SCIENTIFICA HISTORICA

How the world's great science books chart the history of knowledge

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ART DIRECTOR James Lawrence
COMMISSIONING EDITOR Kate Shanahan
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DESIGN MANAGER Anna Stevens
DESIGNER Michael Whitehead
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EDITORIAL ASSISTANT Niamh Jones

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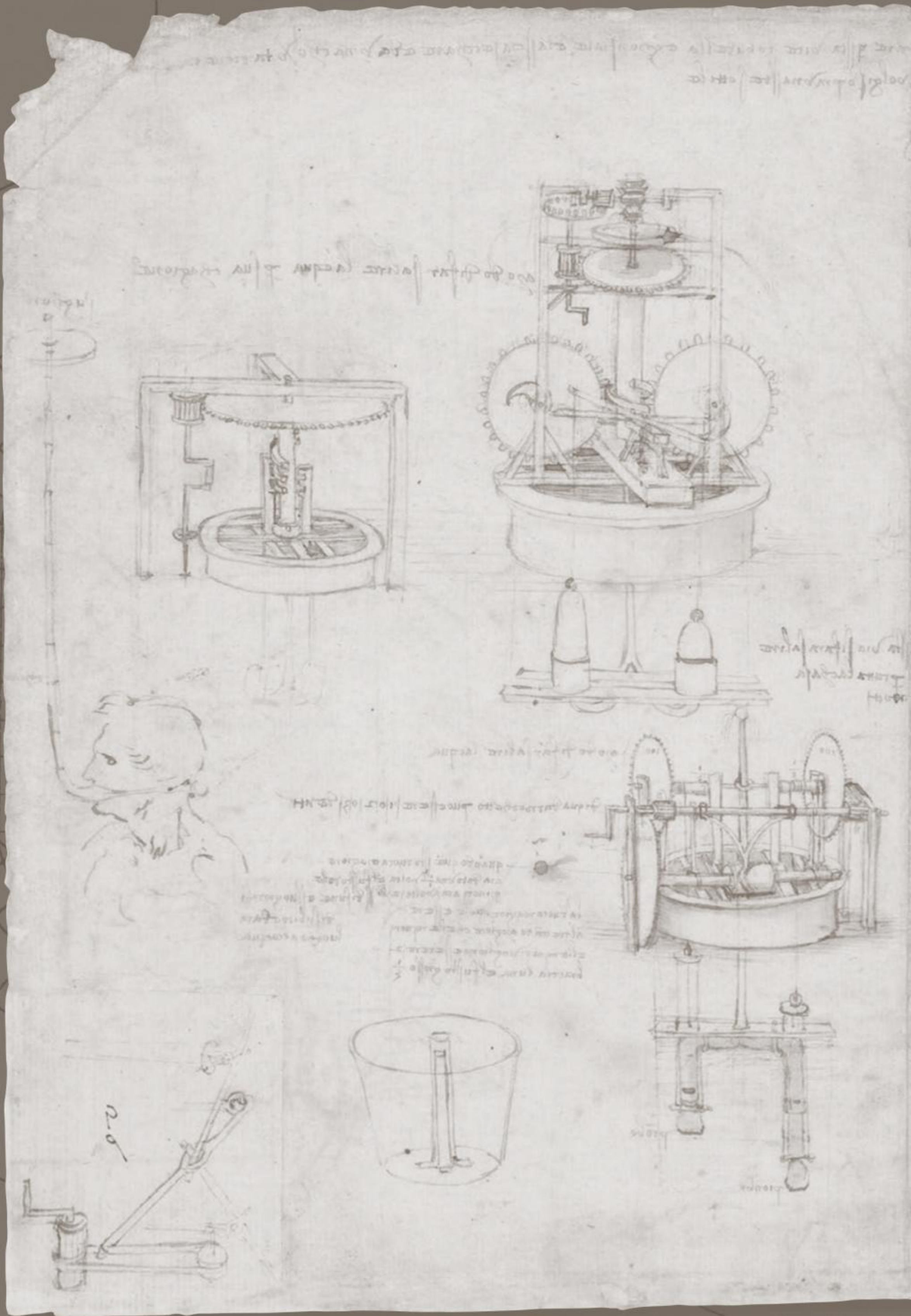
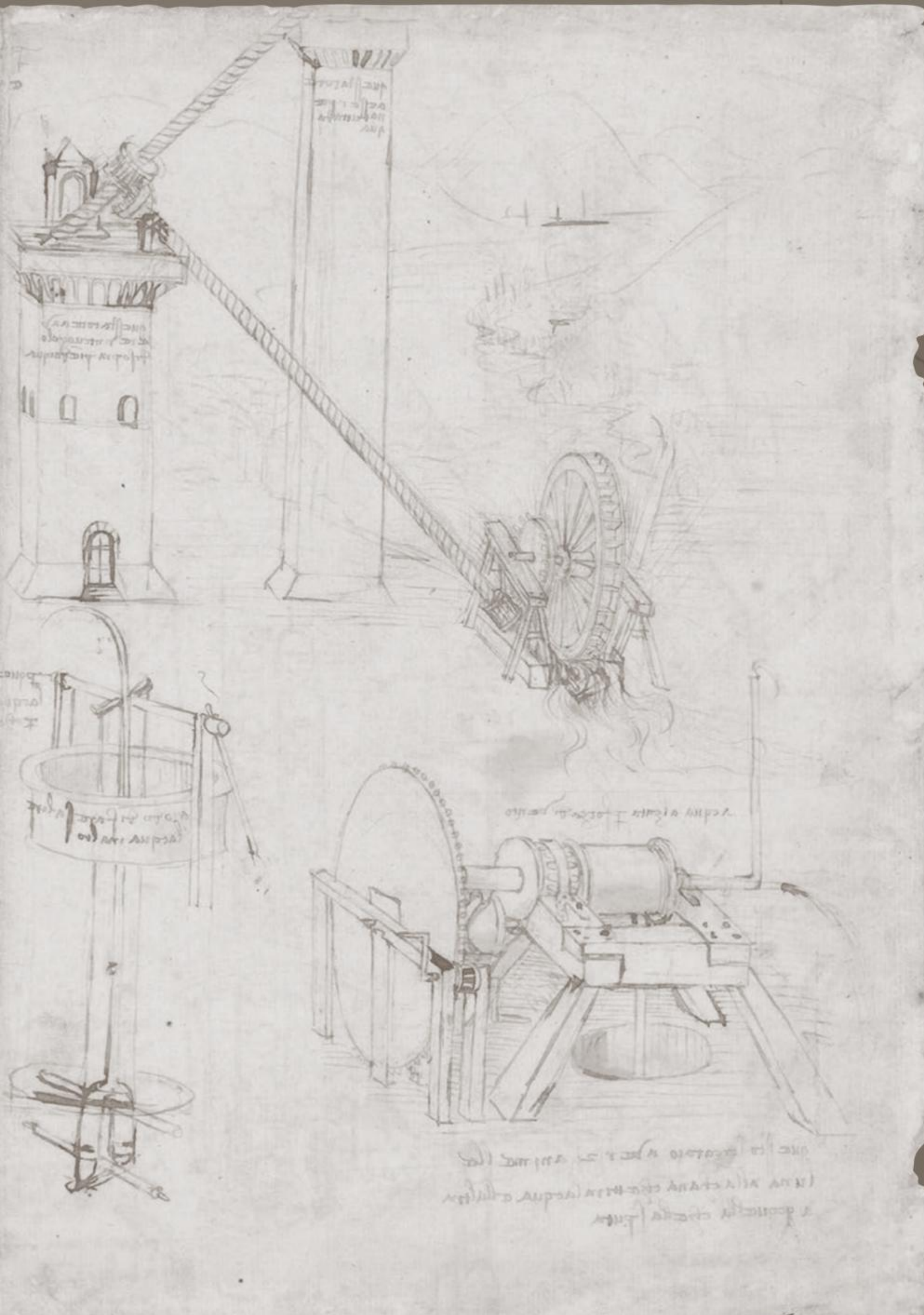




