

# Science and Math

## Agriculture

Agriculture is the science of cultivating soil, planting and harvesting crops. It can be argued that the mastery of agriculture was the single most important step towards creating a civilization, as agriculture allowed people to stop hunting and gathering and settle down in one place. Villages and cities would be unviable without some form of agriculture. Evidence of plant cultivation dates back as far as 6000 BC. Apparently, grains were some of the earliest crops cultivated. Grains are incredibly useful foodstuffs; they can be ground into flour and turned into bread, they can be fed to livestock and, perhaps most importantly, they can be stored for months without spoiling. Over time a number of important tools were invented to aid in cultivation and preparation of grains. The sickle was an early innovation; it allowed the grain to be harvested far quicker than by hand. Hand mills and mortar and pestles were created to grind the finished product, and pots to store it. As man learned about fertilization and irrigation, it became possible to get consistently larger yields, which lessened the chances of famine and increased the numbers that could be fed from each field.

## Animal Husbandry (Domestication)

Animal husbandry possibly started as early as 9000 BC with the domestication of dogs, goats and sheep. During the Neolithic period as people started to settle into fixed agricultural communities this domestication intensified. Originally kept mainly for their meat, sheep and goats became valuable also for their milk and wool. Cattle were domesticated both for meat and skin and as work animals for agriculture; their milk production was not a factor until much later in history when breeding for high milk production produced suitable cows. Horses were also domesticated and became important for transportation and came to play a major part in warfare.

## Aqueduct

A major obstacle to population growth and expansion in early cities was the scarcity of water. In many cases, the solution to this problem was an aqueduct. Aqueducts were large, elevated stone "canals" through which water from nearby hills and mountains was channeled into the city. Aqueducts allowed cities to grow much larger by significantly increasing the amount of available water. At the same time aqueducts reduced the chance of contracting water-borne diseases, by reducing the dependence on stagnant ponds and wells as water sources. Aqueducts also allowed cities to be built in normally inhospitable environments, such as deserts, by providing an outside water source. Modern day Los Angeles, for example, obtains its water supply from the Colorado River, through a system of aqueducts over 200 miles long.

(Roman) An aqueduct is a channel or pipe that carries water. In ancient times the water was carried from the source (a spring or well) to the destination (a city) by the power of gravity alone. Thus it was necessary that the source be higher than the destination, and

that the aqueduct's channel be straight and true, without major dips or kinks to obstruct the flow of water. Also, all seams had to be watertight to prevent leakage. Aqueducts were first employed in the Middle East by ancient Egyptians and Babylonians to supply their massive irrigations systems. However, the form was mastered in ancient Rome. The Roman engineers were the best that the world had yet seen; to quench the thirst of the growing city of Rome they constructed over 260 miles of waterworks, including many remarkable arched bridges to span valleys and rivers. By the first century AD, the complex of aqueducts provided the people of Rome over eighty million gallons of water per day! Many sections of the remarkable structures still stand today, some two millennia after their construction.

## **Astronomy**

Astronomy originated as simple observation and recording of regular celestial movements for the purpose of time keeping and determining directional bearings. The ancient Greeks were among the first to study astronomy in detail. They described the use of stars for navigation at sea, and recorded the position of constellations during each season of the year for purposes of determining times for planting and harvesting. The Greek astronomer Aristarchus developed the theory that celestial motion could be explained by the fact that the Earth revolved on its axis once every 24 hours, and revolves around the sun along with the other planets. This theory was rejected at the time, only to be rediscovered nearly 2000 years later by Copernicus. These early students of astronomy compiled data that became the cornerstone for modern astronomical research.

## **Bronze Working**

Evidence of the use of bronze, an alloy of copper and tin, dates back to Thailand in 4500 BC. Several hundred years later, bronze working was discovered in the Middle East. Artifacts from this period show that bronze was initially used for decorative purposes only. This is because tin was not readily available. It wasn't until approximately 2000 BC, when tin was regularly imported from neighboring regions, that bronze replaced copper in the construction of larger items. Bronze was harder and less brittle than copper, and it held a sharper edge. Tools, weapons, and armor made from bronze were also cheaper to produce and more durable. The period of time when bronze was the metal of choice for such items was known as the Bronze Age. The Bronze Age lasted until iron working became prevalent in approximately 1200 BC.

