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Is science universal? *

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Ernest Renan wrote in 1848 that "science being one of the true elements of humanity, it is independent of any social form and eternal, much as human nature" (1). We may have lost his 19th-century belief in the power of science but many of the underlying assumptions have survived.
For instance, the universality of science is still a widely held belief. In a world in which social systems, spiritual values and aesthetic forms are in constant upheaval, it would be reassuring if science offered a landmark from which to take bearings in a sea of uncertainty. In 1945 Frédéric Joliot-Curie, apparently still convinced of the merits of science, said: "Pure scientific knowledge should bring peace to our soul, dispelling superstition and invisible fears, and giving us a clearer awareness of our position in the universe. It is perhaps one of science's greatest merits, as the fundamental, perhaps the only, factor unifying the thoughts of human beings all over the globe" (2).

Few would dispute the diversity of other cultural components (political organisation, family ties, founding myths, social mores, religion and beliefs, art and literature) that belong to different cultures, in the ethnological sense of cultures. But many argue that science is founded on objective, verifiable, reproducible knowledge. If Pythagoras's theorem, Archimedes's principle, Kepler's laws or Einstein's theory of relativity are valid here and now, are they not by their nature valid everywhere and for all time? However convincing these examples may seem, they all belong to western European culture, as their very naming show, and are rooted in Greek, Jewish and Christian traditions. It would be difficult to find examples that draw on Tibetan, Maori or Aztec traditions to support a claim of universality.
In the 19th century, it was presumed that only western science existed, automatically making it universal. Historians of science have since demonstrated the importance and diversity of other scientific traditions, particularly in India and China, and in Muslim countries. Yet even such recognition often treats these other traditions as tributaries flowing into the great river of universal science. This approach acknowledges that the West neglected their contribution for too long yet still underplays their historical importance (3). As for the unity of science, so actively promoted until the start of the 20th century, it has gradually disappeared with the specialisation of scientific endeavour both in the way work is organised and methods of enquiry.

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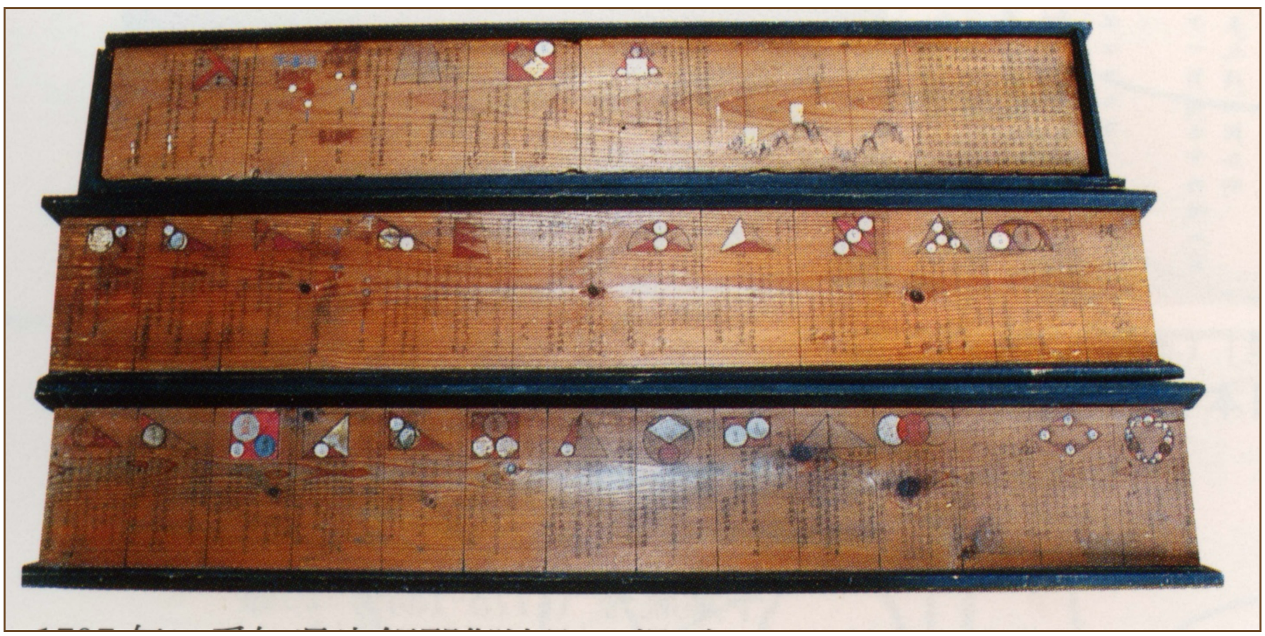
* This text is an English adaptation of chapter 12, « La science est-elle universelle ? », in Jean-Marc Lévy-Leblond, *La vitesse de l'ombre (Aux limites de la science)*, Seuil, 2006.

