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Strategic Technology Institute

Ancient Egypt Provides an Early Example of How A Society's Worldview Drives Engineering and the Development of Science.

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Technology, or if one prefers *engineering*, is a function of societal values.[1] While modern philosophers continue to debate whether technology shapes society or whether society shapes technology, the development of engineering and the science over 5,000 years ago in ancient Egypt vividly demonstrates the extent to which technology can have practical social and religious bases.[2] Unlike the Greeks, who later benefited from the advances of Egyptian and Mesopotamian scholars and who developed an abstract theory of knowledge, the Egyptians used knowledge for the practical accomplishment of goals tied to their religious worldview. An examination of Egyptian engineering and science, principally during the Old Kingdom (c. 2670-2150 BCE) and Middle Kingdom (c. 2040-1650 BCE), shows that religion drove the development of, and was reflected by, their monumental architecture. These architectural wonders served as a societal organizing principle and demonstrated the power of the state, which was believed to be run by either an incarnate god on earth or the son of a heavenly god. In addition, the supporting sciences, such as mathematics, astronomy, geography, and medicine all had practical purposes in support of the Egyptian religious worldview. One also finds that the most accomplished practitioners of engineering and science were accorded high status as priests and established a role model for later cult heroes. Finally, one can observe how ancient Egyptian engineering and

[1] *Technology* is how society does things, not how it thinks of them. Suffice it to say for our use that *technology* is science plus purpose. While *science* is the study of the nature around us and subsequent development of scientific 'laws,' technology is the practical application of those laws, in sometimes non-rigorous ways, toward the achievement of some material purpose (Dorf 1).

[2] But just what do we mean by the word '*science*'? For our purposes, let us define *science* as the body of knowledge obtained by methods of observation. It is derived from the Latin word *scientia*, which simply means knowledge, and the German word *wisenschaft*, which means systematic, organized knowledge. Thus, science, to the extent that it is equivalent to wisenschaft, consists not of isolated bits of knowledge, but only of that knowledge which has been systematically assembled and put together in some sort of organized manner (Fischer 5-7). In particular, the science with which we are concerned is a body of knowledge that derives its facts from observations, connects these facts with theories and then tests or modifies these theories as they succeed or fail in predicting or explaining new observations. In this sense, science has a relatively recent history, perhaps four centuries (Platt).

science, and the storehouse of knowledge in Alexandria, formed a foundation for the classical Greek mathematical philosophers of the Hellenistic Age.

Egypt's Early Development

The land of Egypt (Kemet) emerged from the waters of the Nile's marshes and lakes about ten thousand years ago. The habitable Egypt developed about 8,000 BCE after the deposit of alluvium from the Nile's source in Upper Egypt, to the south, in modern Sudan. (Davidson 28). The Nile Valley is a strip of green hemmed in by the Sahara Desert to the west, mountains to the south, the Red Sea to the east, and the Mediterranean to the north. It forms a narrow strip twelve to twenty five miles wide and hundreds of miles long (McClellan 35). The geological and archaeological history of ancient Egypt, even in Stone Age times, showed how favorable conditions for farming and settlement allowed the ancients to change their way of life, and in the process, they gradually became different from their ancestors and the nearby nomadic tribes.

While Mesopotamian society, with its collection of cities, is perhaps the first known *civilization*, in the strictest sense of the word, Egypt was the first state and was by far the oldest continuous state.[3] About 5,000 years ago in Mesopotamia, modern Iraq, and shortly thereafter in Egypt, the emergence of ruling classes, religion, writing, and cities formed the standard ingredients of what we refer to as *civilization* (Roaf 19). A rich delta and Nile valley, and some very ingenious hydraulic engineering, allowed for extensive irrigation and highly productive farmlands.[4] Under the influence of irrigation, "Former subsistence-level farming gave way to the production of large surpluses of cereals that could be taxed, stored, and redistributed," according to James McClellan and Harold Dorn of the Stevens Institute[5] (McClellan 31). So, by 4,000 BCE, the Tasian Culture of the Middle Nile and the Badarian Culture who came into the Nile region from the southwest, were cultivating crops[6] (Davidson 14-15). By 3,500 BCE they had formed themselves into early states, by 3,200 BCE the nomadic Upper Egyptians and the agriculturalist Lower Egyptians were unified by the legendary Menes, and soon after 2,600 BCE the Pharaoh Khufu, whom the Greeks called Cheops, ordered the building of the Great Pyramid at Giza, the

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[3] Urban-based civilizations unfolded independently in multiple centers across the world. A pattern of Neolithic settlements coalescing into centralized kingdoms based on intensified, hydraulically-enabled, agriculture occurs at least six times in different sites: Mesopotamia after 3500 BCE, Egypt after 3400 BCE, Indus River Valley after 2500 BCE, along the Hwang Ho (Yellow River) after 1800 BCE, Mesoamerica after 500 BCE, and South America after 300 BCE (McClellan 32).

[4] McClellan and Dorn argue that environmentally restricted agricultural zones bounded by desert, cataracts, and sea, beyond which traditional farming was possible or practical, coupled with the expanding Neolithic populations, drove the need to intensify food production. This led to creative use of the water management, canals, and irrigation (McClellan 33).

[5] Increased crop yields allowed for further growth of cities into city-states and enhanced the social stratification into classes and skilled specialties. This urban revolution sustained armies, tax collectors, a priestly class, and centralized political authorities (McClellan 31-32).

[6] Davidson notes that the pre-dynastic migrations into the Nile Valley may have been due to desiccation of the previously green Sahara and Sudan in the Makalian Phase (c. 5500-2500 BCE) (Davidson 14-15). Likewise, Hornung believes that the Badarian and Naqadan cultures avoided desiccation by making a gradual descent from the desert plateau into the Nile valley (Hornung 3).

greatest structure the world has seen. As Basil Davidson notes, "The time span from *homo habilis* with his earliest tools to Neolithic man with his farming cannot in any case be much less than two million years. Yet not much more than two thousand years separate the earliest farmers who settled along the river Nile from the mathematically precise builders of the monuments of Egypt" (Davidson 14). They benefited from a fruitful interaction with the environment through invention, and they experienced a 'feedback relationship' between environment, biological evolution, and cultural change. The settled life enabled the Egyptians to be handier, more skillful, and better able to think and to act by thought than their ancestors (Davidson 13).

Egypt's Religious Worldview

Religion and rituals also played a fundamental role in the life of Egypt. Given its precarious dependence on water from cyclical Nile River flooding and the critical nature of the rebirth of crops, it is not surprising that Egyptian religion dominated so many aspects of society. The war chief of the Falcon clan, who first united the valley of the Nile, became thought of as a god, because he controlled the river's gift of fertility, enforced submission, and exacted tribute from every dweller on the river's banks (Derry 7). Religious centers acted as focal points for the surrounding regions and concentrated wealth and power through gifts to the temples or through tax.

In the Archaic Period (3100-2670 BCE), the falcon Horus, god of the sky, ruled the world in the form of each reigning king and the sun god Re (Ra) illuminated it in the form of a changing and renewed sun (Hornung 4). In fact, the worship of the deified king through repeated acts of cult was thought to be essential for the prosperity of Old Kingdom society (Morenz 85). "The magical powers at the king's command, by virtue of his divine nature, were omnipotent," notes Erik Hornung of the University of Basel. H.W.F. Saggs of the University of Wales puts it more explicitly, "From the point of view of an ancient Egyptian, the king was, quite literally, a fertility giver and controller of the Nile and all life of the land; from whom the Egyptians' point of view he was, without question, a god upon whom the life of the land depended" (Saggs 26).

