**Growth of Technology In Human Society**

The **history of technology** is the history of the [invention](http://en.wikipedia.org/wiki/Invention) of [tools](http://en.wikipedia.org/wiki/Tool) and techniques, and is similar in many ways to the [history of humanity](http://en.wikipedia.org/wiki/Human_history). Background knowledge has enabled people to create new things, and conversely, many scientific endeavors have become possible through [technologies](http://en.wikipedia.org/wiki/Technologies) which assist humans to travel to places we could not otherwise go, and probe the nature of the universe in more detail than our natural senses allow.

*Technological artifacts* are products of an [economy](http://en.wikipedia.org/wiki/Economic_system), a force for economic growth, and a large part of everyday life. Technological innovations affect, and are affected by, a society's cultural traditions. They also are a means to develop and project military power.

**Measuring technological progress**

Many [sociologists](http://en.wikipedia.org/wiki/Sociology) and [anthropologists](http://en.wikipedia.org/wiki/Anthropology) have created [social theories](http://en.wikipedia.org/wiki/Social_theory) dealing with [social](http://en.wikipedia.org/wiki/Social_evolution) and [cultural evolution](http://en.wikipedia.org/wiki/Cultural_evolution). Some, like [Lewis H. Morgan](http://en.wikipedia.org/wiki/Lewis_H._Morgan), [Leslie White](http://en.wikipedia.org/wiki/Leslie_White), and [Gerhard Lenski](http://en.wikipedia.org/wiki/Gerhard_Lenski), declare [technological progress](http://en.wikipedia.org/wiki/Technological_progress) to be the primary factor driving the development of human civilization. Morgan's concept of three major stages of social evolution (savagery, [barbarism](http://en.wikipedia.org/wiki/Primitive_culture), and [civilization](http://en.wikipedia.org/wiki/Civilization)) can be divided by technological milestones, such as [fire](http://en.wikipedia.org/wiki/Fire), the [bow](http://en.wikipedia.org/wiki/Bow_(weapon)), and [pottery](http://en.wikipedia.org/wiki/Pottery) in the savage era,[domestication of animals](http://en.wikipedia.org/wiki/Domestication_of_animals), [agriculture](http://en.wikipedia.org/wiki/Agriculture), and [metalworking](http://en.wikipedia.org/wiki/Metalworking) in the barbarian era and the [alphabet](http://en.wikipedia.org/wiki/Alphabet) and [writing](http://en.wikipedia.org/wiki/Writing) in the civilization era.

Instead of specific inventions, White decided that the measure by which to judge the evolution of culture was [energy](http://en.wikipedia.org/wiki/Energy). For White "the primary function of culture" is to "harness and control energy." White differentiates between five stages of human development: In the first, people use energy of their own muscles. In the second, they use energy of [domesticated animals](http://en.wikipedia.org/wiki/Domestication_of_animals). In the third, they use the energy of plants ([agricultural revolution](http://en.wikipedia.org/wiki/Neolithic_Revolution)). In the fourth, they learn to use the energy of natural resources: coal, oil, gas. In the fifth, they harness [nuclear energy](http://en.wikipedia.org/wiki/Nuclear_power). White introduced a formula P=E\*T, where E is a measure of energy consumed, and T is the measure of efficiency of technical factors utilizing the energy. In his own words, "culture evolves as the amount of energy harnessed per capita per year is increased, or as the efficiency of the instrumental means of putting the energy to work is increased". Russian astronomer, [Nikolai Kardashev](http://en.wikipedia.org/wiki/Nikolai_Kardashev), extrapolated his theory creating the [Kardashev scale](http://en.wikipedia.org/wiki/Kardashev_scale), which categorizes the energy use of advanced civilizations.

Lenski takes a more modern approach and focuses on [information](http://en.wikipedia.org/wiki/Information). The more information and knowledge (especially allowing the shaping of natural environment) a given society has, the more advanced it is. He identifies four stages of human development, based on advances in the [history of communication](http://en.wikipedia.org/wiki/History_of_communication). In the first stage, information is passed by [genes](http://en.wikipedia.org/wiki/Gene). In the second, when humans gain [sentience](http://en.wikipedia.org/wiki/Sentience), they can [learn](http://en.wikipedia.org/wiki/Learn) and pass information through by experience. In the third, the humans start using signs and develop [logic](http://en.wikipedia.org/wiki/Logic). In the fourth, they can create [symbols](http://en.wikipedia.org/wiki/Symbol), develop [language](http://en.wikipedia.org/wiki/Language) and [writing](http://en.wikipedia.org/wiki/Writing). Advancements in the technology of communication translates into advancements in the [economic system](http://en.wikipedia.org/wiki/Economic_system) and[political system](http://en.wikipedia.org/wiki/Political_system), [distribution of wealth](http://en.wikipedia.org/wiki/Distribution_of_wealth), [social inequality](http://en.wikipedia.org/wiki/Social_inequality) and other spheres of social life. He also differentiates societies based on their level of technology, communication and economy:

(1)hunters and gatherers, (2)simple agricultural, (3)advanced agricultural, (4)industrial, (5)special (such as fishing societies).

