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Introduction

Technology is typically defined by the following sentence. "The integrated system of knowledge, skills, tools, and methods developed within or used by a *culture* to successfully carry purposeful and productive tasks." [1] Although many scholars date the advent of continuous technology and related scientific applications to early modern times, the groundwork was laid well before the modern period in 1400 C.E. [2]

This paper will focus on the role of technology and related applications of science that occurred in the world island of Eurasia (specifically in the Middle East, China, India, and Europe) with occasional reference to areas outside of the world island before this period.

Ancient Times—Adjustment and Accommodation with Nature and the Environment

Ancient history is usually dated from 8000 to 500 B.C.E. The products taken from the natural world subdivide the period. The Neolithic period begins in the first date wherein the tools that were used came directly from the environment—usually stone which gave its name Neolithic or new Stone Age to the period. In the latter half of the period, copper began to be used. When it was combined with other metals (chiefly tin), the Bronze Age began. Bronze was more durable than stone and was suited for a wide variety of uses. After 1500 B.C.E., iron gradually replaced bronze throughout the world.[3]

If the technological conversion of raw materials gave its name to an age, it also forwarded trade since metals unlike stone were not available everyone. Therefore, some degree of specialization was required to trade products (usually farm produce) for the desired metals. Trading places were established, then markets, and then cities which grew up around them, then recognizable states when cities combined for protection. Most historical states were based on trade and fertility of soil that produced food (agricultural) to grow and led to a settled society as opposed to hunting and gathering.

Therefore, environments that started the process were usually river valleys such as the Tigris-Euphrates valley in Mesopotamia (land between two rivers) and its extension westward to the Jordan River as part of the overall Fertile Crescent. [4]

Technological development was advanced in the last part of the period as iron produced iron weapons as well as iron tools, so that there were both craftsmen and soldiers who now became prominent. Iron hoes and later the iron plow competed with iron weapons as the exemplars of society at this time. This led to both expansions of populations due to greater farming output as well as military expansion. A classic example was the spread of Bantuspeaking populations from their original home in northern Cameroon/Nigeria (Nok) throughout much of central and southern Africa after 500 B.C.E.

Iron had also been produced in the present-day republic of Sudan and also spread southward to what is now Ethiopia, which helped that country in later centuries preserve its independence from Muslim attacks.[5]

Technology, especially the use of metallurgy in China, for example, allowed the Han Chinese to expand from their northern nucleus around the Hwang-Ho or Yellow River southward. Overall, the environment was important in ancient times and societies organized through dams and irrigation works to avoid extremes of too much and too little water.

This age saw the beginning of technological use and a sociological subsystem as societies were organized into farmers, craftsmen, soldiers and related occupations derived from nature such as fishing and animal husbandry (developed in India to a 4-part caste system with occupational sub-castes by 1000 B.C.E.) [6] and as the agricultural revolution included the domestication of animals especially, along with the plow and eventually the concept of the wheel. However, the ideological system was unchanging.

Nature and the deities that represented it were unknown, unknowable, and objects of fear and veneration. Societies had deities which represented the sun and water among other natural elements, since society depended upon the benevolence of nature. The natural world was linked to the supernatural through ancestors who had passed and joined nature in the next world. These gods and their ancestral links were accordingly worshipped. In this manner, the pharaoh of Egypt was a representative of supernatural deities as a god on earth. Egypt, actually the upper Nile River Valley, was a theocratic socialist society as land was held in the Pharaoh's name, and he issued commercial licenses in his name.[7] The major constructional enterprises were in the building of tombs or pyramids to ensure the afterlife of the monarch.

In the Mesopotamian city-states, the central building was the temple or ziggurat.[7] The settled societies in the Americas such as the Olmec and the Mississippian also had religious buildings as the center of their cities.[8] In China, dynasties received the mandate of heaven. If through wrongful action they injured their subjects, the mandate of heaven was withdrawn and the dynasty came to an end.[9] The later Hindu trinity of gods of creation, preservation, and "creative" destruction as well as the pantheistic belief that divinity lies in nature dates from Indus River Valley civilization, while the later devotional works (the Vedas) are attached to the Aryan or Indo-European arrivals and date from 1500 to 500 B.C.E. as the center of Indian culture moved eastward to the Ganges plain. Monotheism was only practiced by a small people, the Hebrews, and during one brief period in Egypt.[10]

The specific developments in regard to the applied use of technology had direct links to the sociological and ideological aspects of society as new segments arrived. In global societies, increased interaction that began during this period led to increased segmentation in the society undergoing technological change. The simple small-scale nomadic life of hunter-gatherers gave way to more complex socio-economic patterns as new methods of production led to a specialization of labor. This ultimately led to an exchange of goods and services that necessitated places where this trade could take place, or urban centers. Technology intermingled with religion as the use of improved tools still depended on the abundance of natural elements – the sun, water, etc. – that provided the raw materials in a society dependent on the elements for agricultural bounties (even with improved tools) and whose representatives had to be placated.

