# Keeping books of nature:
# An introduction to Leonardo da Vinci's Codices Arundel and Leicester

**A British Library Online Gallery feature by**
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A series of drawings held in the Royal Library at Windsor composed in the latter years of Leonardo da Vinci's life (1452-1519) depict the Deluge. Torrid, fierce, uncontrollable nature consumes human and animal forms, and trees and buildings:

> And let some mountains collapse headlong into the depths of a valley and dam up the swollen waters of its river But soon breached, the river bursts the dam and gushes out in high waves. Let the biggest of these strike and demolish the cities and country residences of that valley. And let the disintegration of the high buildings of the said cities raise much dust which will rise up like smoke or wreathed clouds through the descending rain ….[1]

Awesome and graphic, the images and instructions also depict how to draw nature unleashed, suggesting a list of topics for Leonardo's planned 'Treatise on Painting' (parts of which were published posthumously in 1651).

The contemporary resonance of Leonardo's Deluge Drawings is emphasised by recent events: the New Orleans flood, the Asian tsunami, climate change and its framing in terms of moral imperatives for human civilisation.

Codices Arundel and Leicester offer much of the scientific background to Leonardo's nature studies. They comprise notes on his observation, analysis, measurement and attempts to control nature, especially water, and are in effect among the first surviving notebooks of a 'scientist'.[2] In them we are able to recognise many of the things we

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[1] Quoted in Martin Kemp, 'The Vortex', chapter 5 in *Exhibition Catalogue, Leonardo da Vinci, Hayward Gallery London, 26 January to 16 April 1989*, (Southbank Centre: London), 1989, p. 131.

[2] This is an anachronistic term. Contemporaries might refer to those who made natural knowledge as natural philosophers (although Leonardo was most commonly referred to as an artist). Leonardo, it is suggested here, represents a social role in transition. His notebooks contain impromptu 'ricordi' of ideas, designs for inventions, thought and possibly actual experiments, and field notes, in addition to drafts in the more traditional form of scholastic treatises. To portray the manuscripts as a scientist's notebooks perhaps communicates some of the sense of them in today's terms.

associate with modern science: field work, laboratories and instruments, the application of mathematics to physical problems, induction and deduction, and the privileging of experience as a way of knowing the world. Yet in many instances the natural philosophy and cosmology underpinning Leonardo's scientific work are alien to us. The physical sciences have been presented in the terms of at least three revolutions since Leonardo's time: Copernican, Newtonian, and relativistic. Yet later students of Leonardo's manuscripts found his ideas to be incisive and often prescient of thinkers of the modern scientific age on a wide range of subjects, the seeds and off-shoots of a fertile mind.

Although Leonardo is a clear expositor of many sound principles, the immediacy and conviction of his ideas stem from their artistic and literary presentation, aspects of persuasion to which historians of science have in recent decades paid increasing attention. In the Codex Leicester (folio 34r), for example, Leonardo presents an evocative conception of the earth as organism:

> So when we say that the earth has a spirit of growth, and that its flesh is the soil; its bones are the successive strata of the rocks which form the mountains; its cartilage is the tufa stone; its blood the veins of its waters. The lake of the blood that lies around the heart is the ocean. Its breathing is by the increase and decrease of the blood in its pulses, and even so in the earth is the ebb and flow of the sea. And the vital heat of the world is fire which is spread throughout the earth; and the dwelling place of its spirit of growth in the fires, which in divers parts of the earth are breathed out in baths and sulphur mines, and in Vulcanus and Mongibello in Sicily, and in many other places.[3]

On the one hand Leonardo invokes a familiar metaphor of the human body, employing the classical analogy of microcosm and macrocosm. On the other, he evokes the vitality of earth processes, what some scientists after James Lovelock might term 'geophysiology'. Like the Deluge Drawings *vis-à-vis* recent events, the Gaian imagery of Codex Leicester can be appreciated, as current scientific techniques provide evidence that the earth is possessed of connections and feedback cycles of great complexity and sensitivity.

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[3] Quoted in *The Codex Hammer of Leonardo da Vinci* translated into English and edited by Carlo Pedretti (Florence: Giunti Barbera), 1987, p. 26.

Five hundred years on, the work of Leonardo challenges and enlightens the concept of scientific revolutions. Things, and our understanding of things, come full circle, but not without countless iterations through the application of new techniques, increasing accuracy, and shifts in whole world views. The potential of the manuscripts to be reinterpreted by successive generations in the light of new circumstances and developments is seemingly inexhaustible, and that surely is their greatest appeal.