As the society grew in numbers and geographic size, as water and land had to be distributed, as squabbles had to be settled, and as Egyptian civilization became more acquisitive and complex, the kings began to regulate society through deified edicts. Because of the ease of navigation from one end of the country to the other by means of the gentle Nile, it was relatively easy to produce a unified system of government (Saggs 26).

The Egyptologist Siegfried Morenz of the University of Leipzig argues that the all-pervading religion was the basis of Egyptian civilization. For example, Egyptian pictorial art performed a function in the magic or cult that had religious ends. In the early years, art did not have to display any aesthetic appeal, since it was destined for a dark burial chamber, rather than for human viewers. The art only had to be there, its very existence provided god (the dead king) with a body that could be given vitality by the performance of rites and which could dispense salvation and receive gifts (Morenz 6). Words themselves and the objects they described were identical, therefore there was magic in the power of words, incantations, and spells[7] (Morenz 9).

[7] Writing appeared in Egypt before the 4th millennium BCE. Ancient Egypt had three main scripts. *Hieroglyphics* were used for formal royal inscriptions on monuments since before 3,000 BCE. *Hieratic* was a priestly shorthand that evolved soon afterwards. *Demotic*, a much faster cursive method developed shortly before 600 BCE (Davidson 29).

When it comes to history, the only acceptable subject was the sacrosanct ruler, who was appointed by god, whom or in relation to whom all essential things happened (Morenz 11). The large number of mythological and ritual funerary inscriptions from the later pyramids, the so-called *Pyramids Texts*, are the earliest examples of Egyptian literature, but their function was wholly religious (Morenz 7). According to Morenz, "The Egyptians' peculiarly intense preoccupation with the service of the dead, which involved donations to secure a proper funeral and provision for the hereafter, had a very considerable impact on property relationships and thus also on economic life, administration, and law" (Morenz 12). The core concept of harmonious justice, called *maat*, was defined by religion, bestowed by the creator-god (e.g., Atum), defended and guaranteed by the sacrosanct king, and administered by viziers who bore the title of 'priests of maat' (Morenz 12-13). In this way, ancient Egyptian art, language, literature, law, and government were based on religion, which Morenz calls the 'womb of culture.' He also suggests that the close ties between religion and the Egyptians' basic outlook on life, their way of thinking, their goals, social order, and philosophies, created a fundamental harmony that explains the longevity of the ancient culture (Morenz 13).

Advanced Technological Society

Like Mesopotamia, Egypt showed evidence of having a very advanced engineering capability, by its accomplishments if not by its technological means.[i] Settled city life facilitated new forms of technologies, such as metalworking, pottery, stone carving, and new forms of social organization. Bronze metals (copper alloyed with tin) offered distinct advantages over stone as tools and weapons, so control over Sinai copper mines was of great importance to Egypt. Metalworking involved a complicated set of technologies, including mining ore, smelting, hammering or casting the metal into useful tools. Bronze metallurgy required furnaces with bellows to raise temperatures to 1,100 degrees Celsius (McClellan 41). Ultimately, the city-states were conquered and consolidated into a nation-state, and later into an empire. Increased crop yields, surpluses, and wealth led to a desire to trade with neighbors, even distant ones, for luxury items and raw materials, including Nubian gold. By the close of the Bronze Age, the tomb of Tutankhamen showed the exquisite achievements of the Egyptians in fine arts, in the service of the religious mortuary cults. Here we find works in gold, silver, semi-precious metals, ivory, and curved furniture unrivalled by European technique until the Renaissance (Derry11).

It is also important to recognize that the omnipresence of religion as the basis for art, literature, law, government, and philosophy, was also the driver of Egyptian science, engineering, and skilled trades. However, the goals of science and engineering were practical ones. According to McClellan and Dorn,

> "Writing and reckoning were first and foremost practical technologies with practical origins meeting practical needs. Knowledge in the first civilizations was subordinated to utilitarian ends and provided useful services in record keeping, political administration, economic transactions, calendrical exactititude, architectural and engineering projects, agricultural management, medicine and healing, religion, and astrological prediction" (McClellan 46-47).

Almost half of all known pharaonic doctors practiced during the Old Kingdom, during which, specialization was well advanced (Nunn 11). The medical profession was associated with the priesthood, since religion was the basis of Egyptian medicine (Morenz 7-8). “Death was seen as caused by a message from the deity, except in those cases where violence was obviously involved,” notes Morenz. Medical diagnoses, practices, and prescriptions were closely associated with magical incantations.

The Egyptian conservatism ensured that favorable remedies would be retained and used as the basis for further advances. Their early development and use of papyrus provided the means for codifying and distributing successful remedies (Nunn 23). By the Middle Kingdom (c. 2040-1650 BCE), many important medical papyri had been written. In fact, six of the forty two books of human knowledge possessed by the ancient Egyptians were medical texts. They included: The structure of the body, diseases, the instruments of doctors, remedies, the diseases of the eyes, and diseases of women (Nunn 24).

Like the formulaic mathematical procedures, medicine was practiced using prescriptions and incantations that seemingly were unrelated to the underlying causes of problems. For example, a gynecological papyrus from year 38 of Amenemhat III’s reign was found at el-Lahun and contains thirty four prescriptions on three long pages. The prescriptions are structured around the questioning of a patient, then proclamation of the symptoms, followed by a stock remedy (Parkinson 78-79). These ‘diagnoses’ and prescriptions looked somewhat like trial-and-error ‘home remedies’ that centuries of American farm families adopted, without much understanding of the underlying causes of maladies.

Egyptian astronomy evolved out of the need to establish the exact periods of time deemed indispensable for the performance of certain rites. Morenz provides an example from the Osirian cult, where the service was divided up on an hourly basis. “In the mortuary service, astronomical observations played a significant part, in view of the mythical links deemed to exist between the dead and celestial bodies and the need to compile a simple chronology on behalf of the occupant of the tomb” (Morenz 8). The invention of the calendar provided an ecclesiastical year or a calendar of festivals, which listed dates for observances and sacrifices. Astronomy not only developed in this way, but also was kept alive by the continuous observations necessary to fulfill the requirements of the cult (Morenz 8).

Even the science of cartography, in its earliest representations, was concerned with the geography of the afterworld. It was designed to serve as an aid to the dead on their journey and can be found on the bottoms of Middle Kingdom coffins. Not until the Ramesside period, five hundred years later, were maps compiled for economic or other practical purposes, such as the plan of the gold mines at Wadi Hammamat (Morenz 9).

Mathematics was supported by the state’s temple authorities and it was a critical tool for organizing and maintaining Egypt’s agricultural economy. The administrative nature of mathematics also explained the Egyptians’ tradition of recording verbal and quantitative information in the form of lists. According to R.V. Parkinson, “They [were] not analytic or theoretical treatises, but lists of practical examples for solving problems encountered in administrative and building works (Parkinson 77-780). For example, to determine the daily share of some ten-gallon annual ration given to workers, the Egyptians would solve the problem formulaically in the following manner:

> You shall make this fat (worth) 10 gallons into *ro*; this makes 3200.[8] You shall make the year into days; this makes 365. You shall divide 3200 by 365; this makes 8 + 2/3 + 1/10 + 1/2190 (= 8.767), making in ro: 1/64 of a gallon (= 5 ro) + 3 ro + 2/3 + 1/10 + 1/2190. This is the daily share (Parkinson 78).