The technical expertise which produced irrigation works and dams meant to mitigate the excesses of too much and too little water, for instance, also somewhat paradoxically made the societies that used them feel more dependent upon the raw material in these hydraulic-based societies. They continued to believe that the natural world which furnished these raw materials was governed by the extra-natural world dominated by deities which must be propitiated. Innovation in technology thus was not isolated from other sectors of culture and society.

The Classical Period: Observation of Nature and New Methods

The classical period -- which dates from approximately 500 B.C.E. to 500 C.E. -- saw the emergence of cultural patterns which have become characteristic of societies to this day. Some scholars have termed this age "the axial age," as many of the great religions or theological concepts emerged at this time or soon after.

Buddhism and Christianity emerged, high Brahmanism led to Hinduism in its final form, and Islam emerged a century later. Confucianism and Daoism became dominant ideologies in China. It was an age which saw the emergence of great empires. Quite often, technological as well as scientific research were results of the emerging Chinese (Han), Indian (Mauryan, Gupta) and Mediterranean (Hellenistic states and Roman Empire) population centers with specific state needs. The noted scholar Dr. Joseph Needham in his *Science and Civilization in China* series noted advancements during the Han Dynasty such as the start of systematic study in botany and zoology, as well as work in astronomy and calendar calculation. There was even a rather abortive attempt at a rational analysis of science.[11]

The Han ruled from approximately 200 B.C.E. to 200 C.E. and came to power just after the short lived Ch'in dynasty which united the country. They were in control except for a very short period in the middle of their rule that facilitated change The technological developments were meant to be practical. Seismography was meant to measure and predict earthquakes—a wise invention since natural disasters often presaged a change of dynasty.[12] Iron was developed and used as elsewhere for tools, utensils, and weapons.[13] A paper making process that produced goods for export along with silk and other textile goods via the process of spinning and weaving developed in the pre-Han period. [14] The water wheel and water clock were developed for agriculture [15] and China became famous for its ceramics and porcelain products which could be used for containers and domestic use. [16] By the end of the period, the Great Silk Road (named after the most famous Chinese product traded) began in China and included many Chinese finished products; it became the major overland link between China, the Mediterranean, and parts in-between.[17] As a result, urban centers already extant at the beginning of the period multiplied, as did the existing classes already associated with urbanization such as tradesmen, weavers, and iron workers.[18]

India also applied scientific concepts in technology. During the Mauryan and Gupta eras between 300 B.C.E and 500 C.E., with an interregnum of about three centuries in-between, they also developed iron and textile industries based on scientific breakthroughs.[19] In order to help farmers, they used astronomy to calculate both lunar and solar years.[20] As in the case of China, they used the availability of iron and other applied aspects of metallurgy to strengthen roads.[21]

It was in the mathematical sciences that India made its most lasting contribution in applied technology. In addition to the application of astronomy mentioned previously in terms of plotting the seasons for agricultural purposes, India developed coinage based on weights and measures for trading purposes.[22] It also developed the concept of zero as well as the decimal system –although the use of the latter does date back to the Babylonians. India developed it further for practical purposes. The rudiments of algebra were imported from India via the Middle East as were aspects of geometry. The most long-lasting achievement from India during this period was in the creation of ordinal numbers of 1 to 9. Originally called Indian numerals, when transferred to the Middle East and then to Europe, it became Arabic numbers and is the basis for numeracy today.[22] These imports from India had an enormous effect on commerce and business particularly, as they replaced the cumbersome Roman numeral system and made transactions such as double-entry book-keeping much easier.[23]

It was the Greeks, or Hellenes as they termed themselves, who made the greatest shift in scientific thought in the classical period. They were the first to observe nature on a systematic basis. Even before the start of the classical period, Pythagoras had developed the basic geometric notion of the right triangle.