For clarity I shall restrict myself to mathematics and natural science, even though the task of countering claims to the universality of science would be much easier if we considered social and human sciences.

Wasan maths

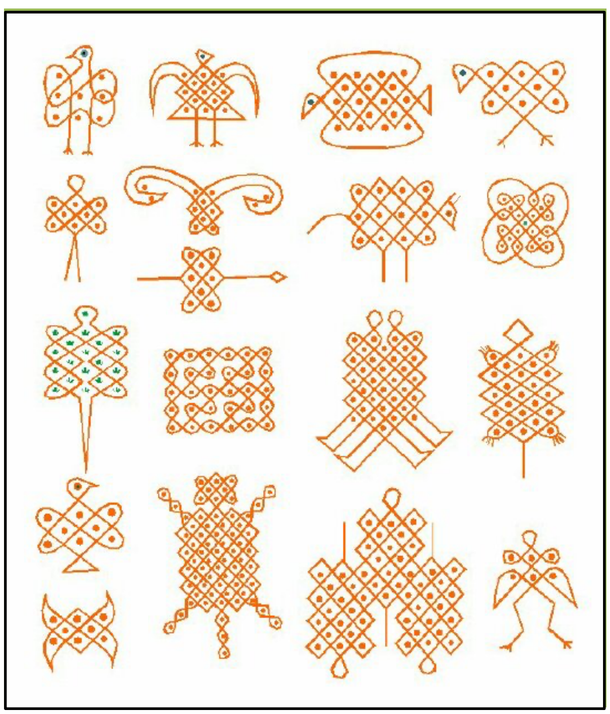
Visitors to Japan's Shintoist or Buddhist temples may have noticed many tablets hung as offerings to local divinities and painted with seascapes, views of Mount Fuji, sacred horses or just calligraphy. Sometimes they include complex geometrical figures, with intriguing arrangements of circles, triangles and ellipses. The text accompanying these contains a mathematical theorem, often without a proof (4). The *sangaku* (tablets) date to the 17th-19th century Edo era, during which Japan deliberately cut itself off from outside influences, particularly the West. At this time, it developed some of its most original cultural creations: kabuki theatre, haiku poems and *wasan*, a special form of mathematics, of which *sangaku* are the public expression.



Un exemple de sangaku

Wasan maths concentrates on the metric or projective properties of flat and three-dimensional figures, and on certain aspects of whole numbers. *Wasan* is not a corpus of doctrine characterised by self-evident principles, as has been western maths since Euclid, but rather a collection of results, some of which may be extremely complex. Some *sangaku* expound theorems which precede, by one or two centuries, their western equivalent (5). But it is the presentation and purpose of the *sangaku* rather than their mathematical content that intrigues. Who would expect to find a religious offering representing Pascal's triangle at Lourdes? The *sangaku* are works of art, meticulously painted, often the work

