NON-WESTERN SCIENCE—MINING CIVILIZATIONAL KNOWLEDGE

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Contents

Summary

Recent Asian histories of science indicate considerable areas of mutual influence across civilizations, for example between Europe and South Asia. When the classical age collapsed in the fifth century C.E., European and South Asian contacts continued through Arab intermediaries. Arab transmissions to Europe from Asia covered astronomy and mathematics to medicine, the transmitted arithmetic facilitating the Renaissance.

Some of these transmissions continued during the Renaissance, as in botany and later as in Indian procedures adopted in nineteenth-century plastic surgery. But these transmissions did not exhaust stores of useful Asian knowledge. Recently, there has been an increase in transfers in medicine to psychology to mathematics. Some illustrative examples and possibilities are:

- In medicine, starting with the first tranquilizer Reserpine, several Ayurvedic remedies have entered the Western system.
- South Asia's different traditions in describing mental processes have been shown to have some parallels in theories from Freud to Maslow. Different offshoots of meditation techniques have been used to show a variety of physical and mental benefits.
- Some arithmetic methods that did not get transmitted through the Arabs have been discovered and found to be very effective.
- South Asian philosophical systems have a wide variety of positions in ontology and epistemology. These, combined with the vast store of South Asian metaphors, could nudge the imagination at times of paradigmatic breaks. Thus, Varela has applied some Asian epistemological approaches to problems in cognitive science, artificial intelligence, and biological evolution.
- Conventional two-fold logic is problematic in areas like quantum physics but could be helped by the manifold logics of South Asia. In information technology and biotechnology, aspects of the body and the mind are cloned. They pose new ethical problems that have echoes in South Asian philosophies and so could provide useful insights.

Present-day science is the result of vigorous amalgams in Europe. Now, a new, more global, construct is possible.

1. Civilizational Knowledge

Traffic of formal ideas about physical reality has historically occurred across different civilizations. Such traffic began at the formation of the European tradition itself with the Greeks having interactions with South Asian and East Asian civilizations. These interactions continued during subsequent centuries leading up to the Renaissance and the scientific revolution. In the period immediately before the Renaissance, Arabs were significant intermediaries in this cross-regional knowledge traffic.

Recently, that is, since Asian countries got their independence in the 1940s, there have emerged significant histories of science that describe, for example, the scientific heritage of West, South, and East Asian countries **(see *Global Science*)**. These have led to rethinking what were considered nodal points in the trajectory of science, raising the distinct possibility that there could still be elements useful to science in non-Western civilizational knowledge. I will consider—out of familiarity—the case only of South Asia. The same general points would apply to the civilizations of West and East Asia. (In this article, the terms South Asia and India are used interchangeably to refer to the cultural area now occupied by the countries of Pakistan, Nepal, India, Bangladesh, and Sri Lanka.)

2. The European Classical Period

A detailed study of the historical growth of the European and the South Asian scientific traditions indicates considerable areas of overlap and mutual influence from very early times. Thus, for example, if the scientific and cultural tradition of the Renaissance looked back to Greek sources for new inspiration, they were in fact looking to Greek sources partly influenced by the South Asians.

Generally speaking, South Asia had been outside the common world of shared ideas and values out of which pre-classical Greece operated. The East enters into the Western psyche after the wars with the Persian Empire, and the myth of a division into Orient and Occident is born, as is the concept of Europe. This created the conditions for a large-scale traffic of culture and ideas between Greece and Asia.

These repeated interactions between the two regions probably resulted in traffic in some key concepts from South Asia to Greece. For example, the five-element concept of *panchabhuta-prthvi*, *ap*, *tejas*, *vayu*, and *akasa*—earth, water, heat (fire), air, and emptiness (ether)—have their later counterpart in Empedocles, who believed that matter had four elements: earth, water, air, and fire. A similar situation occurs in atomic theories, "an atomic theory being taught by Pakudha Katyayana, an older contemporary of the Buddha, and was therefore earlier than that of Democritus." The Buddhists also had sophisticated discussions before Heraclitus did on the concept of everything being in a state of flux.

The Buddhists and others taught a doctrine of the mean several centuries earlier than Aristotle (340 B.C.E.). In medicine, "the Hippocratic treatise *On Breath* deals in much the same way with the pneumatic system as we find in the Indian concept of *Vayu* or *Prana*. In his *Timaeos*, Plato discussed pathology in a similar way to the doctrine of *tridosa*."

The above illustrative examples of probable or suggested traffic of concepts from East to West at this early date should not distract from transmissions in the opposite direction. A well-known example from Greece to South Asia is ideas on geometry and astronomy. The ancient world had much cross-flow of intellectual traffic.

