Beginnings

Hand Stencils
Grotte de Gargas
Southern France
27,000 ybp

These hands were painted on the wall of a cave by early humans. The hand was placed on the wall and paint sprayed around it by blowing using a pipe. Early interpretations of why the fingers are shortened involved hunting-trauma, frostbite, leprosy or self-mutilation.Most now believe that the fingers were bent to make these stencils, and that the shapes meant something. Some primitive tribes communicate during hunting, when any noise would scare off the prey, by means of such silent hand signals. These stencils deep within a dark cave indicate that our ancestors used fire for illumination, communicated with each other using signs, and left records for others to see.

Science is the process whereby we understand how things work. With science we can control these things so as to improve our quality of life. Science requires communication. Science requires records.

I would like to begin by acknowledging that the land on which we gather is the traditional territory of the Haudenosaunee (h oh - D EE - n oh - SH oh - n ee), and most recently, the territory of the Mississaugas (m ih - s ih - s aw - g uh) of the New Credit First Nation. The territory was the subject of the Dish With One Spoon Wampum Belt Covenant, an agreement between the Iroquois Confederacy and the Ojibwe and allied nations to peaceably share and care for the resources around the Great Lakes. This territory is also covered by the Upper Canada Treaties. Today, the meeting place of Toronto (from the Haudenosaunee word Tkaronto) is still the home to many Indigenous People from across Turtle Island and we are grateful to have the opportunity to work in the community, on this territory.

We all eat out of the Dish - all of us that share this territory- with only one spoon. That means we have to share the responsibility of ensuring the dish is never empty; which includes, taking care of the land and the creatures we share it with. Importantly, there are no knives at the table, representing that we must keep the peace.

Fire

Fire is the rapid oxidation of material with release of heat and light. On Earth the main oxidizer is molecular oxygen (O_2) and the main materials are carbon based compounds. As land plants evolved the amount of oxygen increased in the air and wildfires were ignited by lightning.

Ancestors of *Homo sapiens* were exposed to such fires. They learned to maintain small fires for warmth, protection and cooking. The human ability to initiate and control fire was widespread about 200,000 BP with *Homo erectus*. Recent evidence, such as hearth stones and burnt animal bones, suggests that the use of fire might have begun over 1,000,000 BP.

One interesting idea is that *Homo habilis* and other human ancestors such as *Australopithecus* may have changed their lifestyle and diet from their predecessors – becoming hunters as well as gatherers. Meat is much easier to digest when cooked.

Gowlett, J. A. J., & Wrangham, R. W. (2013) Earliest fire in Africa: towards the convergence of archaeological evidence and the cooking hypothesis, *Azania:Archaeological Research in Africa*, 48, 5-30.

Quest for Fire, Jean-Jacques Annaud, 1981

The movie is a French-Canadian production and many of the settings were filmed in Canada. This one on the Bruce Peninsula (Greig's Caves)

https://blogto.com/sports_play/2017/06/surreal-greigs-cave-system-three-hours-toronto/

In this scene, Naoh (Everett McGill) learns from an elder of the Ivaka tribe (with their characteristic body paint) how to make fire using a hand-drill. Later versions of this technique would use a bowed string to rotate the spindle with greater speed.

Stone Tools

Several types of stone, such as flint, jadeite, obsidian and onyx, can be split to give edges that are sharper than steel.

Over a million years ago, *Homo habilis*, one of our early predecessors, was able to shape these flints by "knapping." This gave simple hand-axes and scrapers.

Homo sapiens developed the technology to a fine art. The example shows an arrowhead with barbs and a tang for fixing it to the shaft.

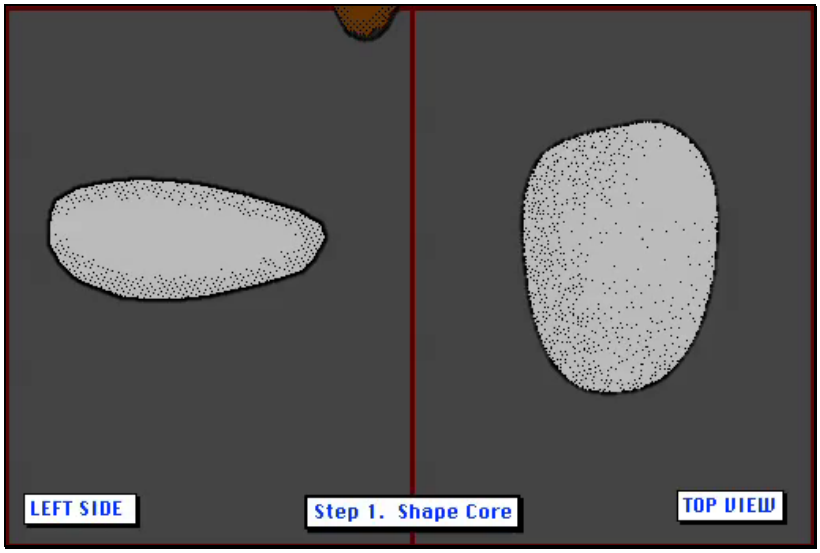
Olduwan hand axe (15 cm) 1 million BP

Egyptian arrowhead (2.8 cm) 7000 BP

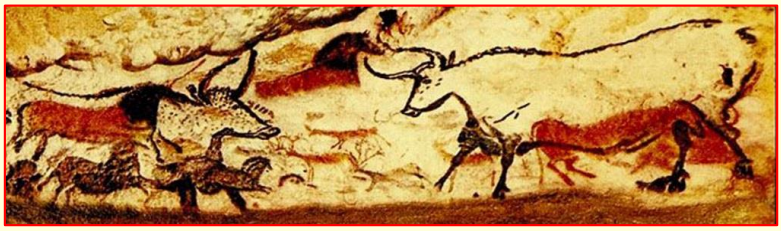
The name *Homo habilis* means "handy man" (*habilis* – skillful).

Flint has a long association with weapons. The edge of a flake of flint can strike tiny particles off steel. Because of the heat released by the collision these tiny particles become red-hot sparks. In a flintlock pistol these sparks then fall into the pan to fire the gunpowder.