Finally, from the late 1970s sociologists and anthropologists like [Alvin Toffler](http://en.wikipedia.org/wiki/Alvin_Toffler) (author of [*Future Shock*](http://en.wikipedia.org/wiki/Future_Shock)), [Daniel Bell](http://en.wikipedia.org/wiki/Daniel_Bell) and [John Naisbitt](http://en.wikipedia.org/wiki/John_Naisbitt) have approached the theories of [post-industrial societies](http://en.wikipedia.org/wiki/Post-industrial_society), arguing that the current era of [industrial society](http://en.wikipedia.org/wiki/Industrial_society) is coming to an end, and [services](http://en.wikipedia.org/wiki/Service_(economics)) and information are becoming more important than [industry](http://en.wikipedia.org/wiki/Industry) and [goods](http://en.wikipedia.org/wiki/Good_(economics)). Some of the more extreme visions of the post-industrial society, especially in [fiction](http://en.wikipedia.org/wiki/Fiction), are strikingly similar to the visions of near and post-[Singularity](http://en.wikipedia.org/wiki/Technological_singularity) societies.

### Prehistory

#### Stone Age

During the [**Paleolithic Age**](http://en.wikipedia.org/wiki/Paleolithic_Age)**,** all humans had a lifestyle which involved limited use of tools and few permanent settlements. The first major technologies, then, were tied to survival, hunting, and food preparation in this environment. Fire, stone tools and weapons, and clothing were technological developments of major importance during this period. Stone Age cultures developed [music](http://en.wikipedia.org/wiki/Prehistoric_music), and engaged in organized [warfare](http://en.wikipedia.org/wiki/Prehistoric_warfare). A subset of Stone Age humans, including [Ngaro Aborigines](http://en.wikipedia.org/wiki/Ngaro_people), developed ocean-worthy [outrigger canoe](http://en.wikipedia.org/wiki/Outrigger_canoe) technology, leading to an eastward [migration](http://en.wikipedia.org/wiki/History_of_Papua_New_Guinea) across the[Malay archipelago](http://en.wikipedia.org/wiki/Malay_archipelago), across the Indian Ocean to [Madagascar](http://en.wikipedia.org/wiki/Madagascar) and also across the Pacific Ocean, which required knowledge of the ocean currents, weather patterns, sailing, [celestial navigation](http://en.wikipedia.org/wiki/Celestial_navigation), and star maps. The early Stone Age is described as [Epipaleolithic](http://en.wikipedia.org/wiki/Epipaleolithic) or [Mesolithic](http://en.wikipedia.org/wiki/Mesolithic). The former is generally used to describe the early Stone Age in areas with limited glacial impact. The later Stone Age, during which the rudiments of agricultural technology were developed, is called the [Neolithic](http://en.wikipedia.org/wiki/Neolithic) period. During this period, polished [stone tools](http://en.wikipedia.org/wiki/Stone_tool) were made from a variety of hard rocks such as [flint](http://en.wikipedia.org/wiki/Flint), [jade](http://en.wikipedia.org/wiki/Jade), [jadeite](http://en.wikipedia.org/wiki/Jadeite) and [greenstone](http://en.wikipedia.org/wiki/Greenschist), largely by working exposures as quarries, but later the valuable rocks were pursued by tunnelling underground, the first steps in mining technology. The polished axes were used for forest clearance and the establishment of crop farming, and were so effective as to remain in use when bronze and iron appeared.

Although Paleolithic cultures left no written records, the shift from nomadic life to settlement and agriculture can be inferred from a range of archaeological evidence. Such evidence includes ancient tools,[[1]](http://en.wikipedia.org/wiki/History_of_technology#cite_note-1) [cave paintings](http://en.wikipedia.org/wiki/Cave_painting), and other [prehistoric art](http://en.wikipedia.org/wiki/Prehistoric_art), such as the [Venus of Willendorf](http://en.wikipedia.org/wiki/Venus_of_Willendorf). Human remains also provide direct evidence, both through the examination of bones, and the study of [mummies](http://en.wikipedia.org/wiki/Mummy). Though concrete evidence is limited, scientists and historians have been able to form significant inferences about the lifestyle and culture of various prehistoric peoples, and the role technology played in their lives.

#### Copper and Bronze Ages

The Stone Age developed into the [**Bronze Age**](http://en.wikipedia.org/wiki/Bronze_Age) after the [Neolithic Revolution](http://en.wikipedia.org/wiki/Neolithic_Revolution). The Neolithic Revolution involved radical changes in agricultural technology which included [development of agriculture](http://en.wikipedia.org/wiki/History_of_agriculture), animal [domestication](http://en.wikipedia.org/wiki/Domestication), and the adoption of permanent settlements. These combined factors made possible the development of metal [smelting](http://en.wikipedia.org/wiki/Smelting), with [copper](http://en.wikipedia.org/wiki/Copper) and later [bronze](http://en.wikipedia.org/wiki/Bronze), an alloy of [tin](http://en.wikipedia.org/wiki/Tin) and copper, being the materials of choice, although polished stone tools continued to be used for a considerable time owing to their abundance compared with the less common metals (especially tin).

This technological trend apparently began in the [Fertile Crescent](http://en.wikipedia.org/wiki/Fertile_Crescent), and spread outward over time. These developments were not, and still are not, universal. The [three-age system](http://en.wikipedia.org/wiki/Three-age_system) does not accurately describe the technology history of groups outside of [Eurasia](http://en.wikipedia.org/wiki/Eurasia), and does not apply at all in the case of some isolated populations, such as the [Spinifex People](http://en.wikipedia.org/wiki/Spinifex_People), the [Sentinelese](http://en.wikipedia.org/wiki/Sentinelese_people), and various Amazonian tribes, which still make use of Stone Age technology, and have not developed agricultural or metal technology.