Afterward, Anaxagoras studied the eclipse of the sun and the moon; Theophrastus wrote on features of plants and animals; Thales of Miletus wrote on the atom; Aristarchus observed that the earth rotated on its axis and revolved around the sun; and Eratosthenes calculated that the world was round and the distance between the sun and the earth. Hippocrates developed the medical oath which is still administered today.[24]

The major philosophers who were to dominate the succeeding Middle Ages, Plato and Aristotle, brought a new perspective to what is science. Although Plato claimed that the natural or material world was composed of a mere reflection of eternal unchanging forms which are the true reality (the famous allegory of the cave), he did bring reasoning to his observations and considered mathematics with its abstract figures as the central discipline.[25]

But it was Aristotle who was the first world-famous natural scientist. Although he agreed that there was a central eternal truth, he maintained that the material world constituted reality for the individual. He spent a lifetime in observation of natural sciences and developed a system of reasoning based on use of the inductive method of individual observation and experimentation followed by general conclusions based on deduction—the building blocks of the future scientific method. He further maintained that the world is in flux and we cannot make eternal generalization based on the ever-changing material world.[26]

The succeeding Hellenistic and Roman periods, 320 B.C.E. to 27 C.E., and 300 B.C.E. to 476 C.E., respectively, put to practical use the ideas developed by the Greeks. Archimedes laid the basis of pre-Newtonian physics with its applied aspect of motion and Euclid, a founding father of geometry, applied his findings to levers and pulleys. Other Hellenistic applications included the Greek form of architecture based on human needs not on the metaphysical world, and with graceful columns in perfect symmetry which are universally recognized today.[27] The Hellenistic rulers of Egypt went even further as they built the largest library and museum of the known world at that time.[28] One unfortunate result was the tenet that the earth was the center of the universe, which was to dominate Western thinking for fifteen centuries.[29]

The Romans were the engineers and architects of the classical age as they built a whole series of public buildings in the Greek style throughout their empire. They were famous for their roads, bridges, and aqueducts – some of which are in use today.[30] Science writing tended to be classifications of previous Greek writings. Galen, a Roman citizen of Greek extraction, compiled known writings of anatomy and physiology. Pliny collected Greek descriptions of the physical to write an encyclopedic book that described the known world.[31]

The Classical period brought changes to the socio-economic roles identified with large-scale empires such as the Han, Mauryan, Gupta, Hellenistic, and Roman Empires (also the Persian Empire, which developed an international phalanx of administrators) through employment of engineers, architects, scientists, educators, and administrators to serve the needs of empire, as well as craftsmen and artisans who produced goods for these large-scale empires.

Facets of cultures reflected the emerging technological and economic innovations including ideology. Classical Hinduism, for example, connected the spiritual aspects of Brahmanism in terms of the creator deity, Brahma, and his various parts with the caste divisions which were used to justify the emerging economic order. The Brahmins, the scholarly priestly class represented the often technically trained individuals versed in Classical Sanskrit who were the bureaucrats in the Mauryan and Gupta empires as well as in the regional states in the Deccan and the South. They were said to represent the spiritual head of the creator deity. The Kshatriya or warrior caste represented the heart of the deity, and they used advanced weaponry composed of iron tools as well as the traditional cavalry. The loins which dealt with worldly concerns were represented by the commercial and artisan classes (Vaishya). The feet which supported the other elements were the sudras or peasants. As technology developed and called for specialized skills, sub-castes or the jati system appeared whereby occupational groups such as spinners and weavers came underneath the overall Vaishya caste.

Chinese philosophy in its various forms, especially Daoism (or Taoism) and Confucianism, emphasized harmony among the elements of the universe, nature, and the universe in search of order. In the realm of worldly affairs, this harmony was interpreted as the selection of individuals of high intelligence and ability who could enforce this cosmic order. These individuals would be revealed through a series of written examinations that included religious and philosophical knowledge. Those few who passed became an aristocracy of merit or mandarin class of wealth and influence sanctioned by Chinese spiritual underpinnings.[33]

The Greeks married the Hebrew concept of the high God or Yahweh (later Jehovah) to the Platonic ideal of universal forms that were reflected in everyday life. Thus, for instance, the form of justice would be mirrored by a just government. The rational system of the good based on the deductive ideas of Plato and the inductive observations of Aristotle was transformed from good to god as Greek rationalism was added to Hebraic faith so that natural philosophy became the term for science until the fifteenth century. [34] This fusion passed to the Hellenistic and Roman empires and then to their successors in the Middle East and Europe.