The Egyptians of 3,500 BCE to about 1,700 BCE used a symbolic hieroglyphic number system. The symbols were combined to form intermediate numbers and formed a base-10 system that was not positional (Kline 19). Egyptian numbers operated like later Roman numerals, with separate signs for the decimal numbers and no place value. The Egyptian system was essentially additive, but they used a method of duplication, an approach of multiplication by doubling and redoubling numbers, that worked with a Roman-style number system (Kline 19). They also arrived at a superior calculation of pi, 256/81 or 3.16, compared to the rough value of 3 found in Babylonian mathematics, and developed tables that facilitated working with fractions (McClellan 49-51). In general, the Egyptian system was cumbersome and less efficient than its contemporary Mesopotamian system in handling advanced calculating requirements[9] (McClellan 49).

It is clear that the development and evolution of advanced mathematics by the priestly classes and the practical applications by the scribes of Egypt existed long before the Greeks and has had a considerable influence on a number of societies, including our own. As Lancelot Hogben notes, "There is no doubt that the raw materials of Greek mathematics were imports." He also cites the influence of the Phoenicians of the Levant on the Greek colony of Miletus, on the father of Greek geometry, Thales of Miletus (640-546 BCE), and their influence on the travels of Pythagoras in Egypt and Mesopotamia (Hogben 60-61). One might also surmise that Alexander's conquests of Egypt, Persia, and India provided ample opportunity for his teacher, Aristotle, to 'borrow' the works of Egyptian, Babylonian, Persian, and Indian scholars to further expand and refine Greek philosophy into a rigorous scientific method.

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[8] A *ro* is 1/320 of a gallon (Parkinson 78).

[9] So, how did Egyptian mathematics compare with its contemporaries and subsequent systems? The Sumerians of Mesopotamia invented two different number systems. Administration and business mainly used the decimal system based on powers of 10 (1-10-100-1,000, …) and the *sexagesimal* system was used primarily for mathematical and astronomical calculations (Saggs, Civilization 222). Like the river-based agricultural societies in Mesopotamia and Egypt, the Indian and Chinese societies developed a bureaucratically practical system of applied mathematics. By the first unified empire under Chadragupta Maurya (321-291 BCE) and his grandson, Asoka (272-232 BCE), the elaborate Indian bureaucratic structure made use of mathematical recipes for practical concerns. Significantly, however, the Indian system developed into one that used nine Arabic numerals plus a zero. The Indians were keen mathematical astronomers and were adept at measurement, algebra, trigonometry, negative numbers, irrational numbers, and the calculation of pi to four decimal places (McClellan 141-146). Examination of Chinese symbolic numerals indicated unique symbols for 1 through 10 and further symbols for powers of 10 (e.g., 100, 1000, …) that seem very similar to our modern Arabic numeral system (McClellan 130). They had a decimal place-value system by the 4th century BCE, knew the Pythagorean Theorem by the 3rd century BCE, and they used counting rods and the abacus to facilitate arithmetic operations by the 2nd century BCE. The Chinese mastered large numbers using a base-10 system, handled squares, cubes, and, like the Babylonians, solved problems by what we today would call quadratic equations. Though by the early current era's seemingly playful exploration of numbers by Zu Chougzhi (429-500 AD), who calculated pi to seven decimal places, Chinese problem texts principally dealt with practical measurements of agricultural fields, cereal exchange rates, construction, and distribution problems (McClellan 130-131). The later Roman numeral system also had distinct disadvantages versus the Mesopotamian system in that every time the Romans multiplied by ten, they required a new signs such as X, C and M, that were ultimately limited by the number of letters in their alphabet (Hogben 39).

It is from this technically advanced pharaonic empire that the famous pyramids and monumental temples were organized, funded, and developed. As one considers the achievements of Egypt, it is important to remember, as Derry and Williams note, "…a civilization which had reached such perfections before Moses lay in his cradle, and which, though its thirty dynasties continued until the time of Alexander the Great, passed its zenith more than 3,000 years ago" (Derry 11).

Architecture and Engineering

The early dynasties of Egypt, having stone to work with, left a memorial that, fifty centuries after the Great Pyramid of Giza was raised over the mummified body of Cheops, is still the most magnificent tomb in the world (Derry 10). Among the temples at Thebes, there stands the Great Hall of Karnak, still the world's largest colonnaded room (329 x 170 feet) that covers as much space as the cathedral of Notre Dame (Derry 11).

According to Hornung, in the course of a single generation, the pharaonic architecture experienced a transition from its modest beginnings of brick, wood, and woven mats into the mighty stone edifice in which the king was to reside in death. Saggs notes that the earliest burial customs of Lower Egypt included burying the dead in settlements, sometimes under the floor of a house. Since the Egyptians believed that a dead person had the same need for a house as a living person, a *mastaba*, or box-like structure of mud brick, was erected over a subterranean tomb. The early mastabas had the burial pit divided into compartments for the body and the dead person's treasured possessions. Inside the larger structure above ground, there were compartments for food, drink, a wooden boat for travel in the afterlife, and other necessities. (Saggs 50-51). But the people from Upper Egypt had a custom of burying the dead with a mound of sand above the grave. Remember also, that deep in the Egyptian psyche is not only the myth of the mound rising from the waters, but the fact that the land of Egypt was built up from the alluvial deposits from the Upper Nile (Davidson 28). So, in myth and in fact, Egypt arose from the waters. In addition, the mythology of ancient Egypt includes the story of creation arising from Atum sitting on the primeval hill. The mound of sand over a grave came to be equated with this primeval hill, and was thought to have life-giving power. As such, it came to be considered an indispensable part of the tomb (Saggs 51).

It was Djoser (c. 2654-2635 BCE) who in Dynasty III established his kingdom at Memphis, the symbolic balance of Upper and Lower Egypt, and thus combined the burial customs of the north and south in the form of the first pyramid. Djoser was the royal sponsor of this technological and artistic wonder and his chief architect, Imhotep, brought into being the Step Pyramid of Saqqara, west of Memphis. Imhotep transformed the old mound of sand, incased in a stepped arrangement of bricks, into a massive structure that covered and enclosed the complete tomb. The Step Pyramid was a stone replica of the 'primeval mound' that emerged at the moment of creation from the chaotic waters to serve as the basis for the ordered cosmos, according to Egyptian cosmology. Thus, its visual effect was the replication of a religious event (Saggs 50-51).

Djoser and Imhotep experimented with several tomb designs, beginning the tomb as a mastaba. At Saqqara, they built a stone mastaba of unusual size and shape. It was square instead of oblong like its predecessors, and it was over 200 feet on a side and 26 feet high. They later enlarged this mastaba twice by adding stone to the sides. Before the second of these enlargements was completed, the king decided to make it into a layer of four square mastabas of decreasing size piled one atop the other (De Camp 22-23). Then Djoser, or Imhotep acting on his behalf, changed his mind again. The novel feature that Imhotep added was the layering of six successive stages of lesser lengths, and those layers were in permanent stone, rather than mud brick. These six successively smaller layers of stone blocks gave it a 'stepped' look, which rose to over 204 feet (Saggs 51). The massive stone mound encompassed a rectangular area 596 yards long and 306 yards wide. It had an elaborate network of shafts, tunnels, ramps, corridors, and chambers in its substructure. It also had a central chamber for the king's body and other chambers to accommodate members of the royal family (Saggs 50-51). The king's chamber was built entirely from pink granite from Aswan and was located at the bottom of the shaft (Edwards 37). The entire compound was surrounded by an enclosure wall of glistening white limestone that was about 33 feet in height and over a mile in circumference (Saggs 51). Within the wall was a festival court, where Djoser could celebrate an unending series of *sed* festivals of renewal, and chapels for his mortuary cult. A life-size statue, which was walled up in a chamber on the north side of the pyramid, depicted Djoser in his festival regalia. Even ceiling beams and half open doors were made of imperishable stone. As Hornung observes, "…the statue's visage gives some hint of the controlled sense of purpose that enable the nearly superhuman accomplishments of the age…[and] Djoser's funerary enclosure served as a new and highly visible symbol for Memphis, which, as implied by its name 'Balance of the two lands,' was situated at the juncture of Upper and Lower Egypt" (Hornung 14-16).