## The changing nature of books and knowledge

Leonardo's surviving manuscripts consist of some 7,000 pages of notes and drawings, bound and unbound, about half of what is believed to have existed at the time of Leonardo's death. They are the most important sources for understanding Leonardo's work as a natural philosopher, engineer and, in addition to his surviving paintings, an artist.

They were created at a transitional period in the history of communication of the written word in Europe and beyond brought about by the emergence of movable type printing in the 15th century. As a result, they represent a tension between the published and the unpublished in the work and the world of Leonardo.

For centuries, knowledge had been created, retained and rediscovered through the labour of scribes who copied texts by hand, transferring them between cultures and continents. The scribal art resulted in works that ranged from utilitarian tracts to illustrated marvels, and were often intended to be semi-public in nature; read by scholars and elites with knowledge of written languages such as Latin and access to personal and institutional libraries. The uptake of the new technology of printing in the West following the *Gutenberg 42-line Bible* (1455), published only a few years after Leonardo's birth, was accompanied by other, gradual transformations: use of the written vernacular languages; growth in literacy; and the democratisation of knowledge.

The literary works of Leonardo offer a vignette of wider transformations taking place in the production, circulation and display of recorded knowledge. They are written primarily in what Antonio de Beatis, secretary to the Cardinal of Aragon who visited Leonardo in

France in 1517, called 'the vulgar tongue',[4] or vernacular Italian. For much of his life, Leonardo posed as a man without letters, a disciple of experience who drew on his own observations rather than relying on the word of authorities. At the same time, his manuscripts contain Latin word-lists reflecting his attempts to learn the language and lists of books in his collection, including those by contemporaries alongside classical and medieval authors. In some cases, scholars today are unclear as to whether he had access to the works of particular authors in print or manuscript; both were possible in this period of transition. In any case it is clear that Leonardo read books on natural philosophy and studied nature first-hand.

Leonardo contributed illustrations to the book of his friend, the mathematician Luca Pacioli (*Divina proportione*, 1509). Yet he never published his own work in his lifetime. His manuscripts show internal evidence of the preparation of treatises for publication, in their reference to books, cases to discuss, lists of headings, and addresses to the reader. Passages are crossed out and repeated elsewhere. One of the most famous passages is on the first page of the Codex Arundel, which sets out his plans for ordering and arranging his manuscripts according to subjects. Similar intentions are stated in other of Leonardo's manuscripts including the Codex Leicester. He describes his entries as 'ricordi' or notes, yet some are neat copies of earlier drafts with careful diagrams, each time rephrasing ideas that Leonardo returned to throughout the course of keeping his notebooks, which he began around 1480 and continued until his death.

There would no doubt have been a readership for the philosophical and practical treatises of Leonardo. The visitor of 1517, Antonio de Beatis, thought that Leonardo's anatomical drawings, and writings on 'water, diverse machines and many other matters … set down in an infinite number of volumes'[5], which Antonio claimed to have seen with his own eyes, would be very profitable and enjoyable should they be published. This was not to be; yet Antonio witnessed the display of the manuscripts as something potentially to be shared and understood more widely.

While visitors may have seen the manuscripts and admired their drawings, it is unlikely they would have been able to read them. Leonardo's characteristic mirror script, written backwards from right to

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[4] Quoted in Edward McCurdy, 'A record of the manuscripts', *The Notebooks of Leonardo da Vinci*, arranged, rendered into English and introduced by Edward McCurdy, 2 vols., (London: Jonathan Cape), 1977, vol. 1, 42-55, p. 44.
[5] *Ibid.*

left, ensured that his manuscripts could only be read when held in front of a mirror. As Leonardo's manuscripts evidence aspects of the transformations taking place in written communication so, too, they suggest the emerging tensions between openness and discretion in modern science.

The reason why Leonardo adopted mirror-writing for his notebooks is not known, and explanations range from the fact that he was left-handed and it was simply easier for him to write that way with ink, to the intention to keep his ideas secret.

It is unlikely that he wished to do so for esoteric reasons. Leonardo was on at least one occasion scathing of alchemists and others who protected their knowledge from wider discovery, although alchemists were among his associates. It is more likely that Leonardo's mirror-writing was intended to protect priority in discovery – to stop others stealing, or perhaps worse, ridiculing, his ideas in draft form.

Decades later, early modern astronomers like Galileo Galilei acted similarly by recording their observations and discoveries in the form of anagrams, sending them to adversaries, and revealing the code, once having consolidated their knowledge of the phenomenon in question.[6]

Issues relating to the transmission of knowledge are intimately tied to cultures of knowing. As in regard to the published and the unpublished, openness and discretion, Leonardo was once again at the crux of the hybrid traditions of scholastic and craft knowledge.

