Pelagic Waters, Arabian Sea, India". *Marine Pollution Bulletin* 77, no. 1–2 (November 2013): 100–106.

Hayward, Eva. "Fingeryeyes: Impressions of Cup Corals". *Cultural Anthropology* 25, no. 4 (2010): 578–599.

Hill, Gabrielle and Sophie McCall. "Introduction", in *The Land We Are*, edited by Gabrielle Hille and Sophie McCall, 1–12. Winnipeg: ARP Books, 2015.

Latour, Bruno. *We Have Never Been Modern*. Cambridge: Harvard University Press, 1993.

Mirzoeff, Nicholas. "Visualizing the Anthropocene". *Public Culture* 26, no. 2 (2014): 213–232.

Phillips, Patricia C. *Mierle Laderman Ukeles: Maintenance Art*. Queens Museum: Prestel, 2016.

Robertson, Kirsty. "Plastiglomerate". *e-flux* 78 (December 2016), https://www.e-flux.com/journal/78/82878/plastiglomerate/

Roniger, Taney. "Art, Science, and the Question of Convergence". *The Brooklyn Rail* (December 2017–January 2018), https://brooklynrail.org/2017/12/editorsmessage/Art-Science-and-the-Question-of-Convergence

Roosth, Sophia. "Evolutionary Yarns in Seahorse Valley: Living Tissues, Wooly Textiles, Theoretical Biologies". *Differences: A Journal of Feminist Cultural Studies* 23, no. 3 (2012): 9–41.

Stengers, Isabelle. "The Cosmopolitical Proposal", in *Making Things Public: Atmospheres of Democracy*, edited by Bruno Latour and Peter Weibel, 994–1003. Cambridge, MA: MIT Press, 2005.

Wertheim, Margaret and Christine Wertheim. *Crochet Coral Reef*. Los Angeles: Institute for Figuring Press, 2014.

Yang, Jun, Yu Yang, Wei-Min Wu, et. al. "Evidence of Polyethylene Biodegradation by Bacterial Strains from the Guts of Plastic-Eating Waxworms". *Environmental Science and Technology* 48, no. 23 (2014): 13776–13784.

Yoshida S., et al. "A Bacterium That Degrades and Assimilates Poly(ethylene terephthalate)". *Science* 351 (2016): 1196–1199.

Zettler, Erik, Tracy Mincer and Linda Amaral-Zettler. "Life in the 'Plastisphere': Microbial Communities on Plastic Marine Debris". *Environmental Science and Technology* 47 (2013): 7137–7146.

35

Becoming disaster literate

Reflections on *X AND BEYOND* (2015–2017)

Jacob Lillemose

The beginning

In the summer of 2015 I curated an exhibition on "prepping" with Danish artist Søren-Thilo Funder. The central piece in the exhibition was a video that cast French poet Voltaire and American terrorist Ted Kacynski in a bunker during the 1755 Lisbon earthquake. During the production of the exhibition, we spent many hours discussing disaster preparedness (and appeared together in a number of media contexts). When we closed the exhibition, we decided to extend the collaboration into the summer. I did not want to look after an exhibition during the hot month of July, but X AND BEYOND had a great window front (it was a former grocery store) so we decided to do a show for that "space". Since the show was improvised a month in advance, we did not have money to realize anything big, but the conditions turned out to be a great conceptual inspiration for what became "Survivalist Toolshed". We gave a group of twenty international artists – from Olafur Eliasson and Heath Bunting to Daniel Keller, Jesper Just, Rolf Nowotny, and Klara Hobza – fifteen euros in cash to produce a tool that they felt would be "useful" in the event of a disaster (either real or imagined). Moreover, the definition of what useful meant in this context could be openly interpreted by each individual artist. It could be practical use as well as more poetic use. The only restriction we noted in the invitation was that the artists could not produce weapons—because X AND BEYOND was located in a gang neighbourhood where weapons are part of the daily scene and we did want to add more to that uneasy atmosphere. The tools that the artists sent us varied greatly. Olafur Eliasson sent one of his *Little Sun*s, Daniel Keller contributed a soda streamer, Jesper Just returned the cash and had me go buy a magic wand at a local toy store, and the duo Hesselholdt & Mejlvang painted the classic PH7 lamp designed by Louis Poulsen in mud camouflage colours. All the tools were displayed in a setting that mimicked a toolshed for passers-by to inspect. As an add-on to the show, we decided to auction all the tools away at the end and give the money to Doctors Without Borders, specifically for their work in post-earthquake Nepal. The auction end result went beyond our wildest hopes: 2200 EUR.

Changing disasters

From March 2015 to July 2017, I ran the exhibition space X AND BEYOND in a 100 m^2 former grocery store in the multi-ethnic Nørrebro neighbourhood of Copenhagen. In

DOI: 10.4324/9780429437069-44

the course of that time, I produced over 20 exhibitions and 120 events on a wide variety of disaster-related topics, from asteroid strikes, space colonies, and pandemics to clothing, alarms, survivalism, architecture, and ecology. No discipline owned X AND BEYOND. Contemporary art, of course, played a central role, but I made a continuous effort out to level the hierarchy between the many different actors who I included in the program. Whether it was recognized artists, young biology researchers, B-movies directors, fashion designers, writers, or professors of law or philosophy, I engaged them with the same professional excitement. Not only to make them feel welcome and respected but to emphasize that, given the challenge at hand, contemporary disaster scenarios, we need every discipline on board, and we need all disciplines to be at eye-level with each other.

X AND BEYOND was part of my curatorial postdoc at the transdisciplinary research project Changing Disasters at the University of Copenhagen. Changing Disasters involved researchers from all six faculties at the University of Copenhagen. The project originated at the Copenhagen Centre for Disaster Research (COPE), which offers an MA in Disaster Management with a focus on environmental and health themes. The ambition was to facilitate exchanges between an international group of researchers from different disciplines – law, economy, theology, literature, anthropology, and biology – around a common theme: How disasters change humans and societies and how humans and societies change disasters. The origin of this transdisciplinary endeavour was the recognition that the effects of disasters span multiple fields and that no single discipline owns disaster studies. Only by developing a truly transdisciplinary discourse can disaster studies, therefore, meet the complex challenges of contemporary disasters.

From discussions with my colleagues at Changing Disasters, I quickly realized that my work would not be comparable to any kind of actual disaster management in the field. No exhibition I did was going to save people from infectious diseases due to flooding or win court cases to allow citizens to return to their homes after emergency evacuation. To think that would be naïve and arrogant. Hence, the fundamental question shaping my work at X AND BEYOND became, if art and popular culture cannot save people in the situation of actual disasters, then what do they contribute to our disaster-prone world? And what and how can curating contribute to addressing such problems?

Listen to the sirens

An institutional inspiration for X AND BEYOND was the Copenhagen experimental music venue Mayhem, which, since the early 2010s, had featured an amazing program of international musicians and sound artists. Tobias R. Kirstein and Claus Haxholm, who were associated with Mayhem, approached me with an idea of doing a show about sirens. After some discussion, we came up with a concept: we would invite eight international artists/musicians to produce a disaster alarm, reflecting on the aesthetics and imaginary aspects of disaster sirens. The show was called "These Are Your Horizons", a reference to the fact that a disaster alarm is, in fact, a horizon, albeit an audible one. Claus Haxholm built a loudspeaker for the occasion using a car stereo. For one hour a day, during the entire month of December, people could come in, sit down, and listen to the eight disaster alarms as if it was a record or a map. The contributions were extremely diverse ranging from abstract noise tracks to "breath performances" to theatrical narratives. The contributions, as well as visitors' willingness to listen to them, dramatically exceeded my expectations, expanding my understanding of the disaster alarm and disaster aesthetics.

Anthropogenic disasters

Following the trend in Disaster Studies of the past two decades, Changing Disasters was based on the understanding that there are no longer such a thing as natural disasters; there are only human-made disasters. Disasters are a consequence of civilization, as Paul Virilio argued, when he observed that with the invention of the train came the invention of the train disaster.[1] Even if ostensibly natural phenomena such as hurricanes and tsunamis are part of an event, any disaster that results is the consequence of how humans and societies respond – before, during, and after the event. Such is the condition of the Risk Society described by Ulrik Beck; society can minimize risk but never eliminate it.[2] Thus, the question becomes: how do societies become more resilient?

Disaster Studies is a field that focuses on engaging critically with social and politico-economic structures, technological conditions, and ways of living in environments, all of which contribute to disasters. While practical fieldwork remains at the core of the discipline, understanding and handling of the complexity of hazardous events frequently involve theorists from social studies of science and technology, anthropology, legal studies, economics, and cultural studies. How art, mythologies, and popular culture shape our disaster imaginary has also been recognized as important in the development of the discipline. Within this transdisciplinary academic context, X AND BEYOND was established in spirit of experimental openness and public dialogue, which allowed the program of exhibitions to reflect ongoing discussions within Changing Disasters and respond in a timely matter to broader cultural concerns.

Architecture Z

My entrance ticket to Changing Disasters was an article I had written on the zombie apocalypse as a social scenario. Hence, the second exhibition I did at X AND BEYOND was entitled "Society Z" and took place in the context of the Copenhagen film festival CPH:PIX. The exhibition was not about zombies but rather about what the living dead do to human society. The form of the exhibition was a sort of large-scale mood board. The exhibition featured a vast amount of material related to the theme of a pandemic, in fiction and in real life, placed on seven wooden boards placed against the wall. Throughout the exhibition, I removed and added material to the boards, often during opening hours. In some sense, "Society Z" was less an exhibition than a research lab, conceived primarily as a framework for a series of events on the topic, featuring scholars such as Evan Calder-Williams and Lars Bang Larsen. Inverting the conventional art gallery programming format, the events were the focus and not the add-on to the material on show.

When I closed "Society Z", I felt like I had just scratched the potential of the topic. However, it was not until artist Florian Dombois invited me to speak at Zürcher Hochschule der Künste (Zhdk) in Zürich that I figured out how to develop the research. What I came up with was a performance in which I would be the only performer. From my time in the university, I had grown sour with the conventional academic presentation format and entertained the idea of changing the format with some kind of performativity as a means to engage the audience, play tricks on them, and myself, as a matter of fact. I presented the idea to Florian as a "mockumentary talk" and he agreed. Entitled "Architecture Z. Towards New Paradigm for Human Housing", the talk was an account of a trip I had taken to visit an institute that did research in disaster architecture. Dressed in a suit and a tie, I described the increasingly inhuman tactics that the institute was employing to improve the quality of disaster architecture. I did not criticize their tactics nor did I praise them. I simply explained their rationale. The reaction from the

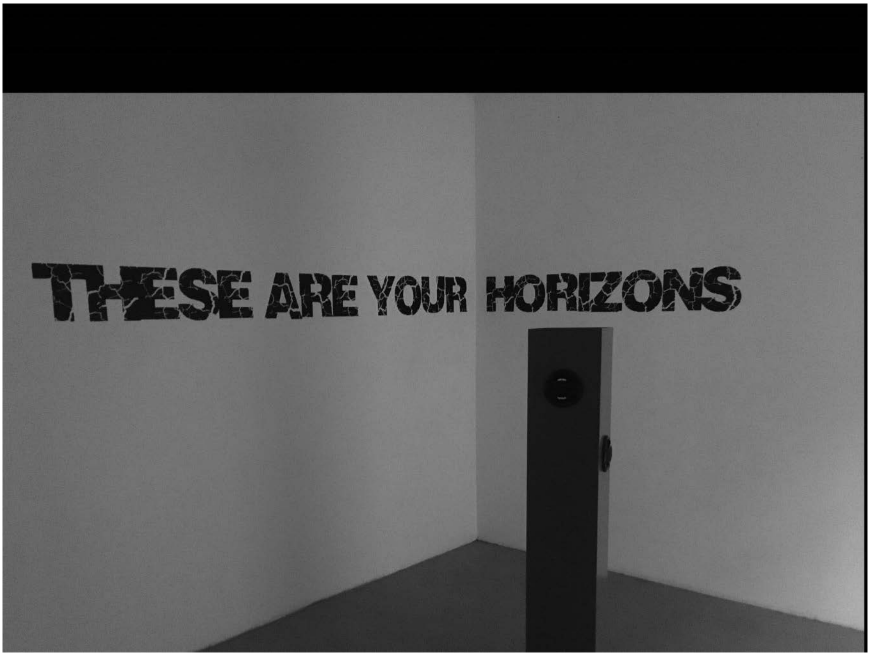


Figure 35.1 Tobias R. Kirstein and Claus Haxholm, *These Are Your Horizons*, Exhibition View, X and Beyond, 2015/16, Photo: Jacob Lillemose

audience was remarkable. Of course, some people figured out that part of the talk was parodic – but not all. One man in particular, a professor from the nearby engineering school ETH, demanded that he got the last word to issue a warning against these architectural tactics, and he would not talk to me until he was let in on the premises during dinner. The talk became the seed of a novelistic account of X AND BEYOND, titled *Architecture Zero*, a hybrid of academic research, movie analyses, auto fiction, and science fiction (Figure 35.1)[3].

A source of experience and knowledge

Art is a rich source of human experience and knowledge about disasters. While many of us lack personal experience of a major incident, we have witnessed disasters through art. This makes understanding the significance of art in relation to disaster studies important. People have been using art, in one form or another, to reflect on the existential and social conditions that disasters create for thousands and thousands of years, whether the disasters they refer to are actual or imagined. From the first cave painting of volcanic eruptions to the Great Flood of the Bible, to films like *The Day after Tomorrow* and many more, works of art tell us something very real about what it means to be human in a world on the edge of catastrophe. As such, they constitute a unique and detailed vocabulary for addressing disasters critically. Moreover, such cultural images and stories offer resources to address aspects of disasters that technical and practical vocabularies cannot.

When I decided to open X AND BEYOND, I expected to curate a program heavy on documentary-based works. It did not turn out that way. On the contrary, as my research developed in response to the work of my colleagues at Changing Disasters, it became more engaged with art as fiction and drama and with investigating and conceptualizing art's significance as more than mere speculation or entertainment.

Although dangerous events can make for sublime spectacles and thrilling tales, art does not necessarily distance us from the reality of disasters. In the best of cases, it has the potential to engage us more deeply, opening our eyes and minds to the immeasurable aspects and irrationalities that are part of coping with catastrophes – to the sense of existential void that lies at the heart of all disasters. Meeting the challenges of disasters is not only a question of better engineering or better management; it is also a matter of using fiction and drama to imagine and reflect on "unknown" effects. To be truly resilient, we need to continue expanding our cultural vocabularies.

Art plays an important role in disaster studies, but it does not solve the problems addressed by other disciplines. On the contrary, art has much to learn from other areas of disaster studies, and its significance manifests within a transdisciplinary discourse. I intended X AND BEYOND to be a meeting space for all the disciplines involved in Changing Disasters. I did not want people to feel like they were visiting an art space; rather, I wanted to present disciplinary practices in their own right. Thus, many of the events that I curated were not art-centred or even necessarily art-oriented. While art needs to be included in disaster studies, it can only do so by leaving the exclusiveness of the art world behind. Ultimately, my focus on fiction and drama led me to begin writing the chronicles of X AND BEYOND as a sci-fi novel; partly documentation and partly wild speculation.

The end

At X AND BEYOND, I programmed a series of events under the title "The End", where I invited artists from different disciplines to talk about the end of a work, a novel, a film, or a piece of music. The series was motivated by some fundamental questions asked by disaster studies: Is a disaster an end? – If so, for whom? Or, is it a beginning? Again – if so, for whom? In most cases, the answer is both: It is an end for someone and a beginning for someone else.

Disaster capitalism, as described by Naomi Klein, clearly demonstrates how people in economic and political power exploit disasters to accumulate assets and privatize public goods. Disasters become an occasion to enforce the mechanisms of social reproduction. The rich get richer, the poor get poorer.[4] On the other hand, as many of my colleagues from anthropology as well as Rebecca Solnit and Alan Weisman have shown, there are also cases where humans are able to not only rebuild but also reconfigure communities through new beginnings, creating new visions and new hopes.[5] One book became important to me in this regard, the novel *The Drowned World* (1962) by J. G. Ballard. The novel imagines a flooded London in the year 2145, a post-apocalyptic setting where a group of people are trying to cope with the transformed landscape. One of the characters manages to drain the water from London, exposing the city after years submerged. While some celebrate this return to normal city life, another character decides that he does not want to return to old London and instead decides to wander into the jungle. While he essentially walks towards his own death, his decision also embodies another point, namely that, instead of returning to civilization, he would rather embrace the new ecological situation. In other words, he has also been transformed by the transformation of the landscape, and in the jungle, he sees a new beginning for humankind – a beginning dating back to before civilization.

The end of a disaster "narrative" offers an important clue to critical engagement with disasters, as it poses the question as to whether the disaster leads to a return to business as usual or to a change. The critical as well as visionary potential of disaster art lies in reimagining *the end* as a truly new beginning for life in a disaster-prone world. I hope X AND BEYOND is a testimony to that potential.

Notes

1 Paul Virilio, *The Original Accident*. Cambridge: Polity, 2007.
2 Ulrich Beck, *Risk Society—Towards a New Modernity*. London: Sage, 1992.
3 Lillemose, Jacob, *Architecture Zero*, A Mock Book, Copenhagen 2021.
4 Naomi Klein, *The Shock Doctrine: The Rise of Disaster Capitalism*. Toronto: Random House Canada, 2007.
5 Rebecca Solnit, *Hope in the Dark: Untold Histories, Wild Possibilities*. Edinburgh: Canongate, 2005; Alan Weisman, *Countdown*: *Our Last, Best Hope for a Future on Earth*? Boston: Little, Brown & Company, 2013.

36

An Anthropocene journey

Walking as embodied research

Nick Shepherd and Christian Ernsten

> Walking is the speed for noticing – and for thinking. The Table Mountain Walking Seminars suggest just how much we need walking to imagine alternatives to the intertwined human and non-human catastrophes of the Anthropocene.
>
> *Anna Tsing (in Shepherd et al. 2018:1)*

"Part living laboratory, part performance, part decolonial enactment"

You hear the city before you see it. Climbing Table Mountain from the South involves a two-day hike, with a night spent in the "Overseers Cottage". At some point on the second day, you become aware of a new element in your sensory landscape, a dull persistent roar, like surf on a beach or the ruminations of a giant beast. Cresting the final rise, you see the city of Cape Town spread before you, 1,000 meters below. You realize that what you have been hearing is an expression of the compound life of the city: cars, sirens, cell phones, the grinding business of daily life. After your days on the mountain, this strikes you as a kind of violence, an assault on the senses. It seems terrible that anyone should have to live in the midst of such a racket. However, a second surprise is in store. Walking down into the city, you are at first very aware of the noise and then not aware of it at all. You have filtered out the noise, just as we learn to filter out and ignore so many things that are harmful or inconvenient. In 2014, we started convening "walking seminars" together with our collaborator, the documentary photographer Dirk-Jan Visser, and a changing cast of participants. Our research profiles are as scholars, pursuing fairly orthodox research tracks. Nick Shepherd is an archaeologist who works in the areas of Science and Technology Studies (STS), Critical Heritage Studies, and decolonial thinking and practice. In 2017–18, he held a position as artist-in-residence at the Amsterdam University of the Arts (AHK), a departure from an otherwise conventional scholarly track. Christian Ernsten is an urbanist who works in the areas of Critical Heritage Studies and decolonial thinking and practice. Our starting idea with the walking seminars was simple: invite the most interesting possible group of people to walk, talk, and share ideas and approaches. Since then, our ideas have evolved. We always invite a mixed group of scholars, creative artists, curators, and activists. One of the intentions of the walking seminars is to flatten out hierarchies between theory and practice and between scholarly and creative

DOI: 10.4324/9780429437069-45

practices. We favor hybrid collaborations involving, for example, an architect, a philosopher, and a choreographer in thinking about the micro-politics of collecting water from a particular city spring. We also favor a model of quick publication, whereby work is produced in multiple formats inside and outside the formal academic apparatus (Shepherd et al. 2018).

This raises questions about the possibilities and limitations of institutionalized systems of peer review, and standard academic formats like the journal article. It also raises questions about the terms of engagement between scholarly and creative practices in the process of research and the production of knowledge. Typically, in such engagements, creative practices play a supplementary role and the real business of knowledge production is understood to take place in the scholarly disciplines (Borgdorf 2012). We specifically reject such a characterization. Drawing inspiration from the field of STS and the debate around artistic research methods and practice as research, we are interested in a richer dialogue between these modes. On the one hand, we are interested in the forms of knowledge that emerge out of creative practices and artistic research methods (Busch 2009, Kara 2015, Klein 2010, Leavy 2018). On the other hand, we are interested in using creativity and imagination as resources in more conventional forms of scholarship and empirical research (Klein 2010, Shepherd 2015a).

At the core of the seminars is the practice and craft of walking as a form of embodied research, and as a way of engaging the new and emergent landscapes of the Anthropocene. In her beautifully realized book, *Wanderlust: A History of Walking*, Rebecca Solnit writes: "The history of walking is an unwritten, secret history whose fragments can be found in a thousand unemphatic passages in books, as well as in songs, streets, and almost everyone's adventures" (Solnit 2001: 3). She notes that:

> Walking itself is the intentional act closest to the unwilled rhythms of the body, to breathing and the beating of the heart. It strikes a delicate balance between working and idling, being and doing. It is a bodily labor that produces nothing but thoughts, experiences, arrivals.
>
> *(Solnit 2001: 5)*

In this regard, she writes of "walking's peculiar utility for thinkers":

> The rhythm of walking generates a kind of rhythm of thinking, and the passage through a landscape echoes or stimulates the passage through a series of thoughts. This creates an odd consonance between internal and external passage, one that suggests that the mind is also a landscape of sorts and that walking is one way to traverse it.
>
> *(Solnit 2001: 5–6)*

Walking is good for thinking in general, as Solnit suggests, but it can also be good for thinking in particular, and for working away at a problem or issue. Each walking seminar is convened around a theme. Our most ambitious and successful walking seminars have taken place along the chain of mountains linking Cape Point to Cape Town in South Africa. Lasting a week, they traverse the approximately 80 kilometers of the Hoerikwaggo Trail. Accommodation is in tented camps along the way. A Table Mountain Walking Seminar that took place in December 2015 in the aftermath of the events of #RhodesMustFall, the student-led social movement that contested the legacy of Cecil Rhodes – itself deeply inscribed in the landscape of Table Mountain – was themed around "Decolonizing Table Mountain" (Shepherd in press a). A Table Mountain Walking Seminar that took place in March 2018 was themed around "Fire and Water", picking up on the contemporary water crisis in the city (Robins in press, Shepherd 2018a, Shepherd in press b and c). A walking seminar in Berlin in 2017 with students from the AHK was themed "My Berlin" and explored subjective responses to the city. In the same year, a walking seminar in Groningen Province in the Netherlands explored the recent incidence of earthquakes in the area, a probable consequence of mining for natural gas (Shepherd et al. 2018).

Seminar participants are invited with the theme in mind, and we share readings and resources, as in a conventional seminar. We also invite "resource people" to drop in and share their knowledge and experience. The seminar becomes an opportunity to walk, talk, share work, and plan collaborations. More profoundly, it becomes an opportunity to dwell in a particular landscape, to pass deeply into your thoughts and the thoughts of others, and to engage the body and the senses in ways that are both challenging and pleasurable. The walking seminars – and particularly the Table Mountain Walking Seminars – are a kind of experiment that grew out of our own biographies as researchers and the work of our collaborators. Part living laboratory, part performance, part decolonial enactment, they respond in particular ways to the challenges and opportunities of our contemporary contexts of practice. As a particular manifestation, they respond to more general issues around what it means to do research and how we position ourselves in relation to our materials as scholars, artists, and activists. In this chapter, we will address this more general context, by describing some of the conceptual underpinnings of the walking seminars. In particular, we situate the idea of the walking seminars in relation to three areas of debate and discussion. The first is a discussion on embodied research methods, drawing on ideas from the Anthropology of walking, artistic research methods, feminist theory, and critical race theory. The second is a debate around the Anthropocene, and its implications for modes of knowledge production and forms of engagement. The third is a discussion around decolonial theory and practice, and the notion of decolonial aesthesis. Having done this, we describe a single iteration of the walking seminar, the Table Mountain Walking Seminar focused on the 2018 water crisis in Cape Town, as a way of exemplifying some of these ideas and practices. The form of this chapter is somewhat meandering, rather like the act of walking itself. Rather than setting out to demonstrate a proposition, or arrive at a set of definite conclusions, we have different aims in mind: to suggest a set of openings, to try to break with conventional modes of scholarly and creative practices, and to reach for forms of engagement that feel more adequate to addressing the extraordinary times in which we live (Figures 36.1–36.3).

"Oh my body, make me always a (person) who questions"

A first point of departure for the idea of the walking seminars is an irritation with the "white cube" of the typical seminar room, and an awareness of all that it excludes. The discourse of the seminar room imposes a stringent set of rules: we sit in chairs around desks; we meet as disembodied intelligences, eyes that see, and mouths that speak; we speak one of the imperial ("global") languages; we talk about "theory"; we cite from approved canons; we mention the five or six currently trending keywords (Shepherd 2018a). Apart from a few important exceptions – discussions in queer theory, certain strands of feminist theory, and forms of decolonial thinking and practice – we agree to leave at the door, as it were, many aspects of what defines us as embodied beings in the world: memory, experience, desire, imagination, fear, delight, the small details of daily life that saturate our affective selves. The discourse of the seminar room is presented here in slightly parodied form. Nevertheless, it is true that our principle forms of scholarly engagement are remarkably disembodied and that they tend to be based on and to reinforce a set of distinctions: mind versus body, reason versus emotion

Figure 36.1 The Table Mountain Walking Seminar
Source: Barry Christianson.

and imagination, thinking versus feeling (Mignolo 2013). We are interested in the political and epistemic consequences of this dominant form of scholarly engagement. What happens to black bodies, or to queer bodies, or to women, or to people that have grown up speaking languages other than English in such a setup? Nick Shepherd's past experience as a scholar based at the University of Cape Town in South Africa presented this situation to him on a daily basis as nothing less than a savage indictment of the coloniality of the university as institution. In the average seminar situation, students were required to discuss abstract knowledge in an imperial language, parking at the door, as it were, the things that condition their daily experience: being black, being a woman, being worried about personal safety, being worried about money, having to negotiate the long journey to and from the university each day, being denied the forms of discourse through which to have a meaningful discussion about any of these things. In other words, their relationship to knowledge begins by excluding the very thing that so profoundly conditions their experience under and after apartheid: embodied being in the world (Shepherd 2018a).

Figure 36.2 Time-out on Table Mountain. From left: Nick Shepherd, Hedley Twidle, Linda Shamma, and Christian Ernsten

Source: Barry Christianson.

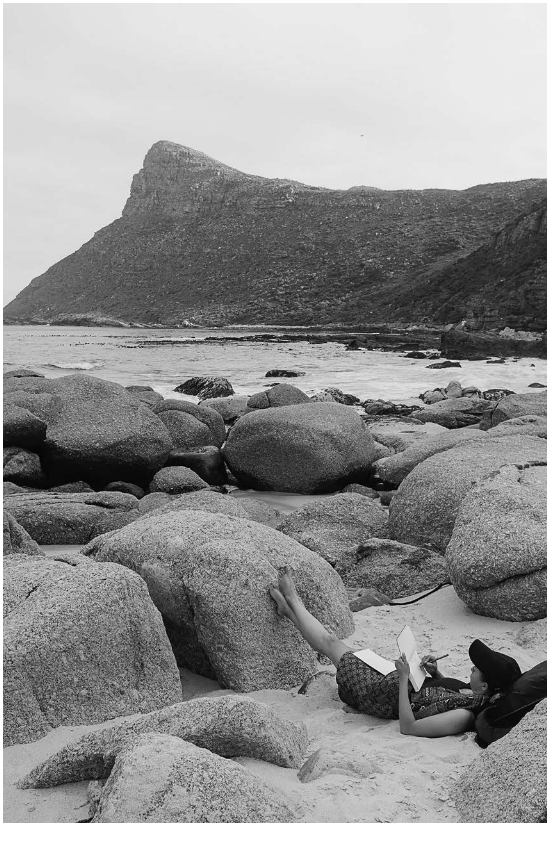


Figure 36.3 Ilze Wolff at Smitswinkel Bay; the landscape becomes an active presence on the walking seminars

Source: Barry Christianson.

We would argue that this is a form of scholarly practice that is not so much about making the connections between things, as it is about making and enforcing a set of disconnections: disarticulating knowledge from experience, and thinking from feeling. So, how do we bring the body into play in more embodied forms of research practice? And how do we break down some of the distinctions set up by the discourse of the seminar room in ways that are productive and open out to new research understandings? There are many ways of answering these questions, with the walking seminar being one modest answer. The idea of walking as a form of embodied research practice draws from a rich literature on the anthropology of walking, referencing the work of Tim Ingold, Rebecca Solnit, and many others. It also draws from a rich and productive strand in Urban Studies on walking as a methodology through which to engage city spaces, referencing the work of Michel de Certeau and others. Recent scholarly interventions explore walking as a form of collaborative knowledge practice (Anderson 2004), comment on the transdisciplinary potential of walking (Pink et al. 2010), employ a form of walking ethnography (Yi'En 2014), and experiment with walking interviews (Evans and Jones 2011). They also explore the potential of walking to open minds and reshape thinking (Salin and Pesso 2017). Yarimar Bonilla (2011) used embodied "memory walks" to research histories of labor activism in Guadeloupe, and Richard Keating (2012) describes his "art-walking practice" in which walking becomes a form of participatory action research driven by his sense of loss at declining biodiversity and the consequent diminished aesthetic experience and quality of life.

We draw on affective and sensorial research methods, to ask questions about what it means to encounter emergent Anthropocene landscapes through the surfaces of the body. We also draw on the debate around artistic research methods and practice as research, to ask questions about the productive uses of imagination, creativity, and desire in the pursuit of empirical research and about the use of experience as a resource. We are inspired by artists like Richard Long and Francis Alÿs who use walking as a core part of their method, as well as by the many artists, activists, and practitioners who walk as a form of creative practice, to explore emotional states, as a way of engaging landscapes, or as a form of protest. This long list includes artists and practitioners as different as Marina Abramovich and Ulay (*The Lovers: The Great Wall Walk*, 1988), Eve Mosher (*HighWaterLine*, 2007), Amanda Coogan (*Floats in the Aether*, 2018), and the Zapatistas, who are articulate on the question of walking as a form of political pedagogy. Karen O'Rourke (2013) describes a set of walking/mapping projects by contemporary artists, some of whom chart "emotional GPS" or engage in speculative mapping. Other, established projects closely parallel our work with the walking seminars. *WalkingLab* is a Canadian, US, and Australian research-creation project "to advance the theory and practice of walking methodologies". It aims to foster collaboration between activists, scholars, educators, and artists (WalkingLab 2019). The *Walking Artists Network* is for "everyone who defines themselves as a walking artist, and everyone who is interested in walking as a mode of art practice, as well as related fields including, but not limited to, architecture, archaeology, anthropology, cultural geography, history, spatial design, urban design and planning" (Walking Artists Network 2019).

Finally, we ground our conception of embodied research by drawing on contemporary discussions in decolonial thinking and practice around challenging hegemonic modes of knowledge production. In his recent work, Walter Mignolo has described the forms of knowledge attendant on colonial modernity as an "ego-politics of knowledge", grounded in the Cartesian dualism between mind and body. Against this ego-politics of knowledge, he proposes a "body-politics of knowing/ sensing/ understanding", grounded in an understanding of the place from which knowledge proceeds (Mignolo 2013: 132). In conversation, he talks of linked processes of "reasoning" and "emotioning" (Mignolo, Pers. comm., 2014). Some of Mignolo's most engaging writing takes place in his evocation of this embodied other place of knowledge, imagined not as an essentialized outside of Western reason, but as an embodied inside/outside: the place of "border thinking" and of things known "in the bones". As a source for these various ideas, Mignolo cites the "prayer" with which Fanon so memorably concludes *Black Skin, White Masks*:

> Oh my body, make me always a man who questions.

He writes: this single sentence expresses "the basic categories of border epistemology" (Mignolo 2013: 132).

A history of fragments

One of the things that we like about the walking seminars is that they involve passages of hard work and are sometimes physically challenging. We become aware of our bodies in new ways as we sweat our way to the end of the trail. We rely on basic things like water, good shoes, a map, and the ability to find our way around an unfamiliar landscape. We are thrown back on ourselves, and on the idea that our technology will not save us. All of this seems like good training as we journey deeper into the Anthropocene. We like the idea that walking involves a certain kind of dwelling in the landscape, with ideas around duration (being in the landscape for a passage of time) and exposure (being open to, or exposed to, external influences). This works in both busy urban environments and the more contemplative environments of the Table Mountain National Park. We also like the idea that the physical work of walking points toward a certain practice of respect, like a pilgrimage, as we pass through known and beloved or new landscapes (Frey 1998). As climates change and beloved landscapes are transformed before our eyes, as is happening in Cape Town right now, the act of walking takes on an elegiac quality as we say goodbye to the landscapes that we know and begin our ambiguous journey into the future, into landscapes shaped by fire and drought and as-yet-unchartered social formations. As raced and gendered bodies, subjected to local histories of colonial modernity, our relationship to these landscapes will be very different and will run the spectrum from hedonism to bare life. Table Mountain, one of the most heavily touristed sites in Africa and a recently proclaimed "natural wonder of the world", was historically a site of refuge for escaped slaves from the Cape Colony, and is currently a refuge for migrants fleeing conflict and economic hardship on other parts of the continent (Shepherd et al. 2018).

A second point of departure for the walking seminars is an interest in deep time and in history as a form of material inscription on the landscape. Bringing an archaeological sensibility to bear, one can interpret the landscape as a palimpsest of a particular kind. The site of Peers Cave on the northern edge of the Fish Hoek Valley has archaeological deposits that attest to half a million years of hominin occupation (Shepherd 2015b). Further south, the ruins of Red Hill Village and the dystopian dormitory town of "Ocean View" speak of apartheid-era forced removals and the racial cleansing of urban spaces (Shepherd et al. 2018). What would it mean to push these sites into the same frame, or to read them together as part of a story of human dwelling and being in this space? We are used to chopping-up and segmenting time and then parceling out this segmented time to the different disciplines. Is there a way in which we could think about water trickling through time to open up new furrows and new understandings? Steams, pools, and springs speak of a different order of time and link us in ways that open out to transhistorical experiences. With the current water crisis in

Cape Town, there is a push to relocate and reopen historical springs and watercourses, some of them canalized and paved over as part of a process of urban modernization (Shepherd 2018b, Shepherd in press b and c).

Viewing history as a form of material inscription in the landscape opens up ideas around attentiveness and the possibilities for a close reading of landscape based on fragments and traces. Our engagement with the past and with elapsed time is then potentially mediated by something other than text, image, and the forms of narrative history, and rather by fragments, traces, and the signs of ruination. In recent work, Shepherd (2015a, b) explores this mode of engagement with the past under the heading of "a history of fragments". If some forms of narrative history are premised on text, voice, and a certain kind of plenitude, which may be the plenitude of the archive, then the idea of "a history of fragments" works from other sources: shells, bones, bricks, pieces of ceramics, graffiti, the temporary shelters of the dispossessed, plastic containers for holding water, house foundations, remains of footpaths, discarded toys, orphaned photographs, trees scorched by fire. We like it that these fragments do not tell a story with a recognizable beginning, middle, and end, and that their status as sources is ambiguous and unreliable. We also like the fact that they present us with the entangled processes by which they were made and discarded, and the accident of their survival, as assemblages without reason. This kind of detritus forecasts the future, in that it is precisely by such signs that our civilization will be known, in the archaeological way.

One of the key points to be taken from the current debate around the Anthropocene is that it gives us a strong mandate to try out new formats and modes of scholarly and artistic production. We would argue that this goes well beyond the familiar debate about inter- and transdisciplinarity, and that it challenges us to rethink foundational ideas and practices in scholarship and the arts. In his influential and widely cited essay, "The Climate of History", postcolonial historian Dipesh Chakrabarty makes a startling admission. He writes: "As the crisis gathered momentum in the last few years, I realized that all of my readings in theories of globalization, Marxist analysis of capital, subaltern studies, and postcolonial criticism over the last twenty-five years, while enormously useful in studying globalization, had not prepared me for the making sense of this planetary conjunction within which humanity finds itself today" (Chakrabarty 2009: 199). He goes on to wonder what it will mean to think and practice, as he puts it "under the cloud of the Anthropocene" (Chakrabarty 2009: 212). This sense in which conventional ideas and formats are challenged has been a starting point for many scholars, as they begin their own Anthropocene journey. In their opening editorial to the first issue of the journal *Environmental Humanities* titled "Thinking Through the Environment, Unsettling the Humanities", Deborah Bird Rose, Thom van Dooren, Matthew Chrulew, Stuart Cooke, Matthew Keenes, and Emily O'Gorman write: "we are required to re-imagine the proper questions and approaches to our fields. How can our accumulated knowledge and practice, built over centuries, be refashioned to meet these new challenges and to productively rethink 'the human' in more than human terms?" (Rose et al. 2012). More succinctly, Bruno Latour says in a recent exchange with Isabelle Stengers and Anna Tsing: "I think that, in a way, it is one of the slight advantages of being in the ruins; it demands a new kind of dialogue with science" (Latour et al. 2018: 12).

