COSMOLOGY without HEADACHES

(Lecture Series)

(compiling, transcribing, researching, editing in progress)

LECTURE II: The Shift to Agriculture and Rise of Civilization; the Sky Clock

The era 4000 to 3500 B.C. generally sees an end of the Paleolithic period around the Mediterranean basin. Sumerian settlers with the founding of Babylon between the two rivers, nearest the banks of the Euphrates, begin an age of tremendous influence in this area of Asia, echoes of which are still felt throughout the world.

Before civilization, pre-agrarian/pre-civilized wanderers looked to the heavens in gratitude for warmth, for moisture, and came to understand that seasonal changes were connected with, if not regulated by the movements of the celestial denizens. But they did not need much in the way of astronomy. The lunar cycles were the most obvious means of keeping track of what little concept of time they needed for migratory movements, and they learned how to generally keep the time of day by the height of the sun. They hadn't the luxury, in most cases, to contemplate the whys and wherefores or the mechanics of the cosmos.

Only with the dawn of agriculture, which naturally and necessarily rose in areas which were the most fertile and easiest to plant without excessive clearing of heavy vegetation, did a need for more accurate time orientation arise. This occurred first, as far as we have been able to determine, near the delta areas of major rivers (notably the Nile) and where two great waterways, the Tigris and Euphrates joined. The annual cycles of inundation were observed and the means found (careful observation and recording) of predicting these 'seasons' by the corresponding movement of the heavenly bodies.

The knowledge came gradually to the early farming tribes. At first they must have planted only the most rudimentary crops, mainly wheat-like grasses, the grains of which were supplemented by fishing (which must have been plentiful prior to the establishment of upstream urban and industrial centers). But the flooding was a terrific problem and must have often wiped out whole communities. In fact the flooding was exceptionally great in Mesopotamia around 4000 to 3500 B.C. (Could these have been behind the great deluge stories in later religious lore, including the Old Testament?)

Only by controlling the river to some degree with dikes and levees and irrigation canals, and by establishing their villages on higher ground nearby, could any sort of stability have been achieved. They also needed the accumulation of celestial lore to time their planting and harvesting with the ebb and flow of the rivers. This required intellectual and time consuming effort beyond the capability of any particular tribe of simple farmers, ideas that would not even occur to a nomadic culture. A larger organization was needed, allowing a division of labor. A means of keeping records for long periods had to be invented: a method beyond oral history and tall tales. A city was necessary, and ‘cities,’ at first mere villages and then small towns, began to take shape.

There are few records of the earliest of towns. Often they must have just seemed to establish themselves, almost certainly family based. When their success—their surpluses—came to the notice of marauders (non-agrarian tribes who found it easier to rob than hunt), the less aggressive agrarians, no doubt, were often wiped out (a recurring theme even with mighty civilizations) and their works left unattended to rot or to be erased by the next inundation. The more foresightful of conquering groups may have seen an opportunity for a better life than that meagerly provided by nomadic wandering and rather than slaughtering the farmers, enslaved them—at first simply stealing but eventually marrying their daughters and assimilating into the farming culture. It was, of course, the farming community’s *knowledge* that the hunters most needed in order to move up in life-style; to become successful river people. The spared farmers likely would continue in their way of life, except forced, henceforth, to provide nourishment as well as wives for their oppressors. In turn the oppressors became also guardians; a security force in defense of the conquered property against other intruders. This was probably not the plan when their ancestors first raided the town. One would expect many such inevitable occurrences to have turned out badly. If they didn’t exterminate the locals during the attack, they oppressed them so heavily as to reduce their capacity and/or their will to produce. But if they were smart and persistent (and very fortunate), together they prospered. A new society was born: a new level of living achieved.

Through a common bonding of river peoples, who were all subjected to the same dangers, or by conquest of several of these towns by an even larger barbarian force, or by the conquest of the weaker towns by the most powerful and aggressive, or (most likely) all of the above, the required larger organization was formed by which the river itself could be partially tamed. Then even greater defense efforts were necessary. Perhaps rudimentary fortifications were constructed, which would need to be maintained in order to secure residences and a market place. Permanent buildings could then be erected—most notably a temple. So now the farmers are supporting an army, laborers, priests, a chief and the families of managers and their servants—i.e., a system of government for social control emerged quite naturally—it didn’t have to be invented—complete with taxation), and—*voila!*—civilization occurred through force and reason.

