A Blueprint for Bacterial Life: Can A Science-art Fusion Move the Boundaries of Visual and Audio Interpretation?

Elaine Shemilt

I am a practising fine art printmaker whose work extends to installation and film, often with the use of sound. Recently, I have worked in collaboration with scientific colleagues at the Scottish Crop Research Institute (SCRI) who have sequenced a bacterial plant pathogen for the first time in the United Kingdom. This is also the first inter-bacterial plant pathogen to be sequenced worldwide.

The analytical tool that was developed by the SRCI, GenomeDiagram, is probably the most advanced comparative genomics visualization tool available worldwide and it is being adopted by an increasing number of genomics laboratories internationally, including the Sanger Institute in Cambridge and the Universities of Minnesota and Madison in the United States.

The SRCI approached me with a view to collaboration, in the hope that artistic expression, communication and methodologies might help the wider community understand their complex scientific discovery and at the same time generally raise awareness about their research. For my part, I was particularly interested in looking into the question of whether a science-art fusion could move the boundaries of visual and audio interpretation.

During a pilot study something occurred which made us realize that our collaboration reached beyond the initial objective into deeper research issues on the possible usefulness of artistic methodologies. That is, the role of the artist in the visualization of complex data, and the subsequent impact upon scientific understanding and insights.

As an artist, I found the images that the scientists created in order to represent the genetic data very beautiful and without a doubt they lent themselves to artistic expression and exploration. Immediately, however, a question arose. Could the collection and visualization of a huge amount of data derived from the study of a genome really enable the production of works of art with high impact and resonance? More generally, what are the effects of artistic expression, communication and methodologies on our understanding of complex scientific discoveries?

Science-art projects are commonplace now and there are various ongoing debates. I refer back, for example, to C. P. Snow, who proposed the existence of 'two cultures'.[1] However, encouraged by our initial discovery, added to by our particular combination of expertise and now firmly-established teamwork, we believe that our collaboration contests this view and that is the basis of this paper.

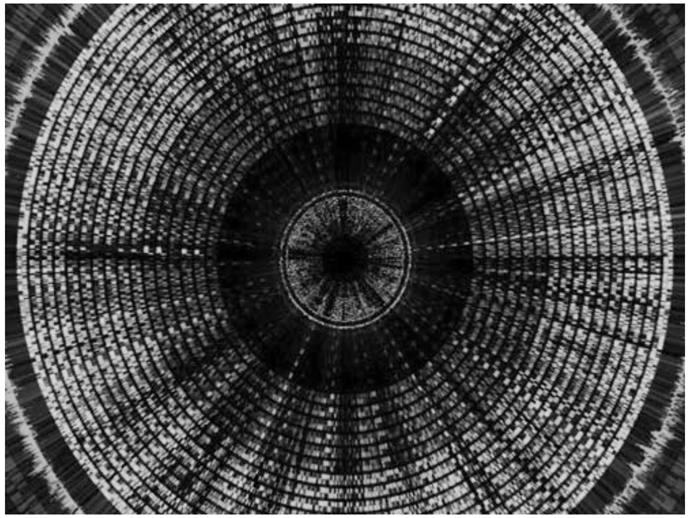


Fig. 1 *Elaine Shemilt,* E. Coli 1. © *Elaine Shemilt.*

Printmaking has been referred to as the 'poor man's painting', but this pejorative phrase indicates an underestimation of the discipline. Maybe, more correctly, printmaking should be described as a group of media, which utilize ancient and modern techniques and technologies. This would include my own definition of printmaking**,** which amongst other things attempts to convey complex ideas and insights or may simply present data as digital animation.

I was initially approached by Dr Leighton Pritchard (SCRI). Dr Pritchard works at the interface between biology and computing. His first thoughts when this project was suggested concerned the aesthetic value inherently present in scientific information, even in the absence of a context. The presentation of scientific information has a deserved reputation for being literal and representational, with a minimum of embellishment and extrapolation. This is required for the clear and precise dissemination of information. The guiding theme in preparing scientific figures for publication is often that they should be interpretable without reference to the main text.

What exactly is 'print'?

