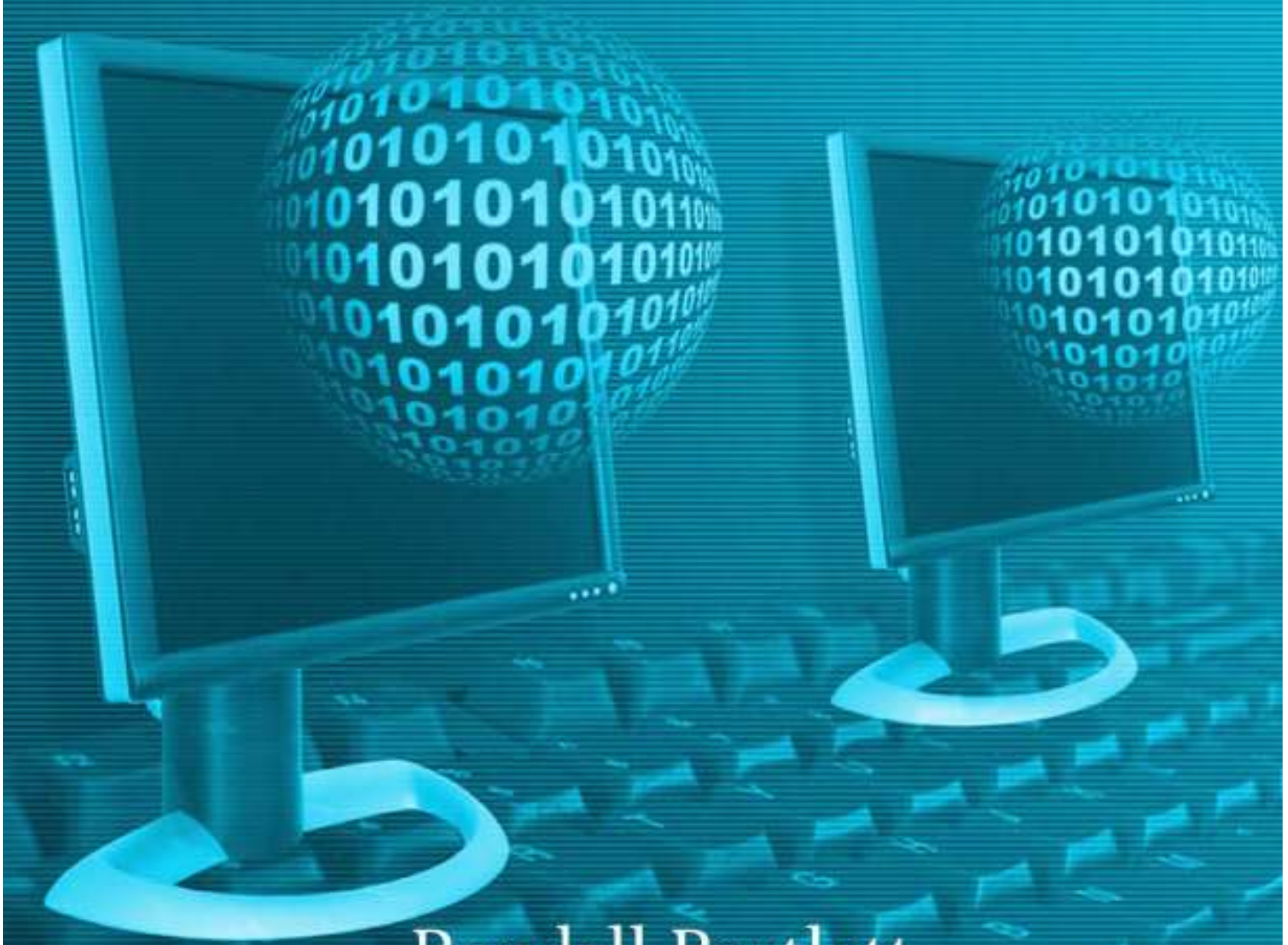
Nature of Technology



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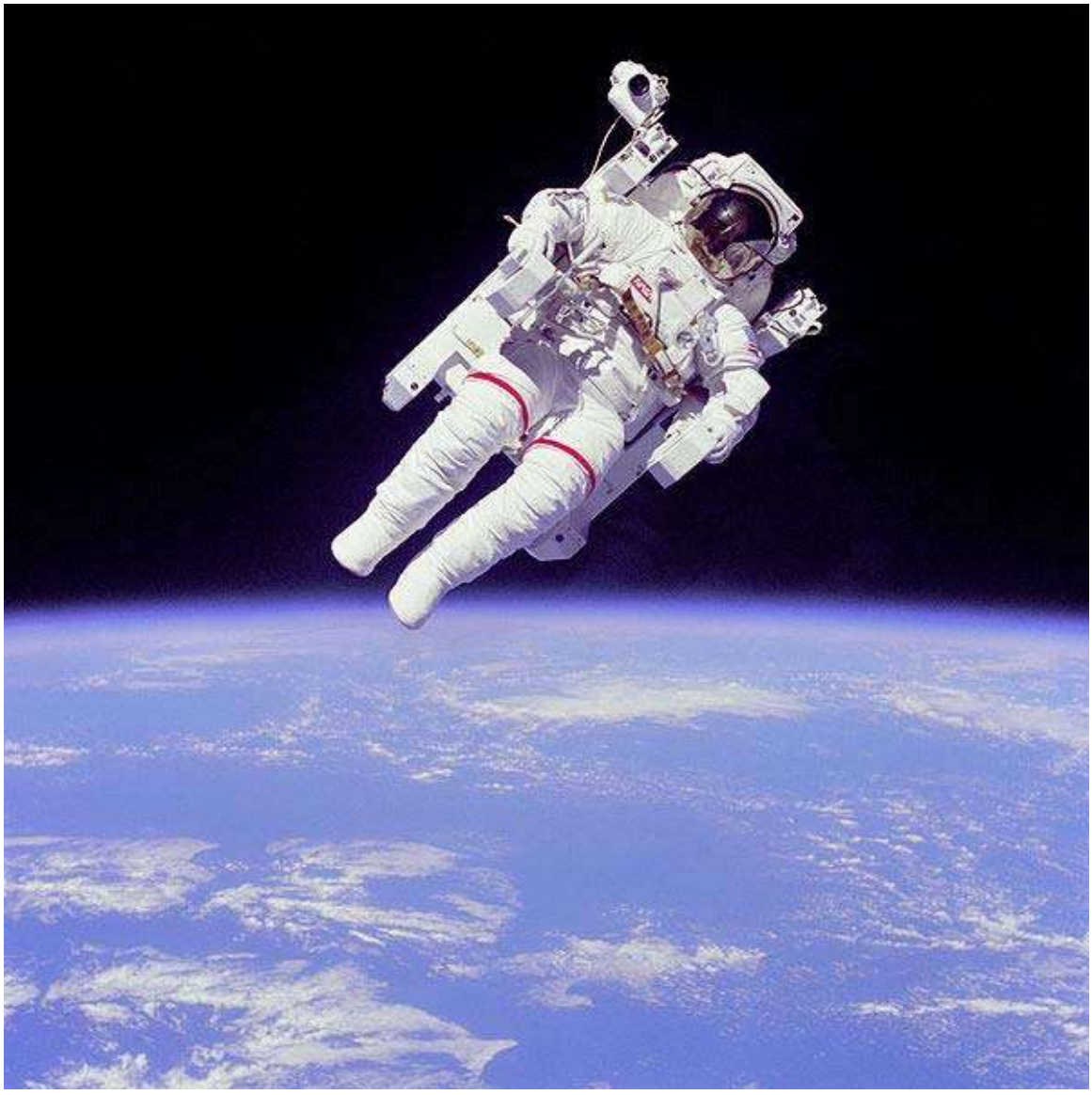
Technology



By the mid 20th century, humans had achieved a mastery of technology sufficient to leave the atmosphere of the Earth for the first time and explore space.

Technology is the usage and knowledge of tools, techniques, crafts, systems or methods of organization in order to solve a problem or create an artistic perspective. The word *technology* comes from the Greek *technología* (*τεχνολογία*) — *téchnē* (*τέχνη*), an "art", "skill" or "craft" and *-logía* (*-λογία*), the study of something, or the branch of knowledge of a discipline. The term can either be applied generally or to specific areas: examples include *construction technology*, *medical technology*, *information technology*, or *high technology*.

Technologies significantly affect human as well as other animal species' ability to control and adapt to their natural environments. The human species' use of technology began with the conversion of natural resources into simple tools. The prehistorical discovery of the ability to control fire increased the available sources of food and the invention of the wheel helped humans in travelling in and controlling their environment. Recent technological developments, including the printing press, the telephone, and the Internet, have lessened physical barriers to communication and allowed humans to interact freely on a global scale. However, not all technology has been used for peaceful purposes; the development of weapons of ever-increasing destructive power has progressed throughout history, from clubs to nuclear weapons.

Technology has affected society and its surroundings in a number of ways. In many societies, technology has helped develop more advanced economies (including today's global economy) and has allowed the rise of a leisure class. Many technological processes produce unwanted by-products, known as pollution, and deplete natural resources, to the detriment of the Earth and its environment. Various implementations of technology influence the values of a society and new technology often raises new ethical questions. Examples include the rise of the notion of efficiency in terms of human productivity, a term originally applied only to machines, and the challenge of traditional norms.

Philosophical debates have arisen over the present and future use of technology in society, with disagreements over whether technology improves the human condition or worsens it. Neo-Luddism, anarcho-primitivism, and similar movements criticise the pervasiveness of technology in the modern world, opining that it harms the environment and alienates people; proponents of ideologies such as transhumanism and techno-progressivism view continued technological progress as beneficial to society and the human condition. Indeed, until recently, it was believed that the development of technology was restricted only to human beings, but recent scientific studies indicate that other primates and certain dolphin communities have developed simple tools and learned to pass their knowledge to other generations.

Definition and usage

The invention of the printing press made it possible for scientists and politicians to communicate their ideas with ease, leading to the Age of Enlightenment; an example of technology as a cultural force.

The use of the term *technology* has changed significantly over the last 200 years. Before the 20th century, the term was uncommon in English, and usually referred to the description or study of the useful arts. The term was often connected to technical education, as in the Massachusetts Institute of Technology (chartered in 1861). "Technology" rose to prominence in the 20th century in connection with the second industrial revolution. The meanings of technology changed in the early 20th century

when American social scientists, beginning with Thorstein Veblen, translated ideas from the German concept of Technik into "technology." In German and other European languages, a distinction exists between *Technik* and *Technologie* that is absent in English, as both terms are usually translated as "technology." By the 1930s, "technology" referred not to the study of the industrial arts, but to the industrial arts themselves. In 1937, the American sociologist Read Bain wrote that "technology includes all tools, machines, utensils, weapons, instruments, housing, clothing, communicating and transporting devices and the skills by which we produce and use them." Bain's definition remains common among scholars today, especially social scientists. But equally prominent is the definition of technology as applied science, especially among scientists and engineers, although most social scientists who study technology reject this definition. More recently, scholars have borrowed from European philosophers of "technique" to extend the meaning of technology to various forms of instrumental reason, as in Foucault's work on technologies of the self ("techniques de soi").

Dictionaries and scholars have offered a variety of definitions. The Merriam-Webster dictionary offers a definition of the term: "the practical application of knowledge especially in a particular area" and "a capability given by the practical application of knowledge". Ursula Franklin, in her 1989 "Real World of Technology" lecture, gave another definition of the concept; it is "practice, the way we do things around here". The term is often used to imply a specific field of technology, or to refer to high technology or just consumer electronics, rather than technology as a whole. Bernard Stiegler, in *Technics and Time, 1*, defines technology in two ways: as "the pursuit of life by means other than life", and as "organized inorganic matter."

Technology can be most broadly defined as the entities, both material and immaterial, created by the application of mental and physical effort in order to achieve some value. In this usage, technology refers to tools and machines that may be used to solve real-world problems. It is a far-reaching term that may include simple tools, such as a crowbar or wooden spoon, or more complex machines, such as a space station or particle accelerator. Tools and machines need not be material; virtual technology, such as computer software and business methods, fall under this definition of technology.

The word "technology" can also be used to refer to a collection of techniques. In this context, it is the current state of humanity's knowledge of how to combine resources to produce desired products, to solve problems, fulfill needs, or satisfy wants; it includes technical methods, skills, processes, techniques, tools and raw materials. When combined with another term, such as "medical technology" or "space technology", it refers to the state of the respective field's knowledge and tools. "State-of-the-art technology" refers to the high technology available to humanity in any field.

Technology can be viewed as an activity that forms or changes culture. Additionally, technology is the application of math, science, and the arts for the benefit of life as it is known. A modern example is the rise of communication technology, which has lessened barriers to human interaction and, as a result, has helped spawn new subcultures; the rise of cyberculture has, at its basis, the development of the Internet and the computer. Not all

technology enhances culture in a creative way; technology can also help facilitate political oppression and war via tools such as guns. As a cultural activity, technology predates both science and engineering, each of which formalize some aspects of technological endeavor.

Science, engineering and technology

The distinction between science, engineering and technology is not always clear. Science is the reasoned investigation or study of phenomena, aimed at discovering enduring principles among elements of the phenomenal world by employing formal techniques such as the scientific method. Technologies are not usually exclusively products of science, because they have to satisfy requirements such as utility, usability and safety.

