Chapter 3

Ancient Science of Mesopotamia, Egypt and China

The first signs of science began to emerge in ancient Mesopotamia, Egypt and China as these agricultural political economies began to develop technologies to enhance their economies. The knowledge or science that they began to acquire was not systematized and no attempt was made to relate the different discoveries that they were making into a theoretical understanding of their universe. This development had to await the emergence of Greek philosophy, which we will examine in Chapter 4. Nevertheless the three ancient cultures that we will examine in this chapter began to acquire knowledge of mathematics, astronomy, chemistry, botany, zoology, medicine and mechanics and in the case of the Chinese all of these plus magnetism and clockworks.

Mesopotamian Writing and Science

The culture of Mesopotamia refers to the cultures that developed in the valleys of the Tigris and Euphrates river systems. The first culture there was the Sumerian, a non-Semitic speaking people whose origin and language remains a mystery to this day. They were conquered by a Semitic-speaking people, the Akkadians, who are known more commonly as the Babylonian. The Sumerians were the first culture to have invented writing and a mathematical notation. It is believed that the idea of writing spread to China in the East and Egypt in the West and from there to all the cultures of the Old World. Writing was invented independently in the New World by the Mayans. It spread from there to a few other cultures before the arrival of the Europeans. It is possible that the Inca also had a notation systems based on knots tied in ropes, known as quipas but it never flowered into a true writing system as far as we know. The existence of a writing system it seems is essential for a culture to engage in scientific activity. It was only those cultures that possessed a writing system and a system for numerical notation that ever engaged in formal scientific activity.

Not only did writing first emerge in Sumer it was also here that the first formal schools were organized to teach the 3R's, the mysterious skills of reading, writing and arithmetic. It was in these scribal schools that the first primitive forms of science appeared. The major aim of the scribal school quite naturally was professional training to satisfy the economic and administrative needs of temple and palace bureaucracies. "However, in the course of its growth and development, and particularly as a result of the ever widening curriculum, the school came to be the center of culture and learning in Sumer. Within its walls flourished the scholar-scientist, the man who studied whatever theological, botanical, zoological, mineralogical, geographical, mathematical, grammatical, and linguistic knowledge was current in his day, and who in some cases added to the knowledge (Kramer 1959, p. 2)."

Writing and mathematical notation emerged simultaneously in Sumer in 3100 BC as was shown by the work of Denise Schmandt-Besserat (1978, 1980, 1981 & 1992). She showed how clay accounting tokens used throughout the Middle East circa 8000 to 3000 BC were the forerunners of writing and mathematical notation. Manual labourers in Sumer were divided into two groups, farmers and irrigation workers. The farmers had to pay tributes to the priests in the form of agricultural commodities that were redistributed to the irrigation workers. The farmers were given clay tokens as receipts for their tributes. These tokens two to three centimeters in size and each with a unique shape to represent a different agricultural commodity were sealed inside of opaque clay envelopes. This system developed because of an information overload; it was impossible using spoken language to remember all of the tributes that the priests received. Some brilliant civil servant/priest suggested that before placing the tokens inside the clay envelopes they should impress the token on the surface of the clay envelope while it was still wet so they would not need to break open the envelope each time they wanted to know what was inside. Within fifty years of this development they did away with storing the tokens inside the envelopes and just pressed the tokens on the surface of the envelope without sealing the tokens inside. The impressed envelopes became tablets.

The next development occurred within the city-state of Sumer where they dealt with large quantities and hence a new information overload arose. They developed a system where the token for a ban, a large measure of wheat (a bushel), was used to represent the abstract number ten and a token for the bariga, a small measure of wheat (a peck), was used to represent the abstract number one. If they wanted to record a transaction involving 13 lambs what they did instead of pressing the lamb token into a tablet 13 times was to press the ban token into the wet clay once, the bariga token three times and then they etched the shape that the lamb token into the wet clay with a stylus and this was read as 13 lambs. The reason they etched the shape of lamb token into the clay rather than pressing the lamb token into the clay is that the tablet would be read as one ban of wheat, three barigas of wheat and one lamb instead of 13 lambs. These etched outlines of tokens became the first written words and the impressed ban and bariga tokens the first notated numbers.