The earliest cities were probably established in Africa or in China. The earliest of the great civilizations seems to have been that of Egypt—perhaps as ancient as 8,000 B.C. We know that cities in Mesopotamia formed around 5000 B.C., by which time the Egyptians already had a rough calendar (360 days of 12 months, which needed adjustment every three years to be of use agriculturally). But even by this seemingly early date, though the records are sparse and fragmented, recent and continuous archeological work confirms that civilization was already old.

While might of arms was the common denominator in the rise and growth of civilization, due to the security provided by such force and the need for learning and recording and regulating, the necessary intellectual class arose that would pave the way to the higher echelons of civilization. By stealth and their apparent power over the unknown —the 'dark' things—the 'magi' made themselves somewhat immune to hostility and violence; or even took control of it—as long as the river succored the society. When things went wrong, naturally, everyone was in jeopardy—though the priests could always find ways to blame someone or something other than themselves for causing discontent among the gods. These, then, were the first mathematicians, architects, and astronomer/astrologers; the inventors of letters and numbers; the regulators; the keepers of the log that made possible the 'cradle' cultures, or what E.T. Bell calls, the "Age of Empiricism" [THE DEVELOPMENT OF MATHMATICS: McGraw-Hill, NY, 1940].

The Assyrian, Babylonian, Egyptiac, Sumerian, Akkadian (i.e., Pre-Hellenic) peoples of the Mediterranean and Middle-East, though these civilizations are revered as the first of the truly high cultures, reached a level of scientific and mathematical sophistication that does not even reach today's (well—perhaps yesterday's) high school level of geometry and algebra. They were, first of all, hampered by the restriction of their numbering system, and they had virtually no theory of numbers. One might say they were pretty much *a*-theoretical. The most advanced of these cultures in the area of mathematics—we should say 'arithmetic', since there was not much understanding beyond that needed for simple measuring and counting—were the Babylonians (often referred to as Chaldeans by early Greek writers such as Thales). The Egyptians, however, since they built their biggest monuments of stone, left us much more remarkable evidence of their knowledge of geometry: their temples and pyramids. Their geometry was, of course, pre-Euclid. They did understand how to do elementary computations of areas and volumes of basic shapes and forms—but through memorized formulas rather than by theories or axioms. They did not have π, but roughly found the circumference of a circle using 3-times its diameter, which was close enough for their general purposes. (This is also found in the Old Testament, I. Kings, Chpt.vii, v.23; & II. Chronicles, Chpt.iv, v.2.) But they did not write out or multiply by squares or cubes, etc. Without modern numbers they couldn't. They did their multiplying by many additions. They did not have a decimal system and did not even use fractions beyond ½ and ⅓, smaller divisions being made by more and more halving, etc. With further progress, when fractions were used, they were all (excepting that of ⅔) expressed with a common, unitary numerator. E.g., 7/16 would be indicated as 1/4 + 1/8 + 1/16, etc. (But not exactly like this, of course, as numerals had not been invented—more like 'one of four plus one of eight plus one of sixteen, etc.) Mathematical calculations had to be done by lengthy descriptions of the problem—a rather complicated operation necessary for a solution the method for which the magi kept hidden among their 'dark secrets'.

Because all civilizations require an agricultural base, these 'cradle' civilizations depended heavily on a method of land surveying. The ebb and flow of the river significantly changed properties from season to season—requiring adjustments in taxation as well as expectations for future crop production, all of which was assigned and estimated by the priests. The biblical Joseph, son of Jacob (re: Tim Rice and Andrew Lloyd-Webber's *Joseph and the Amazing Technicolor Dreamcoat*), advised Pharaoh to take 1/5 of the produce for feeding his administration and for storage against lean years. [*This is of course an archaic concept. Modern economics has it that we don't need to store anything. In fact, we must destroy surplus produce that might drive down prices. Modern governments only need to extract ever more money from the citizens—or, even easier, from their descendents. So, if they want to fund projects beyond present capacity, they just increase taxes or borrow the money from the future: from our grandchildren. You, by the way, are the ultra-grandchildren of those who first conceived of this idea. Your debt is inconceivable.*] Over time (due partly to failure to pay taxes in bad growing seasons) the priests confiscated much of the productive lands for their gods and kings, operating them much like modern agri-business, indenturing the former owners and their workers. Among the tools needed for the success of such enterprise, a practical, even if not precise, astronomical lore was mandatory so as to establish a reliable calendar. Astronomy, surveying, and large scale architecture require a grasp of more sophisticated mathematics than what might be developed by primitive or nomadic people who needed only a vague notion of the workings of the heavens and their affect on the seasons and climate, and perhaps a particular star to guide their wandering. But even astronomically the 'cradle' civilizations have a bigger reputation than is perhaps deserved.