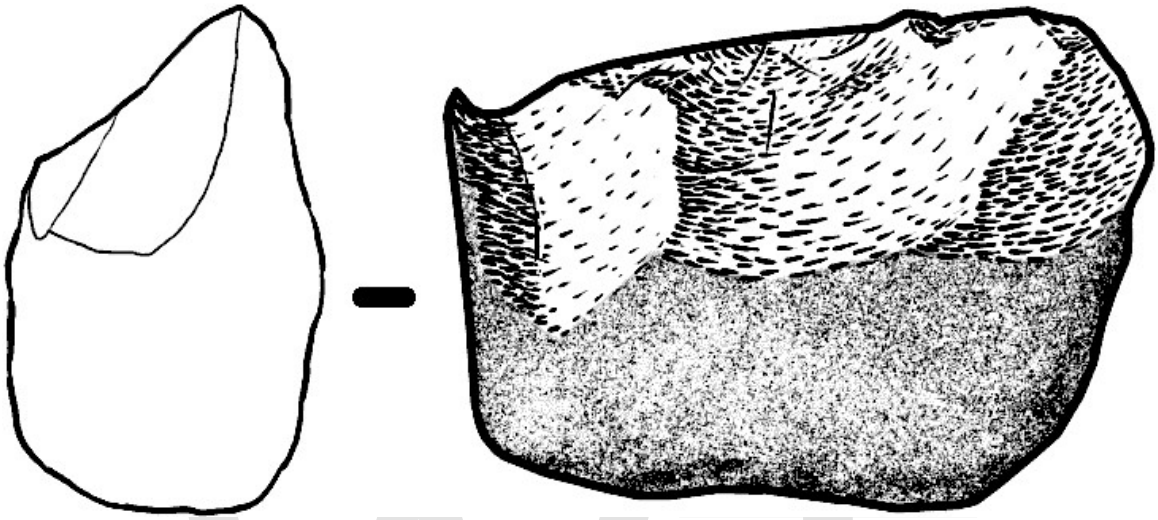
Engineering is the goal-oriented process of designing and making tools and systems to exploit natural phenomena for practical human means, often (but not always) using results and techniques from science. The development of technology may draw upon many fields of knowledge, including scientific, engineering, mathematical, linguistic, and historical knowledge, to achieve some practical result.

Technology is often a consequence of science and engineering — although technology as a human activity precedes the two fields. For example, science might study the flow of electrons in electrical conductors, by using already-existing tools and knowledge. This new-found knowledge may then be used by engineers to create new tools and machines, such as semiconductors, computers, and other forms of advanced technology. In this sense, scientists and engineers may both be considered technologists; the three fields are often considered as one for the purposes of research and reference.

The exact relations between science and technology in particular have been debated by scientists, historians, and policymakers in the late 20th century, in part because the debate can inform the funding of basic and applied science. In the immediate wake of World War II, for example, in the United States it was widely considered that technology was simply "applied science" and that to fund basic science was to reap technological results in due time. An articulation of this philosophy could be found explicitly in Vannevar Bush's treatise on postwar science policy, *Science—The Endless Frontier*: "New products, new industries, and more jobs require continuous additions to knowledge of the laws of nature... This essential new knowledge can be obtained only through basic scientific research." In the late-1960s, however, this view came under direct attack, leading towards initiatives to fund science for specific tasks (initiatives resisted by the scientific community). The issue remains contentious—though most analysts resist the model that technology simply is a result of scientific research.

History

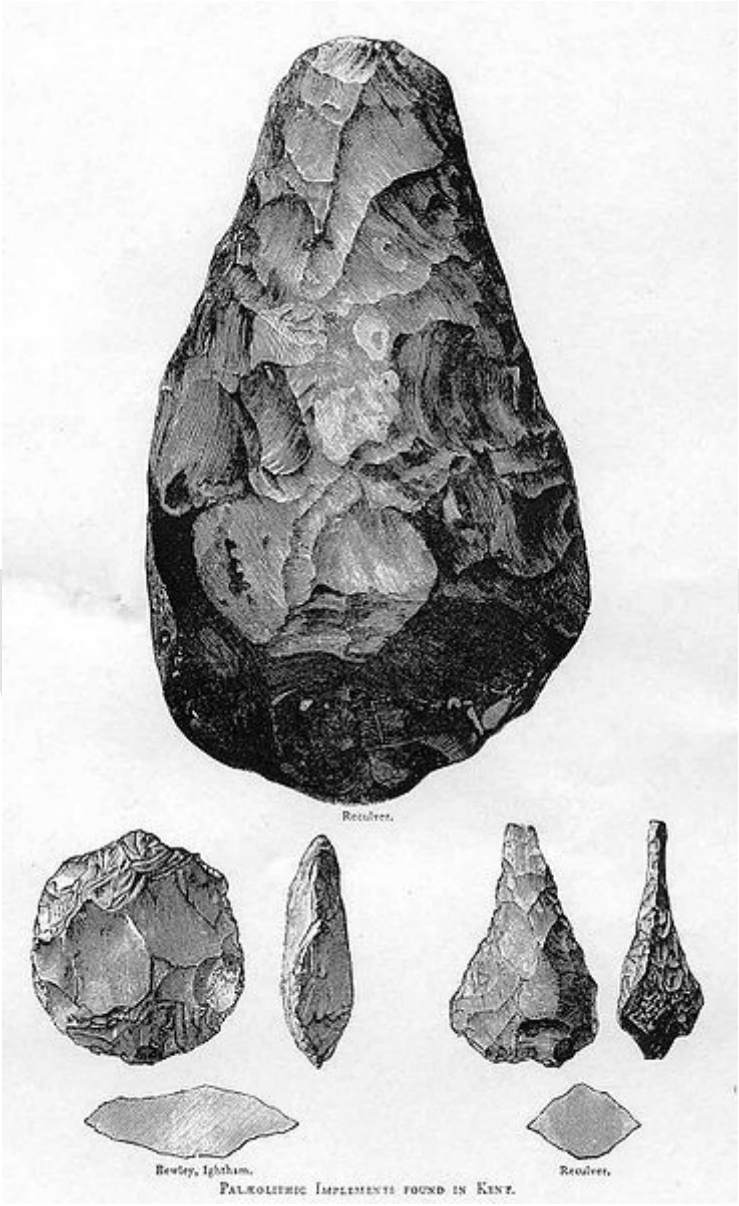
Paleolithic (2.5 million – 10,000 BC)



A primitive chopper

The use of tools by early humans was partly a process of discovery, partly of evolution. Early humans evolved from a species of foraging hominids which were already bipedal, with a brain mass approximately one third that of modern humans. Tool use remained relatively unchanged for most of early human history, but approximately 50,000 years ago, a complex set of behaviors and tool use emerged, believed by many archaeologists to be connected to the emergence of fully modern language.

Stone tools



Hand axes from the Acheulian period

A Clovis point, made via pressure flaking

Human ancestors have been using stone and other tools since long before the emergence of *Homo sapiens* approximately 200,000 years ago. The earliest methods of stone tool making, known as the Oldowan "industry", date back to at least 2.3 million years ago, with the earliest direct evidence of tool usage found in Ethiopia within the Great Rift Valley, dating back to 2.5 million years ago. This era of stone tool use is called the *Paleolithic*, or "Old stone age", and spans all of human history up to the development of agriculture approximately 12,000 years ago.

To make a stone tool, a "core" of hard stone with specific flaking properties (such as flint) was struck with a hammerstone. This flaking produced a sharp edge on the core stone as well as on the flakes, either of which could be used as tools, primarily in the form of choppers or scrapers. These tools greatly aided the early humans in their hunter-gatherer lifestyle to perform a variety of tasks including butchering carcasses (and breaking bones to get at the marrow); chopping wood; cracking open nuts; skinning an animal for its hide; and even forming other tools out of softer materials such as bone and wood.

The earliest stone tools were crude, being little more than a fractured rock. In the Acheulian era, beginning approximately 1.65 million years ago, methods of working these stone into specific shapes, such as hand axes emerged. The Middle Paleolithic, approximately 300,000 years ago, saw the introduction of the prepared-core technique, where multiple blades could be rapidly formed from a single core stone. The Upper Paleolithic, beginning approximately 40,000 years ago, saw the introduction of pressure flaking, where a wood, bone, or antler punch could be used to shape a stone very finely.

Fire

The discovery and utilization of fire, a simple energy source with many profound uses, was a turning point in the technological evolution of humankind. The exact date of its

discovery is not known; evidence of burnt animal bones at the Cradle of Humankind suggests that the domestication of fire occurred before 1,000,000 BC; scholarly consensus indicates that Homo erectus had controlled fire by between 500,000 BC and 400,000 BC. Fire, fueled with wood and charcoal, allowed early humans to cook their food to increase its digestibility, improving its nutrient value and broadening the number of foods that could be eaten.

Clothing and shelter

Other technological advances made during the Paleolithic era were clothing and shelter; the adoption of both technologies cannot be dated exactly, but they were a key to humanity's progress. As the Paleolithic era progressed, dwellings became more sophisticated and more elaborate; as early as 380,000 BC, humans were constructing temporary wood huts. Clothing, adapted from the fur and hides of hunted animals, helped humanity expand into colder regions; humans began to migrate out of Africa by 200,000 BC and into other continents, such as Eurasia.

Neolithic through Classical Antiquity (10,000BC – 300AD)

An array of Neolithic artifacts including bracelets, axe heads, chisels and polishing tools.

Man's technological ascent began in earnest in what is known as the Neolithic period ("New stone age"). The invention of polished stone axes was a major advance because it allowed forest clearance on a large scale to create farms. The discovery of agriculture

allowed for the feeding of larger populations, and the transition to a sedentist lifestyle increased the number of children that could be simultaneously raised, as young children no longer needed to be carried, as was the case with the nomadic lifestyle. Additionally, children could contribute labor to the raising of crops more readily than they could to the hunter-gatherer lifestyle.

With this increase in population and availability of labor came an increase in labor specialization. What triggered the progression from early Neolithic villages to the first cities, such as Uruk, and the first civilizations, such as Sumer, is not specifically known; however, the emergence of increasingly hierarchical social structures, the specialization of labor, trade and war amongst adjacent cultures, and the need for collective action to overcome environmental challenges, such as the building of dikes and reservoirs, are all thought to have played a role.

Metal tools

Continuing improvements led to the furnace and bellows and provided the ability to smelt and forge native metals (naturally occurring in relatively pure form). Gold, copper, silver, and lead, were such early metals. The advantages of copper tools over stone, bone, and wooden tools were quickly apparent to early humans, and native copper was probably used from near the beginning of Neolithic times (about 8000 BC). Native copper does not naturally occur in large amounts, but copper ores are quite common and some of them produce metal easily when burned in wood or charcoal fires. Eventually, the working of metals led to the discovery of alloys such as bronze and brass (about 4000 BC). The first uses of iron alloys such as steel dates to around 1400 BC.

Energy and Transport

The wheel was invented circa 4000 BC.

Meanwhile, humans were learning to harness other forms of energy. The earliest known use of wind power is the sailboat. The earliest record of a ship under sail is shown on an Egyptian pot dating back to 3200 BC. From prehistoric times, Egyptians probably used the power of the Nile annual floods to irrigate their lands, gradually learning to regulate much of it through purposely built irrigation channels and 'catch' basins. Similarly, the early peoples of Mesopotamia, the Sumerians, learned to use the Tigris and Euphrates rivers for much the same purposes. But more extensive use of wind and water (and even human) power required another invention.

According to archaeologists, the wheel was invented around 4000 B.C. The wheel was probably independently invented in Mesopotamia (in present-day Iraq) as well. Estimates on when this may have occurred range from 5500 to 3000 B.C., with most experts putting it closer to 4000 B.C. The oldest artifacts with drawings that depict wheeled carts date from about 3000 B.C.; however, the wheel may have been in use for millennia before these drawings were made. There is also evidence from the same period of time that wheels were used for the production of pottery. (Note that the original potter's wheel was probably not a wheel, but rather an irregularly shaped slab of flat wood with a small hollowed or pierced area near the center and mounted on a peg driven into the earth. It would have been rotated by repeated tugs by the potter or his assistant.) More recently, the oldest-known wooden wheel in the world was found in the Ljubljana marshes of Slovenia.

The invention of the wheel revolutionized activities as disparate as transportation, war, and the production of pottery (for which it may have been first used). It didn't take long to discover that wheeled wagons could be used to carry heavy loads and fast (rotary) potters' wheels enabled early mass production of pottery. But it was the use of the wheel as a transformer of energy (through water wheels, windmills, and even treadmills) that revolutionized the application of nonhuman power sources.

Medieval and Modern history (300 AD —)

Innovations continued through the Middle Ages with new innovations such as silk, the horse collar and horseshoes in the first few hundred years after the fall of the Roman Empire. Medieval technology saw the use of simple machines (such as the lever, the screw, and the pulley) being combined to form more complicated tools, such as the wheelbarrow, windmills and clocks. The Renaissance brought forth many of these innovations, including the printing press (which facilitated the greater communication of knowledge), and technology became increasingly associated with science, beginning a cycle of mutual advancement. The advancements in technology in this era allowed a more steady supply of food, followed by the wider availability of consumer goods.

Starting in the United Kingdom in the 18th century, the Industrial Revolution was a period of great technological discovery, particularly in the areas of agriculture, manufacturing, mining, metallurgy and transport, driven by the discovery of steam power. Technology later took another step with the harnessing of electricity to create such innovations as the electric motor, light bulb and countless others. Scientific

advancement and the discovery of new concepts later allowed for powered flight, and advancements in medicine, chemistry, physics and engineering. The rise in technology has led to the construction of skyscrapers and large cities whose inhabitants rely on automobiles or other powered transit for transportation. Communication was also improved with the invention of the telegraph, telephone, radio and television.

The second half of the 20th century brought a host of new innovations. In physics, the discovery of nuclear fission has led to both nuclear weapons and nuclear energy. Computers were also invented and later miniaturized utilizing transistors and integrated circuits. These advancements subsequently led to the creation of the Internet. Humans have also been able to explore space with satellites (later used for telecommunication) and in manned missions going all the way to the moon. In medicine, this era brought innovations such as open-heart surgery and later stem cell therapy along with new medications and treatments. Complex manufacturing and construction techniques and organizations are needed to construct and maintain these new technologies, and entire industries have arisen to support and develop succeeding generations of increasingly more complex tools. Modern technology increasingly relies on training and education — their designers, builders, maintainers, and users often require sophisticated general and specific training. Moreover, these technologies have become so complex that entire fields have been created to support them, including engineering, medicine, and computer science, and other fields have been made more complex, such as construction, transportation and architecture.