Imhotep's use of stone was an important innovation in tomb building that would later culminate at Giza. The use of stone as a medium, plus the geometrical symbolism of the pyramid tomb as a place of ascent to heaven marked a change in the Egyptian religious symbolism. The realization of the symbolic purpose, according to the renowned Egyptologist Jan Assmann of the University of Heidelberg, was intimately connected with its elevation and its orientation to the cardinal points. The accuracy of the Old Kingdom pyramids with the south, east, north, and west reproduced the course of the sun and the constellations. Assmann interprets this iconographic symbolism as, "The sacred space of the pyramids was understood as an enclave in which the earth and its directions mirror the topography of the heavens" (Assmann 59).

Djoser's Third Dynasty successors built other step pyramids. At Meidum, a pyramid with eight steps was built. At some later stage, perhaps in the reign of the Fourth Dynasty king Sneferu, the steps themselves were filled in with stone packing and then faced with white limestone, producing the first true pyramid shape (Saggs 52).

Following Sneferu, Khufu (c. 2589-2566 BCE) institutionalized the practice of architecture and the skilled crafts associated with engineering to such a level, unparalleled even by modern standards, that the Great Pyramid at Giza could be built. Consider the immensity of the Great Pyramid that sits on the west bank of the Nile just above Cairo. It is the largest stone structure ever built. "The cathedrals of Florence, Milan, St. Peter's at Rome, St. Paul's in London, and Westminster Abbey could all be placed at once on an area the size of its base," according to L. Sprague De Camp (De Camp 24). Except for the Great Wall of China, it was the largest single human construction of antiquity (De Camp 25). It required 94 million cubic feet of masonry (2.6 million cubic meters), made up of 2.3 million blocks averaging 2.5 tons each. Its total weight is 6 million tons. It stands 485 feet high in 210 layers of stone, with 763 feet on each side, and covers 13.5 acres (McClellan 42-43). The outer façade is polished stone and its interior has chambers, buttresses, and passageways. "The architects and engineers who built the Great Pyramid and the others like it commanded some elementary and not-so-elementary practical mathematics,

…design and material requirements demanded such expertise, as did the very exact north-south and east-west alignment", notes McClellan and Dorn. The Great Pyramid was laid out true to the axes within 2.5 to 5.5 minutes of an angle, the sides of the base come to within seven inches of forming a perfect square,[10] and, in spite of its enormous 53,077 square meters, is almost perfectly level with a maximum error of only 21 millimeters (Strouhal 170-171).

The pyramids were symbolic as well as literal exercises in state building (McClellan 45). Archaeologist Michael Hoffman of the University of Virginia observes, "The impact of contrived and monumental architecture – the ways it manipulated space and scale – certainly were linked to the social function of the royal mortuary cult itself. As Egypt consolidated from local chieftainships into regional kingdoms, into the world's first national state, it developed the royal tomb as its flag: a symbol of political integration, under god" (Hoffman 336).

Not only were the pyramids symbolic, they served a practical purpose. Since the Egyptians believed that the afterlife could be enjoyed only as long as the body was kept intact, the mummified corpses laid in massive stone tombs were designed to foil tomb robbers forever (De Camp 22). For example, Khufu's mummy was placed in a wooden coffin, which was then placed inside a granite sarcophagus. The sarcophagus had a heavy stone lid, that, when slid into place, stone bolts dropped into recesses in the trough and secured the lid for all time (De Camp 27). Djoser's tomb chamber was closed with a six-foot long granite plug that weighed three tons (Edwards 38).

It is common to think that the Egyptians must have had powered machinery to build the pyramids. Some even speculate on secret magical powers of the occult or aliens from space. On the contrary, the Egyptian engineers of Khufu's time used very simple methods. Since they lacked pulleys, had only copper, tin, bronze, and gold metals, and made very little use of the wheel, the exact methods are unclear. However, tool marks on stone, quarries with blocks half detached, ancient tools found at work sites, and ancient paintings give one the indication that the Egyptians used three key things, according to De Camp – intensive and careful use of the simple instruments and devices they had, such as sleds, barges, ramps, and ropes; unlimited manpower and the ability to organize and command it; and, no need for haste (De Camp 31).

The last Egyptian pyramids were built around 1600 BCE. Perhaps, Ahmose I constructed the last one. By this time, about seventy pyramids dotted the Egyptian landscape. None were as grand and as well built at the Great Pyramid and, therefore, many have eroded away (De Camp 28-29).

Organization of Labor

Like the two great provinces on which the First Dynasty pharaonic state rested, Egypt's governing power and revenue were drawn from control of the water supply, taxation of landowners and peasants, and tribute from Egyptians and from vassal states, such as military service (Davidson 29). The Pharaoh took over and reshaped the administrative services of the two pre-dynastic states and developed a large corps of clerks, tax gatherers, commanders, governors, artists, and technicians. According to Davidson, "It brought a wider peace and security to the peasants of the Nile, although the price they paid was not a small one" (Davidson 29).

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[10] De Camp, p. 25.

Pyramid building, certainly in the Old and Middle Kingdoms, served as a dominant activity around which Egyptian society was organized. Egyptologist Mark Lehner of Harvard asks the question 'how the pyramids built Egypt' might be more interesting than 'how the pyramids were built' (Shaw 45). Likewise, Assmann refers to Egypt as a case of *ethnogenesis*. As Assmann explains. "The old Kingdom is not only the period in which pyramids are built, but also the time that was defined and indeed 'created' by the pyramids – as planning time, building time, cult time, and eternal time" (Assmann 53). It was a time when collective construction of gigantic structures caused laborers from all over the country to speak the same language in order to plan, agree, and live together (Assmann 53). In this sense, Egypt as a culture and as a nation was created.

The sequence of early pyramids were giant public works projects designed to mobilize the population during the agricultural off-season and to reinforce the idea and reality of the state of ancient Egypt (McClellan 44-45). "Monumental building was therefore a kind of institutional muscle-flexing by the early Egyptian state, somewhat akin to the arms industry today," notes McClellan and Dorn. Lehner observes, "The colossal marshaling of resources required to build the three pyramids at Giza – which dwarf all other pyramids before or since – must have shaped the civilization itself" (Shaw 46).