Their calendars, for thousands of years, even if sufficient for their survival, were not all that accurate. Adjustments had to be made based on long experience and the accumulation of records kept by the priesthood/astronomers (rather than generated by sophisticated mathematical formulae); records which gradually revealed the cycles. At the dawn of civilization, expects Thomas Kuhn:

> …men must have counted new moons and quarters to measure time intervals, and as civilization progressed they repeatedly attempted to organize these fundamental units into a coherent long-term calendar—one that would permit the compilation of historical records and the preparation of contracts to be honored at a specified future date.
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> But at this point the simple obvious lunar unit proved intractable. Successive new moons may be separated by intervals of either 29 or 30 days, and only a complex mathematical theory, demanding generations of systematic observation and study, can determine the length of a specified future month…. Most societies (but not all, for pure lunar calendars are still used in parts of the Middle East) must adjust their calendars to the sun-governed annual climatic variation, and for this purpose some systematic method for inserting an occasional thirteenth month into a basic year of 12 lunar months (354 days) must be devised. These seem to have been the first difficult, technical problems encountered by ancient astronomy. More than any others, they are responsible for the birth of quantitative planetary observation and theory.

[*from* Thomas Kuhn, THE COPERNICAN REVOLUTION: *Planetary Astronomy in the Development of Western Thought*; Harvard, Cambridge MA, 1957 (19th printing, 1997); pp.46-47]

The Egyptian priests, at least, understood the difference between a lunar and solar year. They first devised the 365 day calendar, without regular adjustments, by simply adding five extra days at the end of each year. Finer adjustments had to be made over longer periods by royal decree (as determined by the priests) to make up for the missing quarter of a day. It would be 4,000 years before 'leap years' were introduced. Most pre-philosophical civilizations used the lunar calendar of even earlier people (new moon to new moon), giving only 354 days per year. Due to various cosmic imperfections, of which they had no understanding, this required significant adjustment every three years to get back into sync with the sun, otherwise the difference between calendar and seasonal climate changes (more than a month gained by the calendar in only 3 years) would have quickly compounded to create problems with the timing of river inundations, upon which their entire agricultural system and their very lives depended.

As Kuhn pointed out, these ancient calendars are still observed by certain peoples (e.g., traditional Jews, many Muslims, and certain middle-eastern sects), but in most cases this is only carried on traditionally: a sort of remembrance of things past, while business with the rest of the world follows the modern system. The Chinese, however, relatively isolated from Mid-East and Western development, continued to use the lunar calendar, officially and seriously, until 1912. The Egyptian system was also invented, apparently independently, by the Mayans. The actual beginning of civilization, however, is buried much deeper in the past than 4241 B.C., the date given by E.T. Bell for the first Egyptian calendar. By that time wheeled vehicles were already in use by Sumerians, who also gave us coins, barley bread and beer, oil-burning lamps, and more agile numerical systems based on 6 & 12 but, even so, they had nothing like modern symbolic arithmetical notation. Upgraded to 365 days in 2772 B.C., with leap years added in 239 B.C., the Egyptian calendar was finally adopted in the west only about 50 years before Christ (actually 46 B.C.) by the Romans (Julius Caesar—thus the 'Julian' calendar—after his visit with Cleopatra).

Whatever was known of such things among the ancients was kept secret by the architects and the priests and the royal accountants – probably more out of a need for job security than a sense of magic—or perhaps to prevent the 'unwashed' from finding out how *little* was really known. But they really had no worries in that regard. Throughout the ancient world—and well into the late Renaissance, despite Gutenberg (& Fust, his financier)—literacy and 'numeracy' was rare. The writing systems, fundamentally flawed from their ancient beginnings, grew extremely complex and thus somewhat restrictive of new ideas and/or deep concepts. The numbering system in Europe (actually up to the early Medieval period when the West finally discovered the use of Arabic numerals) was at least as unwieldy—try multiplying and dividing using Roman Numerals, for instance.

Babylon was considerably better than Egypt at arithmetic, used mostly in trade (keeping inventory, etc.). The Babylonians have left us a great many tables of such calculations, and quite a few tablets that were used as teaching aids—some with only the problems (indicating that they knew how to solve these problems); some with answers included, though rarely showing how the solutions were reached.