INTRODUCTION

The Latin word *scientifica* describes something that produces knowledge; from this broad scope, 'science' has come to describe our understanding of the universe and the objects in it. One invention has been central to the development of science. It's not an incredibly complex piece of hardware like the Large Hadron Collider, nor a sophisticated concept like Einstein's general theory of relativity, but something far more familiar. Without this technology, we would be left with little more than folk tales and mysteries, because the invention is writing.

The importance of writing gives us the *historica* of the title, which defines something based on research or producing an account – the fundamental requirement for science to benefit from the written word. In conceptual terms, writing is the technology that frees up communication from the limits of time and space, destroying the shackles of the here and now.

Most animals and even some plants communicate at some level, but usually that communication is immediate and local, after which it is gone forever. Writing transcends that limitation. I can take a book off the shelf and read words that were written thousands of miles away and hundreds, or even thousands, of years ago. There are probably more communications on my bookshelves from dead people than there are from the living – and certainly very few of the books I own were written by authors who live near to me. Writing takes care of time and space. And that is its significance in making science possible.

The power of writing for science is that books act as a storage medium for ideas and discoveries; we don't have to reinvent the wheel every time. Science can only work as it does by building on the discoveries and theories of others. Isaac Newton famously said (probably paraphrasing Robert Burton), 'If I have seen further it is by standing on the shoulders of Giants.' Newton's ability to make use of others' ideas was only possible thanks to the written word. And books have been central to the spread of science in this manner ever since humanity began to look for rational explanations of what they observed around them over 2,500 years ago.

The role of books in transcending time and space is illustrated well in the complex web of written works that ties together the ancient Greek world, Islamic scientists of the latter part of the first millennium and medieval European scientists. The ancient Greeks wrote many books on scientific topics following the revolutionary ideas of Thales of Miletus, who seems to have been amongst the first to make the shift from mythological explanations of the natural world to ones that came closer to a scientific view, from around 600 BCE.

Many of the books of the ancient Greek period were lost as their civilisation fell and their libraries were ransacked. Just one example gives a poignant reminder of this. In a strange little book called *The Sand-Reckoner*, the remarkable third-century BCE

THALES OF MILETUS, FIFTEENTH CENTURY

A representation of the sixth-century BCE ancient Greek philosopher and mathematician Thales of Miletus.

mathematician and engineer Archimedes of Syracuse attempted to work out how many grains of sand it would take to fill the universe. (By 'universe' he had in mind roughly what we would think of as the solar system.) This was not quite as useless a task as it sounds. The Greek number system of the time was very limited. The largest named number was a myriad – 10,000 – which meant that the largest number usually considered was a myriad myriads, or 100 million. But Archimedes wanted to show that it was possible to go far beyond this limitation by devising a new type of number that could easily handle any required value. He demonstrated its flexibility by attempting the remarkable calculation with grains of sand.

The Sand-Reckoner has survived the ravages of time, but in it, Archimedes referred to another volume that otherwise we would not have known existed. To work out the number of sand grains required, Archimedes first used geometry to estimate the size of the universe. He based his calculation on the accepted astronomical model of the time, where the Earth was at the centre of the universe with everything orbiting around it. But he also noted:

Abū Ja'far Muḥammad ibn Mūsā al-Khwārizmī
AL-KITĀB AL-MUKHTAṢAR FĪ ḤISĀB AL-ĞABR WA'L-MUQĀBALA,
COPY, 1342

Covering algebra, calendars, inheritance and more, this was one of the principal mathematics textbooks from its first publication circa 820 CE to the sixteenth century.

Aristarchus of Samos brought out a book consisting of some hypotheses, in which the premises lead to the result that the universe is many times greater than that now so called. His hypotheses are that the fixed stars and the Sun remain unmoved, that the Earth revolves around the Sun in the circumference of a circle, the Sun lying in the middle of the orbit . . .

This lost book by Aristarchus, referenced only by Archimedes, is the first known suggestion of what would become the heliocentric Copernican theory. As is the case for so many other titles from the period, we will never know exactly what Aristarchus wrote.

The books of ancient Greece were largely forgotten in Europe after the fall of the Roman Empire, but as the interest in science grew in the flourishing Islamic world, surviving Greek titles were translated into Arabic and supplemented a growing body of new work, notably in mathematics, physics and medicine. A good example of the new life being brought into the books of the period was *Al-kitāb al-mukhtaṣar fī ḥisāb al-ğabr wa'l-muqābala* (The Compendious Book on Calculation by Completing and Balancing)

GREEK AND ARABIC PHILOSOPHY, FOURTEENTH CENTURY

The left-hand illustration depicts Hippocrates (ca. 460–ca. 377 BCE), Hunayn ibn Ishaq (808–73 CE), and Claudius Galenus (ca. 131–ca. 201 CE) discussing ideas; the illustration on the right shows an Arabic scribe working on a philosophical text.

by Abū Ja'far Muḥammad ibn Mūsā al-Khwārizmī, born around 780 CE, possibly in Baghdad in modern-day Iraq. This title was not just influential in the Islamic world. Although some Greek works did start to filter directly back into European awareness in the thirteenth century, Arabic works were first translated a century earlier – both Arabic translations of Greek titles and the original work of scholars such as al-Khwārizmī. *Al-kitāb al-mukhtaṣar* led the way in introducing practical algebra to the West (the word 'algebra' comes from *al-ǧabr* in the title). Al-Khwārizmī tells the reader that the book would be useful for 'inheritance, legacies, partition, lawsuits, and trade'.

So, thanks to the medium of the book, ideas from ancient Greece helped inspire the flourishing scientists, medics and mathematicians of the Arabic-speaking world, while translations of the Greek books and new titles by Islamic writers would kick-start a scientific revolution in Europe. These titles linked thinkers who were separated by centuries, languages, distance and culture. It was the books that tied everything together.