This video demonstrates how to make a “biface” by flint-knapping. Demonstrator is John Olsen using obsidian. The video is available at
https://youtube.com/watch?v=8KH_cToPdiA



This video demonstrates a more advanced technique to obtain pointed edges useful for arrowheads. The core is shaped and then a pointed flake is knapped off the top. The core can then be reshaped and the process continued. Note that the flint is seen from the side on the left and from the top on the right. The final strike at the base of the flint produces a thin pointed flake from the top of the core.
Video (and further explanation is available at
http://www.anth.ucsb.edu/faculty/stsmith/classes/anth3/courseware/LithicTech/8_Middle_Paleolithic_Tool.html



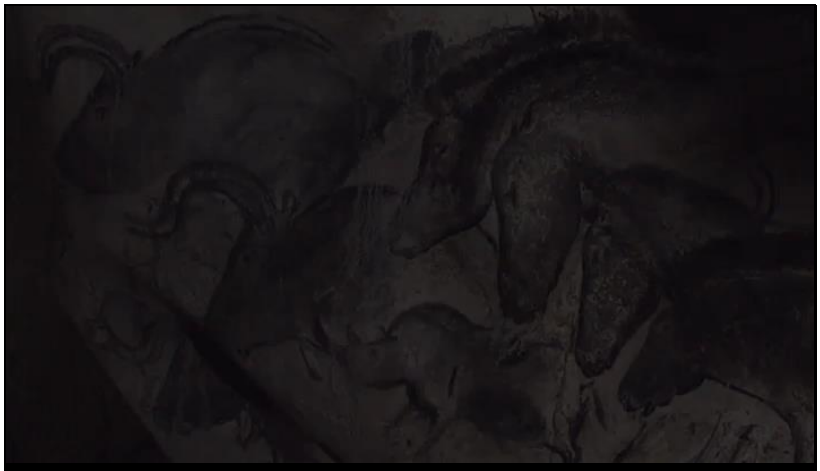
Cave Painting

Lascaux, 30,000 BP

Paintings dating back to 40,000 BP have been found on the walls of caves in many different areas of the world. Many of these are in Southern France or Northern Spain. Most of the paintings depict animals. No one is certain about the purpose of these works of art. They may have recorded hunting activities or been part of shamanistic rituals to invoke success in hunting. The expertise of the artists varies with the location and there is no evidence that technique improved over the years, since one of the earliest sites (Chauvet) is one of the most impressive

Recent evidence has shown that some non-representational Spanish cave paintings date back to over 60,000 BP, thus occurring more than 20,000 years before the arrival of *Homo sapiens*. These must therefore be attributed to *Homo neanderthalensis*.

The relationship to hunting is problematic since the people who painted the pictures did not hunt these large animals. The animal bones left in the caves come from smaller animals (deer, wild goats). This suggests that the painters depicted animals that they admired or feared. Many of the paintings also show abstract patterns, often superimposed on the animals. David Lewis–Williams has suggested that the paintings might represent visions seen by shamans in a trance state.



Cave of Forgotten Dreams, 2010, Werner Herzog

This shows some of the images from the Chauvet cave (Southern France) from 30,000 ybp A striking characteristic of the art is the depiction of groups of animals rather than single figures – the multiple equines and the two woolly rhinoceroses butting heads.

Shamanism

Löwenmencsh (lion-man) a 31 cm figurine carved from mammoth ivory tusk, 35,000 BP, Ulm. This likely represents a shaman under the guidance of a lion spirit.

In the tribes of Eastern Siberia, shamans are able to contact the spirit world usually by entering into a trance. The altered state of consciousness can be brought on by ritualistic behavior or drugs (entheogens). The shaman often takes a spirit guide (e.g lion). The goal is to heal disease (caused by malevolent spirits) or to divine the future.

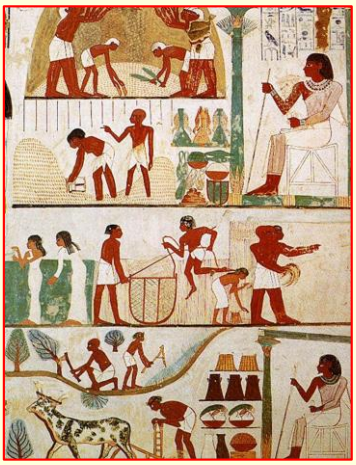
There were no scientists in prehistoric times. However, one might possibly consider shamans as being analogous to modern scientists. The process of science requires making a new hypothesis then testing this hypothesis by observation and experiments. The mystery of science concerns where the hypotheses come from. There are an infinite number of possible hypotheses – why is one selected? The process of making the hypothesis might be akin to entering the spirit world. Certainly the goals of science – being able to predict (and control) the future and being able to improve the quality of human life – are similar to the hopes of the shaman for divination and healing.

Agriculture

Human beings began to eat wild grains about 15000 BP. Beginning in 10,000 BCE, we began to cultivate our own grains and to domesticate animals - changing from hunter-gatherers to farmers.

This agricultural revolution occurred in regions where there was abundant water available for irrigation: the valleys of the Tigris and Euphrates in Mesopotamia, the Nile in Egypt and the Yellow River in China.

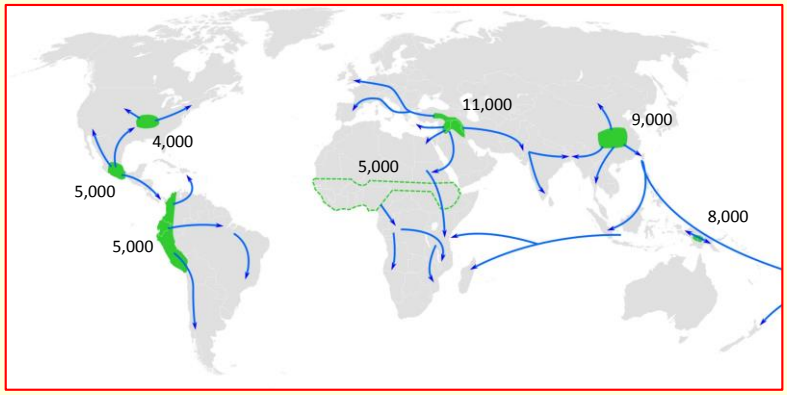
The cultivation and storage of grain led to urbanization. This facilitated the development of learning ("culture") but also caused increased diseases.