Of course, there are many ways of having a new kind of dialogue with science. The walking seminar is our modest attempt to refashion knowledge relationships and try something new. We like the everydayness of walking, the fact that it is often overlooked or regarded not as a practice in its own right but as a means to get from A to B. We also like that it throws us back on our own resources and that – apart from some exceptional cases – technology is very little use in the act of walking. Like clean air and clean water, we take the act of walking for

Figure 36.4 Nick Shepherd; writing "a history of fragments"
Source: Barry Christianson.

granted until we cannot walk, and then, it strikes us with the force of a catastrophe. It seems appropriate that we should turn to something humble and taken for granted as we think and speak, as Latour puts it, "in the ruins". Writing well before the current debate around the Anthropocene, Rebecca Solnit says: "If there is a history of walking, then it too has come to a place where the road falls off, a place where there is no public space and the landscape is being paved over, where leisure is shrinking and being crushed under the anxiety to produce, where bodies are not in the world but only indoors and in cars and buildings, and an apotheosis of speed makes bodies seem anachronistic or feeble. In this context, walking is a subversive detour, the scenic route through a half-abandoned landscape of ideas and experiences" (Solnit 2000: 12) (Figures 36.4 and 36.5).

Cape Town water: an Anthropocene moment

A third intention of the walking seminars is to bring together the debate around the Anthropocene with a debate around social justice and decolonial futures. Our impression is that these debates have tended to run on separate tracks, and that the "environmental" debate has been seen as a predominantly white, middle-class affair, at least in the global south. The argument here has been that while the middle classes fuss about the destruction of habitats and the endangerment of species, ordinary people are caught up with the daily struggle for survival amidst conditions of bare life. From a decolonial perspective, the problem with the notion of the Anthropocene is that it represents a radical flattening out of history. Who is this "Anthropos" that is said to be driving global environmental change, and how can it encompass equally capitalist and peasant, former slave and former slave master, and over-consumer in a global north suburb and precarious urban dweller in a global south slum? The answer is that while it becomes important to disaggregate agency, going forward we are all in this together – only some will be more "in" it than others. The startling and sobering fact of the Anthropocene is that, as Chakrabarty and others point out, a disproportionate burden of the cost of global environmental change is currently, and will in all likelihood continue to be, borne by precarious populations in the global south – the same populations immiserated through historical processes of racial slavery, colonialism/imperialism, and capitalist underdevelopment (Parenti 2012). Industrialized populations in the global north – the historical agents and

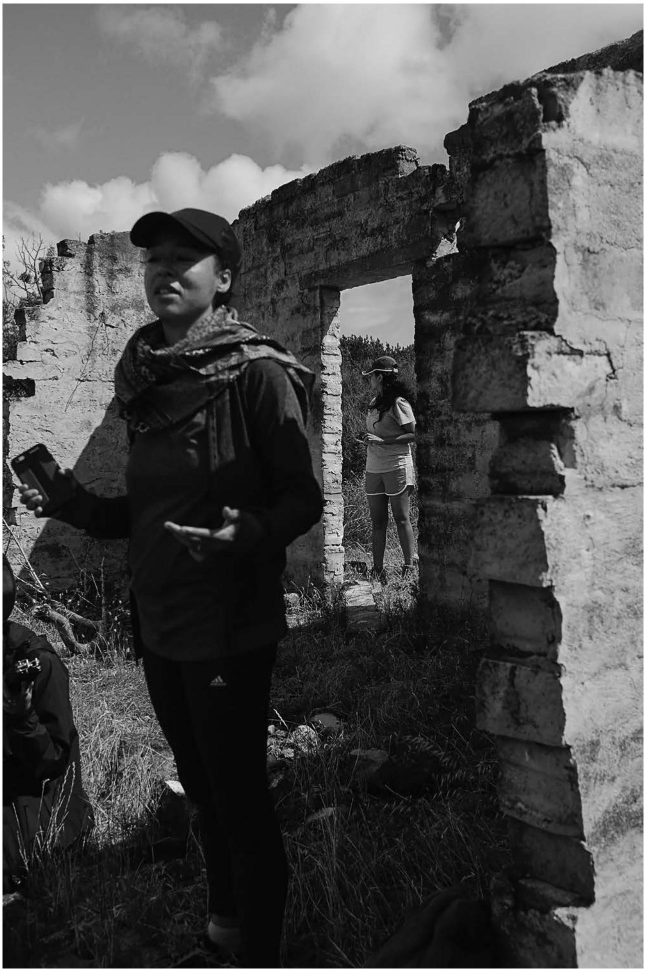


Figure 36.5 Ilze Wolff and Meghna Singh at the Red Hill Village forced removals site
Source: Barry Christianson. Photo credits: Dirk-Jan Visser, Hannah Lowenthal, Nicola Visser, and Barry Christianson.

perpetrators of these disastrous changes – are likely to pay a disproportionately smaller cost: socially, politically, and economically. In South Africa, we are used to the fundamentally unjust idea that historical injustice frequently translates into forms of contemporary social injustice. This is the real injustice of apartheid: that black South Africans continue to make up the vast majority of the poor, the socially excluded, and the most precarious of urban dwellers (Shepherd 2015b). The Anthropocene threatens us with a kind of global apartheid as the historically underdeveloped and exploited populations of the global south, pillaged in the course of the overdevelopment of the global north, now pay a disproportionate share of the costs of that overdevelopment in the form of disastrous environmental changes.

Anthropogenic environmental changes take many forms, and many of them have to do with water: too much water, too little water, melting ice, rising sea levels. The focus of attention shifts from location to location as first one place, then another, experiences its Anthropocene moment. In late January 2018, a major story broke in the global media. Cape

Town, a city of approximately 4 million people, was about to run out of water (e.g., see Allie 2018, Baker 2018, Dixon 2018, Kane 2018, Laing 2018, Onishi and Sengupta 2018). Cape Town lies in a winter rainfall region. After three years of lower-than-expected winter rains, the dams supplying the city's drinking water were at a critically low level. Domestic water consumption had been regulated by city officials for some time via a progressively more stringent water regime. By January 2018, it stood at 50 liters of water per person per day. This had to cover all uses, including water for drinking, cooking, keeping clean, and flushing the toilet. However, the real cause for concern was "Day Zero", the day when dam levels fell below a critical point and city officials cut off the water supply to households and businesses. Day Zero was projected to fall in April 2018, depending on consumption. Come Day Zero, city officials announced that 200 water points would be opened across the city, and residents would have to queue for a daily ration of 25 liters (Robins in press, Shepherd in press b and c).

Cape Town is characterized by vast disparities in wealth and living conditions. In 2017, Cape Town was listed by one residential property index as the ninth most profitable city in which to invest in residential property, after Berlin and ahead of Melbourne (Knight Frank Prime Global Cities Index 2017). According to a report published in 2016, it has the second highest seasonal fluctuation of dollar multimillionaires, after The Hamptons in New York (Brown 2016). At the same time, hundreds of thousands of city residents live in improvised shacks in sprawling informal settlements with rudimentary provision of services (State of Cape Town Report 2016). More than twenty years after the democratic elections of 1994, Cape Town remains by many accounts the most racially divided city in South Africa. It is not at all clear how the proposed 200 water points would intervene in this social and political landscape, apart from the logistics of requiring 4 million people to join a daily queue for water. Some commentators predicted a Mad Max scenario with criminal gangs and local warlords seizing control of water points and extorting money from city residents (Nace 2018, Zille 2018). Already by early 2018, thousands of people were queuing every day at freshwater springs around the city, filling an improvised variety of containers. Some springs, like the one at the South African Breweries site, were regulated and had guards. Others were more informally organized, like the spring off Kildare Road in Newlands (Robins in press).

The third Table Mountain Walking Seminar took place in the second week of March 2018 with between twelve and eighteen participants joining for different periods, and lasted one week. Participants included water activists and scholars working on water rights issues, as well as a range of people whose work and practice was more tangentially related to questions of water: an architect who designs buildings as multi-species habitats, a musician, two movement artists, a textile artist working on questions of place and home, an educationalist working on forms of conviviality in the city and "minor relationships", and a documentary photographer. From the beginning, we were confronted with the social and environmental impacts of the drought. On Day Two, we detoured around wildfires in the Cape Point reserve. Many of the springs and watercourses that we would have relied on in the southern peninsula were dry. Water regimes in the overnight camps were strict. Over the course of the week, we spent time at water points close to the mountain, talked with water activists, traced historical springs and watercourses on the mountain, and shared work, ideas, and approaches (Shepherd et al. 2018). As we write, the first articles and reports that draw material from the walking seminar are beginning to appear, along with a musical composition, a movement residency in Copenhagen, a portfolio of images, and many other projects and outputs. Also, at the time of writing, the first winter rains have fallen in Cape Town, and Day Zero has been averted for the time being. Nick Shepherd will begin a three-year research project focused on Cape Town Water, with a small team of researchers at Aarhus University working with colleagues from Cape Town. By these conventional metrics, the walking seminar was a success, but we would argue that they do not capture its full meaning or effect.

It felt important to understand the water crisis in an embodied way. It also felt important to physically be in a landscape experiencing the effects of prolonged drought for large parts of each day. Fear, surprise, and delight were part of our emotional repertoire, as in the surprise discovery of a flowing stream in Orange Kloof, or a stand of Disa flowers on the precipitous edge of a mountain path. At times it felt ridiculous to be walking across mountains in the midst of a social and environmental crisis. However, it would surely have felt more ridiculous to be housed in a conference facility at the University of Cape Town. A sense of the ridiculous would seem to be a useful resource to take along on an Anthropocene journey, as would a spirit of playfulness. Many discussions of anthropogenic climate change take on a serious and censorious tone. On the walking seminar, we are interested in exploring the uses of playfulness as a response to this most serious topic.

Our own research biographies are entangled with the city of Cape Town. For twenty years, Nick Shepherd was based as a researcher at the University of Cape Town, before moving to Denmark. Christian Ernsten did both his master's and PhD degrees at the University of Cape Town and has published on the contemporary stylization of the city. The walking seminar enabled us to make the connection between places and ideas and to rethink our own involvements with the city. A forthcoming research project will explore the politics and poetics of water shortage in Cape Town, thinking about Anthropocene futures. There is a substantial technical literature dealing with water policy, management, infrastructure, and the geopolitics of water in southern Africa. Less studied is our everyday relationship to water, the micro-politics of water at a local level, and the kinds of improvised coping strategies that people come up with in times of crisis. Social media are full of ingenious ideas for recycling gray water, building composting loos, and rigging small trolleys to carry a 25-liter can of water. The Mad Max scenario plays well in the media, but there is another scenario in which water shortage acts as a social leveler (Robins in press, Shepherd 2018a, Shepherd in preparation a, b). For residents of Cape Town's informal settlements, queuing for water is nothing new, as many of them rely on standpipes for their daily supply. Perhaps the water crisis will teach the city's wealthier residents humility and empathy, something that twenty years of Mandela-inspired reconciliation policies have signally failed to do. In their preparations for Day Zero, city officials announced that while the water supply to Cape Town's suburbs would be cut off, the water to standpipes in the informal settlements would keep running, potentially inverting the accustomed order of things.

If there is a single question that haunts us, then it is this: What does it mean to think and practice in the midst of what Anna Tsing calls "the intertwined human and non-human catastrophes of the Anthropocene"? Many of us are so enmeshed in institutional and disciplinary relationships and accustomed ways of working that it feels difficult to mark a sudden departure in how we think and practice, and yet it seems that nothing less will do. Water seeps, trickles, and pools. We like how water lays things bare, and how it cuts away at top-heavy structures and ideas. Our relationship to water is intimate, embodied, and inescapable. The discussion around the Anthropocene often seems abstract and vast. Manifested as water shortage, it becomes as immediate as thirst and the irritation of unwashed skin. It is likely that the meanings of water will change as our everyday relationship to water is transformed under the pressure of acute shortage. Already, Cape Town's residents report dreaming of water, running taps, wastefully protracted showers, an icy plunge into the swimming pool (Monteiro 2018). A key implication of the debate around the Anthropocene is that the distinctions between categories begin to break down and become complicated and entangled. This includes not only the distinction between nature and culture, but also the kinds of distinctions that underlie more conventional forms of research, between the self of the researcher and the thing that is researched, studied, and observed. This is an enormous challenge for scholars, as we have to rethink our own sense of involvement and implication. Bodily and sensorial implication becomes one way of addressing this challenge, and walking becomes one way of implicating the body. For conventional disciplinary scholars, the idea of a walking seminar can seem daunting or unserious, but really it is easy: you just put one foot in front of the other.

Bibliography

Abrahamovich, Marina and Ulay. 1988. *The Lovers: The Great Wall Walk*. https://www.newyorker.com/magazine/2010/03/08/walking-through-walls. Accessed on February 27, 2019.

Allie, Mohammad. 2018. "Cape Town Water Crisis: 'My Wife Doesn't Shower Anymore'", *BBC News*. January 24, 2018. https://www.bbc.com/news/world-africa-42787773. Accessed on January 7, 2018.

Anderson, Jon. 2004. "Talking Whilst Walking: A Geographical Archaeology of Knowledge", *Area*, 36(3): 254–261.

Baker, Aryn. 2018. "Cape Town Is 90 Days from Running Out of Water", *Time Magazine*. January 15, 2018. http://time.com/5103259/cape-town-water-crisis/. Accessed on January 7, 2018.

Bonilla, Yarimar. 2011. "The Past Is Made by Walking: Labor Activism and Historical Production in Postcolonial Guadeloupe", *Cultural Anthropology*, 26(3): 313–339.

Borgdorf, Henk. 2012. *The Conflict of the Faculties: Perspectives on Artistic Research and Academia*. Leiden: Leiden University Press.

Brown, Justin. 2016. "Wealthy Flock to Cape Town", *City Press*. July 11, 2016. https://city-press.news24.com/Business/wealthy-flock-to-cape-town-20160711. Accessed on February 26, 2019.

Busch, Kathrin. 2009. "Artistic Research and the Poetics of Knowledge", *Art and Research: A Journal of Ideas, Contexts and Methods*, 2(2): 1–7.

Chakrabarty, Dipesh. 2009. "The Climate of History", *Critical Inquiry*, 35(2): 197–222. https://www.jstor.org/stable/10.1086/596640. Accessed on January 7, 2019.

Coogan, Amanda. 2018. *Floats in the Aether*. http://www.amandacoogan.com. Accessed on February 27, 2019.

Dixon, Robyn. 2018. "In Cape Town, 'Day Zero' Is Coming Very Soon – the Day the Water Runs Out", *Los Angeles Times*. January 19, 2018. https://www.latimes.com/world/africa/la-fg-south-africa-water-crisis-20180119-story.html. Accessed on January 8, 2019.

Evans, James and Phil Jones. 2011. "The Walking Interview: Methodology, Mobility and Place", *Applied Geography*, 21: 849–858.

Frey, Nancy Louise. 1998. *Pilgrim Stories: On and Off the Road to Santiago*. Berkeley: University of California Press.

Kane, Dianna. 2018. "Running Dry in Cape Town", *The New York Times*. February 1, 2018. https://www.nytimes.com/2018/02/01/opinion/cape-town-drought-day-zero.html. Accessed on January 7, 2019.

Kara, Helen. 2015. *Creative Research Methods in the Social Sciences: A Practical Guide*. Bristol: Polity Press.

Keating, Richard. 2012. "Landscape Aesthetics in Practice", *Journal of Visual Arts Practice*, 11(1): 15–25.

Klein, Julian. 2010. "What Is Artistic Research?", *Gegenworte*, 23: 1–8.

Knight Frank. 2017. *Knight Frank Prime Global Cities Index, Second Quarter 2017*. https://content.knightfrank.com/research/323/documents/en/prime-global-cities-index-q2-2017-4862.pdf. Accessed on February 26, 2019.

Laing, Aislinn. 2018. "Cape Town Will Run Out of Water Within Weeks", *The Times* (UK). January 29, 2018. https://www.thetimes.co.uk/article/cape-town-weeks-away-from-running-out-of-water-stgfdx0g6. Accessed on January 7, 2019.

Latour, Bruno, Isabelle Stengers, Anna Tsing and Nils Bubandt. 2018. "Anthropologists Are Talking – About Capitalism, Ecology, and Apocalypse", *Ethnos*, 83(3): 587–606.

Leavy, Patricia (ed). 2018. *Handbook of Arts-Based Research*. New York: Guilford Press.

Mignolo, Walter. 2013. "Geo-Politics of Sensing and Knowing: On (De)coloniality, Border Thinking, and Epistemic Disobedience", *Confero Essays on Education Philosophy and Politics*, 1(1): 129–150.

Monteiro, Catie. 2018. "Water Crisis Grips Cape Town, South Africa, after Drought Stretching Years", *NBC News*. January 29, 2018. https://www.nbcnews.com/news/world/water-crisis-hits-cape-town-south-africa-day-zero-looms-n841881. Accessed on February 26, 2019.

Mosher, Eve. 2007. *HighWaterLine*. http://highwaterline.org/nyc/. Accessed on February 27, 2019.
Nace, Trevor. 2018. "Mad Max Scenario: Cape Town Will Run Out of Water in Just 90 Days", January 18, 2018. https://www.forbes.com/sites/trevornace/2018/01/18/mad-max-scenario-cape-town-run-out-water-90-days/#4859f9675414. Accessed on January 7, 2019.
Onishi, Norimitsu and Somini Sengupta. 2018. "Dangerously Low on Water, Cape Town Now Faces 'Day Zero'", *The New York Times*. January 30, 2018. https://www.nytimes.com/2018/01/30/world/africa/cape-town-day-zero.html. Accessed on January 7, 2019.
O'Rourke, Karen. 2013. *Walking and Mapping. Artists as Cartographers*. Cambridge: MIT Press.
Parenti, Christian. 2012. *Tropic of Chaos: Climate Change and the New Geography of Violence*. New York: Nation Books.
Pink, Sarah, Phil Hubbard, Maggie O'Neill and Alan Radley. 2010. "Walking across Disciplines: From Ethnography to Arts Practice", *Visual Studies*, 25(1): 1–7.
Robins, Steven. in press. "'Day Zero', Hydraulic-Citizenship and the Defence of the Common in Cape Town: A Case Study of the Politics of Water and Its Infrastructures (2017–2018)", *Journal of Southern African Studies*.
Rose, Deborah Bird, Thom van Dooren, Mathew Chrulew, Stuart Cooke, Mathew Keenes and Emiliy O'Gorman. 2012. "Thinking Through the Environment, Unsettling the Humanities", *Environmental Humanities*, 1(1): 1–5.
Salin, Ossi and Kaija Pesso. 2017. "Open Minds, Open Spaces: Mind-Set Changes during Urban Walking", *Space and Culture*, 20(4): 385–398.
Shepherd N. 2015a. *The Mirror in the Ground: Archaeology, Photography and the Making of a Disciplinary Archive*. Cape Town: Jonathan Ball Publishers and the Centre for Curating the Archive.
Shepherd, N. 2015b. "Digging Deep: A Hauntology of Cape Town". In: Cherry, J. and Rojas, F. (eds.) *Archaeology for the People: Joukowsky Institute Perspectives*. Oxford: Oxbow Books: 96–107.
Shepherd, N. 2018a. "Escaping from the 'White Cube' of the Seminar Room". In: Shepherd, N., Ernsten, C. and Visser, D.-J. (eds.) *The Walking Seminar: Embodied Research in Emergent Anthropocene Landscapes*. Amsterdam: Reinwardt Academy Press: 12–13.
Shepherd, N. 2018b. "Cape Town Water: Anthropocene Futures". In: Shepherd, N., Ernsten, C. and Visser, D.-J. (eds.) *The Walking Seminar: Embodied Research in Emergent Anthropocene Landscapes*. Amsterdam: Reinwardt Academy Press: 44–47.
Shepherd, N. in press a. "After the #Fall: The Shadow of Cecil Rhodes at the University of Cape Town". In: *City: Analysis of Urban Trends, Culture, Theory, Policy, Action*. Milton Park: Taylor & Francis.
Shepherd, N. in press b. "Slow Catastrophes: Cape Town Water and Anthropogenic Climate Change". In: Riede, F. et al. (eds.) *Catastrophes in Context*. New York: Berghahn Books.
Shepherd, N. in press c. "Cape Town Water: Notes on Urban Dwelling in the Anthropocene". In: *Space and Culture*. Thousand Oaks, CA: Sage.
Shepherd, N., C. Ernsten and D.-J. Visser. 2018. *The Walking Seminar: Embodied Research in Emergent Anthropocene Landscapes*. Amsterdam: Reinwardt Academy Press.
Solnit, Rebecca. 2000. *Wanderlust: A History of Walking*. New York: Penguin Books.
State of Cape Town. 2016. *State of Cape Town Report 2016 – Overview with Infographics*. Development Information and Geographic Systems Department, Development Information Branch. https://resource.capetown.gov.za/documentcentre/Documents/City%20research%20reports%20and%20review/16429%20CCT%20State%20of%20Cape%20Town%20Report%202016%20-%20Summary%20Report%20V7.pdf. Accessed on January 7, 2019.
Walking Artists Network. 2019. *Walking Artists Network*. http://www.walkingartistsnetwork.org. Accessed on February 27, 2019.
WalkingLab. 2019. *WalkingLab. Performing Lines & Research-Creation*. Designed and maintained by Sarah E. Truman. https://walkinglab.org/about/. Accessed on February 27, 2019.
Yi'En, Cheng. 2014. "Telling Stories of the City: Walking Ethnography, Affective Material, and Mobile Encounters", *Space & Culture*, 17(3): 211–223.
Zille, Helen. 2018. "From the Inside: The Countdown to Day Zero", *Daily Maverick*. January 22, 2018. https://www.dailymaverick.co.za/opinionista/2018-01-22-from-the-inside-the-countdown-to-day-zero/. Accessed on January 7, 2019.

37

As we used to float

Within Bikini Atoll

Nadim Samman and Julian Charrière

> The true eye of the earth is water
>
> —*Gaston Bachelard*

Pʲ ɪ͡ɯɡɯ͡ɪNʲɪ̯

Images are atoms of human attention. They combine to form molecules which, together, constitute the *atmosphere* of a culture. While particular arrangements of these molecules are experienced as discrete objects, they are nothing of the sort, but *complexes*. One should speak of the identity of an island-complex, just as one should a painting, in terms of density, dynamics, and stability. The cultural space is a continuum of complexes *as* atmospheric conditions. We are always immersed. Sometimes, we float, suspended within a specific condition for years, taking local equilibrium for a universal composition. Sometimes we swim.

Pikinni

Bikini lies beyond the forty-eight-hour delivery rule. A global network of cars, trains, and airplanes can only get you to the dock at Majuro, capital of the Marshall Islands, before an ocean journey must begin. There is no ferry, and only one suitable vessel is available for charter—the Windward, a beaten-up pearl diver from the 1970s. Once you have concluded negotiations with its owner you can embark, entering a parenthesis in your life; a capsule, outside time and phone signal. Out in the wide Pacific, flows of energy run up against the beam, tipping the boat from side to side, constantly, in the spell it takes for you to become a sailor. The passage is an initiation, or sickness, that finally breaks with sunrise and first sight of land.

The island is a line of green floating on a raft of yellow sand, a shock of luminous color like a gem set within another—the lagoon. It is a picture of *the good* as a geographical figure, so related in brochures promising space beyond the metropolitan everyday. You cannot help but recognize it as a place you have wanted, a figure centrally located in a dream that is our culture.

DOI: 10.4324/9780429437069-46

It is only after fully indulging this reflex that your gaze steadies. For the last seventy years, it has been a veritable ghostland. Between 1946 and 1958, twenty-three of the most powerful man-made explosions in history, delivering a combined fission yield of 42.2 megatons, occurred here. The force of one of these, Castle Bravo, was enough to vaporize three islands and gouge a massive crater—measuring 800 meters in diameter—out of the primordial reef. Another threw a fleet of captured and decommissioned World War II battleships—some of them more than 250 meters long—up into the air. A few were ripped to shreds. Others, like the USS Saratoga and the HIJMS Nagato—storied flagships of the United States and Japanese navies—eventually sank to the bottom, where their rusting hulks remain. During this period, obliterated geology would become radioactive particles, carried on the wind to then fall on communities in neighboring atolls. Meanwhile, the people of Bikini, who had been asked to "temporarily" leave their home to make way for a series of experiments disingenuously ventured "for the good of mankind and to end all wars," began to learn the meaning of a dispossession that continues until present. Today, the atoll bears architectural scars that stand as profane registers of this program and its unresolved consequences—a series of concrete bunkers, jutting out from the shore. A terminal beach.

The Bomb

There is a photograph of the atoll taken in 1946. It was created on Bikini Island from a position overlooking the lagoon. In the foreground, a few architectural forms are followed by a row of palms, then the land ends. But you don't notice any of this at first. Instead, your attention is drawn to a cumulonimbus filling much of the frame, sitting atop a giant column, rising up from the water's surface into the sky. This is not a naturally occurring cloud, but the fruit of human experiment. It is an extraordinary image: the world's first hydrogen bomb, captured mid-explosion during the Baker shot. The strangeness of this picture intensifies the more you look at it: While the terrible violence of the nuclear reaction, ripping molecules apart, unfolds on the horizon, it has yet to affect the place where the photograph was taken. During the click of the camera's shutter, and not a second longer, the island still experiences calm: the leaves of its trees unmoved by wind; not a grain of sand out of place on the beach. A last moment of peace.

But there is more. Atop the water's skin, positioned in consecutive rings that ripple outward from the column, numerous silhouettes announce an armada. Battleships, all of them, anchored at various distances from the epicenter to settle a disagreement between the navy and the air force concerning how such behemoths might hold up in the face of a blast. The shadow of these vessels throw the magnitude of the cloud into relief: At 264 meters long, the largest of them, the aircraft carrier USS Saratoga, appears utterly dwarfed. Beyond this, it is the register of an outrageous power that stirs the mind: At the bottom right of the column, the 171-meter USS Arkansas is being sucked up into the sky. You can only imagine the moment afterward: a fiery wind and an atomic tsunami, overturning the palms, washing the beach away, scattering ships like so much flotsam.

In 1968, the Apollo 8 Astronaut William Anders would capture the whole Earth in a photograph. Some have claimed that this picture, which was distributed worldwide on magazine pages and TV screens, helped to spur broader understanding of the planet as a single system, bolstering the nascent environmentalism movement. But if *Earthrise*, as the picture has come to be known, was the birth of a new mass-cultural relation to ecology, the US Department of Energy's documentation of Baker was its birth pang: For the image of a jewel-like planet, suspended in space, to contribute to the urgency of conservation initiatives, there had to be a prior vision of the stakes involved. Photographs of Baker are that vision. One of immense tumult, wrought by man on the scale of earthquakes and hurricanes; an exponential increase in our species' capacity to destroy; a hazard raised to the all-encompassing dimensions of clouds and oceans—climate itself.

At the time of the Able and Baker tests, eighteen tons of cinematography equipment and more than half the world's supply of film stock was present at Bikini; every bomb photographed and filmed from a multitude of angles. While much of this effort served an analytic enterprise on the part of military scientists and engineers, it also had a propaganda function. It was in the Marshall Islands that the nuclear blast as an image project reached its apogee: a performance writ large, attended by a huge public relations machine. This aspect of Operation Crossroads rendered one of the most remote places in the world the most photographed. In this light, just as one talks about the science of the bombs, or the testing of warheads at Bikini, one must also talk about the manipulation of the global visual imaginary—deploying pictures as munitions.

But in order to *shoot*, the camera had to take on a new dimension. The array of concrete housings that it would leave behind on white-sand beaches stand as the ruins of a studio apparatus dedicated to producing visions of a new world order. Bikini's modern trauma—its culture exiled, its land blasted, vaporized in places, burned, and irradiated—issued from the desire to create an atomic iconography. A dense cloud of images resulted from the explosions there, particles of which continue to circulate, today, constitutive of our cultural atmosphere. As we float within them, it bears remembering that, in the geopolitical Cold War, what was cold was only the surface of the pages and screens that bore the sign of the mushroom cloud. Bikini burned hotter than anything before.

The Windward

For the people of the Marshall Islands, in centuries past, geography was not only a question of fixed reference points like islands and stars, but moving ones too: ocean currents and human bodies. Their traditional mode of navigation relied on the raft as a body-auxiliary that would help them *feel* their way into familiar currents, reading them through a kind of touch, using knowledge of their ebb and flow to effect a floating passage across huge swathes of the open Pacific, in order to arrive safely at an intended destination. This, without the use of a sail or constant reliance on oars. Theirs was navigation by means of drift, for the most part.

Rafts are about letting the waters beneath set a pace of movement and direction for most of time spent navigating. This navigation outsources much of its process. It is an open style of seamanship, which relies on personal exertion only when absolutely necessary. A motor boat plows forward into the future, charting the closest approximation to a straight line possible. It fights the swell, and the flow, on principle. When the waves resist, you can feel the boat push on harder. So much of today's technology shares the motor boat's distaste for drifting. Rafts have little truck with such pugnaciousness.

⋆⋆⋆

The Windward was built in the 1970s. Though it sits high in the water, Brendan, the captain, swears he wouldn't want to be on another in heavy weather. It is tried and tested, and looks it too. Noisy, smelling of fuel and paint, to us it appears a rather alien piece of machinery—a chunk of steel that should contravene the rule of flotation.

Its broad aft deck is where the compressors, tanks, and dive gear are stowed. But the main feature of this area is a mean-looking hyperbaric chamber, hidden partially under a shroud of tarpaulin—a thick steel tube, like a torpedo, studded with bolts, a few gauges, and a little porthole. As far as we are aware, it is the only such piece of equipment in the Marshalls—save for one on the closed US naval base at Kwajalein Atoll. Though it looks a bit rusty and primitive, it is a necessity: Deco diving in the middle of nowhere should not be attempted without one. The dive profiles at Bikini will give you the bends, as a rule, unless you plan meticulously and successfully perform your decompression procedures. As we're admiring the facility, John steps out from the galley to tell us that dinner is ready. But not before he approaches and asks if we like what we see. Yes, we say—*and* we never want to see its inside. We have to ask, though. He says of course he has had to operate the chamber a few times. People push their limits, especially with closed-circuit rebreather systems. A couple just weren't good enough divers to be taking on the sites—basic mistakes, like losing control of their depth during the safety stop.

***

The Narc

Diving the wrecks of Bikini Atoll requires intense preparation. Lying some sixty meters below the water's surface, only the successful performance of a host of specialized scuba processes can deliver you to them and bring you back without the bends. The aim of this kind of diving is to operate at the limits of the feasible, in terms of depth, time, and human physiology. It is a system for managing the greatest degree of risk while remaining in control and achieving objectives underwater. Technical diving is a practice wholly concerned with the outer regions of safety, defined *technically* as opposed to recreationally.

The theoretical aspect of this sort of diving involves studying the interplay between physics and biology relevant to a person's consumption of multiple gas mixtures over the course of a single dive. Breathing regular air at pressure causes progressively increased degrees of physiological impairment the deeper you go, due to nitrogen narcosis. It also ushers in the risks of oxygen toxicity based on the partial pressure of the breathing mixture. Switching gases to avoid both of these factors is the name of the game. But this practice requires an understanding of when to switch and at which depth. Such factors are unique to each dive profile and must be planned every time, individually. Switching too soon or at the wrong depth, or miscalculating the length of time needed for any stage of the decompression procedure, is no benign mathematical error, but can bring on fits, paralysis, incontinence, bubbles in the brain, and even death.

In addition to the theory, there is an exponential increase in gear: You don't use a Buoyancy Control Device (BCD), which is a kind of a plug-and-play system. Instead, you put on "wings"—a kind of streamlined harness incorporating a thin steel plate and numerous metal rings for attaching things. It looks closer to rock climbing equipment than something for scuba and requires a lot of attention to set up before each dive. You strap two tanks onto the back of it instead of a normal single. To the front, you clip another, containing a higher percent oxygen mix. Instead of two regulators, you have three. You also need three delayed surface marker buoys (DSMBs): one to deploy during decompression, another if you have a problem and need to alert the surface, and a third in case you lose one. In addition to your first dive computer, you wear a backup. And if both fail, your dive plan is also written out on a slate, which you strap to your other forearm. You carry a spare mask and two torches. You wear a knife on your leg, should you need to cut yourself out of a tangle, and whatever other tools your mission requires—in our case, cameras and lights.

Laden with all these things, underwater, you need to be comfortable and in control. You also need to be much more aware of your buoyancy than on a recreational dive, as the border between safety and danger can hinge on a meter during decompression. To maintain your depth, precisely, you need to be alert to your body, noticing subtle changes in pressure before you have to look at an altimeter. With so many objects to take care of, you cannot be constantly checking throughout the forty-something minutes you spend hanging on the line.

At the end of the theoretical and practical training, our instructor, Nico, says that he is passing us. According to the terms of his insurance, thus far, he has only brought us to forty-five meters and no deeper. Now that you are newly minted technical divers—he states with a wry smile—I'll take you down to sixty, *just so you can feel it*. This seems like a figure of speech. So far, everything appears the same, whether at twenty, thirty, or forty. Once you pass that second atmosphere, at ten meters, and have equalized, your inner ear is set up. He tells us that the plan is to jump in and go straight down until we hit depth, then we will ascend. *Just a bounce*, he says.

We tip backward over the side of the zodiac and purge the air from our wings, descending headfirst for a few seconds amid a rumble of bubbles. We feel a squeeze around our necks as the pressure increases as well as the swift chill of the thermocline, sitting high-up in the water column. As we slide down a little deeper into the water, righting ourselves, it takes on the green-brown color of crocodile skin, and before long visibility is just a meter, our fins barely visible through the fog. We are sinking, but apart from the initial visceral register of the pressure, there is no way to tell that we are moving, except for the altimeter function on our computers, ticking away. In less than a minute, we are at forty. Forty-one. Forty-two—and there is no bottom, just blurry darkness.

At this rate of descent, you start to think that you will soon hit your limit and that, as a matter of necessity, it is time to slow down. So, you inject some air into your wing—a conservative amount, so you don't shoot up like a rocket toward the surface. It has no effect, and the computer keeps ticking the meters away. Deeper. Still negative buoyancy. You reason that the pressure at this depth is greater than anything encountered in training, so you give it double. No result. Still falling, now scared. The thought of sinking further into the yawning chasm, beyond recovery, is horrifying. At fifty-five meters, you are charged with adrenalin, alert, and trying to work it out, when—all of a sudden—you are dunked into a pool of insanity. A wave of intoxication breaks throughout your bloodstream; your brain enveloped by a tsunami of nitrogen, rendering you dizzy and confused.

What makes the intoxication so terrifying is that you possess just enough awareness to know that you have lost the thread—that you are unable to make a plan, barely able to make sense of the numbers on your computer. You are out of control and the abyss is taking you. In panic at this realization, you start to breathe heavy. And with heavier breathing comes more narcosis—a downward cognitive spiral. Now you are hyperventilating. You can't get enough air out of the regulator. It feels like the device is the problem—stopping you from getting the breath you need. You feel like spitting it out, opening your mouth wide and drinking the air, even though the still-useful part of your mind knows that this is the worst thing you could do. You know, too, that freaking out is a grave mistake, and so you panic even more. You kick your legs because you no longer trust your wing. No escape. Fifty-nine. Sixty. Sixty-one—and you turn to look for Nico, gesticulating wildly to indicate that you have lost control; that you are fucked up. Later, Nico says he saw the fear of death in your eyes.

Once Nico sees it, he takes over. He firmly grabs your shoulder, extending his arm and locking his elbow—placing maximum distance between his body and yours while keeping hold. The reason for this, we learned in our rescue training, is that panicking divers have a tendency to claw at the person trying to save them, sometimes ripping away their mask or regulator, perhaps even trying to steal the latter, abandoning themselves to shameful instinct.

He holds you there and stabilizes your depth. Then, he looks you in the eye and holds you with his gaze, making you understand that he is in control; that *somebody* is—delivering you from the anxiety of having to take care of yourself. This done, the panic is gone—despite the remaining narcosis. A few seconds, then a simple gesture: a thumb pointing up, indicating that we should now ascend. And we do, slowly, meter by meter. Sixty. Fifty-nine. Fifty-eight. His hand still gripping your shoulder. When you reach forty, though still intoxicated, you can feel it start to drop off, like you have passed the apex of its bell curve. You can see, now, that you will not fall any deeper into the trip. You are ready to take back control of your life. You point to yourself, then offer Nico the classic hand sign for OK. He lets you go, and the rescue part of the dive is over. All that is left is to make a controlled ascent.

Bikini

The skiff pulls up at a short jetty, running out from a beach of the most refined sand one might ever hope to see. The word "unspoiled" immediately springs to mind: not a single thing floating in the water, gentle waves lapping at the shore. The brightness is phenomenal.