The Medieval World – 500 - 1400: Consolidation and Synthesis

This long period was characterized by the building upon what had gone on before. China under the Tang, Song, and Yuan dynasties developed earlier ideas to create the compass, gunpowder, an early version of napalm, and movable print. These inventions were to be fully realized elsewhere. Nonetheless, the Chinese did develop a considerable array of astronomical instruments. Labor-saving devices were started, such as the watermill and wheelbarrow.[35] India, which lacked a central dynasty until 1526, tended to develop products that could be sold via the Indian Ocean and the Great Silk Road such as refined sugar, spun textiles, and indigo dye. They had developed advanced medical technical practices such as surgery, which found its way to the world.[36]

During this period, Europe retreated from the classical heritage and elevated faith over reason as the source of all knowledge. The Catholic (Universal) Church combined Platonic teachings with the idea of a high god from the Hebrews via Christians. In fact, Plato’s form of good as the greatest of forms had been converted to god. Knowledge including scientific theory and technology was available through unquestioned faith, not through reason. The material world would inevitably decay but the eternal truth lay not in the environment but in the heavens or not in the physical world but in the metaphysical world beyond the senses. Life on earth, including the environment, was transient but beyond the human sphere it was eternal. [37] The hereafter, not the here and now, was to be cherished. As most of the scholars and educators were churchmen, it was an easy equation.

A more conducive environment for the development of science and technology came with the arrival of Greek texts, especially Aristotle, which re-emerged via the Muslim-occupied Iberian Peninsula and Southwest Asia by 1200. The Muslims had salvaged and translated classical texts and they were one reason that this period was called the Golden Age of Islam.

With the availability of these texts, the dominant view that faith in Holy Scriptures came before rational inquiry and was superior to an empirical examination of the environment was challenged. This challenge came to be called scholasticism.[38] The High Middle Ages saw a group of churchmen such Abelard, Ockham, and especially the greatest scholar of the age, Thomas Aquinas, who argued that reason could be used. They attempted to synthesize classical and Christian learning. They still used faith as superior to reason but argued that reason, especially that proceeding from the empirical observation of nature and from logic, was compatible with the eternal truths that revelation brings. Human reason was the servant of faith and was part of the understanding of god. [39]

Within Christendom, there was a break between the Catholic West and the Orthodox East but both put their beliefs into elaborate architecture in magnificent structures which were meant to signify their allegiance to the Almighty. Based on Roman architecture, the churches and cathedrals were first called Romanesque then Gothic in the west; in the east, they were designated as part of Byzantine architecture.[40]

The Golden Age of Islam occurred between approximately 800 and 1200 C.E. For these four centuries, Muslim culture including scientific endeavor was probably the most vibrant in the world. This Golden Age was a perfect example of how a synthesis of two cultures (in this case Greek and Indian) could enrich the recipient culture.

Geographically, the Islamic world was perfectly positioned to take advantage of more than one culture as it stretched from the Atlantic Ocean to Central Asia. It was itself influenced by a number of strains: Arab with an admixture of Persian, and Byzantine Greek. As it spread, it came into contact with other cultures—Turkish in central Asia and then Anatolia; South Asian/Indian and Malay/ Southeast Asian. As it expanded west, there were Berber influences in North Africa and Roman/Gothic influences in the Iberian Peninsula.

Quite often, synthesis involved syncretism between local culture and imported Muslim culture. The Swahili culture, for example, combined local primarily Bantu customs with imported Muslim ideas. Geographically, the central Muslim lands of Syria and Egypt had been centers of Hellenistic Greek culture; after 750 as the caliphs or religious heads of Islam, who often also had political power, established their capital at Baghdad, Indian and Persian influence became greater.[41]

The Golden Age would not have been so golden if there had not been official support between the 9th and 13th centuries. Early in the 9th century, the Bayt al-Hikma or House of Wisdom was established to translate foreign texts especially from Greek.[42] At first, the goal was practical. Greek (including Aristotle's writings) texts on medicine (as well as Indian texts) on medicine and pharmacology were imported to maintain the health of the elite. There was the medieval quest to turn base metal into gold so that the elite eagerly translated works on Alchemy.[43]

The greatest and most lasting work, as indicated earlier, was in mathematics. The Arabs imported Indian numerals which, when introduced to Europe, were called Arabic numbers. The concept of zero as well as decimals was borrowed from India, as well as the notion of linear and quadratic equations which form the basis of elementary geometry. Algebra – an Arabic word originally—was introduced to Europe via the Middle East. The abstract concepts of mathematics had a practical side, as they could be used for banking, bookkeeping, and probate issues. [44]

The translation of Greek and Latin works introduced rationalism as a philosophical strain by the 10th century when Arabic itself became the language of philosophical and scientific inquiry. Well in advance of the scholastics, Muslims argued for the use of reason as well as faith in addressing worldly problems and in the search for knowledge. Some even went so far as to maintain that reason was superior to revelation. The scientists of the golden age not only translated classical works but did pioneering work in epidemiology in areas such as measles and smallpox. The comprehensive *Canon of Medicine* was used in European medical schools as late as the 17th century. Other scholars did work in physics and astronomy, with treatises on light refraction and reflection, the radius of the earth, the calculation of the solar year, as well as mathematic adjustments to astronomy. When classical theories were reintroduced to Europe, it was often through the translation of Arabic into Latin.