Agricultural scenes from the Tomb of Nakht in Luxor, about 1350 BCE

Nakht was likely a high official in the court of the pharaoh. His tomb shows scenes of Egyptian life. This particular panel shows the threshing of wheat, storage of grain, digging, tree tapping, harvesting grain with sickles, hoeing and ploughing. More information on the tomb: https://osirisnet.net/tombes/nobles/nakht52/e_nakht_01.htm

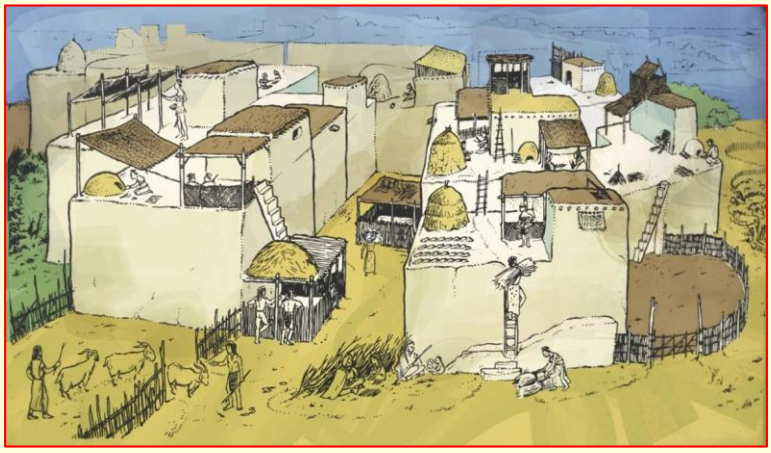
The Agricultural Revolution



approximate dates are years before present

It is possible that changes in the Earth's climate facilitated the change to agriculture. The last ice age ended around 11700 BCE. The retreating glaciers would have left behind fertile land.

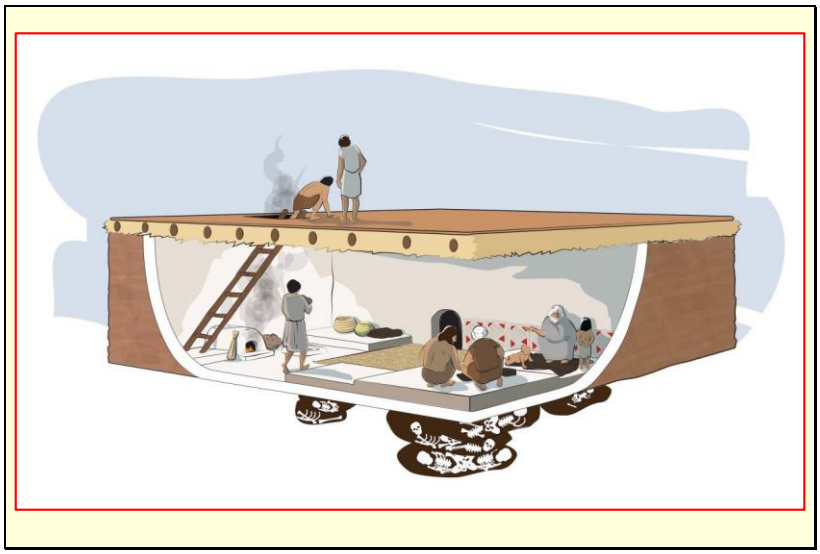
Çatalhöyük



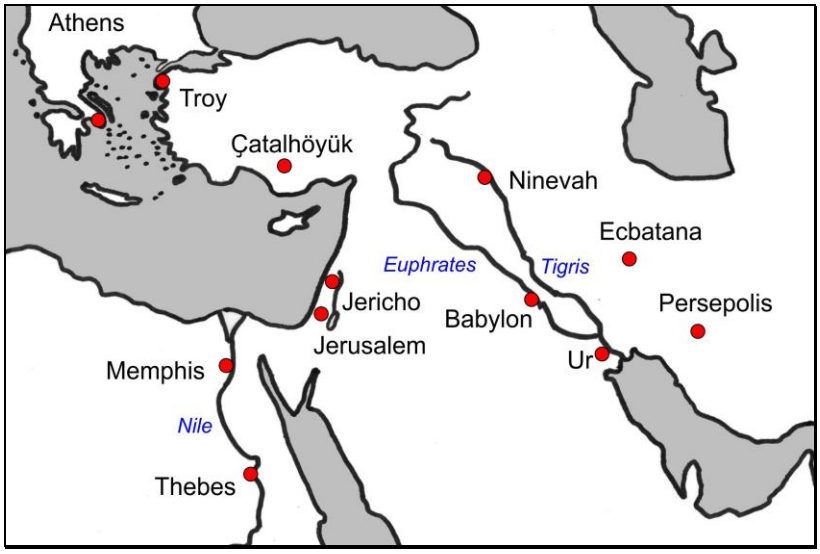
This is an impression of the proto-city of Çatalhöyük in Southern Turkey. Artist is John Swogger http://catalhoyuk.com/site/architecture

Çatalhöyük was initially built around 9000 BCE but reached its largest size in the years 7000 to 6000 BCE, when it may have had a population of around 7000 people. The mudbrick houses were notably without doors. They were entered through the roof and the houses were connected roof to roof. There was evidence of grain and other foodstuffs like peas. The inhabitants had domesticated cattle and sheep. The society was apparently egalitarian. There was no suggestion of an aristocracy or any religious hierarchy.

It is not known why the city ended. Perhaps there was some change in climate which disrupted the food supply. Perhaps there was some invasion by other tribes of people.



Within each dwelling there was an oven – located under the roof-opening to allow the smoke to escape. Bodies were buried under the floor. The walls were sometimes decorated. Heads of wild bulls (aurochs) and murals of men hunting indicated that the people were hunters as well as farmers. Some lead was smelted but no copper.