So writing and math started out as a back of the envelope doodle. They were not the invention of writers or mathematicians but humble priests/civil servants who were record keepers. Once reading and writing emerged schools had to be organized to teach these new skills because one cannot learn how to read, write and do arithmetic by watching others do it. It is not the automatic learning that takes place when we learn to talk as young children by listening to our parents and other caregivers speak. The first schools were rectangular rooms that held 30 to 40 students sitting on benches and one teacher at the head of the class (Kramer 1956). The lessons were in reading, writing and arithmetic, a tradition that has lasted 5000 years and will probably continue as long as humans walk upon this Earth.

To prepare their lessons teachers created lists of similar objects like trees, animals, fish, kings, and rivers. These teachers subsequently became scholars. The teacher who prepared the lists of trees headed the botany department and the one who created the list of kings became the political science expert. With scholarship another information overload developed from all the scholars, which was resolved with the emergence of science, a form of organized knowledge beginning around 2000 BC.

Science emerged as organized knowledge to deal with the information overload created by teacher/scholars. The methods and findings of science are expressed in the languages of writing and mathematics, but science may be regarded as a separate form of language because it has a unique way of systematically processing, storing, retrieving, and organizing information, which is quite different from either writing or mathematics.

The elements of universality, abstraction, and classification that became part and parcel of Babylonian thinking under the influence of phonetic writing subliminally promoted a spirit of scientific investigation, which manifested itself in the scribal schools. The major aim of the scribal school quite naturally was professional training to satisfy the economic and administrative needs of temple and palace bureaucracies.

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During the reign of Hammurabi both the writing system and the legal system in the form of the Hammurabic code were regularized and reformed. The writing system that was phonetic and based on a syllabary was reduced to 60 symbols representing the 6o syllables in terms of which all of the words of their spoken language could be represented. Weights and measures were also standardized. These developments were not coincidental. These reforms promoted the paradigms of abstraction, classification, and universality and thus encouraged the development of scientific thinking.

The next two centuries after these reforms represent the first great scientific age of mankind. A new spirit of empiricism and scholarly interest in astronomy, magic, philology, lexicography, and mathematics arose. A primitive place number system was invented as well as algorithms for arithmetic calculations. Mathematical tables were created to simplify calculations. Achievements in algebra included solutions of quadratic equations. Lists of stars and constellations were compiled and the movements of the planets were charted. The scholars of the Hammurabic era "showed such taste and talent for collecting and systematizing all recognized knowledge that Mesopotamian learning nearly stagnated for a thousand years thereafter. ...We find a pervasive idea of order and system in the universe, resulting in large part from the tremendous effort devoted to the systematization of knowledge (Albright 1957, pp. 197-99)."

The Mesopotamians' spirit of order and system is reflected in their cosmology or concept of the universe (Kramer 1959, pp. 77-79). The Babylonian universe, an-ki, is divided into two major components: the heaven (an) and the earth (ki), which emerged from and remain fixed and immovable in a boundless sea, Nammu. Nammu acts as the "first cause" or "prime mover" of the universe. Between heaven and earth there moves Lil, a divine wind (also air, breath, or spirit) from which the luminous bodies (the sun, moon, planets, and stars) arose. The order of creation is as follows: 1) the universe, an-ki (heaven-earth), emerges from the boundless sea Nammu; 2) it separates into heaven and earth; 3) Lil then arises between heaven and earth; 4) from which the heavenly bodies emerge; 5) followed finally by the creation of plants, animals, and human beings. The order of creation found in this cosmogony closely parallels the story of creation found in the Bible in the book of Genesis.

Although Mesopotamian cosmology and cosmogony was polytheistic in nature, there nevertheless evolved some rather abstract notions of the deities that created and controlled the universe. All the elements of the cosmos were attributed to four gods who controlled the heavens, earth, sea, and air. "Each of these anthropomorphic but superhuman beings was deemed to be in charge of a particular component of the universe and to guide its activities in accordance with established rules and regulations (ibid.)." These four spheres of influence correspond to the four elements of fire, air, water and earth from which the Greeks composed their universe more than a thousand years later.