An edition, in printmaking terms, is a numbered set of identical prints. In commercial terms, the numbering is a safeguard of the value of the prints, and professional artists' plates or blocks are cancelled after an edition has been completed. This convention adds the necessary 'aura' (in Walter Benjamin's famous use of the term) to make each single print a work of art.[2] This tradition of limitation continues but seems barely relevant in what I have recognized through my practice over the past thirty years. For me, contemporary printmaking is neither defined nor confined by tradition or medium. The essence of contemporary printmaking lies in a process of empirical experimentation, discovery, analysis, resolution and critical reflection – the **pursuit** of the image – the **unlimited** image. The limitations placed upon the artist in this sense, therefore, are mostly technical. The best printmakers make art that goes beyond the limitations and

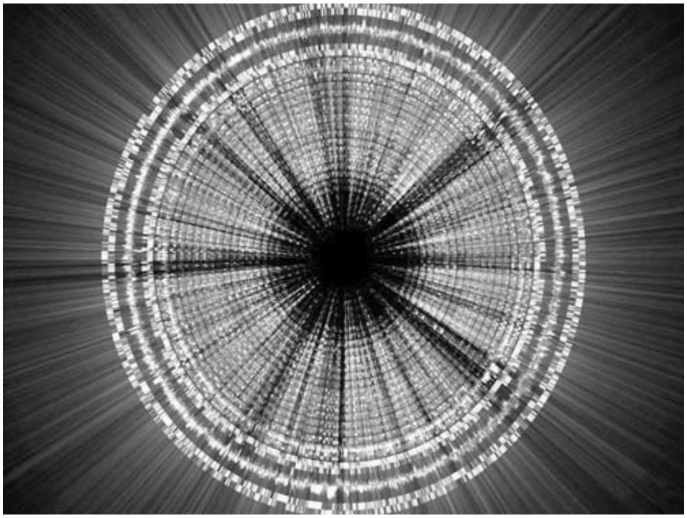


Fig. 2 *Elaine Shemilt,* E. Coli 2. © *Elaine Shemilt.*

continues to break with tradition. However, in order to illustrate the impact that successive technological breakthroughs have had on printmaking it is perhaps important to note the most important breakthroughs in this tradition. I hope that the following potted history of printmaking will offer an insight into how artistic reinterpretation can enhance understanding and offer new insights into routes for the analysis of scientific data.

Mechanical western printmaking was invented early in the middle ages with the woodcut. Printmaking quickly developed as the first efficient way of imparting information and ideas, and especially for the Christian church for the motivation of piety and reflection. However, the woodcut, which was the primary early print medium, was a rather crude vehicle. The very nature of the process meant that the viewer was not provided with much more information than an iconic or simple graphical representation of the object depicted. Further information such as perspective or temporal issues was restricted. It would take the 'new' concepts of the Renaissance to ensure that new techniques and technologies were developed in order to transmit more complex information.

As time went on the means of printmaking developed to include copper engraving, then etching, then wood engraving. The world was changing even though Galileo might recant his 'heresy' that the earth was not the centre of the universe. The media theorist Marshall McLuhan claimed that 'the increasing precision and quantity of visual information transformed the print into a three-dimensional world of perspective and fixed point of view.'[3]

The next major printmaking breakthrough came at the beginning of the nineteenth century when Aloys Senefelder (1771–1834) developed lithography. Over a period of fifteen years, through a wonderful mixture of chemistry and physics with art, craft, skill and luck, Senefelder made it possible to print multiples of an illustration drawn upon a perfectly flat stone surface. He was a Bavarian dramatist who found it too expensive