Lehner drew on strands of evidence from various disciplines to determine that, unlike the popular notion reinforced by the Judeo-Christian tradition and by Hollywood movies, such as *The Ten Commandments*, a vast slave class did not build the pyramids. He studied geological history, the living arrangements, bread-making, animal husbandry and remains to determine that the workers who built the pyramids were part of a rotating labor force in a modular, 1,600-2,000 person, team-based organization. The workers' graffiti revealed team names, such as 'Friends of Khufu,' and 'Drunkards of Menkaure.' He also discovered that these workers lived in a barracks-style setting near the site of the pyramid being built, and were fed prime beef. These were not common laborers, but skilled workers. (Shaw 99). Along with these skilled workers from all over the country, the manual labor of quarrying and hauling massive stone blocks was done by unskilled labor and slaves. A surplus of idle agricultural workers available seasonally for three months a year during the Nile floods provided the labor pool. "Contrary to a once-common belief," says McClellan and Dorn, "forced slave labor did not build the pyramids, but labor was conscripted (like military conscription today) and organized in work gangs." Lehner explains that obligatory labor in the ancient world ranged from slavery to the highest levels of society, somewhat like a feudal system, where everyone owed service (*bak*) to a lord. Even the highest officials owed *bak*. So, like cathedral building in Medieval Europe or barn raising among America's Amish, the combination of a strong sense of community obligation and the lack of a sense of individual political and economic freedom explain the advanced social organization of this period (Shaw 49-99).

The massive public expenditure entailed in the development of the pyramids was not solely for the glorification of a king, but rather for the welfare of the state, according to Hornung. Since the Egyptians believed that the king's creative powers held together the very order of the world and had to be preserved even beyond death, the construction of a pyramid was a communal religious effort on the part of Old Kingdom Egyptians. These people were not 'free' in the modern sense of the word, but rather were in various ways bound to and dependent upon the king and other divine powers (Hornung 24). According to Hornung, "The clear structure, the firm order, and the tight organization of the state, which made it possible for all its energies to be concentrated on a single cultic task, found symbolic expression in the form of the pyramid" (Hornung 24).

Meritocracy, the First Cult Figure, and the Model of the 'Renaissance Man'

We know of Imhotep through the discovery in 1926 of his name and titles on the base of a statue of King Djoser who reigned at the beginning of Dynasty III (c. 2654-2635 BCE). His name recurs on temples, in books, and through the Greek translations of writings that refer to him. One Greek translation notes, "The entire Greek language will relate thy tale and every Greek will worship Imouthes [Imhotep], son of Ptah" (Morenz 250). Also, the St. Petersburg Pushkin Museum has a votive statuette of Imhotep among it collection (Strouhal 245). In addition, we know of amulets from Dynasty XXVI that commemorate Imhotep's deification (Redford 16). Other than kings, he is the earliest historical personage supported by tangible proof of his existence.

Tradition revered Imhotep as a great architect, physician, and sage. Every official was first and foremost a royal scribe. Imhotep achieved such great importance that in later years he was revered as the 'patron saint' of scribes (Hornung 16). As his name implies – 'He who cometh in peace'[11] -- Imhotep was the author of the earliest work of wisdom literature, what one might think of as works on ethics, or 'instructions in wisdom' and 'directives for life' (Morenz 111). The advice given by the senior officials who wrote the surviving five complete and seven partial texts was meant to ensure personal success in concert with the needs of the state and the norms of ancient Egyptian society. These treatises cover truth-telling, fair dealing, rules for a well-ordered life, justice, wisdom, obedience, restraint, and humanity. They generally took the form of verses addressed by a father to his son or a king to an heir. These books were used as teaching texts in the schools for scribes and, at least in the cases of Imhotep and Prince Hordjedef, the authors of these ancient works were held in such high esteem that they were deified (Strouhal 31).

Among his titles were those of High Priest of Heliopolis, Chief of the Observers, and Grand Vizier. As a vizier (*tjaty*), to which the king would delegate his own priestly functions to officials, Imhotep would have been responsible for management of the state-run economy, administrative functions of the state, and the judicial system. Dating back to the Dynasty II, the Vizierate alone was responsible to the king for proper order in the land (Hornung 21).

Imhotep was also the royal chamberlain and court physician to Djoser and in later years he was worshiped as a god of healing (Nunn 10). Sir William Osler[12] refers to Imhotep as, "…the first figure of a physician to stand out clearly from the mists of antiquity" (Jackson 13). He was worshiped as a medical demi-god from 2850 to 525 BCE and as a full deity from 525 BCE to 550 CE (Jackson 14). As such, the Egyptians placed him as one of only three mortals with the healing powers of the gods Amun, Thoth, Min, Horus, Isis, and Serapsis[13] (Strouhal 251). His image graced the Temple of Imhotep, perhaps one of the first hospitals (Jackson 13). In the Ptolemaic period, according to Donald Redford of the Pennsylvania State University, "Temples often had

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[11] See Jackson, p. 13.

[12] Evolution of Modern Medicine, London, 1921, p. 10.

[13] The other mortals worshiped for their healing power were Amenhotep, the son of Hapu who was an architect and senior official in the court of Amenophis III, and Antinous, the Emperor Hadrian's lover (Strouhal 251).

sanatoriums on their premises where the afflicted in mind and body could come to spend the night and, in dreaming, be approached and helped by the resident deity of the temple" (Redford 79). Likewise, sufferers would come to Imhotep's temple for prayer, peace, and healing. The Greeks came to identify him with their own Asclepius (Hornung 16). Asclepius was mentioned as a wise physician in Homer's Iliad and later, like Imhotep, was promoted to godhood (De Camp 23).

Imhotep is the most ancient engineer whom we know by name and inventor of the pyramid, which among the Seven Wonders of the Ancient World, only the pyramids survive to this day[14] (De Camp 19). The technical feat is attributed to such outstanding cultural memory due to the significance of Imhotep's use of stone as a medium of immortality (Assmann 55). According to De Camp, Imhotep was born in Memphis and was the son of the royal architect Kanofer, and the father of a son, Rahotep, from whom a long line of architects descended[15] (De Camp 21).

He is best known as the architect and director of the work on Djoser's mortuary complex, which included the Step Pyramid of Saqqara. As mentioned previously, the Step Pyramid was the first pyramid, but it was more than that; it was a tomb, a temple, a festival court, and an entire residence for Djoser made out of imperishable stone. This allowed Djoser's memory and reverence to remain alive into the Ptolemaic Period (Hornung 13-17). Hieratic graffiti on the passage walls of the northern and southern buildings record the admiration felt by Egyptians who visited the monument more than a thousand years after it was built (Edwards 51).

In addition, as head architect, Imhotep had to survey the site, calculate and decide on the type and quality of material to be used, the quantities required, arrange for it to be hewn in the appropriate quarry, arrange for transportation of the materials to the building site, estimate the size and qualifications of the labor force, and manage junior scribes who would make arrangements for housing, feeding, and equipping the workers (Strouhal 170). The architect would also employ astronomers to lay down the north-south axis, which in the case of the Step Pyramid, was only off by three degrees (Strouhal 170).

As the greatest architect of the ancient world, Imhotep authored a book on the traditional schemes for temple construction. It was found in a temple library and was said to be the model for the Ptolemaic temple at Edfu. This temple was, "one of the best preserved monuments in antiquity," according to Morenz. The temple at Dendra, also of the Ptolemaic period, was based on this ancient tradition as well (Morenz 85). These temples refer to an adherence to Imhotep's plans in wording that is similar to Holy Scripture – 'without taking [anything] away from it or adding to it …' (Morenz 85).