When the classical age collapsed in the fifth century C.E., European and South Asian contacts continued in the Middle Ages through Arab intermediaries. The Arabs performed the functions earlier performed by the Persian, Alexandrian, and Greek empires, bringing together the ideas of East and West.

3. Arab and Other Transmissions

Arab transmissions covered fields from astronomy and mathematics to medicine.

The elements of Indian astronomy incorporated into Arabic astronomy were the Indian planetary system, the sine tables, the table of solar declinations, the use of the Indian city Ujjayini as the zero meridian (which was named *Arin*), the beginning of the *Kaliyuga* on Feb 17–18, 3102 B.C.E., which was designated the "Era of the Flood," spherical trigonometry, ascensional difference, parallax calculation, and their use in, for example, solar eclipse calculations.

Mathematics was called by the Arabs *hindsat*, “the Indian art,” illustrating their own perceptions of the order of things. Among Indian influences, through the Arabs, on mathematics in Europe were a) the spread of place value numerals and the associated modes of calculations; b) Indian trigonometry, especially the sine function and its uses; c) solutions to differential equations, with particular emphasis on indeterminate equations, and the “rule of three,” *rashikat* (“if *p* yields *f*, what will *i* yield?”).

Relatively rudimentary approaches in the applications of trigonometry were found in Hipparchus (ca. 150 B.C.E.), Menelaus (ca. 100 C.E.), and Ptolemy (ca. 150 C.E.). But trigonometry changed its character from the time of Aryabhatiya 1 (500 C.E.) and began to resemble the modern subject. It was then transmitted onwards by the Arabs and was described in Europe in detail in 1464 in a work by Regiomontanus, *De triangulis omni modis*.

The method of extracting a square root was transmitted from South Asia around the middle of the eighth century to the Arab region. A similar approach is found at least six centuries later in European works such as those of Peurbach (1423–1461), Chuquet (1484), La Roche (1520), Gemma Frisius (1540), and Cataneo (1546). In Arabic and Latin texts, the Indian rule of three is adopted along with its name and appears later in the sixteenth century.

The modern methods of division appear in the rules laid down by such writers as Mahavira, Sridhara, and Aryabhatiya I, but were probably known earlier, as indicated by other writings and other internal evidence. These were transmitted from Arabs to Europe. A method of multiplication first stated in Europe in Pacioli’s *Suma* as “more fantastic and ingenious than the others” had also traveled through the Arab countries from the subcontinent. It is described as the method of multiplication in which the numbers stand in the same place, in contradistinction to the approach where “the multiplier moves from one place to another.”

The gelosia method—known also as the method of the quadrilateral, cell, or square—first appeared in Ganesa’s commentary on the *Lilavati* and in other Indian works. Pacioli (ca. 1464 C.E.) and Tartaglia (ca. 1545) later used this same method.

In algebra, Indians pioneered on several fronts. Present-day algebra immediately evokes the usage of symbols to stand for unknown quantities. An unknown term was known as *yavat tavat*, shortened to the algebraic symbol *ya*. In other works, Sanskrit letters that stand for abbreviations of names of different colors are used for the unknowns.

The arithmetic that was transmitted played an important function in the Renaissance. It helped facilitate the increasing trade and commerce. Pisano’s *Liber abaci* is considered the beginning of the Renaissance in arithmetic. The new arithmetic based on the South Asian decimal place value system and transmitted through Arab intermediaries was called “algorism.” In due course, Asian methodology replaced the abacus in calculations used in “commerce, government and technology.” The sudden appearance of many works on the topic from the sixteenth century onwards indicates that algorism became one of the key facilitators of the Renaissance. Some of these books were Cardano’s

Practica arithmatice et mensurandi singularis (1501), Boissiere's *L'art d'arythmetique* (1554), Jacob Koebel's *Rechenbiechlin* (1514), and Robert Recorde's *The grounde of artes, techying the worke and practise of arithmetike,* which ran to seventeen printings before 1601.

The pre-Christian classical medical texts *Susruta Samhita* and *Charaka Samhita* had been also translated into Arabic. The transmission westward continued when al-Razi or Rhazes (865–925 C.E.) produced a comprehensive book incorporating Indian medical knowledge. This book, *Liber continens* (*kitab-al-hawi*), was translated into Latin by Moses Farachi in the thirteenth century and became the standard medical work in the Middle Ages.

Alchemy was an important transmission in the development of chemistry. Yet, Greek alchemical texts did not show an interest in the pharmaceutical chemistry, a marked contrast with China and India. In the *Atharva Veda* (eighth century B.C.E.) there are references to the use of gold for preserving life. The transmutation to gold of base metals is discussed in the Buddhist texts of the second century C.E. to the fifth century C.E. by concoctions using vegetables and minerals.