Penny, the Windward's first mate, a heavy-set Tahitian with a quiet demeanor, has radioed ahead, and we are met by a pickup truck full of five young guys who, we will later understand, are nearly all of the island's current inhabitants. Our skiff isn't just loaded with camera gear but also cool-boxes full of frozen steak, tinned food, and beer for them—a necessary courtesy if you call in here, a kind of exchange for the use of their vehicle and its precious, limited fuel. Once loaded, we drive along a straight road flanked on each side by coconut groves for a half a kilometer or so, until we reach the geographical center of the Bikinian nation. It is a cul-de-sac, no more than ten small buildings, many of them clearly disused. A few are utilities, seemingly offices or sheds as well as a tin building full of machine parts with a sign hanging above its door inscribed with the statement "We can fix anything, except a broken heart." On the left, a fence surrounds a small parcel of land containing a few graves and palms.

The island is narrow, like all the others that make up the atoll, and most of the buildings are situated directly on the waterfront. To our left, the architecture looks familiar. There is a gazebo with a bar underneath it and a few uniform bungalows on the edge of the sand—the remains of a defunct diving resort. The venture was an attempt to establish an economic motor here, one that might eventually allow the island to support a more representative proportion of the Bikinian people. Its core customer base was to be dive tourists and their families. And it worked, for a minute, before coming to a quick halt. The atoll's remoteness, compounded by the incredible unreliability of the national airline, which frequently left guests stranded for weeks onsite, as well as the misgivings that many holiday planners had about visiting a nuclear blast zone, made it untenable. Nobody wants their child to make sandcastles out of radioactive sand. And that was it. Now, like the rest of the town, the resort's buildings stare down an inexorable march toward becoming driftwood.

Almost everything here is in limbo; a confection or a stopgap. The buildings that aren't rotten are on life support. The best kept is a diesel-run "power plant" administered by the US Department of Energy, which supplies electricity to the other buildings. The main function of these buildings is to house the workers who take care of the plant. That, and a few unnecessary streetlights, as well as the resort's air conditioning system. It is the simulacrum of a town: a *mise en abyme* of utility. Given that they rotate on and off of the island only once, for a period of six months, and mostly never return, the few persons residing here constitute placeholders in lieu of any settled community. In a kind of birthright scheme, Bikinian youngsters based in Majuro, and elsewhere, apply for a tour of duty, the only chance most of them will ever have to encounter their homeland. It is a kind of privilege to get selected.

At least in terms of their official mission, those who pass through perform a minimal image of inhabitation—"keeping things running"—according to a desiccated economic, industrial, and spatial outline: putting diesel in the generator. Witnessing their honest attempt to work with the thin script that they have been handed, to keep this place human and maintain a fragile edifice of occupation in the face of staggering dispossession—effected by their people's enforced exodus—does nothing to foreclose an impression of failure. It's sad. One of the most beautiful places on Earth, struck through with an unshakable sense of inertia. And yet, without the aporia of the generator, this vortex of colonial infrastructure, there would be no birthright travel at all: No fishing on an ancestral beach. No swimming. No boxes of fish to address to relatives back in Majuro, for us to carry back with us. We take the packages and promise that they will be delivered.

⋆⋆⋆

Instant coffee as the sun climbs above the water, its rays casting an optimistic glow over the morning. The night's fog beginning to lift, we discuss the possibility of returning, someday, and filling the resort with friends. We decide to walk around the town to check out the mechanical depot and houses. Opposite the former, there are three steel shipping containers that have been welded together to comprise a makeshift building, above whose doorway a sign is mounted that reads "King Juda Memorial Laboratory." Juda was the last leader of the Bikinians to reside here, the man who agreed to nuclear exodus, pressured into accepting the notion that his people should leave their ancestral home "for the good of mankind and to end all wars." Here, in symbolic exchange for acquiescence to the greatest of geophysical experiments, stands his hollow recognition, as if his capitulation inaugurated a new age of scientific enterprise for his nation; as if, rather than marking a future of dispossession, participation in the nuclear project would secure the Bikinians a path toward the world's intellectual–industrial big table. The cipher for this putative legacy, out of sight from the rest of the world, and crumbling away in front of our eyes, is nothing more than a shell—open to the elements, empty, and in no better condition than the rusting oil drums nearby. The "laboratory," some kind of gift from the United States, was a lie. A lie so badly told, and without effort, that its offense issues as much from contempt for its audience as for the truth itself. An untended falsehood. A perjury, disgracing science and humanity—rotting away at the center of an excuse for a society, in a place that once was; an empty concession, offered without care, and immediately forgotten.

⋆⋆⋆

The Body

You push the compressed foam buds deep into your ears. At first, they do little to counteract the noise, but as they expand, it diminishes—the boat's movement beginning to separate from the sonic dimension. You begin to feel like you have left part of the disorder behind that you are less subject to it. In this, you think—intellect reaching out from the depths of nausea, for a hold, for a second—there is a symptom: Culture is subject to atmospheric conditions, which include various complexes that are all sometimes called the Environment. Some of those who float within them are convinced that they are *not* immersed at all. But their outlook betrays a narcosis, like the sort a diver feels when they have gone too deep, for too long. When you are properly in its grip, you get sloppy. You forget both what you were doing and what to do next. Narcotic floating entails just letting things happen; running out of time, onward, to death. The floater's epistemological disorder—wherein they do not recognize the dynamic composition of their own image within the apparent Environment—is no less dangerous.

The earplugs work. You start to feel yourself calm as the last of the noise dissolves. You begin to nestle, more deeply, into the bunk's cocoon. Against unsettled surroundings, you focus on simple breathing. You want to re-inhabit your body, without that churning feeling. The cot rocks, again, and again. Deeper, until sea-change. That dizzy hope of shutting out the surge and retreating within now telescopes, in reverse: Equilibrium is a tide you can feel, attending the dissipation of your body—into the boat, and the waves; a flow, running out from your interior molecules to a blanket, a cot, a cabin, a craft, a crest, then another. Another, still, bearing a plastic bottle in its foam, swimming, like your thoughts, through the Pacific.

It is often said that people who are unaware of an imminent environmental problem, or who imagine nothing needs to change, are living in a bubble—you think, right-hand pulling the blanket around your chest. Paying attention to a system designed to manage actual bubbles and sustain human life facilitates a deeper dream. The scuba circuit is—a wave, lifting you. Carried by the hand of the boat. Palm of the night. The scuba circuit is—now falling, further into reverie. It is a microcosm. A microcosm of a body relationship with a surrounding atmosphere, mediated by technology and subject to clear resource constraints. Deeper. Technical diving is—the nadir—an object lesson: an intense reckoning with the reality of the *atmospheric*, that swirl of physical, biological, mechanical, and symbolic conditions—their flows in and out of one another and our life within them. Listing, now, and rising—swell turning. It is a spring from which a vision of the relationship between culture and materiality emanates.

The cabin rolls to port, and your body too—almost out of the bunk. Your hands swim down each side of the mattress, until they find the belt straps attached to the bed frame, before drawing and clipping them together. It was always going to be like this. Now that you are lashed to the boat, and the sea, you give over, falling away from the feeling in your skin, and your stomach. Sinking. Further, toward a dark keyhole—down there. A line runs out from it, to you. You swim in its direction, half drifting. Closer. You reach for it with languid arms and slow hands. Your fingers clasp. It tugs, gently, willing your descent. You begin to follow it, one hand in front of the other. Pulling, slowly. A rhythm. An easy rhythm and the weight of gravity. Once you have begun, it requires no effort at all. The water column presses you on. One hand, then another. A meter. A second. More. Further, onward. One hand, then another. Deeper—one hand full of nylon, then another, as you pick up the BCD. That clumsy assemblage—weighty and damp, sprouting a mess of belts, tubes, and metal rings, harnessed to a pair of tanks. It always takes more effort than you expect to discover if it is up, or down, or inside out. Clinking noises as you heave it over your shoulders. Your left arm misses the correct hole, going between a rubber hose and a strap. Another attempt, this time correct. It is intensely heavy. You slump down onto a bench. Then, you begin to gather a pair of straps around your hips, pulling them tight at the buckle. Then another pair, which clips together at your sternum, tighter still, digging, a little, into the bone. Plugging in, you notice that technology is a body atmosphere—an exoskeleton. Clothes are exoskeletons. So are cars and houses, just like this scuba rig. All are tools that supplement viability. One reason we fail to recognize this on the surface is because, here, its markers are often so much bigger, relative to our biological selves. More tightening. The terrestrial exoskeleton is not dense enough for us to perceive it as such—spread out; urban sprawl. Against this, the sea compresses the topic, pushing its registers back toward a corporeal measure. Air, it seems, has been the agent of our alienation.

More layers of gadgets—atop the BCD, itself atop the wetsuit; clips, lines, bags, lights, a knife, a computer, fins, a hood, and mask. You stick a regulator into your mouth, connected to a hose that must deliver air from the twin cylinders strapped to your back. You test it. Having plugged your fleshy self into a pneumatic circuit made of rubber pipes, plastic, and beat-up aluminum, the crudeness of the construction repulses, and the first breath suffocates.

You wake up with a gasp. You can taste salt in your mouth, having sucked the damp from your pillow. You roll over, still tethered to the bunk. The boat is moving a little less violently now, and your mind's part-surfacing grasps that the ocean is more pacific. Still rocking, but with a steady rhythm. You start to drift, again. Deeper, this time.

A giant stride into the water, where the burden lightens. Descent. As you sink, investment in your rig grows. Above, it felt constraining. Now you are totally dependent on it, to pilot and survive. Above, recognizing your reliance on a given technical apparatus seemed optional; an intellectual matter. Here, in the blue, there is no bubble large enough to support such vanity. Your head is no longer in the clouds.

You lean forward a little, letting the weight of your tanks take over, pushing you into prone. You move your hands and feet without thinking—a crawling reflex—until you are ready to take that breath. The deeper one. The one imbued with a reordering of the relation between air and water, within you and without. That expansion of your subaquatic body, in your mind, and your intentional drift into this place. Twenty million years of human evolution served to consolidate your species' passage toward verticality. Having given up the horizontal orientation of our ancestors, in waking life, we reserve the prone position for sleeping. Now you are ready to reassert the dynamic potential of this alignment. You begin to kick. After three strokes, it doesn't feel as though your feet have left a ground for action. Here, underwater, you are starting to move *within* one.

Ten meters below. The environment squeezes in, around you. On the surface, you were subject to one atmosphere. Here, the pressure is two. The mask sucks painfully at your face. You dove in order to *see*, but the ocean resists—compressing the air between your eyeballs and the glass. You blow into this space, to stop your capillaries from rupturing. And you keep descending. Twenty meters. Three atmospheres. Your wetsuit feels vacuum-packed around your legs and groin. You urinate. This method of reordering the density of molecules between your body and its second skin—and the wide ocean—is not mentioned in any dive manual. Not mentioned, despite the fact that scuba competency requires being able to use your lungs as a higher-order buoyancy device, supplementary to your BCD. In as much as they operate as pneumatic swim bladders, here, your actual bladder has a hydraulic role to play. Like the practice of equalizing the pressure differential between your inner ear and the water, it is a pain management device. Thirty. Four atmospheres. The deeper you dive, the more you are compressed. Parts of your body that you never thought could be squeezed, and some you never knew existed, register their objections. Until they don't.

Airok

The zodiac approaches Airok. As we enter the shallows, Penny points out a small black tip, right off the port rail, and another shark of about a meter in length that is almost luminous yellow in color. Nearby, between tangles of rusting metal and pipes, there are giant clam shells. But none of these strange milestones hold our attention for long. There it is: a huge bunker, lying right on the beach at the waterline, as if it had washed ashore in a storm. Waves of erosion look to have opened up a cavity beneath it on one side, such that half of its base is now an overhang, resembling a brutalist cantilever. As we circle a little, looking for a place to anchor, its back comes into view. There, jammed between the cantilever and another elevated slab of concrete, is a massive plug of pulverized coral, recalling limestone from the Jurassic period. This material conjunction is strange, but its twisted logic soon becomes apparent: During an almost unimaginably powerful explosion, billions of particles were pushed into motion, flying through the sky before smashing into it with such intensity that they were forced into a compound: squeezed into stone.

On the beach, now facing it head-on. This was a filming station, housing cameras to document the size and shape of mushroom clouds, so that each blast might be analyzed, so that bigger and better bombs might be brought into the world. With its four eye-like openings, the structure resembles a giant skull—a totem for an alien religion. Beneath them, a gaping doorway beckons. The Geiger counter objects a little more than it did when we were on the boat, but not too much, so in we go. Rust and slime. It is like the inside of a mollusk. Stalactites of calcite drip from the ceiling and flaking rebar pokes out from the walls and up from the floor. Throughout, a rushing sound reverberates: We are listening to the sea, in a shell.

Once back outside, we reflect on the meaning of the structure, whose hulking form now takes on a new valence—not just a building, but a camera body. The photo negative has always been an invertebrate, reliant on an exoskeleton. It is as if, at the birth of the atomic age, it outgrew its shell: In order to capture the image of the bomb, its housing had to scale up to the dimension of battlements. In the manner of a hermit crab, it had to leave its old armor and crawl into the space of architecture. In fact, architectural symptoms are standard mutations precipitated by atomic enterprise. There is no atomic technology without the development of special facilities, built of super-strength materials, and so on. The nuclear entails an envelope that reflects its colossal power.

⋆⋆⋆

Crater

Daybreak. Our wakeup call, the same as every day, is a holler from the galley—loud enough to cut through our earplugs and shake us away from sleep. We fall out of our bunks and fly up the ladder, into coffee and plates of scrambled eggs, before heading out onto deck to check the swell. On the way out the door, Brendan says Trump has won.

It's light, and our torpor abates as we spy today's site: Castle Bravo, the biggest anthropogenic crater in the world, a circle of sand two kilometers across whose center is another lagoon. The result of an almost laughable miscalculation, Bravo was two and a half times more powerful than expected, delivering an explosion of fifteen megatons, leaving the scar that we are here to visit. As the caffeine kicks in, we are reminded that this means diving it.

Bravo seems like a place that you should never visit, a place that does not belong in any positive sense to anyone. It is one of the few places that might be happily erased from the memory of the Earth. Staring it down, like every other fright we've gone to meticulous lengths to encounter on this expedition, we only have ourselves to blame. No one forced us here. Sometimes, you get what you wish for. We put on our gear, more carried along by the group dynamic than anything like enthusiasm. And yet, in the face of our reluctance, dawn starts to break, more exquisite than any other so far on this trip: The sea is flat and mirrorlike; the sky free of clouds and without wind. As the morning comes on, we're given to understand why the Pacific has its name. Now, fully geared up, everything seems a little better. And without needing to put together an enhanced dive plan for deco, our spirits are doubly improved. We get into the zodiac, cameras in hand, and chart a course a few hundred meters into the epicenter.

The thing that normally springs to mind when you imagine a lagoon is turquoise water and a shallow, yellow, sandy bottom: the fish bowl experience, that cliché image sold in tourist brochures. But after the green almost-open-water current attending the Saratoga and Nagato, we've come to expect otherwise. As we throw ourselves backward over the edge and into the crater, the situation immediately surprises. Eyelids unclenched after the splash, the water is suffused with a vivid luminosity, almost blinding bright as the sun bounces off the internal parabola of the crater, concentrating in its center like the flash of a camera stilled in time.

The bottom is soft and welcoming, its sand incredibly fine. Was it bleached by the explosion? Apart from not being in possession of an underwater Geiger counter, everything is perfect. In any case, worrying about radiation is, counterintuitively, a bit fanciful. The water here has been constantly changing over the last seven decades, passing in and out of the great surrounding ocean. All this time, local radioactive particles have been picked up and carried along for hundreds of miles before sinking into deep currents and spreading throughout the globe. A bit of Bravo might be just as easily found in Antarctica, Australia, or anywhere else, for that matter. In fact, marine microbiologists all over the world use the presence of its isotopes to establish a baseline when dating their samples. Today, we are not diving a crater but the central gear of a clock.

There are small fish here. Shrimps too, and hermit crabs. Everywhere, there is movement. We imagined a desert and we find the opposite. Instead of a dead zone, the caldera is alive. For all of its reputation as contaminated, Bikini is also a kind of marine park. The proscription afforded by its nuclear past has meant that coral has been left free to return, unassailed by trawlers, dynamite, or pollutants.

A clang—the sound of a knife hitting a tank. A call for attention. We swivel to find out why and there, right behind us, are two gray reef sharks that have been approaching unseen by all of us except John. We turn to face them, as you must always look a shark in the eye. They continue to approach before turning sharply away on the perpendicular, just a few meters out, to give us a full view of their size. Then, they head back the way they came, before once again repeating the challenge. It is a little too close for comfort. We gather closer together, as if to suggest that we're one large creature, defiantly blowing bubbles to show them, we hope, who is in control of the space. They circle us, perhaps to demonstrate that we're trapped, or to push us more tightly together, into a human bait ball. There's nothing to do but keep moving, though, as we have our objective—to shoot the steepest part of the crater cone—and it is not here. So, we continue our swim, each one of us turning around regularly, so that our group has no tail—eyes everywhere. Later, John tells us that the grays were being territorial, like dogs, and that they saw us more as competitors than lunch.

Once we've exited their stalking grounds, the sharks lose interest, and we can turn our attention back to the general scene. As we swim in the direction of the slope, tracking the bottom, we encounter pinnacles of coral sticking out of the sand, randomly, like so many stones in a Japanese garden. Each of them seems to function as its own microcosmos, orbited by tiny fish. Against the shocking turquoise, they almost look like they might be features in an aquarium. Strange. It is as if the crater served as a barrier, protecting the waters within, establishing a new test site—a biological petri dish on an even gradient. Despite once being the epicenter of a fission bomb blast, seventy years of human absence has allowed the reef to regenerate, fusing man-made landscape and the will of the sea.

Arkansas

The days and nights pass, one after the other. The routine: gearing up, jumping in, sinking, equalizing, breathing, ascending, emerging, resting, then jumping back in again; long walks across the sand; or shuffling through jungle with crates strapped to our backs, lugging gear through Pandanus groves, walking atop generations of palm fronds; attending concrete temples.

At the bottom of the lagoon, you are staring up at the inverted bow of the dreadnought USS Arkansas—which looks like the gigantic dorsal fin of a behemoth, something between machine and animal, a tower, or the face of a mountain. Its powerful figure rises against a color field of dark blue. But this optical minimalism is no void. It is completely full, a dynamic volume that pushes against you, around you. Every part of this volume is in motion, and there is no way to take a fixed position. You can't stand and meditate. You're being pulled all over the place. You have to fight to approach the wreck. If you manage, on first sight, the broad outline of its figure might seem simple or rationalized. But in detail, it is another teaming hive of life: Things are crawling over it, growing out of it, circling it, moving in and out of it, hiding behind it, and nestling within its cracks.

To look at it, you have to breathe in a certain way, to control your body as much as respire. To get here and look at it you have to squeeze into a second skin, strap on weights, bite down on a hose, and trust in a material outsourcing of your lungs. You have to study a system and follow it; believing that you are ready to approach the scene. You have to cast off from a life-world you know and commit yourself to another space, *its* atmosphere, understanding that you cannot stay. It is more than any artwork has ever asked of you. More than any church you know about. It is the greatest installation in the world. It wasn't put here to be loved or looked at. It was put here to be forgotten.

You're looking at one of the largest human constructions ever offered in sacrifice. Think of the mythos that this object encapsulates—how it enchanted industrial creation. Think of the hundreds of people whose labor served to manufacture it, and beyond them, the millions more mobilized in its service. All of this is implicated here, in this object, a vessel in the truest sense of the word, containing the will of its creators. Think of the will of the vanquished, also, obtaining in the Nagato and the others, likewise given up to a tumult of fire and fury. These vessels, too, along with a whole way of life that had no stake in such enterprise, rendered unto a victory ritual of an entirely modern order: the experiment.

Today, we parse the bones in what must be considered an underwater museum. If it is not a museum, then it is nothing at all. And if it is nothing, then we have not learned, and Bikini never mattered. But it mattered to *them*. And if Bikini doesn't matter to us, then how can we be sure that anything we attempt ever can? This museum is a place without labels, and minimal onsite interpretation. Its sole guardian is George, the only Bikinian equipped to enter it, and he is employed ad hoc. Here, sixty meters down from the impression that all is sunny is an atrocity exhibition, gathering together the insane cult objects of the world's leading industrial powers. It is underexposed—almost lost—and *that* is what is crazy about it.

Bereft of true resettlement and attention, Bikini is asleep. And through its sleep, the outlines of our present blur, as if we are dreaming. Few will ever visit these ships, and so their resonances are unfelt. But they comprise a museum. This, we assert. And every museum presupposes a public, as witness, who, through attending, become a community. Without visitors, a museum cannot shape identity that locus of care and thought. A lost exhibition hardly exists at all. Though named an essential part of the world's heritage, Bikini's wrecks are, in practice, a private collection—less accessible than the most exclusive vernissage. Against the very concept of public good, their display is only available to a few. This is one of the most significant exhibitions ever opened. No one was invited, and hardly anyone knows about it.

We should raise these ships and deposit them on the famous squares of the world—Trafalgar, Concorde, the Washington Mall—like beached whales. We should haul up these rotten tokens of a civilization we have yet to overcome. What is unrealistic about hoisting the wrecks of Bikini lagoon, transporting them across the globe, and installing them at the center of our leading nation-states at a cost of billions of dollars? What is impractical about burning fuel enough to power the armada it would take to carry them back? How is any of this expenditure, pollution, and effort unrealistic compared to the power and waste effected during their genesis—not to mention their sacrifice? Comparatively speaking, it is a modest proposal.

But we can't bring the ships back. And while it is obvious that there is no medium capable of capturing the experience of encountering them here, in the lagoon, we must try. At the end of the world and a journey deeper than we ever imagined, we float, facing sights that nearly defy our powers of comprehension, to say nothing of representation. Can we fix them in an image? No. It is clear that any attempt to place this reality in a single reckoning is doomed. There is no frame big enough.

In this atoll, reverie flows like water. One image leads to another: A photograph leads to a film; a film leads to a book; a journey leads to a story—that we tell once, twice, again and again; at the bar; after dinner; to anyone who will listen. Sometimes, the currents are navigable, moving in and out of the lagoon: A tide pulls us out into the past, that ocean of what has come. Another carries us into days that have yet to be, and all that we want to say. But there are also vortices, orbiting a mass of dreaming as dense as a planet, here at the center of the atoll. In them, our images move. People recognize the signs but don't know what we mean. We say Pikinni. *Bikini.* And people answer, Yes. We promise something clear, but it is nothing of the sort. Adrift, we can only embrace the current, heading forward into the past, and backward into the future. In this tide, there is no swimming for shore. Bikini. Pʲi͡ɯɡɯ͡inʲii̯—we never left your lagoon. The truth of our drift is submerged, somewhere in the South Pacific. Deep, past gun turrets and propellers, over the edge of a hull, beyond the monstrous hulk of a battleship, amid a column of seawater, running over coral sand, out into the blue. It is a tide containing us. Witnesses. Image makers—as we used to float.

END

Further reading

Jacquelyn Allen-Collinson & John Hockey, 'Feeling the way: Notes toward a haptic phenomenology of distance running and scuba diving', *International Review for the Sociology of Sport*, Vol. 46, 2010, pp. 330–345.

Gaston Bachelard, *Water and Dreams: An Essay on the Imagination of Matter*, The Pegasus Foundation—Dallas Institute of Humanities and Culture Publications, Dallas, 2006.

Stefan Helmreich, *Alien Ocean: Anthropological Voyages in Microbial Seas*, University of California Press, Berkeley, 2009.
Sara Malou Strandvad, 'Under water and into yourself: Emotional experiences of freediving contact information', *Emotion, Space and Society*, Vol. 27, 2018, pp. 52–59.
Stephanie Merchant, 'Negotiating underwater space: The sensorium, the body and the practice of scuba-diving', *Tourist Studies*, Vol. 11, Issue 3, 2011, pp. 215–234.
Jack Niedenthal, *For the Good of Mankind: A History of the People of Bikini and Their Islands*, Bravo Publishing, Maduro, 2013.
Felicity Picken & Tristan Ferguson, 'Diving with Donna Haraway and the promise of a blue planet', *Society and Space*, Vol. 32, 2014, pp. 329–341.
Richard Rhodes, *Dark Sun: The Making of the Hydrogen*, Bomb, Simon & Schuster, New York City, 2005.
Nadim Samman (ed.), *Julian Charrière: Second Suns*, Hatje Cantz, Berlin, 2019.
Nadim Samman & Julian Charrière, *As We Used to Float: Within Bikini Atoll*, K. Verlag, Berlin, 2018 (Full text).
Jack A. Tobin, *Stories from the Marshall Islands*, University of Hawai'i Press, Honolulu, 2002.
Simon Winchester, *Pacific: The Ocean of the Future*, William Collins, London, 2015.
Stories from the Marshall Islands, edited by Jack Tobin, Honolulu: University of Hawaii Press, 2002, pp. 11–26.

Section 9
Atmospherics

Dehlia Hannah

> If you really want to know how a culture works, ask how it reads the sky.[1]
>
> —*John Durham Peters*

The previous section foregrounded a variety of modes of *exposure to the elements*—practices of bodily encounter and critical reflection upon environments in crisis, developed by artists, curators, and theorists. Inspired by Gaston Bachelard's studies of material imagination, the essays collected there track a move from the classical elements of earth, water, air, and fire to the new materials of the Anthropocene: plastic, nuclear radiation, synthetic chemicals, real and speculative organisms adapted to novel conditions. Mediated by scientific knowledge and technological apparatuses, as well as their critical understanding within Science and Technology Studies (STS), encounters with novel anthropogenic substances inform contemporary environmental aesthetics and politics. The large-scale displacement of matter constitutes a second-order assault on the geography of the elements, disturbing geophysical cycles of circulation between land, sea, and sky. This is perhaps nowhere so urgently felt as in the reassessment of the status of *air*. Saturated with fossil fuels disinterred from within the bowels of the earth, air becomes the locus of anthropogenic climate change and its attendant strange weather, airborne pollution, a hole in the ozone layer, a thinning atmosphere, a medium of communication, and an object of intense quantification, among other foreboding propositions. As clear skies give way to more troubled air-conditions, ways of noticing, imagining and speaking about (the) atmosphere is changing, diverging from the floaty aesthetics of Bachelard's philosophical moment.[2] Organized as a case study of air, this section presents contemporary artists' and theorists' efforts to image, read and write Anthropocene skies.

If air was once clear and empty, so transparent that it might be forgotten (cf. Irigaray 1999), then something in its concept and its content has changed.[3] By the twentieth century, air had become a problem, as discussed in the following essays. Peter Sloterdijk dates its problematization precisely to the advent of poison gas warfare during World War I.[4] But like the unresolved (perhaps unresolvable) question of when the Anthropocene began, the question itself is a symptom of a problem, which registers awareness of a rift between an idea and its worldly referent. Once the discrepancy has been highlighted, one wonders how long it has

DOI: 10.4324/9780429437069-47

gone unnoticed, when the chasm began to open, what set it into motion, how far the idea has diverged from its historical predecessors, and what its futures may hold. These are queries that the authors in this section take up, marshaling a body of shared theoretical resources, historical and contemporary artworks, and an acute sensitivity to air as a space of scientific and political controversy. Through their writings on atmosphere, climate, weather, clouds, wind, gases, and other aerial matters, air is deprived of its obviousness. It appears, instead, through the artifices of artistic and technological apparatus and bulky socio-technical configurations. Rather than a stable background of everyday life, a basic substance to be sampled and analyzed (or even reduced into simpler substances), it becomes a site of operations: a domain to be conditioned.

Turning our attention skyward, it is evident that air registers the imprint of human agencies. Yet, its temporality differs from that of the geological record. Long before the dust settles, before radioactive tracers are circulated through the atmosphere and oceans, before being deposited into layers of sediment; before bubbles of CO_2 are frozen into ice which may last for millennia, traces of human activities are manifest in every layer of the atmosphere—albeit in fleeting forms and shifting concentrations. Like the temporary patterns created from the exhausts of jet airplanes, these inscriptions demand special modes of attention. Instead of looking down into the strata for marks that will last for eons, we must look up in the here and now, so as not to miss rapid shifts (e.g., pressure or wind direction), changeable shapes (clouds and weather systems), moving currents, and gradual trends. At the short end of the temporal spectrum, sudden storms and fluctuations in air quality are so ephemeral that they may escape notice or official detection. Enter citizen scientists, storm chasers, unauthorized reports and attendant questions of epistemic authority, objectivity, and witnessing. At the other end, the longue durée of climate change—known indirectly through climate models, statistics, and scenarios—strains cultural imagination, opening up fertile space for doubt and denial. As Robert Markley argues, climate change opens up a rift between the temporality of embodied experience and the intensively mediated time of global trends and model projections, which he calls "climatological time".[5] This section addresses some of the challenges that these qualities pose to narrative and visual representation, foregrounding a diversity of artistic and creative writing practices for engaging air's turbulent modes of being. Each of the essays collected here attests to the importance of art and creative, transdisciplinary practices in articulating emergent notions of atmosphere and its dynamics.

Where gods were once borne along on ethereal gusts and winged sandals, messages are now carried on every wavelength of the electromagnetic spectrum. In this sense, air has always been a space of a mediation—and hence of mesoaesthetics (cf. Yang, this volume). Yet, if it was once air's changeable and insubstantial qualities that allowed it to mediate between the heavens and earthly affairs (among other axes), these qualities are now subsumed by sophisticated communications, transportation, and computing technologies. Erected in the early twentieth century, the global infrastructure for weather prediction and communications laid the ground for contemporary climatology and the confirmation of anthropogenic climate change—hypothesized since the mid-nineteenth century.[6] Air as a medium is, itself, intensely mediated. Indeed, its most visible figural motif, the cloud, has been appropriated in the service of a digital economy committed to the ideology of lightness, immateriality, and instantaneous transmission. These strange transubstantiations are a focus of media studies, which has emerged as a theoretical discipline central to thinking contemporary air. As such, the following essays present media studies as a crucial next of art and STS and offer complementary takes on a set of key theoretical and artistic references. Air is presented here as entangled, swirling, and sometimes suffocating. On the other hand, it is intensely material, particulate, and heavy with unwanted components in gaseous, liquid, and solid states—greenhouse gases including carbon dioxide and methane, poisonous gases such as chlorine, acid rain, and particulates. Indeed, what is contested here is which of the classical elements may be considered dominant in our contemporary atmosphere.

The word 'atmosphere' denotes the gaseous layer that surrounds the earth and renders our planet uniquely habitable by insulating it from the heat of the sun and the cold of space—*the atmosphere.* It also refers to the ambience or feeling of a place or a moment—a tense political atmosphere, for example. Thus, atmosphere is a crucial term for architecture and cultural discourse as well as for the environmental sciences. The title of this section, *Atmospherics*, likewise carries a double meaning, referring to electrical phenomena such as lightning in the atmosphere and their audible effects on radio transmissions as well as to actions and 'special' effects intended to influence the mood of a literary, musical, political, or other context. Today, we must attend to the actions used to influence not only the material composition and habitability of the atmosphere, but also the *atmosphere of the atmosphere*—the actions which influence political, aesthetic, and cultural context in which crucial decisions are made regarding how we shall inhabit this gaseous envelope. Here art and its critical analysis must join STS.

Opening the section, *Archiving Atmosphere* by architect and architectural theorist James Graham proposes that the atmosphere itself be understood as a document inscribed by historical events, much as we imagine the fossil record, ice cores, and layered earth strata. Air's movement and constantly shifting concentrations demand different practices of reading or interpretation than do the inscriptions registered in solid states of matter, yet proper inspection of the gaseous domain discloses traces of an entangled natural and social history, in particular legacies of colonial extractivism and capitalist exploitation. In order to learn to 'read' the atmosphere, Graham examines a series of art and architectural projects which, he offers, "propose something like an exhibitionary practice of air," or approaches to making air legible in its historical particularity. In doing so, he presents a theoretical foundation which is crucial for this section, approaches from philosophy, media studies, anthropology, and art history that have sought to counter air's deceptive transparency, offering in its place a conception of "atmosphere *as* media"—an insight which emerges perhaps most clearly from the perspective of a discipline tasked with managing the boundary conditions dividing outdoor from indoor environments. Graham concludes with a provocation that extends beyond his own text to the following essays: "What these projects and the ideas embedded within them collectively make manifest, then, is something like the respiratory system of capitalism."

Drawing a compelling link between an understanding of atmosphere as media and practices of bodily exposure to the elements, Brett Zehner's *Becoming Tornadic: Towards a Meteorology of Media* follows the path of artists and citizen scientists engaged in storm chasing. In a constructive departure from Jussi Parikka's seminal *A Geology of Media* (2015), Zehner invokes meteorology, whose grappling with rapid fluctuations and flows, the immediacy of weather and the abstraction of climate, and reliance on a particular historical infrastructure of measurement and prediction differ in important ways from geology as a paradigmatic science from which to extrapolate a theory of media. And yet, even within meteorology, tornados present an especially problematic case: their condensed temporality and overwhelming force rendering them both elusive and high priority for forecasters and government agencies tasked with responded to the havoc they regularly wreak. Within the tense ecological and political matrix configured by the temporary phenomenon of the tornado, the storm chaser emerges as an unlikely supplement to the vast apparatus of meteorology—an individual in whom knowledge, risk, and vulnerability are radically condensed. The chaser—who observes the tornado from close but (hopefully) safe proximity—often provides the only "ground truth" (cf. Fine, 2006) observations capable of corroborating remote sensing technologies and the accounts of individuals impacted by the winds. Where Parikka looks to Robert Smithson and the land art tradition in service of a geology of media, Zehner draws on the artwork of Francis Alÿs and examples from his own ethnographic work with the former Tornado Videos Network to elaborate the haptics and politics of tornadic encounters. Ultimately, he makes a case for storm chasing as an exemplary form of a what Gilles Deleuze and Félix Guattari (1987) call "nomad science"—a methodology drawn from art and science that is specifically attuned to the vagaries of atmosphere.

In *Environmental Ecologies in New Media Art* Anne-Sophie Witzke and Jonas Fritsch deepen our engagement with Guatari's conception of *ecology* via an analysis of an artwork by Olivia Tartaglia and Alex Tate titled *The Bureau of Meteoranxiety* (2018). Witzke and Fristch begin tracing an 'environmental turn' in new media art—a term that gained prominence in the 1990s to refer to art that employs or responds to emerging digital and computational technologies. While exploring the formal properties and aesthetic potential of such technologies, new media art has also become an important critical space for reflecting on their political implications, particularly for issues such as privacy, online identity, labor, and surveillance. More recently, as argued here, new media artists are attending to the psychosocial implications of environmental crisis and technology's role therein. Guattari's (2008) insistence on the importance of not only one but three ecologies—environmental, social, and mental—offers a crucial theoretical resource for examining how digital technologies moderate *our awareness and experience of* climate change, pollution, and many other environmental transformations that are invisible to the bare senses. This is perhaps nowhere so important as in the atmospheric domain, where a vague yet pervasive sense of foreboding in the face of charts and numbers is a primary indicator of ecological distress. *The Bureau of Meteoranxiety* (or BoMa, resonant of the Australian Bureau of Meteorology, or BoM) offers a parodic array of mental health diagnostic and treatment plans for coping with the trauma associated with untenable environmental futures, a humorous—if scathing—indictment of technological solutionism in the form of Virtual Reality simulations of lost natural habitats, Artificial Intelligence-guided meditations, 3D-printed trees, and so on. Through Witzke and Fritsch's analysis, we come to understand art's force as a space of reflection on the modes of subjectivity that must be cultivated (or critically deconstructed) in the face of environmental crisis.

Changing imaginaries and new technoecologies of urban air, the result of an ongoing collaboration between artist Hannah Husberg and environmental scientist Agata Marzecova, draws artistic research methods into dialogue with STS in an investigation of the perception of air pollution in Bejing. Juxtaposing snippets of conversation with scientific and theoretical reflection, the text sketches changing impressions of air and how they have been mediated by new technologies, such as the numerical Air Quality Index (AQI), apps, and public service announcement broadcast by SMS, as well as new terms and linguistic connotations of Chinese and English words. What emerges is an evocative snapshot of embodied yet intensely technologically mediated awareness of air's condition in the specific geographical and political context of early 21st-century Beijing—material that also served as a basis for a mixed media installation by Husberg. Through their critical reading of emerging "technologies of imagination" of air and its atmospheres, Husberg and Marzecova disclose how the lived experience of datafied air is becoming entangled with new regimes of power particularly compatible with neoliberal propensities to distribute environmental risk and responsibility for self-care to the individual (rather than state or corporate actors). In its thematic and para-ethnographic approach, the text offers important complementary approaches to the anthropological and sociological work by scholars such as Timoth Choy (2012), Jerry Zee (2015), and Jennifer Gabrys (2016), while highlighting the methodological affordances of art-science collaboration for the production and exhibition of affective, embodied knowledge.