Though archaeologists can verify Imhotep's existence, and his obvious magnificent works of stone, the sheer range of expertise attributed to Imhotep may have grown as his legend became cult. The worship of Imhotep from the New Kingdom (c. 1550-1070 BCE) into the Greco-Roman period resulted in him being given divine lineage, as the son of Khereduankh, his real

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[14] The Seven Wonders known by the Greeks around 100 BCE were: The Pyramids of Egypt, the Hanging gardens of Babylon, the Statues of Zeus by Pheidas at Olympia, the Temple of Artemis at Ephesus, the Tomb of King Karia at Halikarnassos, the Colossus of Rhodes, and the Pharos (lighthouse) of Alexandria (De Camp 19).

[15] As late as the Persian King Darius (c. 490 BCE), the Minister of Public Works, Khnumabra, claimed descent from Imhotep. He listed a line of 25 architects, beginning with Kanofer and ending with himself. De Camp notes that this line of 25 is too small to cover 2,000 years. However, it shows the esteem given to Imhotep from generations of architects who yearned eminent ancestry (De Camp 21).

mother, and the god Ptah (Redford 70). Not unlike the legends of Medieval European Saints of the Catholic Church, a truly great man may have been given attributes beyond reasonable human capabilities. Because if the legends are true, Imhotep stands as a truly unique historical multi-genius, exceeding both Aristotle, who wrote on a wide array of subjects from mathematics, to zoology, to ethics, and Leonardo da Vinci, who was both a great artist, scientist, and inventor.

Few people in the history of the world have set the standard for excellence in multiple disciplines. Hippocrates and Galen discerned the causes of disease as biological, rather than spiritual, but they did not simultaneously run the economy of an empire. Newton, Galileo, and Copernicus introduced the world to revolutionary laws of physics and astronomy, but they did not simultaneously practice medicine. Even in modern times Albert Einstein set the standard for physicists and Thomas Edison for inventors, but neither wrote wisdom literature or philosophy. Modern Nobel Laureates are renowned for their excellence in a single domain, including great works of literature, but they are not simultaneously architects of monumental stone works meant to last forever. If one is to believe the legend, none of these great personages of history mastered the scope of disciplines and the depth of expertise as Imhotep, the first 'Renaissance Man.'

One explanation for the extent of Imhotep's skill set might be the general practice in the Old Kingdom of bestowing honorific titles on members of the royal court. Some titles that began as a mark of function became marks of rank within the hierarchy. Saggs cites Klaus Baer's findings of some individuals having as many as 200 titles, a sign that the ancients were obsessed with considerations of rank in relation to the king (Saggs 27). When it came to rank, the most important officer of the state was the Vizier. The earliest viziers were royal princes, a relic from when the king kept all authority within his circle of kinsmen. By Dynasty V, viziers no longer had to be princes by birth, but they had to be men of considerable ability, since his task was to oversee the whole administration and be second to the king in status, and in some cases, of greater importance in practice (Saggs 28). So, Imhotep as a vizier would have been considered at the very height of power, prestige, influence, and control of Djoser's kingdom.

Another explanation may lie in the motivation of the Ptolemies. Ptolemy V Epihanes, the Greek pharaoh in an effort to cope with a famine and the revolt of King Ergamenes of Meroe, sought to associate himself with the founder of the Memphite Dynasty – Djoser – to attain legitimacy in the eyes of the Egyptians (Grimal 64-65). This motivation to discover, cultivate, embellish if necessary, and propagate Third Dynasty heroes by the Ptolemies may also have contributed to the growth of the Imhotep legend. As Nicolas Grimal of the Sorbonne reminds us,

> "Imhotep the courtier is now better known than Djoser the king, and it was Imhotep, rather than Djoser, who later became the object of a popular cult. In fact, the cult of Imhotep was spread from Alexandria to Meroe (via a temple of Imhotep at Philae), and even survived pharaonic civilization itself by finding a place in Arab tradition, especially at Saqqara, where his tomb is supposed to be located. Djoser on the other hand, was not deified, and he only achieved immortality through his pyramid" (Grimal 65-66).

Yet another explanation lies in the profitability of cults. "The driving force behind these enormous cults was that they paid," according to Redford. "They were expensive to run, but they attracted worshipers and pilgrims in the thousands, in some cases from outside Egypt, as can be seen from hieroglyphic dedications on bronze votive statues." This is a pattern of religious exploitation that European Christians should be well familiar with, since the sale of relics and benefices was so common in the medieval period that Giovanni Boccaccio and Geoffrey Chaucer lampooned it in the Decameron and the Canterbury Tales, respectively.[16]

Whatever the reasons behind his popularity -- whether it is as crass as the profit motive, a public relations move by the Ptolemies, a veneration of great leaders of the skilled architectural and engineering trades, or whether he is the impetus for wisdom in the manner that Benjamin Franklin became in 18th century America -- it is clear that the collective cultural mind of the Egyptians was so impressed by the innovative and inspiring work of Imhotep, that 5,000 years later, we still speak of him. He is an iconic symbol of the values of ancient Egypt: skill in service of the king (god), wisdom, literacy, healing, and the ability to transcend time through immortal acts of monumental creation and through legendary good works.

The Foundations of Western Science and Engineering

By the untimely death of Alexander the Great, the Egypt of the Ptolemies, who themselves ruled as Egyptian Pharaohs of Greek origin, ushered in a Hellenistic age (330 BCE – 350 CE) of great technological and scientific activity. With Alexandria as its capital, the Ptolemies were distinguished for city planning, good water supplies, drainage systems, fine government buildings, increasingly comfortable and luxurious houses, labor-saving inventions, and important advances in mathematics, astronomy, and medicine. At Alexandria, a great library brought together all the learning of the known world and its museum functioned as a university. Although Alexander destroyed the military power of Egypt and the Near Eastern empires, the imprint of the older civilizations allowed religion and its associated worldview, as one of the great indigenous forces, to continue to travel from east to west (Derry 16).

The roots of modern western scientific inquiry can be traced back to the classical philosophies of the Greeks, who were influenced by Phoenician,[17] Egyptian, and Mesopotamian scholars. As the archaeologist C. Leonard Woolley noted,

> "We have outgrown the phase when all the arts were traced to Greece and Greece was thought to have sprung, like Pallas, full-grown from the brain of the Olympian Zeus; we have learnt how the flower of genius drew its sap from Lydians and Hittites, from Phoenicia and Crete, from Babylon and Egypt" (Wooley 194).

Likewise, Hogben argues that,

> "The veneration of the Greeks by their successors is indeed due to the fact that they were the first to insist explicitly on the need for proof." Though

[16] The Church sanctioned and profited from the supposed healing powers of the relics of Christian martyrs (White 2: 26). One finds in literature caricatures, such as Chaucer's Pardoner, who is openly larcenous, and yet operates with the full authority of a Papal Bull. This seller of relics is an "entirely viscous man" who has no interest in the message of Christianity, other than how it is used to profit him (Chaucer 348). Through the sale of benefices, Boccaccio describes the clergy in Rome as, "… having carried on more trade and had more brokers than there were engaged in the textile or other business in Paris" (Boccaccio 30).

[17] See Gionanni Garnini's analysis of the history of the Phoenician alphabet and its adaptations by the Greeks in The Phoenicians edited by Sabatinoi Moscoti (Moscati 101-119).

> Greek mathematics were imports, "…they had to pass the customs of Greek incredulity," among a society partial to dispute resolution and competition among rival teachers (Hogben 60-61).