Although he made attempts to correct this later in life, Leonardo started professional life without preparation as a scholar. The illegitimate son of a notary, Ser Piero, and Caterina, presumed to be a young woman from the village, Leonardo was primarily trained as a craftsman in the workshop of Andrea del Verrocchio in Florence. Andrea was primarily known as a sculptor and one of the most technically accomplished and successful Florentine artists of the period. His commissions ranged widely and included the design of festivals and pageants, architectural embellishments and decorative public works.

Leonardo was to develop this remit even further by embracing the tradition of the peripatetic engineer, following Filippo Brunelleschi and

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[6] Ernan McMullin 'Openness and Secrecy in Science: Some Notes on Early History', *Science, Technology and Human Values*, **10:2**, 1985, 14-23, p. 18.

others, earning by this means the patronage of the Medici of Florence, the Dukes of Milan, and the King of France. His notebooks detail aspects of numerous commissions and projects relating to waterways, festivals, residences and memorials.

However, Leonardo conceived of himself as more than an engineer, as the engineers conceived of their role as more than craftsmen maintaining the traditional practices within the guild. Leonardo witnessed and progressed a tendency to underpin the arts with philosophical understanding drawn from ancient and medieval authorities and to enlighten recorded knowledge with the lessons of experience. In attempting to meld the traditions of craft and written knowledge, Leonardo and others began to cultivate a new social role that no longer relied on the collective knowledge of the guilds or elites, but that cultivated an individual persona of ingenuity.

## The arrangement and interpretation of Leonardo's books on nature

Leonardo’s prolific legacy of manuscripts documents scientific and technological practice before the scientific revolution. Their significances derive not only from their documentation of his works and biography, but for what they reveal of Leonardo’s wider intellectual landscape. This is more the case to the extent that in comparison few of the literary works of his contemporaries have survived. As Leonardo was poised between the end of the Middle Ages and the beginning of the Renaissance, his manuscripts offer insight not only into the cultivation of new personae but also into earlier cultures of knowledge.

Leonardo was famous in his own time as an artist, portrayed by early biographers such as Giorgio Vasari (*Lives of the Painters*) as one whose remarkable talents were wasted on philosophical and technical inquiries. It was not until the rediscovery and translation into English of his notebooks by scholars such as the art historian Jean-Paul Richter in the late 19th century that these were seriously considered by scholars working in the English language. Since that time Leonardo’s corpus has been treated in three distinct ways, each based on different systems of arrangement of Leonardo's writings and supporting different kinds of history.

Following Jean-Paul Richter, who produced the first extensive transcription and translation from the original manuscripts,[7] the American scholar Edward McCurdy published an English edition of extracts from Leonardo's manuscripts in the 1930s. By this time, facsimile editions including Italian transcriptions of many of the manuscripts had in addition been published. Like Richter, McCurdy chose to classify Leonardo's writings by subject, and justified this on the basis of Leonardo's stated intentions regarding his treatises, most clearly in the Codex Arundel.[8] 'This is a disordered gathering taken from numerous papers which I have copied here, in the hope that I will subsequently arrange them in proper order according to their different subjects.' This classification by subject to some extent followed the categories of contemporary scientific disciplines and was most suited to the history of science as the history of ideas. In particular, it facilitated the study of the emergence of new scientific ideas by comparison with earlier (and knowledge of later) texts.

Between the two World Wars, historian of science George Sarton was inspired by Leonardo's manuscripts to study medieval thought in order to find out what distinguished Leonardo from his predecessors. During World War 1 Sarton delivered a series of lectures on Leonardo then, 'having realised that it was impossible to appreciate correctly Leonardo's scientific thought without a deeper understanding of medieval thought than I then possessed, I undertook a systematic investigation of all the medieval writings'.[9] At the time of reviewing the Richter and McCurdy compilations in 1944, Sarton admitted he had been engaged in that work for the past 25 years and was 'still a century short of Leonardo!'[10] As the medieval roots of much Leonardo's thought were brought to light, he lost, in Sarton's view, his status as 'the universal inventor'.[11] Sarton nonetheless described Leonardo as 'a giant who helped to bridge two spans, the one separating the Renaissance from the Middle Ages, and the other separating Science from Art',[12] although these categories probably appeared closer to Leonardo's contemporaries than to Sarton. Scholars today have in addition benefited from studying Leonardo's manuscripts in different ways.