#### Iron Age

The [**Iron Age**](http://en.wikipedia.org/wiki/Iron_Age) involved the adoption of iron [smelting](http://en.wikipedia.org/wiki/Bloomery) technology. It generally replaced bronze, and made it possible to produce tools which were stronger, lighter and cheaper to make than bronze equivalents. In many Eurasian cultures, the Iron Age was the last major step before the development of written language, though again this was not universally the case. It was not possible to mass manufacture steel because high furnace temperatures were needed, but [steel](http://en.wikipedia.org/wiki/Steel) could be produced by [forging](http://en.wikipedia.org/wiki/Forging) bloomery iron to reduce the carbon content in a controllable way. Iron ores were much more widespread than either copper or tin. In Europe, large [hill forts](http://en.wikipedia.org/wiki/Hill_fort) were built either as a refuge in time of war, or sometimes as permanent settlements. In some cases, existing forts from the Bronze Age were expanded and enlarged. The pace of land clearance using the more effective iron axes increased, providing more farmland to support the growing population.

### Ancient

It was the growth of the ancient civilizations which produced the greatest advances in technology and engineering, advances which stimulated other societies to adopt new ways of living and governance.

The [Egyptians](http://en.wikipedia.org/wiki/Egyptians) invented and used many simple machines, such as the [ramp](http://en.wikipedia.org/wiki/Inclined_plane) to aid construction processes. The [Indus Valley Civilization](http://en.wikipedia.org/wiki/Indus_Valley_Civilization), situated in a resource-rich area, is notable for its early application of city planning and sanitation technologies. Ancient India was also at the forefront of seafaring technology—a panel found at [Mohenjodaro](http://en.wikipedia.org/wiki/Mohenjodaro) depicts a sailing craft. Indian construction and architecture, called '[Vaastu Shastra](http://en.wikipedia.org/wiki/Vaastu_Shastra)', suggests a thorough understanding of materials engineering, hydrology, and sanitation.

The peoples of [Mesopotamia](http://en.wikipedia.org/wiki/Mesopotamia) ([Sumerians](http://en.wikipedia.org/wiki/Sumerians), [Assyrians](http://en.wikipedia.org/wiki/Assyrians), and [Babylonians](http://en.wikipedia.org/wiki/Babylonians)) have been credited with the invention of the [wheel](http://en.wikipedia.org/wiki/Wheel), but this is no longer certain. They lived in cities from c. 4000 BC,[[2]](http://en.wikipedia.org/wiki/History_of_technology#cite_note-2) and developed a sophisticated architecture in mud-brick and stone,[[3]](http://en.wikipedia.org/wiki/History_of_technology#cite_note-3) including the use of the true arch. The walls of Babylon were so massive they were quoted as a [Wonder of the World](http://en.wikipedia.org/wiki/Wonder_of_the_World). They developed extensive water systems; canals for transport and irrigation in the alluvial south, and catchment systems stretching for tens of kilometres in the hilly north. Their palaces had sophisticated drainage systems.[[4]](http://en.wikipedia.org/wiki/History_of_technology#cite_note-4)

Writing was invented in Mesopotamia, using [cuneiform](http://en.wikipedia.org/wiki/Cuneiform) script. Many records on clay tablets and stone inscriptions have survived. These civilisations were early adopters of bronze technologies which they used for tools, weapons and monumental statuary. By 1200 BC they could cast objects 5 m long in a single piece. The Assyrian King [Sennacherib](http://en.wikipedia.org/wiki/Sennacherib) (704-681 BC) claims to have invented automatic sluices and to have been the first to use water screws, of up to 30 tons weight, which were cast using two-part clay moulds rather than by the 'lost wax' process. The Jerwan Aqueduct (c. 688 BC) is made with stone arches and lined with waterproof concrete.

The Babylonians were meticulous astronomers, keeping a series of records spanning 800 years. They were able to plot the motions of the planets and to predict eclipses.

The Chinese were responsible for numerous technology [discoveries and developments](http://en.wikipedia.org/wiki/List_of_Chinese_inventions). Major technological contributions from China include early [seismological](http://en.wikipedia.org/wiki/Seismology) detectors, [matches](http://en.wikipedia.org/wiki/Matches), [paper](http://en.wikipedia.org/wiki/Paper), [cast iron](http://en.wikipedia.org/wiki/Cast_iron), the iron [plough](http://en.wikipedia.org/wiki/Plough), the multi-tube [seed drill](http://en.wikipedia.org/wiki/Seed_drill), the [suspension bridge](http://en.wikipedia.org/wiki/Suspension_bridge), the [parachute](http://en.wikipedia.org/wiki/Parachute), [natural gas](http://en.wikipedia.org/wiki/Natural_gas) as fuel, the [magnetic compass](http://en.wikipedia.org/wiki/Magnetic_compass), the [raised-relief map](http://en.wikipedia.org/wiki/Raised-relief_map), the [propeller](http://en.wikipedia.org/wiki/Propeller), the [crossbow](http://en.wikipedia.org/wiki/Crossbow), the [South Pointing Chariot](http://en.wikipedia.org/wiki/South_Pointing_Chariot), and [gunpowder](http://en.wikipedia.org/wiki/Gunpowder).