Technology and philosophy

Technicism

Generally, technicism is a reliance or confidence in technology as a benefactor of society. Taken to extreme, technicism is the belief that humanity will ultimately be able to control the entirety of existence using technology. In other words, human beings will someday be able to master all problems and possibly even control the future using technology. Some, such as Stephen V. Monsma, connect these ideas to the abdication of religion as a higher moral authority.

Optimism

Optimistic assumptions are made by proponents of ideologies such as transhumanism and singularitarianism, which view technological development as generally having beneficial effects for the society and the human condition. In these ideologies, technological development is morally good. Some critics see these ideologies as examples of scientism and techno-utopianism and fear the notion of human enhancement and technological singularity which they support. Some have described Karl Marx as a techno-optimist.

Pessimism

On the somewhat pessimistic side are certain philosophers like Herbert Marcuse and John Zerzan, who believe that technological societies are inherently flawed *a priori*. They suggest that the result of such a society is to become evermore technological at the cost of freedom and psychological health.

Many, such as the Luddites and prominent philosopher Martin Heidegger, hold serious reservations, although not *a priori* flawed reservations, about technology. Heidegger presents such a view in "The Question Concerning Technology": "Thus we shall never experience our relationship to the essence of technology so long as we merely conceive and push forward the technological, put up with it, or evade it. Everywhere we remain unfree and chained to technology, whether we passionately affirm or deny it."

Some of the most poignant criticisms of technology are found in what are now considered to be dystopian literary classics, for example Aldous Huxley's *Brave New World* and other writings, Anthony Burgess's *A Clockwork Orange*, and George Orwell's *Nineteen Eighty-Four*. And, in *Faust* by Goethe, Faust's selling his soul to the devil in return for power over the physical world, is also often interpreted as a metaphor for the adoption of industrial technology.

An overtly anti-technological treatise is *Industrial Society and Its Future*, written by Theodore Kaczynski (aka The Unabomber) and printed in several major newspapers (and later books) as part of an effort to end his bombing campaign of the techno-industrial infrastructure.

Appropriate technology

The notion of appropriate technology, however, was developed in the 20th century (e.g., see the work of Jacques Ellul) to describe situations where it was not desirable to use very new technologies or those that required access to some centralized infrastructure or parts or skills imported from elsewhere. The eco-village movement emerged in part due to this concern.

Other animal species

This adult gorilla uses a branch as a walking stick to gauge the water's depth; an example of technology usage by primates.

The use of basic technology is also a feature of other animal species apart from humans. These include primates such as chimpanzees, some dolphin communities, and crows. Considering a more generic perspective of technology as ethology of active environmental conditioning and control, we can also refer to animal examples such as beavers and their dams, or bees and their honeycombs.

The ability to make and use tools was once considered a defining characteristic of the genus Homo. However, the discovery of tool construction among chimpanzees and related primates has discarded the notion of the use of technology as unique to humans. For example, researchers have observed wild chimpanzees utilising tools for foraging: some of the tools used include leaf sponges, termite fishing probes, pestles and levers. West African chimpanzees also use stone hammers and anvils for cracking nuts, as do capuchin monkeys of Boa Vista, Brazil.

Future technology

Theories of technology often attempt to predict the future of technology based on the high technology and science of the time. This process is difficult if not impossible.

Referring to the sheer velocity of technological innovation, Arthur C. Clarke said "Any sufficiently advanced technology is indistinguishable from magic."

Chapter- 2

High Tech

High tech is technology that is at the cutting edge: the most advanced technology currently available. The adjective form is hyphenated: **high-tech** or **high-technology**. (There is also an architectural style known as high tech.)

There is no specific class of technology that is high tech — the definition shifts over time — so products hyped as high tech in the 1960s would now be considered, if not exactly low tech, then at least somewhat obsolete. This fuzzy definition has led to marketing departments describing nearly all new products as high tech.

Origin of the term

In a search of the best *New York Times* articles, the first occurrence of the phrase "high tech" occurs in a 1950s story advocating "atomic energy" for Europe: "...Eastern Europe, with its dense population and its high technology..." The twelfth occurrence, in 1968, is, significantly, in a story about Route 128, described as Boston's "Golden Semicircle":

It is not clear whether the term comes from the high technologies flourishing in the glass rectangles along the route or from the Midas touch their entrepreneurs have shown in starting new companies.

By April 1969, Robert Metz was using it in a financial column—Arthur H. Collins of Collins Radio "controls a score of high technology patents in variety of fields." Metz used the term frequently thereafter; a few months later he was using it with a hyphen, saying that a fund "holds computer peripheral... business equipment, and high-technology stocks." Its first occurrence in the abbreviated form "high tech" occurred in a Metz in 1971.

Economy

Because the high-tech sector of the economy develops or uses the most advanced technology known, it is often seen as having the most potential for future growth. This perception has led to high investment in high-tech sectors of the economy. High-tech startup enterprises receive a large portion of venture capital. However, if, as has happened in the past, investment exceeds actual potential, then investors can lose all or

most of their investment. High tech is often viewed as high risk, but offering the opportunity for high profits.

Like Big Science, high technology is an international phenomenon, spanning continents, epitomized by the worldwide communication of the Internet. Thus a multinational corporation might work on a project 24 hours a day, with teams waking and working with the advance of the sun across the globe; such projects might be in software development or in the development of an integrated circuit. The help desks of a multinational corporation might thus employ, successively, teams in Kenya, Brazil, the Philippines, or India, with the only requirement fluency in the mother tongue, be it Spanish, Portuguese or English.

OECD has two different approaches: sector and product (industry) approaches.

High-tech sectors

The sector approach classifies industries according their technology intensity, product approach according to finished products.

- Aerospace technology
- Artificial intelligence
- Biotechnology
- Energy
- Instrumentation
- Nanotechnology
- Nuclear physics
- Optoelectronics
- Robotics
- Telecommunications
- Electrical Engineering

It can be noted that technologies which are not seen as high-tech, like Information technology, may also be considered in the scope of being part of higher technological developments.

High-tech industries

Further analysis from OECD has indicated that using research intensity as only industry classification indicator is also possible. The OECD does not only take the manufacturing but also the usage rate of technology into account. The OECD's classification is following (stable since 1973):

Industry name	Total R&D-intensity (1999, in %)	ISIC Rev. 3
High-Technology		

Pharmaceuticals	10.46	2423
Aircraft & spacecraft	10.29	353
Medical, precision & optical instruments	9.69	33
Radio, television & communication equipment	7.48	32
Office, accounting & computing machinery	7.21	30
Medium-High-Technology		
Electrical machinery & apparatus	3.60	31
Motor vehicles, trailers & semi-trailers	3.51	34
Railroad & transport equipment	3.11	352+359
Chemical & chemical products	2.85	24 (excl. 2423)
Machinery & equipment	2.20	29

Furthermore, OECD's product-based classification supports the technology intensity approach. It can be concluded, that companies in a high-technology industry do not necessary produce high-technology products and vice versa. This creates a problem of aggregation.

High-tech society

An overall society based in high-tech is something generally unattainable by the definition comprising its scarcity among every technology available. Many countries and regions like United States, Canada, Italy, Denmark, Belgium, the Netherlands, Israel, Japan, the United Kingdom, Estonia, Australia, Germany, South Korea, Taiwan, Hong Kong, Finland, Spain, Sweden, Brazil and France can be in general considered high-tech societies in relation to other countries, since it is common for its citizens having access to technology that is presently at the cutting edge, in consumer's terms, as can parts of India (Bangalore, Mumbai) and China (Shanghai, Beijing). Research oriented institutions such as ESA, MITRE, NASA, CERN, and universities with high research activity such as MIT and the Technion might be considered high-tech microsocieties in relation to the general surrounding socio-economic region or overall activity sector.

Some geographical areas can be consider as a high-tech startups society like for instance the Silicon Valley:

The spark that set off the explosive boom of "Silicon startups" in Stanford Industrial Park was a personal dispute in 1957 between employees of Shockley Semiconductor and the company's namesake and founder, Nobel laureate and co-inventor of the transistor William Shockley... (His employees) formed Fairchild Semiconductor immediately following their departure... After several years, Fairchild gained its footing, becoming a formidable presence in this sector. Its founders began to leave to start companies based

on their own, latest ideas and were followed on this path by their own former leading employees... The process gained momentum and what had once began in a Stanford's research park became a veritable startup avalanche... Thus, over the course of just 20 years, a mere eight of Shockley's former employees gave forth 65 new enterprises, which then went on to do the same...

An organization's department dealing with the latest technology in their projects, may also be considered a high-tech microsociety within the organization's and partners' scope. Students and faculty related with ENAEE or ABET accredited programs might be considered high-tech society members, regarding other traditional degrees. In industry, companies working in the leading edge may be considered high-tech societies along with its main competitors, regarding the rest of the sectorial competition.

Chapter- 3

Technological Convergence

Technological convergence is the tendency for different technological systems to evolve towards performing similar tasks.

Convergence can refer to previously separate technologies such as voice (and telephony features), data (and productivity applications), and video that now share resources and interact with each other, synergistically creating new efficiencies.

Today, we are surrounded by a multi-level convergent media world where all modes of communication and information are continually reforming to adapt to the enduring demands of technologies, "changing the way we create, consume, learn and interact with each other".

Convergence in this instance is defined as the interlinking of computing and other information technologies, media content, and communication networks that have arisen as the result of the evolution and popularization of the Internet as well as the activities, products and services that have emerged in the digital media space.

Many experts view this as simply being the tip of the iceberg, as all facets of institutional activity and social life such as business, government, art, journalism, health, and education are increasingly being carried out in these digital media spaces across a growing network of information and communication technology devices.

Also included in this topic is the basis of computer networks, wherein many different operating systems are able to communicate via different protocols. This could be a prelude to artificial intelligence networks on the Internet eventually leading to a powerful superintelligence via a technological singularity.

The rise of digital communication in the late 20th century made it possible for media organizations (or individuals) to deliver text, audio, and video material over the same wired, wireless, or fiber-optic connections. At the same time, it inspired some media organizations to explore multimedia delivery of information. This digital convergence of news media, in particular, was called "Mediamorphosis" by researcher Roger Fidler, in his 1997 book by that name.

The Internet

The Internet is a globalized network and was officially launched in 1969. Over the past 40 years, its role has changed rapidly from its original use as a communication tool to provide easier and faster access to information for universities and various other educational institutions. In today's world, it is an important tool used to reach various audiences around the world. Its users have been constantly trying to create more uses for the Internet than the mere sharing of academic information. The television, radio and newspapers are the world's main mediums for accessing news and entertainment. Now, all three mediums have converged into one, and people all over the world now can read news on the Internet. They can also watch videos, television shows, listen to music, and download and upload pictures, music and videos. One doesn't have to wait until the next day to hear the latest in news, fashion, and music. The Internet is so easy to access that should anything happen, it would be displayed to the whole world within minutes.

Convergence of media occurs when multiple products come together to form one product with the advantages of all of them, also known as the black box. This idea of one technology, concocted by Henry Jenkins, has become known more as a fallacy because of the inability to actually put all technical pieces into one. For example, while people can have e-mail and Internet on their phone, they still want full computers with Internet and e-mail in addition.

Convergence is a concept in which old and new media intersect; when grassroots and corporate media intertwine in such a way that the balance of power between media producers and media consumers shifts in unpredictable ways. Jenkins states that convergence is,

"the flow of content across multiple media platforms, the cooperation between multiple media industries, and the migratory behaviour of media audiences."

Media convergence is not just a technological shift or a technological process, it also includes shifts within the industrial, cultural, and social paradigms that encourage the consumer to seek out new information. Convergence, simply put, is how individual consumers interact with others on a social level and use various media platforms to create new experiences, new forms of media and content that connect us socially, and not just to other consumers, but to the corporate producers of media in ways that have not been as readily accessible in the past.

For example, the Wii is not only a games console, but also a web browser and social networking tool. Mobile phones are another good example, in that they increasingly incorporate digital cameras, mp3 players, camcorders, voice recorders, and other devices.

This type of convergence is very popular. For the consumer, it means more features in less space, while for the media conglomerates it means remaining competitive in the struggle for market dominance. With the advance in technology comes the ability for

technological convergence which Rheingold believes alters the "social-side effects" in that "the virtual, social and physical world are colliding, merging and coordinating"

However, convergence can have its downside. Particularly in their initial forms, converged devices are frequently less functional and reliable than their component parts (e.g. a DVD may perform better on a traditional DVD player than on a games console). As the amount of functions in a single device escalates, the ability of that device to serve its original function decreases. For example, the iPhone (which by its name implies that its primary function is that of a mobile phone) can perform many different tasks, but does not feature a traditional numerical pad to make phone calls. Instead, the phone features a touchpad, which some users have found more troublesome than a conventional phone numberpad. As Rheingold asserts, technological convergence holds immense potential for the "improvement of life and liberty in some ways and (could) degrade it in others" He believes the same technology has the potential to be "used as both a weapon of social control and a means of resistance"

Regardless, an ever-wider range of technologies are being converged into single multipurpose devices.

Since technology has evolved in the past ten years or so, companies are beginning to converge technologies to create demand for new products. This would include phone companies integrating 3G on their phones. In the mid 20th century, television converged the technologies of movies and radio, and television is now being converged with the mobile phone industry. Phone calls are also being made with the use of personal computers. Converging technologies seems to be squashing many types of demanded technologies into one. Mobile phones are becoming manufactured to not only carry out phone calls, text messages, but also hold images, videos, music, television, camera, and multimedia of all types. Manufacturers are now integrating more advanced features such as video recording, GPS receivers, data storage, and security mechanisms into the traditional cellphone.