Babylonians, apparently had a concept of zero, which even the much later and greater Romans did not know. Numbers were basically understood by knotted ropes and instruments of calculation such as 'swan-pans' and the abacus, etc., so that a simple merchant might do accurate computations without understanding anything about number theory (as do modern bank tellers and tax accountants with their calculators). This lack of theory, however, did not seem to have interfered with the development of the mystical concepts that still plague our un-scientific majority: numerology and astrology. Due to the religious basis of cosmology, astronomy (as we understand it—that is observation and recording of celestial mechanics) was little more than a handmaiden to astrology. Stars and planets were understood as living gods rather than dense consolidations of matter; the sun and moon were disks or bowls rather than globes, and acted as vehicles (if they were not the gods themselves) for transporting the associated god across the firmament.

To compress the above discussion: there was very little of what we know as theorizing. These were highly practical, pre-philosophical ages. Though Kuhn points out that "the Babylonian astronomers…solved these [calendar] difficulties between the eighth and third centuries B.C., a period during most of which Greek science was still in its infancy [and] accumulated much of the fundamental data subsequently incorporated into the developed structure of the two-sphere universe" [*Ibid.*], no names of famous intellectuals or scientists have come down to us. We know only of way too many gods, most of the rulers, and some priests and generals, along with a few scribes who named themselves in certain records that happen to have been among those uncovered in modern times.

The prime example of the latter is in the British Museum, a document called the Rhind Papyrus by a scribe named Ahmes, of more than 1,000 years B.C. His name appears on what is apparently a copy of a treatise written yet another 1,000 years earlier: "Directions for Knowing All Dark Things". This is a collection of problems in arithmetic and geometry, including the answers but, again, without revealing the solutions. He does show a formula for the area of a circle—equivalent to our equation: $(d - {}^{1}/_{9}\, d)^2$, which would make the value of *pi* equal to 3.1604 compared to our 3.1416—not bad! But theoretical *pi* did not occur to them. Of course, the formula given by Ahmes was not in the algebraic form shown, but was related to a particular circle of 12 'units' in diameter. No actual unit of measurement was given. The answers were attained not by a universal concept for all circles or for an ideal circle, but by measuring real ones. This left them uncertain that areas and circumferences of such very large circles or very small ones as could be not actually measured, i.e., empirically 'tested' in their common way, could be trusted as correct.

It was not until the Greeks that mathematical theorizing along with science, logic, and philosophy came into being. The system of 'exhaustion' gave them their early formulae. The prime example is the inscribing of polygons of increasing numbers of sides inside a given circle, and computing the area of the polygon—ad infinitum, i.e., until the numbers of sides could not be increased with any useful accuracy, so that they could continually approach, but never reach the actual area of the circle—that is to say, the attempt to 'square' the circle was unsuccessful (we still can't do it. Since we know *pi* to have no final resolution we can get only reasonably close to a true 'square' area).

Evidence at least suggests that the Babylonians received their mathematical start from the talented and inventive Sumerians, who reached their summit around 3500-3000 B.C. This approximately corresponds with the first recorded year in Mayan chronology, while Western Europe was still asleep—just entering its Neolithic Period. Meanwhile Egypt was building her pyramids and the Sphinx and learning mummification so the souls of their dead kings (immortality was for kings only) might have an imperishable base of operations. The Sumerian base-60 counting system still survives in our modern clocks and in geographical coordinates of 'minutes' & 'seconds,' not to mention the 360 degrees used in the compass and in the cumulative angles of plane, four-side figures. They also seem to have invented the cuneiform symbols that made possible the expression of these ideas. Despite their later absorption, politically, by their intellectual inferiors (c.2000 B.C.), they invented the rudiments of a painstakingly descriptive algebra, which developed quickly. There may have been mathematical advances by other peoples but the records of the Middle-East (due to the climate being right for preservation; the Egyptians finding that old, useless papyrus records were just the right thing for stuffing mummified sacred crocodiles; and the practically ineffaceable baked clay records of the Sumerians and Babylonians) gave Egypt, Sumer, Assyria, and Babylon the edge in the realm of recorded immortality.

But what did their mathematics and astronomy teach them about the cosmos? That is what we want most to learn through this investigation. – And how did it affect their culture? Why did they not proceed with their knowledge (through Western-like reformations, for instance) all the way to science and enlightenment?

Some answers will be forthcoming in future sessions.

HANDOUT :

Ch.13 *from* E.C.Krupp: ECHOES OF THE ANCIENT SKIES;

Dover Ed. (2003) of Oxford Univ. (1994) *of* Harper & Row, NY 1984; pp.315-349