The written word

Of course, the physical mechanism used to convey written communication has changed several times from the earliest days of science books. Hippocrates' or Aristotle's notion of a book would be very different from a modern-day ebook on a Kindle. Greek books came in the form of scrolls – continuous sheets of writing material rolled up to form a cylinder. The Greeks inherited the format from ancient Egypt, where papyrus made from reeds would have been the standard medium, though later, parchment (treated animal skins) and paper were also used.

Although scrolls were reasonably practical for relatively small books (which is why ancient books, such as the books that make up the Bible, appear so short to modern eyes), they presented difficulties as a text got longer. A scroll could be a good number of metres long, which made it unwieldy and easy to get into a tangle. With more substantial scrolls there would often be spindles at each end, but managing these presented their own challenges. The reader had to unroll the scroll from one spindle and roll the far side onto another spindle. Depending on the orientation of the text, they would then either read continuously down the scroll like an autocue (which was particularly difficult on the wrists) or across it, with text printed in chunks like pages, in which case, there was a considerable delay in getting onto the next section of text. The format was particularly cumbersome if the aim was to find a particular section rather than read the book from beginning to end.

Although the Romans made surprisingly little contribution to science itself, they gave science books (and literature in general) a huge boost by devising the codex, introduced in the first century CE. This was what we now think of as a traditional book – sheaves of leaves, bound together, which could be flicked through to a particular location and read easily page by page. The codex was also significantly easier than a scroll to copy – a process that was essential to the role of the book in spreading the word of science. A whole industry of book copying sprung up, particularly within religious institutions, which made it possible for books to transmit scientific theories far beyond their initial

SEATED SCRIBE, CA. 2500–2350 BCE

An ancient Egyptian scribe working on a papyrus in a statue from the fifth dynasty.

TWO SCRIBES, CA. 2400 BCE

Fifth dynasty relief from the Mastaba of Akheteps at Saqqara, the necropolis for the ancient Egyptian capital of Memphis.

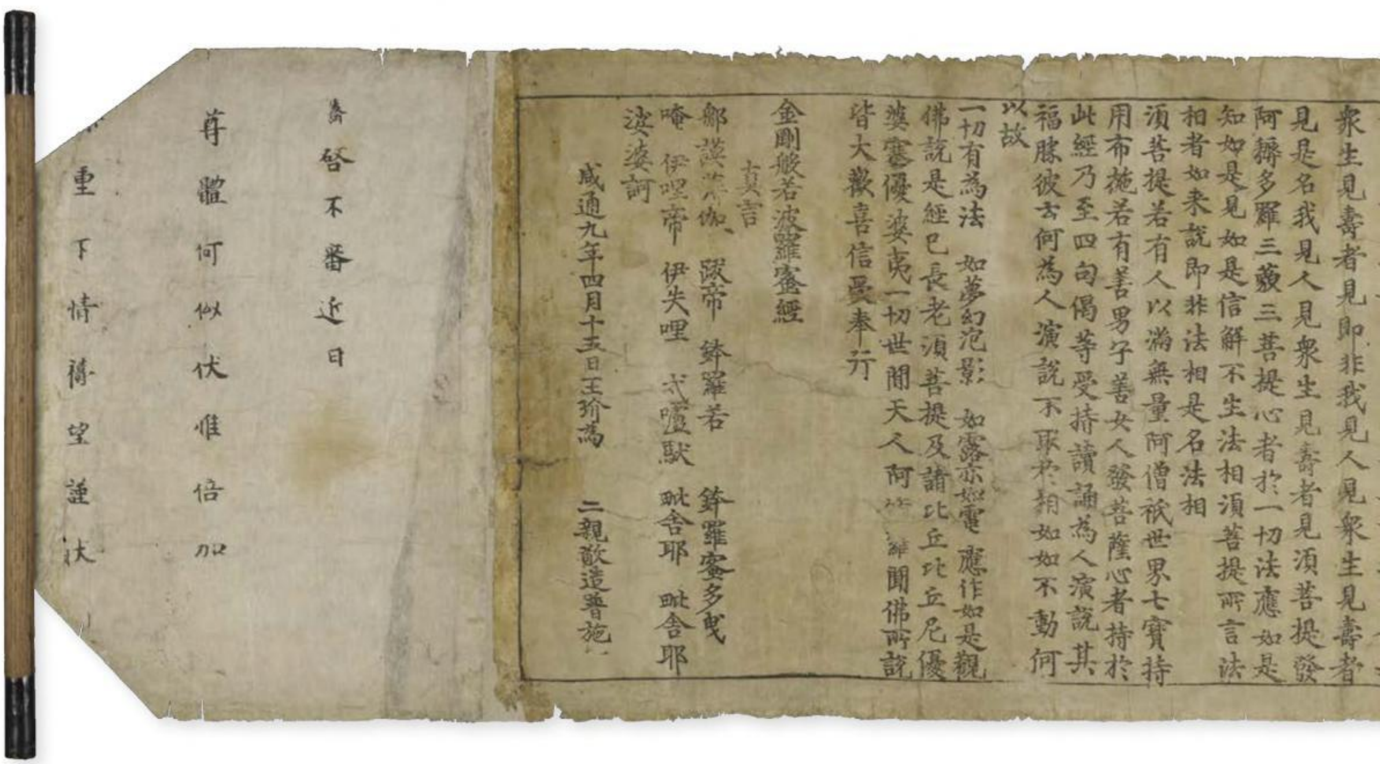
WOMAN WITH BOOK, FIRST CENTURY CE

A portrait of a Roman woman known as Sappho holding a book and a stylus, painted on plaster at Pompeii.

sources. This first flowering of copying blossomed wildly with the invention of the printing press, transforming the written word from an extremely expensive vehicle for communication to the few into a mechanism by which science could reach the masses.