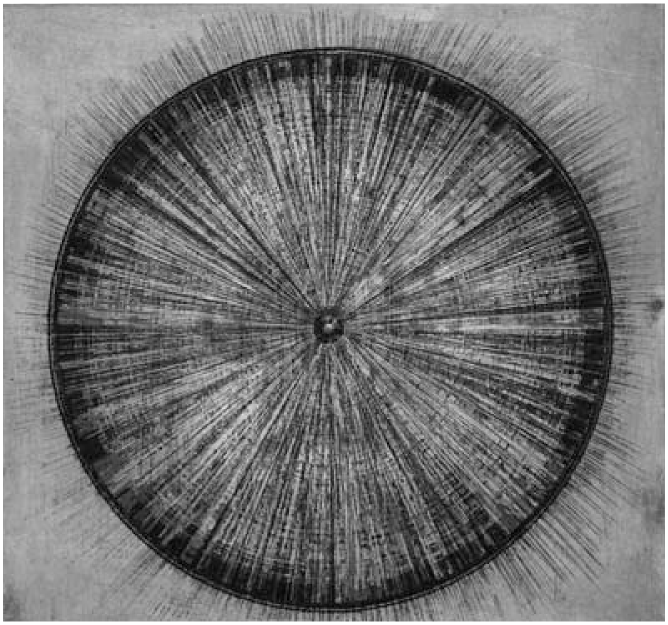


Fig. 3 *Elaine Shemilt,* Etching. © *Elaine Shemilt.*

to make enough copies of his plays for his actors. Lithography is the result of his search for a cheap means to do this. Lithography is a natural process for the draughtsman as of all the printmaking processes it is most like drawing. The artist could work with pencil, ink or crayon. Unlike etching, where the artist uses a needle to draw through a wax ground onto metal before putting the plate into acid, with lithography the artist makes the tonal variation and nuance of the mark at the time of drawing.

Stone lithography became widely popular towards the end of the nineteenth and right through the twentieth century. As a result of this breakthrough, a revolution in the dissemination of images became possible, including offset lithography, utilizing thin metal plates and high-speed printing machines, along with the photographic transfer of images.

This dramatic development in the pre-electronic age is repeated by the new 'stone' of the latter half of the twentieth century (the digital age): silicon, with the opportunities it gives to combine art with electronics, algorithms and binary code. The silicon chip has reinvented print and brought with it the next revolution in image production, manipulation, dissemination and distribution; in short – contemporary printmaking!

It is important to recognize that the basis of artists' printmaking still relies on the traditional crafts of woodcut, linoleum block, etching, stone lithography and screen-printing. But the artist-printmaker's knowledge, skill, artistic integrity and determination means that at the beginning of this new century many are using these techniques combined with digital imaging processes to address new dimensions and contexts. Photomechanical techniques were a printmaking mark of twentieth century art. In the twenty-first century we are in an age of electronic and digital technology, new media, and installation strategies.

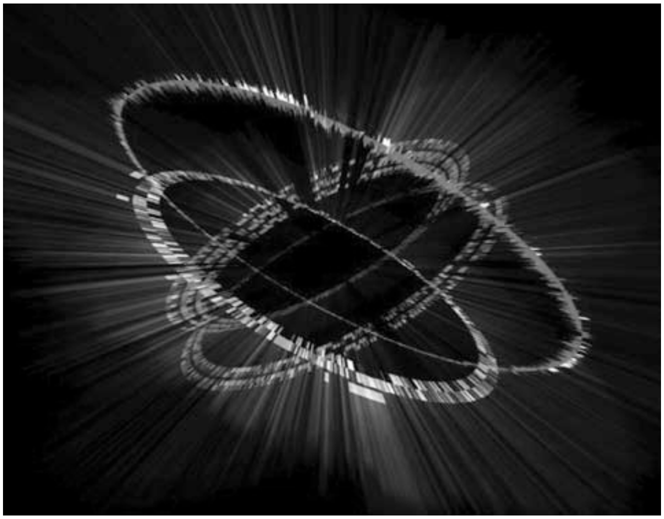


Fig. 4 *Elaine Shemilt*, Rings Rays. © *Elaine Shemilt.*

Currently artist-printmakers define themselves in many different ways. There is now renewed interest in traditional techniques such as mezzotint, *chine collé* and photogravure, whilst simultaneously there are rapid developments in the field of non-toxic printmaking technologies. Again, remembering those early experiments by Senefelder, printmakers now appropriate materials such as photo-polymers and commercial silicon to develop new methods of printmaking.