Even when the golden age had passed after 1200, the Muslim world with an earlier tradition of rationalism was more advanced than Europe in areas of astronomy (until the 16th century) and thus was more accepting of the Copernican theory of the solar system being sun-centered rather than earth-centered than both Catholics and Protestants who often looked upon this theory as a refutation of their own theology.[45]

China

China, located at both the beginning and end of the major trading land route, the Great Silk Road, and newly expanded to the Indian Ocean with ports located on its south, had been a center of technological developments for much of its history. As early as 3500 B.C.E., the people of what became China had been producing silk. By 1000, they had begun a tradition of bronze-casting and ceramics that were used to decorate tombs of rulers and the nobility. Even before the Middle Ages began around 500 C.E., they were using various media such as gold, jade, and lacquerware for various products such as urns and tools.[46] Not long before this period, which is often called their classical period because of its influence on Chinese culture (The Han Era of 210 B.C. to 220 C.E), the Chinese had developed a cartography tradition for use in travel and had produced a seismograph to warn of the ever present danger of earthquakes; the crossbow for military purposes; and the horse collar and wheel barrow for agricultural purposes.[47]

These advances in technology led to economic advances which stimulated trade that began in earnest during this period. While the Chinese imported from the West such items as wool, linen, and silver, the West, beginning with the Romans, desired gems, spices, and above all, Chinese silk which gave its name to the whole trading network.[48]

One of the enduring mysteries about Chinese technology is that while China developed many inventions first, other regions made greater use of them through the widespread use of Chinese inventions, whether it was gunpowder combined with ordnance in Europe and the Islamic World or movable print combined with the printing press. The prevailing Chinese philosophies of Confucianism and Daoism, which emphasized individual harmony in accordance with nature, may have acted as a barrier to scientific and technological applications which emphasize the use of nature and the environment to produce a desired result.

Confucius stressed conformity to tradition while Daoism put the emphasis on tranquility with the understanding that follows the unity inherent in nature. The net effect was to discourage the experimentation and empiricism that are part of scientific applications and technology.[49]

In spite of the previously mentioned inhibiting factors, China during this period did build upon previous efforts of the Han Dynasty with the goal being the application of principles found in nature to the production of labor-saving devices. To this purpose, the watermill was developed not only to provide power for machinery but to grind tea leaves. Other efficient inventions extended some of the previous innovations of the Han period such as the foot stirrup and stem-post rudder.[50] The Chinese, perhaps independently perhaps borrowing from India, began iron and steel casting.

These innovations were adopted in a basically orderly society. Even during moments of weakness that presaged the decline of the long-lived Tang Dynasty (618-906) and the Song Dynasty (960-1279), China was governed by a bureaucratic class (the mandarin system) selected on the basis of examinations derived from traditional texts on conduct, religion, history, and religion including the teachings of Confucius. This system was instituted in 605 and was to last until 1905. The examinations never changed but held the country

together. At the same time, it was not a system that encouraged the innovations associated with applications of science and use of technology. [51]
Whatever the climate of the times, it is clear that the four greatest inventions of this time were built upon earlier developments. These were the compass, printing, papermaking, and gunpowder. All of these breakthroughs had made an earlier appearance, but were put into operation during the Tang and Song periods.

They had immediate practical uses. The compass was useful for river and ocean navigation, papermaking as a means of communication, printing for mass dissemination of information, and gunpowder and "Greek fire" (an early form of napalm) for the same purpose.

Nevertheless, the Chinese never made full use of these breakthroughs.

- Although the Chinese did use the compass to locate the magnetic North Pole in their astronomical work, long-term use of the compass and their early version of the astrolabe really occurred widely only early in their brief period of exploration in the early 15th century.
- Paper was not widely used for printing as the Chinese became famous for the aesthetic value of their calligraphy imprinted on both paper and ceramics.
- The number of Chinese characters—by some calculations 1,500 in number—made movable type impractical so that it was not until Gutenberg in the 15th century that there developed a machine for movable type.
- Gunpowder was used (as was Greek Fire) for firearms but mostly for fireworks or explosives.[52] It took the Europeans and the Muslim world to make use of gunpowder in conjunction with the appearance of new ordnance such as cannon and muskets at the end of the period with their use by the Iberians in the Americas and by the appearance of the "Gunpowder Empires" centered on the Muslim empires of the Ottomans, Safavids, and Moghuls.