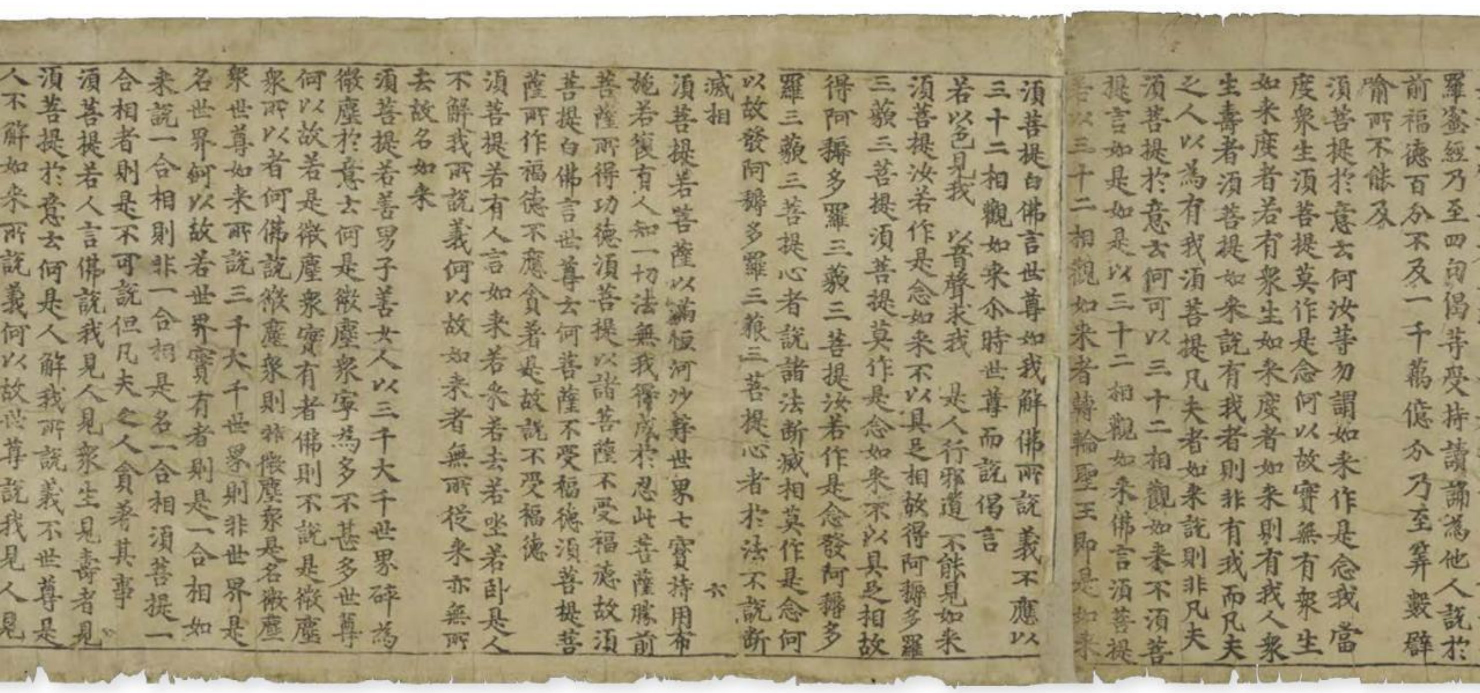
Printing presses per se date back as far as the codex, but early presses relied on carving the original words and images in reverse, typically into a wooden block, which would then be used to impress the ink onto the paper. The woodcut technique (and later the process of lithography, based on stones or metal plates marked with ink-resistant materials) would be used for illustrations until modern photographic techniques could be incorporated. However, woodcuts were slow to produce, making it impractical to print many whole books of any length. Nonetheless, from the ninth century, China was producing short scrolls using this method. The earliest known book printed this way was the Dunhuang *Diamond Sutra* from the year 868 CE. The Chinese would continue to print books from wooden blocks well after their development of moveable type.

Like many great ideas, moveable type was a simple one. Rather than trying to carve the whole of a book's page into a single block, a large quantity of individual characters on small blocks were produced, which could be bound together to form a page. The set page could be used until the print run was completed, then dismantled so that the individual blocks could be reused to create another page. Setting up the page (a process called typesetting) took a considerable amount of time – until mechanical typesetting devices were introduced in the nineteenth century – but this was only comparable to the time taken to painstakingly copy a few manuscript pages, after which as many copies as were required could be run off.



DIAMOND SUTRA, COPY, 868 CE

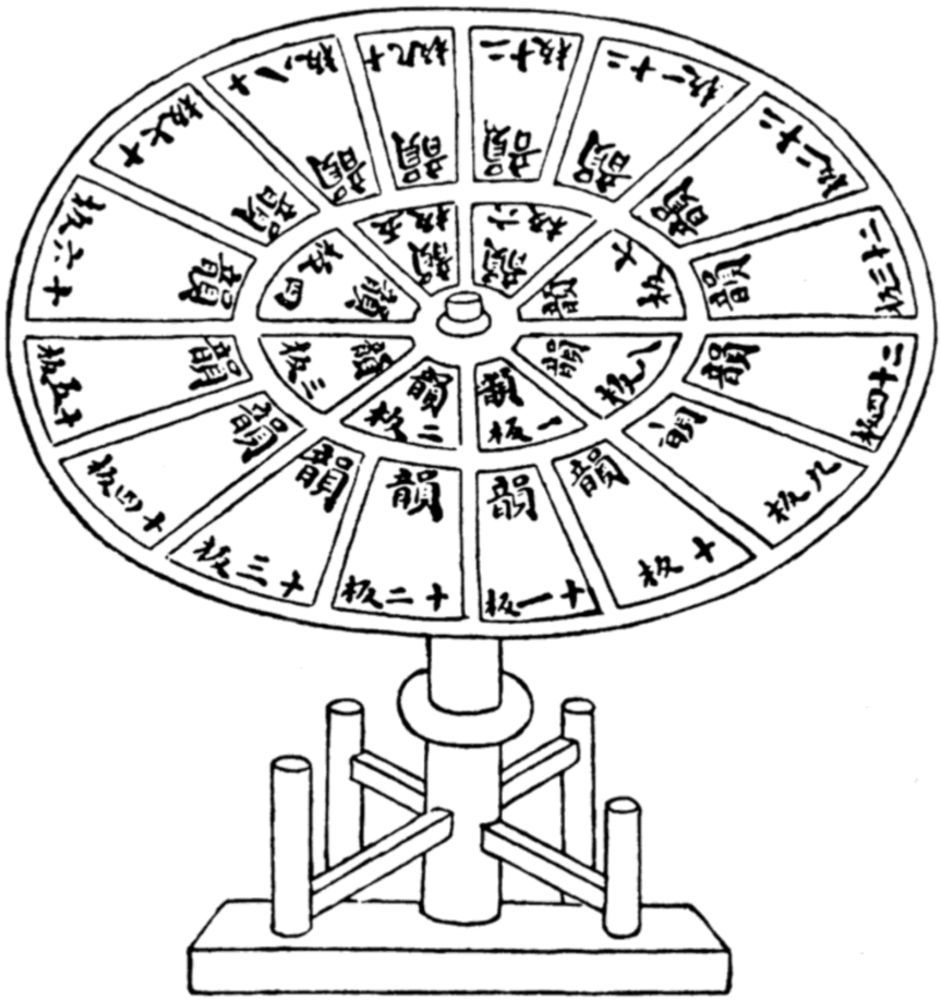
This Chinese copy of the Indian Buddhist *Diamond Sutra* (below) is the world's earliest dated, printed book. The scroll is made from seven panels and includes a frontispiece (left).



The early Chinese moveable-type blocks were made of ceramic or wood, first developed in the eleventh century, though the earliest known book printed using moveable type is *Notes of the Jade Hall* from 1193, which used fired clay characters. By the fourteenth century, metal, which has the advantage of being more durable, took over. Yet despite this early lead, moveable type would not prove hugely popular in China in the way it would rapidly become so in Europe when it was introduced in the fifteenth century. This seems to have been down to the economy of scale. Those using the Roman alphabet only had to produce around 50 varieties of type block (lower case and upper case), leaving aside special fonts for titles. But for the Chinese market, with characters running into the thousands, there was far less benefit to be gained from moveable type over carving a whole page as a block.