[Greek](http://en.wikipedia.org/wiki/Ancient_Greece) and [Hellenistic](http://en.wikipedia.org/wiki/Hellenistic_civilization) engineers [were responsible for myriad inventions and improvements to existing technology](http://en.wikipedia.org/wiki/Ancient_Greek_technology). The [Hellenistic period](http://en.wikipedia.org/wiki/Hellenistic_period) in particular saw a sharp increase in technological advancement, fostered by a climate of openness to new ideas, the blossoming of a mechanistic philosophy, and the establishment of the [Library of Alexandria](http://en.wikipedia.org/wiki/Library_of_Alexandria) and its close association with the adjacent [museion](http://en.wikipedia.org/wiki/Museion). In contrast to the typically anonymous inventors of earlier ages, ingenious minds such as [Archimedes](http://en.wikipedia.org/wiki/Archimedes), [Philo of Byzantium](http://en.wikipedia.org/wiki/Philo_of_Byzantium), [Heron](http://en.wikipedia.org/wiki/Hero_of_Alexandria), [Ctesibius](http://en.wikipedia.org/wiki/Ctesibius), and [Archytas](http://en.wikipedia.org/wiki/Archytas) remain known by name to posterity.

Ancient Greek innovations were particularly pronounced in mechanical technology, including the ground-breaking invention of the [watermill](http://en.wikipedia.org/wiki/Watermill) which constituted the first human-devised motive force not to rely on muscle labour (besides the sail). Apart from their pioneering use of waterpower, Greek inventors were also the first to experiment with wind power (see [Heron](http://en.wikipedia.org/wiki/Hero_of_Alexandria)'s windwheel) and even created the earliest steam engine (the [aeolipile](http://en.wikipedia.org/wiki/Aeolipile)), opening up entirely new possibilities in harnessing natural forces whose full potential would not be exploited until the [Industrial Revolution](http://en.wikipedia.org/wiki/Industrial_Revolution). The newly devised right-angled [gear](http://en.wikipedia.org/wiki/Gear) and [screw](http://en.wikipedia.org/wiki/Screw) would become particularly important to the operation of mechanical devices.

Ancient agriculture, as in any period prior to the modern age the primary mode of production and subsistence, and its irrigation methods were considerably advanced by the invention and widespread application of a number of previously unknown water-lifting devices, such as the vertical [water-wheel](http://en.wikipedia.org/wiki/Water-wheel), the compartmented wheel, the water [turbine](http://en.wikipedia.org/wiki/Turbine), [Archimedes' screw](http://en.wikipedia.org/wiki/Archimedes%27_screw), the bucket-chain and pot-garland, the [force pump](http://en.wikipedia.org/wiki/Force_pump), the [suction pump](http://en.wikipedia.org/wiki/Suction_pump), the double-action [piston pump](http://en.wikipedia.org/wiki/Piston_pump) and quite possibly the [chain pump](http://en.wikipedia.org/wiki/Chain_pump).

In music, the [water organ](http://en.wikipedia.org/wiki/Water_organ), invented by Ctesibius and subsequently improved, constituted the earliest instance of a [keyboard instrument](http://en.wikipedia.org/wiki/Keyboard_instrument). In time-keeping, the introduction of the inflow [clepsydra](http://en.wikipedia.org/wiki/Water_clock) and its mechanization by the dial and pointer, the application of a [feedback system](http://en.wikipedia.org/wiki/Feedback) and the [escapement](http://en.wikipedia.org/wiki/Escapement) mechanism far superseded the earlier outflow clepsydra.

The famous [Antikythera mechanism](http://en.wikipedia.org/wiki/Antikythera_mechanism), a kind of analogous computer working with a [differential gear](http://en.wikipedia.org/wiki/Differential_gear), and the [astrolabe](http://en.wikipedia.org/wiki/Astrolabe) show great refinement in astronomical science.

Greek engineers were also the first to devise [automata](http://en.wikipedia.org/wiki/Automata) such as [vending machines](http://en.wikipedia.org/wiki/Vending_machine), suspended ink pots, automatic [washstands](http://en.wikipedia.org/wiki/Washstand) and doors, primarily as toys, which however featured many new useful mechanisms such as the [cam](http://en.wikipedia.org/wiki/Cam) and [gimbals](http://en.wikipedia.org/wiki/Gimbal).

In other fields, ancient Greek inventions include the [catapult](http://en.wikipedia.org/wiki/Catapult) and the [gastraphetes](http://en.wikipedia.org/wiki/Gastraphetes) crossbow in warfare, hollow bronze-casting in metallurgy, the [dioptra](http://en.wikipedia.org/wiki/Dioptra) for surveying, in infrastructure the [lighthouse](http://en.wikipedia.org/wiki/Lighthouse), [central heating](http://en.wikipedia.org/wiki/Central_heating), the [tunnel excavated from both ends by scientific calculations](http://en.wikipedia.org/wiki/Tunnel_of_Eupalinos), the [ship trackway](http://en.wikipedia.org/wiki/Diolkos), the [dry dock](http://en.wikipedia.org/wiki/Dry_dock) and plumbing. In horizontal vertical and transport great progress resulted from the invention of the [crane](http://en.wikipedia.org/wiki/Crane_(machine)), the [winch](http://en.wikipedia.org/wiki/Winch), the [wheelbarrow](http://en.wikipedia.org/wiki/Wheelbarrow) and the [odometer](http://en.wikipedia.org/wiki/Odometer).

Further newly created techniques and items were [spiral staircases](http://en.wikipedia.org/wiki/List_of_ancient_spiral_stairs), the [chain drive](http://en.wikipedia.org/wiki/Chain_drive), [sliding calipers](http://en.wikipedia.org/wiki/Caliper) and [showers](http://en.wikipedia.org/wiki/Shower).