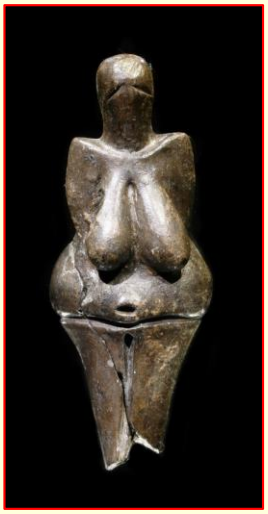
The Ancient Middle East – where cities were born.
Jericho was initially settled around 9000 BCE. It is famous for being sacked by Joshua during the Israelite invasion of Canaan though there is little evidence for this. The city was destroyed by the Egyptians around 1500 BCE

Çatalhöyük was founded near 7500 BCE and flourished for about 2000 years.
Jerusalem dates back to 7000 BCE. The city of Solomon and David was around 1000 BCE
Nineveh was initially settled around 6000 BCE. It became the center of the Assyrian Empire from 1800 to 800 BCE
Ur was founded around 4000 BCE. It was located on what was then the shore of the Persian Gulf. Abraham was perhaps from the land of Ur, though others have suggested that this indicates Urfa in Southern Turkey.
Babylon began in about 2300 BCE, and became prominent by the time of Hammurabi around 1800 BCE. A later Babylonian Empire was under Nebuchadnezzar around 600 BCE.
The fall of Troy is dated to around 1200 BCE.
Memphis was settled before 3100 BCE (the First Dynasty). It was abandoned around 700 CE
Thebes began around 3200 BCE.
Athens became a continuously inhabited city around 5000 BCE and was a part of the Mycenaean civilization around 1400 BCE. It became powerful by 600 BCE.
Ecbatana was settled around 1200 BCE. It became prominent in the Median Empire around 600 BCE.
Persepolis was the capital of the Persian (Archaemenid) Empire beginning around 500 BCE.

Urbanization appears to have begun in the Middle East. However by 5000 BCE other centers also flourished in the Indus valley in Pakistan and Afghanistan and in the Yellow River valley in China

Pottery

Early human beings found that clay would become hardened in a fire. This led to figurines and to vessels formed by pinching or coiling. The first potter's wheel, which facilitated shaping and thinning of the pottery, occurred about 3500 BCE in Mesopotamia. Increasing the temperature of the fires by using kilns allowed for glazes to made the terra cotta less porous and for water-proof stoneware. Ash glazes first occurred in China about 1500 BCE. Special clays such as kaolin allowed the production of porcelain (3rd century CE) in China.



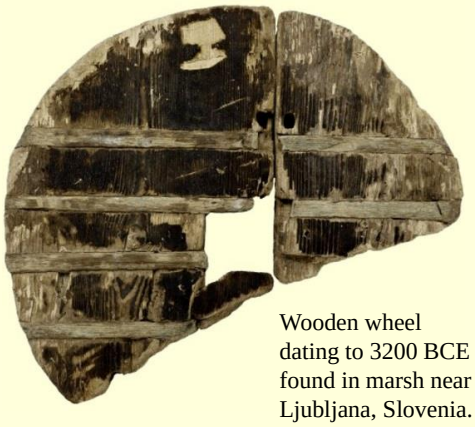
Venus of Dolní Věstonice,
ceramic figurine, 30,000 BP
Brno, Czech Republic

This pottery figurine is similar in shape and age to the Venus of Willendorf, which was carved out of limestone.
The earliest pottery vessels so far found were discovered in Xianrendong cave in central China. They date to 20,000 BP. Scorch marks indicates that they were likely used for cooking. This was before the agricultural revolution – so the cooking was to soften tubers or to make stew from meat.

In this demonstration, the potter is using a wheel that it operated by an electric motor. The original potter's wheels were turned by a heavy flywheel that was itself rotated by kicking.

This slide shows examples of pottery over the ages. The Jomon pot was made using coils of clay. The Khabur pot was made using a potter's wheel. The Greek pot shows improvements in glazing and painting. The Ming dynasty pot shows painted porcelain.

Glassware came much later than pottery. Glass requires high temperatures to fuse crushed quartz (silica). Although glass beads were made several thousand years BCE, glass containers and architectural glass (window panes) did not become widely used until Roman times.



Wooden wheel dating to 3200 BCE found in marsh near Ljubljana, Slovenia. Diameter of the wheel is 140 cm (about 4.5 ft) Note the square axle, which rotated along with wheel. This axle was 120 cm long.

Wheels

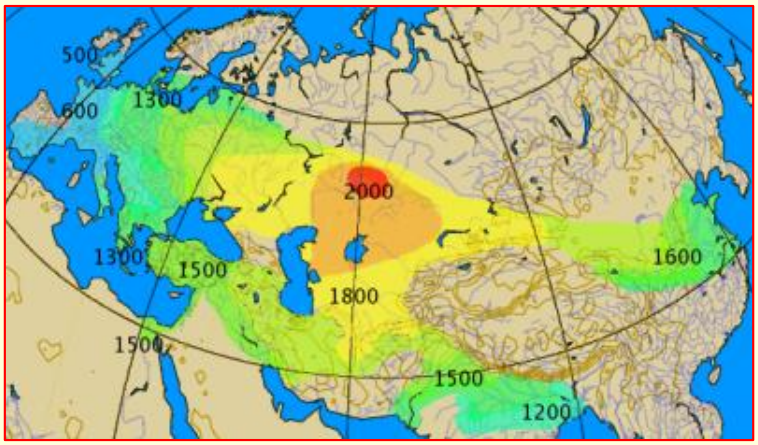
Wheels first appeared in around 4000 BCE. It is possible that they might have derived from the potter's wheel.

Together with the domestication of horses this allowed for trading.

War chariots came next. Around 3500 BCE Indo-Europeans from the steppes invaded Europe bringing their language.

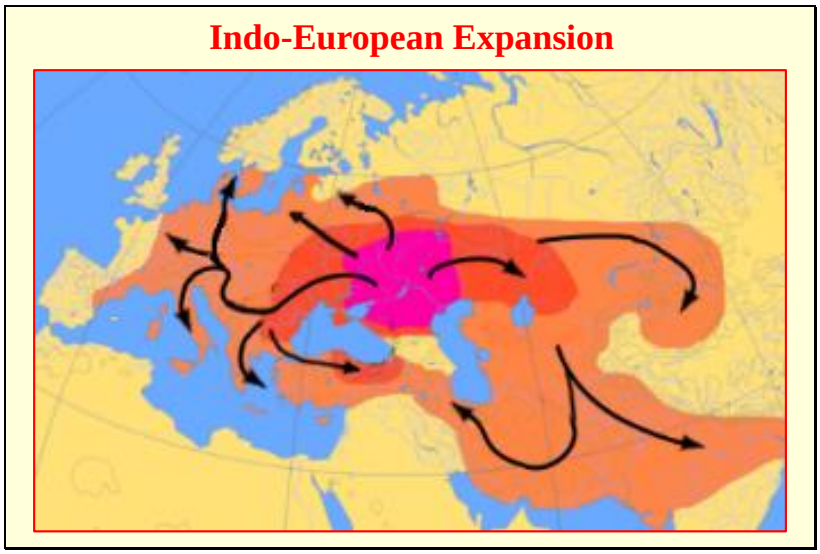
The wheel illustrated is the oldest known example of a wheel. It was preserved in a marsh. http://sloveniatimes.com/world-s-oldest-wheel-home-after-decade-under-restoration

The Spread of the Spoke-Wheeled Chariot



The invention of spokes made wheels lighter and the vehicles faster. This facilitated transportation. It also led to the war chariot, which became one of the most important military weapons in the ancient world. The battle of Qadesh in Southern Syria (1274 BCE), wherein the Hittites defeated the Egyptians, was likely the largest chariot battle ever fought. More than 5000 chariots were used. War chariots were not used in warfare much after about 100 CE though they continued to be used in racing. Chariot warfare requires relatively flat land. Simple cavalry is more adaptable.