Essentially Chinese applications had two uses during the period: practical uses and export potential so as to bring in specie. Under the first category were matches, the double-action piston pump, the iron plough, the horse collar, the multi-tube seed drill, the suspension bridge, the parachute, natural gas as a fuel, the raised-relief map, the sluice gate, and the pound lock. Under the second category—export potential-- came currency.[53]

Trade flourished both within China and overseas, and the encouragement of technology led to breakthroughs in currency as mints were set up in the cities of Kaifeng and Hangzhou. They gradually increased production so that by 1080, the mints produced five billion coins (roughly 50 per Chinese citizen). In addition, the first banknotes were produced in 1023. These coins were so durable that they would still be in use 700 years later, in the eighteenth century.[54]

As a result, in spite of silver and gold from America, after 1500, China still had the largest supply of specie in the globe. During this period, China also became the world's leading exporter on the basis of its desirable goods, which made it the largest holder of wealth (as well as population) until 1700. It became especially notable for its luxury goods. Its preeminence in woven silk produce which gave the name to the largest trade outlet at this time was joined by other products of the loom and wheel such as wool, cotton, and linen.

It made progress in turning its long-sought ceramics – through a technology which glazed through high heat and imparted colors that were impervious to water – into a new product of porcelain which soon equaled the demand for silk on a global basis. The various objects made of porcelain, such as bowls and utensils, became so dominant in the marketplace that the generic term "china," usually coupled with the adjective "fine," dominated the world marketplace. Chinese porcelains, silks and other woven textiles which were based on technology (along with spices, carved ivory and lacquerware itself produced through applied science) ensured China a favorable balance of trade long after its Middle Ages had come to a close. [55]

The period of medieval innovation and invention gradually declined after 1279, when the native Song Dynasty was overthrown by the Mongol Yuan Dynasty. This foreign dynasty was more involved with adapting to Chinese culture than in embarking upon any new uses of applied science and technology of its own. It was replaced by the native Ming Dynasty in 1368. This dynasty except for its global expeditions in the Indian Ocean and to Africa in the early 15th century was basically inward looking and conservative.[56] As a result, innovations and inventions that involved scientific and technological applications were not encouraged.

India

After 500, except for a brief period in the early 7th century, India lacked a central government which might encourage science and technology. However, it had a number of flourishing regional states where such applications of science and technology were encouraged. In addition, its caste system gave a high place to the Brahmin scholar caste, which included mathematicians and scientists as part of the learned elite. The sub-continent's location athwart both the great Silk Road and the Indian Ocean encouraged trade, which in turn encouraged the development of new products.

Culturally, India, through the extension of both Buddhist and Hindu culture, vied with China for influence in Southeast Asia. It also directly joined the World of Islam, which in fact occupied portions of the sub-continent during this period and, as has been seen, was influenced by it.

As recounted earlier, Indian innovations in mathematics were translated to the Middle East and then to Europe and applied to business with a resultant stimulus to commerce.[58] Mathematical discoveries in northern India and later in Kerala which explored the concept of *pi* were applied to astronomical observations. The Kerala School of mathematics revised the discoveries of the great Indian mathematician Aryabhata in the late fifth century to accurately trace the paths of Venus and Mercury around the Sun well before Kepler. [59] (In passing it should also be noted that the nature of the atom was explored by Buddhist scholars just before this time). [60]

On a more practical level, Indian chemists developed the world famous dye indigo and exported it globally. They were pioneers in cotton textiles. The origins of the spinning wheel may have been in India, among other places. The device certainly reached Europe from India by the 14th century. The cotton gin was invented in India as a mechanical device known as charkha, the "wooden-worm-worked roller." [61]

India was active in metallurgy. It was the first to produce wootz, a form of steel. It was also active in the extraction of metals such as zinc, which was used for both manufacturing and medical purposes. During this period diamonds were produced and exported.[62] Another luxury product that was the product of applied science and technology during this period was the refining of sugar. Candied sugar was also refined in India at this time for those who had a sweet tooth and as an aid to dentistry.[63] Kashmir produced the world-famous Cashmere wool during this period with its most famous item being the Cashmere shawl. Jute from what is now Bengal was also produced. The final product of Muslin, although identified with the city of Mosul in Iraq, was actually produced in Dhaka in what is now the republic of Bangladesh (formerly east Bengal).[64]

Other technological advancements at this time included the diffusion of Indian and Persian irrigation technologies, which gave rise to an advanced irrigation system, thus bringing about significant economic growth. It was particularly vital to the rise of the Cashmere wool industry.