In the West, iatrochemists, especially Paracelsus, the key figure in the beginning of the modern chemical tradition, was of the view that the human body was a chemical system of mercury, sulfur, and salt. Alchemists already knew sulfur and mercury; Paracelsus introduced salt. This theory of triaprima as constituting the body was contrary to the four-humoral theory of the Greeks advocated by the authority of Galen (131–201 C.E.) and Avicenna (980–1037 C.E.). An Indian alchemist by the name of Ramadevar taught a salt-based alchemy in Saudi Arabia in the twelfth century.

Garcia D'Orta's classic *Cloquios dos simples e drogas da India* was published in 1563 and had a major impact on European medicine. D'Orta can also be considered a progenitor of the scientific revolution, not only for this work in medicine and botany but also because he never considered the physicians of Greek antiquity as the final authority. He wrote "the testimony of an eye-witness is worth more than that of all the physicians, and all the fathers of medicine who wrote on false information." Just as Vesalius corrected Galen through his dissections, D'Orta corrected other ancient authors including Dioscorides. The book had a special influence during the Renaissance because it was taken up by Charles de l'Ecluse, a Dutch physician who translated the work into Latin from its original Portuguese. The book became very popular, running to five editions in a few years.

C.R. Boxer, a modern historian of the Portuguese empire, describes D'Orta's influence as follows: "From the perusal of Garcia d'Orta's *Coloquios*, it seems obvious that the Indian physicians were on the whole decidedly more advanced than their European colleagues. It is also significant that the local Viceroys preferred Hindus as their medical attendants rather than trust themselves to the tender mercies of the European Physico-More, and this despite the promulgation of decrees condemning the practice."

The Indian side contributed more to the Portuguese than the other way round. According to the Portuguese commentator Antonio Sergio, writing in 1972, "If Garcia d'Orta had not left the European environment he would not have dared get rid of the superstition of the authorities, and turn from the attitude of the Homo credulous to the attitude of the critical spirit." Another culture, another set of assumptions, partly helped free Garcia D'Orta.

In medicine, the work of Susruta had laid the foundation for the art of surgery in the pre-Christian era. Susruta emphasized observation and dissection, much before Vesalius. He described many instruments like those used in modern surgery, several kinds of sutures and needles, and classified operations into types. The operations described included those on hydrocele, dropsy, fistula, abscess, tooth extraction, and the removal of stones and foreign matter. The ancient Indian surgeons were the first to practice laparotomy and lithotomy, plastic surgery, and perineal extraction of stones from the bladder. The region had considerable knowledge in dentistry including artificial teeth making. In 1194 C.E., the king Jai Chandra when beaten in battle was recognized by his false teeth. Susruta describes details of operations for the conditions of ascites, obstructions in the rectum, and for removal of a dead fetus without killing the mother, considered a very difficult procedure. A section describes plastic surgery of the nose and cataract operations on the eye.

The British at the end of the eighteenth century studied Indian surgical procedures for skin grafting to correct deformities of the face, which became "the starting point for the modern specialty of plastic surgery."

Dharmapal collected several illuminating British accounts on Indian medical practices in the eighteenth century. This included one by J.Z. Holwell, who gave a detailed report on the widespread practice of inoculation against smallpox practiced in the region. The smallpox epidemics in the nineteenth and early twentieth centuries have been attributed to the stopping of this practice before the vaccination system could become widespread.
The *Encyclopedia Britannica* lists three major innovative transformations in British agriculture in the "era of Improvement" in the eighteenth century: (a) the invention by Jethro Tull in 1731 of the drill plough, "whereby the turnips could be sown in rows and kept free from weeds by hoeing thus much increasing their yields"; (b) the introduction of rotation of crops in 1730–1738 by Lord Townshend; and (c) the selective breeding of cattle introduced by Robert Bakewell (1725–1795). There is evidence that all three were in existence in India, as recorded by British scientists of the eighteenth and nineteenth centuries working in India.

Roxburgh, generally recognized as the "father of Indian botany" in the contemporary tradition, put it thus: "the Western World is to be indebted to India for this system of sowing," meaning the rotation of crops in the Vedic period where rice was sown in summer and pulses in winter in the same field.

Three other British works support this view. These were the report of Dr. John Augustus Voelcker; the book on agricultural conditions in India by R. Wallace in 1887; and the three-volume source *A Text-Book on Indian Agriculture* by J.Mollison (1901), the first Inspector General of Agriculture in India.

These three have attested to the use of “careful breeding of cattle” (Mollison), various kinds of drill ploughs (Wallace), and rotation of crops and mixed cropping, which “are much more varied and numerous than in England.”