This is a wall-painting form the Temple of Abu Simbel depicting Ramesses II (1303-1213 BCE), also known as Ozymandias, conquering the Nubians. The painting is from the temple of Beit el-Wali in Northern Nubia. The photograph is of a plaster cast in the British Museum.
Photograph taken by Margaret Lucy Patterson on Flickr



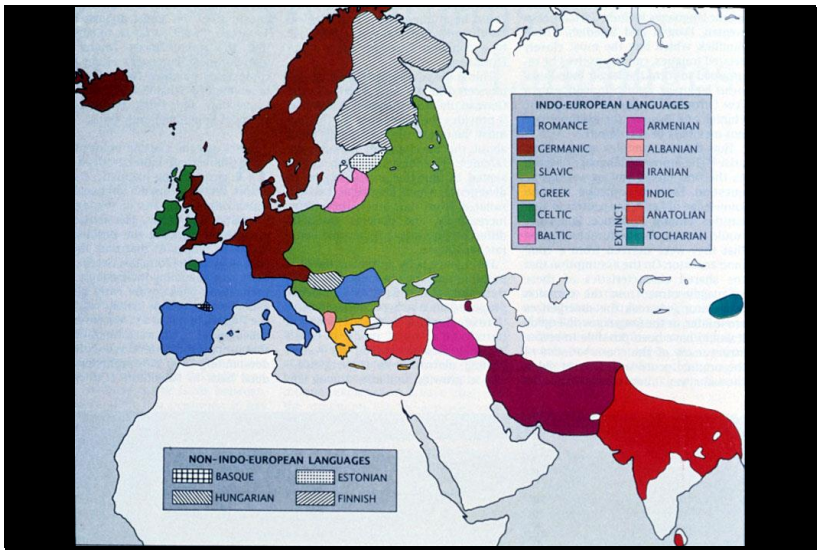
With the war chariot came a new language – Indo-European.

Similarities between different languages had long been noted. In 1786 a British judge in India postulated Indo-European as a proto-language from which derived Sanskrit, Persian, Greek, Latin, German, English and Celtic.

There are various theories for the spread of the Indo-European Languages. The migration of peoples from the Eurasian steppes (Eastern Ukraine and Southern Russia and the Caucasian mountains is the most widely accepted. These people had mastered the use of the wheel and the horse. By 2000 BCE they had light chariots with spoked wheels.

The map shows the *Urheimat* (original homeland) of the Indo-Europeans around 4000 BCE. The red indicates their expansion to 2500 BCE and the orange to 1000 BCE.

The Indo-Europeans spread widely – into Europe and also into Persia and the Indus Valley where they supplanted the original Indus Valley Civilization around 1800 BCE. Some of the Indo Europeans migrated to present day Turkey as the Hittites. These defeated the Egyptians in 1274 BCE at the battle of Qadesh, Syria, mainly because of the superiority of their chariots.



This shows the main Indo-European Languages. The map shows the languages before the effects of imperial colonization in the rest of the world, when English, French and Spanish were exported to the rest of the world.
The Tocharian languages are now extinct.

As an example of how an Indo European root lies behind the words of different languages:
The Proto Indo European (PIE) *bheroh* (I carry) becomes *phero* in Greek, *bharami* in Sanskrit, *bara* in Persian, *fero* in Latin, *bear* in English. Note the changes from “b” to “p” to “f“
PIE *phate*r (father) becomes *pater* in Greek and Latin, *pitar* in Sanskrit, *pidar* in Persian, *Vater* in German, and *father* in English.

Other examples are at
https://en.wikipedia.org/wiki/Indo-European_vocabulary

Metals

Gold can be found naturally in a pure state. The earliest gold jewelry and decorations were found at the Varna Necropolis in Bulgaria (~4000 BCE).

Copper can be obtained by smelting malachite. The required temperatures are obtained using charcoal fires driven by bellows or blow-tubes. Mixing copper with tin leads to bronze. The bronze age began around 4000 BCE

Iron smelting requires a higher temperature than copper. This can be obtained in a "bloomer" – a small furnace where charcoal is burned together with the iron ore. The iron age began around 1200 BCE in the Middle East

Bronze consists mainly of copper (70-90%) alloyed with tin and a variety of other metals such as lead, zinc, nickel and silver. Brass is an alloy of copper and zinc. Bronze is red-brown; brass is yellow.

The bronze statue is the one of the two Riace Warriors from Reggio Calabria. These were cast around 450 BCE. The bronze is mainly copper (88%) and tin (11%), although the arms of this statue differ – copper (82%) tin (5%) and lead (12%). Which heroes or warriors are represented is not known. The two statues were found in the sea near Riace. They had probably been lost in a shipwreck. They were likely being transported from Greece to Rome as collector's objects several centuries after than they had been sculpted.

Smelting of metals occurred much later in the Americas and although bronze was used in Middle and South America, there was never any iron before the Europeans arrived. One suggested explanation is that there were no beasts of burden to carry ore from mines to places where the ore could be smelted.

Approximate melting points of metals (degrees centigrade):

tin	230
lead	330
zinc	420
silver	950
gold	1050
copper	1100
iron	1300

This is taken from a YouTube video from AllHistories:
https://youtube.com/watch?v=_OrBw4L490Y

Occasionally copper is found in its pure form. North American indigenous people used such copper in ornaments but did not begin to smelt copper ores. Copper smelting began in the Middle East and the Balkans about 4000 BCE. The most common copper ore is malachite.