While Mesopotamian cosmology contains mythic elements, the core of its world picture is based on empirical observations of the natural environment including the heavens. Systematic astronomical observations were not part of the Sumerian tradition but were begun by the Akkadians, worshipers of the sun god Shamash. Their observations were somewhat crude (Neugebauer 1969, p. 97) and it was only with the flowering of the Assyrian empire in approximately 700 B.C. that accurate quantitative measurements were made (ibid., p. 101). Tablets recording these observations have been used to date the chronology of the Hammurabic period (ibid., p. 100). Part of the motivation for these observations was what we could term scientific and part astrological, though the Babylonians made no distinction between science and astrology. Observations made for the purpose of divination served science as well, and paradoxically, vice versa.

Sumerian and Babylonian mathematical tables provide further evidence for the development of scientific thinking in Mesopotamia. These tables were combined with tables of weights and measures indicating that they were used in daily economic life (ibid., p. 31). The clear influence of writing and a notational system upon the development and organization of mathematical skills is easily discernible from these tables. Economics proved to be a motivating factor for both writing and mathematics, which mutually reinforced one another's development.

The results were tables of multiplication, reciprocals, squares, square roots, cubes, cube roots, sums of squares and cubes needed for solutions to algebraic equations and exponential functions (ibid., pp. 33-34). The sexagesimal number system 60 was developed in response to the Babylonians' concern for astronomy. The parallel between the approximately 360-day year and the 360-degree circle are obvious.

Tables of quadratic and cubic functions were prepared for civil-engineering projects of dam building, canal dredging, and the construction of attack ramps to breach the ramparts of besieged walled cities. Certain Babylonian mathematical tablets indicate that astronomy, banking, engineering, and mathematics were practiced in a systematic and scientific manner. Two types of tablets were prepared. In one set, only problems are given, but each tablet contains problems related to the other and carefully arranged beginning with the simplest cases. The second set of tablets contains both problems and their solutions worked out step by step (ibid., p. 43). The achievement of Babylonian mathematics, which has been likened to that of the Renaissance (ibid., pp. 30 & 48), is all the more remarkable when one considers the short period in which it developed and flowered: all within two hundred years or so of the major reforms in the writing system.

The existence of these tablets illustrates two important impacts of writing on science. The first is the impulse to organize information in an orderly and systematic manner. The ordering of individual words that the use of syllabic signs creates in the thought patterns of their users inspires a similar ordering of the contents of their writings. That this was critical for the development of science is beautifully illustrated by the

Babylonian mathematical texts created as aids to various scientific and engineering activities.

The second impact of writing is the ability to preserve the accomplishments of one age so that they can form the basis of a later development. Little if no progress was made in Babylonian mathematics from the time of the Hammurabic explosion of knowledge to the Assyrian empire of 700 B.C. Yet the tablets preserved the knowledge that an earlier age had created and they served as the foundation for the Assyrian development.

The mathematical and scientific achievements of the Mesopotamian civilization we have just reviewed are certainly worthy of our respect and admiration. We must be careful, however, not to jump to the conclusion that this culture had solidly embarked upon the road of scientific thinking because of the progress in astronomy, mathematics, and engineering that has been described. The reader must bear in mind that the very same practitioners of this rudimentary form of science were also engaged in astrology, the reading of animal entrails, the interpretation of omens, and other forms of superstition. The early forms of science as practiced in Babylon are not a scaled down or less advanced version of science as we know it today but rather a mixture of logic, superstition, myth, tradition, confusion, error, and common sense. No distinction was made between "religious" and "scientific" thinking. "Medicine grew out of magic, and in many cases was indistinguishable from it (Cottrell 1965, pp. 169-71)." What is important about Babylonian science from a historical point of view was its influence on future generations, on the Hebrews, on the Greeks, on the Arabs, and eventually on Renaissance Europe.