The concluding chapter of this section, Anne-Sophie Witzke and Dehlia Hannah's *Variations on Air* (originally published in Danish in 2014) returns to philosophical and historical discourses that have attended the cluster of airy concepts at stake in *Atmospherics*. Reading these theoretical concerns through a selection of historical and contemporary artworks, some of which are also examined in Chapter 38, *Archiving Atmosphere*, this chapter makes a case for the air's performativity and the importance of moving beyond visual tropes in an aesthetics of atmosphere. Borrowing the musical concept of variation as repetition through formal alteration, this chapter examines how air's ever-shifting materiality and metaphors are 'played,' or mobilized into different sensuous and discursive ensembles, by various artistic and theoretical approaches. Moving from an emphasis on expository approaches to air that have sought to make air's absences and presences palpable, visible, and comprehensible to focus on air's active configurations, Witzke and Hannah draw on Karen Barad's (2003) and Judith Butler's (1993) theories of matter's performativity—key resources for Hannah's (2013, Kirksey et al. 2016) work on the performativity of scientific experiments. This focus on how air is arranged and exhibited draws out the importance of attending to the history of science, specifically the history of alchemy and chemistry and early theories of gases, in understanding the traffic between materiality and metaphor that has tended to render air particularly elusive among the (classical) elements. Today, as previous essays have emphasized, air's materiality manifests through communications and data clouds, real-time quantification, and medium- and long-term predictions—indeed through contemporary concepts of *global* climate that rely on technological modes of interface with atmosphere.

Finally, as a reprint and translation, the text's emphasis on variation and repetition also attests to the importance of returning to key points of reference for the critical discourse of air that has emerged recently within art and STS. Among these, artist Amy Balkin's *The Atmosphere: A Guide* (2013), reproduced in the gallery section of this Handbook, represents a key source. Balkin describes the work as "a poster-essay depicting various human influences on the sky and their accumulated traces, whether chemical, narrative, spatial, or political."[7] Bearing a visual resemblance to the Cloud Code Chart and other cloud atlases in use in meteorology, the *Guide* marks interventions at each level of the earth's atmosphere, from sea level to space, and across history, documenting in concise diagrammatic form the saturation of airspace by communications, military, commercial, and other agenda—alongside unintended anthropogenic impacts. Among Balkin's air-related projects, including *Public Smog* (2004–present), discussed by multiple authors in this section, *The Atmosphere: A Guide* stands as an exemplary contribution to art and STS, a paradigmatic work within the field whose contours this Handbook aims to articulate.

Notes

1 https://news.yale.edu/2017/04/27/conversation-john-peters-marvelous-clouds-and-rethinking-nature-and-media

See John Durham Peters, *The Marvelous Clouds*: Toward a Philosophy of Elemental Media. Chicago, IL: University of Chicago Press, 2014.

2 Bachelard, Gaston, *Air and Dreams: An Essay on the Imagination of Movement*, trans. Edith R. Farrell and C. Frederick Farrell, Dallas Institute of Humanities and Culture, Dallas, 1988.

3 Irigaray, Luce, *The Forgetting of Air in Martin Heidegger*, trans. Mary Beth Mader. Austin: University of Texas Press, 1999.

4 Sloterdijk, Peter, *Terror from the Air*. Los Angeles: Semiotext(e), 2009.
5 Markley, R. (2012). Time: Time, History, and Sustainability. In T. Cohen (Ed.), *Telemorphosis: Theory in the Era of Climate Change* (Vol. 1, pp. 43–64). (Critical Climate Change). Ann Arbor, MI: Open Humanities Press.
6 See Edwards, Paul N. 2013. *A Vast Machine: Computer Models, Climate Data, and the Politics of Global Warming*. Cambridge, MA: The MIT Press.
7 See http://tomorrowmorning.net/atmosphere

References

Barad, K. (2003). Posthumanist performativity: Toward an understanding of how matter comes to matter. *Signs*, *28*(3), 801–831.

Butler, J. (1993). *Bodies That Matter: On the Discursive Limits of "Sex"*.London: Routledge.

Choy, T. (2012). *Ecologies of Comparison: An Ethnography of Endangerment in Hong Kong*. Durham, NC: Duke University Press.

Deleuze, G. and Guattari, F. (1987) *A Thousand Plateaus: Capitalism and Schizophrenia*. Minneapolis: University of Minnesota Press.

Fine, G.A. (2006). Ground truth: Verification games in operational meteorology. *Journal of Contemporary Ethnography*, *35*(1), 3–23.

Gabrys, J. (2016). *Program Earth: Environmental Sensing Technology and the Making of a Computational Planet* (Vol. 49). Minneapolis: University of Minnesota Press.

Guattari, F., (2008). *The Three Ecologies (1989)*. London: Continuum.

Hannah, D. (2013). *Performative Experiments: Case Studies in the Philosophy of Art, Science and Technology*. Doctoral dissertation, Department of Philosophy, Columbia University.Kirksey, E., Hannah, D., Lotterman, C., and Moore, L. (2016). The Xenopus Pregnancy TestA Performative Experiment. *Environmental Humanities*, 8, 37–56.Parikka, J. (2015) *A Geology of Media*. Minneapolis: University of Minnesota Press.

Zee, J.C. (2015). *States of the Wind: Dust Storms and a Political Meteorology of Contemporary China*. Doctoral dissertation, Berkeley, University of California.

38
Archiving Atmosphere

James Graham

> Some people say not to worry about the air /
> Some people never had experience with air
>
> – Talking Heads, "Air," from *Fear of Music* (1979)

In classical physics, air was often described as a "medium," a transmitter of light and heat. The usage has something of an eighteenth-century ring to it, and yet the founding precepts of this new geological epoch we find ourselves in, whatever –cene we choose to call it, might ask us to reclaim it for the twenty-first. As we grapple with a recognition that the byproducts of industrial capitalism have diffused across the earth, rewritten fossil records, and become thoroughly environmental in character, one of our tasks is surely to learn to read our atmosphere as a historical register, to understand air as a document—and in so doing to help make visible the complex dynamics of economics and chemistry, society and violence, technopolitics and architecture that all of us breathing, planetary subjects are inextricably bound up in.

Air, however, is difficult to keep an eye on. As fundamental as it is to our collective and individual beings, it tends to leave us perceptually adrift, beset by an "inability to translate fluid realities into discursivity," as the theorist Luce Irigaray puts it (Irigaray 1999, 3). How do we even begin to reconcile the immense political urgencies of our atmosphere with our experience of it? Or to bring the planetary scale of climate modeling (the "infrastructural globalism" of Paul N. Edwards's *A Vast Machine*) into more immediate, localized focus? How can we account for the asymmetries of air, the uneven distribution of its changes and effects, the violence of its withdrawal, whether at the scale of the individual body or the planet? How to legibly index the changing composition of the atmosphere, which was always made up of far more than the oxygen gifted to us by cyanobacteria some 2.5 billion years ago, as we release a bewildering array of gases and particles into it? These are questions of sustained scientific inquiry and necessary political action, but they are also questions of representation, and thus questions of the art–science complex that has long participated in the visualization of truths—whether those truths are wrapped in the representations of scientific objectivity (Daston and Galison 2007) or as documents of more personal encounters with the world.

That our atmosphere has always been an elemental site of capitalism's circulations, one within which the politics of air must be actively contested, has been demonstrated in a range of

DOI: 10.4324/9780429437069-48

scholarly thought from Timothy Mitchell's *Carbon Democracy* to the more recent coinage of the term "settler atmospherics" at stake in the conditions of breath itself (Simmons 2017)—whether its suppression by means of tear gas, pepper spray, and chokeholds (Mbembe 2020) or the "slow violence" of environmental degradation (Nixon 2011). The presence of living, breathing bodies within the complex of climate and capital is inextricable from the necessary but reductive abstractions of climate science: "The movement of energy between enslaved bodies in plantations, plants, long-dead fossilized plants, and industrialized labor," writes Kathryn Yusoff, "is a geochemical equation of extraction in the conversion of surplus" (Yusoff 2018, 16). Recognizing the entwinement of capitalism and carbon and resisting its further entrenchment, however, brings evidentiary challenges, which is where the necessity of thinking archivally comes into focus. This essay explores several recent projects by architects and artists that propose something like an exhibitionary practice of air, a practice of making air palpable and reading the atmosphere as a document, to the end of amplifying both the tools and the motivations for resisting the exploitation of our atmospheric commons. Such practices straddle art, science, and architecture in the process of making claims on behalf of air itself and in doing so insist that histories of extraction, so often confined terrestrially, necessarily cast an eye skyward.

On air

That the material stuff of *geology* might offer something like an archive—not only of the sedimentations and cataclysms that preoccupied Charles Lyell's *Principles of Geology* but of human intervention as well—was thinkable in the nineteenth century. In 1873, Italian geologist Antonio Stoppani, likely expanding on the propositions of George Perkins Marsh's *Man and Nature* (1864), went so far as to propose the advent of the Anthropozoic:

> By now the ancient earth disappears under the relics of man or of his industry. You can already count a series of strata, where you can read the history of human generations, as before you could read in the amassed bottom of the seas the history of ancient faunas.
> *(Stoppani 2013, 38)*

But the sublimations of ground into air that define the era of "carboniferous capitalism," as Lewis Mumford evocatively termed it, have proven more difficult to reconcile with an archival outlook (Mumford 1934, 156). This a disciplinary problem concerning the methodological and technical registers of scientific knowledge (the imbrications of earth and air within Enlightenment thought notwithstanding); it is a question of racial capitalism as well, Yusoff observes, grounded in what she terms "white geology" and "the role of earth archives as material deposits that maintain a colonial relation through the extractive and waste industries" (Yusoff 2018, 49). The elusiveness of air's representability is crucial to both.

If the "Airborne Toxic Event" of Don Delillo's *White Noise* (1985) belongs to the megafauna of palpable (if fictive) airs, giving perceptible shape if never stable form to the toxic fallout of American industry, the realities of our atmosphere are seldom that dramatically visible—as demonstrated by the silent, night-borne methyl isocyanate of Union Carbide's Bhopal disaster, which claimed thousands of lives in the month before the release of Delillo's novel. What separates Bhopal or the Airborne Toxic Event from everyday life is, to some extent, a matter of scale. "Nowadays," writes Peter Sloterdijk in his much-discussed *Terror from the Air*, "what human beings meet in the weather are the expectorations—become atmospherically objective—of their own industrial-chemical, militaristic, locomotive, and tourist activities" (Sloterdijk 2009, 89). Sloterdijk's book focuses on the moment when air becomes knowable, or "explicit," in his terms, and his subject is the twentieth-century history of atmoterrorism—the idea, a comparatively recent one in human history, that we can be killed by the very thing that sustains us. He marks the advent of this atmospheric modernity with the deployment of airborne gas on the battlefields of Ypres. In that moment on April 22, 1915, he argues, air became explicit, made sensible by its withdrawal, and conceptually dislocated from the sphere of the "natural" into the sociotechnical world of human activity. It was no longer an externality to be assumed, but a site of anxiety and violence.

For Irigaray, writing some twenty years earlier, the imponderability—the inexplicitness—of air strikes to the core of philosophy itself. If "metaphysics always supposes, in some manner, a solid crust from which to raise a construction," she writes, then air would be something like an "unthinkable that exceeds all declaration, all saying. Or posing, phenomenon, or form. While remaining the condition of possibility, the resource, the groundless ground" (1999, 2, 5). In what follows—a recursive and ruminative critique of Heidegger's insistence on a philosophical and ontological notion of "ground"—Irigaray asserts the centrality of air as our foundational element, which in turn asserts breathing as the definitional act of being. There is a politics of precarity here, with philosophy complicit in "using up the air for telling without ever telling of air itself," but also a politics of sharing and exchange (1999, 7). If Sloterdijk primarily describes the threat of atmospheric violence, Irigaray's account evokes something closer to care, mediated by breath; both modify one of Heidegger's more famous terms in reframing his "being-in-the-world" as fundamentally "being-in-the-air."

Sloterdijk critiques Irigaray for what he reads as a kind of immaterialism. "She does not ever meditate on the fact that the newer aero-technical practice of this supposedly unthought-of factor has long been used as a field of application for highly explicit procedures," he writes. "It is plain to see: at the edge of the phenomenal world, any thinking that stays phenomenological for too long turns into an internal water-color, which in the best of cases fades into non-technical contemplation" (2009, 93–94). The point is well taken—understanding our atmosphere as a technical object, historically constituted and incessantly mobilized, overtly and as byproduct, for interests that are not often ours, is an urgent task. This materialism of air might learn in turn from the "metabolic rift" of capitalism observed by Marx (granted, with an emphasis on the problem of soil degradation) and later expounded on by thinkers like John Bellamy Foster and Jason W. Moore. And yet, Sloterdijk's derision of watercolors notwithstanding, both technical and non-technical contemplations have their place in understanding air as a medium, and Irigaray's insistence on not reducing air to its managed technicity asks for other lenses through which to see and read the atmosphere.

"What kind of message inheres in this medium, what kind of subject/particulate?" ask Timothy Choy and Jerry Zee.

> Scenes in which air's qualities, composition, or movements come to be of concern are easy enough to find: mobilizations around an area's atmospheric load of particulate or sand; questions into how specks of substance may drift before settling to the ground or in a lung; experimental explications of weight, diameter, composition, toxicity, or climate-changing activity of potentially and potently airborne matter.

These sites of atmospheric inquiry mark a "growing form of thought and being" that offers "an exhortation to a form of attention that is also a mode of relation" (Choy and Zee 2015). That we live within this "turbulent medium" even as we study and represent it is an existential conundrum that requires the interpretations of creative practices to work alongside the urgent rigor of climate science.

Air's impressions

If one atmospheric modernity begins with the gas attacks at Ypres on April 22, 1915, another is said to begin in the French port city of Le Havre, on November 13, 1872, with the painting of Claude Monet's "Impression, Sunrise." In the foreground, silhouetted rowboats familiar from Romantic landscapes; in the background, smokestacks, shipping cranes, masted and coal-driven ships, all objects of an atmosphere-polluting modernity, fogged in with the effusions of industry. This is the painting that gave an artistic movement the name Impressionism, and we might take it as a non-technical record of technical conditions. The precise date in November for the painting of "Impression, Sunrise" is not given by the canvas but by an astrophysicist who calculated the sun angles (Monet et al. 2014). Similar techniques have been used on Monet's obsessive repaintings of the Houses of Parliament (19 are known to exist), which have since come to be taken as archival documents in their own right, testimonies to the density and composition, on knowably particular days, of London's famous smog.

Only a year before, the British critic John Ruskin had taken note of what he called a "plague-wind"—a choking, particulate kind of weather that spoke to him of something other than the capital-N Nature that he had previously known the weather to be. "It looks partly as if it were made of poisonous smoke," he writes:

> Very possibly it may be: there are at least two hundred furnace chimneys in a square of two miles on every side of me. But mere smoke would not blow to and fro in that wild way. It looks more to me as if it were made of dead men's souls.

He included this journal excerpt from July 1, 1871, in a lecture by the now-iconic name "The Storm-Cloud of the Nineteenth Century" (1844), comprised principally of such readings from his own meteorological diaries—an archive assembled over fifty years, though which took a particular turn in the 1870s as the "dense manufacturing mist" and "Manchester devil's darkness" had an ever-greater effect on England's atmosphere. Hailed now as one of the first acts of atmospheric activism, Ruskin himself was circumspect and above all melancholic about this environmental malignancy, with more than a hint of messianism—resolving, in the end, to follow "the paths of rectitude and piety" and make his own lot right with the heavens, even as they continued to threaten with blustery gloom.

Ruskin's archives of air were multiply literary, comprised of his diaries but also an exhaustive hunt through his canon of classics to track whether these clouds were, in fact, novel ones:

> Neither Homer nor Virgil, neither Aristophanes nor Horace, acknowledge any such clouds among those compelled by Jove. Chaucer has no word of them, nor Dante; Milton none, nor Thomson. In modern times, Scott, Wordsworth, and Byron are alike unconscious of them; and the most observant and descriptive of scientific men, De Saussure, is utterly silent concerning them. Taking up the traditions of air from the year before Scott's death, I am able, by my own constant and close observation, to certify you that in the forty following years (1831 to 1871 approximately—for the phenomena in question came on gradually)—no such clouds as these are, and are now often for months without intermission, were ever seen in the skies of England, France, or Italy.
>
> *(Ruskin 1860)*

Nor were these clouds only textual. Ruskin was no dilettante where artistic clouds were concerned, having devoted fifty-four pages to them in the fifth volume of his *Modern Painters*.

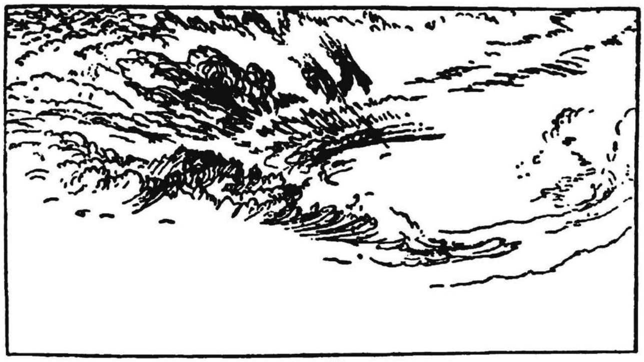


FIG. 83.

Figure 38.1 John Ruskin, diagram of the clouds in J.M.W. Turner's "Pools of Solomon," demonstrating concentric cloud arrangement, from *Modern Painters*, vol. 5 (1860), 134

It is difficult to imagine anyone but Ruskin painstakingly diagramming the cloud patterns found in works by his beloved J.M.W. Turner (Figure 38.1).

The ground (if you will) was thus laid for the twentieth-century's documentary practices of air, which took increasingly quantified shape—and whose chemistry would then on occasion be translated back into the cultural realm. For if Monet and Ruskin offer their own archives of air circa 1872, the sciences would develop their own answers. Atmospheric archives can now be assembled through the kinds of monitoring networks described by Edwards that track climate (when deployed at the planetary scale) or the "air report" (when deployed locally). Archives can be reconstructed through geological stratigraphy and fossil records—fossilized pollen spores being especially useful for indicating what the air was like in a given place at a given moment. Archives can be extrapolated anthropologically from migrations and the cultural effects that result from broader climatic phenomena. And archives of air can be gathered physically (a conceptual project introduced by Marcel Duchamp's so-called "50cc of Paris Air," bottled on December 27, 1919, not in Paris but in Le Havre, the site of Monet's "Impression" a half-century before). Each of these archival genres warrants being read back into the arenas of art and architecture, as acts of public communication, certainly, but also to probe the epistemic ground on which such archives are built.

Monumental airs

Trench with Chlorine Gas (1970) by the artist Robert Morris—a proposed war memorial, one of five in a series—is as potent an example as any of the simultaneously retrospective and futurative nature of artistic and architectural propositions around the experience of air. Such projects are generally posited as speculations yet to be built, but nevertheless would provide some form of experiential access to the airs of history. Morris's lithograph depicts an earthwork X with a cloud of chlorine, more than twice as heavy as air, settled in to its excavations. In evoking the atmospheric violence of World War I as the ongoing war in Vietnam ground on (and at a moment of late capitalism's increasing consolidation), Morris's *Trench* presages a series of later projects as climate change entered more fully into the cultural sphere. That Morris's atmosphere was an explicitly militarized one is a reminder of the violence that inheres in the more diffuse and everyday forms of intervention on the Earth's climate (Figure 38.2).

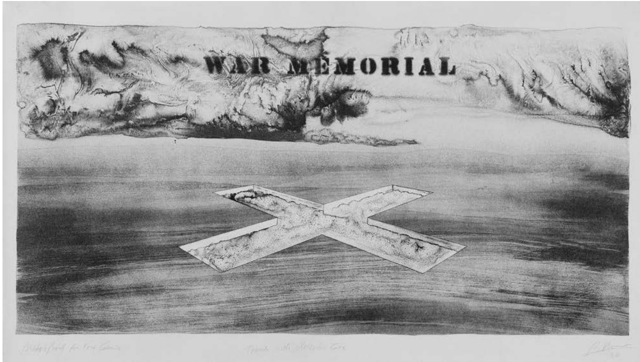


Figure 38.2 Robert Morris, *Trench with Chlorine Gas*, 1970; from the series Five War Memorials. © 2021 The Estate of Robert Morris/Artists Rights Society (ARS), New York

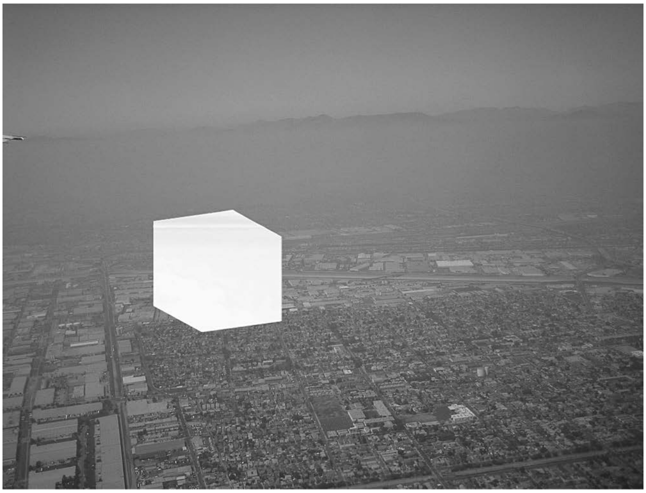


Figure 38.3 Amy Balkin, "Smog over Los Angeles," from the Public Smog project (2004–). Courtesy of the artist

An early and iconic example of the twenty-first century's entries into this lineage is Amy Balkin's "Public Smog," a project begun in 2004 that centered around the proposition that our atmospheric commons should be included on UNESCO's World Heritage list, in the form of a park to be "constructed" by the usual financial, legal, and political means that constitute such spaces. This Public Smog park was first imagined over California, coterminous with the South Coast Air Quality Management District encompassing Los Angeles, Santa Ana, San Bernadino, and stretching some 150 miles east into the California desert (on Balkin's work, see Scott 2016). Included in the conceptual aspects of the project—organized around postcard mailing campaigns—Balkin produced a number of visualizations of the physical scale of emissions over Los Angeles (Figures 38.3 and 38.4).

The architect and historian David Gissen, taking Pittsburgh as his site, offers a similar set of visualizations in 2006, drawing on the graphical language of 1970s radical practices in architecture as well as emerging strands of thought in the field of experimental preservation (which asks how conservation practices might mark moments of historical

Figure 38.4 David Gissen, "Reconstruction—Smoke," Pittsburgh (2006). Courtesy of the artist

importance rather than restoring buildings to a supposedly ideal originary state). The historian Jorge Otero-Pailos reminds us that "smoke was the most common material produced by nineteenth-century industry" (Otero-Pailos 2011) and that pollution's speedy degradation of stone was a vital factor in the rise of terracotta cladding in smoke-filled cities like Pittsburgh and London at the end of the nineteenth century, giving the smoke of Gissen's drawings a twofold role in reshaping Pittsburgh (as a threat to stone that inspired new materials and as a material presence unto itself).

Balkin's interest was in documenting present conditions and advocating for improvements in the future, assigning the atmosphere to the status of a monument that warrants protection; Gissen asks the parallel question of what it would mean to monumentalize pollution, in the word's sense of creating markers that carry historical memory—in this case, of the soot-choked air that defined Pittsburgh and its architecture in the early twentieth century. Or, rather than forming a conceptual dyad, the different valences of these projects might instead demonstrate the dialectical monumentality of atmospheric objects, in which the thing being made legible—the threatened commons or the material threat itself—oscillates. That pollution could and should be read as an architectural edifice, not as a byproduct but as a fundamental part of the materiality of construction, asks difficult questions about how we imagine architecture's entanglement with atmospheric violence.

The question of historical smog—its monitoring and the possibility of granting it a kind of representational presence in the present day—is perhaps most fully made material by a 2014 project called "Air Manifest," by the International House of Architecture team of Mark Wasiuta and Marcos Sánchez with Adam Bandler. Grounded in archival data gathered by the sampling stations of the South Coast Air Quality Management District, "Air Manifest" explores two moments in the city's atmospheric history. The first is September 14, 1955, one of LA's first smog emergencies, representing the ordinary (if heightened) environmental consequences of carbon-fueled urbanism. The second is August 13, 1965, in the early days of the weeklong Watts Rebellion—a properly historical event, to be sure, but also a culmination of the kinds of racial discrimination and exploitation that had long been naturalized into the post-Great Migration American city. The project enters into these historical junctures by observing that this archive of air conditions can be used to reproduce those selfsame conditions, taking the air report as a kind of recipe (twinned processes the curators refer to as "record" and "replay"). This point is made clear in the title of the authors' writing on the topic, titled "Instructions for the Reconstitution of Historical Smog," which notes that the archiving of air composition evinces a "peculiar mediatic reversibility" (Sánchez and Wasiuta 2014).

At first glance, it might appear that the two dates represented in "Air Manifest" are paired for contrast. The first could be any day, an intense but expectable sampling of the ubiquity of smog, while the second documents instead a conflagration that remains seared into the city's memory. Far more unites them than separates them, however, and reading these dates through the molecular abstractions of the air report helps us see these seemingly disparate events for their fundamental relations, atmospheric and otherwise. What goes in and comes out is chemical, but it is also social, spatial, and political. Freeways and policing practices are but two of the myriad techniques that distribute humans, wealth, and architectural objects around the city, and these systems of control were wholly involved in producing the events of 1955 and 1965. A car might burn gasoline more politely than a protestor, but from the atmospheric point of view, it's a fire either way.

There is an important multiplicity in the project's title, "Air Manifest," one that speaks to a tendency that runs through many of the projects discussed here. The first reading might be the noun form, a manifest of air, a documentary register of our insertions into our atmosphere—hydrocarbons, nitrous oxide, sulfur dioxide, and ozone. But it is also air *made* manifest, as this is also intended as a thoroughly experiential project. Through the venue's storefront windows, one first sees a band of backlit photographs that speak to the project's historical content, but beyond that one encounters a large volume of sealed air, glowing ethereally, inside a two-story cubic metal frame that is surrounded by the various infrastructures of its treatment—fans for inflation, particle injections, and fluorescent and UV light radiation—to create the atmospheric makeup of these two dates of air reports. The original design for the installation was to be still more immersive, with a ducted helmet the visitor could don to sample the smog being produced inside (Figure 38.5).

To the extent that historical air is defined by records of chemical composition, then, one can imagine untethering the experience of air from its "proper" time and place. This is a proposition that is likewise taken up in Michael Pinsky's "Pollution Pods," commissioned as part of a Norwegian project called Climart, led by the environmental psychologist Christian

Figure 38.5 International House of Architecture (Mark Wasiuta, Marcos Sanchez, and Adam Bandler), installation view of *Air Manifest*, Istanbul, Turkey (2014). Courtesy of the architects

Klöckner, that aims to deploy visual art in the name of climatic and scientific awareness. The installation is comprised of a linked series of geodesic domes, each of which plays host to "carefully mixed recipes," as the artist describes it, "emulating the relative presence of ozone, particulate matter, nitrogen dioxide, sulphur dioxide, and carbon monoxide" in cities like London, New Delhi, São Paulo, and Beijing—contrasting the climate of the installation's host city, Trondheim. Climart describes their hope that this atmospheric experience will galvanize its visitors to resist the excesses of global capitalist consumerism: "Perhaps the visceral memory of these toxic places," their website (see https://www.climart.info/pollutionpods) writes of these industrial elsewheres, "will make us think again before we buy something else we don't really need." There is certainly some truth to this premise—a 2014 study from Peking University in Beijing, for example, ascertained that some one-fifth of Chinese air pollution was in the service of manufacturing goods for U.S. markets. And yet, this bit of didacticism also neglects a fact, observed by thinkers like Dipesh Chakrabarty, that a vast reduction in the percentage of the global population living in extreme poverty, a shift that brings air pollution with it given the current conditions of industrialization, is another aspect of our so-called Anthropocene.

Complicating the idea that we might imagine tidily emplaced environments indexing locality, air also refuses to stay put—where the atmosphere is concerned, there is no industrial elsewhere, only points of origin whose pollutants begin their process of diffusion and circulation. In a project called "Air Drifts," exhibited in 2016 at the Oslo Architecture Triennale, a team of three architects, a scientist, and a filmmaker—Kadambari Baxi, Janette Kim, Meg McLagan, David Schiminovich, and Wasiuta—visited the NASA Goddard Institute for Space Studies, which hosts the GEOS-5 model that aggregates and animates real-time climate patterns on the planetary scale. As "Air Drifts" makes clear, there is an aesthetics at work in the fruits of the GEOS-5 model. Its data comes from widely varying sources and observational techniques, which are then stitched together into what the project's authors describe as an "organic" whole. On a more local level, "In the Air," a Madrid-centered project led by Nerea Calvillo, asks how these kinds of real-time, site-specific visualizations might enter the political arena by providing a common platform through which to understand and make decisions about our effects on the atmosphere.

The geopolitical stakes of this kind of atmospheric modeling are vividly illustrated by the ongoing "Climate Crimes" research of the architect Adrian Lahoud. Described as "forensic climatology" and first developed under the auspices of Forensic Architecture at the Goldsmiths Center for Research Architecture, Lahoud explores the violence wrought by climate change and the representational and juridical forums through which claims to justice might be articulated. He asks us to consider two bodies—an aerosol particle, floating from north to south, and a climate refugee making the journey from south to north. They are engaged in a kind of reciprocal motion, each partaking in a complex of global circulation brought on by the remaking of our atmosphere by industrial capitalism. The question is how we might read the atmosphere as a kind of evidence—in this case, relying on the unique signatures of aerosol particles, which come with their own fingerprints, as it were, of manufacture—a rare atmospheric object that allows us to trace their origins, offering their own archive of drifting emissions. At the Victoria and Albert Museum in 2018, this body of research was materialized in the form of a suspended geodesic half-dome that hosts a projection. The projection and voiceover tells a series of stories about the gathering of atmospheric data, with particular focus on the question of scale, from the planetary body to the particle body.

As in the case of "Air Drifts," the project is alert to the aesthetics of climate modeling—in this case, fragmenting at the end into a kaleidoscopic mosaic of different types and scales of climate information—“a kind of secular cosmology, an animated fresco,” as Lahoud puts it (Lahoud 2016). Planetarity, these various architects indicate, is constructed by the integration of data (whose differences in the manner of collection are reconciled by computational modeling) plus the aesthetic seamlessness of that data’s representation.

Atmospheric media

Taken together, such artistic and architectural efforts at representing a range of atmospheric depredations offer an understanding of atmosphere *as* media—as a historical register of environmental culpability—as well as understanding atmosphere *through* media, re-presenting the unseeable realities of air in a conceptually legible and occasionally affective state (for more on air as medium, see Horn 2018). Moreover, these projects are a reminder that environmental biopolitics are not solely a matter of direct state intervention. Certainly, the environment has long been a scene of military action (as described by Sloterdijk), and the experience of the twentieth century has been frequently and rightly described as a history marked by emerging techniques of ecological violence—from the gas attacks of World War I to the U.S. ecocides of Vietnam, Cambodia, and Laos (and their many imitators). These are clarifying moments both in the stark demonstration of our reliance on an environment that has been suddenly withdrawn and in their evident moral weight. These archives of air ask us to see anthropogenic climate change with a similar clarity. As Rebecca Solnit argued in response to reports that climate change would “cause” an increase in global violence, such phrasing inverts the matter, because climate change is already an act of violence.

These projects ask us to acknowledge that the atmosphere, this fundamental sustenance that eludes our conceptual and experiential grasp, exists within a subtle triangulation of economies, institutions, urbanisms, and behaviors, whether banal or exceptional. We are participants in that production, distribution, and withdrawal of air, every day, and yet, our participation is all too invisible to our own eyes. For all the far-flung effects of our current regimes of industrialization, globalization, and neoliberalization, the atmosphere is among their most central sites of evidence and action. What these projects and the ideas embedded within them collectively make manifest, then, is something like the respiratory system of capitalism.

Bibliography

Bellamy, John Foster, *The Ecological Rift: Capitalism’s War on the Earth* (New York: Monthly Review Press, 2010).

Calvillo, Nerea, “Political Airs: From Monitoring to Attuned Sensing Air Pollution,” *Social Studies of Science*, vol. 48, no. 3 (July 2018): 372–388.

Chakrabarty, Dipesh, “The Climate of History: Four Theses,” *Critical Inquiry*, vol. 35, no. 2 (Winter 2009): 197–222.

Choy, Timothy and Jerry Zee, “Condition—Suspension,” *Cultural Anthropology*, vol. 30, no. 2 (2015): 210–223, https://doi.org/10.14506/ca30.2.04.

Daston, Lorraine and Peter Galison, *Objectivity* (New York: Zone Books, 2007).

Delillo, Don, *White Noise* (New York: Viking, 1985).

Edwards, Paul N., *A Vast Machine: Computer Models, Climate Data, and the Politics of Global Warming* (Cambridge, MA: MIT Press, 2010).

Horn, Eva, “Air as Medium,” *Grey Room*, vol. 73 (Fall 2018): 6–25

Irigaray, Luce, *The Forgetting of Air in Martin Heidegger*, trans. Mary Beth Mader (Austin: University of Texas Press, 1999).

Jones, Caroline A., Peter Galison, with Amy Slaton, eds., *Picturing Science, Producing Art* (New York: Routledge, 1998).

Lahoud, Adrian, "Scale as Problem, Architecture as Trap," in *Climates: Architecture and the Planetary Imaginary*, ed. James Graham (New York: Columbia Books on Architecture and the City, 2016), 111–118.

Mbembe, Achille, "The Universal Right to Breathe," trans. Carolyn Shread, *Critical Inquiry* "In the Moment," April 13, 2020, https://critinq.wordpress.com/2020/04/13/the-universal-right-to-breathe.

Mitchell, Timothy, *Carbon Democracy: Political Power in the Age of Oil* (New York: Verso, 2011).

Moore, Jason, *Capitalism in the Web of Life: Ecology and the Accumulation of Capital* (Brooklyn: Verso, 2015).

Monet, C., Mathieu, M., Lobstein, D., Bergeret-Gourbin, A.-M., Penwarden, C., & Musée Marmottan. (2014). *Monet's Impression Sunrise: The Biography of a Painting* (New Haven: Yale University Press, 2014). Mumford, Lewis.

Mumford, Lewis, *Technics and Civilization* (New York: Harcourt, Brace, and World, 1934).

Nixon, Rob, *Slow Violence and the Environmentalism of the Poor* (Cambridge, MA: Harvard University Press, 2011).

Otero-Pailos, Jorge, "The Ambivalence of Smoke: Pollution and Modern Architectural Historiography," *Grey Room*, vol. 44 (Summer 2011): 90–113.

Otero-Pailos, Jorge, "The Atmosphere as a Cultural Object," in *Climates: Architecture and the Planetary Imaginary*, ed. James Graham (New York: Columbia Books on Architecture and the City, 2016), 243–250.

Ruskin, John, "Part VII—Of Cloud Beauty," *Modern Painters*, vol. 5 (London: Smith, Elder, 1860), 118–171.

Ruskin, John, "The Storm-Cloud of the Nineteenth Century," lecture delivered at the London Institution on February 4, 1884.

Sánchez, Marcos and Mark Wasiuta with Adam Bandler, "Instructions for the Reconstitution of Historical Smog," in *(In)formal L.A.: The Space of Politics*, ed. Victor J. Jones (New York: eVolo, 2014), 33–39.

Scott, Emily Eliza, "Archives of the Present–Future: On Climate Change and Representational Breakdown," in *Climates: Architecture and the Planetary Imaginary*, ed. James Graham (New York: Columbia Books on Architecture and the City, 2016), 130–140.

Simmons, Kristen, "Settler Atmospherics," *Cultural Anthropology*, "Fieldsights," November 20, 2017, https://culanth.org/fieldsights/settler-atmospherics.

Sloterdijk, Peter, *Terror from the Air* (Los Angeles, CA: Semiotext(e), 2009).

Solnit, Rebecca, "Call Climate Change What It Is: Violence," *The Guardian* (April 7, 2014).

Stoppani, Antonio, "First Period of the Anthropozoic Era," from *Corso di Geologia* (1873), trans. Valeria Federeighi in *Making the Geologic Now: Responses to Material Conditions of Contemporary Life*, ed. Elizabeth Ellsworth and Jamie Kruse (Brooklyn: Punctum Books, 2013), 36–41.

Yusoff, Kathryn, *A Billion Black Anthropocenes or None* (Minneapolis: University of Minnesota Press, 2018).

39

Becoming tornadic

A meteorology of media

Brett Zehner

> The wild embodied wind of the prairies is like a presence among the fields.[1]
>
> –*Meridel Le Sueur*

I

Tornado impacts tend toward the surreal. Cars wrapped around trees stripped bare of their bark, school busses thrown through the air like toys, toothpicks driven through engine blocks. People impacted directly by tornadoes report a sudden drop in air pressure; eardrums explode, the lungs are stripped of air just before impact. The body's atmosphere becomes attuned to the radical change around it, undermining any simple division between human and environment. The sheer force of a tornado can be staggering: they can move laterally at speeds of 100 feet per second, while the internal wind speeds of the worst storms may exceed 200 miles per hour, enough to rip the skin from bone. In one instant, normality; in the next instant, an explosion of debris. Violent winds disarticulate the architectures of the everyday, turning nearly every mundane object into a deadly missile. The split second of a tornado's impact acts as a threshold between altered states. In its vortex, seemingly solid things become matter in flux. Some things will remain, while others vanish. But for a fleeting moment, what remains and what disappears are held together in catastrophic coherence. Everything is up in the air.