of enlightened amateurs. They reflect an idea of maths that gives priority to aesthetic issues. An offering to the divine should be beautiful, whether it takes the form of a magnificent horse or an elegant geometrical result.
Of course, the purpose of *sangaku* was not exclusively aesthetic. They also played a part in the formation and subsequent rivalry of schools of mathematics. They are almost a sport, the expression of challenges between masters of mathematics or gifted amateurs (5). Unlike western maths, they cannot be fully understood in relation to technical applications nor as part of a philosophical construct. Nor, despite the religious context, are they part of some mystical explanation of the world, as is the case with numerology in the Jewish kabbalah.
In querying the universality of science there is no question of rehabilitating, even implicitly or unconsciously, the idea that western civilisation was inherently superior and therefore developed this form of knowledge alone. On the contrary, we must emphasise that all cultures have the intellectual equipment needed to develop scientific understanding. Long before societies based on trade and industry existed, humanity needed proto-scientific skills. To make the best use of natural resources, hunter-gatherers, livestock herders and crop growers all needed effective means of classifying animal and plant species, backed by detailed understanding of their behaviour and properties: the beginnings of botany and zoology. To find their way and forecast the weather our forebears had to understand the sky and the motions of celestial bodies, laying the foundations of astronomy. To manage their flocks and harvests, they needed to count and calculate, using primitive arithmetic. The decoration of dwellings and a love of ornamentation encouraged the development of complex graphic designs, foreshadowing geometry.



Dessins de sable Tshokwe (Angola)

Games demanded sophisticated powers of reasoning and logic. Family ties were also sometimes governed by complex rules, which might have led to algebra. Skill in producing wooden, metal or pottery tools and containers required an accurate understanding of materials, surely the beginnings of physics.

Number systems

Despite this universal basis, the results are astonishingly varied. Consider number systems (6). The base 10, on which modern systems are founded, probably corresponds to our fingers. But it is far from being widespread. The Yuki Native Americans of California use a base eight system (a precursor of our computer bytes, with their eight binary digits), counting not on but between their fingers. The Babylonians used two bases, 12 and 60. Our approach to aggregating numbers, as in "twenty-five" (20 + 5), is not inevitable, either. In Chol, a Maya language in the Chiapas region of Mexico, people count in units of 20, working towards the next unit, so 25 would be expressed as "five towards two times 20".
At a more complex level many languages have words for classifying numbers that provide qualitative information about the objects being counted. The word designating the number differs (thanks to affixes, or additions) depending on the category to which it refers. Maori has two categories, depending on whether people are being counted. Some languages have several dozen such classifiers; the Bouyei language of southern China has 55, for such classes as debts, loans and accounting; mountains, walls and districts; opium pipes, whistles; paddy fields; garments and blankets; medical preparations; spirits, people, workers, robbers; girls and young women; roads, rivers, ropes; children, small coins and pebbles; paired objects.
Paternalistic 19th-century western ethnologists thought such systems were a throwback to a primitive system of thought that had not yet achieved a full abstraction of numbers, unrelated to whatever was being counted. Yet such systems of classification corresponded to distinctions of considerable value to their way of organising society. Furthermore, the persistence of such a rather elaborated number system in the language of as an advanced technoscientific society as Japan, is sufficient proof that it cannot be relegated to the darkness of archaism.

What is science?

The word science has several meanings, illustrated by the definitions in our dictionaries. If we compare astronomy as studied by Babylonian priests for purposes of prophecy with the geometry of the ancient Greeks, more philosophical than practical in its concerns, it is clear we are dealing with different activities. They have little in common in the manner in which they organised the acquisition of new learning or the social use to which it was put, so we refer to these forms of knowledge as proto-sciences. Though effective and

connected to an external reality, they were intrinsically linked to a technical, economical, mythical or leisure activity. Science should only refer to abstract forms of knowledge, detached, at least to a large extent, from their practical origin and use.
The mathematics of the ancient Greeks qualifies as a basic example of science. The ancient Egyptians had methods for surveying and calculating the area of plots of various shapes. But these empirical methods, strictly utilitarian in purpose, were sometimes accurate, sometimes approximate and sometimes totally erroneous. They were never proven. The Greeks, though, developed a body of doctrine which transcended any practical application and was founded on the essential concept of proof, culminating in Euclid's Elements. It is this mathematics that we still recognise today as archetypal science.
But the Greek miracle was no irreversible breakthrough, putting western civilisation on course for its subsequent scientific development. The Romans showed little interest in this abstract learning and made only a meagre contribution to it, in contrast to all they borrowed from Greek literature and philosophy.
Only with the rise of Arab-Islamic civilisation did science become a key concern again. From the eighth century on the Arabs, far from restricting themselves to passing on the science of ancient Greece and India, gave new impetus to a wide range of disciplines (7). From Samarkand to Zaragoza most new discoveries in maths, optics, astronomy, geography and medicine were recorded in Arabic. Mathematicians such as Al-Khwarizmi (9th century), Omar Khayyam (the 11th century poet) or physicists including Ibn al-Haytham (10th-11th century) were several centuries ahead of their European successors, especially in algebra and optics.