These paradigm shifts are ongoing in the media, and often occur from time to time as the technology to create better devices evolves. It was predicted in the 1990s that a digital revolution would take place,and that old media would be pushed to one side by new media. Broadcasting is increasingly being replaced by the Internet, enabling consumers all over the world the freedom to access their preferred media content more easily and at a more available rate than ever before.

However, when the dot com bubble of the 1990s suddenly popped, that poured cold water over the talk of such a digital revolution. In today's society, the idea of media convergence has once again emerged as a key point of reference as newer as well as established media companies attempt to visualize the future of the entertainment industry. If this revolutionary digital paradigm shift presumed that old media would be increasingly replaced by new media, the convergence paradigm that is currently emerging suggests that new and old media would interact in more complex ways than previously predicted. The paradigm shift that followed the digital revolution assumed that new

media was going to change everything. When the dot com market crashed, there was a tendency to imagine that nothing had changed. The real truth lay somewhere in between as there were so many aspects of the current media environment to take into consideration. Many industry leaders are increasingly reverting to media convergence as a way of making sense in an era of disorientating change. In that respect, media convergence in theory is essentially an old concept taking on a new meaning.

Media convergence in reality is more than just a shift in technology. It alters the relationship that already exists between industries, technologies, audiences, genres and markets. Media convergence changes the rationality in which media industries operate and also the way that media consumers process news and entertainment. Bearing in mind that media convergence in reality is essentially a process and not an outcome, there is no single black box that controls the flow of media into our homes and workplaces. With the proliferation of different media channels and the increasing portability of new telecommunications and computing technologies, we have entered into an era where the media is constantly surrounding us. Believe it or not, today's modern society is already existing within a convergence culture.

Media convergence requires companies operating within the scope of the media to rethink existing assumptions about media from the consumer's point of view, as these assumptions affect both marketing and programming decisions. Media producers have to respond to these newly empowered consumers in today's society to reinvent existing concepts to keep them up to date with emerging trends. Consumers these days do not just want to be on a one way transmission model where they simply receive information. They want to interact with it. They want to create it. They want to participate within it. Media convergence has allowed that to happen and as the proliferation of new communication technologies continues to occur, this trend is here to stay.

Fan culture

Media scholar Henry Jenkins has described the media convergence with participatory culture as:

a "catalyst" for amateur digital film-making and what this case study suggests about the future directions popular culture may take. Star Wars fan films represent the intersection of two significant cultural trends -- the corporate movement towards media convergence and the unleashing of significant new tools which enable the grassroots archiving, annotation, appropriation, and recirculation of media content. These fan films build on long-standing practices of the fan community but they also reflect the influence of this changed technological environment that has dramatically lowered the costs of film production and distribution.

Messaging convergence

Combinational services include those which integrate SMS with voice, such as voice SMS - providers include Bubble Motion, Jott, Kirusa, and SpinVox. Several operators have launched services that combine SMS with mobile instant messaging (MIM) and presence.

Text-to-landline services also exist, where subscribers can send text messages to any landline phone and are charged at standard rates. This service has been popular in America, where fixed and mobile numbers are similar.

Inbound SMS has been also converging to enable reception of different formats (SMS, voice, MMS, etc.). UK companies, including consumer goods companies and media giants, should soon be able to let consumers contact them via voice, SMS, MMS, IVR, or video using one five-digit number or long number. In April 2008, O2 UK launched voice-enabled shortcodes, adding voice functionality to the five-digit codes already used for SMS.

This type of convergence is particularly helpful for media companies, broadcasters, enterprises, call centres and help desks who need to develop a consistent contact strategy with the consumer. Because SMS is very popular today with any demographic, it became relevant to include text messaging as a contact possibility for consumers. To avoid having multiple numbers (one for voice calls, another one for SMS), a simple way is to merge the reception of both formats under one number. This means that a consumer can text or call one number and be sure that the message will be received.

Multi-play

Multi-play is a marketing term describing the provision of different telecommunication services, such as Broadband Internet access, television, telephone, and mobile phone service, by organisations that traditionally only offered one or two of these services. Multi-play is a catch-all phrase; usually, the terms triple play (voice, video and data) or quadruple play (voice, video, data and wireless) are used to describe a more specific meaning.

A dual play service is a marketing term for the provisioning of the two services: it can be high-speed Internet (ADSL) and telephone service over a single broadband connection in the case of phone companies, or high-speed Internet (cablemodem) and TV service over a single broadband connection in the case of cable TV companies.

The convergence can also concern the underlying communication infrastructure. An example of this is a triple play service, where communication services are packaged allowing consumers to purchase TV, Internet, and telephony in one subscription.

A quadruple play service combines the triple play service of broadband Internet access, television, and telephone with wireless service provisions. This service set is also sometimes humorously referred to as "The Fantastic Four" or "Grand Slam".

The broadband cable market is transforming as pay-TV providers move aggressively into what was once considered the telco space. Meanwhile, customer expectations have risen as consumer and business customers alike seek rich content, multi-use devices, networked products and converged services including on-demand video, digital TV, high speed Internet, VoIP, and wireless applications. It's uncharted territory for most broadband companies.

Incidentally, the "mobile service provisions" aspect refers not only to the ability of subscribers to be able to purchase mobile phone like services as is often seen in co-marketing efforts between providers of land-line services. Rather, it is one major ambition of wireless - the ability to have access to all of the above including voice, Internet, and content/video while on the go and requiring no tethering to the network via cables.

Given advancements in WiMAX and other leading edge technologies, the ability to transfer information over a wireless link with a variety of speeds, distances, and non-line-of-sight conditions is rapidly improving. It is possible that one could never need to be connected by a wire to anything, even while at home.

One fundamental aspect of the quadruple play is not only the long awaited broadband convergence but also the players involved. Many of them, from the largest global service providers to whom we connect today via wires and cables to the smallest of startup service providers are interested. The opportunities are attractive: the big three telecom services - telephony, cable television, and wireless - could combine the size of their respective industries.

The next level of service might be the integration of RFID into the quadruple play which will add the capability for home equipment to communicate to the outside world and schedule maintenance on its own.

In the UK, the recent merger of NTL:Telewest and Virgin Mobile resulted in a company offering a quadruple play of cable television, broadband Internet, home telephone, and mobile telephone services.

Home network

Early in the 21st century, home LAN convergence so rapidly integrated home routers, wireless access points, and DSL modems that users were hard put to identify the resulting box they used to connect their computers to their Internet service. A general term for such a combined device is a residential gateway.

"Black box fallacy"

Some expect we will eventually access all media content through one device, or "black box". As such, media business practice has been to identify the next "black box" to invest in and provide media for. This has caused a number of problems.

Firstly, as "black boxes" are invented and abandoned, the individual is left with numerous devices that can perform the same task, rather than one dedicated for each task. For example, one may own both a computer and a video games console, subsequently owning two DVD players. This is contrary to the streamlined goal of the "black box" theory, and instead creates clutter.

Secondly, technological convergence tends to be experimental in nature. This has led to consumers owning technologies with additional functions that are harder, if not impractical, to use rather than one specific device. For example, Intel has created a surfboard with an in-built laptop. Whilst interesting, it would be more practical to use a conventional computer rather than a laptop on a surfboard. Additionally, LG has created a microwave with a television screen. Many people would only watch the TV for the duration of the meal's cooking time, or whilst in the kitchen, but would not use the microwave as the household TV. These examples show that in many cases technological convergence is unnecessary or unneeded, in favour of a specialized device for each task.

Furthermore, although consumers primarily use a specialized media device for their needs, other "black box" devices that perform the same task can be used to suit their current situation. As a 2002 Cheskin Research report explained:

...Your email needs and expectations are different whether you're at home, work, school, commuting, the airport, etc., and these different devices are designed to suit your needs for accessing content depending on where you are- your situated context.

Despite the creation of "black boxes", intended to perform all of one's tasks, the trend is to use devices that can suit the consumer's physical position.

Due to the variable utility of portable technology, convergence occurs in high end mobile devices. They incorporate multimedia services, GPS, Internet access, and mobile telephony into a single device, heralding the rise of what has been termed the "smart phone", a device designed to remove the need to carry multiple devices while away from the home.

Conversely, it would seem that hardware is instead diverging whilst media content is converging. Media has developed into brands that can offer content in a number of forms. Two examples of this are Star Wars and The Matrix. Both are films, but are also books, video games, cartoons, and action figures. Branding encourages expansion of one concept, rather than the creation of new ideas. In contrast, hardware has diversified in order to accommodate the convergence of media. Hardware needs to be specific to each

function. In a "black box" situation, a consumer would only need to purchase one form of media (say, the Matrix) and would be able to do everything with it.

Chapter- 4

State of the Art

The **state of the art** is the highest level of development, as of a device, technique, or scientific field, achieved at a particular time. It also applies to the level of development (as of a device, procedure, process, technique, or science) reached at any particular time usually as a result of modern methods.

Origin

The earliest usage of the term "state of the art" documented by the Oxford English Dictionary dates back to 1910 from an engineering manual by Henry Harrison Suplee (1856-post 1943), an engineering graduate (U. Of Pennsylvania, 1876), titled *Gas Turbine: progress in the design and construction of turbines operated by gases of combustion*. It reads: "In the present state of the art this is all that can be done."

Patent law

In the context of the European and Australian patent law, the term "state of the art" is a concept used in the process of assessing and asserting novelty and inventive step, and is a synonym of the expression "prior art". In the European Patent Convention (EPC), "[the] state of the art shall be held to comprise everything made available to the public by means of a written or oral description, by use, or in any other way, before the date of filing of the European patent application" according to Article 54(2) EPC. Due account should be taken of Article 54(3) EPC as well, but merely for the examination of novelty.

The expression "background art" is also used in certain legal provisions, such as Rule 42(1)(b) and(c) EPC (previously Rule 27(1)(b) and (c) EPC 1973), and has the same meaning.

Prior art

Prior art (also known as **state of the art**, which also has other meanings, or **background art**), in most systems of patent law, constitutes all information that has been made available to the public in any form before a given date that might be relevant to a patent's claims of originality. If an invention has been described in prior art, a patent on that invention is not valid.

Information kept secret, for instance, as a trade secret, is not usually prior art, provided that employees and others with access to the information are under a non-disclosure obligation. With such an obligation, the information will typically not be regarded as prior art. Therefore, a patent may be granted on an invention, although someone else already knew of the invention. A person who used an invention in secret may in some jurisdictions be able to claim "prior user rights" and thereby gain the right to continue using the invention. As a special exception, earlier-filed and unpublished patent applications do qualify as prior art as of their filing date in certain circumstances.

In order to anticipate a claim, prior art is generally expected to provide a description sufficient to inform an average worker in the field (or the *person skilled in the art*) of some subject matter falling within the scope of the claim. Prior art must be available in some way to the public, and in many countries, the information needs to be recorded in a fixed form somehow. Prior art generally does not include unpublished work or mere conversations. It is disputed whether traditional knowledge (*e.g.,* of medical properties of a certain plant) constitutes prior art.

Patents disclose to society how an invention is practiced, in return for the right (during a limited term) to exclude others from manufacturing, selling, offering for sale or using the patented invention without the patentee's permission. Patent offices deal with prior art searches in the context of the patent granting procedure. To assess the validity of a patent application, patent offices explore the prior art that was disclosed before the invention occurred (in the United States) or before the filing date (in the rest of the world).

First-to-invent versus first-to-file

A *first-to-file rule* is followed in most countries other than the United States. Under the rule, regardless of who the first inventor was, the person or legal entity who files a patent application first is the one who is granted the patent.

A *first-to-invent* rule is followed in the United States. Invention is generally defined to comprise two steps: conception of the invention and reduction to practice of the invention. When an inventor conceives of an invention and *diligently* reduces the invention to practice (by filing a patent application, by practicing the invention, and so on), the inventor's date of invention will be the date of conception. Thus, provided an inventor is diligent in reducing an application to practice, he or she will be the first

inventor, and the inventor entitled to patent, even if another files a patent application (reduces the invention to practice) before the inventor.

Efforts are currently being made to unify the patent laws of various countries, so that inventors have the same rights regardless of the country where a patent is granted.

Other considerations

Although patents normally go to the first inventor under a first-to-file system, an inventor who keeps the information secret or does not publish it does not establish prior art and loses the right to the patent. Without prior art, a subsequent inventor can get a valid patent on the same invention and then apply it against earlier inventor(s). An earlier inventor can forestall such an act by a subsequent inventor by recognizing the invention and applying for a patent, or by publishing details of how to practice the invention, thus creating prior art.

Searching

A "novelty search" is a prior art search that is often conducted by patent attorneys, patent agents or professional patent searchers before an inventor files a patent application. A novelty search helps an inventor to determine if the invention is novel before the inventor commits the resources necessary to obtain a patent. The search may include searching in databases of patents, patent applications and other documents such as utility models and in the scientific literature.

A "validity search" is a prior art search done after a patent issues. The purpose of a validity (or invalidity) search is to find prior art that the patent examiner overlooked so that a patent can be declared invalid. This might be done by an entity infringing, or potentially infringing, the patent, or it might be done by a patent owner or other entity that has a financial stake in a patent to confirm the validity of a patent.

A clearance search is a search of issued patents to see if a given product or process violates someone else's existing patent. If so, then a validity search may be done to try to find prior art that would invalidate the patent. A clearance search is a search targeting patents being in force and may be limited to a particular country and group of countries, or a specific market.

Duty of disclosure

In the United States, inventors and their patent agents or attorneys are required by law to submit any references they are aware of to the United States Patent and Trademark Office that may be material to the patentability of the claims in a patent application they have filed. The patent examiner will then determine if the references qualify as "prior art" and may then take them into account when examining the patent application. If the

attorney/agent or inventor fails to properly disclose the potentially relevant references they are aware of, then a patent can be found invalid for inequitable conduct.