Encounters between earth and air, at the point of a vortex, highlight the strange singularity of tornadoes, troubling distinctions between subjects and objects; scale and movement; culture and nature. Tornadic encounters—touching down, piercing, and transgressing the liminal boundary between earth and sky—thus pronounce the entanglement of earth systems with social processes. The weather event exemplifies the earth's condition as not merely a passive recipient of human impact but a continually changing set of physical dynamics.

This essay presents a media theory for tornadic encounters: a meteorology of media. My approach is inspired by Jussi Parikka's *Geology of Media*, which translates the methods of geological science to analyze the stratified, nonlinear layers of media history. Parikka expands

DOI: 10.4324/9780429437069-49

media theory to include the raw minerality of technological environments. I, however, turn to meteorology, a science reliant on probabilistic prediction, as a methodological lens. As a source for media theory, I argue, meteorology draws our attention to local singularities and events-in-the-making that falls outside the grand scope of media theory and history. In this regard, it is important in the first place to distinguish between climatology and meteorology, two epistemologies that are often conflated. Paul Edwards writes that:

> meteorological data systems are built for real-time forecasting. Their priority is speed, not precision, and they absorb new instrumentation, standards, and models quite quickly. In contrast, climatology requires high precision and long-term stability – almost the opposite of the rapidly changing weather observing system.
>
> *Edwards (2010, p. 14)*

It is within the technological assemblage of meteorological knowledge production that the storm chaser's act of citizen science offers a necessary supplement to the temporal gap of computational weather predictions. The speed and rhythm of the storm chaser's movements are what make them unique. Chasers fuse real-time data flows with embodied environmental awareness as they navigate gridded road networks to intercept erratic tornadic paths. In this essay, I follow the artist Francis Alÿs through his project *Tornado, Milpa Alta* (2000–2010). My response to these artistic performances is informed by my ethnographic fieldwork with storm chasers through the Tornado Videos Network (TVN), who I read as practitioners of what Deleuze and Guattari call "nomad science." Through these figures, I explore the aesthetics of tornadic encounters and their capacity for troubling meteorological modes of knowledge production and opening environmental experience to other possibilities of shared risk. With Alÿs, I find the rupture of the tornado productive in disrupting discourses of hubris around climate risk and mediation. Ultimately I ask, as a theorist of environmental media, what do we gain by considering storm chasing as a form of art?

II

To begin, we must consider the centrality of art to Parikka's paradigmatic use of environmental science as a model for media studies. Parikka's elaboration of a geological imaginary for media studies builds upon the work of the American artist Robert Smithson (1938–73), a key figure in the land art movement of the 1960s and '70s. Smithson's artistic practices throughout the 1970s engage technological landscapes from the perspective of geologic time. Smithson's critical essays and artworks such as *Spiral Jetty* (1970) enact the technological milieu not as an extension of humanity but as fundamentally made up of the raw materials of the earth (Smithson, 1996). Parikka reads Smithson's experimentation with the given materiality of the earth as an elaboration of nonhuman timescales. Smithson decenters the classical humanist perspective of aesthetics and replaces it with something akin to a psycho-geophysics. Writing over three decades after Smithson, Parikka theorizes what he calls the "earth media arts," which experiment with premediated materials and the afterlives of dead technologies. The geology of media attends to "notions of temporality that escape any human-obsessed vocabulary and enter into closer proximity with the fossil."[2] The materiality of the fossil is essential to deep time perspectives in such artwork. If we focus rather on the motion of the spiral in Smithson's signature work, however, we return to the scale and temporality of the human individual.

Smithson muses on the construction of Spiral Jetty:

> On the horizon–a horizon is an impossible point to locate. Even though it is right there in front of you, it is constantly evading your grasp. It is only a mirage that can't be fixed, arrested or stopped, or transferred into an abstract condition, and that is the arrested moment. Those moments constantly change and are giving way to other moments; so you can get into a kind of vertigo situation. A point is like a whirlpool or central vortex. The piece in Salt Lake will be built on a meandering zone, that is unstable, and the idea is to stabilize something that is unstable.[3]

The spiral form in Smithson's work supervenes on its material substrate and concatenates deep time with embodied experience via vortical motion. The vortex of *Spiral Jetty* offers a break from the temporal norm, sending viewers into the vertigo of an atemporal drift. The vortex opens an interval and triggers a network of responses that create a general attitude and set of alienated relations to the environment. The vortex highlights the difference between the geology of media and the meteorological approach I propose. The shift between the geologic and the meteorological register occurs in the temporal scale of the individual subject. What the geology of media cannot account for is the event, the immediate experience of the vast timescale of environmental risk. And the emergency of severe weather occurs at the immediate human scale—for this is precisely where the deep time-accumulated effects of climate shifts will come into contact with the individual.

III

Tornado Alley, spanning the central plains of the United States, is an area in which conditions have historically been ripe for tornadoes. Today, it is migrating further east into more densely populated areas. This geographic shift is brought on by a generally warming climate and, in turn, a wider area of atmospheric instability.[4] In this region, a tornado is an explicit effect of human activity, if not of direct intentions. It is a ricochet of human endeavor, not a relation emerging from direct causality, but a haunting, an intense (re)turn of cultural (re) production.

For a hurricane, preparations can begin a week or more in advance. For tornadoes, by contrast, the average warning time is less than fifteen minutes. As the temporality of preparation is compressed, anticipation heightens. The tornado siren is the first aesthetic cue to rapidly changing weather. In their haunting pitch and tone, tornado sirens articulate an atmosphere of foreboding, anticipation, and doom. At many sites, Cold War air raid sirens remain as the public address system for tornado warnings.[5] The warning itself is a system of imperatives, organized around a structure of command and control: *be warned!* The state enacts sirens, messages, maps with trajectories—an entire communications network externalizing the responsibility of environmental protection to the individual. During the Super Tornado Outbreak of 2011, for instance, local weather presenters across the South shepherded their respective publics through the catastrophe in firm but calm voices. Phrases such as "unsurvivable above ground" and "guaranteed catastrophic damage" mixed with the weather broadcaster's calm (usually) masculine voice, in a live play by play—"if you are in the path of this tornado, take your tornado precautions."[6] The role of the weather presenter is that of a conductor, translating between machines and between human and nonhuman. The forecast creates a cartography of isobars and isotherms—the weather map wrapping together air and subjects. The raging atmosphere can be known, up to a point, but not fully controlled. The subject is directed away from harm. As the weather presenter choreographs the viewers' self-protective pattern of response to an orchestrated threat, there is a breakdown of the division between the television studio, the weather station, and the theater.

In reaction, the citizen turns away from an outside threat and toward *home*. In Sara Ahmed's analysis of the cultural aftermath of 9/11, home becomes a symbol of the nation. Ahmed argues that emotions are not solely located within the subject; they circulate and stick to objects infusing them with a charged tension. Under the threat of the tornado warning, the midwestern family home similarly becomes a "sticky" symbol of American identity under attack, in this case from arbitrary forces of nature.[7] The individual is thereby bound to the retrenched material cultures of home via the emotional attachments brought on by the dual relationship of threat and security. After the tornado has passed, once the family has emerged from their bunker and homes have been destroyed, we see countless photos of the flag, battered, yet still flying. The basement rec[reation] room doubles as a setting for a certain wistful longing. The temporal drag of Cold War anxiety refocuses on a collective sense of a threat from above. There is a nostalgia for the air raid shelter, where families endlessly practiced resilience in the face of the end of the world. The storm shelter, in turn, becomes a refuge from the tornado menacing the countryside. Sirens blare a generic call, atmospheric in their own right. The dressage of the citizen subject passes through all of its disciplinary training. The senses are trained to recoil; a heavy book protecting the head in the school hallway, a public safety lecture, emergency protocols at work, and family emergency plans. These are not at all insignificant moments in shaping a national identity.[8] Bleating their shrill warning, the sirens recall nuclear war simulations, hailing national subjects. The tornado bunker, qua home, becomes the space of the family—under threat, yet protected.

When one hears the sirens, the performative command and control message is activated: citizens should take cover, turn toward safety. Terranova refers to this as "soft control," a form of control that need not necessarily emanate from a central authority.[9] It is more banal, more automated. The siren is an infrastructural language, directed toward the preindividual, aimed at moderating flows of affect, sensation, and desire—relations on their way to becoming subject. Here, following Maurizio Lazzarato, we can comprehend the production of subjectivity as *both* a preindividuated process operating at the level of affect *and* an individuating process operating through authority and social connection.[10] The subject is produced within a sociotechnical assemblage made up of urban infrastructures, earth forces, communication systems, and bodily capacities, at once individuated and dividuated by forces that exceed language.

In her analysis of Hurricane Katrina, Marita Sturken draws our attention to the public service campaigns of ready.gov, which were produced to warn citizens of the dangers of severe weather events. In its appeal to middle-class suburban families, the government agency displays a blatant refusal to imagine any citizen subject that does not fit within the bounds of the nuclear family, linking the state, environment, and normative social structures (Sturken, 2006). This meteorological communication network primarily views the weather from satellites and Doppler radar stations. The typical vantage point is a depopulated one. Giant swirling storms are seen from above rather than felt from below. This de-bodied perspective converges with urban planning discourse and architectural models. A generic subject is implied by a structured landscape. FEMA response plans, scripted for the idealized middle-class family, prove catastrophic for the majority of the population. Meteorological media is a global system of information wielded to externalize the responsibility of environmental risk to the level of the individual. Yet, by ignoring both the on-the-ground reality of the citizens affected by storms, and the fine-grained movement of the storms themselves, pressing social concerns appear in the gaps of state knowledge. The ability of the state to control natural threats to its sovereignty breaks down. The storm is not entirely predictable. Engineering systems can only hold so much force. And these shortcomings converge with an unevenly distributed disregard for the realities of people affected on the ground.

IV

In an artwork titled *Tornado, Milpa Alta 2000–2010*, Francis Alÿs opens himself to nonhuman resistance by willingly throwing himself into tornadoes—albeit very weak "dust devils"—in the Mexican countryside. Alÿs sees the dust storm as a symbol of the imminent collapse of all systems of order. In the description of his installation at the Tate Modern, we can read Alÿs' attraction to the tornadic vortex:

> The act of running into the storm, which we see repeated over and over, also invites interpretation: is the artist no longer able to combat the chaos he encounters? Or is it only within the chaos that he can challenge the turmoil around him? Reaching the epicentre of the storm, the artist is breathless and almost blinded, yet he encounters a furtive moment of peace that could hint at a new moment of possibility.[11]

In the work of Alÿs, it is too simple to imagine leaping into a tornado as a nihilistic impulse. The artist sees the tornado as a positive force. Through the chaos of the vortex, through its excessive noise, its blinding debris, and its sheer physical force, the vortex becomes a symbol of regeneration, an imperceptible, but open future. The indeterminate act of Alÿs flies in the face of a seemingly overdetermined world of big data.

From the artistic gesture of abandonment through storm chasing to the citizen science of meteorological storm chasing, we can track an openness to the radically indeterminate. The globalized atmospheric sensing systems that underpin the meteorological apparatus seem omnipresent in the planetary scope of their infrastructures.[12] However, there is still a great need for citizen science to fill in the particulate gaps in local environmental knowledge.[13] The storm chaser, in the context of the tornado, is the eyes and ears that are necessary to confirm the existence of a "tornado on the ground." The storm chaser's role in detection and warning is central in defining the exact path a tornado is taking. Even though Doppler radar has become an important tool for meteorologists in tracking tornado development, it still has a broad range of error, and it cannot calculate the infinite complexity of atmospheric data.[14] The storm chaser has the advantage of the haptic, close-up experience of the tornado, whose path is often erratic. The chaser follows singular fluid dynamic developments in supercell storms, often by sight or sound only, and using an innate sense of timing to intercept tornado paths.

Much of my interaction with the storm-chasing community occurred through the now defunct Tornado Videos Network of storm chasers. TVN was an online platform which provided live streams of chasers in the field along with chat interaction features. These networks of chasers, of course, have access to mobile Doppler radars and the latest mobile technologies, but their immediate senses are what allow them to follow the singular flows of storm morphology. Chasers are often forced into situations that require sophisticated navigation. Their choices for movement are constrained typically to north-south or east-west movements on the gridded road networks of the Midwest. The timing has to be perfect to intercept a tornado's path, which pays no heed to the grid, but cuts diagonally across this striated space. For the chaser, the experience of the tornado chase is an aesthetic one, a dance of contradictory timing between the wind and the built environment. The chaser operates between two atmospheres—in the words of Tim Ingold—"one of meteorology and one of aesthetics—straddling the uneasy division between nature and humanity, materiality and the sensory, the cosmic and the affective."[15] The split between meteorological materiality of the atmosphere and its cultural production runs through much of the burgeoning field of air studies. In the *Life of Lines* (2015) Ingold argues that these two bodies of knowledge are intimately intertwined. It is the concatenation between the built and the atmospheric, the following of singular atmospheric flows, and not overdetermining the tornado, that offers the chaser insight.

The epistemic form of the chaser is akin to what Deleuze and Guattari call—"nomad science." The nomad scientist is defined through specific attention to materiality, not by representation, but by working with and making connections between material singularities and irregularities.[16] They offer the example of a woodworker using the unique flaws and knots in the material they manipulate. Instead of merely cutting a predesigned pattern onto the wood, the woodworker works with the wood to find singular intensities. Nomad science refuses top-down representations of matter that smooth difference into easily standardized coordinates. The key aspect of this approach is its mode of assessment, which is not one of quantification, but rather of practice and interpretation and of affective intensities, aesthetics, and singularities.[17] The Chaser, working as a nomad scientist, begins their work where quantification and information leave off. Radar and computational models generalize an area of tornadic development, yet an attunement of the senses to rapidly changing conditions allows chasers to enact a much finer-grained environmental awareness.

A successful storm chaser requires an organization of affect, labor, and social space. The process of following intensities and affects requires a particular form of embodiment in the storm chaser that stands apart from the flattened view of computer screens and televisual machinery. The chaser, as opposed to the television weather forecaster, is out in the open, exposed to the elements. They join with the populace in a live, shared risk. In many instances, the storm chaser is also the first responder on the scene once a tornado has done damage, making their primary role one of care, protection, and repair. In the context of environmental media—to borrow Michel De Certeau's distinction between *strategy* and *tactics*—perhaps the state issuance of meteorological warnings is the overall strategy of infrastructural adjustment to environmental threat, while the chaser provides the short-term tactics of everyday analysis.[18]

Chasers engage what Elizabeth Grosz calls *geopower*, where the nonhuman forces of the earth make their mark on human expression (Grosz, 2008). This nonsubjective form of power, through its temporality and destructive force, script the chaser's movements. Aesthetics here is not merely a "distribution of the sensible" (cf. Rancière, 2003), but a process of experimenting with the material forces of the earth. Art, then, may be construed not merely as a cultural achievement, or a solely human endeavor per se, but merely as a repurposing of the forces of geography and time for elaboration and experimentation. In directly engaging the material forces of the earth to experiment with indeterminacy, the chaser's act of citizen science, then, is not far-off from that of Francis Alÿs. In moments of environmental disaster, both Alÿs and the storm chaser harness the vast forces of the earth as processes that radically reorient the personal. It is only that the storm chaser ventures further, using a larger toolset in hopes of a shared survival and a future otherwise.

Both Alÿs and the storm chaser remind us that a monolithic object of nature does not exist. The environment resists prediction. It is erratic, chaotic, and without a subjective will. Environmental change always shirks an external ordering by idealizing forces. Thus, it will not suffice to overcode a closed human interiority onto every nook and cranny of nature.

Instead, storm chasers risk themselves for the survival of communities unknown to them. Rather than turning within in response to the threat of outside force, the chaser joins with the forces of the earth. As such, the nonhuman substrate is not merely a passive background for the projection of human knowledge; it is fundamentally constitutive of the personal. Thus, the chaser performs the meteorology of media as an ongoing attunement to hybrid ways of knowing personal timescales within climate systems.

The tornadic vortex is a strange bending of time and space that does not easily fit into periods, monoliths, archives, or maps. The vortex disrupts and breaks normative modes of epistemology; perhaps this is why, in its metaphoric usage across diverse theoretical fields, it is implied as an outside, an excess, chaotic, or something unthinkable. The tornado forces an immediate response from the scientific mediation apparatus that requires a complex interaction between computation, communication, and individual citizen scientists. A close reading of the tornado suggests an approach to environmental media that follows the short-term breaks and disruptions in the changing weather in search of new relational trajectories between individual and environment.

Notes

1 Le Sueur, Meridel (1940, p. 8), *Salute to Spring.*
2 See Parikka (2015, p. 7).
3 Smithson (1996, p. 12), *Robert Smithson, the Collected Writings.*
4 See Agee et al. (2016).
5 For more on meteorological infrastructure and communication systems, see Paul Edwards, *A Vast Machine: Computer Models, Climate Data, and the Politics of Global Warming.*
6 I am referencing here Gary England's *Breaking News Weather Emergency* broadcast in Oklahoma, City in May of 2011.
7 Sara Ahmed (2013, pp. 70–74), *The Cultural Politics of Emotion*.
8 For more on dressage as an embodied training paradigm, see Lefebvre's (2004, p. 39), *Rythmanalysis.*
9 For more on de-centralized soft control, see Terranova (2004, pp. 98–131), *Network Cultures.*
10 Lazzarato (2014) claims that the contemporary condition under late capitalism is characterized by the simultaneous individuation of subjects as marked by the state as well as the disintegration of the subject via capitalist trajectories of affect and desire.
11 This is taken from Tate's room guide online at http://www.tate.org.uk/whats-on/tate-modern/exhibition/francis-alys/francis-alys-story-deception-room-guide/francis-alys-6
12 See Jennifer Gabrys *Program Earth* and Paul Edwards *A Vast Machine* for the necessity of planetary scale computation in the prediction of atmospheric phenomena.
13 For a key text on citizen science and environmental knowledge, see *Irwin's Citizen Science: A Study of People, Expertise and Sustainable Development*.
14 For the tension between the instrumental knowledge of meteorology i.e.—"meteorologists are at the mercy of their machines"—and the need for trained and embodied verification of severe weather, see Gary Fine's (2006), *Ground Truth: Verification Games in Operational Meteorology.*
15 Ingold (2015, p. 76), *The Life of Lines.*
16 Gilles Deleuze and Félix Guattari (1987, pp. 360–362), *A Thousand Plateaus.*
17 Ibid., pp. 360–362.
18 Michel De Certeau (1984), *The Practice of Everyday Life.*

References

Agee, Ernest, Jennifer Larson, Samuel Childs, and Alexandra Marmo. (2016) Spatial Redistribution of USA Tornado Activity between 1954 and 2013. *Journal of Applied Meteorology and Climatology*, 8, 8–22.

Ahmed, Sara. (2013) *The Cultural Politics of Emotion*. London; New York, Routledge.

de Certeau, Michel. (1984) *The Practice of Everyday Life*. Berkeley, University of California Press.

Deleuze, Gilles and Félix Guattari. (1987) *A Thousand Plateaus: Capitalism and Schizophrenia*. Minneapolis, University of Minnesota Press.
Edwards, Paul. (2010) *A Vast Machine: Computer Models, Climate Data, and the Politics of Global Warming.* Cambridge, MA, MIT Press.
England, Gary. (2011) Breaking News Weather Emergency. *News9.com*, KWTV, Oklahoma City, May 24, 2011.
Fine, G.A. (2006) Ground Truth: Verification Games in Operational Meteorology. *Journal of Contemporary Ethnography*, 35(1), 3–23.
Grosz, Elizabeth. (2008) *Chaos, Territory, Art: Deleuze and the Framing of the Earth*. New York, Columbia University Press.
Ingold, Tim. (2015) *The Life of Lines*. London; New York, Routledge.
Lazzarato, Maurizio. (2014) S*igns and Machines: Capitalism and the Production of Subjectivity.* Los Angeles, CA, Semiotext(e).
Le Sueur, Meridel. (1940) *Salute to Spring*. New York, International Publishers.
Lefebvre, Henri. (2004) *Rhythmanalysis: Space, Time and Everyday Life*. Paris, A&C Black.
Parikka, Jussi. (2015) *A Geology of Media*. Minneapolis, University of Minnesota Press.
Rancière, Jacques. (2003) *The Politics of Aesthetics*. New York, Bloombsury Press.
Smithson, Robert. (1996) *Robert Smithson, the Collected Writings*. Berkeley, University of California Press.
Sturken, Marita. (2006) "Weather Media and Homeland Security: Selling Preparedness in a Volatile World." *Understanding Katrina*. Social Science Research Council Web Forum.
Terranova, T. (2004) *Network Culture: Cultural Politics for the Information Age*. London, Pluto Press.

40

Environ/mental ecologies in new media art

Anne Sophie Witzke and Jonas Fritsch

Introduction

Over the past few decades, the field of new media arts has become marked by a distinctive "environmental sensitivity" (Pold & Andersen, 2015).[1] This sensitivity is provoked by a coupling of two parallel events: first, new media art is responding to the urgency of multiple environmental changes, most notably climate change and its far-reaching and irreversible consequences for ecosystems, animals, and humans. In this respect, new media art's environmental orientation can be situated within the "environmental turn" presently unfolding across the arts and humanities, which has led to a renewed emphasis on human beings' fundamental interconnectedness with the world on all scales.

Second, new media art's interest in the environment stems from an engagement with new technologies and their wider role in societal issues. Various forms of new technological developments, ranging from ubiquitous and mobile computing that can be used to track and monitor individual behavior, to interventions on a planetary scale like geoengineering, are frequently presented as solutions to clearly demarcated environmental issues – what Morozov has criticized as a form of "technological solutionism" (2013). For new media art, which often engages in a self-reflexive exploration of its own materials and technologies, the prospect of using technologies to remedy problems related to environmental issues and to generate environmental consciousness on the part of citizens hence provides an obvious area of artistic inquiry.

In this chapter, we highlight a specific subset of environmental new media art practices that address the social and existential implications of the pervasive climate and cultural crises we are facing today. We primarily attend to *The Bureau of Meteoranxiety* (2018) by Australian artists Olivia Tartaglia and Alex Tate, a hybrid of performance art and mixed-media installation, which explores the intertwining of mental health and climate change by offering technology-mediated therapy for the mental health condition of "meteoranxiety." Coined by ecophilosopher Glenn Albrecht, meteoranxiety denotes "the specific anxiety that people feel when their climate and the weather… becomes so abnormal as to give them a sense of foreboding that the future is going to be more difficult than the present" (Albrecht in Francis, 2018). Meteoranxiety is one in a number of concepts, including concepts like "pre-traumatic

 DOI: 10.4324/9780429437069-50

stress response" and "nature-deficit disorder" (NDD), which have recently been proposed by ecophilosophers and ecopsychologists to capture various forms of mental distress that are emerging in the wake of climate change and environmental detachment.[2] As these concepts indicate, the escalating human impact on the planet not only causes bio-physiological pathologies in climate and environmental systems but also gives rise to negative affects and perceptions for individuals—and even to psychological disease. Indeed, for a growing number of people, the uncertainty and overwhelming complexity presented by climate and environmental problems are accompanied by existential responses like anxiety, fear, grief, powerlessness or resignation (Light, Powell & Shklovski, 2017; Fritsch, 2018). Albrecht hence warns that "[t]he 'unsafe' biophysical space that we are creating for ourselves will have its correlates in a self-generated unsafe psychoterratic (psyche-earth) space" (Albrecht, 2014: 58). A recent report by the American Psychological Association together with the organization ecoAmerica emphasizes the importance of recognizing and attending to these negative mental implications of environmental change, as they "are keeping us [...] from properly addressing the core causes of and solutions for our changing climate, and from building and supporting psychological resiliency" (ecoAmerica & the American Psychological Association, 2017: 4). Yet, within mainstream environmental management policies and the logic of corporate, tech-based environmental solutions, the individual's relationship with climate change is predominantly framed as a matter of personal accountability, rational behavior, and sustainable consumption. Here, we can identify risk in proposing technologies as helpful tools that can provide quick fixes to complex environmentally related issues.[3] Indeed, the existential implications of climate change are rarely taken into account, and the mental, cultural, political, and economic factors that cause climate change in the first place are often left unquestioned.

Artists like Tartaglia and Tate respond to this flawed approach through a critical exploration of the application of technology to climate change issues. Their artistic practice may be located within the variegated field of new media art – art that in some way is created, stored and transmitted by 'new' media technologies and grounded in a contemporary technological episteme. Following artist Mark Tribe's definition, we take new media art to describe art forms that employ "emerging media technologies and are concerned with the cultural, political, and aesthetic possibilities of these tools" (Tribe, 2007: 1).[4] As a term, *new media art* gained prominence in the 1990s, when the spread of the personal computer and the advent of the World Wide Web gave rise to new forms of creative and artistic expression and led to genres such as interactive art, net art, computer art, software art, mixed-media art forms, game art, virtual art, and sound art as well as activist practices like hacktivism and tactical media.[5] These practices have typically focused on the formal properties of new media technologies or the role that these technologies play in shaping our society and identity, taking up issues such as code, software, open source, surveillance, network culture, participation, and online identity. Recently, however, this focus has been extended to include an interest in the environment and its current state of crisis, which can be identified in the work of artists like Natalie Jeremijenko, Beatriz da Costa, YoHa, Amy Balkin, and Marko Peljhan and collective projects like *The People Speak* and *World of Matter*. These are all artists who explore the complex intersection of technology, environment, and society and locate technology within a broader ecological web of human, social, political, and environmental factors, a complex of factors also present in the work of Tartaglia and Tate.

In this chapter, we read the new media artistic approach of Tartaglia and Tate through the work of French philosopher and psychoanalyst Félix Guattari, whose approach to technological and artistic explorations of new value systems and forms of subjectivity is conceptually grounded in a transversal, pluralistic understanding of ecology. Ecology, for Guattari, consists of (at least) three ecological registers: environmental ecology, social ecology and mental ecology, which cross-fertilize each other and therefore must be addressed together. The scope of his project thus goes well beyond the conventional sense of ecology (as concerned with saving the environment and maintaining biodiversity) to include a focus on social relations and conditions of subjectivity. As he asserts, the environmental crisis "can be traced to a more general crisis of the social, political and existential" (Guattari, 2006: 119), and for such reasons, "[i]t is quite wrong to make a distinction between action on the psyche, the socius and the environment" (Guattari, 2008: 28). Guattari, moreover, relates this vital reintegration to art and technology, arguing for a need for artistic expression and technological practices that explore and articulate alternatives to, openings in, or critiques of the prevalent condition of existential, social and environmental ecologies. Thus, Guattari provides us with a very useful vocabulary for grasping new media art's engagement with environmental change and its assorted problems and entanglements.

Our interest in Guattari's thinking resonates with a more general interest in elaborating the notion of *ecology* as a term that may circumvent old dualisms such as culture/nature, technology/biology and subject/object. In an article about Guattari's ecosophical perspective, technology theorist John Tinnell has termed this interest an "ecological turn" associated with the evolution of a form of "ecocriticism" or "eco-humanities" (Tinnell, 2011).[6] Tinnell outlines a genealogical starting point in Arne Naess' "deep ecology" (Naess, 1995) and Gregory Bateson's *Steps to an Ecology of Mind* (Bateson, 1972/2000), to which Herzogenrath adds the joint work of Gilles Deleuze and Guattari (Herzogenrath, ed., 2009). More recently, thinkers have also employed the concept of ecology in new ways, for instance, Timothy Morton's *Ecology without Nature* (Morton, 2009), Bruno Latour's idea of "ecologization" (Latour, 1998, 2008) and Isabelle Stengers' notion of "an ecology of practices" (Stengers, 2005). In light of the proliferation of ecological perspectives, philosopher and cultural theorist Erich Hörl suggests a whole "new ecological paradigm" under the auspices of "general ecology," one that combines research in the humanities with research in cybernetics, systems theory, process philosophy, and discourses on the Anthropocene (Hörl in Anon., 2016; Hörl, 2017). Hörl argues that an ecologization of thought has "traversed the whole 20th century" culminating within the last ten to fifteen years, in which "we are witnessing a powerful form of expression of new ideas that are all somehow under the umbrella of this term 'ecology,'" making ecology "our new historical semantics" (Hörl in Anon, 2016: 26). Indeed, the term *ecology* has been applied across a broad variety of fields from ecopsychology, ecofeminism, and eco-historicism to ecocriticism and ecological media, just to mention a few. Here, we are particularly interested in the strands that explicitly deal with technology within this broader ecological perspective, e.g., with media technologies as ecologies (Fuller, 2005; Brunner and Fritsch, 2013) or "technoecologies" (Parisi, 2009) as well as with strands that explore creative and artistic practices that adopt such a generalized ecological understanding, e.g., with aesthetic ecologies.[7]

Within the diverse theoretical landscape of ecological thinking, this chapter focuses on Guattari's ecosophy, which, we contend, allows us to grasp the complex connections between media, environment, subjectivity, and aesthetics at work in *The Bureau of Meteoranxiety*. In so doing, we argue that this artwork highlights the inherent connection between environmental and existential conditions and thus reveals the bio-physiological crisis in the environment as a crisis of mental and existential ecologies. The artwork critiques the social and political application of technologies as a means to solve this 'environ/mental' crisis and points to art as having a therapeutic effect that mobilizes more usable responses to our contemporary ecological condition.

Guattari on ecology and aesthetics

Félix Guattari develops his ecosophy in his later writings *The Three Ecologies* (Guattari, 1989/2008) and *Chaosmosis: An Ethico-Aesthetic Paradigm* (Guattari, 1992/2006). His notion of ecology, or more precisely ecologies, is a way of addressing a range of paradigmatic problems in all their complex interdependence, instead of compartmentalizing them into separate domains. Guattari calls this comprehensive approach a "generalized ecology," which, more than the "restricted" disciplines of the life sciences, refers to a relational mode of thinking. Generalized ecology connects seemingly disparate elements running from the micro, through the intermediary, to the planetary in scale. As a radical mode of thinking that emphasizes connections, interfaces, and experimentation to "radically decenter social struggles and ways of coming to one's own psyche," its orientation is simultaneously activist and political (Guattari, 2008: 35). In so doing, Guattari opens a conceptual path for thinking alternative forms of environ/mental subjectivity and the role of art and aesthetics in this endeavor.

Taking inspiration from anthropologist, cyberneticist and ecologist Gregory Bateson, who famously claimed that there is "an ecology of bad ideas just as there is an ecology of weeds," Guattari is particularly concerned with the condition and production of subjectivity (Bateson, 1972/2000: 492).[8] Subjectivity is, in Guattari's understanding, a multivalent, performative, pre-personal and pre-individual assemblage of elements. It emerges, in Gary Genosko's formulation:

> as it finds a certain existential consistency, without getting tied down to an identity once and for all, in the crossing points of components, in their intra- and interassemblage relations, sometimes deflating into involutions, blockages, and encystments; at other times taking off through transformations (potential consistencies).
>
> *Genosko (2009: 107)*

Subjectivity can take different forms: it may stiffen in uniform, homogenized ways, becoming trapped in "stratified and deathly repetitions," or conversely, it may open up toward multiple existential territories and unfold in transformative and heterogeneous ways (Guattari, 2008: 35).

Guattari argues that it is vital to support the ongoing creation of "a nascent subjectivity," one that unfolds in all its unique singularity and gives rise to autonomous and unique ideas, expressions, tastes and ways of being (Guattari, 2008: 45). Only by engaging with the conditions of mental ecology, including the fears and anxieties, as well as the homogenized and commodified lifestyles that drive many people, may we prevent the major crises of our time. As Michael Goddard contends:

> [n]o amount of dire warnings, backed up as they may be by hard empirical evidence, about such phenomena as global warming, for example, are ever going to result in the slightest political change without addressing [...] vectors of subjectivation, especially if they are merely imposed as part of a larger culture of fear and the cultivation of toxic and paranoid forms of subjectivity.
>
> *Goddard (2011: 9)*

What Guattari proposes when he speaks about subjectivity and singularity is not the figure of the fully formed liberal individual. Rather, he articulates the emergence of a processual subjectivity that deterritorializes standardized, conformist modes of living that have been shaped through the established, dominant signifying order. The cultivation and affirmation of new subjectivities is hence a fundamentally political and critical practice, one which aims at cultivating dissensus. Yet it does so without presupposing a determinate telos in the form of an alternative dominant ideology or normative order. Thinking mental ecology with Guattari is, in other words, a far cry from any environmentalism that prescribes what actions and reflections the individual should make to live more sustainably. Likewise, it diverges from attempts to control or soothe the inconvenient and difficult feelings that may arise under conditions of crises through various forms of quick fixes and technical solutions (Morozov, 2013).

Guattari's discussion of mental ecology is tightly coupled to his analysis of the dominance of Integrated World Capitalism – or post-industrial capitalism, as we could call it – and to the role of media technologies herein. Post-industrial capitalism captures and grafts subjectivity through a continuous spreading of capitalist semiotics that targets the individual at the level of their thoughts, perceptions, affections, sensations, imagination and desires. This ideological dissemination is facilitated by mass media technologies like television and films, which he criticizes for promoting capitalist interests and engendering infantilized, serialized and "somnolent" individuals that are "reductionistically bound to equivalence and beholden to market fluxes" (Genosko, 2013: 17). Newer technologies of communication and information, like the computer and Internet, are also involved in the production of subjectivity on a signifying and an affective register. Thus, Guattari emphasizes the importance of recognizing technologies as not just representational machines that "convey representative contents," but as machines that are productively involved in modeling subjectivity (Guattari, 2013: 2).

In contrast to his critique of mass media, Guattari's perspective on digital and networked technologies is often seen as overly optimistic, especially when read in concert with his concept of "post-media." In his late writings, Guattari speculates that we are about to enter a post-media era, in which "[t]he information and telematic revolutions are supporting new 'stock exchanges' of value and new collective debate, providing opportunities for the most individual, most singular and most dissensual enterprises" (Guattari, 2008: 43). New participatory and networked technologies show potential to escape the unidirectionality and the 'mass' of the mass media, and to reinvent communication, reinstall participation, and inspire new modalities of subjectivity (Genosko, 2013: 18). Reaching a post-media condition hence becomes a programmatic point in Guattari's ecological thinking, as it involves turning technologies away from capitalism's application of them as conduits of conformity and growth, toward dissensual, re-singularizing and democratizing ends.

At the time of writing, Guattari was fully aware that the values connected with advanced informatics and communication technologies reflected the interests of post-industrial capitalism. The post-media reinvention of the technosphere requires the aesthetic reappropriation and recreation of media practices and uses. It is hence tightly connected with Guattari's notion of the "new aesthetic paradigm," in which aesthetic processes and values permeate the development and employment of digital media technologies, and, at a more basic level, subjectivity, society, and politics (Guattari, 2006). Accordingly, aesthetic creation represents for Guattari the most potent form of political resistance to capitalism's overdetermination of values, feelings, and thoughts. It holds the capacity to foster deviant and heterogeneous blocks of sensation, percepts and affects that transport us into new sensual and imaginary worlds – ultimately, into new ways of being. In this sense, an aesthetic paradigm is imbued with ethical and political concerns:

> The new aesthetic paradigm has ethico-political implications because to speak of creation is to speak of the responsibility of the creative instance with regard to the thing

> created, inflection of the state of things, bifurcation beyond pre-established schemas, once again taking into account the fate of alterity in its extreme modalities.
>
> *Guattari (2006: 7)*

An aesthetic paradigm cannot be limited to what is conventionally considered art, but rather should be considered "as an expanded field of creative life practices" (O'Sullivan, 2010: 259). Art holds a privileged position within this paradigm, however, as art has the "function of rupturing with forms and significations circulating trivially in the social field" and "takes its capacity to invent mutant coordinates to the extremes: it engenders unprecedented, unforeseen and unthinkable qualities of being" (Guattari, 2006: 106, 130–131). Consequently, art's force of creation can be directly linked to the production of subjectivity as a processual, aesthetic mode of existence.

As media art scholars have noted, Guattari's coupling of the post-media condition and the aesthetic paradigm resonates well with the aspirations and assumptions of critical new media art, which has a long tradition of exploring digital technologies in the pursuit of change within the social and personal realm (Goddard, 2011; Apprich, 2013). Yet, one might well argue that environmentally aware new media art extends this critical approach and goes further by acknowledging the biophysical realm as equally important to that of the social and mental. Environmentally aware new media art is, in this respect, exemplary of the type of generalized ecology that Guattari articulates, which emphasizes the interdependent emergence of ecologies across mental, social, and biophysical registers. In the next section, we unfold the art project, *The Bureau of Meteoranxiety*, which attends to exactly these interdependences through an ethico-aesthetic exploration of the intertwinement between meteorological disruptions and human mental distress and critiques the use of neoliberal tech-based solutions to this environ/mental crisis.