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[7] *The Literary Works of Leonardo Da Vinci*, compiled and edited from the original manuscripts by Jean Paul Richter, 2 vols., (New York: Dover), 1970, unabridged edition of the work first published in London by Sampson, Low, Marston, Searl and Rivington, 1883.
[8] McCurdy, 'A record of the manuscripts', p. 42.
[9] George Sarton, 'The Literary Works of Leonardo da Vinci; The Notebooks of Leonardo da Vinci', *Isis*, **35:2**, 1944, 184-7, p. 185.
[10] *Ibid.*
[11] *Ibid.*
[12] *Ibid.*

Richter, the pioneer of subject arrangement of Leonardo's works according to his intentions, was dismissive of other arrangements of Leonardo's manuscripts. Volumes such as the Codex Arundel compiled by collectors of Leonardo's manuscripts had 'no justification beyond the fancy of the collector who first brought them together to make volumes of more or less extent'. Richter was even doubtful of Leonardo's own arrangements because 'their order, so far as the connection of the texts was concerned, was obviously a matter of indifference to him.'[13] Richter nonetheless allowed his reader the possibility of reconstructing both the original, chronological order created by Leonardo to the limited extent that this was possible to ascertain from dated notebooks and the collectors' arrangements as evidenced in the bound volumes preserved in libraries and private collections. These two alternative sequences allowed for new opportunities to study the manuscripts.

It was McCurdy who pointed out the interest in studying Leonardo's own composition and arrangement as showing 'the mind in its workshop, busied in researching, in making conjecture, and in recording phenomena, tempering to its uses, in so far as human instrument may, the vast forces of Nature'.[14] This has been the favoured approach to the manuscripts in the latter part of the 20th century, represented in a new series of facsimile editions and other scholarship that reconstruct a chronological arrangement tying the composition of the diverse manuscripts to Leonardo's biography and works of art and engineering.[15] Scholars drew on the previous insights concerning Leonardo's ideas in relation to his predecessors and were particularly concerned to see how these informed Leonardo's practice; how, for example, Leonardo the artist was particularly concerned to develop the scientific basis of his craft in terms of optics, perspective, proportion and other disciplines.[16] These insights are supported by techniques of palaeography and historical scholarship used to reconstruct Leonardo's activities through and in relation to his manuscripts, identifying how Leonardo composed his papers to organise his thoughts over time. Such work is aided by the observation first made by Richter that Leonardo usually confined his discourse on

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[13] Richter, preface to *The Literary Works of Leonardo Da Vinci*, p. xv.
[14] McCurdy, 'A record of the manuscripts', p. 42.
[15] Leonardo da Vinci, *Il Codice Arundel 263 nella British Library*, edizione in facsimile nel riordinamento cronologico die suoi fascicoli, a cura di Carlo Pedretti, transcrizione e note critiche de Carlo Vecce, (Firenze: Giunti Barbera), 1998.
[16] For example, see ed. Paulo Galluzi, *Leonardo da Vinci, Engineer and Architect* (Montreal: The Montreal Museum of Fine Arts), 1987.

separate topics to one sheet of paper at a time,[17] which has led to scholars' interest in studying the sheets disbound and indeed leading to the disbinding of many of the original manuscript volumes. This of course has practical advantages for the study and exhibition of the manuscripts, but might also lead to a loss of understanding of the arrangement and use of the manuscripts for much of their history.

The third approach to the manuscripts and possibly one of the least explored relates to the history of collecting, that is, the arrangement, use and interpretation of the manuscripts by collectors. Such studies provide a crucial link between Leonardo's times and our own, helping to understand the transformations not only of the manuscripts but the historical transformations regarding the use of the texts taking place around them in the past 500 years. This would be supported in part by the preservation of the manuscripts in the order which collectors compiled and preserved them.[18] This is the order adopted in this instantiation of Turning the Pages, in keeping with its original purpose to bring readers closer to the experience of the collections of the British Library, while facilitating access to the Library's greatest treasures.

However, it is recognised that study of the works of Leonardo da Vinci needs to be approached from several perspectives supported by various arrangements: subject, chronological and codicological. Digital technologies potentially allow for all of these approaches to be adopted, ideally complementing one another.

## Codices Arundel and Leicester in Turning the Pages

The opening sections of the Codex Arundel, and the Codex Leicester, were composed around 1508-1510, begun in Leonardo's native Tuscany and probably returning with him to Milan later in the year. The Codex Leicester is a shorter, more self-contained work of 36 folios (72 pages), whereas Codex Arundel contains papers written over a much longer period (c. 1478-1517) encompassing almost all of Leonardo's working life. It is the compilation of a later collector and contains several smaller gatherings, some of which appear to be more self-contained drafts of treatises along the lines of Codex Leicester, totalling 283 folios (566 pages) in all.

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[17] Richter, preface to *The Literary Works of Leonardo Da Vinci*, p. xv.
[18] Carmen Bambach (forthcoming).