At least Japan also has a duty of disclosure. Australia has abolished its duty of disclosure with regard to the results of documentary searches by, or on behalf of, foreign patent offices, except where: (a) normal exam was requested before April 22, 2007, and (b) the foreign patent office search issued before April 22, 2007, and (c) acceptance (allowance) was officially advertised before July 22, 2007.

Public participation in patent examination

With the advent of the Internet, a number of initiatives have been undertaken to create a forum where the public at large can participate in prior art searches. These forums have been related to both issued patents and pending patent applications.

Pending patent applications

More recently, different attempts to employ open Internet-based discussions for encouraging public participation commenting on pending U.S. applications have been started.

Chapter- 5

Appropriate Technology

The Universal Nut Sheller in use in Uganda, an example of appropriate technology

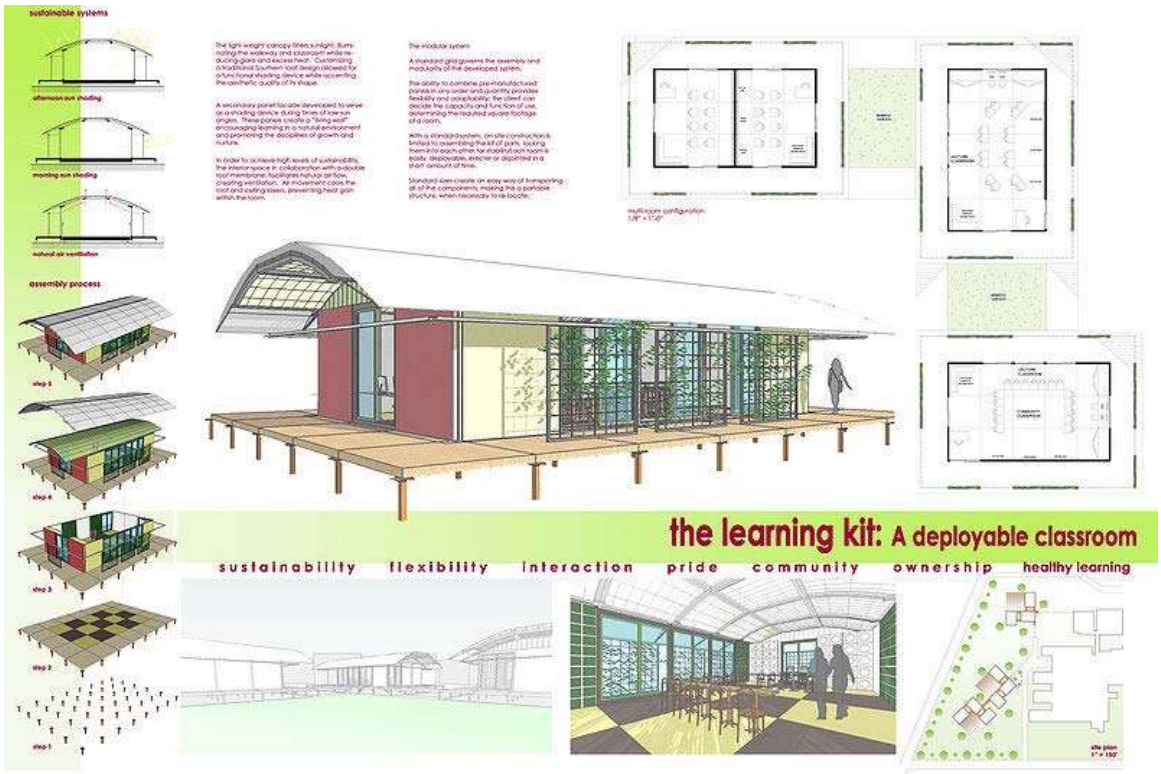
Appropriate technology (AT) is technology that is designed with special consideration to the environmental, ethical, cultural, social, political, and economical aspects of the community it is intended for.

With environmental and ethical goals in mind, AT proponents claim their methods require fewer resources, are easier to maintain, and have less of an impact on the environment compared to techniques from mainstream technology, which they contend is wasteful and environmentally polluting.

The term is usually used to describe simple technologies proponents consider suitable for use in developing nations or less developed rural areas of industrialized nations. This form of "appropriate technology" usually prefers labor-intensive solutions over capital-intensive ones, although labor-saving devices are also used where this does not mean high capital or maintenance cost. In practice, appropriate technology is often something

described as using the simplest level of technology that can effectively achieve the intended purpose in a particular location. In industrialized nations, the term *appropriate technology* takes a different meaning, often referring to engineering that takes special consideration of its social and environmental ramifications.

Background and definition



Sustainable portable classroom design proposal

The term *appropriate technology* came into some prominence during the 1973 energy crisis and the environmental movement of the 1970s. The term is typically used in two arenas: utilizing the most effective technology to address the needs of developing areas, and using socially and environmentally acceptable technologies in industrialized nations.

Appropriate technology founders

In the modern world appropriate technology is supposed to commence from Mahatma Gandhi who advocated small, local, mostly village-based technology to help India's villages become self reliant and thus aid in the freedom struggle against British and wealthy Indians. Gandhi's philosophies on technology were contrary to the belief that technological development was inherently synonymous with progress. He believed the powers of technology should be produced and used artfully and the benefits should be close to the individual and widely produced and distributed in a decentralised fashion. Gandhi claimed that his favorite technologies were the sewing machine, because it was

invented out of love, and the bicycle, because it kept one's feet close to the ground. He felt that the paradigm of technology should not be one that disenfranchises people and be used in the pursuit of violence, rather, it should be used in a way that empowers people broadly. Integrated with the movement for self-rule, which was based on local economies, Gandhi championed the spinning wheel, or *charka*, employed in the khadi movement in the 1920s, which produced cloth locally in an act of civil disobedience of the imperial system, causing the British monopoly on textiles to collapse. However, in the movement for *Swaraj*, or home rule, Gandhi believed in a total revolution of production, saying that "It is not about getting rid of the tiger and keeping the tiger's nature". Having said "it is better for a machine to be idle than a man to be idle", Gandhi rejected the factory model of industrialisation, which valued production over the worker. He raised money to offer a reward for someone to invent a spinning wheel that could employ people in the same way, while producing more thread.

E. F. Schumacher who was very strongly influenced by Gandhi's philosophy took his village development further and coined "intermediate technology" in early 1970s. It is Schumacher through his book Small is Beautiful and later by creating the Intermediate Technology Development Group, now known as Practical Action, that really started the appropriate technology movement.

Stewart Brand, editor of the Whole Earth Catalog aided in popularizing the movement's roots and contributed ideas which inspired it, to the point where he is sometimes listed as a founder.

Appropriate technology practitioners

Some of the well known practitioners of the appropriate technology-sector include: M K Ghosh, B.V. Doshi, Buckminster Fuller, William Moyer (1933–2002), Amory Lovins, Sanoussi Diakité, Victor Papanek, Johan Van Lengen and Arne Næss (1912–2009)

Appropriate technology in developing areas

The term has often been applied to the situations of developing nations or underdeveloped rural areas of industrialized nations. The use of appropriate technology in these areas seeks to fill in the gaps left by conventional development which typically focuses on capital-intensive, urban development.

Appropriate technologies are not necessarily "low" technology, and can utilize recent research, for example cloth filters which were inspired by research into the way cholera is carried in water. A type of high-efficiency, white LED lights is used by the Light Up the World Foundation in remote areas of Nepal to replace more traditional forms of lighting that cause health problems associated with kerosene lamps or wood fires.

Intermediate technology

Coined by E. F. Schumacher, the term **intermediate technology** is similar to appropriate technology. It refers specifically to tools and technology that are significantly more effective and expensive than traditional methods, but still an order of magnitude (one tenth) cheaper than developed world technology. Proponents argue that such items can be easily purchased and used by poor people, and according to proponents can lead to greater productivity while minimizing social dislocation. Much intermediate technology can also be built and serviced using locally available materials and knowledge. This intermediate technology is conducive to decentralization, compatible with the laws of ecology, gentle in its use of scarce resources, and designed to serve the human person instead of making him the servant of machines.

Appropriate hard and soft technologies

According to Dr. Maurice Albertson and Faulkner, appropriate hard technology is "engineering techniques, physical structures, and machinery that meet a need defined by a community, and utilize the material at hand or readily available. It can be built, operated and maintained by the local people with very limited outside assistance (e.g., technical, material, or financial). it is usually related to an economic goal." Some have explored the use of classroom projects for university-level physics students to research, develop and test appropriate hard technology.

Albertson and Faulkner consider Appropriate soft technology as technology that deals with "the social structures, human interactive processes, and motivation techniques. It is the structure and process for social participation and action by individuals and groups in analyzing situations, making choices and engaging in choice-implementing behaviors that bring about change."

Appropriate technology in developed countries

The term *appropriate technology* is also used in developed nations to describe the use of technology and engineering that results in less negative impacts on the environment and society. E. F. Schumacher asserts that such technology, described in the book *Small is Beautiful* tends to promote values such as health, beauty and permanence, in that order.

Often the type of appropriate technology that is used in developed countries is "Appropriate and Sustainable Technology" (AST); or appropriate technology that, besides being functional and relatively cheap (though often more expensive than true AT), is also very durable and lasts a long time.

Determining a sustainable approach

Features such as low cost, low usage of fossil fuels and use of locally available resources can give some advantages in terms of sustainability. For that reason, these technologies

are sometimes used and promoted by advocates of sustainability and alternative technology.

Besides using natural, locally available resources (e.g. wood or adobe), waste materials imported from cities using conventional (and inefficient) waste management may be gathered and re-used to build a sustainable living environment. Use of these cities' waste material allows the gathering of a huge amount of building material at a low cost. When obtained, the materials may be recycled over and over in the own city/community, using the cradle to cradle design method. Locations where waste can be found include landfills, junkyards, on water surfaces and anywhere around towns or near highways. Organic waste that can be reused to fertilise plants can be found in sewages. Also, town districts and other places (e.g. cemeteries) that are subject of undergoing renovation or removal can be used for gathering materials as stone, concrete, or potassium.

City construction

In order to increase the efficiency of a great number of city services (efficient water provisioning, efficient electricity provisioning, easy traffic flow, water drainage, decreased spread of disease with epidemics, ...), the city itself must first be built correctly. In the developing world, many cities are expanding rapidly and new ones are being built. Looking into the cities design in advance is a must for every developing nation.

Building construction

- Adobe (including the variation called Super Adobe),
- Rammed earth,
- Compressed earth block,
- Dutch brick,
- Animal products,
- Cob
- and/or other green building materials could be considered appropriate earth building technology for much of the developing world, as they make use of materials which are widely available locally and are thus relatively inexpensive.

The local context must be considered as, for example, mudbrick may not be durable in a high rainfall area (although a large roof overhang and cement stabilisation can be used to correct for this), and, if the materials are not readily available, the method may be inappropriate. Other forms of natural building may be considered appropriate technology, though in many cases the emphasis is on sustainability and self-sufficiency rather than affordability or suitability. As such, many buildings are also built to function as autonomous buildings (e.g. earthships, ...). One example of an organisation that applies appropriate earthbuilding techniques would be Builders Without Borders.

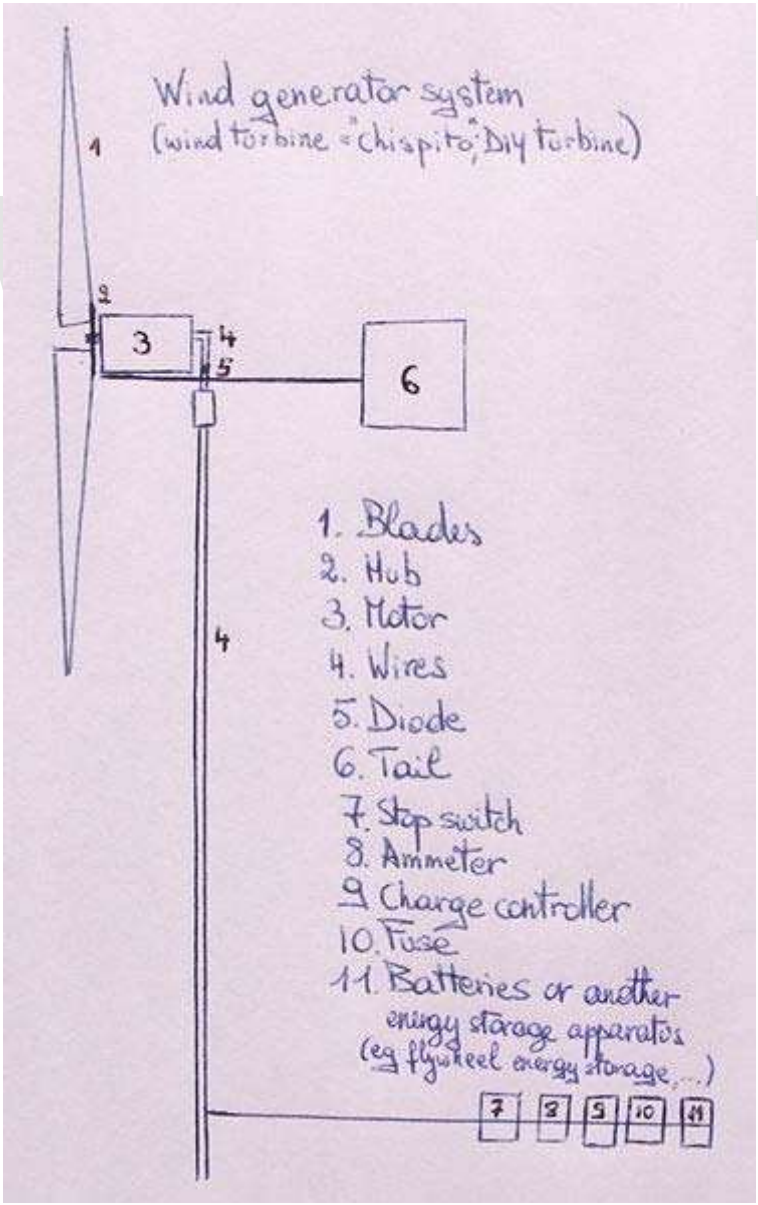
The building structure must also be considered. Cost-effectiveness is an important issue in projects based around appropriate technology, and one of the most efficient designs

herein is the public housing approach. This approach lets everyone have their own sleeping/recreation space, yet incorporate communal spaces e.g. mess halls, Latrines, public showers, ...