So, it is not that the Greeks monopolized abstract thinking; they refined it.[18] Ionian Greek philosophy and its classical definitions of truth and beauty, exemplified by the Socratic logic of Plato, and the later Hellenic-era metaphysics of Aristotle, laid the foundation for rational scientific inquiry.[19] Plato believed that truth emerged through the power of reason and we observe truth as making sense. Aristotle, the son of a physician and Plato's pupil of twenty years, took his master's basic philosophy, added more structure and advocated verification of intuitive natural laws with objective observation (Loomis vii-xiii). Both a great thinker and a great scientist, Aristotle set the tone for future scientists by his method of inquiry and an avowed determination to yield to observation as the final arbiter.[20] As a result, an atmosphere of sober empiricism distinguished the Hellenic Greeks from the Ionians, with Aristotle being credited as being a great dividing line in Greek history. Aristotle's pupils and their successors carried on his teachings at the *Lyceum* for over 800 years, until, like Plato's *Academy*, it was closed by order of a Christian emperor in Constantinople (Loomis X).[ii]

Greek science, by the sheer process of speculation, argument, intuition, plus a dash of empirical reasoning, had moved, within the space of two generations, from the early mythical notions to a point that is surprisingly close to modern concepts (Goldstein 52). Having channeled the power of Greek philosophical thought into a logical system of scientific classification, Aristotle came to exercise an enormous influence over European science for the next two thousand years (Loomis, xi-xxxviii). When Europe awakened from the feudal Dark Ages and the Medieval suffocation of theocracy to an enlightened approach to knowledge that included the works of Francis Bacon, Sir Isaac Newton, and Nicolaus Copernicus, it embraced the process of

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[18] Thales of Miletus, Anaximander, Pythagoras, Socrates, and Plato developed many of their ideas using earlier ancient works as their base (Goldstein 48-64).

[19] The Ionian Greeks had an earthy tradition that stressed the enjoyment of life, commercial property, aesthetic refinement, and acceptance of newcomers. This allowed free thought and inquiry to flourish. From its earliest manifestations, the Greek mind had turned to natural philosophy, which was indistinguishable from Greek science. Led by Thales of Miletus, the Greeks saw the formation of the earth by natural processes, no longer through an act of the gods. "The Ionians conceived of nature as a completely self motivating entity," according to science historian, Thomas Goldstein. The workings of the universe occurred as mere extensions of the primordial chaos, automatic functions of its basic elements. Matter possessed its own evolutionary quality. 'Order' and 'law' were mere concepts superimposed by the human mind on the autonomous processes of nature. It was Pythagoras who is credited with the introduction of the vision of an intrinsic natural order and Plato adopted this vision (Goldstein 52).

[20] Unlike Plato, Aristotle did not believe in a world of ephemeral appearances of changeless ideas. Loomis notes that Aristotle argued that, "…the world really is, has been, and will continue to be, regardless of human eyes and imaginings" (Loomis xvii-xviii). However, like Plato, Aristotle thought it necessary to, first of all, understand and explain the workings of the human mind and to show what kinds of reasoning were valid and could be relied upon to provide knowledge with surety. In his *Organon*, Aristotle made clear the processes of logical, reasoned thinking and for proving the correctness of its conclusions. He made plain the steps by which a science or body of knowledge may be firmly built up from its starting point in certain fundamental axioms or obvious statements, perceived intuitively to be true. Every science, as Aristotle pointed out, must begin with a few general truths. They cannot be logically proved, but our minds by simple intuition accept them as obviously true. Without such assumptions as foundations, we could never start to build anything (Loomis, xi-xxxviii). Louise Loomis, editor of a 1940's translation of Aristotle's *Metaphysics*, noted that he reasoned like Plato, from ideal abstract principles, whenever the subject of the reasoning lay outside his field of observation.

observation, generalization, explanation, and prediction that was fully rooted in an earthy materialism, indicative of the age.[iii] This view of knowledge became pervasive, changing assumptions not only in science but also in the entire social fabric of Europe. Europe came to understand that the physical realm of nature is real, orderly, and, in part, understandable.

Conclusion – Values and Societal Worldview Drives Science and Technology

It is very easy for the modern citizen of a technologically dependent society to assume that the social structure and human interactions are being driven by the unfettered, and often unintentional, consequences of a spiral of accelerating technological developments. Likewise, it has become fashionable for warnings of the potential evils of technology to be screamed from the pages of prophetic socio-political novels and science fiction films. However, on the contrary, a careful study of the history of technology shows that, rather than it being the driver of society, indeed society's values, motivations, beliefs, and worldview drive and shape the evolution of technology.[iv] Also, it is common to find abstract science standing on the shoulders of historical techniques and technological innovation.[21] This has been the case since the earliest of recorded history.

Though one might argue for the theoretical neutrality of science as pure abstract knowledge, it is clear that *technology* or *technique,* upon which *science* is built, is never neutral. From its earliest uses in the advanced civilizations of Mesopotamia, Egypt, India, China, Greece, Rome, and Mesoamerica, through its applications by Medieval Arabs and Europeans, through its acceleration from scientific developments of the Renaissance, Industrial Age, and the modern Information Age, technology has been the servant of human needs, desires, intents, and actions. Technology's potential to address human needs and motivations is a function of the state of earlier technologies accelerated by the sum of a civilization's social values, which are in turn functions of society's *worldview*. What we know, i.e., *scientific knowledge*, and what we don't know but try to explain, i.e., *belief systems* form the worldview.

As ancient Egypt shows us, the technology of monumental construction, calculation, record keeping, and organization, and especially what society does with these techniques, is a matter of cultural values and societal choice. In the Egyptians' case, the cultural values centered on religion and the societal choice was one of maintaining an idealized world.

Traditionally, technology as a trial-and-error art is thought to have developed separately from science as an abstract discipline throughout most of recorded history. As seen in Egypt, the practical techniques of arithmetic can be used for organizing labor and trade, geometry can be used for construction, and astronomical observation can be used to produce calendars and the determination of ideal planting cycles. In this sense, it can be sometimes viewed as *applied science.* Yet, from the ancient Egyptians until modern times, much of *technique* continues to be developed with little or no basic scientific knowledge. As McClellan and Dorn cite, "…in many instances technology directed the development of science, rather than the other way around" (McClellan

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[21] There are intimate relationships between *science* and *technology*; yet science is not technology and technology is not science. Technology relies very heavily upon basic scientific knowledge in addition to existing technologies. There is also a strong influence in the reverse direction. Modern science relies to a large extent upon current technology as well as prior scientific knowledge. Science and technology reinforce each other by complex interactions. Each one, science or technology, can build upon itself or upon a linkage from one to the other. Indeed, science is not technology and technology is not science, but they are firmly interrelated. One could not exist in modern society without the other. (Dorf)

2). One can certainly see the links in the case of Egypt, where accounting techniques led to a mathematical system, which when combined with the observational impetus provided by religion, led to documentation of general rules that were precursors to engineering as a profession.

If one accepts this as true, then by extrapolation, modern society's technological prowess owes its birth to the religious motivations that drove ancient Egyptian engineering and science, and the subsequent abstract thinking that its culture fostered.