Bringing these two codices together in Turning the Pages is significant for three reasons. It is the first time they have been displayed together in their entirety since Leonardo composed them,[19] and possibly ever to the extent that it is possible Codex Leicester did not travel with Leonardo to France. They are his two manuscripts that deal primarily with scientific topics and show Leonardo in the persona of what we would today consider a scientist. In addition, they raise intriguing questions about the composition and provenance of the manuscripts.

There are several points of comparison between the two codices. Both refer to Tuscan landscapes and projects relating to local waterways. Both deal primarily with scientific subjects such as astronomy of which Leonardo's discussion in both codices can be linked. While the first part of Codex Arundel is intended as a treatise on mechanics, although later sections cover manifold subjects, the Codex Leicester primarily relates to Leonardo's studies of water

In addition to the similarities between the two codices there are also important codicological differences. Scholars have identified several different kinds of Leonardo's manuscripts, from loose sheets of drawings on paper to pocket notebooks that retain the form in which Leonardo kept them. Each of the codices presented here is of a different, arguably more complex, kind. Codex Leicester was originally a notebook or volume, bound, probably in soft paper covers, by Leonardo, that has since been dismembered and each sheet mounted separately. Codex Arundel contains pages from notebooks or gatherings which may have been bound separately by Leonardo, for example the first section on mechanics, that have subsequently been rebound in 'miscellaneous' collections.[20]

Both of the codices are described as quarto volumes. Most of the sheets comprising Codex Arundel are approximately 22 cm x 16 cm, with variations; the Codex Leicester consists of sheets more uniformly sized around 30 x 22 cm.[21] It has not been possible to represent the variations in the size of individual pages within each Codex in this edition of Turning the Pages, so that all pages in each Codex appear a uniform size, scaled to the average dimensions given above.

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[19] Individual folios drawn from each Codex were exhibited in Montreal in 1987.
[20] Martin Kemp, *Leonardo da Vinci, Experience, Experiment and Design*, (London: V&A Publications), 2006, p. 191.
[21] Carlo Vecce, 'Nota Al Testo' in *Il Codice Arundel 263 nella British Library*, p. 50.

Codex Leicester is here represented in bound order in a soft-bound cover. In the case of the larger Codex Arundel images of the 19th century British Museum binding have been used. In 1872, ff. 136-7 were removed from the smaller binding to be placed in a landscape volume and similar action was taken in regard to ff. 253-256 in 1947. Other oversize folios were similarly treated in a later, 1960s binding. Here they have been reintegrated into the order of the Codex as it was foliated by the British Museum. The Codex Leicester retains its 16th century foliation.

For the shorter Codex Leicester, synopses of the content of every page have been included. In the case of the Codex Arundel, pages have been selected for interpretation to facilitate comparison with Codex Leicester, to represent the wide range of contents of Codex Arundel as a whole, and with regard to visual interest.

The way in which the Codex was bound by subsequent collectors and the form in which it was retained by the British Library presented in this Turning the Pages edition is not the same as the way it was composed by Leonardo. In particular, it should be noted that pairs of pages as seen at many openings of this Turning the Pages edition do not relate to one another in content, date and style of composition; although sometimes they do.

To picture this, it is important to remember that Leonardo worked on loose sheets of paper, covering both sides of each sheet. Then imagine that he piled some of these papers one on top of the other and bound them together. Following this, a collector may have put some of these smaller ‘books’ together, or disbound and rearranged them, perhaps interleaving other, unrelated, pages or sheets. Some of the pages were even bound upside down in the British Museum volume and thus require to be rotated in Turning the Pages in order to view them the right way up.

What on one side of a sheet composed by Leonardo began as two related pages no longer appear side-by-side in the larger volume. This is why, in some of the synopses relating to selected pages of Codex Arundel, only one page of the opening is referred to, and sometimes other pages occurring elsewhere in the Codex are in addition mentioned. At this point it will be necessary to navigate within the Turning the Pages edition in order to see the other pages referred to.

Furthermore, in some of the synopses relating to Codex Arundel pages, related or similar pages in the Codex Leicester are cross-

referenced. It will then be possible to open the Turning the Pages edition of the Codex Leicester and to compare these pages with those discussed in the Codex Arundel.

Part of the intriguing circumstances of presenting the codices together is that they also have rather different provenances, which in both cases are yet to be fully documented and so continue to pose challenging problems for researchers and curators. However, like the work of Leonardo himself, it is clear that both have benefited from private and state patronage and, in the case of Turning the Pages, represent a collaboration between the two.

**Provenance**

Most of Leonardo's manuscripts were gathered together by Leonardo at the time of his death and kept by his pupil and heir Francesco Melzi but subsequently dispersed, traded and inherited by artists and collectors and their heirs.