Le traité d'algèbre de Omar Khayyam (1070)

The same is true of Chinese science, which developed independently until Europeans (particularly Jesuit priests) arrived in the 17th century. It was different both in topics investigated and the manner of its organisation.

Why Europe?

What may be termed modern science emerged in Europe at the beginning of the 17th century. It was original and closely linked to its context. The emancipation and increasing power of urban craftworkers endowed manual work and practical activities with new dignity and status. Galileo's celebrated text on the Venice arsenal (8) is a fine illustration of how technical issues helped science establish itself. Technology suggested topics for research (such as the principles behind the operation of simple machines) and revolutionary means of investigation, with active experimentation taking over from passive observation.

Galileo Galilei, The Discourses and Mathematical Demonstrations Relating to Two New Sciences, 1638

At the same time the ideological and religious context provided valuable metaphorical representations of learning. The idea of nature as a "great book" (Galileo) and the associated idea, so strange at first, of "laws of nature" originated in the political and religious organisation of society. The large-scale practical application of theoretical knowledge (illustrated by statements such as Francis Bacon's "knowledge is power" or René Descartes' injunction "to become the masters and owners of nature") was directly linked to the mechanisation of nascent capitalism and its subsequent industrialisation.

But it would be a mistake to treat episodes in the development of science as successive phases of a steady, continuous advance. Each period of scientific growth, however intense or varied, usually ended before the next picked up the thread elsewhere. The breakthroughs and disparities in the process were far more striking than the continuity. Nor did this make the process less productive. In his monumental tribute to Chinese science (9) Joseph Needham (1900-1990) sought to demonstrate its role as a precursor and its contribution to western science. Whatever his intentions, this approach seems too restrictive. Science in China was sufficiently different, epistemologically and sociologically, for it to be impossible to consider it as just a tributary of the great river of "science". The same applies to Arab-Islamic science. Western science owes much to both cultures, but that is no justification for denying their specific characteristics.

Several sciences?

As a matter of fact, we should recognize that there are several "sciences" (10). Not only are there are differing scientific disciplines, but the techniques for producing, expressing and applying knowledge vary radically in time and place. One of the best demonstrations of the plurality of scientific achievement is the fact that it is limited in time. Each period of learning, in ancient Greece, China, or the Islamic world, ended in decline, for specific reasons related to the society in which it was rooted. There is a parallel between the great moments of scientific endeavour and the lost cities of the past: both fell into ruin and were abandoned, opening the way for others to pillage freely, reusing materials for structures and purposes often different from their original design.

For conclusive proof that the universality of science is a misconception, we need only look at civilisations that developed and prospered despite having no science of their own. The most obvious example is Rome. Most people can name several ancient Greek scholars such as Pythagoras, Euclid and Archimedes. But when asked about their Roman counterparts our minds remain blank. Pliny the elder was an eminent naturalist, Vitruvius a celebrated architect, and there was the agronomist Columella, but that is about as far as it goes. The Romans, who borrowed so much from the conquered Greeks in philosophy, poetry, mythology, sculpture and architecture made no attempt to acquire their scientific heritage. The Roman empire nevertheless prospered and dominated western Europe and the Mediterranean for centuries.

One of the most exciting questions that science is currently addressing is the existence of other forms of intelligent life outside the solar system. Let us imagine a living, thinking species quite unlike ourselves. Under biochemical conditions similar to those found on Earth, it might be an invertebrate living in the ocean depths of its home planet. It is conceivable that evolution might result in such beings developing the ability to communicate and some form of collective organisation, leading to an active understanding of their habitat — a civilisation. After all the cephalopods found on Earth (squid, octopus) are quite intelligent.

The senses deployed by such beings would be organised differently from ours. In the gloomy depths sight would be secondary, and touch, which would have evolved into a wide range of finely tuned chemotactile sensations, would come first. This would affect the means of communication and overall world view. Such beings would acquire knowledge in a completely different order from us. In their undivided fluid world, the mathematics of continuity would precede the arithmetic of the discrete and separate.