So we have established that from the medieval period (in western art), artists have made prints. With the advent of digital technology contemporary printmaking incorporates ancient *and* modern techniques and allows for an increasing precision and quantity of visual information to convey complex ideas and insights. In the past I have created large-scale installations using printed elements on different materials. Various printmaking methods (including digital media) were used in an attempt to continue and develop the work of the installations, rather than to record an event simply by documentary photography. To refer again to Walter Benjamin, this relates to his comment that 'even the most perfect reproduction of a work of art is lacking in one element: its presence in time and space, its unique existence at the place where it happens to be.'[4]

Although the installation 'event' is inevitably lost, the creative dynamic continues as themes and subjects occur and re-occur through the various media. In scientific terms this might be thought of as a transition or 'tipping point' where new possibilities open up.

This is where the science takes precedence. Dr Ian Toth is an expert on bacterial pathogenesis, molecular approaches to host/pathogen interaction, genome sequencing and functional genomics. Dr Leighton Pritchard, as mentioned before, is a scientist working at the interface of biology and computer science (and the

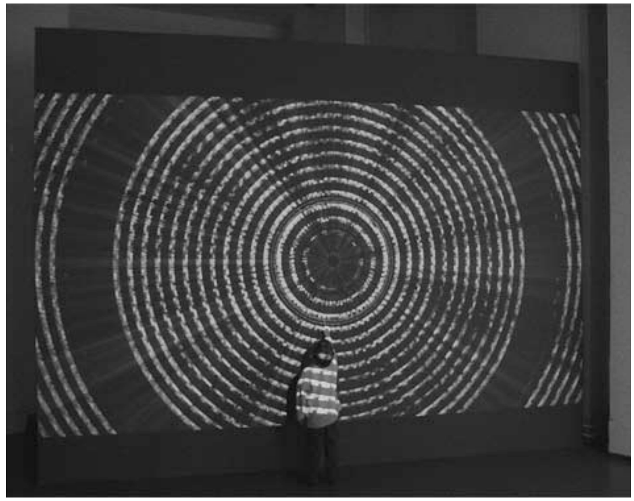


Fig. 5 *Elaine Shemilt,* Installation.
© *Elaine Shemilt.*

creator of GenomeDiagram) concentrating on how micro-organisms cause disease in plants. Both scientists won the international race to sequence a plant pathogen from the same family as E.coli and the Black Death bacterium. They pioneered the software GenomeDiagram, which enables simultaneous visualization of billions of gene comparisons of hundreds of fully-sequenced bacterial genomes, including those of animal and plant pathogens. The results have helped to identify the acquisition of foreign DNA by pathogens, potentially representing novel mechanisms involved in disease (represented by clearly defined white 'spokes' radiating from the centre of the image. They have also helped to trace the evolution of this gene acquisition (and loss) over millions of years. Black Death (*Yersinia pestis*) and Blackleg (*Erwinia*), diseases of humans and potatoes respectively, seem worlds apart but without this foreign DNA these bacteria are remarkably similar. At root, DNA transfer is the single most significant source of the outward differences between the diseases caused by these closely-related bacteria. The acquisition of foreign DNA may culminate in a microbe changing into either a human or plant pathogen, the point at which this occurs again being a 'tipping point' in that microbe's evolution. This foreign DNA in turn leads to novel biological traits being introduced into the microbe and incorporated into existing regulatory circuits such as quorum sensing. As pathogen populations grow in their host, they produce a regulatory hormone that gradually increases in concentration. At a critical (or quorate) population, the concentration of that regulator hormone becomes sufficient to trigger a series of events essential to symptom development and disease initiation. The point at which this trigger occurs and true disease begins is yet again a 'tipping point', this time dividing invasion from the successful outcome of disease. Thus 'tipping points' in both the visualization of biological data and in the biology itself can be related to the artistic event.

Genome diagrams, even in their scientific context, are fairly abstract figures. These 'maps', after all, represent biological concepts that do not really exist. Most of the processes and entities with which modern micro-biology concerns itself are invisible to the naked eye. Aspects of genomics are similarly invisible. Each genome is the result of four billion or so years of evolution.

My first experiments began with a series of prints where I removed all trace of the relationship of the GenomeDiagram to the thing it described. It was a scientific image stripped of its contextualizing information. In other words the image, a circular map of genes and their relationship to other bacteria, represented something essentially invisible that could only be 'seen' in an abstract representation. Then I concentrated on subtleties of colour and tonal variation. I began by focusing on the precision and quantity of visual information and I created a series of etchings, screen-prints and animations. With the screen-prints I used a very subtle range of silvery blues and greys and worked with some very specific inks (known in the trade as interference inks – these have a slight three-dimensional quality.)