Malachite is copper carbonate hydroxide $Cu_2CO_3(OH)_2$
During smelting this is first reduced to cupric oxide in a reaction that requires temperatures of 350° C

$$Cu_2CO_3(OH)_2 \rightarrow 2CuO + CO_2 + H_2O$$

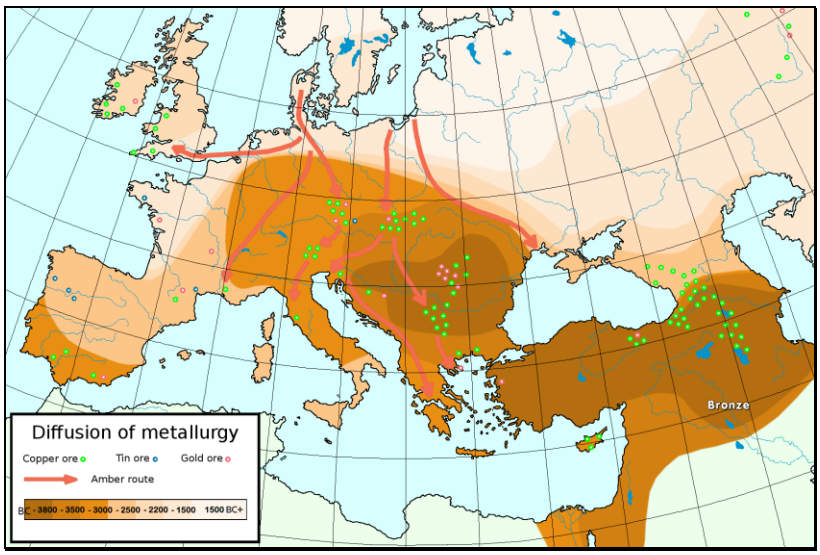
Then the cupric oxide is reduced to copper and carbon dioxide by the charcoal or by carbon monoxide

$$2CuO + C \rightarrow 2Cu + CO_2$$

$$CuO + CO \rightarrow Cu + CO_2$$

These reactions require temperatures of about 1000° C

The reduction of iron oxide to give free iron requires temperatures of 1250° C

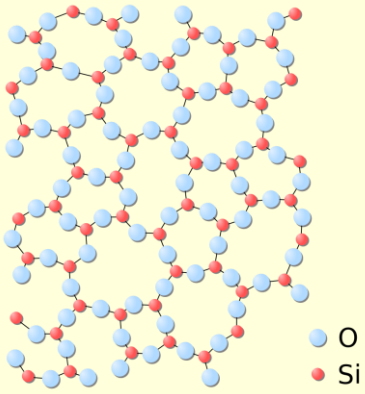


This map shows how metallurgy – the smelting of copper and tin - began in the Middle East and the Balkans and spread to the adjacent regions of the inhabited world.

The map also shows how there were extensive trading connections between different regions. The amber route is illustrated, bringing amber from the Baltic states to the Mediterranean in exchange for gold and bronze.

The Bronze Age began in China around 2000 BCE. This is later than the 4000 BCE beginnings in the Middle East. It is not clear whether this was independent of the Middle East or whether the technology was transmitted by trade. There were connections between East and West although the main Silk Road trade routes did not really being until much later (at the height of the Roman Empire). However, there were earlier contacts – silk was found in Egypt from around 1000 BCE.

Glass

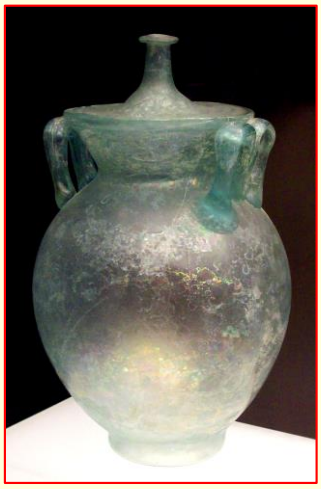


Glass is formed by melting silica (SiO_2), which is the main component of quartz and sand. This requires very high temperatures (1700 ^{0}C). Other materials such as lime (CaO), lead, or magnesium are usually added to the molten material. When the molten silica solidifies it forms an amorphous non-crystalline structure.

The first glass objects were beads likely made as a byproduct of metal smelting. These date to around 2000 BCE and are found in the Middle East, India and China. Cast objects such as plaques and vessels were made around 500 BCE in Syria and China.

Development of Glass Technology

Glass blowing began around 100 CE in Egypt and Syria (part of the Roman Empire). This allowed the craftsmen to produce vessels such as goblets and urns. Windows could be made of flattened bottles or cast glass but were not very transparent. The Anglo-Saxons became particularly adept at making and working glass (~700 CE). Glassblowing was further refined in the islands near Venice (Murano, Torcello) at the end of the first millennium CE. The first glass mirrors were made in Murano around 1500 CE using techniques that were closely guarded secrets.



Roman Cinerary Urn, ~300 CE

Earlier mirrors were made of polished metal. Around 500 CE the Chinese coated metal with a silver-mercury amalgam. This increased the reflectivity but was toxic. Vanity was a sin that could kill.

Stained glass window depicting the Marriage at Cana (when Jesus turned water into wine)

Chartres Cathedral

13th Century CE

Some earlier stained glass has been found, but it was not until 1000 CE, when the Christian Church embarked on an extensive building program, that stained glass windows became a glorious art form.

The church had long used paintings and mosaics to teach the scripture. Now it had another brilliant method of making pictures.

Writing

Evidence for symbolic writing dates back to about 5000 BCE. **Cuneiform,** which began in Mesopotamia around 3500 BCE, is the first interpretable writing system. This was used to represent the Sumerian, Akkadian, Hittite and other languages of the time. **Hieroglyphs** were used in Egypt by 3200 BCE. The **Phoenician** alphabet (1400 BCE) based on earlier cuneiform and hieroglyphic systems led to our modern European writing systems. Other scripts were developed in the Indus Valley around 2600 BCE and in China around 1200 BCE.

Amulet (about 10 cm in diameter) showing Vinca symbols from Tărtăria, Romania, ~5000 BCE

This illustrates how one can write in cuneiform. The writing is done by Irving Finkel from the British Museum.
The full video is at
https://youtube.com/watch?v=HbZ2asfyHcA

Code of Hammurabi (1754 BCE)

A stele containing the a set of laws from the time of Hammurabi was discovered in 1901 in what is now Iran. The upper part shows Hammurabi (left) being instructed by the God of the Sun (Shamash). The code is written in cuneiform Akkadian. The stele is now on display in the Louvre.