In addition, to decrease costs of operation (heating, cooling, ...) techniques as Earth sheltering, Trombe walls, ... are often incorporated.

Organizations as Architecture for Humanity also follows principles consistent with appropriate technology, aiming to serve the needs of poor and disaster-affected people.

Energy



Small-scale (DIY) generation system

The term soft energy technology was coined by Amory Lovins to describe "appropriate" renewable energy. "Appropriate" energy technologies are especially suitable for isolated and/or small scale energy needs. Electricity can be provided from:

- Photovoltaic (PV) solar panels, and (large) Concentrating solar power plants. PV solar panels made from Low-cost photovoltaic cells or PV-cells which have first been concentrated by a Luminescent solar concentrator-panel are also a good option. Especially companies as Solfocus make appropriate technology CSP plants which can be made from waste plastics polluting the surroundings.
- Solar thermal collector
- wind power (home do-it yourself turbines and larger-scale)
- micro hydro, and pico hydro
- human-powered handwheel generators
- other zero emission generation methods

Some intermediate technologies include:

- Biobutanol,
- biodiesel,
- and straight vegetable oil can be appropriate, direct biofuels in areas where vegetable oil is readily available and cheaper than fossil fuels.
- Anaerobic digestion power plants
- Biogas is another potential source of energy, particularly where there is an abundant supply of waste organic matter. A generator (running on biofuels) can be run more efficiently if combined with batteries and an inverter; this adds significantly to capital cost but reduces running cost, and can potentially make this a much cheaper option than the solar, wind and micro-hydro options.
- Feces (e.g. cow dung, human, etc.) can also be used. For example DEKA's Project Slingshot stirling electricity generator works this energy source to make electricity.
- Biochar is another similar energy source which can be obtained through charring of certain types of organic material (e.g. hazelnut shells, bamboo, chicken manure, ...) in a pyrolysis unit. A similar energy source is terra preta nova.

Finally, urine can also be used as a basis to generate hydrogen (which is an energy carrier). Using urine, hydrogen production is 332% more energy efficient than using water.

Electricity distribution could be improved so to make use of a more structured electricity line arrangement and universal AC power plugs and sockets (e.g. the CEE 7/7 plug). In addition, a universal system of electricity provisioning (e.g. universal voltage, frequency, ampère; e.g. 230 V with 50 Hz), as well as perhaps a better mains power system (e.g. through the use of special systems as perfected single wire earth returns; e.g. Tunisia's MALT-system, which features low costs and easy placement)

Electricity storage (which is required for autonomous energy systems) can be provided through appropriate technology solutions as deep-cycle and car-batteries (intermediate technology), long duration flywheels, electrochemical capacitors, compressed air energy storage (CAES), liquid nitrogen and pumped hydro. Thanks to Daniel Nocera, low-cost hydrogen storage is now also possible as a mid to short-term storage solution. Many solutions for the developing world are sold as a single package, containing a (micro) electricity generation power plant and energy storage. Such packages are called remote-area power supply

Water supply and treatment

Hand-operated, reciprocating, positive displacement, water pump in Košice-Tahanovce, Slovakia (walking beam pump).

As of 2006, waterborne diseases are estimated to cause 1.8 million deaths each year while about 1.1 billion people lack proper drinking water.

Water generally needs treatment before use, depending on the source and the intended use (with high standards required for drinking water). The quality of water from household connections and community water points in low-income countries is not reliably safe for direct human consumption. Water extracted directly from surface waters and open hand-dug shallow wells nearly always requires treatment.

Appropriate technology options in water treatment include both community-scale and household-scale point-of-use (POU) designs.

The most reliable way to kill microbial pathogenic agents is to heat water to a rolling boil. Other techniques, such as varying forms of filtration, chemical disinfection, and exposure to ultraviolet radiation (including solar UV) have been demonstrated in an array of randomized control trials to significantly reduce levels of waterborne disease among users in low-income countries.

Over the past decade, an increasing number of field-based studies have been undertaken to determine the success of POU measures in reducing waterborne disease. The ability of POU options to reduce disease is a function of both their ability to remove microbial pathogens if properly applied and such social factors as ease of use and cultural appropriateness. Technologies may generate more (or less) health benefit than their lab-based microbial removal performance would suggest.

The current priority of the proponents of POU treatment is to reach large numbers of low-income households on a sustainable basis. Few POU measures have reached significant scale thus far, but efforts to promote and commercially distribute these products to the world's poor have only been under way for a few years.

On the other hand, small-scale water treatment is reaching increasing fractions of the population in low-income countries, particularly in South and Southeast Asia, in the form of water treatment kiosks (also known as water refill stations or packaged water producers). While quality control and quality assurance in such locations may be variable, sophisticated technology (such as multi-stage particle filtration, UV irradiation, ozonation, and membrane filtration) is applied with increasing frequency. Such microenterprises are able to vend water at extremely low prices, with increasing government regulation. Initial assessments of vended water quality are encouraging.

Whether applied at the household or community level, some examples of specific treatment processes include:

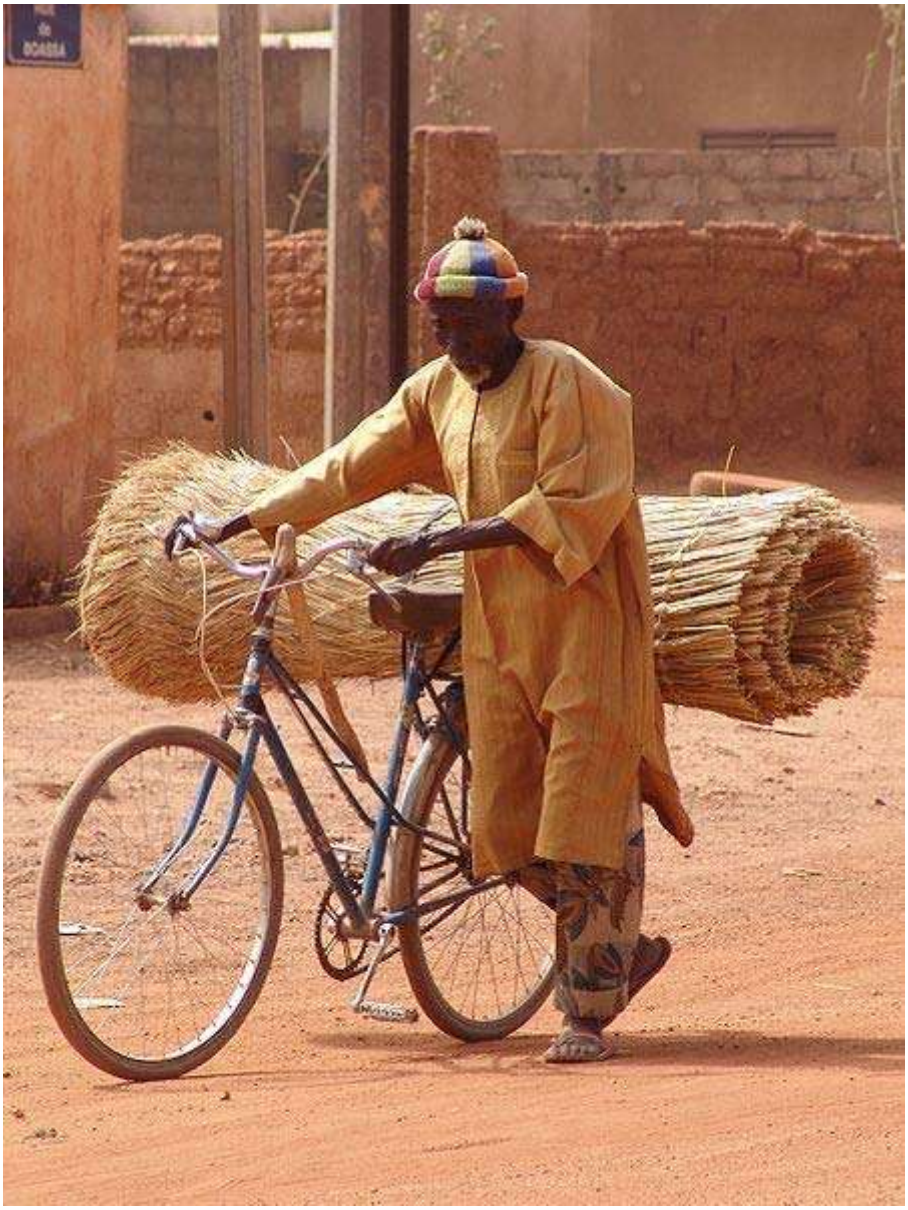
- Porous ceramic filtration, using either clay or diatomaceous earth, and oriented as either cylinder, pot, or disk, with gravity-fed or siphon-driven delivery systems. Silver is frequently added to provide antimicrobial enhancement
- Intermittently operated slow-sand filtration, also known as biosand filtration

- Chlorine disinfection, employing calcium hypochlorite powder, sodium hypochlorite solution, or sodium dichloroisocyanurate (NaDCC) tablets
- Chemical flocculation, using either commercially produced iron or aluminum salts or the crushed seeds of certain plants, such as Moringa oleifera
- Mixed flocculation/disinfection using commercially produced powdered mixtures
- Irradiation with ultraviolet light, whether using electric-powered lamps or direct solar exposure
- membrane filtration, employing ultrafiltration or reverse osmosis filter elements preceded by pretreatment

Some appropriate technology water supply measures include:

- Deep wells with submersible pumps in areas where the groundwater (aquifers) are located at depths >10 m.
- Shallow wells with lined walls and covers.
- rainwater harvesting systems with an appropriate method of storage, especially in areas with significant dry seasons.
- Fog collection, which is suitable for areas which experience fog even when there is little rain.
- Air well, a structure or device designed to promote the condensation of atmospheric moisture.
- Handpumps and treadle pumps are however only an option in areas is located at a relatively shallow depth (e.g. 10 m). For deeper aquifers (>10 m), submersible pumps placed inside a well) need to be used. Treadle pumps for household irrigation are now being distributed on a widespread basis in developing countries. The principle of Village Level Operation and Maintenance is important with handpumps, but may be difficult in application.
- Condensation bags and condensation pits can be an appropriate technology to get water, yet yields are low and are (for the amount of water obtained), labour intensive. Still, it may be a good (very cheap) solution for certain desperate communities.
- The hippo water roller allows more water to be carried, with less effort and could thus be a good alternative for ethnic communities who do not wish to give up water gathering from remote locations, assuming low topographic relief.
- The roundabout playpump, developed and used in southern Africa, harnesses the energy of children at play to pump water.

Transportation

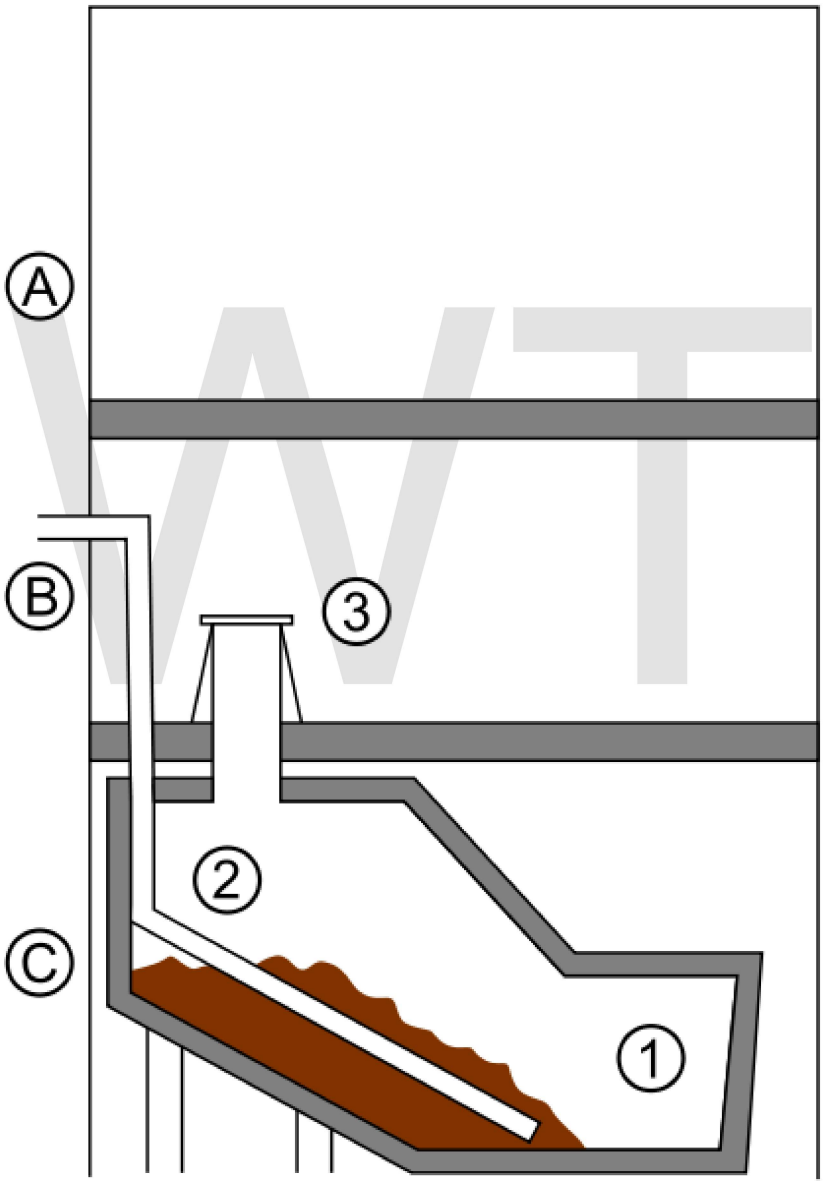


A man uses a bicycle to cargo goods in Ouagadougou, Burkina Faso (2007)

Human powered-vehicles include the bicycle, which provides general-purpose, human-powered transportation at a lower cost of ownership than motorized vehicles, with many gains over simply walking, and the whirlwind wheelchair, which provides mobility for disabled people who cannot afford the expensive wheelchairs used in developed countries. Animal powered vehicles/transport may also be another appropriate technology. Certain zero-emissions vehicles may be considered appropriate transportation technology, including compressed air cars, liquid nitrogen and hydrogen-powered vehicles. Also, vehicles with internal combustion engines may be converted to hydrogen or oxyhydrogen combustion.