REVOLVING TYPECASE, 1313

A revolving table Chinese typecase with individual moveable type characters arranged primarily by rhyming scheme, from Wang Zhen's *Nong Shu* (Book of Agriculture).



PRINTING PRESS, 1440

An illustration of Laurens Janszoon Coster's alleged invention of the printing press, the Dutch rival to German printing-press inventor Johannes Gutenberg.

WOODBLOCK OF *AMBROSIA ALTERA*, CA. 1562

Woodblock designed by Giorgio Liberale and cut by Wolfgang Meyerpeck for the illustrated editions of Pietro Andrea Mattioli's *Herbár* (1562), *New Kreüterbuch* (1563) and *Commentarii in sex libros Pedacii Dioscoridis Anarzabei de Medica materia* (1565).

From technical documents to mass communication

As we move through the different periods of scientific writing, the shift in the availability of texts was matched by a transformation in the nature of science books. Initially, books were the means for one natural philosopher (the predecessor to the term 'scientist', which was not introduced until the 1830s) to communicate with his or her peers. The standard language for writing such books in Europe was Latin. This common language was a way to enable information to pass easily from country to country, just as English is used today as the standard language for scientific papers. However, it was also a conscious mechanism to limit access to the information to the cognoscenti. It was the practice of medieval natural philosophers, such as the thirteenth-century English friar Roger Bacon, to keep scientific knowledge from the common herd. Bacon noted (quoting an earlier source) that 'it is stupid to offer lettuces to an ass since he is content with his thistles.'

By the seventeenth century, though, this attitude was changing. Galileo wrote his scientific masterpieces in Italian, rather than Latin, with the aim of reaching out to the public. Isaac Newton had intended the third volume of his crowning glory, *Philosophiae Naturalis Principia Mathematica*, to work for a wider audience, until a falling out with colleagues changed his mind. Other writers would specifically produce books that

Maurice Quentin de la Tour
MADAME DU CHÂTELET-LOMONT, OIL ON CANVAS, EIGHTEENTH CENTURY

Portrait of the French scientist and author Émilie du Châtelet.

simplified the heavyweight works of science for a wider audience. For example, the eighteenth-century French scientist and author Émilie du Châtelet – who wrote her own impressive review of contemporary science in *Institutions de Physique* (Lessons in Physics) – not only translated Newton's masterpiece, the *Principia*, into French, but offered a commentary to make it more approachable to the general reader.

With the establishment of scientific bodies, such as the Royal Society in London, founded in 1660, scientific journals began to be available for the more focused spreading of scientific ideas amongst experts. By the late nineteenth century, scientists were still writing some books for their peers (and textbooks would always be required for students), but these were gradually eclipsed by books intended for the general public. A good example of a title that straddled the two modes of scientific communication was Charles Lyell's *Principles of Geology* from the 1830s. Though relatively technical, the three-volume book with coloured illustrations was sufficiently approachable to bring the latest thinking in geology – with its profound implications that the Earth was much older than had been previously assumed – to a fascinated wider public. Similarly, when the great nineteenth-century Scottish physicist James Clerk Maxwell wrote his heavy-duty *Theory of Heat*, even as lowly a publication as *The Ironmonger* was able to recommend the book to its readers, noting that 'the language throughout is simple and the conclusions striking'.

Charles Lyell
PRINCIPLES OF GEOLOGY,
JOHN MURRAY, 3 VOLS.,
1830–3

Geological map of South East England: one of the coloured plates from volume III.

In modern times, while the majority of scientist-to-scientist communication is in the form of emails, papers and press releases, the book remains a significant format for communication of science to the wider world. In that sense, science books have transformed from being a vehicle for insider communication between the cognoscenti to something for all of us to appreciate better just what science is doing and how it affects our lives.

A standard cover

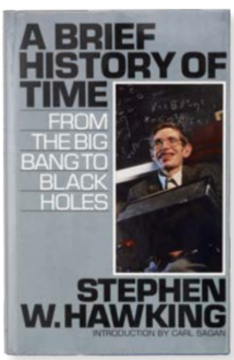
The move to wider science communication has paralleled a change in the nature of book binding. Look at any pre-Victorian title and it is liable to have a dull leather or fabric binding with little more to make it stand out than some decoration on the spine. This is because many books right up to the late nineteenth century would be produced with no covers at all – the publisher would just provide the inner leaves, and these would be taken to a bookbinder, whose job was to produce a uniform cover for the book to match the rest of the owner's library.

As more people began to read, more books were published with cheap paper or board covers, making them instantly accessible. But it is notable that, for example, when the pioneer motion photographer Eadweard Muybridge travelled to America in the 1850s, his first source of income was transporting unbound books from the London Printing and Publishing Company, to sell for binding in the United States, starting in New York and then moving out to the rapidly growing city of San Francisco.

The idea of a standard, illustrated publisher's cover is a relatively modern addition to the science book. Even as recently as the first half of the twentieth century, most science books for the public were fairly dull in appearance. It was thought that any attempt to be too popularist was simply inappropriate for the material. In fact, many scientists who did write for the public were frowned upon by their peers, who considered this an unworthy role for a true scientist. It was only really in the 1960s that the covers of popular science books would start to match the significance of their contents, and the expectations of their audience.

Though by no means the first to achieve bestseller status, a standout example of a book that was bought by a wide range of the public was *A Brief History of Time* by Stephen Hawking, published in 1988. Famously described as the title most likely to have been bought without ever being read, Hawking's book appeared on many shelves where volumes of science would not normally be seen. Crucially, it made publishers realise that the public had an appetite for popular science titles. Since its publication, the genre has flourished, with hundreds of titles published each year.

The nature of science books has changed throughout the existence of the written word. But they remain an essential marker of the progress of science and of its relevance to our society. Science and the book have gone hand in hand in forging the future.



Stephen Hawking
A BRIEF HISTORY OF TIME, BANTAM PRESS, 1988

Hawking's book, here in first edition, was hugely influential on the development of popular science: the introduction by Carl Sagan was later replaced by Hawking's own.

BOOKBINDERY WORKSHOP, EIGHTEENTH CENTURY

This engraving shows a workshop where existing books are given bindings to fit with the buyer's library.

BIRDSALLS BOOK BINDERS, 1888

Staff at work in the Northampton-based bookbinding company from the late nineteenth century.

About this book

In *Scientifica Historica* we will explore the history of science books, splitting roughly 2,500 years into five periods. The first chapter, *Ancient World*, lays the foundations, from the earliest scientific writing through to around 1200. In the second part of the book, *Renaissance in Print*, running through to the end of the eighteenth century, we see how the move from the hand-copied books of the ancient world to printed titles would transform the nature and availability of science writing. The third chapter, *Modern Classical*, covers the nineteenth century, when we see the role of science writing beginning to transform as science comes of age and journals take over as the primary vehicle for scientist-to-scientist communication, leaving science books to take on a broader audience.