Among the laws in the Code of Hammurabi:

142: If a woman quarrel with her husband, and say: "You are not congenial to me," the reasons for her prejudice must be presented. If she is guiltless, and there is no fault on her part, but he leaves and neglects her, then no guilt attaches to this woman, she shall take her dowry and go back to her father's house.

196: If a man destroy the eye of another man, they shall destroy his eye. If one break a man's bone, they shall break his bone. If one destroy the eye of a freeman or break the bone of a freeman he shall pay one gold mina. If one destroy the eye of a man's slave or break a bone of a man's slave he shall pay one-half his price.

Law and judgment are recurrent themes in the history of Babylon. Nebuchadnezzar ruled over the neo-Babylonian Empire just before it fell to the Persians in 539 BCE. He had brought the Israelites in captivity to Babylon. At a banquet one of his sons, Belshazzar, had a vision of a hand writing on the wall. Daniel interpreted the writing :
And this is the writing that was written, Mene, Mene, Tekel, Upharsin.
This is the interpretation of the thing: Mene; God hath numbered thy kingdom, and finished it.
Tekel; Thou art weighed in the balances, and art found wanting.
Peres; Thy kingdom is divided, and given to the Medes and Persians.
(Daniel, 5 25-28)

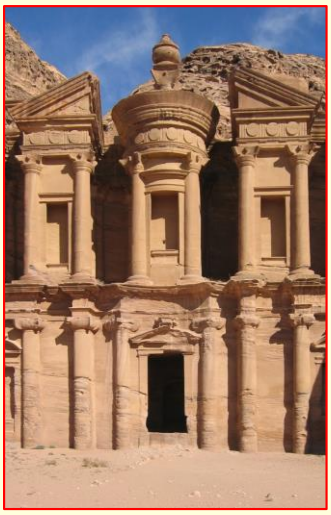
Trade Routes

1. Spice Route - from southern Arabia and from Indonesia via sea, cinnamon, ginger, frankincense, and opium came to the Middle East beginning in 1900 BCE.

2. Amber Road - from the Baltics to the Mediterranean Sea beginning around 1600 BCE

3. Salt Roads - various places in Europe produced salt. An early salt mine was constructed in Hallstatt, Austria, by the Celts in 700 BCE.

3. Silk Road - from Xian, China, around the Taklamakan Desert to Persia and ultimately to Palmyra and on to the Aegean Sea beginning around 200 BCE

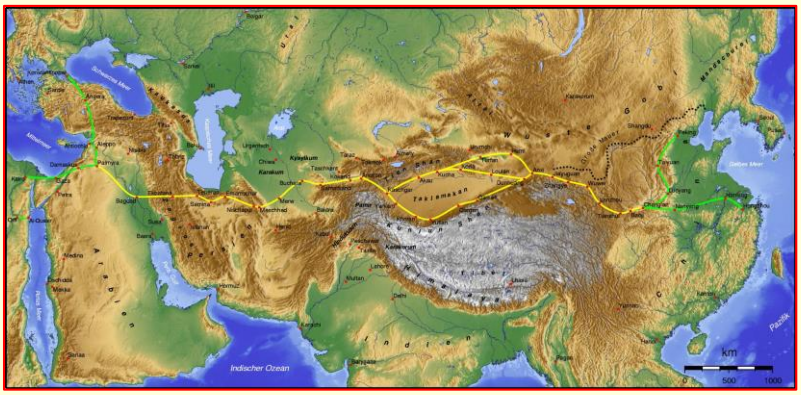


Trade allowed the exchange of ideas as well as goods

From 1900 BCE to 106 CE the Spice Route was largely controlled by the Nabataeans of Petra in Southern Jordan (illustrated).

This salt from Hallstatt was traded to Germany and Italy via Salzburg ("salt fortress")

The Silk Road



Spices and gold traveled eastward and silk and jade traveled westward.

More important than the trading of goods was the exchange of knowledge. The Asians learned the techniques of sculpture from the Greeks. Europe learned many things from Asia, most importantly steel and paper.

Iron and Steel

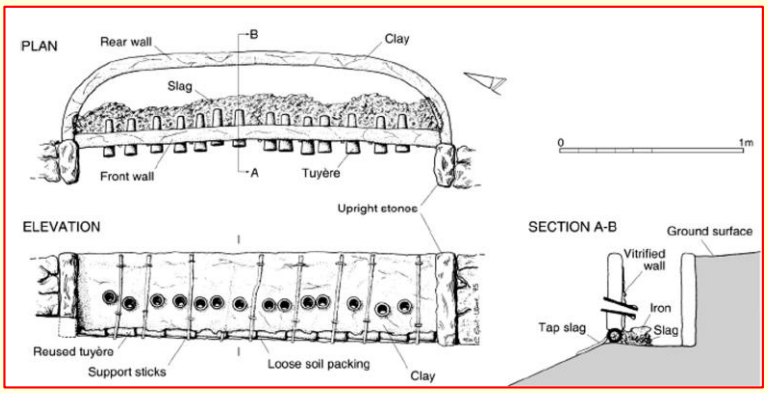
The molten iron obtained from early furnaces was led off into a runner which fed numerous sand molds much like a sow suckling her pigs. This "pig iron" contains high concentrations of carbon (4-5%) and was very brittle. The pig iron could then be re-melted and exposed to high heat and air (oxygen). This separated the iron from the impurities (slag) and reduced the carbon content making either cast iron (2-4% carbon) with high strength but low ductility, or modern steel (less than 2% carbon) with both strength and ductility.

Cast iron could be used to make rigid objects such as cannons; steel can be hammered to an extremely sharp edge and is used for swords. Another kind of iron is "wrought iron." This contains little if any carbon but contains many other impurities (unseparated slag) that allow it to be hammered ("wrought") when heated in a forge.

As was mentioned earlier, smelting of iron began in the Middle East around 1200 BCE. Various techniques for reducing the carbon in the smelted iron were used in the Ancient world. Southern India and Sri Lanka developed many techniques for making steel beginning around 600 BCE.
By 500 CE they were exporting a type of steel called "wootz" steel to the Middle East. This was used in Damascus to make the superb daggers and swords used by Islamic warriors.

The technique also spread to Europe and around 800 CE Carolingian swords (named after the Emperor Charlemagne) were manufactured in the Frankish Empire (what is now France and Germany). These were exported to (or stolen by) the Vikings.