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Notes

[i] Over a 6,000 year period, Mesopotamian technology included advances in carpentry, glassmaking, textile manufacture, leather-working, perfume-making, farming, food preparation, irrigation, flood control, canal-building, water storage, drainage, brewing, and their tablets also provide detail on the economics of various industries (Roaf 126). The first use of the plow in the Near East dates back to the Uruk period. Sledges, wheeled vehicles, boats, and overland animal caravans have been used in Mesopotamia since the 4th millennium (Roaf 72). The most basic indication of a settled, rather than nomadic, lifestyle is pottery. Decorated pottery found at Tell Hassuna indicates a mastery of kilns providing higher temperatures for baking non-porous jars as early as the middle of the 7th millennium BCE (Roaf 39). "During the 4th millennium, there were major developments in metallurgy," according to Roaf. Smelted copper, alloys of copper and arsenic, lead, gold and silver ornaments benefited from the use of lost-wax casting techniques (Roaf 72). Sir Leonard Woolley's excavations of more than 1,000 graves in the Royal Cemetery at Ur show a complete mastery of jewelry making techniques using composite objects, inlaid stones, and sophisticated geometric designs (Roaf 92). Intensified agriculture based on large scale water management networks constructed and maintained as public works by conscripted labor gangs (corvee) and slaves under the supervision of state-employed engineers is the critical foundation of their civilization. Main canals were nearly 75 feet wide, had hundreds of connecting channels, and ran for several miles (McClellan 31-35). Perhaps the most impressive engineering achievements of ancient Mesopotamia are the series of ziggurats found throughout the region as early as 2100 BCE in Ur, 1900 BCE in Babylon, and 900 BCE in Assyria. In addition, the Assyrians of Nineveh under the leadership of Sargon II (722-670 BCE) and his son Sennacherib dominated the Near East with its iron-equipped armies, battering rams, and horse-drawn chariots (Derry 12).

[ii] The classic Roman civilization built upon Greek science to develop their mighty empire with its renowned technical prowess. The Romans, being driven by conquest, glory, commerce, and an increasing need to find new resources never really flowered as scientists. Free thought was not the hallmark of Rome. The Roman way of doing things was impressed upon its citizens and conquered states as a matter of standard procedure. The Romans did, however, undertake massive engineering feats such as extended roads, aqueducts and highly structured cities (DeCamp 172-280). Here technology flourished but no new ideas of philosophical importance stand out. Great translators of other works, the Romans were exploiters of resources and fantastic implementers of technology. As Rome crumbled under the weight of countless invasions, the cosmic vision of the Greeks and the technological achievements of the Romans shriveled. With Europe over-run by the Germanic tribes, scientific inquiry was stunted for a millennium. Europe slept in a stupor of ignorance for one thousand years. "To those who lived through the catastrophe, it seemed that the utter breakdown of civilization had come, the ruin of everything humanity had ever tried to create over thousands of years, a verdict from a wrathful heaven," according to Goldstein (Goldstein 55). Europe reacted with a radical readjustment of mind, turning their backs on the world of the senses, which now seemed unworthy of intellectual scrutiny. The end of Roman civilization meant a steadfast attachment by Europeans to the dogma of Christianity. To Europeans it offered the only hope left.

When the hope given by the Church was no longer needed, new morals and money provided the impetus for Europeans to cast the Church aside in favor of a new age -- the Renaissance. Suddenly, being earthy and gauche was in. Once again Europe entered an age of free inquiry, but this time a novel twist accompanied the new age. The new twist was represented by a view of life advocated by a new breed of wealthy philosopher/scientist.

The European Scientific Revolution of the 16th and 17th Centuries began with Nicolaus Copernicas who overthrew the geocentric view of Ptolemy and The Bible that had been accepted for over a thousand years. After Copernicus, the earth was no longer the center of the universe but merely one of the many planets that circled a minor star in an insignificant galaxy. Radical in its impact, this view of the world robbed humans of their proud position in the center of God's creation. Without dogmatic theological constraints, other scientists such as Johannes Kepler who is credited with the laws of planetary motion, Galileo Galilei the re-discoverer of many of the principles of gravitation and the invention of the telescope, and sir Isaac Newton who combined much of his previous work into the laws of motion each contributed to the Renaissance's spirit of inquiry.

[iii] Two aspects of these scientists' work stand as foundations of modern science. They include the empirical approach based upon objective, rational observation, and the use of mathematics to describe nature. The two criteria for the dynamic entity of scientific truth, either one of which is generally sufficient to cause persons to accept a principle, are first, that it can be checked by observation in a manner in which its consequences lead to its support rather than to contradictions; and second, it can be derived from intelligible principles (Fischer, 49). These principles laid the groundwork for modern scientific methods of inquiry and were forcefully argued by Rene' Descartes, the philosopher, and Francis Bacon, the theologian (Capra 15-120). This new approach also included the process of generalization, explanation, and prediction, or what can be thought of in modern terms as the *hypothesis*, *theory*, and *law*.

A *hypothesis* is a tentative assumption made in order to test its scientific consequences, but which as yet has received little verification or confirmation. A *theory* is a plausible, scientifically acceptable statement of a general principle and is used to explain phenomena. A *law* is a statement of an orderliness or interrelationship of phenomena that, as far as is known, is invariable under the stated conditions (Fischer 47). It should be stressed that the term law is used differently in reference to scientific knowledge than to other areas of everyday life. A scientific law is descriptive rather than prescriptive. It is a statement used to describe regularities found in nature, and is not a statement of what should happen. It is not correct to consider that natural objects obey the laws of nature; rather, the laws of nature describe the observed behavior of natural objects. In contrast, the laws of a human government are prescriptive in that they prescribe how people should behave.

Another guiding principle of science is its supranationality -- its inherent right to transcend national boundaries and allow scientists throughout the world to verify experimental results, challenge, theories, and allow technology to leverage new scientific discoveries.

[iv] James Burke presented a good summary of the ways in which technologists experience the effects of economics and human values in his book, Connections. Burke designates six major initiators of technical innovation. They are: deliberate invention, accidents, spin-offs, war, religion, and the environment.

First, as one might expect, technical innovation occurs as a result of deliberate attempts to develop it. When inventors like Lewis Howard Latimer and Thomas Edison began work on the incandescent bulb, it was done in response to the inadequacy of the arc light. All the means were available: a vacuum pump to evacuate the bulb, electric current, the filament which the arc light used, and carbon for the filament. With these components the remainder of the required work was the synthesis of technologies toward a definite goal --the light bulb's creation.

A second factor that frequently occurs is that an attempt to find one thing leads to the discovery of another. For example, William Perkin, searching for an artificial form of quinine, used some of the molecular combinations available in coal tar and accidentally found that the black sludge produced by one of his experiments turned out to be the first artificial aniline dye.

Unrelated developments have decisive effects on the primary event. An example of such spin-off developments can be seen by the development of paper. The medieval textile revolution, which was based upon the use of the spinning wheel and the horizontal loom, lowered the price of linen to the point where enough of it became available in rag form to revolutionize the paper industry. Burke discusses other examples of how unforeseen circumstances play a leading role in technical innovation. This includes the stimulation of mining activities for metals to make cannons when Chinese gunpowder was exported to

Europe and the development of a barometer as a result of frequent flooding of mines and the failure of pumps.

The fourth and fifth factors are all too familiar: war and religion. The need to find more effective means of defense (or offense) has driven technology from the most ancient of times. The use of the cannon led to defensive architectural developments that made use of astronomical instruments. As previously discussed, ancient Mesopotamian, Egyptian and Mesoamerican religious beliefs led to great strides in engineering and architecture and the Islamic world fostered advanced astronomy because of the need to pray, feast and fast at specific times.

Finally, physical and climatic conditions play important roles. For example, the extreme changes in Europe's winters in the 12th and 13th centuries provided urgent need for more efficient heating. The chimney filled the need and had a profound effect on the cultural life of that continent.