The [Romans](http://en.wikipedia.org/wiki/Roman_Empire) developed an intensive and sophisticated agriculture, expanded upon existing iron working technology, created [laws](http://en.wikipedia.org/wiki/Roman_law) providing for individual ownership, advanced stone masonry technology, advanced [road-building](http://en.wikipedia.org/wiki/Roman_road) (exceeded only in the 19th century), military engineering, civil engineering, spinning and weaving and several different machines like the [Gallic reaper](http://en.wikipedia.org/wiki/Reaper) that helped to increase productivity in many sectors of the Roman economy. Roman engineers were the first to build monumental arches, [amphitheatres](http://en.wikipedia.org/wiki/List_of_Roman_amphitheatres), [aqueducts](http://en.wikipedia.org/wiki/Roman_aqueduct), [public baths](http://en.wikipedia.org/wiki/Thermae), [true arch bridges](http://en.wikipedia.org/wiki/Roman_bridge),[harbours](http://en.wikipedia.org/wiki/Harbour), [reservoirs](http://en.wikipedia.org/wiki/Reservoir) and [dams](http://en.wikipedia.org/wiki/Dam), vaults and domes on a very large scale across their Empire. Notable Roman inventions include the [book (Codex)](http://en.wikipedia.org/wiki/Codex), [glass blowing](http://en.wikipedia.org/wiki/Glass_blowing) and [concrete](http://en.wikipedia.org/wiki/Concrete). Because Rome was located on a volcanic peninsula, with sand which contained suitable crystalline grains, the [concrete](http://en.wikipedia.org/wiki/Concrete) which the Romans formulated was especially durable. Some of their buildings have lasted 2000 years, to the present day.

The engineering skills of the [Inca](http://en.wikipedia.org/wiki/Inca) and the [Mayans](http://en.wikipedia.org/wiki/Mayans) were great, even by today's standards. An example is the use of pieces weighing upwards of one ton in their stonework placed together so that not even a blade can fit in-between the cracks. The villages used irrigation canals and [drainage](http://en.wikipedia.org/wiki/Drainage) systems, making agriculture very efficient. While some claim that the Incas were the first inventors of [hydroponics](http://en.wikipedia.org/wiki/Hydroponics), their agricultural technology was still soil based, if advanced. Though the [Maya civilization](http://en.wikipedia.org/wiki/Maya_civilization) had no metallurgy or wheel technology, they developed complex writing and astrological systems, and created sculptural works in stone and flint. Like the Inca, the Maya also had command of fairly advanced agricultural and construction technology. Throughout this time period, much of this construction was made only by women, as men of the Maya civilization believed that females were responsible for the creation of new things. The main contribution of the [Aztec](http://en.wikipedia.org/wiki/Aztec) rule was a system of communications between the conquered cities. In [Mesoamerica](http://en.wikipedia.org/wiki/Mesoamerica), without draft animals for transport (nor, as a result, wheeled vehicles), the roads were designed for travel on foot, just like the Inca and Mayan civilizations.

### Medieval and modern

#### Medieval Europe

European technology in the [Middle Ages](http://en.wikipedia.org/wiki/Middle_Ages) may be best described as a symbiosis of *traditio et innovatio*. While medieval technology has been long depicted as a step backwards in the evolution of Western technology, sometimes willfully so by modern authors intent on denouncing the church as antagonistic to scientific progress (see e.g. [Myth of the Flat Earth](http://en.wikipedia.org/wiki/Myth_of_the_Flat_Earth)), a generation of medievalists around the American historian of science [Lynn White](http://en.wikipedia.org/wiki/Lynn_White) stressed from the 1940s onwards the innovative character of many medieval techniques. Genuine medieval contributions include for example [mechanical clocks](http://en.wikipedia.org/wiki/Mechanical_clock), [spectacles](http://en.wikipedia.org/wiki/Spectacles) and vertical [windmills](http://en.wikipedia.org/wiki/Windmill). Medieval ingenuity was also displayed in the invention of seemingly inconspicuous items like the [watermark](http://en.wikipedia.org/wiki/Watermark) or the [functional button](http://en.wikipedia.org/wiki/Push_button). In navigation, the foundation to the subsequent [age of exploration](http://en.wikipedia.org/wiki/Age_of_exploration) was laid by the introduction of pintle-and-gudgeon [rudders](http://en.wikipedia.org/wiki/Rudder), [lateen sails](http://en.wikipedia.org/wiki/Lateen_sail), the [dry compass](http://en.wikipedia.org/wiki/Dry_compass), the horseshoe and the [astrolabe](http://en.wikipedia.org/wiki/Astrolabe).

Significant advances were also made in military technology with the development of [plate armour](http://en.wikipedia.org/wiki/Plate_armour), steel [crossbows](http://en.wikipedia.org/wiki/Crossbow), [counterweight trebuchets](http://en.wikipedia.org/wiki/Trebuchet) and [cannon](http://en.wikipedia.org/wiki/Cannon). The Middle Ages are perhaps best known for their architectural heritage: While the invention of the [rib vault](http://en.wikipedia.org/wiki/Rib_vault) and [pointed arch](http://en.wikipedia.org/wiki/Arch) gave rise to the high rising [Gothic style](http://en.wikipedia.org/wiki/Gothic_architecture), the ubiquitous medieval fortifications gave the era the almost proverbial title of the 'age of castles'.