New techniques made possible varieties of glass molding and decoration for Indian products that were exported.[65] As was the case for China, gunpowder and naphtha were used for fireworks and after this period, the province of Gujarat exported saltpeter for gunpowder to Europe. However, the full use of firearms was delayed until the arrival of the Moghuls in 1526. India also produced silver and gold coins in northern and southern India respectively.[66] Indo-Islamic architecture, which combined indigenous Indian patterns with Muslim influences, also developed.

Islamic architecture was highly diverse by culture and climate and can be typically marked for its love of geometrical pattern, arabesque ornamentation and innovative patterns. There were variations among different regions. However, it still stands as an example of a synthesis of different styles built upon previous foundations as represented by mosques, tombs, forts, and palaces. [67]

India was fortunate in that after the unification of northern and central India with the coming of the Moghuls in 1526 many of the applied scientific and technological developments were continued. In fact, for another century and a half many of them were extended. This trend was especially true in the areas of metallurgy, textiles, architecture, and gunpowder. Only with the encroachment of outside European powers such as the

Portuguese, Dutch, French, and English did India as a center of scientific and technological applications decline, as Moghul power gradually disintegrated.

Even then, many Indian technological innovations were transmitted through these same powers to Europe. A number of Indian industries, however, did last longer, such as Indian cottons, Cashmere wool, and Bengal jute and muslin, until they were overwhelmed by machine-made products of the British Industrial Revolution during the course of the nineteenth century (although somewhat ironically the names still exist, such as Cashmere sweaters and Muslin dresses even if not entirely or mostly made in India, so powerful is the brand name and heritage.)[68]

Europe

If there is one area that is characteristic of synthesis and consolidation in the Middle Ages it is Europe, which blended classical traditions, Germanic customs, and the Christian heritage in its overall culture, including applied science and technology. Often, the early part of the Middle Ages in Europe is depicted as the "Dark Ages" for learning, including the uses of science and technology. In fact, this is a relative term. It is true that a period of disorganization set in after the collapse of the Roman Empire at the end of the 5th century and Europe continued to be unsettled by a series of invasions and migrations through the 10th century.

However, there were always exceptions. The Byzantine Empire centered in the southeastern part of Europe (and often called the East Roman Empire) continued in some ways both the Latin and Greek heritage and ultimately helped to convert the Balkan Peninsula and Russia to the Eastern Orthodox version of Christianity, as well using the Greek alphabet to transliterate Slavic languages just as Latin was used for both the Romance and Germanic languages in western and central Europe.

Roman influences did remain in parts of Spain, especially on the Mediterranean coast and much of southeastern Gaul (France). Much of Italy, except for the northern and north-central parts, had remnants of Roman culture. The Roman heritage also brought the Catholic heritage with it, so that German invading tribes after some initial divergences centered on Arianism adopted the Catholic tradition. [69]

There were also glimmers of "light" in these Dark Ages. Charlemagne established the Carolingian empire over France and much of Germany and Italy briefly in the late 8th and early 9th century and attempted to reinstitute the Roman tradition with a German overlay but this "Carolingian Renaissance" was brief. A similar Renaissance in Anglo-Saxon England under Mercian hegemony in the eighth century was also brief. Even on the fringes of western Europe, which had never been formally Romanized or Christianized, the "Celtic Renaissance" centered on Ireland and Wales was brief, as these areas joined the orthodox version or Roman Catholic version, and the latter prevailed.

The early Middle Ages (500-1000) is considered "dark" because other areas of the globe—the Islamic world, China, and India—were undergoing periods of enlightenment in which new information including technological and scientific thought was coming forth. In addition, unlike much of Europe which had lapsed somewhat into rural isolation and lacked the critical mass of urban centers that were always centers of information and innovation, other areas of the globes had thriving urban centers.

Finally, the tradition of higher learning had lapsed so that officially there were no formally recognized 'universities' in this period and therefore what passed for higher learning took place in monasteries (often in basements) and cathedral schools. [70] Myths or rather shibboleths have grown up in regard to the acceptance of science information and its uses. Due to the preeminence of church teaching, any theories which challenged church beliefs regarded as dogma could be derogated and its proponents might suffer consequences in this world—and the next!

Some claim that church propositions could never be challenged in regard to nature. Thus, it is maintained that church intellectuals and their followers held that the earth was flat and to argue otherwise was heresy. In fact, this was never central to church belief. Beginning with Boethius, scientists argued (often quoting Aristotle) that the earth was spherical (some of Aristotle's writings were available even at this time, as were those of other classical writers). Less challenged but not unquestioned was the geocentric theory that the earth not the sun was the center of the universe (or the Heliocentric theory). Again, classical writings based on observations cast doubt on this as did later scholasticists who coupled observations with logic and reason.