Chemistry would come well before physics, and fluid mechanics would precede its solid counterpart. Astronomy would develop very late and would demand complex technology to evade the depths of the abysses.

Their language, whatever its physical medium, would provide scientific learning with metaphorical images, mental associations and epistemic structures so different from ours that genuine exchange with such a civilisation, always assuming it was materially possible, would run into formidable problems of translation. There is no certainty that mutual understanding would be possible.

Back on Planet Earth there is no escaping the fact that science *has been* universalised. Physicists work on the same subjects, with the same (particle) accelerators in Geneva and Chicago. Biologists perform the same experiments in Tokyo as they do in Paris, and astronomers use the same telescopes in Chile and Hawaii. But such worldwide endeavour is no more than the triumph of a certain type of western science, which started in Europe before moving to the United States.

Such physical domination is no guarantee of permanence. It is possible that western, or global, science is as mortal as its predecessors. After four centuries of spectacular growth, it may already be withering (11). The effectiveness that enabled it to achieve the objectives set by Bacon and Descartes is now turning against it. The demands of society, or rather commerce, have subjected scientific development to the constraints of productivity and short-term profit. There is increasingly less scope for speculative basic research without any guarantee of immediate success. The happy combination of speculation and action that characterised western science for two centuries was, after all, surprising and historically special and is falling apart.

But if other places and times have used what we currently consider to be scientific knowledge for markedly different intellectual and material purposes, it would make sense to leave open the question of the role it might play in tomorrow's civilisation(s).

Footnotes

(1) Ernest Renan, *L'avenir de la science*, Calmann-Levy, Paris, 1890.

(2) Frédéric Joliot-Curie, from a speech on 12 November 1945, three months after the nuclear bombings on Hiroshima and Nagasaki.

(3) See Amy Dahan, "La tension nécessaire : les savoirs scientifiques entre universalité et localité", *Alliage*, n° 45-46, Nice, winter 2000.

(4) T Rothman and H Fukagawa, "Géométrie et Religion au Japon", *Pour la science*, no 249, Paris, July 1998; H Fukagawa and D Pedoe, *Japanese Temple Geometry*, Charles Babbage Research Foundation, Winnipeg, 1989.

(5) See Annick Horiuchi, "Les mathématiques peuvent-elles n'être que pur divertissement ? Une analyse des tablettes votives de mathématiques à l'époque d'Edo", *Extrême-Orient, Extrême-Occident*, vol. 20, Presses Universitaires de Vincennes, Paris, 1998.

(6) The examples quoted here are taken from the work by Marcia Ascher,

Ethnomathematics: A Multicultural View of Mathematical Ideas, Brooks/Cole, 1991 and *Mathematics Elsewhere: An Exploration of Ideas across Cultures*, Princeton University Press, 2002). French translation : *Mathématiques d'ailleurs (nombres, formes et jeux dans les sociétés traditionnelles),* Seuil, Paris, 1998. The postscript by Karine Chemla and Serge Pahault, "Écritures et relectures mathématiques", is a most valuable theoretical insight into the cultural aspects of mathematics and the issue of its universality.

(7) See Ahmed Djebbar, *Histoire de la science arabe*, Seuil (Points-Sciences), Paris, 2001. Also, Roshdi Rashed, editor, *Histoire des sciences arabes*, Seuil, Paris, 1997.

(8) Galileo Galilei, *Discorsi intorno a due nuove scienze*, 1636.

(9) Joseph Needham, editor, *Science and Civilisation in China*, Cambridge University Press, 1959.

(10) For a more detailed analysis, see Jean-Marc Lévy-Leblond, "On the Plurality of (Theoretical) Worlds", in Lena Soler & al. eds, *Science as it Could Have Been (Discussing the Contingency/Inevitability Problem)*, Pittsburgh U. Press, 2015.

(11) See Jean-Marc Lévy-Leblond, "Science in the XXIth Century", *Philosophy World Democracy* (2021), https://www.philosophy-world-democracy.org/articles-1/science-in-the-twenty-first-century