## **Calendar**

Calendars played an important role in the development of human culture. Their earliest uses may have been mystical - to chart the courses of the stars and to determine the most auspicious days upon which to perform religious sacrifices - but they were also critical for determining when the best time was to plant and harvest crops. All that is needed to create a calendar is careful observation and record-keeping. After watching the skies for a long time, one might notice that the days gradually get shorter and then longer, and that this process takes 365 days to repeat. This would give the length of a year - the great cycle of life on the planet. Further observations on the movement of the moon and stars would

provide further details. Perhaps the most difficult aspect of creating an accurate calendar is that a year takes 365 and a quarter days rather than exactly 365. If one does not take this into account (say, by the inclusion of an extra day every four years as currently), over the years one's calendar will get more and more out of date with the natural world. The earliest known Egyptian calendar was created in 4000 BC. The earliest known Sumerian calendar was invented around 1000 years later, and the first Chinese one was invented around 1400 BC. The Olmecs invented the first American calendar sometime between 1200 BC and 300 AD.

## **Castle**

In English, the French term "chateau" is often imperfectly translated as "castle." In common English usage "castle" denotes a complex of heavily-fortified stone buildings constructed during the Middle Ages. The stereotypical castle consists of a central building (or "keep") which stands in an open area surrounded by high walls, which in turn are surrounded by a ditch, or moat. A French chateau may have these features as well, but a better translation might be "manor house." At one time the word "chateau" was reserved to describe the feudal home of a member of the French royal house or other high nobility. The original design was based upon the Roman villas; as the empire fell and times became more dangerous, the villas' walls were heightened and eventually the entire structure was fortified. The French chateaux were often centers of art and culture in a region, as the nobility were the only ones who could afford artists and musicians and the like. Eventually life would become more peaceful in France and the chateaux lost their walls, moats and other fortifications. The dwellings of the nobility gradually transformed into large, sprawling homes filled with light and color. Although beautiful indeed, these buildings were quite undefendable, as the nobility discovered during the French Revolution.

## **Chemistry**

The earliest practical use of chemical processes was by metal smiths of the ancient world. These artisans learned how to use heat to melt various naturally occurring metals together to form alloys such as bronze. Early manufacturers of cloth also used primitive chemical processes to set dyes. In the following centuries, chemical processes were studied through the pseudo-science of alchemy, which attempted to change base metals into gold. Although alchemists were, of course, unsuccessful, they did develop many valuable chemical processes as a result. The manuscripts produced by alchemists were studied by succeeding generations, and an effective knowledge of chemistry had been accumulated by the late 13th century. In the 17th century, the ideas of alchemy finally died out as an increasing body of true chemical knowledge was gained through experimental analysis, leading to the modern science of chemistry.

## **Compass**

The ancient Greeks, Romans, and Chinese knew the phenomenon of magnetism. They observed that lodestone, an iron-bearing ore, attracted other iron. They also noted that pieces of iron that came into contact with lodestone gained magnetic properties as well. The electromagnetic force of attraction and repulsion between various substances is due to the

motion of positively and negatively charged electrons. Every magnet has positive and negative sides, called poles. Poles with a like charge repel one another, and poles with opposite charges attract one another. The study of magnetic phenomena soon showed that a free-floating magnet aligns itself with the Earth's magnetic field, one pole pointing north, the other south. This was an important discovery, and led to the invention of the compass in the early 13th century. The use of the compass revolutionized sea travel by reducing the reliance on landmarks and stars for navigation.

## **Education**

Education is the process of passing on the knowledge of previous generations to future ones. The impact of this simple process is not to be underestimated, and in a fundamental way permitted mankind to dominate the planet. Originally a privilege solely of males, it soon became a fundamental right in the United States. Schools of all types began to specialize in certain fields and/or student demographics, allowing people of all kinds the benefit of this wealth of information. Modern curriculums surprisingly cover many of the same subjects taught throughout history, such as literature, language, and mathematics.