[Paper making](http://en.wikipedia.org/wiki/Paper_making), a 2nd-century Chinese technology, was carried to the Middle East when a group of Chinese paper makers were captured in the 8th century. Paper making technology was spread to Mediterranean by the Muslim conquests. A paper mill was established in Sicily in the 12th century. In Europe the fiber to make pulp for making paper was obtained from linen and cotton rags. Lynn White credited the spinning wheel with increasing the supply of rags, which led to cheap paper, which was a factor in the development of printing.

#### Renaissance technology

The era is marked by such profound technical advancements like [linear perceptivity](http://en.wikipedia.org/wiki/Perspective_(graphical)), [patent law](http://en.wikipedia.org/wiki/Patent_law), [double shell domes](http://en.wikipedia.org/wiki/Santa_Maria_del_Fiore) or [Bastion fortresses](http://en.wikipedia.org/wiki/Bastion_fortress). Note books of the Renaissance artist-engineers such as [Taccola](http://en.wikipedia.org/wiki/Taccola) and [Leonardo da Vinci](http://en.wikipedia.org/wiki/Leonardo_da_Vinci) give a deep insight into the mechanical technology then known and applied. Architects and engineers were inspired by the structures of [Ancient Rome](http://en.wikipedia.org/wiki/Ancient_Rome), and men like [Brunelleschi](http://en.wikipedia.org/wiki/Filippo_Brunelleschi) created the large dome of [Florence Cathedral](http://en.wikipedia.org/wiki/Florence_Cathedral) as a result. He was awarded one of the first [patents](http://en.wikipedia.org/wiki/Patent) ever issued in order to protect an ingenious [crane](http://en.wikipedia.org/wiki/Crane_(machine)) he designed to raise the large masonry stones to the top of the structure. Military technology developed rapidly with the widespread use of the [cross-bow](http://en.wikipedia.org/wiki/Cross-bow) and ever more powerful [artillery](http://en.wikipedia.org/wiki/Artillery), as the city-states of Italy were usually in conflict with one another. Powerful families like the [Medici](http://en.wikipedia.org/wiki/Medici) were strong patrons of the arts and sciences. [Renaissance science](http://en.wikipedia.org/wiki/History_of_science_in_the_Renaissance) spawned the [Scientific Revolution](http://en.wikipedia.org/wiki/Scientific_Revolution); science and technology began a cycle of mutual advancement.

The invention of the moveable type [printing press](http://en.wikipedia.org/wiki/Printing_press) (c. 1441) lead to a tremendous increase in the number of books and the number of titles published.

#### Age of Exploration

The sailing ship (nau or [carrack](http://en.wikipedia.org/wiki/Carrack)) enabled the [Age of Exploration](http://en.wikipedia.org/wiki/Age_of_Exploration) with the [European colonization of the Americas](http://en.wikipedia.org/wiki/European_colonization_of_the_Americas), epitomized by [Francis Bacon](http://en.wikipedia.org/wiki/Francis_Bacon_(philosopher))'s [*New Atlantis*](http://en.wikipedia.org/wiki/New_Atlantis). Pioneers like [Vasco da Gama](http://en.wikipedia.org/wiki/Vasco_da_Gama), [Cabral](http://en.wikipedia.org/wiki/Pedro_%C3%81lvares_Cabral), [Magellan](http://en.wikipedia.org/wiki/Ferdinand_Magellan) and [Christopher Columbus](http://en.wikipedia.org/wiki/Christopher_Columbus) explored the world in search of new trade routes for their goods and contacts with Africa, India and China which shortened the journey compared with traditional routes overland. They also re-discovered the [Americas](http://en.wikipedia.org/wiki/Americas) while doing so. They produced new maps and charts which enabled following mariners to explore further with greater confidence. Navigation was generally difficult, however, owing to the problem of longitude and the absence of accurate [chronometers](http://en.wikipedia.org/wiki/Marine_chronometer). European powers rediscovered the idea of the [civil code](http://en.wikipedia.org/wiki/Civil_code), lost since the time of the Ancient Greeks.

**Industrial Revolution**

The British [Industrial Revolution](http://en.wikipedia.org/wiki/Industrial_Revolution) is characterized by developments in the areas of [textile](http://en.wikipedia.org/wiki/Textile) [manufacturing](http://en.wikipedia.org/wiki/Manufacturing), [mining](http://en.wikipedia.org/wiki/Mining), [metallurgy](http://en.wikipedia.org/wiki/Metallurgy) and [transport](http://en.wikipedia.org/wiki/Transport) driven by the development of the [steam engine](http://en.wikipedia.org/wiki/Steam_engine). Above all else, the revolution was driven by cheap energy in the form of [coal](http://en.wikipedia.org/wiki/Coal), produced in ever-increasing amounts from the abundant resources of[Britain](http://en.wikipedia.org/wiki/Great_Britain). Coal converted to [coke](http://en.wikipedia.org/wiki/Coke_(fuel)) gave the [blast furnace](http://en.wikipedia.org/wiki/Blast_furnace) and [cast iron](http://en.wikipedia.org/wiki/Cast_iron) in much larger amounts than before, and a range of structures could be created, such as [The Iron Bridge](http://en.wikipedia.org/wiki/The_Iron_Bridge). Cheap coal meant that industry was no longer constrained by water resources driving the mills, although it continued as a valuable source of power. The steam engine helped drain the mines, so more coal reserves could be accessed, and the output of coal increased. The development of the high-pressure steam engine made locomotives possible, and a transport revolution followed.[[10]](http://en.wikipedia.org/wiki/History_of_technology#cite_note-10)