Since the 16th century, Codex Leicester has been retained by a series of private collectors, for 263 years (1717-1980) belonging to the estate of the Earl of Leicester, Thomas Coke, and his heirs, after whom the Codex was then and, (following a period known as 'Codex Hammer' when in the collection of industrialist Armand Hammer, 1980-1994), is now named.

Codex Arundel was in the collection of notable art collector Thomas Howard, Earl of Arundel on his death in 1646 and donated by his grandson to the Royal Society (c. 1667) then transferred to the British Museum library (now the British Library) in 1831 with other Arundel manuscripts. It has therefore been retained by scientific and public institutions for the best part of 300 years.

Leonardo reached the end of his life in France in the service of the King of France (Francis I) the benefits of whose patronage included the manor house at Cloux where Leonardo died in 1519. In April that year he prepared a will that bequeathed the manuscript legacy then in his possession to his pupil and companion Francesco Melzi. Melzi, a nobleman, returned the manuscripts to his estate near Milan and attempted to compile them into treatises, succeeding only in compiling a manuscript version of the Treatise on Painting from extracts of Leonardo's writings, a version of which was later published (Paris, 1651) and remains, as we have seen, the only published literary work attributed to Leonardo.

On Melzi's death (c. 1570), his son, Orazio, took little interest in the papers of Leonardo and their dispersal began through removals, gifts and sales. Very little is known for certain about the provenance of the manuscript in the following 40 years. What is known is that many of these passed into the hands of the sculptor Pompeo Leoni who made efforts to accumulate Leonardo's papers and spent much of his life in Madrid and died in 1610. Two of the manuscript volumes were then sold there to Don Juan de Espinas.

Many, including the multi-volume Codex Atlanticus known to be Leoni's compilation, were returned Leoni's heir in Milan, Polidoro Calchi, who sold them to Count Galeazzo Arconati. Arconati presented 12 volumes to the Ambriosiana Library in Milan in 1636, withdrawing them to consult from time to time and possibly compare with others remaining in his possession.[22]

Codex Leicester appears to have passed into the hands of the sculptor Guglielmo della Porta who lived in Rome between 1537-1577, suggesting that it might not have been part of the Melzi inheritance, and is foliated in a 16th-century hand. It passed to Guglielmo's heir Teodoro della Porta (d. 1625) in 1577 and was found by Giuseppe Ghezzi in a chest of manuscripts and drawings by Guglielmo in 1690. The manuscript remained with Ghezzi who added a calligraphic title page until it was purchased in 1717 by Thomas Coke, later the Earl of Leicester, who brought the manuscript to England. It was then purchased from the Leicester estate at auction by Armand Hammer and renamed Codex Hammer in 1980.[23] Bill Gates returned the Leicester title to the Codex when he purchased it, by auction, in 1994.

Very little is known about the early provenance of Codex Arundel until it constituted part of a gift to the Royal Society by Henry Howard, 6th Duke of Norfolk in 1667. The Library remained at Arundel House, which served as a meeting place of the Royal Society. When the Society returned to premises at Gresham College in 1679, the Arundel Library was also moved to the College.[24] The manuscript was first catalogued in 1681 by the Fellow and Librarian of the Royal Society, William Perry, as a scientific and mathematical notebook.[25]

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[22] McCurdy, 'A record of the manuscripts'.
[23] Pedretti, 'History of the Codex Hammer', in *The Codex Hammer of Leonardo da Vinci*, liii-lvi.
[24] Linda Levy Peck, 'Uncovering the Arundel Library at the Royal Society: Changing Meanings of Science and the Fate of the Norfolk Donation', *Notes and Records of the Royal Society*, **52:1**, 1998, 3-24.
[25] 'Librorum Manuscriptorum Bibliotechae Norfolcianae in Collegio Greshamensi … accurante Guilielmo Perry' in Edward Barnard, *Catalogi Manuscriptorum Angliae*, 1697, vol. 2, 74-84, No 254.

The notebook was apparently part of the collection of Thomas Howard, Earl of Arundel, on his death in 1646, although it is not listed in an inventory of his Library prepared after his death for the purpose of administering the contested estate. Arundel was a notable art collector, who travelled in Europe during the first part of the 17th century as a diplomat, and he also had collectors working for him on the continent. He is known to be a collector of Leonardo's works and was successful in acquiring the volumes of anatomical drawings now in the Royal Collection at Windsor.[26]

Codex Arundel may originate from one or several sources, including: directly from the estate of Leoni in Spain; Arconati, who purchased the Codex Atlanticus and other manuscripts from Leoni's heir, and from whom Arundel is known to have purchased works of art; Espinas, who was entreated by Arundel to sell him the volumes of Leonardo drawings; and the collection of Willibald Pirckheimer from which Arundel purchased many of his manuscripts in a visit to Nuremburg in 1636. Of these scenarios the last is the more remote possibility to the extent that it is not known whether or not Pirckheimer possessed any Leonardo manuscripts, whereas this is documented in the cases of Leoni, Arconati and Espinas.