It was from looking at those prints that the scientists noticed the occurrence of new elements and a very specific event of gene acquisition. My approach was to simplify the diagram into a tonal variation and in so doing I re-contextualized the data in such a way that it revealed information that the scientists had completely overlooked. Their scientific approach to the data was systematic and empirical. Purely by chance, my artistic re-interpretation of the scientific data contributed to a new insight. Rather than simply identifying genes unique to a pathogen, the screen-prints revealed the presence of other genes in all of the bacteria, possibly representing genes essential to all forms of bacteria.

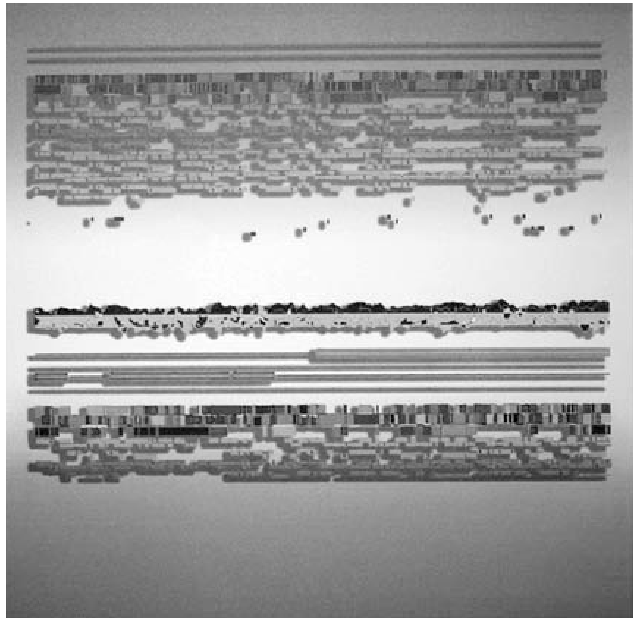
As far as we were concerned this was a breakthrough. It was as though our project drew a comparison between the genome diagram and the work of art in the age of its technical reproducibility. I refer again of course to Walter Benjamin's essay.

We had taken this scientific visualization tool outside the fields of biology and medicine and placed it in the context of interdisciplinary art. Inspired by this we are now exploring the dynamic nature of biological systems using both visual and sound disciplines (and their associated media), and we are going beyond obvious interpretative frameworks. Our goal is to ensure that the relationship of the artwork to the data is reflected and maintained not merely as content but also as elements and structural process.

Walter Benjamin used the term 'aura' to refer to the feeling of awe created by unique or remarkable objects such as works of art or relics of the past. He argued that the proliferation of mass production and reproduction technologies harboured the potential elimination of reflection and imagination causing the decay of the 'aura'. As a printmaker I use current reproduction techniques that allow for a rich diversity of visualization in order to address this idea of the 'aura'.

In recent years the rapid development of computer technology and computer graphics has enabled advanced visualization techniques; an essential part of the huge data-generating potential of genomic technologies. Both scientists and artists are exploiting the latest technologies. Our project enables scientists and artists to share and resolve problems surrounding current uses of visual and audio-visual techniques from different perspectives.

Fig. 6 *Elaine Shemilt,* Linear Screen. © *Elaine Shemilt.*



In the pilot stage we dealt with the linear data of the genome sequence, creating images, animations and simple sound based upon the data translated through MIDI. We aim to progress to more complex systems arising from the sequences' emergent properties.

My partner and I noticed that the DNA image resembled a score of music. It was a tenuous idea, but as Dr Leighton Pritchard trained originally as a chemist and has a view of biological information that is correspondingly physical and chemical he was ready to engage with such a concept. By using a series of mathematical notations he translated the different amino acid letters into sequences of musical notes. I quote:

> Aside from the biological and physical meaning of this letter 'A' inside the computer, it is not even represented as a letter. When my finger hits the 'A' key on the keyboard it initiates a series of electrical pulses. These pulses are interpreted by the computer as a binary number. When we need to 'write' the character to the screen, a different series of electrical pulses is used. These represent not the letter itself, but an image – patches of light and dark on a larger canvas. The use of different font types will result in different patterns, and so different pulses, but still the same recognisable symbol. These representations are at once inexact but precise.