### 19th century

The 19th century saw astonishing developments in transportation, construction, and communication technologies originating in Europe, especially in [Britain](http://en.wikipedia.org/wiki/United_Kingdom). The [steam engine](http://en.wikipedia.org/wiki/Steam_engine) which had existed since the early 18th century, was practically applied to both [steamboat](http://en.wikipedia.org/wiki/Steamboat) and [railway](http://en.wikipedia.org/wiki/Railway) transportation. The first purpose built railway line opened between Manchester and Liverpool in 1830, the [Rocket locomotive](http://en.wikipedia.org/wiki/Rocket_locomotive) of [Robert Stephenson](http://en.wikipedia.org/wiki/Robert_Stephenson) being one of the first working locomotives used on the line. [Telegraphy](http://en.wikipedia.org/wiki/Telegraphy) also developed into a practical technology in the 19th century to help run the railways safely.

Other technologies were explored for the first time, including the [incandescent light bulb](http://en.wikipedia.org/wiki/Incandescent_light_bulb). The invention of the incandescent light bulb had a profound effect on the workplace because factories could now have second and third shift workers. Manufacture of ships' pulley [blocks](http://en.wikipedia.org/wiki/Block_and_tackle) by all-metal machines at the [Portsmouth block mills](http://en.wikipedia.org/wiki/Portsmouth_Block_Mills) instigated the age of [mass production](http://en.wikipedia.org/wiki/Mass_production). [Machine tools](http://en.wikipedia.org/wiki/Machine_tools)used by engineers to manufacture parts began in the first decade of the century, notably by [Richard Roberts](http://en.wikipedia.org/wiki/Richard_Roberts_(engineer)) and [Joseph Whitworth](http://en.wikipedia.org/wiki/Joseph_Whitworth). The development of [interchangeable parts](http://en.wikipedia.org/wiki/Interchangeable_parts) through what is now called the [American system of manufacturing](http://en.wikipedia.org/wiki/American_system_of_manufacturing) began in the firearms industry at the U.S Federal arsenals in the early 19th century, and became widely used by the end of the century.

Shoe production was mechanized and sewing machines introduced around the middle of the 19th century. Mass production of sewing machines and agricultural machinery such as reapers occurred in the mid to late 19th century. Bicycles were mass-produced beginning in the 1880s.

Steam-powered factories became widespread, although the conversion from water power to steam occurred in England before in the U.S.

[Steamships](http://en.wikipedia.org/wiki/Steamship) were eventually completely iron-clad, and played a role in the opening of Japan and China to trade with the West. The [Second Industrial Revolution](http://en.wikipedia.org/wiki/Second_Industrial_Revolution) at the end of the 19th century saw rapid development of chemical, electrical, petroleum, and steel technologies connected with highly structured technology research.

The period from the last third of the 19th century until WW1 is sometimes referred to as the [***Second Industrial Revolution***](http://en.wikipedia.org/wiki/Second_Industrial_Revolution)*.*

### 20th century

20th century technology developed rapidly. Communication technology, transportation technology, broad teaching and implementation of the [scientific method](http://en.wikipedia.org/wiki/Scientific_method), and increased research spending all contributed to the advancement of modern science and technology. Due to the scientific gains directly tied to military research and development, technologies including electronic [computing](http://en.wikipedia.org/wiki/Computing) might not have developed as rapidly as they did in part due to war. [Radio](http://en.wikipedia.org/wiki/Radio), [radar](http://en.wikipedia.org/wiki/Radar), and early [sound recording](http://en.wikipedia.org/wiki/History_of_sound_recording) were key technologies which paved the way for the [telephone](http://en.wikipedia.org/wiki/Telephone), [fax](http://en.wikipedia.org/wiki/Fax) machine, and [magnetic storage](http://en.wikipedia.org/wiki/Magnetic_storage) of data. Energy and engine technology improvements were also vast, including [nuclear power](http://en.wikipedia.org/wiki/Nuclear_power), developed after the [Manhattan project](http://en.wikipedia.org/wiki/Manhattan_project). Transport by [rocketry](http://en.wikipedia.org/wiki/Rocket) was another significant 20th century development. Most of this work occurred in Germany (Oberth), Russia (Tsiolkovsky), and the United States (Goddard). Making use of computers and advanced research labs, modern scientists have recombinant [DNA](http://en.wikipedia.org/wiki/DNA).

### 21st century

In the early 21st century, the main technology being developed is electronics. [Broadband Internet access](http://en.wikipedia.org/wiki/Broadband_Internet_access) became commonplace in developed countries, as did wireless Internet on smartphones that are capable of multimedia playback (video, audio, and eBooks) and running other applications (e.g., navigation, productivity tools, and games). The price of 3D printers is steadily decreasing and finding uses in many areas.