Bicycles can also be applied to commercial transport of goods to and from remote areas. An example of this is Karaba, a free-trade coffee co-op in Rwanda, which uses 400 modified bicycles to carry hundreds of pounds of coffee beans for processing. Other projects for developing countries include the redesign of cycle rickshaws to convert them to electric power. However recent reports suggest that these rickshaws are not plying on the roads.

Sanitation



A clivus Multrum composting toilet
A. Second floor, B. First floor, C. Ground floor, 1. Humus compartment, 2. Ventilation pipe, 3. Water closet.

As of 2006, waterborne diseases are estimated to cause 1.8 million deaths each year, marking the importance of proper sanitation systems. It is clear that the developing world is heavily lacking in proper public sanitation and that solutions as sewerages (or alternatively small-scale treatment systems) need to be provided.

Ecological sanitation can be viewed as a three-step process dealing with human excreta: (1) Containment, (2) Sanitization, (3) Recycling. The objective is to protect human health and the environment while limiting the use of water in sanitation systems for hand (and anal) washing only and recycling nutrients to help reduce the need for synthetic fertilizers in agriculture.

Small scale systems include:

- Composting toilets are the most environmental form of excrement disposal systems. In addition, the toilets design allows the nutrients to be reused (e.g. for fertilising food crops). Also, DIY composting toilets can be build at a very low cost.
- BiPu is a portable system suitable for disaster management, while other forms of latrine provide safe means of disposing of human waste at a low cost. The Orangi Pilot Project was designed based on an urban slum's sanitation crisis. Kamal Kar has documented the latrines developed by Bangladeshi villagers once they became aware of the health problems with open defecation.
- Treatment ponds and constructed wetlands can help to purify sewage and greywater. They consist mostly of plants (e.g. reed, ...) and therefore require only little power, and are hugely self-sufficient.
- Certain other options as Slow sand filters, UV filters, ... may also be employed

Lighting

LED Lamp with GU10 twist lock fitting, intended to replace halogen reflector lamps

- White LEDs and a source of renewable energy (such as solar cells) are used by the Light Up the World Foundation to provide lighting to poor people in remote areas, and provide significant benefits compared to the kerosene lamps which they replace. Certain other companies as Powerplus also have LED-flashlights with imbedded solar cells.
- Organic LEDs made by roll-to-roll production are another source of cheap light that will be commercially available at low cost by 2015.
- Compact fluorescent lamps (as well as regular fluorescent lamps and LED-lightbulbs) can also be used as appropriate technology. Although they are less environmentally friendly then LED-lights, they are cheaper and still feature relative high efficiency (compared to incandescent lamps).
- The Safe bottle lamp is a safer kerosene lamp designed in Sri Lanka. Lamps as these allow relative long, mobile, lighting. The safety comes from a secure screw-

on metal lid, and two flat sides which prevent it from rolling if knocked over. An alternative to fuel or oil-based lanterns is the Uday lantern, developed by Philips as part of its Lighting Africa project (sponsored by the World Bank Group).
- The Faraday flashlight is a LED flashlight which operates on a capacitor. Recharging can be done by manual winching or by shaking, hereby avoiding the need of any supplementary electrical system.
- HID-lamps finally can be used for lighting operations where regular LED-lighting or other lamps will not suffice. Examples are car headlights. Due to their high efficiency, they are quite environmental, yet costly, and they still require polluting materials in their production process.

Food production

Food production has often been included in autonomous building/community projects to provide security. Skilled, intensive gardening can support an adult from as little as 15 square meters of land. Some proven intensive, low-effort food-production systems include urban gardening (indoors and outdoors). Indoor cultivation may be set-up using hydroponics with Grow lights, while outdoor cultivation may be done using permaculture, forest gardening, no-till farming, Do Nothing Farming, etc. In order to better control the irrigation outdoors, special irrigation systems may be created as well (although this increases costs, and may again open the door to cultivating non-indigenous plants; something which is best avoided). One such system for the developing world is discussed here.

Crop production tools are best kept simple (reduces operating difficulty, cost, replacement difficulties and pollution, when compared to motorized equipment). Tools can include scythes, animal-pulled plows (although no-till farming should be preferred), dibbers, wheeled augers (for planting large trees), kirpis, hoes.

Greenhouses are also sometimes included. Sometimes they are also fitted with irrigation systems, and/or heat sink-systems which can respectively irrigate the plants or help to store energy from the sun and redistribute it at night (when the greenhouse starts to cool down).

Food preparation

According to proponents, Appropriate Technologies can greatly reduce the labor required to prepare food, compared to traditional methods, while being much simpler and cheaper than the processing used in Western countries. This reflects E.F. Schumacher's concept of "intermediate technology," i.e. technology which is significantly more effective and expensive than traditional methods, but still an order of magnitude (10 times) cheaper than developed world technology. Key examples are:

- the Malian peanut sheller
- the fonio husking machine
- the screenless hammer mill

- the ISF corn mill
- the ISF rice huller
- all other types of electrical or hand-operated kitchen equipment (grinders, cutters, ...) Special multifunctional kitchen robots that are able to perform several functions (e.g. grinding, cutting, and even vacuum cleaning and polishing) are able to reduce costs even more. Examples of these devices were e.g. the (now discontinued) Piccolo household appliance from Hammelmann Werke (previously based in Bad Kissingen.) It was equipped with a flexible axis, allowing a variety of aids to be screwed on.

Cooking

In Ghana, Zouzugu villagers use solar cookers for preparing their meals

- Solar cookers are appropriate to some settings, depending on climate and cooking style. They are emission-less and very low-cost. Hybrid variants also exist that incorporate a second heating source such as electrical heating or wood-based.
- Hot plates are 100% electrical, fairly low cost (around 20€) and are mobile. They do however require an electrical system to be present in the area of operation.
- Rocket stoves and certain other woodstoves (e.g. Philips Woodstove) improve fuel efficiency, and reduce harmful indoor air pollution. The stoves however still make use of wood. However, briquette makers can now turn organic waste into fuel, saving money and/or collection time, and preserving forests.

Refrigeration

- Solar, special Einstein refrigerators and thermal mass refrigerators reduce the amount of electricity required. Also, solar and special Einstein refrigerators do not use haloalkanes (which play a key role in ozone depletion), but use heat pumps or

mirrors instead. Solar refrigerators have been built for developing nations by Sopology.

- The pot-in-pot refrigerator is an African invention which keeps things cool without electricity. It provides a way to keep food and produce fresh for much longer than would otherwise be possible. This can be a great benefit to the families who use the device. For example, it is claimed that girls who had to regularly sell fresh produce in the market can now go to school instead, as there is less urgency to sell the produce before it loses freshness.

Ventilation and air conditioning

Chunche, naturally ventilated sheds for drying raisins in Xinjiang

- Natural ventilation can be created by providing vents in the upper level of a building to allow warm air to rise by convection and escape to the outside, while cooler air is drawn in through vents at the lower level.
- Electrical powered fans (e.g. ceiling fans) allow efficient cooling, at a far lower electricity consumption as airconditioning systems.
- A solar chimney often referred to as *thermal chimney* improves this natural ventilation by using convection of air heated by passive solar energy. To further maximize the cooling effect, the incoming air may be led through underground ducts before it is allowed to enter the building.

- A windcatcher (*Badgir*; بادگیری) is a traditional Persian architectural device used for many centuries to create natural ventilation in buildings. It is not known who first invented the windcatcher, but it still can be seen in many countries today. Windcatchers come in various designs, such as the uni-directional, bi-directional, and multi-directional.
- A passive down-draft cooltower may be used in a hot, arid climate to provide a sustainable way to provide air conditioning. Water is allowed to evaporate at the top of a tower, either by using evaporative cooling pads or by spraying water. Evaporation cools the incoming air, causing a downdraft of cool air that will bring down the temperature inside the building.

Health care

According to the Global Health Council, rather than the use of professionally schooled doctors, the training of villagers to remedy most maladies in towns in the developing world is most appropriate. Trained villagers are able to eliminate 80% of the health problems. Small (low-cost) hospitals - based on the model of the Jamkhed hospital – can remedy another 15%, while only 5% will need to go to a larger (more expensive) hospital.

- Before being able to determine the cause of the disease or malady, accurate diagnosis is required. This may be done manually (through observation, inquiries) and by specialised tools.
- Herbalist medicines (e.g. tinctures, tisanes, decoctions, ...) are appropriate medicines, as they can be freely made at home and are almost as effective as their chemical counterparts. A previous program that made use of herbal medicine was the Barefoot doctor program.
- A phase-change incubator, developed in the late 1990s, is a low cost way for health workers to incubate microbial samples.
- Birth control is also seen as an appropriate technology, especially now, because of increasing population numbers (overpopulating certain areas), increasing food prices and poverty. It has been proposed to a certain degree by PATH (program for appropriate technology in health).
- Jaipur leg was developed by Dr. P. K. Sethi and Masterji Ram Chander in 1968 as an inexpensive prosthetic leg for victims of landmine explosions.
- Natural cleaning products can be used for personal hygiene and cleaning of clothing and eating utensils; in order to decrease illnesses/maladies (as they eliminate a great amount of pathogens).

Note that many Appropriate Technologies benefit public health, in particular by providing sanitation and safe drinking water. Refrigeration may also provide a health benefit. (These are discussed in the following paragraphs.) This was too found at the Comprehensive Rural Health Project and the Women Health Volunteers projects in countries as Iran, Iraq and Nepal.

Information and communication technology

Netbooks as the Eee PC allow low cost information sharing and communication

- The OLPC XO, Simputer, Eee PC, and other low cost computers are computers aimed at developing countries. Besides the low price, other characteristics include resistance to dust, reliability and use of the target language.
- Eldis OnDisc and The Appropriate Technology Library are projects that use CDs and DVDs to give access to development information in areas without reliable and affordable internet access.
- The Wind-up radio and the computer and communication system planned by the Jhai Foundation are independent from power supply.
- There is also GrameenPhone, which fused mobile telephony with Grameen Bank's microfinance program to give Bangladeshi villagers access to communication.
- Mobile telephony is appropriate technology for many developing countries, as it greatly reduces the infrastructure required to achieve widespread coverage. However, mobile phone network may not always be available (it depends on the location) and may not always provide both voice and data services.
- Loband, a website developed by Aptivate, strips all the photographic and other bandwidth-intensive content from webpages and renders them as simple text, while otherwise allowing one to browse them normally. The site greatly increasing the speed of browsing, and is appropriate for use on low bandwidth connections as generally available in much of the developing world.
- An increasing number of activists provide free or very inexpensive web and email services using cooperative computer networks that run wireless ad hoc networks. Network service is provided by a cooperative of neighbors, each operating a router as a household appliance. These minimize wired infrastructure, and its costs and vulnerabilities. Private Internet protocol networks set up in this way can operate without the use of a commercial provider.
- Rural electrical grids can be wired with "optical phase cable", in which one or more of the steel armor wires are replaced with steel tubes containing fiber optics.
- Satellite Internet access can provide high speed connectivity to remote locations, however these are significantly more expensive than wire-based or terrestrial wireless systems. Wimax and forms of packet radio can also be used. Depending on the speed and latency of these networks they may be capable of relaying VoIP

traffic, negating the need for separate telephony services. Finally, the Internet Radio Linking Project provides potential for blending older (cheap) local radio broadcasting with the increased range of the internet.

- satellite-based telephone systems can also be used, as either fixed installations or portable handsets and can be integrated into a PABX or local IP-based network.

Money lending and finance

Through financial systems envisioned especially for the poor/developed world, many companies have been able to get started with only limited capital. Often banks lend the money to people wishing to start a business (such as with microfinance). In other systems, people for a Rotating Savings and Credit Association or ROSCA to purchase costly material together (such as Tontines and Susu accounts). Organisations, communities, cities or individuals can provide loans to other communities/cities (such as with the approach followed by Kiva.org, MicroPlace and LETS). Finally, in certain communities (usually isolated communities such as small islands or oases) everything of value is shared. This is called gift economy.

Chapter- 6

Medieval Technology

Pumhart von Steyr, a 15th century supergun

Medieval port crane for mounting masts and lifting heavy cargo in the former Hanse town of Danzig

Medieval technology refers to the technology used in medieval Europe under Christian rule. After the Renaissance of the 12th century, medieval Europe saw a radical change in the rate of new inventions, innovations in the ways of managing traditional means of production, and economic growth. The period saw major technological advances, including the adoption of gunpowder, the invention of vertical windmills, spectacles, mechanical clocks, and greatly improved water mills, building techniques (Gothic style, medieval castle), agriculture in general (three-field crop rotation).