The Babylonians made use of a logical mode of thought complete with abstract notions and elements of classification (Albright 1957, p. 198). Their approach was wholly empirical, however, unlike the theoretical and more analytic style of Greek science, which, according to Kramer (1959, pp. 35-36), required "the influence of the first fully phonetic alphabet." For example, the Sumerians compiled grammatical lists and were aware of grammatical classifications, yet they never formulated any explicit rules of grammar. In the field of science, lists were also compiled but no principles or laws were ever enunciated. In the field of law, a legal code was developed but never a theory of jurisprudence.

Egyptian Writing and Science

Like the Mesopotamians the ancient Egyptians also had a writing system and a science tradition. They also engaged in mathematics but unlike the Mesopotamians who were great at algebra the mathematical strength of Egypt was in geometry. Their writing system was not phonetic but pictographic and hence might explain why they did not achieve the same level of abstraction in algebra, which involves the manipulation of a small number of symbols.

The flooding of Nile River was extremely important to the existence of Egyptian agriculture because it supplied the water necessary for farming in a land that was otherwise a desert. The flooding also gave rise to Egyptian geometry in a round about way because of the need to measure the area of land in the possession of a landowner before the inundation of the Nile washed away all the boundary lines between properties. Rather than restore the boundary lines that were destroyed by the flooding, each landowner was provided with a new plot of land more or less in the same location as before and with a total area exactly equal to the amount of land in his possession before the flood. Because of this need to measure the area of land accurately, an empirical science arose called geometry, which literally means earth (geo) measuring (metry). Egyptian geometry is not derived from a set of axioms. There are no theorems or proofs or propositions. There are merely a set of rules that are used strictly for practical applications such as land measuring and construction calculations. They made use of the Pythagorean theorem thousands of years before Pythagoras ever proved the theorem. They did not need a proof. As long as it worked and allowed them to measure land areas accurately and carry out their engineering projects, they were satisfied. It was the Greeks who took the empirical results of Egyptian geometry and turned geometry into a set of axioms and theorems made famous by Euclid's Elements.

In addition to their abilities at geometry the Egyptians were also excellent astronomers, the knowledge of which served their agricultural needs. Agriculture also led to a number of other science based technologies such as irrigation canals and hand powered pumps, the use of yeast to make bread that would rise; pottery; glass making using soda-lime, lead, and various chemical to make tinted glass; weaving, and dyeing in which a number of chemicals were used to achieve a wide spectrum of colours. In addition to agricultural based technologies the

Egyptians excelled at the metallurgy of copper, gold, silver, lead, tin, bronze, cobalt (for colouring) and iron. They also made a variety of different coloured pigments for painting. In addition to all of the chemical skills they developed must be added their ability to mummify the dead.

The Egyptians also developed incredible engineering abilities in building the pyramids, the sphinx at Giza, temples with gigantic columns, and obelisks. These engineering feats required a practical knowledge of many of the principles of physics but as with their geometry and chemistry their scientific knowledge grew out of the practical things that they did. There was not much effort made to systematize their knowledge to create a rudimentary form of science as the Greeks eventually did.

Chinese Science

What makes the lack of theoretical science in China so puzzling is the high level of technological progress achieved there, which exceeded that of the Mesopotamians and the Egyptians that we just reviewed and the ancient Greeks who we will study in the next chapter. The list of significant scientific and technological advances made by the Chinese long before their development in the West includes the equine harness, iron and steel metallurgy, gunpowder, paper, the drive belt, the chain drive, the standard method of converting rotary to rectilinear motion, and the segmental arch bridge (Needham 1979). To this must be added irrigation systems, ink, printing, movable type, metal-barrel cannons, rockets, porcelain, silk, magnetism, the magnetic compass, stirrups, the wheelbarrow, Cardan suspension, deep drilling, the Pascal triangle, pound-locks on canals, fore-and-aft sailing, watertight compartments, the sternpost rudder, the paddle-wheel boat, quantitative cartography, immunization techniques (variolation), astronomical observations of novae and supernovae, seismographs, acoustics, and the systematic exploration of the chemical and pharmaceutical properties of a great variety of substances.