The final two chapters, *Post-Classical* and *The Next Generation*, cover the twentieth and twenty-first centuries, which have seen a huge change in both science and the nature of science writing. *The Post-Classical* chapter reflects the shift in the way that science was undertaken, moving from a mostly amateur activity to a totally professional occupation, where the mathematical component of science grew exponentially, and scientific theories (sometime highly counter-intuitive) became more important than merely collecting information. The *Post-Classical* and *The Next Generation* eras are divided around 1980, when the modern, popular science book began to dominate. Up to this point, many of the key science books were written by leading scientists and tended to take a patronising approach to their audience. But with some notable exceptions, the later popular science titles have been written for a more discerning audience who expect a better quality of writing and accessibility.

Each of the five chapters covers a wide range of titles to illustrate the way that books have been used and how they have changed through the ages. Mostly these have been restricted to original pieces of writing. However, we have also explored the increasingly popular spin-off titles from television series which have indubitably become an important part of science writing in the final period covered.

Timeline of the development of the book

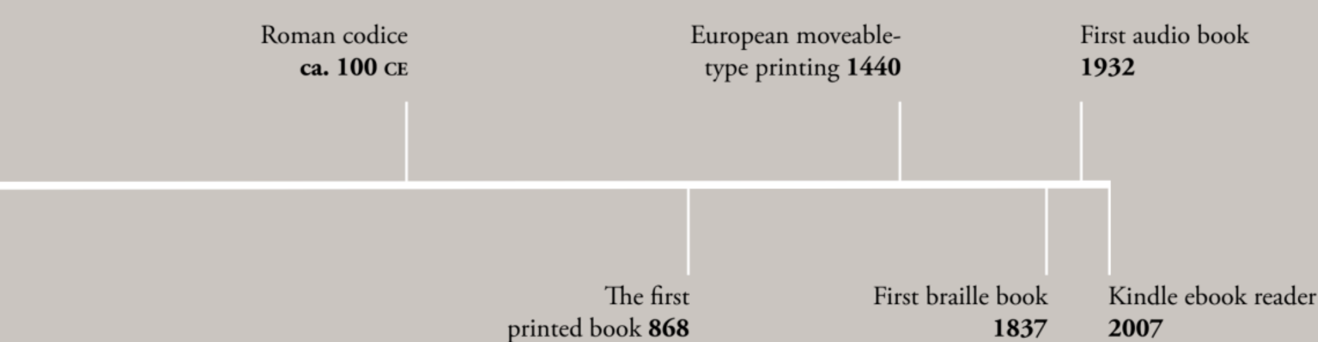
Mesopotamian clay tablet
ca. 4000 BCE

Egyptian scroll
ca. 2600 BCE

Many of these titles are from Europe and North America. This simply reflects the way that the history of modern science communication – and science itself – has developed. For a book to be significant in the history of science, from the Renaissance up to recent times, it will generally have come from these two continents. The reasons that science flourished particularly in Europe and North America from the fourteenth century onwards are disputed, but it seems to have been driven by a combination of growth of trading wealth, luck (particularly in terms of the origins of the Industrial Revolution) and a relative lack of religious suppression. In recent times, countries such as China and India have once more become big players in the sciences, but as yet this has not been reflected in science writing, perhaps in part because of the dominance of English as the universal language of science. This doesn't mean that there have not been very popular titles outside the ones covered in this book, but they have had less influence on our worldwide understanding of scientific matters. The majority of scientific papers are published in English for the same reason – although the great science communicators come from around the world.

Doom-mongers are always announcing the death of books, but science titles have maintained a healthy existence throughout each of our five periods and should do so into the future. Their nature may have changed, but they continue to be an unrivalled mechanism for linking humans to our universe. A television show or YouTube video can only ever skim the surface of a topic. A one-hour programme will typically not be able to cover the contents of a single chapter of a book. A science book enables the reader to take in so many different ways of understanding a topic, to be able to process the information at their own speed and to appreciate it in far more depth than pictures and speech alone can provide.

The science book has been a shining beacon of human progress since the invention of writing – and long may it continue to be so.



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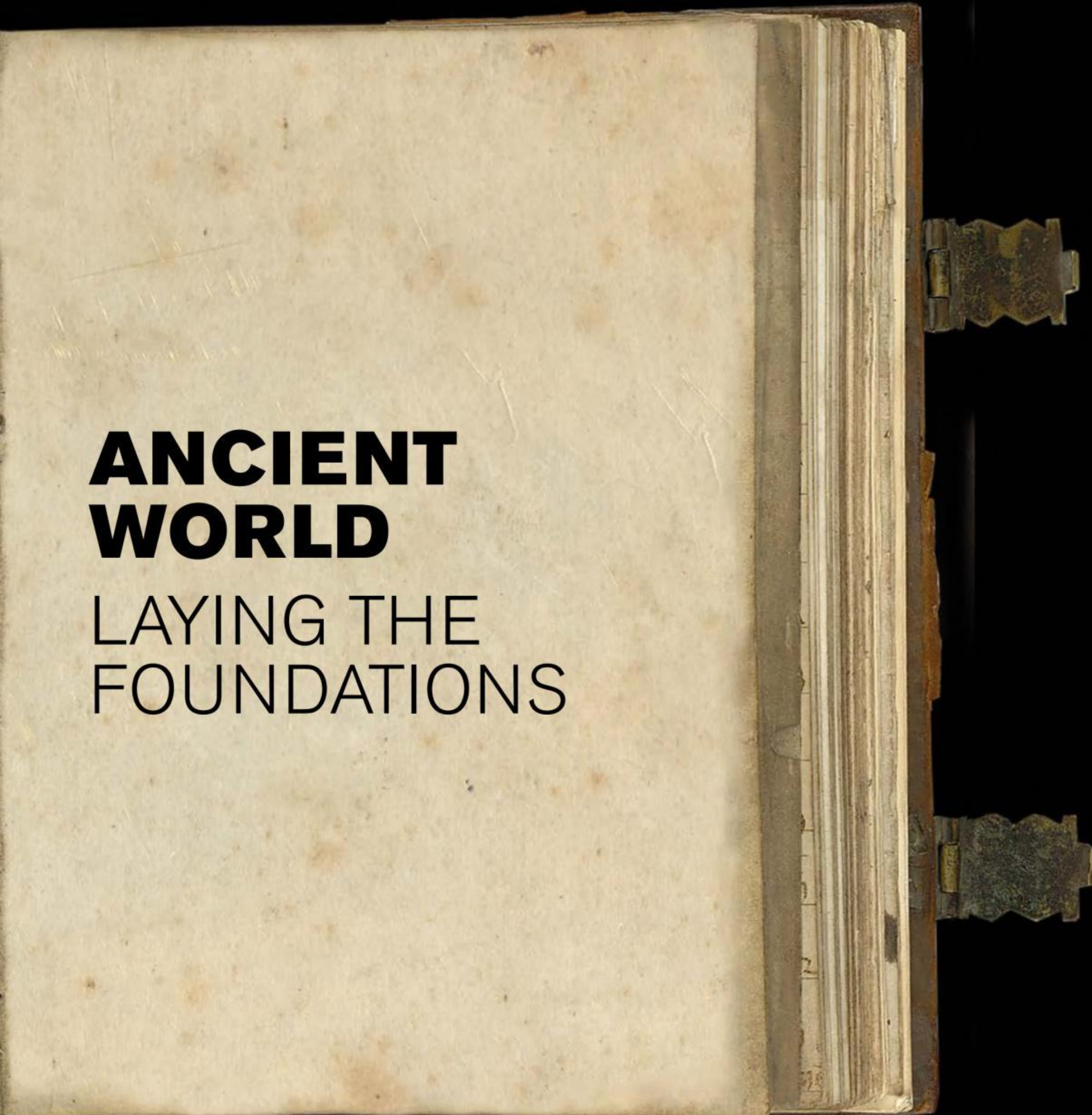