Ancient Steel

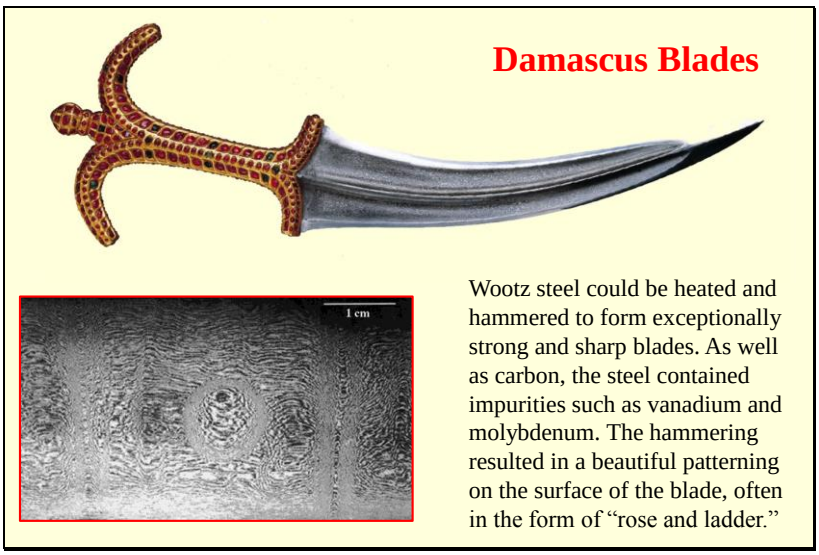


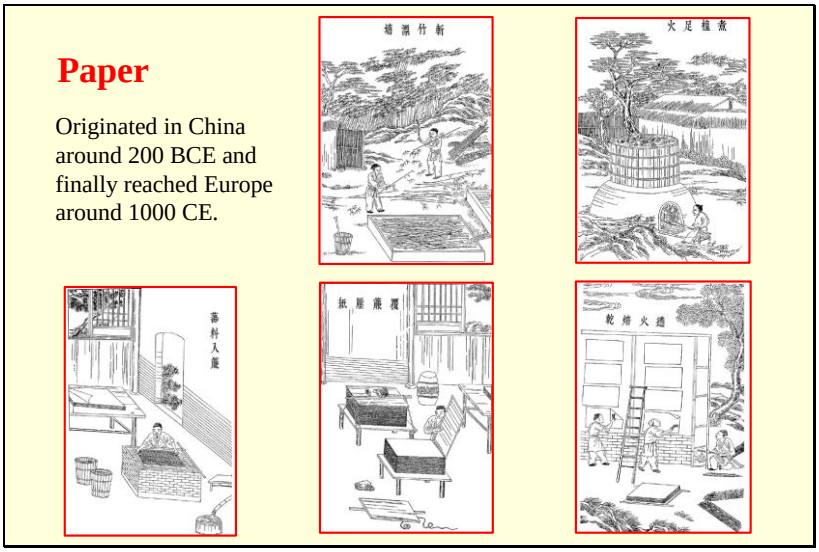
Juleff, G. (1996). An ancient wind-powered iron smelting technology in Sri Lanka. *Nature 379*, 60–63.

In Sri Lanka there were special furnaces that could produce steel directly from the iron ore using a furnace that was driven by the monsoon winds. As well as driving the burning carbon, the wind passing over the top of the furnace prevented the hot air in the furnace from escaping. Such furnaces could attain sufficiently high temperatures, that most of the carbon was burned off without entering the iron. This illustration shows a Sri Lankan furnace from around 1000 CE.

Puddling

The Chinese invented the puddling method for "fining" iron around 100 CE. Melted pig iron was stirred with iron rods to allow the carbon and the impurities to burn off. As the stirring continued, the iron rods slowly melted into the molten metal. The puddling process was re-invented by Henry Cort in 1784 and was widely used in Europe and America until the more efficient Bessemer process.





The five steps for making paper are

- Selecting the source(s) of cellulose - in this case, bamboo. Other sources are wood chips, rags from textiles, plants, e.g. hemp.
- Creating a pulp by mixing with water and heating
- Making thin layers. Often this can be done using a sieve to separate the water from the pulp.
- Pressure to remove more water and bind the material into a thin sheet
- Drying.

Before paper, writing was done on

- stone
- clay tablets

- papyrus (pith from the stems of the sedge *Cyperus papyrus* beaten together and dried to form a thick paper) First evidence of papyrus is from about 2500 BCE in Egypt.
- parchment (made from the skin of animals, especially calves – "vellum"). This also goes back to about 2500 BCE
- bones (e.g. oxen scapula) oracle bones in China date to 1200 BCE. It is possible that some turtle shell Chinese writing may predate this.

Gutenberg Press, ~1440 CE

Video available at:
https://www.youtube.com/watch?v=Aq8zHeiSiEk

The four components of the printing process were

- Movable types were cast with an alloy of lead, tin and antinomy (Gutenberg was trained as a goldsmith and knew his metals). These were put together in lines on a composing stick and then transferred to a frame. Wood block printing of pictures and text had been used in China since about 200 CE and in Europe from about 1200 CE. Metal movable characters had been made in Korea about two centuries before Gutenberg, but they did not spread to other regions of the world.
- Ink – inks made from carbon or ferrous sulfate had long been in use for writing but Gutenberg made a more adherent ink from cupric oxide (CuO) and plumbic oxide (PbO2) varnish and walnut oil. Although the video shows a roller, Gutenberg actually used a ball pad to ink the type.
- Press - Gutenberg used a modified wine press. The platen was lowered onto the paper by a simple screw mechanism. The pressure caused the ink to adhere to the paper. In vino veritas.
- Paper – the technology for making paper had reached Europe from China by 1000 CE

Beginnings

Leonardo da Vinci, *View of Mountains*, 1513

We have taken a rapid tour of the early history of science and technology. We have considered only the peaks.
The most important development was the taming of fire. This allowed human beings to stay warm, cook food, smelt metals, and turn clay to pottery.
The most striking change in human history was the agricultural revolution. This came with both advantages and disadvantages. One major problem was that the cities fostered disease because of the concentration of people in small places. A second problem was that rivalry between groups led to battles and wars. The main benefit of the agricultural revolution was the coming together of people into towns, cities and ultimately civilizations. This allowed knowledge to be recorded and taught from generation to generation. The communication of knowledge was facilitated by writing, by paper and ultimately by printing.