## **Engineering**

Engineering is the application of scientific and mathematical principles to the design and/or manufacture of theoretical systems and physical objects. Prior to the mid-18th century, military engineers carried out all engineering functions. Their work involved the construction of roads, bridges, fortifications, and the performance of other duties relating to the military. In the late 18th century, civil engineers took over all non-military engineering functions. Other fields of engineering prior to the 20th century included mining engineers, who designed mines and methods of mining, and mechanical engineers, who dealt with the design and construction of machinery. As new technologies developed, new fields of engineering developed along with them. Today, there are engineers specifically trained in nearly every field, from electronics and computers to chemistry and atomics.

## **Forge**

A forge is a furnace where metal is heated or melted. In ancient times smiths with small forges could be found in most settlements. The furnaces were stoked with coal, which was fanned by manually pumped bellows to create intense heat. The blacksmith would heat the metal in the oven and then shape it by putting the metal on an anvil and beating it with heavy hammers. The finished product was then put into cold water to harden and cool. The smith might also melt the metal and pour it into molds. Modern forges are huge industrial structures requiring many workers to operate. The operation is similar to that in the smithy; except on a grand scale. Tons of ore are poured into massive vats, which are conveyed into the furnace. Once the metal is smelted, it may be mixed with other materials to create an alloy such as steel, and it may undergo a number of different processes to remove impurities. The finished metal can then be rolled into sheets, poured into molds, stamped into coins, and so forth.

## **Gunpowder**

Gunpowder is a chemical mixture of saltpeter, sulfur, and charcoal. When ignited, it burns rapidly and explodes if contained to any degree. Gunpowder is believed to have been developed by the Chinese, who used it in fireworks as early as the 9th century, but it did not reach Europe until the 14th century. Europeans immediately saw the potential of this substance, and manufactured it for use in weapons as early as 1334. The discovery of gunpowder led to the invention of firearms, such as the musket, which led to the replacement of archers in most armies of the world by the late 1500s. Gunpowder marked one of the major technological turning points in military history; significantly changing the way wars were fought.

## **Horseback Riding**

Tribesmen on the Asian steppes first domesticated the horse for transportation and warfare. These tribesmen used their superior mobility and speed to overwhelm the proto-civilizations just rising in southeast Europe and the Middle East. In approximately 2000 BC, domestic horses were introduced into Babylonia. Within the next several centuries, horses had spread throughout much of Europe and northern Africa. It was not long before nearly every civilization had put horses to work as field animals and as a means of transportation. Horses also went on to play an important role in the military conflicts of nearly every civilization in the world, both as mounts for horsemen and cavalry, and as draft animals for pulling war chariots and heavy weapons into battle.

## **Iron Working**

Some examples of iron ornamentation date back to 4000 BC, but the use of iron for tools, weapons, and other practical purposes did not become common until much later. Prior to this time, bronze was the most widely used metal for such purposes. Although the term "Iron Age" denotes a period of time starting around 1000 BC, iron replaced bronze as the metal of choice at different times in different places. Iron is more common than copper and tin, the component metals of bronze, but iron is seldom found in a free state; it is most commonly found mixed with other minerals and elements. In order to be used, the iron must be separated from the ore. Once this technique was developed, and forges hot enough to melt the iron were developed, iron working became commonplace. Worked iron was harder, less brittle, and could hold a much sharper edge than bronze. Iron has remained an important metal throughout history, and is one of the major components in the production of steel.