ANCIENT WORLD
LAYING THE FOUNDATIONS

For centuries there have been debates over what makes humans unique among the animals. Biologists frequently insist that there is nothing special about the species *Homo sapiens*. The term 'exceptionalism' is used in biology circles in a derogatory fashion to describe the attempt to give us a special status. And, certainly, there are few human abilities that aren't duplicated in some fashion by other animals. However, *Homo sapiens* far exceeds other species in its collective capabilities to adapt its environment for life, and the driver for this ability seems to be creativity.

This remarkable trait was present when *Homo sapiens* first evolved, over 200,000 years ago. Creativity means that humans do not simply accept things as they are and live in the present, but can think outside the moment and ask questions such as 'Why does that happen?' or 'What if I did this?' or 'What could I do to make things different?'

When early humans looked beyond scratching an existence to the full might of nature – from the Sun and the stars to the devastating power of lightning and hurricanes – the first responses to the question 'Why does that happen?' involved deities or magic. The assumption was that there had to be supernatural forces, capable of actions that were forever beyond our understanding, even if they perhaps could be placated by human rituals. However, with the establishment of static gatherings of people in the early cities, there was an opportunity to begin to take what we would now consider a more scientific approach.

First came the use of numbers (although arguably a separate discipline to science, mathematics is so tightly tied to the sciences that we will be considering it an integral part of *Scientifica Historica*). More accurately, what seems to have come first was the tally, a mechanism for counting that did not require numbers. Say, for example, a neighbour borrowed some loaves of bread and you wanted to make sure that your loaves were all replaced. Without numbers, you could put a pebble in a safe place for each loaf the neighbour took. When they handed over a replacement loaf, you would throw away a pebble corresponding to it until there were no pebbles left.

We don't know for certain how long such systems were used as they leave no permanent record, but a number of ancient bones have been discovered that appear to have tally marks on them. The Ishango bone, which is over 20,000 years old, is a baboon's leg bone, found on what is now the border of Uganda and the Democratic Republic of the Congo. It has a series of notches carved into it, which are widely interpreted as being a tally. The even older Lebombo bone, dating back over 40,000 years, also has a series of notches, though there is more dispute about their nature.

Tally markers can preserve information remarkably well, as witnessed by the fact that these bones still exist so long after they were first created. Such bones can be considered the earliest ancestor of a written record. Of a similar age to the Lebombo bone are some of the early cave paintings, which provide another form of communication that had the potential to establish traditions across a period of time.

Keeping a long-term written record may not have had significance for the makers of the bone tallies, but as cities and trade grew, the need for accounting meant that records began to be kept. At the time, these may simply have been markers of financial transactions, however the ability to keep information to a later date, and to share it, would be crucial for the development of a scientific view of the world.

FOUR VIEWS OF THE ISHANGO BONE, CA. 20,000–18,000 BCE

The series of notches on this baboon leg bone are thought to be tally marks, housed in the Royal Belgian Institute of Natural Sciences.

From tallies to writing

Over the centuries, straightforward pictures and simple notch-based tallies developed into pictograms. As the name suggests, pictograms were image-based, but unlike cave paintings they were stylised into a standard form to represent individual concepts. Some modern Chinese characters still take this form – the character for 'door' for example, looks a little like a door.

With some thought, pictograms could also be used to convey less concrete notions. For example, a series of pictograms could be used to communicate the process of putting bread into a basket. If we see a loaf of bread, then a hand, then a loaf in a basket, the message is fairly clear. (For a modern example of a message using pictograms, think of an IKEA instruction sheet.) In that basic form there is no separate symbol to display the concept of 'in' or 'into', meaning that we need an awful lot of pictograms. There would need to be, for example, a different symbol for a loaf in a basket and for a dog in a basket. But it is not hard to imagine something like an arrow being used to indicate the relationship of 'in', after which we just need the pictograms for bread (or dog) and basket with that linking arrow image. A symbol such as this arrow is known as an ideogram, as it indicates something significantly more abstract than an object or an action.

It was this kind of gradual abstraction that led to the formation of proto-writing, the precursor to modern scripts, which seems to have developed at least 6,000 years ago. One early example appearing to carry such proto-writing is a set of tablets found in Tărtăria, located in modern-day Romania, in what was once Transylvania. These are clay tablets marked with a mix of pictograms, lines and symbols. As we don't know what they mean, it's possible they were purely decorative, but they are usually assumed to be a precursor to writing, putting across information in a more structured fashion than simple decoration.

門

TRADITIONAL CHINESE 'DOOR' CHARACTER

Although very stylised, the door character bears a resemblance to a traditional door with a transom.

In some ways similar, Egyptian hieroglyphs also combined pictograms and ideograms, but did so with more distinct structures. The symbols were not restricted to words, but could also form parts of words, making it possible to build compound words from a mix of symbols, requiring a stock of fewer distinct images. We tend to think of hieroglyphics as the standard script of ancient Egypt because it is what we see on ancient tombs and wall paintings, but in fact it was developed as a formal means of writing for special settings and was too complex for everyday use. Another system, hieratic, was developed in parallel and involved far fewer, more stylised symbols – similar to Chinese characters – which could be written more quickly than hieroglyphs.

However, the Egyptians were not to the first to develop a stylised writing system. Another of the ancient powers of the region, the Sumerian civilisation (which later developed into the Babylonians), devised their cuneiform script around 3600 BCE, making it the earliest known writing system. This script originally combined stylus marks representing numbers with a pictogram-based form of writing. A millennium later, it had become more stylised, with all characters made up of combinations of wedge-shaped marks produced on clay tablets using a stylus: this was the origin of the words 'style' and 'stylised'.

The European alphabet has a Greek name (alpha and beta are the first two letters of the Greek alphabet), but a more complex background. It seems to have originally derived from the proto-Canaanite abjad. An abjad is like an alphabet but without vowels, which are implied or shown by accent markers – both Arabic and Hebrew use modern abjads. The proto-Canaanite abjad was in use in parts of the Middle East from around 3,500 years ago. Used by the Phoenicians, it was the source of both Greek and Aramaic letters. Greek, though, appears to have been the first true alphabet, with vowels represented by separate characters, originating about 1000 BCE.