Meteoranxiety – the environ/mental dysphoria of climate change

The Bureau of Meteoranxiety (BoMa) was created by the Australian artists Olivia Tartaglia and Alex Tate for the Next Wave Festival in Melbourne (2018). The artwork maps out an imaginary and semi-futuristic government bureau that offers technology-based therapeutic treatment of environmentally related pre-traumatic stress and meteoranxiety. A hybrid of interactive performance art and mixed-media installation, BoMa allows participants to work through their fears of climate change by exposing them to "experimental visual therapies and sensory remedies" and by providing "new language and coping strategies to help stay above the metaphorical and literal flood line" (Tartaglia & Tate, 2018).

The installation is composed of two main elements: an indoor gallery space turned into the Bureau's fictitious public office, replete with a waiting room and staff, and an outdoor program that consists of a set of posters placed in the vicinity of the 'office.' The posters, which have the form of public awareness campaigns, urge people to be alert of the symptoms of meteoranxiety: "Feeling isolated? Disconnected? You might have Nature Deficit Disorder," reads one poster. "Checking the weather…Again? You might have Meteoranxiety," reads another. And a third contends, "'Weird Weather.' It is more than small-talk. Stop the spread of Meteoranxiety." Concerned people are encouraged to seek professional assistance at the Bureau, to "Visit BoMa and learn the signs."[9]

Inside the bureau's office – a white, clinical and corporate-laboratory-looking space – audience-participants register as 'patients' at a front desk in the waiting room. There they receive a questionnaire from a BoMa staff member to assess their level of meteoranxiety. In response to this "wellness trial," the bureau offers its patients a "public wellness program" that is presented to the participants as the first of its kind, based on "new cutting edge technology, which is guaranteed to help you feel less meteoranxious and identify the feeling" (Tartaglia & Tate, 2018). The public wellness program consists of four therapeutic treatments that combat climate anxieties through different methods: *Exposure Therapy*, cloaked as a guided meditation, starts off with a calm and soothing forest environment, but escalates into a strange, unexpected and troubling weather event that leaves the participants uneasy and disturbed; *Counselling* by an Artificial Intelligent Chatbot therapist called Gail (developed by Howard Melbyczuk), who delivers online advice, which is sometimes understandable and useful, and at others completely random and incomprehensible; *Journal Therapy* – a mode of therapy where the patients are invited to share their feelings with one another and respond to the question "When was the last time you felt Meteoranxious?" on video and in writing through an online group journal; and *Virtual Reality Therapy*, which gives patients a therapeutic dose of 'nature' by immersing them in a realistic VR simulation of a beautiful, native rainforest. The bureau claims that this type of VR "forest bath" can decrease meteoranxiety and cure patients with nature-deficit disorder (NDD), a term for the mental costs of spending more and more time indoors, absorbed in electronic technologies and modern things, and becoming increasingly alienated from the natural world (Louv, 2005). Another element in this form of therapy, which BoMa titles "NatureConnect" therapy, is a 3D print of a tree from the virtual reality simulation, which is mounted on the wall so that patients can touch and feel the grooves of the bark that they see in VR.

Using language and visual design reminiscent of governmental agencies and the health care sector, BoMa is imbued with an air of authority, scientific expertise and effectiveness, which promotes the impression of BoMa as a credible governmental organization established to control and manage the public's mental health in the wake of climate change. This impression that is enhanced by the proximity between the name The Bureau of Meteoranxiety (BoMa) and the actual Australian Bureau of Meteorology (BOM). Yet, the therapies that BoMa propose as solutions to the patients' mental disorders appear absurd and counterintuitive: lack of contact with the natural world is treated with a simulation of nature in the form of a VR environment and a 3D-printed tree rather than with nature itself, and climate worries and anxieties are supposed to be sorted out through the perplexing counseling by Gail, the AI robot. These futuristic technological therapies hardly solve the environ/mental dysphoria and trauma experienced by an increasing number of people and appear as rather useless coping strategies designed to position the individual as responsible for adapting to the existing, dysfunctional conditions.

In BoMa, Tartaglia and Tate use satire and irony coupled with elements of sci-fi and futurism to elicit ridicule for such temporary and diminutive technological quick fixes, which take on a Sisyphean character. The traumas they purport to heal will continue to be reactivated until the overwhelming environmental issues that cause them are solved. This aesthetic strategy is not used just to depict a potential future scenario in a humorous way. Rather, Tartaglia and Tate exhibit a deep skepticism about the logics, motivations and results of current pro-tech politics, which posit new technologies as solutions to all sorts of societal problems from anthropogenic climate change to patient care in the healthcare sector, but are less interested in questioning the structural causes and societal conditions that have generated these problems in the first place. In this respect, BoMa imitates contemporary neoliberal politics, in which the focus is on individual adaptation and symptom treatment rather than systemic change. Rather than changing reality so it becomes more livable, digital technology is used in this context as an instrument that "seizes individuals from the inside," enrolling client-users with negative or divergent behaviors into compliance with existing conditions (Guattari, 2009: 262). Tartaglia and Tate, however, refuse to present this existential model as a viable option. The artwork's built-in flaw – that is, the failure of the technology-based therapies to work – suggests that current politics and its supporting apparatus of capture cannot be the antidote to environ/mental dysfunction, which are bi-products of the culture of growth, consumption, and waste that neoliberalism has created. In this way, BoMa critically negates the techno-neoliberal and individualized model of subjectivity by entangling itself with this apparatus of capture and eliciting its paradoxes from within.

Tartaglia and Tate's project demonstrates the continued relevance of Guattari's transversal ecological thinking, with its emphasis on the interconnectedness of mental, social, and environmental ecologies. By addressing the question of mental distress as part of ongoing environmental disasters, as well as current policies and social structures, the work emphasizes that we cannot bring about changes in one of these ecological dimensions without attending to the others. BoMa also echoes Guattari's dual call for a redirection of technologies and artistic experimentation with the goal of fostering more open and diverse forms of subjectivity. Although Tartaglia and Tate do not propose concrete alternative technological practices designed to achieve a liberating, post-media condition (as many critical new media artists aim to do), their artwork is a creative exploration of how digital technologies as apparatuses of capture take part in the production of subjectivity in an age of climate change. Indeed, Guattari's assertion that "[f]rom now on, no domain of opinion, thought, image, affect or narrativity can pretend to escape from the invasive grip of 'computer-assisted' data banks, the telematic etc." (2013: 1) aptly describes the scenario presented in BoMa, where deviant mental reactions to climate change are molded through technological devices and programs. The model of technology-assisted therapy utilized in BoMa provides an opportunity to critically consider the limitations of an individualized, technologically based approach to the immense environmental impacts on individuals and communities that characterize neoliberal polices.

As an alternative to this flawed model, we might finally consider *The Bureau of Meteoranxiety* as providing a different therapeutic model based on the encounter with the artwork itself. If we apply the schizoanalytic lens of Guattari to the art piece, psychoterratic pathologies may themselves provide a starting point for thinking subjectivity anew. As Guattari emphasizes:

> it's not simply a matter of remodeling a patient's subjectivity – as it existed before a psychotic crisis – but of a production sui generis. […]. These complexes actually offer people diverse possibilities for recomposing their existential corporeality, to get out of their repetitive impasses and, in a certain way, to resingularise themselves.
>
> *Guattari (2006: 6–7)*

The goal of schizoanalysis is, in other words, not to bring the patient back to normality by re-installing dominant norms in their behavior, thus adapting them to the existing world, but to promote new and singularized subjectivities. Through the deterritorialization of the patient's obsessive framework of thought, schizoanalysis involves the creation of new percepts and affects, new beliefs and values, which can help them to gain access to new ways of being.[10]

As an artwork, BoMa assists in this process by offering us new perceptions, understandings, and worldviews, which point toward new realities and subjectivities. Indeed, as Guattari suggests, art has an existential impact and "is capable of engendering mutant subjectivities" (Guattari, 2006: 90). BoMa should be viewed not only as a critique of the present, but also "as a starting point for people thinking about the real world," as one of the artists, Alex Tate, puts it, and for thinking the future anew (Tate in Cockerill, 2018). In this light, the environ/

mental depressions depicted in BoMa contain a potential germ for the cultivation of new, dissident ideas and subjectivities. The piece operates on the edge of the actual and the virtual, concerning itself with the world in which it is created as well as providing the audience with a space of reflection in which to consider the potentialities of a future yet to come. While art surely cannot solve the climate crisis or its negative existential impacts alone, it can provide us with critical insights, speculative proposals, and alternative models, which can inspire us to imagine new and viable environ/mental ecologies. BoMa is an artwork that brings together aesthetics, technology, existential issues and environmental change in order to encourage us to live differently and more ecosophically on the planet.

Notes

1 Smite and Smits similarly identify an emerging "techno-ecological" paradigm within contemporary media art, arguing that "the growing tendency in contemporary media art to address and work with sustainability issues [...] is evidence of an ongoing and fundamental shift from a 'techno-scientific' to a 'techno-ecological' paradigm" (Smite & Smits, 2013: 143).

2 The term *pre-traumatic stress response* is "a before-the-fact version of classic PTSD" proposed by the psychiatrist Lise Van Susteren to capture the anticipatory anxiety about an event that may occur in the future, whereas the term *nature-deficit disorder*, coined by journalist Richard Louv, denotes a range of behavioral problems such as depression and reduced attention span that occurs due to the lack of immersion and interaction with the natural world, for example when living in large cities with minimal amounts of plants, animals or clean air (van Susteren, 2017: 57; Louv, 2005).

3 This is, for instance, evident in recent smart cities proposals that suggest that environmental sustainability and environmentally consciousness can be achieved through a widespread enrollment of digital technologies, which will help people monitor and understand the environmental impact of their actions. The assumption seems to be that individuals, tooled up with digital equipment, will make rational choices based on information derived from digital tools and cybernetic feedback systems coupled with economic incitements to redirect consumption patterns. For more examples and a detailed critique of this approach, see, e.g., Adam Greenfield, *Against the Smart City* (2013); or Evgeny Morozov, *To Save Everything, Click Here: The Folly of Technological Solutionism* (2014).

4 *New media art* is a contested term. For one thing, the term has proven difficult to define due to the rapid changes that digital media and new technologies undergo. Reflecting these changes, new media art practices as well as the theoretical understanding of them constantly evolve and shift, which makes it hard to settle on a commonly accepted definition (Grau, 2016). Another issue that is often critiqued has to do with the term's emphasis on newness. As new media art curator Christiana Paul, among others, has argued, "The problematic qualifier of the "new" always implies its own integration, datedness and obsolescence," signaling an art genre that only employs the newest emerging technologies (Paul, 2016: 1).

5 The term *new media art* is often used interchangeably with *digital art*, with the slight difference that digital art typically also includes artistic practices that take digital technologies as a means to enhance existing art forms such as photography and print, whereas new media art tends to focus more exclusively on art that explores the formal properties or cultural practices associated with new technologies.

6 The ecological humanities are also frequently labeled "the environmental humanities" – a rapidly growing interdisciplinary formation that has emerged within the last two decades as a response to the enormous scope and complexity of the many interrelated environmental crises of the present era. This burgeoning interdisciplinary field of research draws together multiple subfields such as philosophy, literature, history, digital humanities, media studies, post-colonial studies, gender studies and political ecology, transforming and reorienting their conventional topics, methods and practices so they can account for the new perspectives and changed worldviews that arise in the wake of man-made climate changes. For a discussion of the environmental humanities, see, for instance, Bergthaller et al. (2014) and Rose et al. (2012).

7 On media-based aesthetic ecologies, see, for instance, Smite and Smits, "Emerging Techno-Ecological Art Practices: Towards Renewable Futures" (2013); Schick and Witzke, "Atmosfæriske konstellationer – kunsten at økologisere" (2014); and Parikka, *A Geology of Media* (2015). On

ecology and art, more broadly, see, among others, Demos, *Decolonizing Nature. Contemporary Art and the Politics of Ecology* (2016); and Scott, "Artists' Platforms for New Ecologies" (2013).

8 Guattari's notion of three ecologies is also inspired by the work of Gregory Bateson, who formulated the idea of three interrelated systems existing at the level of mind, society and environment in *Steps to An Ecology of Mind* (Bateson, 1972/2000).

9 *The Bureau of Meteoranxiety* (BoMa) by artists Olivia Tartaglia and Alex Tate, exhibited at the Next Wave Festival in Melbourne (2018).

10 Along similar lines, Franco "Bifo" Berardi argues in the text "How to heal a depression" that depression should not be seen "as a mere pathology, but also as a special form of knowledge," a condition of the mind characterized by dissolution and decomposition, which – upon overcoming it – makes room for different re-compositions of the mind (Berardi, 2016). Referring to Guattari's thinking, he suggests that the "schizoanalytic method should be applied as a political therapy in the current situation," arguing that the recent financial collapse in the global economy and the exhaustion of planetary resources are creating a political and economic depression, which gives space for the creation of different political visions and social organizations (Berardi, 2016).

References

Albrecht, G., 2014. Ecopsychology in the Symbiocene. *Ecopsychology*, 6(1), pp. 58–59.

Anon, 2016. Erich Hörl. A continent. Inter-view. *Continent*, 5(2), pp. 25–30. Available at: http://www.continentcontinent.cc/index.php/continent/article/view/242 [Accessed August 30, 2019].

Apprich, C., 2013. *Remaking media practices – from tactical media to post-media*. metamute, pp. 1–13. Available at: http://www.metamute.org/editorial/lab/remaking-media-practices-–-tactical-media-to-post-media [Accessed July 1, 2017].

Bateson, G., 2000. *Steps to an Ecology of Mind (1972).* Chicago and London: The University of Chicago Press

Berardi, F. 'Bifo', 2016. *How to heal a depression?* Available at: https://transversal.at/blog/How_to_heal_a_depression [Accessed September 15, 2019].

Bergthaller, H. et al., 2014. Mapping Common Ground: Ecocriticism, Environmental History, and the Environmental Humanities. *Environmental Humanities*, 5, pp. 261–276.

Brunner, C. & Fritsch, J., 2013. Beyond the Network: Experiential Fields and Urban Media Ecologies. In *Proceedings of the Media Cities 4 Conference*, Buffalo, NY, pp. 277–287.

Cockerill, J., 2018. *Bureau of Meteoranxiety*. unprojects.org.au. Available at: http://unprojects.org.au/un-extended/dear-un/bureau-of-meteoranxiety/ [Accessed July 1, 2018].

Demos, T.J., 2016. *Decolonizing Nature. Contemporary Art and the Politics of Ecology*. Berlin: Sternberg Press.

ecoAmerica & The American Psychological Association, 2017. *Mental Health and Our Changing Climate*. Available at: http://ecoamerica.org/wp-content/uploads/2017/03/ea-apa-psych-report-web.pdf. [Accessed July 1, 2018].

Francis, H., 2018. *Bureau of Meteoranxiety is here to address your climate stress*. Available at: https://www.theage.com.au/entertainment/theatre/bureau-of-meteoranxiety-is-here-to-address-your-climate-stress-20180510-p4zej0.html [Accessed July 5, 2018].

Fritsch, J., 2018. Affective Interaction Design at the End of the World. In *Proceedings of the Design Research Society* (DRS) Conference, Limerick, Ireland, pp. 896–908.

Fuller, M., 2005. *Media Ecologies: Materialist Energies in Art and Technoculture*. Cambridge, MA: MIT Press.

Genosko, G., 2009. Subjectivity and Art in Guattari's *The Three Ecologies*. In B. Herzogenrath, ed. *Deleuze|Guattari & Ecology*. Basingstoke: Palgrave Macmillan, pp. 102–115

Genosko, G., 2013. The Promise of Post-Media. In C. Apprich et al., eds. *Provocative Alloys: A Post-Media Anthology*. Lüneburg: Post-Media Lab & Mute Books, pp. 14–25.

Goddard, M., 2011. FCJ-114 Towards an Archaeology of Media Ecologies: "Media Ecology," Political Subjectivation and Free Radios. *The Fibreculture Journal*, pp. 6–17.

Grau, O. 2016. *New Media Art*. Oxford Research Bibliographies. Available at: http://0-www.oxfordbibliographiesonline.com/view/document/obo-9780199920105/obo-9780199920105-0082.xml [Accessed September 15, 2019].

Guattari, F., 2006. *Chaosmosis*. Sydney: Power Publications.

Guattari, F., 2008. *The Three Ecologies (1989).* London: Continuum.

Guattari, F., 2009. Capital as the Integral of Power Formations. In S. Lotringer, ed. *Soft Subversions. Texts and Interviews 1977–1985*. New York: Semiotext(e), pp. 244–264.

Guattari, F., 2013. *Schizoanalytic Cartographies (1989)*. London: Bloomsbury Publishing.

Herzogenrath, B. ed., 2009. *Deleuze/Guattari & Ecology*. Basingstoke: Palgrave Macmillan.

Hörl, E., 2017. *General Ecology. The New Ecological Paradigm*. London: Bloomsbury Academic.

Latour, B., 1998. To Modernize or to Ecologize? That's the Question. In N. Castree and B Willems-Broun, eds. *Remaking Reality: Nature at the Millenium*. London & New York: Routledge, pp. 221–242.

Latour, B., 2008. *Politics of Nature: How to Bring the Sciences into Democracy*. Cambridge, MA: MIT Press.

Light, A., Powell, A. & Shklovski, I., 2017. *Design for Existential Crisis in the Anthropocene Age*. New York: ACM.

Louv, R., 2005. *Last Child in the Woods*. Chapel Hill, NC: Algonquin Books of Chapel Hill.

Morozov, E., 2013. *To Save Everything, Click Here: The Folly of Technological Solutionism*. New York: Public Affairs.

Morton, T., 2009. *Ecology without Nature*. Cambridge, MA: Harvard University Press.

Naess, Arne, 1995. Self-Realization: An Ecological Approach to Being in the World. In Alan Drengson and Yuichi Inoue, eds. *The Deep Ecology Movement*. Berkeley: North Atlantic, pp. 13–30.

O'Sullivan, S., 2010. Guattari's Aesthetic Paradigm: From the Folding of the Finite/Infinite Relation to Schizoanalytic Metamodelisation. *Deleuze Studies*, 4(2), pp. 256–286.

Parikka, J., 2015. *A Geology of Media*. Minneapolis: University of Minnesota Press.

Parisi, L., 2009. Technoecologies of sensation. In B. Herzogenrath, ed. *Deleuze/Guattari & Ecology*. Basingstoke: Palgrave Macmillan, pp. 182–199.

Paul, C., 2016. Introduction: From Digital to Post-Digital-Evolutions of an Art Form. In C. Paul, ed. *A Companion to Digital Art*. Chichester: John Wiley & Sons, pp. 1–20.

Pold, S. & Andersen, C.U., 2015. How to Experience and Relate to Climate Change: The Role of Digital Climate Art. In C.S. Paldam & J. Wamberg, eds. *Art, Technology and Nature*. Burlington, VT: Ashgate Publishing, Ltd., pp. 163–174.

Rose, D.B. et al., 2012. Thinking Through the Environment, Unsettling the Humanities. *Environmental Humanities*, 1, pp. 1–5.

Schick, L. & Witzke, A.S., 2014, Atmosfæriske konstellationer - kunsten at økologisere. In M. Sørensen & M.F. Eskjær, eds. *Klima og mennesker. Humanistiske perspektiver på klimaforandringer*. Copenhagen: Museum Tusculanums Forlag, pp. 81–107.

Scott, E., 2013. Artists' Platforms for New Ecologies. In T.J. Demos, ed. *Third Text. Contemporary Art and the Politics of Ecology* (27) online supplement, Available at: http://www.thirdtext.org/artists-platforms-for-new-ecologies-arc [Accessed August 30, 2019].

Smite, R. & Smits, R., 2013. Emerging Techno-Ecological Art Practices: Towards Renewable Futures. In C. Apprich et al., eds. *Provocative Alloys: A Post-Media Anthology*. Lüneburg: Post-Media Lab & Mute Books, pp. 142–159.

Stengers, I., 2005. Introductory Notes on an Ecology of Practices. *Cultural Studies Review*, 11(1), pp. 183–196.

Tartaglia, O. & Tate, A., 2018. *Bureau of Meteoranxiety*, Melbourne: Blindside. Available at: https://blindside.org.au/program/bureau-of-meteoranxiety [Accessed August 20, 2021].

Tinnell, J., 2011. FCJ-121 Transversalising the Ecological Turn: Four Components of Felix Guattari's Ecosophical Perspective. *The Fibreculture Journal* (18), pp. 35–64.

Tribe, M., 2007. *New Media Art - Introduction*. Available at: http://atc.berkeley.edu/201/readings/New%20Media%20Art%20-%20Introduction%20-%20Mark%20Tribe%20-%20Brown%20University%20Wiki.pdf.

van Susteren, L., 2017. Our Moral Obligation: The Duty to Warn and Act. In The American Psychological Association & EcoAmerica, eds. *Mental Health and Our Changing Climate*. Washington, DC: ecoAmerica, pp. 57–57. Available at: http://ecoamerica.org/wp-content/uploads/2017/03/ea-apa-psych-report-web.pdf.

41

Changing imaginaries and new technoecologies of urban air

Hanna Husberg and Agáta Marzecová

> Air is part of my memory. It's a very important ingredient of my memory. We breathe in and out; we collect things, emotions that linger in our realities; we take it in. We breathe all the time, in and out, but we don't notice it. It's almost as if we take in reality and transform it into memories that we recall sometimes.
>
> *(CSY)*

DOI: 10.4324/9780429437069-51

In my childhood, I don't really remember the air being smog. We would call it sandy.

(VS)

I came to Beijing in 2008. That was the golden year. I thought, "Oh my god, who told me that the air in Beijing is bad?!" There were blue skies every day and no dust storms, because the Chinese government planted all those trees to fight against the dust and it really worked.

(HS)

Before 1990, we were afraid of the great wind, but since 1990, we hope for the wind to come. Because before the wind brought sand, dust. But now when the wind comes, the air pollution disappears.

(XMF)

There is this word 'sharing the faith, breathing the air together.' It comes from political propaganda. It means, if you breathe air together, you share the same destiny, the same faith. You are connected heart to heart, and you should fight for the same purpose. So that's a very ironic expression now. If we're breathing the same bad air together now, then what future will we share?

(CSY)

This chapter explores the emergence of new datafied imaginaries of urban air by tracing connections between the embodied experience of living in the highly polluted air of Beijing and the spread of new digital technologies for sensing particulate air pollution. Shaped by novel automated air pollution data, this reconceptualisation of notions of air, we observe, is conducive to a shift towards algorithmic distributions of power and agency. This, we argue, is because the ubiquitous data and numbers not only inform city inhabitants about the air quality but also significantly influence and instruct their behaviour.

Developed as a dialogue between an environmental scientist and an artist, our inquiry builds upon artistic research conducted by Hanna Husberg during a three-month residency at Beijing's Institute for Provocation in autumn 2016. Husberg was interested in experiencing the bodily affects and effects of the notoriously dense Beijing air herself; however, the time frame of the residency was relatively short in comparison with the slow and complex ways in which the effects of air pollution manifest. In view of this constraint, the artist adopted dialogue as her central methodology for gathering insight into local imaginaries of air and its pollution. Rather than conducting interviews, the artist engaged people in conversation about their relation to air, how it is noticed, lived with, distributed and governed. The open-endedness of Husberg's questioning allowed for different interpretations and left space for the interlocutors to choose the direction of the encounter. The artist's position as a foreigner and non-Chinese speaker hosted by a cultural institution in central Beijing influenced who she was able to engage in her research, foregrounding middle-class perspectives. Yet, it also resulted in intimate encounters, moments in which interlocutors had to communicate in a foreign language and across cultural differences, highlighting the importance of bodily and non-verbal responses.[1] With the permission of participants, the dialogues yielded a rich collection of "aerial accounts"—audio recordings and transcripts that recount experiences of living in the hazy Beijing air. The narratives collected provide far-ranging and varied perspectives, and sometimes contradictory information about urban air, yet they also contain distinct similarities and patterns, which substantiate our claim of the emergence of broadly shared changes in the perception of air. These changes extended beyond the conceptual question of what air and pollution might be; they included analogous memories and affective impressions, new practices of observing air quality data and changes in daily behaviour in response to such measurements, and concerns about the future.

Elsewhere, the aerial accounts form the basis of an audiovisual installation which has been circulated in art contexts (Husberg, 2017). Employing fragments of the recorded dialogues to construct a collective narrative about living in the dense Beijing air, the installation allows a diversity of voices that bear witness to the changing air quality to be heard directly. The quality and materiality of the recordings—the non-verbal elements, the silences, what is left out—manifest the intimate qualities of air. This essay, which is based on the transcripts of the source material, is written in parallel to the installation with the aim of circulating insights derived from Beijing beyond art contexts. Here, we utilise the aerial accounts as compelling indicators of changing aerial imaginaries and sensibilities.

Atmospheric imaginaries are not merely affective and aesthetic impressions; they are also generative of specific discourses and practices. They matter precisely because how we collectively imagine things influences how we act, what we consider "normal," and how we chart directions towards possible, or desirable, futures. In this way, imaginaries are performative and capable of agency (Gabriel, 2014). What differentiates our art-led approach from more traditional forms of academic analysis is that the observations and experiences raised through open-ended dialogue are not interpreted through a discrete, predetermined theoretical framework. Rather, we take the Beijing narratives as a point of departure, allowing

When I grew older, the sky was always white or grey. Even in my hometown, people got used to that. One day I just opened the TV and people said, "Oh, that is not the fog!"

(YYD)

It was winter something like four years ago. There was bad weather for one week, two weeks. But we didn't know; we thought it was just fog. Because smog, this word, it didn't exist.

(WEL)

Wumai was a new word. I don't even know how to write 'mai' the Chinese character. I probably need to use the pinyin computer system to figure out the word.

(JJ)

We learned about smog from Dickens' novels in middle school. We were reading all those novels and got to know the word 'smog'. But we never associated this word with Chinese air.

(HS)

It's only little by little when you realise that so many people get cancer, get a lung problem. Certain newspapers or media start to talk about it. Then it became a problem.

(SQ)

What I'm saying is that it's perceptible, but people's perception cheated them, they thought it was just the old dust storm, the old air pollution, they did not realise it was actually something new, something very different.

(HS)

them to lead us towards theoretical insights and connections that may not have developed through existing scholarship on this subject but which nevertheless strongly resonate with Beijing residents' air-related observations and concerns. Our writing attempts to extend these dialogues and situate the embodied experience of urban air as a shared concern of art, ecology and cultural theory.[2]

This new air, the one we talk about a lot

The air of Beijing made international headlines in 2008, as the city hosted the 29th Olympic Games. Alongside debates about human rights and rapid urbanisation, Beijing's airborne particulates stirred concern among a legion of scientists, athletes and bureaucrats. Despite the alarming global media coverage, the aerial accounts offered here suggest that many Beijingers remember the weather of the year of the Olympics being great. Indeed, polluting factories and plants were closed down, and much of the road traffic was removed (see, for example, UN Environment, 2019; Yardley, 2008). Moreover, we learn that Beijing's air had never been considered good in the first place. Several people brought up the issue that the North China Plain has long been subject to severe long-distance dust storms from the northwest, and described how, until the construction of the "Green Great Wall" (wind-breaking forest strips holding back the Gobi Desert), seasonal winds regularly covered the capital and the coastal areas in a layer of yellow dust (see also Zee, 2015).[3]

Although particulate pollution may have been critically elevated for decades, it was only in January 2013, when Beijing was hit for several consecutive days by particulate pollution of unimaginable levels, that a new term, wumai/雾霾 was adopted by the general public. "Wumai was a new word," JJ claims. "It was winter something like four years ago," WEL confirms. The January 2013 smog was experienced as a catastrophic event and nicknamed the "airpocalypse event" by newspapers (Ferreri et al., 2018). Suddenly, everyone started talking and sending messages about this newly alarming phenomenon.

The notion of smog had long been registered in China. Images of the London smog have figured in the Chinese press since the 1870s, and the twentieth-century English neologism "smog" was translated into Chinese as yanwu/烟雾 (Li & Svarverud, 2018; Xu, 2017). In view of this, the emergence of a new word describing smog in the twenty-first century might seem surprising. Yet, as we learn from HS, the earlier notion of smog (yanwu) was never associated with Chinese air. Rather, it conveyed an idea of smog as something foreign. In particular, it referred to the smog of Victorian England, which had primarily been understood as mist and fog, and lacked the connotation of health-hazardous air pollution (Wang & Kádár, 2018). In contrast to the earlier word for smog 'yanwu,' 'wumai' conveys a sense of something ominous, as suggested by the words of LL: "Mai is definitely not something nice. It's something quite monstrously dangerous. Wumai means pollution mixed with everything." The shift in terminology in response to the 2013 airpocalypse and other increasingly frequent smog episodes in China suggests that, although the public might have previously been aware of changes or deteriorations in air quality, few realised that the haze from industrial emissions posed serious health risks (Li & Svarverud, 2018). The spread of a new word for the phenomenon of smog marks the disconcerting collective realisation that invisible components of the air may be toxic and a health threat. Further, it indicates a closer alignment of Chinese aerial imaginaries with archetypal western imaginaries of smog (Aunan et al., 2018).

The data, the numbers, made the air become this new air, the one we talk about a lot. Suddenly it becomes a problem, and we realised that this bad air had, in fact, existed for a long time in our lives.

(TGB)

I would say it became visible with technology, with the apps. All of a sudden, you're being introduced to this mechanism. The apps are measuring this and telling you it has already been three years that you have been exposed to very high levels. You called them white skies, but actually, it is pollution.

(AR)

It's called psychological warhead. To make people confused. You have different indexes with different numbers. Then people don't talk about the pollution, they talk about indexes: "Is it 250 or 140?"

(AA)

In Beijing, the air is not air. It's solid, it's a block. Which is true, it's not just a metaphor. This index, it's counting particles in the air. It's a solid material, it's not gas. It's not a metaphor… I mean the air is fine; there is something in the air which is wrong.

(AA)

It easily becomes a bit technical, but it's quite interesting. It's like watching birds or anything else, you learn from where you live. I keep track of these particles that I cannot see through the measuring device.

(HS)

Strikingly, in addition to the new term 'wumai', the importance of numbers and technical words was emphasised in many accounts of Beijing's air collected by Husberg. This highlights how the neologism, which explicitly recognises air's potential toxicity, appeared alongside the digital dissemination of technoscientific concepts, such as $PM_{2.5}$ (an analytical measure of airborne particulate matter smaller than 2.5 µm in diameter) and the National Air Quality Index (AQI). Adopted in China after the infamous airpocalypse event, the AQI is a unitless index designed to provide statistical information about expected health impacts of exposure to common airborne pollutants in urban populations. It is based on $PM_{2.5}$ values, considered the most health-threatening element of the index, and several other atmospheric pollutants (see, for example, http://aqicn.org/city/beijing).[4] Nowadays, all parameters that constitute the AQI index are detected using automated environmental sensors that produce continuous, near real-time data transmissions (see, for example, Snyder et al., 2013). Although not necessarily aware of the technological processes behind the air pollution data, our interlocutors explained how their attunement to the invisible terrain of particles was enabled by "the apps" and other forms of digital access to pollution data in real time. Furthermore, they described how this new awareness about fluctuating particle levels influenced the way they went about their daily lives and made plans for the future. In other words, the aerial accounts bear witness to the ways in which the data-informed notion of wumai not only constitutes a 'new air' but also influences and regulates modes of existing within the city.

A technoecological sense of air

While the actual aerosols that constitute smog are far more complicated in size and chemical composition than the AQI and $PM_{2.5}$ indexes account for, these measurements provide robust enough, real-time approximations of the potential toxicity of air for immediate daily use. As the Beijing narratives attest, AQI or $PM_{2.5}$ data matter because, unlike other, more nuanced, but expensive and time-consuming analytical techniques, they can be relatively easily shared and used by a broad public. In a city subjected to severe air pollution, the real-time, continuous stream of $PM_{2.5}$ data—made accessible by digital communication technologies—has managed to connect findings from worldwide epidemiologic and scientific studies with the daily experiences of urban dwellers. This enables users of these technologies to sense and monitor air pollution beyond its visible manifestations, such as smoke or dust. Encountering the AQI and $PM_{2.5}$ values in the news, through smartphone apps, in weather predictions, or even transmitted through smart sensors installed in homes, has "made the air become this new air, the one we talk about a lot," as expressed by TGB. It has also contributed to novel ways for city inhabitants to sense air and embody awareness of variations of minute airborne particulate matter. The use of these devices generates a distinctly new technological or rather 'technoecological' sense of air.

Discussing the materialisation of the technoecological sense, media theorist Erich Hörl (2017) emphasises that digital environmental technologies do not merely inform us about ecology. Rather, cybernetics and the spread of digital technologies have been essential for the twentieth-century ecologisation of thinking. Resonating with Hörl's observation, in our case, AQI and $PM_{2.5}$ are not discrete material elements there waiting to be discovered, but scientific abstractions wholly dependent on technological apparatus. And yet, as conveyed by the Beijing residents' reflections on what one of our interlocutors aptly calls "this new air," with its emphasis on numbers and technical terms, it might seem as if $PM_{2.5}$ or AQI is actually *in the air.* Assimilated as seemingly natural enhancements of our senses, sensing technologies

We are not safe anywhere, even when we are inside. Even when we are sitting here, I keep on looking at that door opening and shutting. I didn't notice there was an entrance and exit right here. And I'm like, Oh, we should have gone to another cafe.

(VN)

One day last year, early 2015 it was really bad, and the government sent text messages to citizens that the air is really bad, take care of yourselves, drink hot water and wear your masks. The first time, an official suggestion to wear masks.

(AA)

How is it possible that you have a city—there are 25 million people here—and somewhere that choice is being made that these people for the coming two or three weeks are going to live in toxic air? You know, the plan is being executed.

(MT)

Wearing a mask or turning on the air purifier is not helping the air situation. But if you stop wearing a mask or stop turning on the air purifier, is it helpful? That does not make sense! If that's your resistance, I don't think it will bring any change. I think sacrificing your health to demonstrate is not very reasonable or smart. It's sort of extreme from my perspective.

(CC)

The air problem here triggers a very direct reaction; to leave. If you cannot handle the situation, if you don't know what to do, you choose to leave.

(CSY)

What about Beijingers, like us? We live here, we were born here. We have no place we can escape to.

(DL)

and data add new information to our range of experience and may even produce an altogether different experiences. Communicated together with, and analogously to, weather parameters such as air temperature and humidity, AQIs and the sensing and communication technologies that enable them become a naturalised part of the environment. As a result, the AQIs impact conceptualisations of inside and outside, and everyday behaviour and decisions about where to live. In other words, digital air quality data are not merely ecological data representing environmental conditions; rather, they produce *ecologies of data*.[5] Together with sensors and digital communication technologies, digital air data infiltrate relationships that make up the urban fabric, constituting technoecologies of air in which sensors, data, people, particles and humidity are interconnected, mutually influencing one another.

The AQI may appear as a merely technological means to an end. Even so, the work that the technoscientific indexing of air performs is neither natural nor unproblematic and has concrete material consequences and political implications. Anthropologist Tim Choy (2012) emphasises that producing the indexing scale requires making highly generalising assumptions about the toxicity of air and, therefore, about the health response of a statistically constructed population. Further, it is employed as a schematic tool for assessing health risks that associate different levels of air pollution with cautionary recommendations for people to take self-protective actions, such as staying indoors or wearing masks. Thus the AQI, which figures prominently in new urban data ecologies, is not solely an informative tool; it is a technique for managing public perception of risk and ordering behaviours (Choy, 2012). It informs people's everyday choices, their strategies for survival and adaptation. Reducing the materiality and multiple relationalities of air into numerical measurements that supposedly represent the essence of air pollution, air is configured in anthropocentric terms, as the environment for human survival (Liu, 2017). Consequently, the neoliberal social ordering of citizens as entrepreneurs of individual risk, which can also be distinguished in the Beijing accounts, is inscribed in the very logic of AQI. To survive in the context of life-defining air pollution, citizens are expected to observe and evaluate air quality data and take appropriate measurements, such as investing in expensive air purification appliances. By operating as a distinct *technology of imagination*, which, rather than strictly aiming at a scientific or objective reflection of the world, promotes air quality as a matter of individual conduct and personal management of risks, the datafied imaginary of air inadvertently internalises neoliberal rationality (Whitehead, 2011).