## **Machinery**

A machine is an object constructed of several parts that assists in the performance of a task. The machinery technology allows construction of fairly complex machines with metal components that store, modify and transmit energy in a useful fashion. A windmill is a machine of this type, as is a printing press. Man has used primitive machines throughout much of history. A bow can be considered a simple machine, as can a mortar and pestle. More complex machines came into being in the Middle Ages - at least in Europe. The

Persians had windmills back in the seventh century BC. The earliest machines consisted of gears, drive shafts, levers, pulleys, screws, winches and so forth. Some of these elements could be satisfactorily created of wood or stone, but those substances tend to be both fragile and very difficult to work with, particularly in small sizes. Once metallurgy provided stronger and more precise metal components, machines rapidly grew in sophistication and utility.

## **Masonry**

The early dwellings of most tribal cultures were built of materials that were readily available and easy to work with, such as bricks of clay and mud. As tribes gave up their nomadic ways and settled the first cities, they soon found that they had a need for more permanent and durable structures. The skill of masonry was developed to fill this need. The earliest stone structures consisted of little more than rocks that were stacked atop one another to form crude walls. Artisans soon began to square off the rocks, forming them into regular shapes and stacking them. These early examples of masonry used no mortar; the weight of the stacked stones provided overall strength and stability. Without the use of mortar and knowledge of architectural techniques, masonry was used primarily for simple structures such as fortifications. However, some examples of early masonry are quite spectacular, including the Great Pyramids in Egypt, which are still standing after thousands of years.

## **Mathematics**

Rudimentary arithmetic was purely quantitative, used to keep track of quantities and measurements in trade. Building on this fundamental base, ancient civilizations began to formulate more complex mathematical concepts. As early as 1800 BC, the Egyptians had developed a system for working with fractional numbers and simple algebraic problems. They also formulated geometric formulae for finding area and volume, and came up with a constant for determining the area of a circle that was very close to the value of pi. By about the 5th century BC, the mathematicians of Greece had greatly contributed to both geometry and algebra. Around the same time, advanced mathematics was applied to other sciences and fields of study such as astronomy and mechanics. One of the earliest applications of mathematical principles was in the construction of complex weaponry such as the catapult.

## **Metal Casting**

Metal casting is a way to fabricate metal objects. When subjected to extreme heat, metal melts into a liquid. The molten metal is poured into a mold, where it cools and returns to a solid state, holding the shape of the space inside the mold. Once the object is removed, the mold can be reused to make an identical object. Metal casting is a complex process. First the mold is created. The "lost wax" process is an effective way to create a mold which has been in use since the Bronze Age. In this process the artisan creates in wax a replica, or "positive" copy, of the object to be cast. Then the artisan covers the wax object in clay. When fired in a kiln, the clay hardens around the wax, creating a "negative" image of the object. This is the mold. (The original wax positive melts during the process; thus its

title.) Molds are often created in two or more pieces so that the cast metal can be removed without destroying the mold. Metal casting has some important advantages over earlier methods of working metals like blacksmithing. In blacksmithing, a smith heats and pounds metal until it achieves the required shape. This is a difficult process which requires a lot of skill. It's also quite time-consuming, as the smith can only work on one object at a time. Metal casting, on the other hand, is much more efficient. Once a skilled craftsman creates a mold, it can be used over and over again by less-skilled workers, with a large degree of certainty that the finished objects will be identical. Indeed, a mold can be created that will produce multiple copies of smaller objects, such as spearheads and daggers.

## **Mining**

There is evidence of surface mining dating back to prehistoric times. The first mining was probably for flint, which was used for knives, scrapers and arrowheads. The oldest known underground mine was in Swaziland over 40,000 years ago, to mine for ochre to use as a body pigment in ceremonies. During the Neolithic Age shafts were dug to extract flint from deeper in the earth. Gold, copper and silver were other minerals mined early in history

## **Optics**

Optics is the study of the behavior of light. In Civilization IV, the optics technology refers specifically to the branch of optics that concentrates upon improving human sight through the creation of optical instruments such as eye glasses, telescopes and microscopes. Advancements in optics had profound effects upon man's interaction with the world around him. It is not certain when the first working telescope was created. A number of lens-shaped crystals were found in a Viking grave dating from the 10th Century, but there is debate over whether these were purely decorative or were used to enhance vision. In 1609 Galileo created a "telescopium," which he used to study the stars. Accurate star charts allowed sailors to better chart their courses while at sea. The Janssen's, a family of Dutch spectacle makers, are claimed to have built the first working microscope in 1590; but once again, there is debate over that claim. And once again, Galileo is another candidate, credited with constructing his "occhiolino" in 1609. Anton van Leeuwenhoek famously used an early microscope to examine cells, bacteria, and other extremely small living creatures. This research was to revolutionize man's understanding of biology and medicine.