Research is ongoing into [quantum computers](http://en.wikipedia.org/wiki/Quantum_computers), [nanotechnology](http://en.wikipedia.org/wiki/Nanotechnology), [bioengineering](http://en.wikipedia.org/wiki/Bioengineering)/[biotechnology](http://en.wikipedia.org/wiki/Biotechnology) (cheap and accessible [whole genome sequencing](http://en.wikipedia.org/wiki/Whole_genome_sequencing) and personalized medicine, gene therapy, stem cell treatments, vaccine development, bionic body parts, cloning, regenerative proteins), [nuclear fusion](http://en.wikipedia.org/wiki/Nuclear_fusion) (see [ITER](http://en.wikipedia.org/wiki/ITER), [National Ignition Facility](http://en.wikipedia.org/wiki/National_Ignition_Facility), [DEMO](http://en.wikipedia.org/wiki/DEMO), [General Fusion](http://en.wikipedia.org/wiki/General_Fusion) and [Lawrenceville Plasma Physics](http://en.wikipedia.org/wiki/Lawrenceville_Plasma_Physics)), Thorium- (e.g., [LFTR](http://en.wikipedia.org/wiki/LFTR)) and Generation IV-nuclear reactors, [advanced materials](http://en.wikipedia.org/wiki/Materials_science) (e.g., graphene), the [scramjet](http://en.wikipedia.org/wiki/Scramjet) and [drones](http://en.wikipedia.org/wiki/Unmanned_combat_air_vehicle) (along with [railguns](http://en.wikipedia.org/wiki/Railgun) and high-energy laser beams for military uses), [superconductivity](http://en.wikipedia.org/wiki/Superconductivity), the [memristor](http://en.wikipedia.org/wiki/Memristor), and green technologies such as [alternative fuels](http://en.wikipedia.org/wiki/Alternative_fuel) (e.g., [fuel cells](http://en.wikipedia.org/wiki/Fuel_cells), self-driving electric & plug-in hybrid cars), [augmented reality](http://en.wikipedia.org/wiki/Augmented_reality) devices and wearable electronic devices (see [Project Glass](http://en.wikipedia.org/wiki/Project_Glass) and smartwatch), [artificial intelligence](http://en.wikipedia.org/wiki/Artificial_intelligence) ([IBM Watson](http://en.wikipedia.org/wiki/IBM_Watson) and the simulation of the human brain: [Human Brain Project](http://en.wikipedia.org/wiki/Human_Brain_Project), [Blue Brain Project](http://en.wikipedia.org/wiki/Blue_Brain_Project)), and more efficient & powerful [LEDs](http://en.wikipedia.org/wiki/LEDs), [solar cells](http://en.wikipedia.org/wiki/Solar_cells), [integrated circuits](http://en.wikipedia.org/wiki/Integrated_circuits), [wireless power](http://en.wikipedia.org/wiki/Wireless_power) devices, engines, and [batteries](http://en.wikipedia.org/wiki/Battery_(electricity)) (e.g., [molten salt battery](http://en.wikipedia.org/wiki/Molten_salt_battery), [flywheel energy storage](http://en.wikipedia.org/wiki/Flywheel_energy_storage), and [lithium-ion](http://en.wikipedia.org/wiki/Lithium-ion)).

The understanding of [particle physics](http://en.wikipedia.org/wiki/Particle_physics) is also expected to expand through particle accelerator projects, such as the [Large Hadron Collider](http://en.wikipedia.org/wiki/Large_Hadron_Collider) – the largest science project in the world[[11]](http://en.wikipedia.org/wiki/History_of_technology#cite_note-11) and neutrino detectors such as the [ANTARES](http://en.wikipedia.org/wiki/ANTARES_(accelerator)). [Theoretical physics](http://en.wikipedia.org/wiki/Theoretical_physics) currently investigates [quantum gravity](http://en.wikipedia.org/wiki/Quantum_gravity) proposals such as [M-theory](http://en.wikipedia.org/wiki/M-theory), [superstring theory](http://en.wikipedia.org/wiki/Superstring_theory), and [loop quantum gravity](http://en.wikipedia.org/wiki/Loop_quantum_gravity). The underlying phenomenon of M-theory, supersymmetry, is hoped to be experimentally confirmed with the [International Linear Collider](http://en.wikipedia.org/wiki/International_Linear_Collider). Dark matter is also in the process of being detected via underground detectors (to prevent noise from cosmic rays). [LIGO](http://en.wikipedia.org/wiki/LIGO) is trying to detect gravitational waves.

Spacecraft designs are also being developed, like the [Orion](http://en.wikipedia.org/wiki/Orion_(spacecraft)). Whereas the [James Webb Space Telescope](http://en.wikipedia.org/wiki/James_Webb_Space_Telescope) will try to identify early galaxies as well as the exact location of the Solar System within our galaxy in 2018, the [Advanced Technology Large-Aperture Space Telescope](http://en.wikipedia.org/wiki/Advanced_Technology_Large-Aperture_Space_Telescope) has orders-of-magnitude better resolution and sensitivity than its predecessors and will try to find biosignatures of terrestrial exoplanets (planned to be launched with [Ares V](http://en.wikipedia.org/wiki/Ares_V) in 2030).[[*citation needed*](http://en.wikipedia.org/wiki/Wikipedia:Citation_needed)] The finished [International Space Station](http://en.wikipedia.org/wiki/International_Space_Station) will provide an intermediate platform for space missions and zero gravity experiments. Despite challenges and criticism, [NASA](http://en.wikipedia.org/wiki/NASA) and [ESA](http://en.wikipedia.org/wiki/ESA) plan a [manned mission to Mars](http://en.wikipedia.org/wiki/Manned_mission_to_Mars) in the 2030s. The [Variable Specific Impulse Magnetoplasma Rocket](http://en.wikipedia.org/wiki/Variable_Specific_Impulse_Magnetoplasma_Rocket) (VASIMR) is an electro-magnetic thruster for spacecraft propulsion and is more than five times faster than traditional propulsion technology (expected to be tested in 2015).[New Horizons](http://en.wikipedia.org/wiki/New_Horizons) is currently underway and will study the dwarf planet Pluto and its moons in 2015.