Half of the Arundel collection of manuscripts that were donated to the Royal Society by Arundel's grandson, including Codex Arundel, were later transferred to the British Museum library (now the British Library) in 1831 and catalogued in 1834, Codex Arundel being then attributed to Leonardo da Vinci. The manuscript was retained in bound form until the production of the most recent facsimile edition (1998, Florence: Giunti Barbera) edited by Carlo Pedretti and Carlo Vecce.

## Observation, natural philosophy and morality

Considered as scientific documents, Leonardo's manuscripts from today's perspective are a mix of implausible theories and those confirmed by current thinking and techniques. His style of scientific writing is a combination of sharp observations and clear exposition of principles with scholastic dialogue, in which he challenges the claims of an imagined adversary or textual authority. Some of the highlights include studies of water, astronomy, optics, the history of the earth, mechanics, philosophy and morality.

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[26] Jane Roberts, 'The Early History of the Collecting of Drawings by Leonardo da Vinci', *Leonardo and Venice*, Milan, 1992, 155-178; Denys Sutton, 'Thomas Howard, Earl of Arundel and Surrey, as a Collector of Drawings', 3 parts, *Burlington Magazine*, **89:526**, 2-9; **89:527**, 32-34, 37; **89:528**, 75-59.

About one third of the Codex Leicester relates to water and its movement, and there are several passages relating to water in the Codex Arundel, associated with canalisation projects in Tuscany (folio 149r) and France (folio 269r). Leonardo's observations led him to elucidate, for example, how currents flow: 'By so much as you will increase the river in breadth, by so much will you diminish the speed of its course.'

In some cases linked to his studies of water was Leonardo's discussion of the changing character of the earth including phenomena such as erosion (Codex Leicester folios 5v, 32r and 31v) the global circulation of water (Codex Arundel folios 210r and 236v, Codex Leicester folios 3, 27v and 28r) and wind (Codex Leicester folio 30v, Codex Arundel folio 113v).

Among the most famous studies in the Codex Leicester are those exploring the geometry and astronomy of the sun, the moon and the earth (folios 1-2, 35 and 36) paralleling those in the Codex Arundel (folio 104r). This was a key topic in medieval cosmology, and Leonardo, while retaining the Ptolemaic system, developed a geometrical argument for the reflection of light from water on the surface of the moon to illuminate the earth. This implied that the moon, like the earth is possessed of gravity, keeping the four Aristotelian elements – earth, water, air, and fire – in place, in order of density. As Leonardo studied the geometry of light on a cosmological scale, he also considers optical questions of human proportions.

In the Codex Arundel (folios 87v-88r), Leonardo considers Alzahen's problem, after the Islamic philosopher, concerning where an object at a given location is seen in a curved mirror. He also suggests an experiment to coat a mirror with tempera paint removed in thin lines to see the separated rays reflected. Leonardo was interested in the utility of concave mirrors for concentrating light rays on a single point to create heat and fire, recalling Archimedes who used a burning mirror to destroy enemy ships to defend Syracuse. After 1513 in the service of Giuliano de Medici, commander of the papal forces, Leonardo experimented with burning mirrors with a view to using them for industrial purposes. Elsewhere in the Codex Arundel he considers the optical properties of the eye (folio 115v).

Leonardo initially held the traditional view of the continuous circulation of water on the earth. In analogy with the circulation of the blood in the body, authorities such as Ristoro d'Arezzo in *Della composizione*

*del mondo* (*The Composition of the World*, 1282) envisaged a siphonic process in which water from the sea was drawn to the highest mountains, released in springs and flowed downstream to form rivers thence back into the sea. However, in the course of composing the Codex Leicester, Leonardo changed his thoughts on this subject to conclude that precipitation, the evaporation of water to form clouds and rain, explained the gathering of water above the earth, and that the force of water in turn formed the mountains and valleys through erosion.[27]

The debate in Leonardo's texts about the global circulation of water was key to another point upon which Leonardo distinguished himself from the ancients (Codex Leicester folio 3r). Pliny the Elder argued that the highest seas were higher than the highest mountains. Although Leonardo, along with the many thinkers of his time, adopted aspects of classical natural philosophy, he contested the ancients on particular points, in this case using a geometrical argument.