## **Printing Press**

The principle behind printing is not very complicated, but immense amounts of complexity are invested in the mass production of printed documents. Invented by Johannes Gutenberg in the mid-15th century, the early printing presses used a flat tray of inked type. Once paper was placed over the type, a surface was applied and the ink was pressed into the paper. While an improvement over the traditional duplication methods of the time (being meticulous hand-scribing of volumes), it was a slow and tedious process to use. Around 1800 the first cylinder press was created, followed by the large and immensely fast rotary presses. Today, computers have taken this ancient art out of the craftsman's workshop and placed it on the desktop. Desktop publishing revolutionized the creation of

printed documents, not only from the standpoint of speed and accuracy, but also by enabling anyone to mass-produce the printed word without investing the many years it takes to learn the trade.

## **Sailing**

The first sails were probably just a square sheet of animal skin hung from a horizontal pole, while later woven cloths were stretched between poles. While this does allow sailing, there are several problems with these designs. First, the boat can only sail downwind, meaning movement is only possible in the direction the wind is blowing; secondly, this only allows the boat to travel at the speed of the wind. Sail design evolved slowly over the centuries, and eventually the concepts of tacking and trimming started to be understood, allowing sailing to be against the wind and faster than the wind speed. These advancements enabled the exploration and settlement of far off lands, as ships were able to return from uncharted waters.

## **Stable**

A stable is any building in which horses are kept; a military stable would also include training grounds, barracks for the troopers, blacksmiths, armories, and the like. A horse must be extensively trained if it is to be successfully used in battle. In their natural state, most horses quite sensibly seek to run away from dangerous situations - say, when surrounded by screaming men armed with sharp objects. A cavalymen's horse, on the other hand, needs to be able to suppress this instinct and instead instantly carry out any order given it by its rider - no matter how suicidal. Such training takes time and skill - for both mount and rider. Stables provide such training: any civilization which plans to employ large numbers of horsemen would be well-advised to make the investment and build as many stables as possible.

## **Walls**

Before the establishment of centralized governments capable of supporting strong, national armies, individual cities were left to fend for themselves when it came to defense. As a result, many cities constructed city walls to protect against raiders and bandits. City walls represented a major investment in time and materials, requiring years to complete and constant repairs to maintain their strength and integrity. However, these walls turned the city into a fortress capable of withstanding all but the most determined attack. The development of gunpowder largely put an end to the usefulness of walls in stopping large armies.

## **Wheel**

The invention of the wheel represented a major turning point in human civilization. The first wheels, disks carved from solid wood, may have been built as early as 3500 BC. The earliest use of this device was the potter's wheel, used to spin and shape clay pottery. It was not long before the true potential of the wheel was discovered, and wheeled carts soon replaced the sledge as a means of transportation. Rapid developments, such as wheels

consisting of a ring with radial spokes, made the wheel even more practical by reducing its weight. By using the wheel, mankind gained the ability to work more efficiently and travel more quickly. Besides its use in transportation, the wheel went on to become the basic principle behind almost every mechanical device.

## **Writing**

The development of writing is considered one of the most important advances of civilization. The earliest forms of writing were simple symbols and marks, used to keep accounts and inventories. Some cultures developed pictographic symbols to tell stories and record events. Eventually, complete systems of writing were developed, capable of conveying any thought that could be expressed orally. At this point, scribes replaced the oral historian as the chief keepers of records. Writing allowed the presentation of information in a form that could be reliably transmitted from person to person and made it possible for ideas, history, and knowledge to be stored permanently and passed between cultures more reliably than through oral recitation.