My daughter Genevieve, who is a music student at the Birmingham Conservatoire started to work on Leighton's musical note sequences. By developing the scale, tonality and starting octave of the melody, and the intervals for each base transition she succeeded in translating it into the auditory sphere. We used the findings from my prints and this new work to gain our first art-science grant from the Mylnefield Trust.

When the data is set out in a linear way it has a musical appearance whereas genomics are non-linear or may perhaps be better described as simultaneous events – with very different 'musical' or time structures. This leads to the idea of soundscape(s) where all component elements are present at any point on a timeline (structurally more like a painting or print than music) but fluid or not fixed. As well as the animations and music, we are now developing the concept of GenomeDiagram into a multimedia installation event based on the genetic plasticity and evolution of bacterial pathogens. To further develop this we have recently involved the soundscape artist David Cunningham. David Cunningham works with the creation and manipulation of sound by electronic and acoustic processes with a particular emphasis on the integrity of the materials, their innate structure and context. This emphasis on process is a key element in this project, an approach that can creatively maintain the precision of the source data. The primary motivation for developing the installation is to introduce sound and spatial aspects through open, interrogative and responsive modes of thinking, experimentation, processes and techniques, involving time and space.

A unifying thread of our research is that by de-contextualizing scientific data, we obtain a complementary viewpoint to the scientific interpretation. Fine art practice emphasizes subjectivity and ambiguity whereas science practice attempts to identify objective truths. Despite the contrast between the two approaches they can be unified because both disciplines thrive on lateral thinking and observation. As well as refining our mechanisms for creative development, our collaboration aims to enhance scientific visualization of complex data, and for it to impact upon scientific understanding and insights. Common to both artists and scientists is the use of advanced visualization tools and the principles of new media as defined by Lev Manovich: 'Numerical representation; modularity; automation; variability; and cultural transcoding.'[5]

Research development will also continue to involve production, analysis of visualizations in print, digital imaging, 2D and 3D (HiDefinition) animation and sound. By using animation to create time-lapse video clips we will create new dimensions for the expression and interpretation of the data. Our test animations already show movement and uptake/deletion of foreign DNA.

The impact of hybrid technology on the language of the artist has been profound. If the computer outputs from the analysis of the genome sequence are translated into art, we think that we can show that it is possible to aid in the discovery of new pathogenicity determinants. At the same time my challenge as an artist is to make sure that the data – derived from the study of a genome, the scientific process, and analysis – enables the production of works of art.

By way of a conclusion I would like to offer this thought. The development of printmaking has enabled a reinvention of the artist's language. What does the aesthetic manipulation of the image look like in the twenty-first century? To a greater or lesser extent in a culture such as ours, artists will always continue to strive to communicate on social and psychological levels. With the advent of digital technology printmakers can go as far as any artist is capable of going. They can create continuous experiences of moving time and space: a simulation of human consciousness through technology. 'A blueprint for bacterial life and art.' So much for the 'poor man's painting'.

Notes

1. At the 1959 University of Cambridge Rede Lecture, C.P. Snow delivered a paper lamenting the cultural divide between scientists and non-scientists in western society. Snow, C.P. (1993), *The Two Cultures,* Cambridge University Press; contains Snow's 1959 Rede lecture, and *The Two Cultures: A Second Look, originally published in 1964.*
2. Benjamin, W., [1936] (1973), 'The Work of Art in the Age of Mechanical Reproduction', *Illuminations*, ed. by Arendt, H., trans. by Zohn, H., London: Fontana.
3. McLuhan, M. (1964), *Understanding Media*, Routledge and Kegan Paul: London, p. 173.
4. Benjamin, W., [1936] (1973), 'The Work of Art in the Age of Mechanical Reproduction', *Illuminations*, ed. by Arendt, H., trans. by Zohn, H., London: Fontana.
5. Manovich, L. (2001), *The Language of New Media*, Cambridge, MA: MIT Press, p. 20.