Technologies of care and control

In the era of ubiquitous digital sensing, perception is increasingly distributed through numerous sensing technologies, bodies and sites. It can no longer be conceived as a cognitive operation performed by individual humans, a true marking of the Anthropocene era in which the anthropogenic and natural cannot be separated (Gabrys, 2016; Tironi, 2018). Enabled by the emergence of 'smart' communication and ubiquitous computing technologies that can be automatically interconnected, thus advancing real-time online reporting, prediction of exposure risks and constant access to real-time data through websites, displays, dashboards and smartphone apps, new practices of air sensing and distributed sensing allow for new datafied sensibilities of air. The destabilisation of anthropocentric perspectives could be perceived as getting rid of unnecessary instances of human-centred mediations of the world and, consequently, understood as a progressive development. However, as argued by legal scholar Antoinette Rouvroy, in a world that is increasingly represented as too complex to be governed by law, datafication shifts our focus from incalculable social, economic and environmental contexts and perceptual experiences towards invisible but calculable particles and calculations of statistical risks (Rouvroy, 2007). This shift is symptomatic of a more general crisis of representation, in an era in which all representations are seen to be too subjective, partial, ideologically biased or politically incorrect. As data and the digital world become equated with the 'real', rather than merely realistic in their representation, computationally generated knowledge and data streams are expected to algorithmically regulate behaviours and environments to which subjects are tethered through digital devices, with which they must align (Rouvroy, 2013). The epochal shift in the way urban air is imagined and conceptualised as a site of calculation and control managed through data accords with what Hörl describes as a becoming environmental of power (in the Foucaultian sense)—or environmentality (Hörl, 2017). In contrast to direct biopolitical control of populations, environmental data contribute to novel forms of "algorithmic governmentality" (Rouvroy, 2013). Instead of investigating the causes of environmental problems and considering how things could be otherwise, the data-driven automation of governance regulates and organises subjects by structuring their milieu and through pre-emptive modulation of behaviour, ways of life and social relations (Gabrys, 2016; Hörl, 2017). Using big data to construct models of behaviours and patterns, Rouvroy argues, compels governing bodies to dispense with conventions, institutions, fictions, presumptions and projects, i.e. representations of the world, through which the unforeseeable has previously been confronted (Rouvroy, 2016). In other words, the computational turn bypasses and avoids any encounter with reflexive human subjects, sparing human actors the burden and responsibility to interpret and evaluate their situation, and thus to consider causes or intentions at work in shaping it. These processes are, however, core democratic values, which constitute the ethical and moral base that accord human subjects political agency (Rouvroy, 2013).

The effects of this totalising regime of air—that operates through tight entanglement of care and control, bound together by the technologies that sense, make perceptible and manage air quality—have not gone unnoticed among Beijingers. As voiced in the dialogues, there is an awareness of the contested nature of the AQIs and air-purifying devices. Furthermore, Beijingers observed that air-quality-related information and technologies are accessible only to certain groups of society, notably the middle classes with richer future prospects and security in life, excluding others. Data-driven environmental sensing technologies offer adaptive strategies and management solutions for microenvironments, enabling citizens to minimise health risks. Even if some refuse to wear masks or to follow recommendations sent as SMS messages by the government in events of severe pollution, beyond the constant technological sensing of air and endless individual adaptation, there are no real alternatives or clear roads to other forms of public engagement. As one of our interlocutors exclaimed: "The air problem here triggers a very direct reaction; to leave. If you cannot handle the situation, if you don't know what to do, you choose to leave." Yet another adds: "What about Beijingers, like us? We live here, we were born here. We have no place we can escape to."

These situated aerial accounts from Beijing expose a troubling paradox: the datafication of air not only enables essential revelations about the toxicity of air pollution, but it is also entangled in new forms of algorithmic and neoliberal rationality and governance. We do not want to claim that the technoecological entanglements of air are immutable and inherently limiting. Rather, we contend that a nuanced examination of how air pollution data influence the distribution of power and agency provides a productive starting point from which to begin reimagining collective engagements with the atmosphere, in Bejing and elsewhere. With critical reflection, these engagements might go beyond the predominant neoliberal tendencies associated with pre-emptive algorithmic technoecologies and yield new imaginaries of air.

Acknowledgements

This manuscript was developed as part of the art–science collaborative project *Towards Atmospheric Care*, developed jointly by Hanna Husberg and Agáta Marzecová. Both authors contributed equally to this work.

Notes

1 Some initial interviews were conducted in Chinese with the help of an interpreter, but as the artist lost the capacity to interact with her interlocutor, the openness of the questions became a barrier rather than opening in conversation. Therefore English speakers were prioritized in further interviews, shaping the pool of interlocutors.
2 By positing embodied experience of urban air as a shared concern of art, ecology and social theory, this text also reflects our conviction that a more adequate understanding of the natural/cultural characteristics of air necessarily requires experimentation with methods of its analysis.
3 Over the last decades, these dust storms became the target of an intense program of state-led 'ecological construction' of infrastructure, a green wall of trees, with a mission to block the movement of wind and keep the shifting sands in place. In recent years, sandstorms have significantly diminished (Zee, 2015).
4 Findings have shown that most fine particulate matter of this calibre is of anthropogenic origin. High $PM_{2.5}$ values have been found to correlate to a range of medical conditions and increased mortality in epidemiological studies (see for example, World Health Organization, 2003).
5 The notion of 'ecology of data' paraphrases Anne Sauvagnargue's term *ecology of images*, by which she conceptualises images, in our case data, not as reproductions or representations but as individuations capable of generating material relationships.

References

Aunan, K., Hansen, M.H. and Wang, S. (2018). Introduction: air pollution in China. *The China Quarterly*, 234, 279–298.

Choy, T. (2012). Air's substantiations. In: Rajan, S. K. (eds.) *Lively Capital: Biotechnologies, Ethics, and Governance in Global Markets*, Durham and London, Duke University Press, pp. 121–154.

Ferreri, J.M., Peng, R.D., Bell, M.L., Ya, L., Li, T. and Anderson, G.B. (2018). The January 2013 Beijing "Airpocalypse" and its acute effects on emergency and outpatient visits at a Beijing hospital. *Air Quality, Atmosphere & Health*, 1(3), 301–309.

Gabriel, N. (2014). Urban political ecology: environmental imaginary, governance, and the non-human. *Geography Compass*, 8(1), 38–48.

Gabrys, J. (2016). *Program Earth: Environmental Sensing Technology and the Making of a Computational Planet* (Vol. 49). Minneapolis, University of Minnesota Press.

Hörl, E. (2017). Introduction to general ecology: the ecologization of thinking. In: Hörl, E. and Burton, J. (eds.) *General Ecology: The New Ecological Paradigm*, London and New York, Bloomsbury Publishing, pp. 1–74.

Husberg, H. (2017). *Often People Ask How Birds Are Affected by the Air.* Audiovisual installation.

Li, H. and Svarverud, R. (2018). When London hit the headlines: historical analogy and the Chinese media discourse on air pollution. *The China Quarterly*, 234, 357–376.

Liu, X. (2017) Air quality index as the stuff of the political. *Australian Feminist Studies*, 32(94), 445–460.

Rouvroy, A. (2007). *Human Genes and Neoliberal Governance: A Foucauldian Critique*, London and New York, Routledge-Cavendish.

Rouvroy, A. (2013). The end(s) of critique: data behaviourism versus due process. In: Hildebrandt, M. and d'Vries, K. (eds.) *Privacy, Due Process and the Computational Turn: The Philosophy of Law Meets the Philosophy of Technology*, New York, Routledge, pp. 143–168.

Rouvroy, A. (2016). L'art de ne pas changer le monde. *La Revue Nouvelle*, 8, 44–50.

Sauvagnargues, A. (2016). *Artmachines: Deleuze, Guattari, Simondon*. Edinburgh University Press.

Snyder, E.G., Watkins, T.H., Solomon, P.A., Thoma, E.D., Williams, R.W., Hagler, G.S., … Preuss, P.W. (2013). The changing paradigm of air pollution monitoring. *Environmental Science & Technology*, 47, 11369–11377.

Tironi, M. (2018). Regimes of perceptibility and cosmopolitical sensing: the earth and the ontological politics of sensor technologies. *Science as Culture*, 27(1), 131–137, DOI: 10.1080/09505431.2017.1322055.

UN ENVIRONMENT. (2019). "A review of 20 years' air pollution control in Beijing", UNEP report.

Wang, J. and Kádár, D.Z. (2018). Silence and absence in Chinese smog discourses. In: Schröter, M. and Taylor, C. (eds.) *Exploring Silence and Absence in Discourse*, Cham, Palgrave Macmillan, pp. 191–212.

Whitehead, M. (2011). *State, Science and the Skies: Governmentalities of the British Atmosphere*, Oxford, Wiley-Blackwell.

World Health Organization. (2003). *Health aspects of air pollution with particulate matter, ozone and nitrogen dioxide: report on a WHO working group, Bonn, Germany 13-15 January 2003* (No. EUR/03/5042688). Copenhagen: WHO Regional Office for Europe.

Xu, I. (2017). *The Changing Concepts of Smog in Modern China*. UiO: Instiutt for kulturstudier og orientaliske språk 1.2.2017. Available: https://www.hf.uio.no/ikos/studier/voices-from-east-asia/the-changing-concepts-of-smog-in-modern-china.html [Accessed 7th November 2019].

Yardley, J. (2008). Consultant Questions Beijings Claim of Cleaner Air. *NY Times*. 10th January. Available: https://www.nytimes.com/2008/01/10/world/asia/10china.html [Accessed 15th October 2019].

Zee, J.C. (2015). *States of the Wind: Dust Storms and a Political Meteorology of Contemporary China*. Doctoral dissertation, Berkeley, University of California.

42

Variations on air[1]

Anne Sophie Witzke and Dehlia Hannah

I

Air is an elusive notion. At once substantial and metaphorical, air surrounds and immerses us in a gaseous medium of life and peril, of communication and transportation, affect and ambience. Volatile and ubiquitous in nature, it slips away from definitive categorizations and understandings. Air belongs to a constellation of concepts such as atmosphere, climate, gases, and clouds, whose shapes are constantly shifting in relation to scientific knowledge and technological practices. As its material and physical properties are redefined, air's productivity as a cultural concept keeps apace in an ever-expanding vocabulary of emotional and political moods—airs of fear, excitement, dignity, and importance. In this chapter, we take air as a collective term for this cluster of concepts, while avoiding "putting on airs" or pretensions to offer a comprehensive conceptual genealogy. Borrowing from the musical practice of "variation" as repetition with formal alteration, we endeavor to illuminate air's manifold meanings by excavating sites at which air makes itself apparent in new ways: moments in the history of science, philosophy, and art where air is captured with special clarity.

If the traffic between substance and metaphor is one axis of the dialectics of air, then the very appearance of air as a matter in question marks a nodal point in another line of tension: between air as an omnipresent background condition and air as itself conditioned and conditional. Our first task, then, is to consider why and how air forces its way out of the shadows and into the forefront of our attention. The philosophical tradition to address this question most directly traces its lineage to Martin Heidegger and his effort to think that which tends most obstinately to withdraw from attention, and hence to be forgotten. So powerful is this tendency in the case of air that the feminist philosopher Luce Irigaray, in *The Forgetting of Air in Martin Heidegger* (1999), indicts Heidegger for forgetting to look up from the solid ground and take note of the fluid medium within which we erect stable dwellings for living and thinking—an oversight symptomatic air's place within a gendered table of philosophical elements. Irigaray demands attention to air as the primary elemental basis of existence, an infinite domain in which more solid elements, and habitats for living and thinking, can arise:

DOI: 10.4324/9780429437069-52

> Is not air the whole of our habitation as mortals? Is there a dwelling more vast, more spacious, or even more generally peaceful than that of air? Can man live elsewhere than in the air? Neither in earth, nor in fire, nor in water is any habitation possible for him. […]
>
> Were there not air – and always more of it than its consumption by living beings requires, and always more than that air now surrounding them, in which everything appears to them – were there not an unlimited and always irritatingly excessive resource of air, the open expanse would not take place.[2]

In an era of *lack* of clean air, a thinning atmosphere, and a hole in the ozone layer, however, Irigaray's metaphysics of abundance confronts material limitations. By contrast with Irigaray's emphasis on air's inexhaustible and ahistorical qualities, Peter Sloterdijk (2009) presents air as a substance that is constantly being designed and modified. Sloterdijk echoes Heidegger's exposition of how tools arrest our attention—by breaking, or being unavailable when we need them. Like a broken hammer that exposes the whole context and process of building, air moves to the foreground when it becomes *unreliable for breathing*. This occurs at a precise moment in history, he argues, with the advent of gas warfare during World War I:

> air and atmosphere—the primary media for life, in both the physical and metaphorical sense—only become an object of explicit consideration and monitoring in domains such as aero-technics, medicine, law, politics, aesthetics and cultural theory in response to their terrorist deprivation.[3]
>
> *Sloterdijk (2009, p. 25)*

This process of rendering air's material and conceptual dynamics explicit Sloterdijk terms "explication," a process which this chapter elaborates.

After a century of poison gas attacks, smog, and excess greenhouse gases, much talk of air today is about dirty particulate matter and the extinction of airborne life, the commodification of nature in the form of weather insurance and carbon credits, militarized airspace, and new forms of wireless communication. Far from a light and airy matter, air has become heavily implicated in "earthly" social, scientific, political, ecological, and economic concerns. At the same time, these new socio-technical constructions of air are reflected in new metaphors of digital culture and media of contemporary art. What emerges from air's simultaneous *implication* and *explication*, we propose, is an understanding of air as an unevenly fabricated domain of *performative matter*, in which human activities, bodies, concepts, and technologies are inextricably entangled in the ongoing iteration of configurations of air and its contents (cf. Barad, 2003). If air has moved to the foreground of our attention by becoming precarious, the explication of air reveals a history of our social and technological entanglements with air as a space of possibility, experimentation, endangerment, and profit. In what follows, we ask: how do cultural practices help us to track what Tim Choy (2012) aptly calls "air's substantiations"—or the modes through which air's physical conditions are experienced as a matter of medical, political, economic, and ultimately, aesthetic concern? We begin by turning our gaze back to an earlier historical moment in which air called us to attention, before considering a selection of contemporary interventions into the aesthetics and politics of air.

II

The idea of air as a complex substance and a contested, multifunctional domain is strikingly contemporary. Until the seventeenth century, air was cross-culturally regarded as an *element* rather than a *state* of matter. Along with fire, water, earth, and occasionally a fifth element, such as Aristotle's notion of the celestial aether, air was seen as a basic substance, which could become impure by being mixed with other things, but could not lose its essential nature. For the pre-Socratic philosopher Anaximenes, the fine and seemingly infinite qualities of air made it the best candidate for the primary element from which all other things derived, by means, he speculated, of its condensation into wind, clouds, water, fire, and eventually earth. In these early views, air was divided into its aspects, accidents, and appearances, but the idea of a pure and simple form of air persisted, retaining deep etymological associations with the breath and spiritual realm (Balkin, n.d.; Connor, 2010).

In the mid-seventeenth century, new scientific instrumentation emerged in conjunction with new concepts, which together allowed air to be captured and observed, calculated, and experimented upon. Chemists and alchemists had long been concerned to leave holes in their distilling vessels so that any "spirits" that built up during their reactions could be allowed to escape, preventing dangerous and disruptive explosions. When air began to be collected rather than discharged under an emergent paradigm of questions and experimental methods, "air" became "airs" (Crosland, 2000). Along with solid and liquid, a gaseous state of matter was recognized, and regular, atmospheric air came to be understood as a mixture of gases in which liquid and solid matter was suspended.

By the early nineteenth century, the study of gases in the laboratory had begun to transform cultural attitudes toward the atmosphere, while the industrial revolution was filling the skies with smoke and what we would later recognize as greenhouse gases. No longer a matter taken for granted, air's substance became productive of new metaphors and modes of aesthetic representation. Historians and geographers rely on the work of painters such as John Constable (1776–1836), J.M.W. Turner (1775–1851), and Claude Monet (1840–1926) as records not only of how the skies looked during the momentous social and industrial changes of the nineteenth century but also of how they were perceived (Thornes, 2008). Painters represented air, but they also performed and recorded air's substantiations in real time. Thus, as the literary scholar Steven Connor argues, the explication and domestication of the air does not happen suddenly, like the tearing of tectonic plates or an "airquake," as Sloterdijk proposes. Instead, "new understandings like that of the air dissolve and pervade, and in the process form both mixtures and compounds with previous but still persisting ways of thinking and being" (Connor, 2010, p. 34).

In romantic depictions of air, one finds a dialectic between air as light and transcendent and air as concrete physical matter that can be scientifically observed. John Constable's skies capture a transition point between a vision of the sky as a clear unspoiled realm closely associated with the divine and emergent concerns about air quality around burgeoning industrial cities. Later, the Impressionists' self-conscious emphasis on perception combined with the determination to move outside the studio and paint "*en plein air*" brought air quality literally and figuratively into view. Claude Monet's *London Series* (1899–1905) provides a stunning visual record of London's air quality, exhibiting the air as a fabricated mixture of culture and nature. For Monet, however, rather than the harmful aspects of air pollution, it was especially the interplay between the foggy air and light, and its effects on color and visibility, which was of interest. In general, the fogs were "an accepted part of the modern industrial era representing wealth and progress and an integral part of the environment" (Thornes, 2008, p. 576). While Monet's impressionistic studies of London's colorful fogs may resemble contemporary art's instantiations of air pollution and environmental degradation, they were primarily a means to explore air as a thickening substance that, when combined with light, made optical effects and thus visual perception possible, prefiguring more recent conceptions of air as a medium of communication.

What the atmospheric science and artworks of the nineteenth century show us is that air and atmosphere began to be displayed as complex physical and meteorological phenomena to be explored scientifically *and* domains for spiritual and subjective experiences and moods. The word "atmosphere" encapsulates this tension: the atmosphere denotes the physical envelope that surrounds the earth, making life possible, and the phenomenological and perceptual qualities of environmental immersion. What can be inferred from this brief survey is an emerging recognition that atmosphere "is not just affected by contamination and irregularity—it is constituted by it" (Connor, 2010).

In the twentieth century, when air makes its appearance in the arts, it is often encapsulated, bottled, or boxed, as in Marcel Duchamp's *50 cc of Paris Air* (1919). By this time, technological means of isolating and manipulating gases in the laboratory and on the battlefield converged with the advent of air travel and radio transmissions. The modern airscape began to be saturated and crisscrossed with telegraph wires, electricity cables, and radio signals, and therefore intensely monitored and regulated by state and corporate bodies. For the first time in history, air came to be associated with finitude, boundaries, and scarcity, and an attendant nostalgia for airy freedoms.

III

We now turn to contemporary articulations of the materialities and politics of air, to consider air as less a metaphor than a processual materiality (cf. Butler, 1993) entangled in a range of societal practices and environmental concerns. It is by now widely accepted that the emission of second-order greenhouse gases such as carbon dioxide, methane, fluorocarbons, and nitrogen oxides, as well as toxic pollutants such as nitrogen dioxide, sulfur dioxide, lead, ozone, carbon monoxide, and microscopic particulate matter, has initiated irreversible climatic shifts, with unpredictable consequences for ecologies and bodies. Moreover, these materials are understood politico-economically as leftovers from ailing "carbon democracies" (Mitchell, 2009). Three modalities manifest themselves prominently in artistic and philosophical reflection on twenty-first-century air. First, air appears as a *semi-artifactual material substance* permeated by anthropogenic pollutants, excess greenhouse gasses, and particulate matter. Second, air is construed as an *immaterial infrastructure* for transmission of information, communication, and travel. Finally, air is a highly *politicized space* of power struggles, profit, and politics. These substantiations of air are interdependent insofar as communication and transmission of information enables both warfare and scientific studies of air; climate change enables new political conflicts and financial possibilities; politics and warfare spark technological developments; and these examples are far from exhaustive. We emphasize these trends in the cultural explication of air because they highlight arenas in which air remains partially invisible and intractable, and at the same time an urgent matter of concern for contemporary life.

If artists once painted the air, they now work *with* or *on* it, taking air as a material medium to be shaped, experimented upon, and intervened in. An emphasis on air's dense materiality is evident in an array of creative practice projects spanning art, activism, and design. Examples include Kim Abele's *The Smog Collectors* (ongoing),[4] which turns the dirty matter of the air into aesthetic images by letting smog settle on plates overlaid with stencils that, when removed, reveal images composed of particulate matter; HeHe's *Nuage Vert* (2008),[5] a public light installation that mapped emissions from an urban power plant in Helsinki in real time, with the aim of alerting urban dwellers to the correlation between emissions and electricity consumption; and Natalie Jeremijenko's *One Tree(s)* (2003),[6] in which 1,000 cloned walnut trees were planted in pairs, their identical genetic makeup highlighting ecological differences between their respective environs. Each of these works deploys the air itself as creative medium, an object of representation, and a site of experimentation—air here becomes performative and "self-reflective" or capable of exhibiting itself.

Saturated with excess gases and particulate matter, air has also become a vibrant "data fog," a soup of electronic signals and impulses transmitted through airwaves. Although well out of range for the human sensorium, these airwaves are very real in their physical effects on our instruments and bodies (Dunne, 1999). They can be seen as a kind of "immaterials"—a notion coined by Jean-François Lyotard (1985) to denote new extensions of matter that escapes direct human perception. Rather than being opposed to the material, the immaterial "establishes relations between isolated materialities—things and people, wares and individuals, objects and subjects" (Arns, 2010). Existing nearly everywhere in the atmosphere, the immaterial electromagnetic waves transmit signals from technologies such as mobile phones, televisions, wireless sensors, radios, and laptops, constituting a vital infrastructure and latent background for contemporary digital culture.

This relational space is examined in *Sky Ear* by Usman Haque (2004),[7] a sound and light installation consisting of a cloud of balloons equipped with miniature sensor circuits and LED lights that responded to electromagnetic fields created by mobile phones, distant storms, radios, etc. Once the balloons had ascended into the troposphere, they could be dialed, and people could listen to the electromagnetic sounds of the sky. By encouraging people to call the clouds and thereby influence the electromagnetic topography inside "the cloud," *Sky Ear* not only picked up interference, but it itself interfered with the air, enabling us to comprehend how we continually participate in the production of wireless "clouds" of data communication. However, while often promoted as "open air" by the software industry, the data sky is in fact highly regulated and used for military, commercial, and political purposes, and only a tiny fraction of the radio spectrum has been allocated for public use. As Jennifer Gabrys notes, "The spectrum as commons is perhaps a much less popular notion today, even though it seems self-evident on many levels that nothing could be so public as the air" (Gabrys, 2010). This stratification of the air in "open" and "closed" spectrums is also addressed by Michelle Teran's public performance *Life: A User's Manual* (2005).[8]

Moving beyond particulates and waves, these works resonate with notions of air as "atmospheres of democracies," which was explored by Bruno Latour and Peter Weibel in the exhibition *Making Things Public* (2005), at ZKM in Karlsruhe. In the exhibition catalogue, Latour explains that the atmospheric qualities of democratic assembly are bound up with materialities: the purpose of "probing an object-oriented democracy is to research what are the material conditions that may render the air breathable again" (Latour, 2005, 21). The material politics of the atmosphere is taken up in Amy Balkin's *Public Smog*,[9] a political and economic intervention into air as a private market and public commons. The work aimed at creating public "clean air parks" through the activity of purchasing and withholding carbon credits from use in regulated emissions markets, and, ultimately, at having the Earth's Atmosphere added to the UNESCO World Heritage List of sites of "outstanding natural or cultural value." *Public Smog* manipulates the air not by bottling or painting with it, but rather by intervening in the dominant legal, economic, and governmental systems to create a speculative public "counter-space" from within these systems. In doing so, Balkin not only calls attention to the aporias of global governance that permit capital and its off-gases to circulate freely and at the expense of human and non-human life, but also takes air, atmosphere, and sky to be at once a material political, economic, and social formation—a metaphor for promises of revolution and change.[10]

IV

In conclusion, we emphasize the importance of attending to air's elusive and invisible qualities, as well as its performative potential. In this post-natural era, we must continue to look *through* transparent air for what may be hiding in plain view, invisible until we develop the right technical and critical instruments to bring it within our sphere of awareness. While "transparency" in everyday usage signifies clarity, controllability, and given-ness through visibility, critical traditions from social theory to feminism and media studies teach us to view transparency with suspicion, as that which conceals and hides. Transparent air is air that cannot be detected or accounted for. In this sense, the artworks discussed here can be understood to contribute to air's explication. By taking up dense and dirty issues such as air pollution, greenhouse gases, new modes of communication, and political and economic structures, these works render air's complexities "opaque" and therefore perceptible. However, beyond explicating the air's latent physical properties and cultural significance, current approaches to air also move beyond the aspiration of placing airy matters into the foreground. Contemporary artists and theorists are developing ambivalent, experimental, and speculative inquiries not only into what air *is*, but also into what it might *become* through its formal and material variation. By attending to the performative and transformative qualities of air, such artworks take a material approach which allows "matter its due as an active participant in the world's becoming" (Barad, 2003, p. 803). More than a century after impressionist painters started capturing a nascent cultural awareness of what we now call smog, air today is becoming a materially and symbolically fabricated space, one that could be performed differently and attended by different politics and ambiences.

Notes

1 Originally published in Danish as Witzke, A.S., Hannah, D. (2014). Luftvariationer: Nye Kunst og Kulturhistoriske Forståelser af Luft. *Kulturo*, *38*, 1–17.
2 Irigaray (1999, pp. 8, 40).
3 Sloterdijk (2009, p. 25).
4 https://kimabeles.com/portfolio/smog-collectors/
5 http://hehe.org2.free.fr/?language=en
6 http://www.nyu.edu/projects/xdesign/onetrees/
7 http://www.haque.co.uk/skyear/information.html
8 http://www.ubermatic.org/life
9 http://www.publicsmog.org/
10 In one of her texts, Balkin refers to the title of Chris Marker's singular document on the New Left in the 1960s and 1970s, *Le Fond de l'air est Rouge*, which posits this question: if revolution was in the air, why did it fail to materialize? In "Public Smog," the air, like in Marker's title, carries contradictory associations that the possibility of change is palpable and surrounds people, but at the same time illusory and ungraspable (Balkin).

References

Arns, I. (2010). Transparent world. Minoritarian tactics in the age of transparency, in *Interface Criticism: Aesthetics Beyond Buttons* (eds. C. U. Andersen and S. Pold), pp. 253–276 (257), Aarhus University Press, Aarhus.

Balkin, A. (n.d.). Public smog. www.greenmuseum.org. Retrieved 2014, from http://www.greenmuseum.org/c/aer/projects/public_smog/

Barad, K. (2003). Posthumanist performativity: Toward an understanding of how matter comes to matter. *Signs*, *28*(3), 801–831.

Butler, J. (1993). *Bodies That Matter: On the Discursive Limits of "Sex"*, Routledge, London.
Choy, Timothy K. Air's Substantiations. 2012. In Kaushik Sunder Rajan (ed.), *Lively Capital*. Duke University Press.
Connor, S. (2010). *Matter of Air: Science and Art of the Ethereal* (1st ed.), Reaktion Books, London.
Crosland, M. (2000). Slippery substances: Some practical and conceptual problems in the understanding of gases in the pre-Lavoisier era, in *Instruments and Experimentation in the History of Chemistry* (eds. Frederic Lawrence Holmes and Trevor Levere), pp. 79–104, MIT Press, Cambridge, MA.
Dunne, A. (1999). *Hertzian Tales. Electronic Products, Aesthetic Experience and Critical Design* (1st ed.), RCA CRD Research Publications, London.
Gabrys, J. (2010). Atmospheres of communication, in *The Wireless Spectrum: The Politics, Practices, and Poetics of Mobile Media* (eds. Barbara Crow, Michael Longford and Kim Sawchuk), pp. 46–59, University of Toronto Press, Toronto, ON.
Irigaray, Luce. (1999). *The Forgetting of Air in Martin Heidegger* (Mary Beth Mader, trans.), University of Texas Press, Austin.
Latour, Bruno. (2005). 'From Realpolitik to Dingpolitik or How to Make Things Public', in *Making Things Public: Atmospheres of Democracy* (eds. B. Latour and P. Weibel), pp. 14-41, MIT Press, Cambridge, MA.
Mitchell, T. (2009). Carbon democracy. *Economy and Society*, *38*(3), 399–432.
Sloterdijk, P. (2009). *Terror from the Air* (A. Patton and S. Concoran, trans.), Semiotext(e)/Foreign Agents, Los Angeles, CA.
Thornes, J. E. (1985). Press release for "Les Immatérieux" by Jean-François Lyotard.
———. (2008). Cultural climatology and the representation of sky, atmosphere, weather and climate in selected art works of Constable, Monet and Eliasson. *Geoforum*, *39*(2), 570–580.

Section 10
Gallery

Hannah Star Rogers
Design by Molly Renda

This book would not be complete without images of art engaged with science. Artists and Science and Technology Studies (STS) scholars have much to learn from each other: from shared methods to exchange information about issues of concern to working together to draw publics into conversation about science and technology. We include here an image gallery as an opportunity to consider the image as a source of Art, Science, and Technology Studies (ASTS) thinking while acknowledging that images are only one of many alternative ways of knowing including music, film, performance, and installation. Sonifications and music, immersive installations, olfactory pieces, workshop experiences, digital works, and so many other forms of art are difficult to represent in the book medium. Many of the images we selected are not works of art so much as they are documentation of artworks which have taken place. We include some examples of performance and the moving image by way of a group of videos, listed after the Gallery, that relate to ASTS exemplars and concepts, accessible through the Routledge website. The editors hope that these example works will inspire new ideas, offer opportunities for the close analysis of science-engaged artworks and hybrid art–science projects, and encourage ASTS scholars to continue to place art at the center of their investigations.

The works included here trace to many locations and art traditions and respond to different forms of science and technology in specific and general ways. Early art and science practitioner Joe Davis has worked extensively with genetics-related projects with the aim of encoding images and messages into DNA sequences. In 1986, Davis's *Microvenus* was one of the first uses of DNA as a medium of storage. *Microvenus* coded visual icons representing the external female genitalia and, by coincidence, an ancient Germanic rune representing the female Earth, into living *E. coli* cells. Davis is part of a team including artist Dana Dal Bo and biologist Ashley Seifert responsible for *Lucky Mice* (2018), a piece around the experimental performance of a search for a genetic basis for luck. The project queries the limits of what we believe science can or will test experimentally and considers how artistic motivation can drive scientific investigation. The team proposed a novel mouse-driven device consisting of a standard mouse running wheel attached to an Archimedes screw that is preloaded with dice. Using the running wheel, individual mice cause the Archimedes screw to turn, which "tosses" dice, with the number of die being recorded for a fixed number of tosses. Using a

DOI: 10.4324/9780429437069-53

predetermined upper and lower boundary representing "lucky" and "unlucky" toss totals, the artists proposed to determine which mice are lucky. Those individuals would then be bred and their offspring tested using the dice device to determine whether luck can be reflected in genetic code.

Below the dice throwing machines is an image from Kathy High's *Embracing Animal* (2005–2006). This artwork consisted of an extended habitat for transgenic rats housing three rats named Matilda, Tara, and Star. The piece was an extended live meditation on the exchanges between people and animals which the artist framed as a multimedia/interspecies ersatz scientific installation. The three transgenic lab rats (model HLA-B27) were given special housing and made available for public viewing. These particular rats were of interest to the artist because they were used in autoimmune disease research for illnesses similar to her own. But instead of testing treatments on them for use in humans, High treated her rats holistically with methods she used on her own body. The rat housing resembled a small city and included a tower for climbing and a "park." In effect, the installation was a lab environment for observation, an experimental playground for people (and rats) to feel the tension of exchanges, transitions, and trans-play.

In addition to her art–science work with animals, High worked to provide infrastructure for art and science practitioners through Rensselaer Polytechnic Institute's BioArt Initiative beginning in 2007, along with Rich Pell, Daniela Kostova, and Boryana Rossa. High's work continues on the following page with *Kathy As Bowie* (2015), a performative piece in which the artist proposed receiving a fecal microbial transplantation as a treatment for her Crohn's disease from singer-songwriter David Bowie. The piece includes photographs of the artist as David Bowie and a letter to Bowie in which High proposes to trade with the musician for a "poop" sample. The offer went unrealized with Bowie's death in 2016. The artwork embraces metaphors of interspecies love, the function and sharing of gut microbiomes, and interest that extends from the artist's own experiences of her body.

The next spread introduces pioneering bioartist Suzanne Anker, whose artworks and efforts in building the School of Visual Art's Bioart Lab significantly contributed to the development of the field and training of a new generation of artists working with the life sciences. Anker's early work *Zoosemiotics* (1993) suggests the relationship between chromosomes and texts. Producing images from the series *Laboratory Life,* including *Vanishing Point* and *Snowman* (2007), brought the artist into major research laboratories to study the space and work of science. The relationship to STS could hardly be made clearer: Anker uses Latour's idea of following scientists into the laboratory to better understand science, processing the data not into sociology but into art.

Paul Vanouse works with emerging media to address complex issues raised by emerging technosciences using these very technosciences as a medium. Many of Vanouse's projects involve laboratory and software techniques to produce inversions of common lab processes or to perform these processes for alternative goals. Vanouse's *Deep Woods PCR* (2011) was a site-specific experiment at an artists' residency called BioARTCAMP, organized by Jennifer Willet in Banff National Park in the Canadian Rockies. The piece attempted to conduct a PCR protocol in the setting of an alpine encampment in order to consider the meaning of pioneering research. One of Vanouse's protocols involved incubating water from the famed Banff hot springs in an attempt to isolate the *Thermus aquaticus* bacteria, which produce an enzyme (Taq) necessary for commercial PCR. In painstaking fashion, Vanouse thermocycled his own DNA over a campfire for many hours, keeping buckets at very precise temperatures for the amplification process. This "campfire PCR" was a success, producing extremely dense banding in the test gel electrophoresis.

Vanouse also pursues questions that relate more directly to biopolitics at the macro-level. In *Labor* (2019), Vanouse inquired after the smell of human labor. The piece answers its own question with a dynamic, self-regulating art installation that recreates the scent of people exerting themselves created by bacteria propagating in glass bioreactors. In the gallery, the bioreactors are monitored by a Raspberry Pi-based automation system that incorporates stirrers, biosensors, pumps, heaters, and valves to automate these conditions for continuous production. Visitors smell the microbes and hear the sounds of these monitoring and adjusting processes. The artwork reflects on the nature of labor and the role of microbes in bodily processes, raising questions about how humans define themselves with the knowledge that other living things such as microbes are involved in even the most basic biological functions.

Amy Balkin is interested in concepts of the environment through public and conceptual art, often through projects which involve or comment on land use and public resource commons. Balkin's *The Atmosphere: A Guide* (2013-2016) is a poster-essay visualizing some ways humans occupy present, past, and future atmospheres. Drawing on the visual format of the Cloud Code Chart, which provides a basic introduction for the identification of clouds, the piece formally reflects the layers of the atmosphere to depict human influences on the sky. These include accumulated traces of culture and technology from chemical, narrative, spatial, and political sources. The piece encourages us to consider what we are referring to when we talk about the atmosphere and how the concept is defined by our histories, attitudes, cultural associations, and scientific information.

David Bowen works with technology in the medium of sculpture, often using large data sets. His background in kinetic sculpture combined with an interest in data-driven installations has led him to produce sculptures which depict faraway environments in the gallery, often using data gathered for scientific purposes. Bowen's art frequently translates data sets from seemingly natural phenomena into physical aesthetic mediums designed to focus viewer experiences. His *fly revolver* (2013) used specialized software to allow a group of houseflies to control the action of a handgun, while *Tele-Present Water* (2011) draws information from the intensity and movement of the water using data buoy station 51003, which, until it went adrift, was moored 205 nautical miles southwest of Honolulu, to replicate a remote sensing event in the gallery.

Artist and filmmaker Richard Pell is best known as the founder of the Center for Post-Natural History (CPNH). Pell works at the intersection of art and science on a variety of installations which consider living organisms that have been altered through processes such as selective breeding or genetic engineering. Pell describes the mission of the CPNH as acquiring, interpreting, and providing access to a "collection of living, preserved, and documented organisms of postnatural origin." The CPNH collection includes such item as a transgenic American chestnut tree engineered to replace the blighted American chestnut, and sterile male screwworms, developed using radioactive cobalt 60 in the 1950s in an attempt to eradicate the flesh-eating larva from cattle ranches. CPNH also houses a preserved BioSteel Goat, the result of experiments to transform animal bodies into biofactories, in this case to produce modified proteins from the golden orb-weaver spider silk in the goat's milk.

For much of the last decade, artist Charlotte Jarvis has been working on a series of pieces collectively titled *Corpus*, which investigate new contexts for dialogue about the human body – a space in between paradigms. Jarvis's *In Posse* (2018) is a lab-based and public participation-based artwork which raises issues around biological sex, gender, and technology in the context of fertility research. This work is the product of a collaboration with Susana Chuva de Sousa Lopes of Leiden University and the Kersnikova Institute in Ljubljana to make semen from Jarvis's ("female") cells. The collaborators used human-induced pluripotent stem cells (hiPSCs) derived from the artist's skin to grow spermatozoa in an attempt to eventually be able to grow a healthy colony of gender-mutated hiPSCs and differentiate them into sperm-producing cells. Separately, Jarvis held events with groups of women to enact the Greek Thesmophoria festival and to collect blood samples to be used in the development of seminal plasma as part of her effort to refigure patriarchal power dynamics around interpretations of fertility. The original Thesmophoria festival included a feast, the burial of a pig, "ritual obscenity," and serpentine and phallic offerings. Participants worked together to develop new collaborative rites and rituals around the donation of blood and associated laboratory protocols involved in making the project.