Leonardo was similarly sceptical of accounts of the Biblical deluge as the origin of fossils found atop mountains. Leonardo found fossils to be buried in ordered layers and explained the process of sedimentation that led to their formation (Codex Leicester, folio 8v), designing experiments in glass tanks to demonstrate these processes (Codex Leicester folio 9v). Yet the Deluge theory of the origin of fossils and the history of the earth was dominant until the work of Charles Lyell (*Principles of Geology*) and others in the 19th century.

This combination of innovation and tradition in the work of Leonardo sometimes resulted in correct observations explained by wrong theories. For example, while Leonardo's idea that the moon is covered with water was wrong, he correctly explained the secondary light of the new moon, *lumen cinereum,* as light reflected from the seas of the earth (Leicester, folio 7r).[28]

Confident to develop his own theories, Leonardo was often content to elucidate the work of others. In the Codex Arundel (folios 67r-66v), Leonardo shows with clarity how the principles of a balance work, following the 13th-century author Jordanus de Nemore.[29] Equilibrium can be found when the result of multiplying the length of the arms by the weight is the same on both sides. Leonardo stressed that the weight of the arms also needs to be taken into account. He applied this

[27] Pedretti, introduction to *The Codex Hammer of Leonardo da Vinci*, p. xxxi.
[28] *Ibid.*, p. xviii.
[29] Kemp, *Leonardo da Vinci, Experience, Experiment and Design*, p. 25.

principle to the case of uneven balances with one short arm and one long arm (folio 66r), useful in weighing heavy objects and thus suitable for engineering projects. His exposition has something of the character of a textbook.

Observations in the first 'book' of the Codex Arundel on mechanics suggests that Leonardo had a good grasp of the subject. For example, at folios 40v and 41r, Leonardo identified friction as proportional to the force and therefore weight of the objects in contact, a principle formulated by Guillaume Amontons in 1699.

Another example of his grasp of mechanics is his discussion of stationary waves on folio 23r of the Codex Leicester, in which he explains 'waves do not penetrate one another, but leap back from the percussed place, and every reflex motion flies away at equal angles from the percussion place'. Christian Huygens reformulated and established the same principle in 1673.

Leonardo was not only an inspired engineer, he also delved more deeply into the philosophical basis of things. Although Albert Einstein condemned what Leonardo wrote on the concept of naught or 'nothingness' as translated here (Codex Arundel folio 131v) as 'absolute nonsense', Einstein conceded that Leonardo nonetheless conceived of space and time as 'reciprocally independent… continuous entities of point-like nature (deprived of extension) in constant contact' and perceived the non-extended character of time present as a problem.[30]

Like Einstein, Leonardo was concerned with the moral dilemmas posed by innovations in science and technology and their uses. In his discussion of the problem of submarine warfare, Leonardo describes how to extend the time a person can stay underwater and then goes on to reflect on the possible military uses of his inventions: 'I do not describe my method of remaining underwater for as long a time as I can remain without food… this I do not publish or divulge on account of the evil nature of men who would practise assassinations at the bottom of the seas by breaking the ships in their lowest parts and sinking them together with the crews who are in them (Codex Leicester, folio 22v).' In the Codex Arundel, Leonardo nonetheless draws a design for an underwater breathing device (folio 25v).

[30] Quoted in Carlo Pedretti, 'Einstein flunks Leonardo', English translation of an article published in *Corriere della Serra*, 8 September 2002.

Perhaps the most compelling aspects of Leonardo's scientific work, his accurate anatomical drawings, are not represented in the codices presented here on Turning the Pages. Nonetheless, they do offer a glimpse of his concern with the health of man and his environment. Codex Leicester (folio 30v), for example, includes comments on the waterways of Milan and the connections between the character of rivers and plagues. Following Vitruvius whom he read and admired, Leonardo was concerned to promote healthful, as well as architecturally pleasing, living. Like the earth, the city was likened to the human body requiring to be maintained as a healthy organism.

**Curatorial acknowledgements**

Synopses of the content of each page of Codex Leicester are courtesy of Corbis.

The selection of pages of the Codex Arundel to be interpreted and synopses relating to selected pages of the Codex Arundel have been prepared by Juliana Barone (folios 1r, 25r-24v, 29v, 36r, 66r, 66v, 67r, 94v, 104r, 113v-114r, 131v-132r, 134v-135r, 136r, 153v, 155v-156r, 157v-158r, 162r, 236v, 245r-246v, 250r, 269r, 273v-276r, 278r, 283v-282r). Translations of extracts of the Codex Arundel have been prepared by Stephen Parkin.

Thanks are also due to Carmen Bambach, Andrea Clark, Jeremy John, Martin Kemp, and Ann Payne.