Thinkers such as Abelard, Ockham, and Thomas Aquinas intimated that there were grounds to question the geocentric theory but did not directly refute it. It took Copernicus on his deathbed to affirm what had become obvious if not spoken in the minds of many people. The Protestant Reformation made it easier for northern European writers such as Kepler and Brahe to put forth their views on planetary information as well as other writers on science such as Pascal in later times.[71]

In addition, throughout the period, although the presentation of technological and scientific breakthroughs did accelerate after 1000, there were new developments in Europe. These developments can be divided into three categories: early technological innovations which existed throughout the period, internal European innovations, and external scientific and technological applications that were made more effective after arrival in Europe.

The watermill, although in existence elsewhere, was resident in Europe throughout the period. The uses of hydraulic power were manifold. In mining, it multiplied the sources of energy. It could be used for sawmills and timber mills on the same principles. Its major usage was in farming where it was much more efficient in growing more crops on less land with greater efficiency and in less time. Other applications in farming were the cutting of weeds and the increasing of drainage.

Also present throughout the period were stirrups, which made a difference in warfare as they allowed more mobility in close cavalry engagements. Found throughout the period, if available elsewhere earlier, was the iron plough whose strength and flexibility in agriculture was evident in Europe as elsewhere. [72]

Many technological and scientific applications appear to have originated or made their first appearance in Europe. Spectacles, for instance, were in existence by 1300 in Europe. With the growth of towns and universities after 1000 C.E. people often worked into the night so that this application of the refraction of light was very valuable. Also making their appearance during the "High Middle Ages" (ca. 1000-1300) were the mechanical clock and the longbow. A magnetic clock had existed elsewhere, but it had been directed to astronomical calculation. This version of the clock standardized time and allowed individuals the opportunity to schedule their activities appropriately. The longbow also made its appearance during this period. The crossbow had been used elsewhere, but this weapon, which was first observed in use in Wales and then England, made use of both mathematics and physics and was the most effective weapon in terms of accuracy and efficiency. It proved very effective for the English during the earlier phases of the Hundred Years' War. [73]

The third category consisted of technological innovations elsewhere which received additional improvements in Europe as well as added usage. The religious crusades brought Europe directly in contact with the Islamic World for over a century which made easier the acquisition of improvements via practical applications such as "Arabic numbers." [74]

These improvements came in the later Middle Ages (1300-1400/25), which seems appropriate as they were related to sea navigation that was a hallmark of the transformational 15th century -- a century of exploration and related technological development which marks the division between medieval and early modern times. In this vein, ships using the lateen sail whose purpose was to sail for and against the wind were converted into a three or more sail ship called the caravel which could sail into the stormier Atlantic Ocean as opposed to the calmer Mediterranean Sea.[75] The rudder used for steering was strengthened with an iron attachment to the stern.[76] The compass which plotted direction to the north and south magnetic poles was converted from a "wet compass" to a "dry compass" without dependency upon a bowl of water so it could be used for land as well as navigation by sea, plus use for surveying.[77] Finally, the astrolabe, which measured sailing by latitude and for time by utilizing a ship's relationship to sun, moons, and the stars, was strengthened by using metal as the material, not wood, which might be affected by water. [78]

Obviously, later in the 15th century, the innovation of movable type and ordnance to go with gunpowder were revolutionary, but those developments belong to the next period of early modern times.

The one development in Europe which epitomized both synthesis and consolidation during this time in terms of synthesis and consolidation of classical, Christian, and Germanic influences was in medieval architecture, particularly church construction. Romanesque architecture followed the Roman model in terms of both form and material of stone. It had round arches, barrel vaults and cruciform floors which supported vaults.[79] It was succeeded after 1100 C.E. by Gothic architecture, which reflected the Germanic tendency towards verticality with skeletal stone structures in addition to pointed arches and clusters of columns. It was topped by sharply pointed spires and pinnacles. Its windows were of stained glass which showed biblical stories and illustrated lives of the saints.

The bulk of these structures demonstrated the primacy of the Universal Church since they were mostly cathedrals and churches. During this period, civic buildings and palaces exhibited these trends but the outstanding examples were clerical structures.[80] With the advent of the Renaissance and the new emphasis on the here and now instead of the hereafter, architecture became more secular and less dominated by religious symbolism.

The Medieval period witnessed the advent of global trade facilitated by new forms of technology. This development fostered the growth of cities. In turn, growing urban centers served as the incubator of discrete business and professional classes as well as further specialization in the occupational professions. When coupled with improved business practices previously covered, the basis of an emerging middle class was established.

Notes

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[8] Ibid., p.7.

[9] Ibid., p. 21 and Ibid., p. 25.

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[29] Buckley, chapter V.
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