Caitlin Berrigan has also investigated her own body in a biomedical context. Berrigan's *Hepatophagy* (2008) is a Delftware-style coupe plate depicting a portrait of the artist engaging in self-cannibalism. The plate holds a chocolate truffle, cast from a 3D MRI of the artist's liver, that can be eaten. The piece was commissioned by the Whitney Museum, and the chocolates were offered to the public for free. Berrigan's *Imaginary Explosions* (2019) are a set of episodic films, sculpture, and an accompanying book that explore how deep time and interspecies communication might assist us in radical planetary transformation. This cluster of artworks explores what other presents and futures become possible once we begin to think beyond the framework of the human. The work draws on interviews and materials the artist collected in observing and interacting with scientists doing fieldwork, feminist perspectives on science, affective geologies, and the idea of becoming mineral to seek, in the artist's words, "mutual alliances, climate reparation, and cosmology creation."

Kirsten Stolle works with found materials from corporations, recontextualizing them and highlighting their influence on everyday experience. Her research-based practice is grounded in the investigation of corporate propaganda, environmental politics, and biotechnology. Stolle works across mediums and is best known for collaging representative materials and ideas to reveal the influence of agribusiness across many sectors and facets of our lives. *Miracle Grow* (2012), Stolle's bespoke wallpaper, uses images of chemical consumer products to suggest domestic-looking flower patterns gesturing at the hidden-in-plain-sight ubiquity of the chemical industry. In the *Animal Pharm* (2014) collage series, Stolle investigates the use of genetic modification in animals by the pharmaceutical industry.

Adam Zaretsky's bioart draws on traditions of performance and scientific demonstration, with a heavy pinch of humor and satire. Among the important early performative life science pieces is an installation created by Zaretsky and Julia Reodica which considered model organisms and multispecies relationships. *Workhorse Zoo* (2002) was a display of nine of the most-studied industrial organisms of contemporary molecular biology living together in a "glass house," along with the artists. The project emphasized the use and care, particularly feeding and required environments, of the model organisms which included *E. coli* (bacteria), *S. cerevisiae* (yeast), *A. thaliana* (thale cress), *C. elegans* (worms), *D. melanogaster* (flies), *D. rerio* (fish), *X. laevis* (frogs), *M. musculus* (mice), and *H. sapiens* (the artists themselves). In Zaretsky's words, the piece contrasted the "great hopes invested in the products of genetic engineering" with "biophobic visions of environmental apocalypse."

The editors hope this Gallery, designed by Molly Renda, will help readers to explore the questions, methodologies, and theoretical implications of scholarship and practice that arise at the intersection of art and STS. ASTS is predicated on the capacity to see both art and science as constructions of human knowledge-making. Making art the center of ASTS investigation and considering the role art methods can play in STS help posit a new analytical vernacular in enabling new ways of seeing, understanding, and thinking critically about the world.

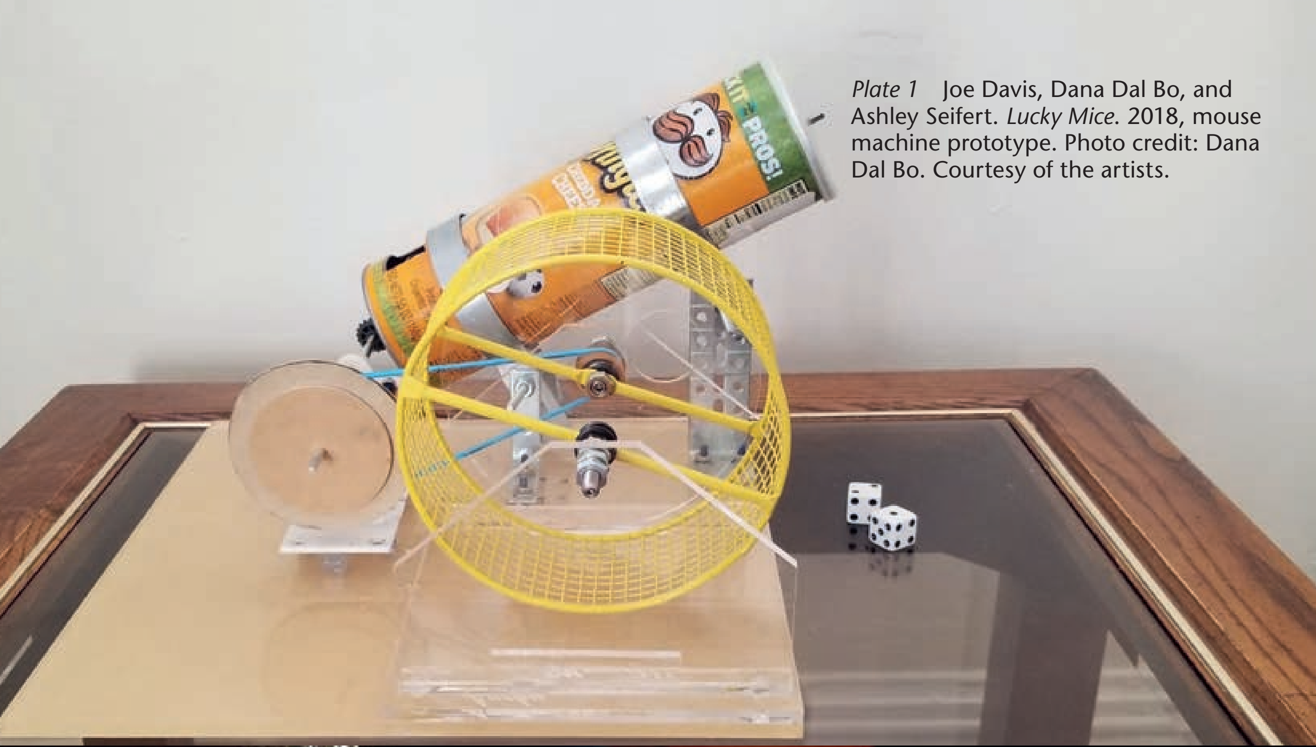


Plate 1 Joe Davis, Dana Dal Bo, and Ashley Seifert. *Lucky Mice*. 2018, mouse machine prototype. Photo credit: Dana Dal Bo. Courtesy of the artists.

Plate 2 Kathy High. *Embracing Animal*. 2005–2006, installation. MASS MoCA *Becoming Animal* exhibition, North Adams, MA. Extended rat housing, three transgenic rats (HLA B27 model), speakers, glass tubes and video screens. Courtsey of the artist.

Plates 3, 4 Kathy High. *Kathy As Bowie: Exchange Project with David Bowie*. 2015, photographs. Images by Eleanor Goldsmith. Courtesy of the artist.

Plate 5 Suzanne Anker. *Zoosemiotics*. 1993, mixed media installation. Exhibited at the J. Paul Getty Museum in Los Angeles in *Devices of Wonder: From the World in a Box to Images on a Screen*, curated by Barbara Maria Stafford and Frances Terpak. Courtesy of the artist.

Plate 6 (*Facing page, top*) Suzanne Anker. *Vanishing Point*. 2007, pigmented inkjet print on archival paper. From the series *Laboratory Life* (*for Oryx and Crake*). Courtesy of the artist.

Plate 7 (*Bottom*) Suzanne Anker. *Snowman*. 2007, pigmented inkjet print on archival paper. From the series *Laboratory Life* (*for Oryx and Crake*). Courtesy of the artist.

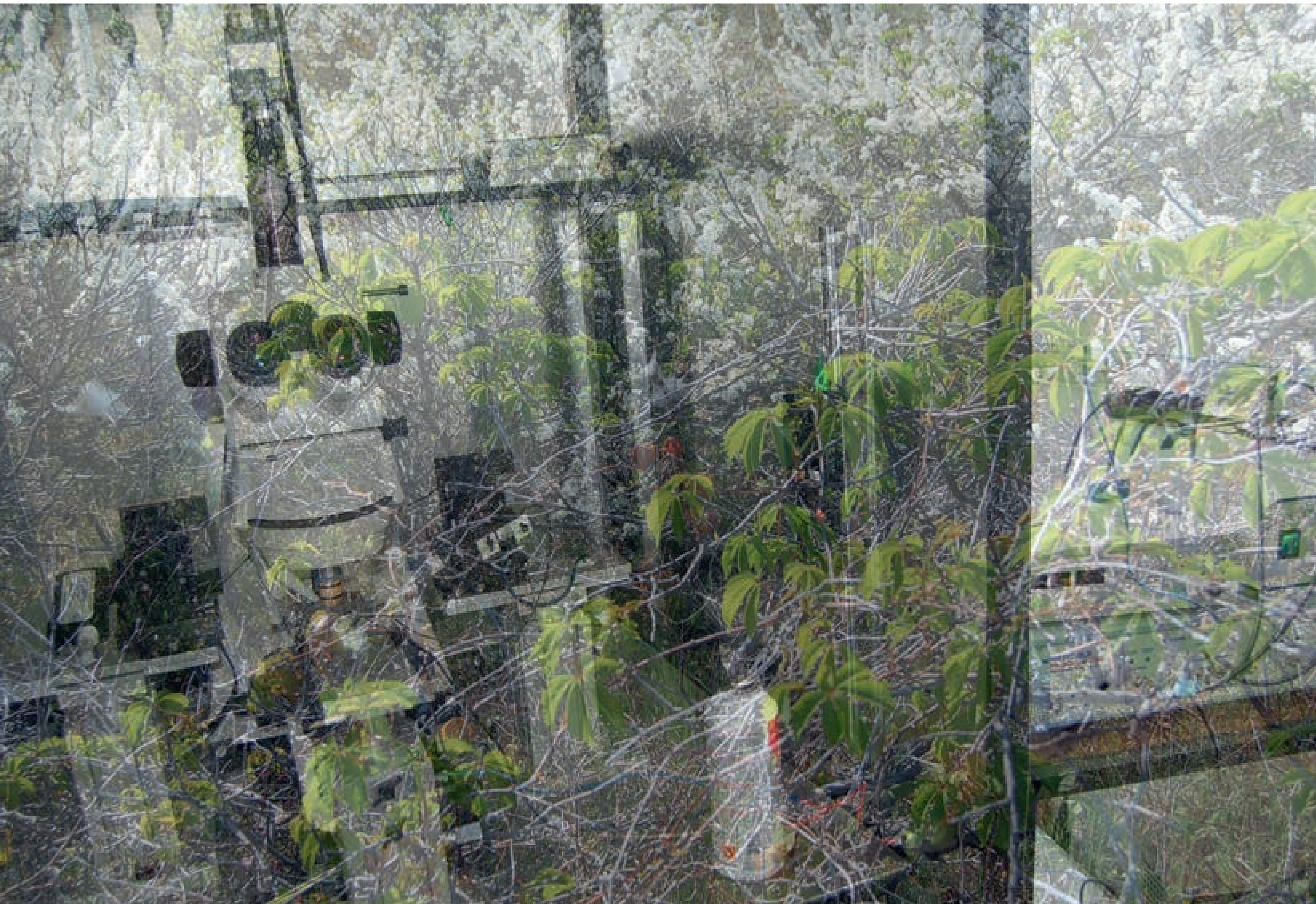


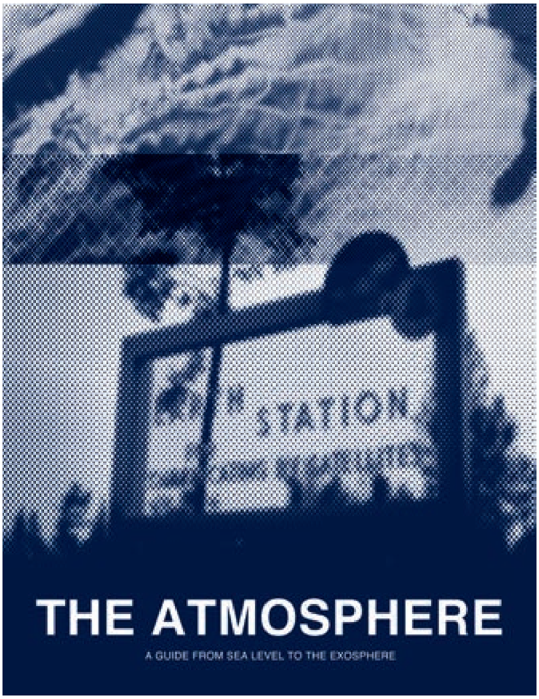
Plate 8 Paul Vanouse. *Deep Woods* PCR.
2011, performance. Banff National Park.
Courtesy of the artist.

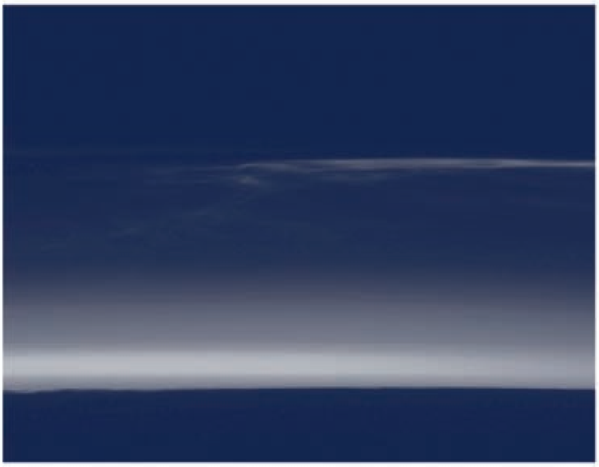
Plate 9 Paul Vanouse. *Labor.* 2019, biomedia installation. Burchfield-Penny Art Gallery, Buffalo, NY. Photo credit: Joan Linder. Courtesy of the artist.

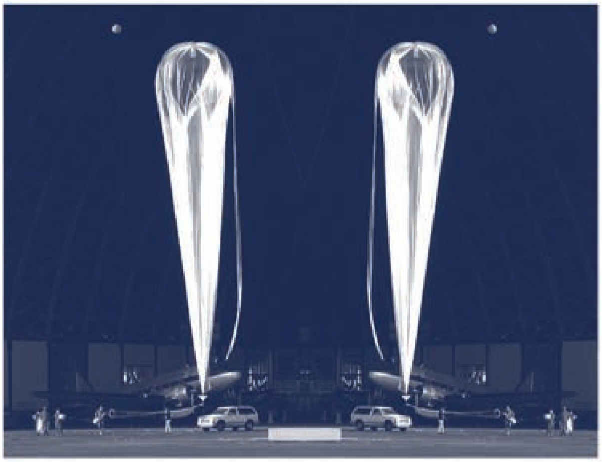
Plate 10 Amy Balkin. *The Atmosphere: A Guide.* 2013–2016. Courtesy of the artist.

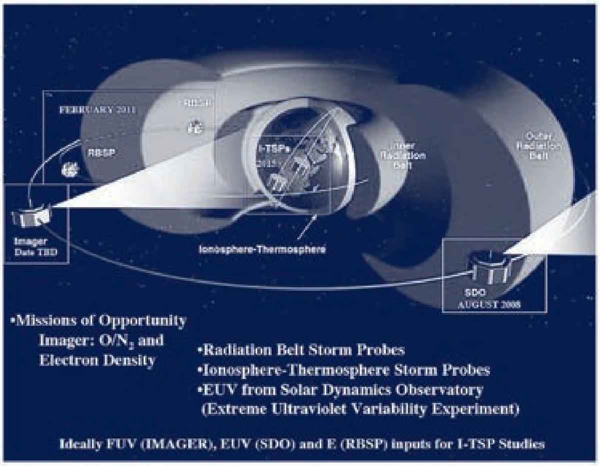
Essay "Charting the Sky" by Megan Prelinger.

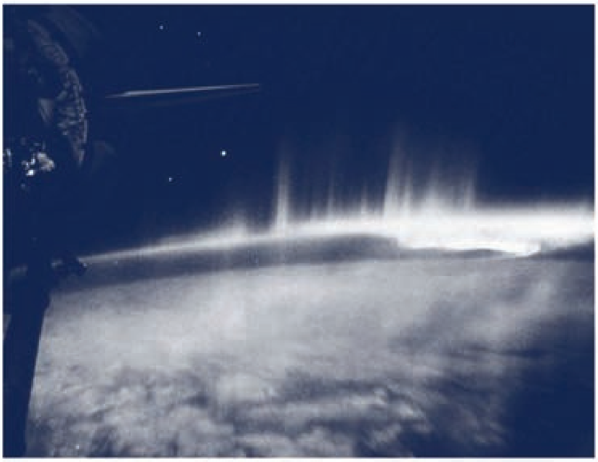
(Right) Verso/Occasional verso/Occasional back (Below and facing page) Details (Overleaf) Recto/Front








FEBRUARY 2011
RBSP
I-TSPs
Inner Radiation Belt
Outer Radiation Belt
Imager
Date TBD
Ionosphere-Thermosphere
SDO
AUGUST 2008
•Missions of Opportunity
Imager: O/N$_2$ and
Electron Density
•Radiation Belt Storm Probes
•Ionosphere-Thermosphere Storm Probes
•EUV from Solar Dynamics Observatory
(Extreme Ultraviolet Variability Experiment)
Ideally FUV (IMAGER), EUV (SDO) and E (RBSP) inputs for I-TSP Studies



THE ATMOSPHERE

As plotted from sea level to the exosphere
People have long sought to understand, map, and occupy Earth's atmosphere. *The Atmosphere: A Guide* depicts some human influences on the sky and the accumulated traces left there—whether chemical, narrative, spatial, or political.

Recent efforts to visualize scale owe a debt to Kees Boeke and his 1957 book *Cosmic View: The Universe in 40 Jumps*. Preceding the first photograph of the Earth taken from space by two years, *Cosmic View* shares some zooming qualities with the bird's-eye perspective of satellite imagery. Boeke's book is a humane essay on scale, using a sequence of photographs and drawings to jump in steps from the relative size of the human body up to the scale of the universe and then back to the scale of the atom. Boeke also developed sociocracy, a model for consent-based pedagogy. *Cosmic View* influenced two films made in 1968, *Cosmic Zoom* by Eva Szasz and *A Rough Sketch for a Proposed Film Dealing with the Powers of Ten and the Relative Size of the Universe* by Ray and Charles Eames.

Which sky?
How do science, social attitudes, economics, and politics intersect in the atmosphere? The intangibility of the atmosphere and much of its composition of gases make it appear resilient and forgiving of anthropogenic damage. However, the future of the atmosphere is altered by how people understand, consider, and act upon it in the present. Current and historic visions of the atmosphere frame our relationship to it and send ripples towards the rights of future people to a familiar climate.

Towards a new map
Which atmosphere is it? The biogeochemical or the geopolitical? A global commons or militarized space? Does the difficulty of human occupation of the atmosphere produce a space for projection and speculation? A space of indeterminacy? *The Atmosphere: A Guide* charts some atmospheric politics and their downward influences.

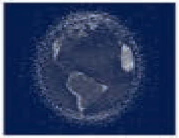
LAYERS OF THE ATMOSPHERE | YOU ARE HERE | POLLUTION | SPATIAL POLITICS | REMOTE SENSING | CLIMATE CHANGE | AIRSPACE | ELECTROMAGNETIC SPECTRUM

EXOSPHERE

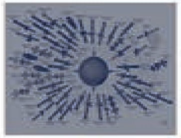
EXOBASE

600–10,000 KM / 375–6,200 MI

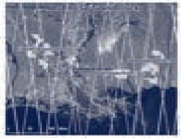
WHAT PEOPLE SHOULD KNOW



SPACE JUNK + CO_2



SATELLITES



SATELLITE REMOTE SENSING

THE SPECULATIVE

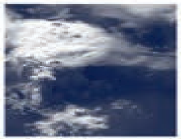
OUTER SPACE TREATY OF 1967

THE SOUND OF SPACE WEATHER

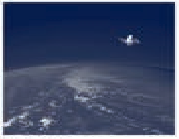
THERMOPAUSE

THERMOSPHERE

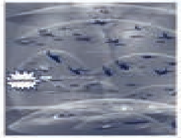
90–600 KM / 56–375 MI



ENMOD

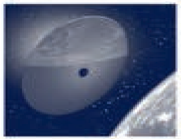


SHRINKING SKY



WEAPON GRIDS

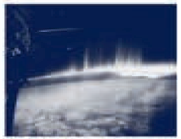
IONOSPHERE–THERMOSPHERE PROBES



GEOENGINEERING

KÁRMÁN LINE

KÁRMÁN LINE (100 KM / 62.1 MI)



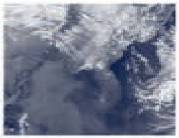
AURORA

MESOPAUSE

MESOSPHERE

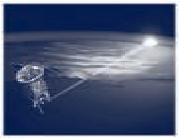
50–90 KM / 31–56 MI

NOCTILUCENT CLOUDS



GENEVA CONVENTION ON AIR POLLUTION

SCIENCEWASH



AERONOMY OF ICE IN THE MESOSPHERE

ATMOSPHERIC & CLIMATE JUSTICE

CLIMATE MODEL

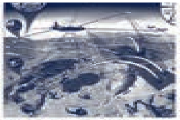
SKYWAVE (IONOSPHERIC REFRACTION)

STRATOSPHERE

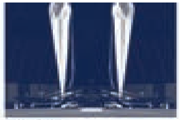
20-50 KM / 12-31 MI

JOSEPH KITTINGER (19.5 MI)

ARCTIC AIR POLLUTION TRANSPORT



WAR IN THE LOWER ATMOSPHERE

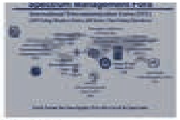


DRIFTSONDE

STRATOSPHERIC OZONE LAYER

OZONE (O_3)

DIVERSIONS



SPECTRUM

TROPOPAUSE

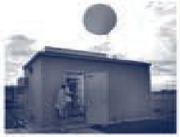
TROPOSPHERE

0-20 KM / 0-12 MI

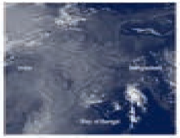
ARCTIC BALLOON EXPEDITION OF 1897

TRANSBOUNDARY AIR POLLUTION

ATOMIC TESTS IN THE ATMOSPHERE



RADIOSONDE



ATMOSPHERIC BROWN CLOUDS

VERTICAL EXTENT OF SOVEREIGNTY

TROPOSCATTER

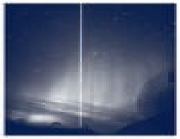
SEA LEVEL

0 KM / 0 MI

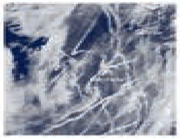
SF-BAY AREA AIR BASIN

THE DONORA SMOG

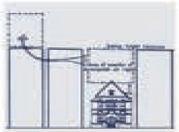
HAARP



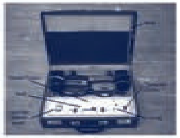
LIDAR (LIGHT DETECTION & RANGING)



SHIP TRACKS

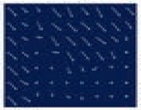


AIR RIGHTS



PUBLIC RADIO

CHARTING THE SKY



SOURCES & CREDITS

LAYERS OF THE ATMOSPHERE

POLLUTION

SPATIAL POLITICS

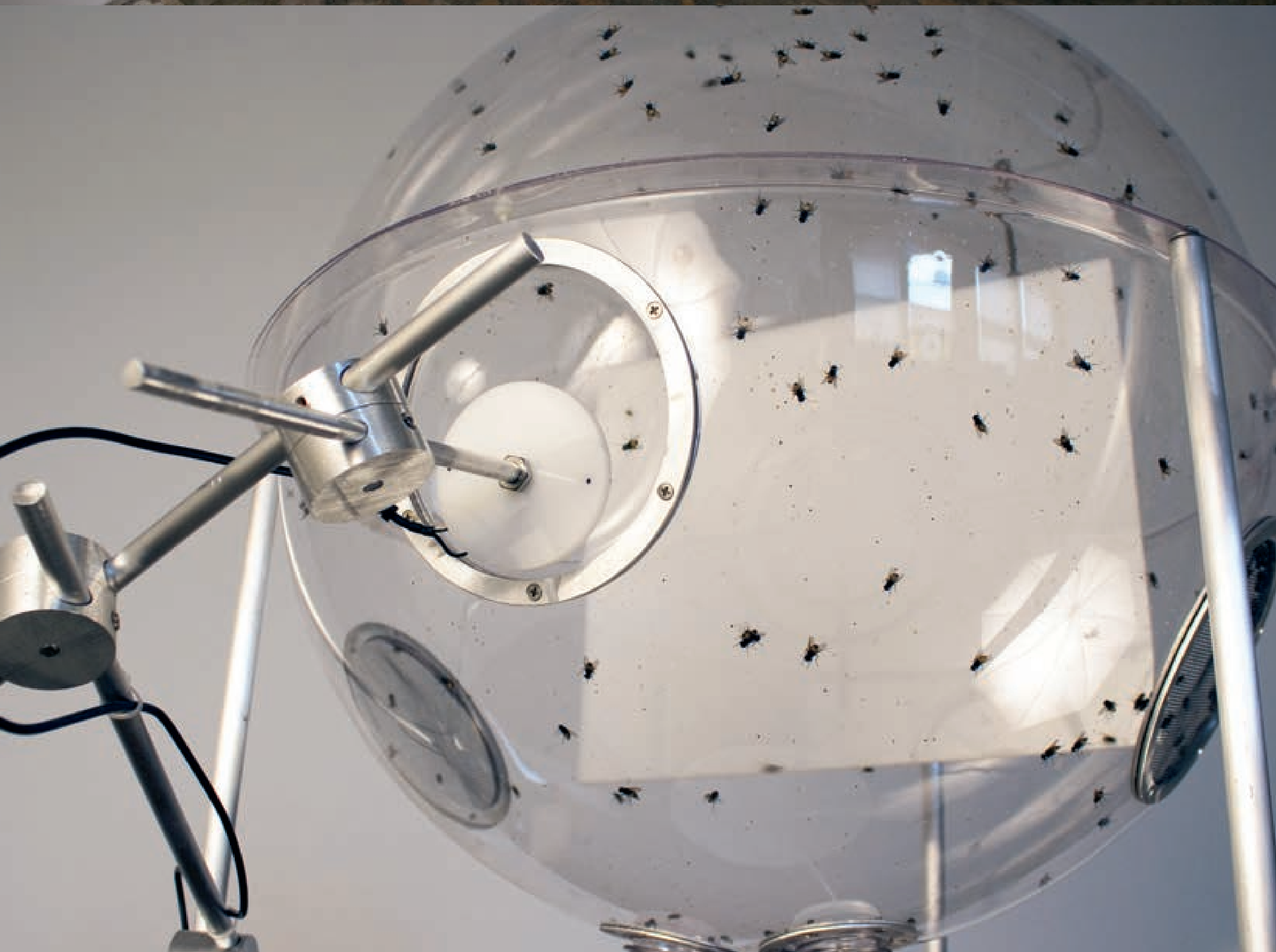
REMOTE SENSING

CLIMATE CHANGE

AIRSPACE

ELECTROMAGNETIC SPECTRUM

CREDITS



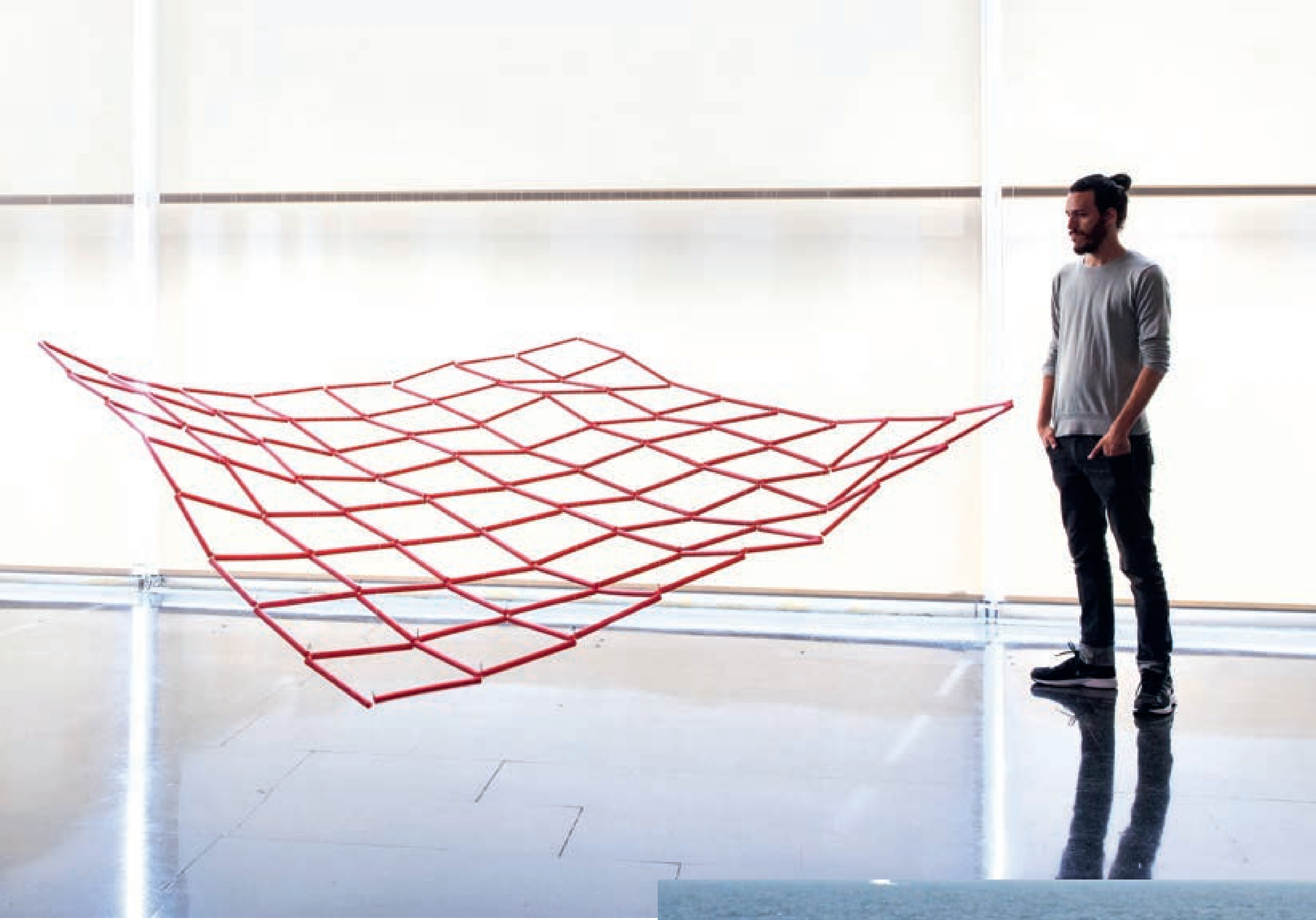


Plate 11 (*Facing page top*) David Bowen. *fly revolver*. 2013, housefly controlled revolver, fly housing, electronic components. Courtesy of the artist.

(Bottom) David Bowen. *fly revolver*. 2013, detail of housefly housing, installation photograph. Courtesy of the artist.

Plate 12 (*This page top*) David Bowen. *Tele-present Water*. 2011, installation photograph. Gunner Knechtel Photography, CCCB, Barcelona. Courtesy of the artist.

Plate 13 (*Right*) David Bowen. Source of data for *Tele-present Water*: National Oceanic and Atmospheric Administration data buoy station 51003. 2011, Image credit: NOAA

Plate 14 Richard Pell. *Center for PostNatural History* (CPNH). 2013, photograph of the facility. Image credit: Dror Yaron. Courtesy of the artist.

Plate 15 (*Above*) Charlotte Jarvis. *In Posse: Making Female Sperm*. 2018, photograph. From the series *Corpus*. Charlotte Jarvis in collaboration with Susana Chuva de Sousa Lopes. Photo credit: Miha Godec. Courtesy of the artist.

Plate 16 (*Right*) Charlotte Jarvis. *In Posse: Making Female Sperm*. 2018, film still. From the series *Corpus*. Charlotte Jarvis in collaboration with Susana Chuva de Sousa Lopes and Kapelica Galler/Kersnikova Institute with support from MU Gallery Eindhoven. Camera credit: Eleni Papazoglou. Courtesy of the artist.

Plate 17 (*Above*) Caitlin Berrigan. *Imaginary Explosions*, *Episode 1*. 2018, video still. Eyjafjallajökull, single-channel video (2k color, with sound); 12 minutes. Courtesy of the artist.

Plate 18 (*Below*) Caitlin Berrigan. *Imaginary Explosions, Episode* 2. 2019, video still. Chaiténn, single-channel video (2k color, with sound); 23:04 minutes. Courtesy of the artist.

Plate 19 Caitlin Berrigan. *Hepatophagy*. 2008, illustrated porcelain and chocolate cast from a 3D MRI of the artist's liver; 4.25 in. Courtesy of the artist.

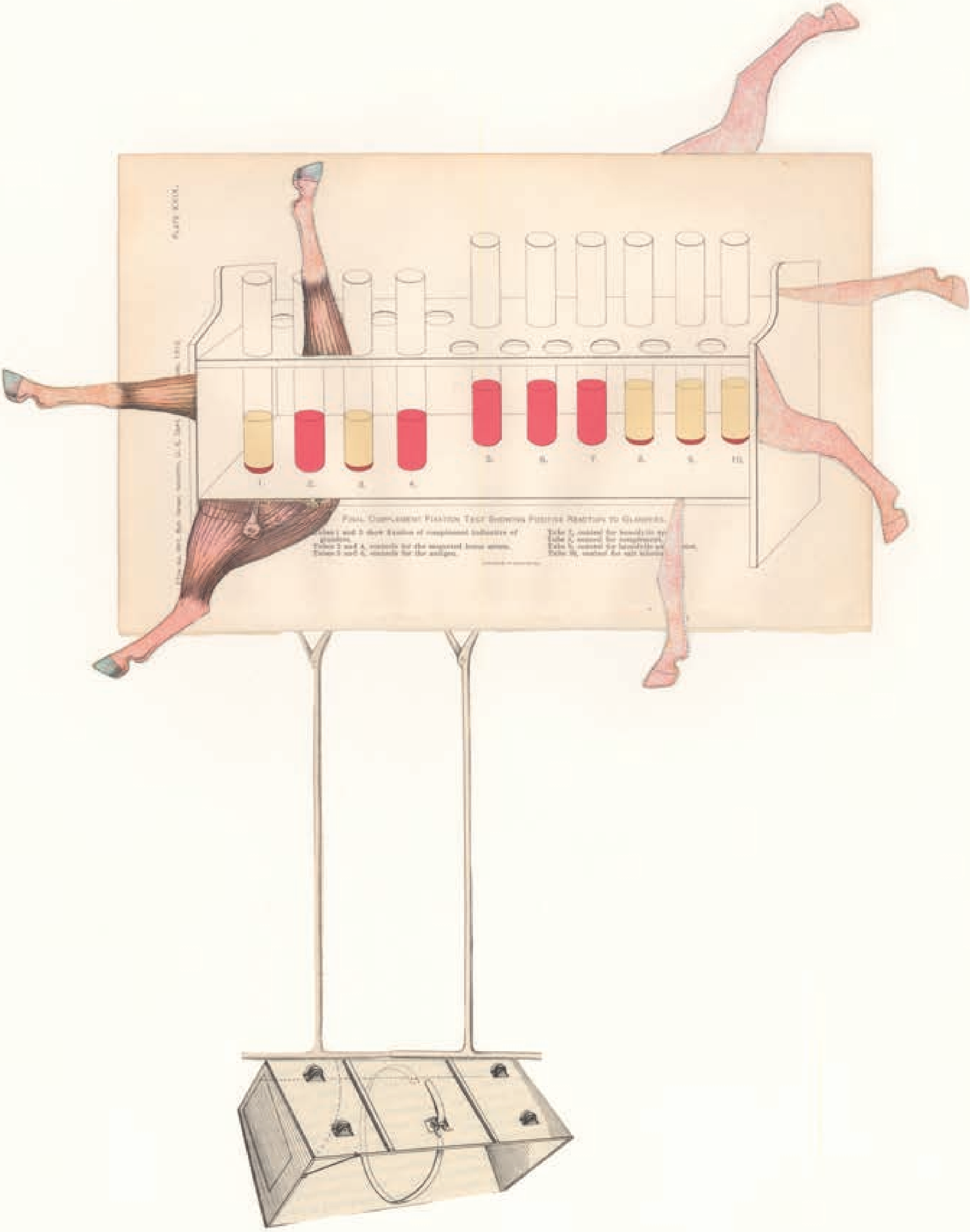


Plate 20 (*Facing page*) Kirsten Stolle. *Miracle Grow.* 2012, detail, custom wallpaper. Courtesy of the artist.

Plate 21 (*This page*) Kirsten Stolle. *Animal Pharm* 3. 2014, collage on paper. Courtesy of the artist.

Plate 20 (*Right*) Adam Zaretsky and Julia Reodica, *Workhorse Zoo*. 2002, design. Courtesy of the artists.

(*Below*) Adam Zaretsky and Julia Reodica, *Workhorse Zoo*. 2002, digital collage. Courtesy of the artists.

Index

Note: **Bold** page numbers refer to tables; *italic* page numbers refer to figures and page numbers followed by "n" denote endnotes.