Joseph Needham carefully documented through years of historical research the contribution of Chinese science and its influence on the West. Although he championed Chinese technology he nevertheless posed the following question: "Why, then, did modern science, as opposed to ancient and medieval science, develop only in the Western world? (ibid., p. 11)" What Needham meant by "modern science," was abstract theoretical science based on experimentation and empirical observation, which began in Europe during the Renaissance.

Abstract theoretical science is a particular outgrowth of Western culture that is not more than four hundred years old. Nonabstract practical science as it occurs in ancient China, Mesopotamia, Egypt and the remainder of the world is a universal activity that has been pursued by all cultures, literate and non-literate, as part of their strategy for survival. Claude Lévi-Strauss (1960) in *The Savage Mind* gives numerous examples of elaborate classification schemes of preliterate cultures, based on their empirical observations and demonstrating their rudimentary concrete scientific thinking.

China created the most sophisticated form of technology and nonabstract science that the world knew before the science revolution in Europe during the Renaissance. Technological sophistication by itself, however, does not guarantee the development of abstract theoretical science. Other factors (social, economic, and cultural), obviously present in the West and not the East, must have played a crucial role as well. In fact in the next chapter we will show that the critical difference was the difference of the Western writing systems based on the phonetic alphabet of 20 to 30 characters as opposed to the Chinese writing system that contains thousand of characters and makes use of pictorial elements and a limited amount of phonetics.

Before delving into the impact of the Chinese writing system, let us first review the fundamental elements of Chinese science. According to classical Chinese scientific thought the universe consists of five elements: earth, water, fire, metal, and wood. The five elements are ruled by the two fundamental universal and complementary forces of yin and yang, which represent, respectively, the following pairs of opposites: cold and warm; female and male; contraction and expansion; collection and dispersion; negative and positive. The five elements and the two forces of yin and yang form a blend of opposites in which a unity emerges more through harmony than through the fiat of preordained laws (Needham 1956). Chinese scientific thought always had a mystical and mysterious aspect to it. The Confucians and Logicians, who were rational, had little interest in nature. The Taoists, on the other hand, who were interested in nature were mystics who mistrusted reason and logic. Chinese science was colored by the Taoist attitude toward nature, which is summarized by the following passage from the Huoi Nan Tzu book:

"The Tao of Heaven operates mysteriously and secretly; it has no fixed slope; it follows no definite rules; it is so great that you can never come to the end of it; it is so deep that you can never fathom it (ibid., p.16)."

It is not difficult to understand how the Taoist mystical attitude toward nature might preclude the development of abstract science. We are still left, however, with the question of why those who were rational, such as the Confucists and the Logicians, were not interested in nature and why those who were interested in nature, such as the Taoists, were mystical. In other words, why wasn't there a group in China that was both rational and interested in science and nature? Eberhard (1957) offers an explanation: Science had only one function, namely, to serve the government and not its own curiosity. All innovations were looked upon as acts of defiance and revolution. The difficulty with the explanation provided by Eberhard is that it applies to the West as well. Western scientists faced the same problems in Europe. The work of Copernicus was openly contested and then suppressed by the Church, yet the Copernican revolution succeeded.

Yu-lan Fung (1922) explains the lack of interest in theoretical science in the following terms: "Chinese philosophers loved the certainty of perception, not that of conception, and therefore, they would not and did not translate their concrete vision into the form of science." The aim of Chinese culture was to live in harmony with nature with no need to subdue it or have power over it as is the case in the West. The philosophical disposition of the Chinese was to focus on their internal reflective state rather than take the external active stance that the West adopted to develop scientific thinking. Fung's explanation is similar to that of Latourette (1964), who claimed that Chinese thinkers, unlike their Western counterparts, were more interested in controlling their minds than nature itself, whereas in the West, the opposite was true. We will see in the next chapter that the difference in the Western and Eastern writing systems also played a role.