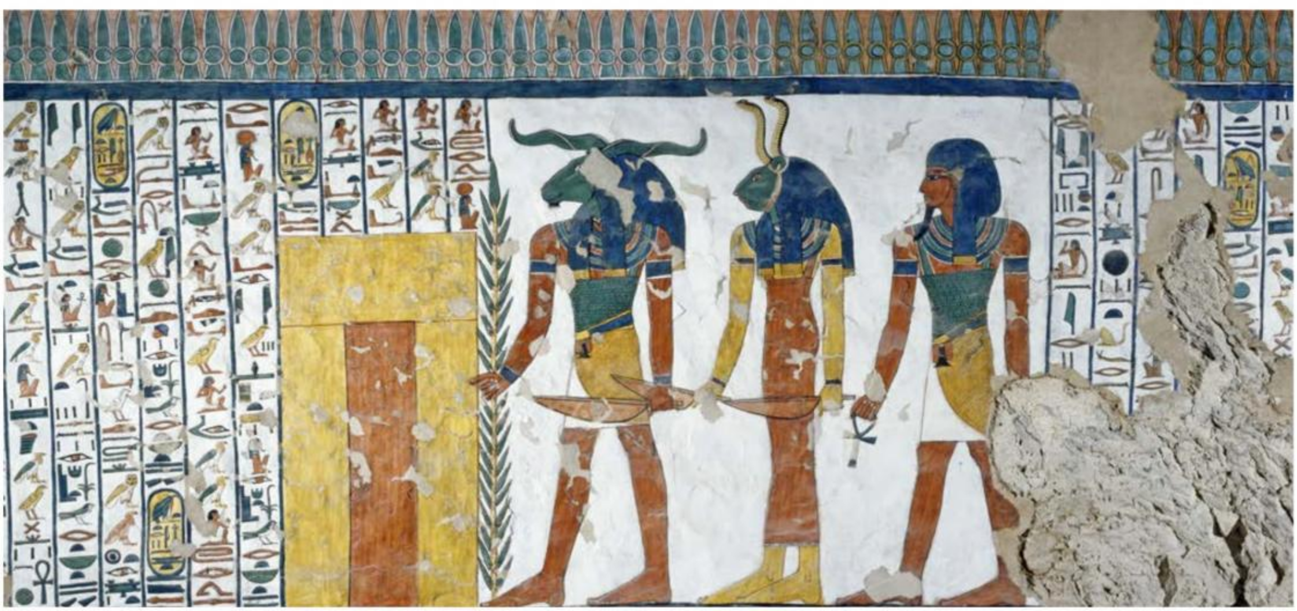
The alphabet used in most Western countries is often called Latin or Roman; our upper-case letters are pretty much the same as those used for carving inscriptions by the Romans – their equivalent of Egyptian hieroglyphs. (The character set is not identical, as the Romans didn't have separate letters J and U, using I and V, which were easier to carve.) Like the Egyptians with hieratic, the Romans also had an everyday set of characters, known as Roman cursive, which morphed into our lower-case letters. For the Romans these were two totally separate styles which would not be mixed, but after the fall of the Roman Empire various options of combining them were tried, such as using capitals to emphasise new sections of writing, or to pick out nouns (as is still the case in modern German).

When first introduced, though, these letters would not have been called upper case and lower case. This terminology dates from the moveable type printing era, when pages of type were set using individual metal letters, bound together to form a page (see page 14). The two kinds of character were kept in separate boxes, with the basic letters (technically referred to as minuscule) in a lower case and the fancier capital versions in a higher 'upper case'.

Why is the development of writing so important? Because without writing, it is hard to see how a scientific tradition could be built. Stories of the gods at work in the heavens or throwing lightning do not need precision. They benefit, if anything, from the

FRESCO FROM THE TOMB OF NEFERTARI, TWELFTH CENTURY BCE

The burial chamber of Nefertari in the Valley of the Queens, Luxor, features excerpts and scenes from several chapters of the *Book of the Dead*. Here, three genii guard the Second Gate of the Kingdom of Osiris.



GREEK STELE, 163/4 CE

Stelae were stone slabs with inscriptions often used as grave or boundary markers. This stele records the eponymous archon (chief magistrate), Philisteides, and the kosmetes (military trainer of young men), Claudius, at the top, beneath is a list of trainers and trainees, as well as a variety of festivals and events.

THE LYON TABLET, 48 CE

The Latin text reproduces emperor Caludius's speech in favour of some leading citizens from Gaul being allowed to sit on the Senate.

embellishment and modification that inevitably accompanies an oral tradition. As verbal stories are passed from person to person, less and less of the original remains. But for scientific ideas to be tested and built on, nothing else could match the unchanging foundation provided by the written word.

The permanence of clay

As we have seen, the earliest written records were not books, but pieces of clay. Working on a far greater scale than the Tărtăria tablets, the Sumerians and the later Babylonians of Mesopotamia produced vast quantities of clay tablets, originally for accounting purposes. These blocks of clay could be easily marked using the stylus-end 'cuneiform' markers which were first used to represent numbers, but soon also used in combination to form the stylised characters derived from earlier pictograms.

If the markings were just a temporary note, the clay could be moistened, wiped and reused – but by baking the clay tablet in an oven it became a permanent store of the information recorded on it. It would be an exaggeration to describe these tablets as scientific, but some did give guidance on, for example, practical mathematics. They did not contain mathematical proofs, but there were examples of Pythagorean triples – collections of numbers such as 3, 4, 5 and 8, 15, 17, which reflect the relationship of lengths of the sides of a right-angled triangle that would later be proved in Pythagoras's theorem.

ASSYRIAN CLAY TABLETS

An accounting tablet (left) from Anatolia, ca. twentieth – nineteenth century BCE, and an astronomical tablet (right) from Nineveh, whose date and origin is debated.

Unknown
EDWIN SMITH PAPYRUS,
CA. 1600 BCE

The 4.7 metre (15 foot)-long scroll may have originated in Thebes and was bought by American archeologist Edwin Smith in 1862.

Remarkably, these numerical records date back around 3,800 years. Such tablets also began to be used to record what we would now think of as scientific data, specifically astronomical observations. This information provided the basis both for calendars and for astrological use – there is no evidence at this stage of the application of scientific theories – yet like the invention of writing itself, such collections of data were necessary precursors to the scientific approach.

Similar practical examples (rather than work that had a detailed theoretical basis) began to crop up in the Egyptian civilisation. Practical geometry was an essential for both the measurement of fields and the construction of buildings, again bringing in the guidance of Pythagorean triples. And medicine took the first steps in its long journey from magic to science. The oldest-known example of a written document giving medical guidance with some resemblance of a scientific approach – although not long enough to be considered a true book – is the Egyptian Edwin Smith papyrus, which is around 3,600 years old. It takes the form of a papyrus scroll around 4.7 metres (15 feet) in length, and deals primarily with injuries and surgical techniques, though it does also include a number of magic spells intended for medical purposes.

China was the next of the great civilisations to venture into proto-scientific fields, with mathematical documents dating back at least 3,000 years. It would be relatively late coming to physical or biological sciences, however, as there were philosophical barriers in the way of accepting a purely mechanistic view of the world. India, too, would produce