4. Independent “Modern” Discoveries

There are many independent previous discoveries in mathematics that predate without having necessarily influenced parallel European discoveries. For example, the ideas of infinity developed by the Jains find their parallels in Europe only late in the nineteenth century, especially in the work of Georg Cantor; aspects of the binomial theorem attributed to Newton and Pascal appear in Pingala (200 B.C.E.); an interpolation formula by Brahmagupta (b. 598 C.E.) is equivalent to what later came to be known as the Newton-Sterling formula; Bhaskara II (12th century C.E.) gives the diagonals of quadrilaterals in terms of their sides, rediscovered in Europe by W. Snell in the seventeenth century; some of the principles of the differential calculus are found in Bhaskara, who calculated the daily motion of a planet by the *Tatkalika* (instantaneous) method by dividing time into a large number of very small intervals; ideas of integration occur again in Bhaskara, who found the volume of a sphere as consisting of the summation of a set of small pyramids; Madhava of Sangamagrama (1340–1425 C.E.) was the first to shift from the finite approaches and procedures of ancient mathematics to “treat their limit passage to infinity,” the essence of modern classical analysis, and Madhava’s other work pre-dated part of the mathematics known as the Gregory series after James Gregory (1638–1675) and the Taylor series after its discoverer Brook Taylor (1685–1731).

A notable achievement just now coming to the fore through recent translations and their examination by competent mathematicians was the development of a heliocentric mathematics by Nilakantha Somasutvan (1444–1550 C.E.), earlier than the European tradition. In his treatise *Tantrasangraha* (1500 C.E.), he made a major revision of the earlier planetary model then prevailing in India. In this scheme the five planets Mercury, Venus, Mars, Jupiter, and Saturn move around the mean sun in eccentric orbits, the sun in turn moving around the earth. This formulation fitted the observational data then available without telescopes better than the pure heliocentric system did. In the European tradition Tycho Brahe at the end of the sixteenth century developed a similar heliocentric model in a reformulation of the Copernican planetary model.

In the West after Democritus, atomic theories were further expanded by Lucretius in the first century B.C.E. but then virtually vanished from intellectual view for 1600 years. In the seventeenth century Gassendi, Boyle, Newton, and Huygens revived the atomic perspective. Atomic views were developed by several schools such as the Buddhists, the Jains, and the Vaisesiks and persisted, The Vaisesika’s theory of atomism considered atoms as eternal and spherical in form. The disintegration of a body results in its breaking down to constituent atoms. A solid block like ice or butter melts, and this is explained as loosening of the atoms giving rise to fluidity.

Evolution is an important element in the modern set of key scientific ideas **(see *The Grand Patterns of Change and the Future*)**. Evolutionary ideas had existed among pre-Socratic Greek and Indian thinkers. But evolutionary thinking in the Greek tradition was brought to a sudden end by the ideas of Plato and Aristotle. Plato viewed the real world as consisting of unchanging forms or archetypes solely captured by thought. Aristotle viewed the physical world as a hierarchy consisting of kinds of things. For Aristotle the universe was unchanging and eternal. The theory of evolution was reborn in Europe after the Renaissance following advances in natural sciences. The idea of evolution, however, is found in many Indian schools such as in the Upanishads, the Buddhists, and others.

The largest number known to the ancient Greeks was the myriad, 10 000, or 10^4. But from early times there was familiarity with large numbers in South Asia. Even in Vedic times, there were names for powers of 10 up to 62, the Buddhists had numbers up to 10^{53}, and the Jains' religious beliefs made them believe in very large numbers containing up to 194 digits.

Negative numbers, zero, and fractions were accepted in South Asia as a matter of fact. Numbers in the Greek tradition were considered "rational" when they were commensurable with units. Those that were not were considered "irrational." In India this dichotomy did not arise, although there was a dichotomy between exact and inexact numbers. Operations on "irrational" numbers go back very early. Irrational numbers are used in the *Sulvas* dated to between 800 B.C.E. and 500 B.C.E. In 499 C.E., Aryabhatiya gave the approximation for *pi* as 3.1416. Nilakantha-Somayaji (1444–1545) stated in his commentary on the Aryabhatiya that *pi* is an irrational number, meaning that the result of operations will always give a remainder. Conventionally, the formal proof that *pi* was an irrational number is attributed to Lambert (1671).

The scientific revolution had a deep impact on the civilizational underpinnings of Europe. There was, for example, the dethroning of human exclusivity as the special creation of God, as exemplified by the trials of Copernicus or the criticisms of Darwin's evolutionary theory. The discovery of the unconscious by Freud and others is also in this class. Neither of these events would have had the same impact on South Asia, whose cosmology allowed for a large number of worlds, for evolution and change, for humans as part of a larger living world, and for a subconscious.

The above examples question the canonical history of science and illustrate examples of important discoveries elsewhere. Are there examples where innovations are occurring even now that are drawing sustenance from the earlier South Asian traditions?

The old regional knowledge systems still could be fruitfully used for modern scientific enterprise. Let us take one regional civilization, namely, that of South Asia.

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Biographical Sketch

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