The development of water mills from its ancient origins was impressive, and extended from agriculture to sawmills both for timber and stone. By the time of the Domesday Book, most large villages had turnable mills, around 6,500 in England alone. Water-power was also widely used in mining for raising ore from shafts, crushing ore, and even powering bellows.

European technical advancements in the 12th to 14th centuries were either built on long-established techniques in medieval Europe, originating from Roman and Byzantine antecedents, or adapted from cross-cultural exchanges through trading networks with the Islamic world, China, and India. Often, the revolutionary aspect lay not in the act of invention itself, but in its technological refinement and application to political and

economic power. Though gunpowder had long been known to the Chinese, it was the Europeans who developed and perfected its military potential, precipitating European expansion and eventual imperialism in the Modern Era.

Also significant in this respect were advances in maritime technology. Advances in shipbuilding included the multi-masted ships with lateen sails, the sternpost-mounted rudder and the skeleton-first hull construction. Along with new navigational techniques such as the dry compass, the Jacob's staff and the astrolabe, these allowed economic and military control of all seas adjacent to Europe and enabled the global navigational achievements of the dawning Age of Exploration.

At the turn to the Renaissance, Gutenberg's invention of mechanical printing made possible a dissemination of knowledge to a wider population, that would not only lead to a gradually more egalitarian society, but one more able to dominate other cultures, drawing from a vast reserve of knowledge and experience. The technical drawings of late medieval artist-engineers Guido da Vigevano and Villard de Honnecourt can be viewed as forerunners of later Renaissance works such as Taccola or da Vinci.

Civil technologies

In the following, a list of some important medieval technology. The approximate date or first mention of a technology in Medieval Europe is given. Technologies were often a matter of cultural exchange and date and place of first inventions are not listed here.

Agriculture

Heavy plough (5th->8th)

The heavy wheeled plough with a mouldboard first appears in the 5th century in Slavic lands, is then introduced into Northern Italy (the Po Valley) and by the 8th century it was used in the Rhineland. Essential in the efficient use of the rich, heavy, often wet soils of Northern Europe, its use allowed the area's forests and swamps to be brought under cultivation.

Hops (11th)

Added to beer, importance lay primarily in its ability to preserve beer and improve transportability for trade.

Horse collar (6th->9th)

Multiple evolutions from Classical Harness (Antiquity), to Breast Strap Harness (6th) to Horse collar (9th). Allowed more horse pulling power, such as with heavy ploughs.

Horseshoes (9th)

Allowed horse to adapt to non-grassland terrains in Europe (rocky terrain, mountains) and carry heavier loads. Possibly known to the Romans and Celts as early as 50 BC.

Wine press (12th)

First practical means of applying pressure on a plane surface. The principle later used for printing press.

Architecture and construction

Artesian well (1126) A thin rod with a hard iron cutting edge is placed in the bore hole and repeatedly struck with a hammer, underground water pressure forces the water up the hole without pumping. Artesian wells are named after the town of Artois in France, where the first one was drilled by Carthusian monks in 1126.

Rib vault (12th)

Essential element for the rise of Gothic architecture. Allowed vaults to be built for the first time over rectangles of unequal lengths. Also greatly facilitated scaffolding. Largely replaced older groin vault.

Segmental arch bridge (1345)

The Ponte Vecchio in Florence is considered medieval Europe's first stone segmental arch bridge.

Treadwheel crane

Treadwheel crane (1220s)

Earliest reference to a treadwheel in archival literature in France about 1225, followed by an illuminated depiction in a manuscript of probably also French origin dating to 1240. Apart from tread-drums, windlasses and occasionally cranks were employed for powering cranes. However, such devices were probably used by the Romans.

Stationary harbor crane (1244)

Stationary harbor cranes are considered a new development of the Middle Ages, its earliest use being documented for Utrecht in 1244. The typical harbor crane was a pivoting structure equipped with double treadwheels. There were two types: wooden

gantry cranes pivoting on a central vertical axle and stone tower cranes which housed the windlass and treadwheels with only jib arm and roof rotating. These cranes were placed docksides for the loading and unloading of cargo where they replaced or complemented older lifting methods like see-saws, winches and yards. **Slewing cranes** which allowed a rotation of the load and were thus particularly suited for dockside work appeared as early as 1340.

Floating crane

Beside the stationary cranes, floating cranes which could be flexibly deployed in the whole port basin came into use by the 14th century.

Mast crane

Some harbour cranes were specialised at mounting masts to newly built sailing ships, such as in Danzig, Cologne and Bremen.

Wheelbarrow (1170s)

Proved useful in building construction, mining operations, and agriculture. Literary evidence for the use of wheelbarrows appeared between 1170 and 1250 in North-western Europe. First depiction in a drawing by Matthew Paris in the middle of the 13th century.

Art

Portrait of a Man in a Turban, oil painting by Jan van Eyck (1433)

Oil paint (ca. 1410)

As early as the 13th century, oil was used to add details to tempera paintings. Major breakthrough by Flemish painter Jan van Eyck around 1410 who is credited with introducing a stable oil mixture.

Clocks

Hourglass (1338)

Reasonably dependable, affordable and accurate measure of time. Unlike water in a clepsydra, the rate of flow of sand is independent of the depth in the upper reservoir, and the instrument is not liable to freeze. Hourglasses are a medieval innovation (first documented in Siena, Italy).

Mechanical clocks (13th->14th)

A European innovation, these weight-driven clocks were used primarily in clock towers.

Mechanics

Compound crank

The Italian physician Guido da Vigevano combines in his 1335 *Texaurus*, a collection of war machines intended for the recapture of the Holy Land, two simple cranks to form a compound crank for manually powering war carriages and paddle wheel boats. The devices were fitted directly to the vehicle's axle respectively to the shafts turning the paddle wheels.

Metallurgy

Blast furnace (1150-1350)

European cast iron first appears in Middle Europe (for instance Lapphyttan in Sweden, Dürstel in Switzerland and the Märkische Sauerland in Germany) around 1150, in some places according to recent research even before 1100. Technique considered to be an independent European development.

Milling

Paper mill (13th)

The first certain of a water-powered paper mill, evidence for which is elusive in both Chinese and Muslim papermaking, dates to 1282.

Rolling mill (15th)

Used on producing metal sheet of even thickness. First used on soft, malleable metals, such as lead, gold and tin. Leonardo da Vinci described rolling mill for wrought iron.

Tidal Mills (6th)

The earliest tide mills were excavated on the Irish coast where watermillers knew and employed the two main waterwheel types: a 6th century tide mill at Killoteran near Waterford was powered by a vertical waterwheel, while the tide changes at Little Island were exploited by a twin-flume horizontal-wheeled mill (c. 630) and a vertical undershot

waterwheel alongside it. Another early example is the Nendrum Monastery mill from 787 which is estimated to have developed 7–8 HP at its peak.

Vertical windmills (1180s)

Invented in Europe as the pivotable post mill, first surviving mention of one comes from Yorkshire in England in 1185. Efficient at grinding grain or draining water. Later also as the stationary tower mill.

Water hammer (12th latest)

Used in metallurgy on forging the metal blooms from bloomeries and Catalan forges. Replaced manual hammerwork. Eventually superseded by steam hammers in the 19th century.

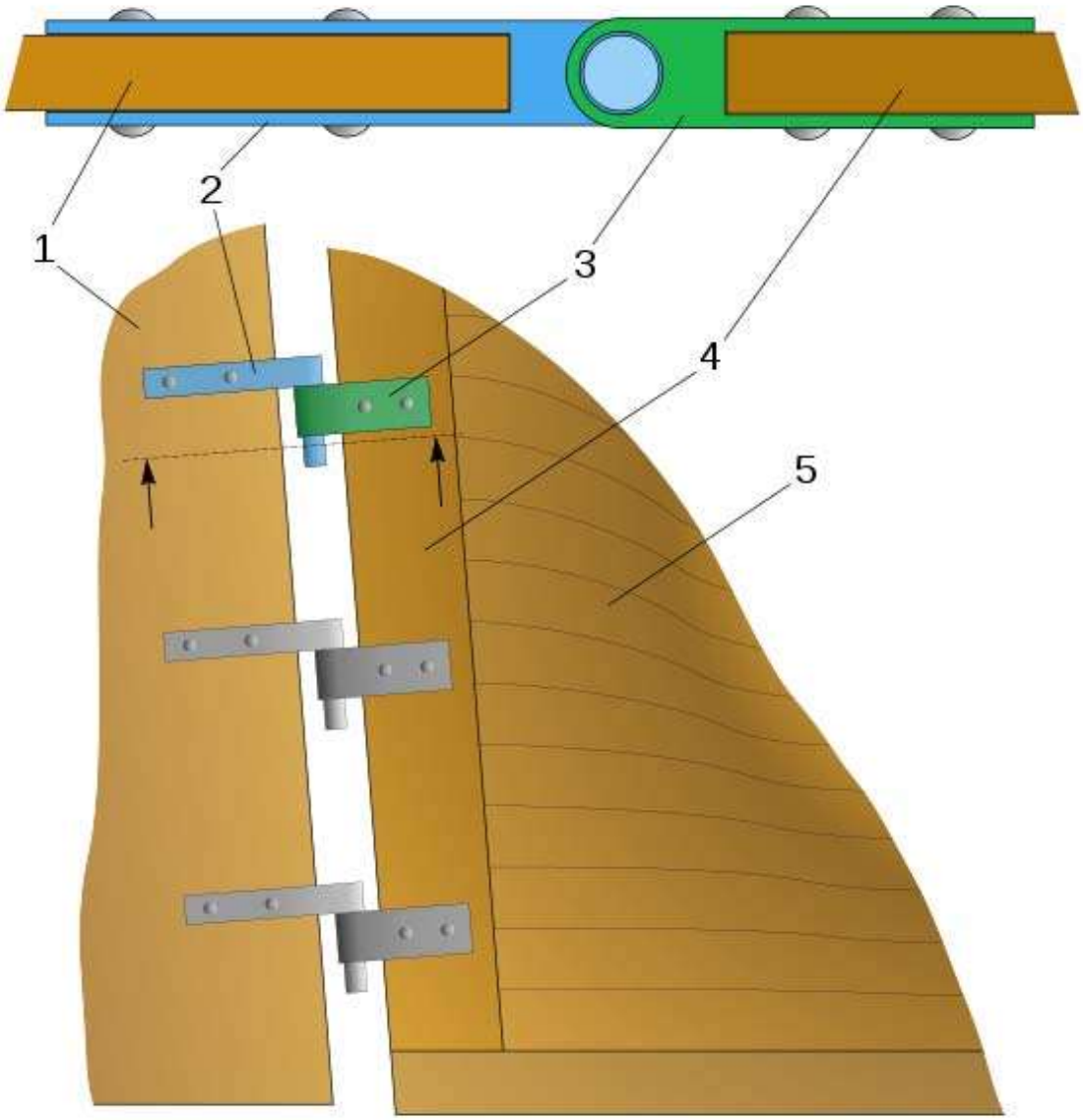
Navigation

Dry Compass (12th)

The first mention of the directional compass is in Alexander Neckam's *On the Natures of Things*, written in Paris around 1190. Either transmitted from China or the Arabs or an independent European innovation. Dry compass invented in the Mediterranean around 1300.

Astronomical compass (1269)

The French scholar Pierre de Maricourt describes in his experimental study *Epistola de magnete* (1269) three different compass designs he has devised for the purpose of astronomical observation.



Scheme of a sternpost-mounted medieval rudder

Stern-mounted rudders (1180s)

First depiction of a pintle-and gudgeon rudder on church carvings dating to around 1180. First appeared with cogs in the North and Baltic Sea, quickly spread to Mediterranean. The iron hinge system was the first stern rudder permanently attached to the ship hull and made a vital contribution to the navigation achievements of the age of discovery and thereafter.

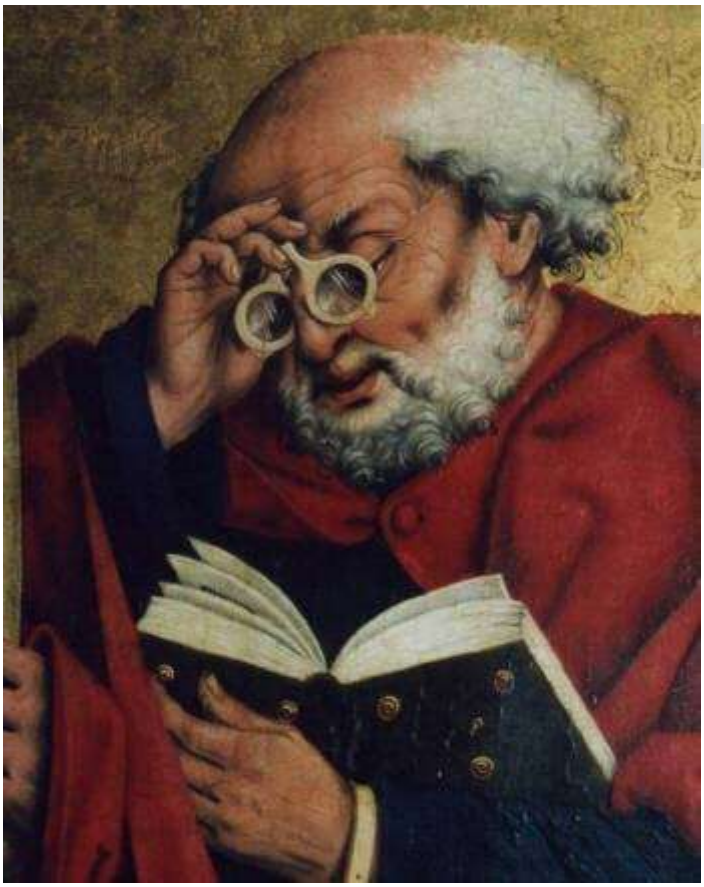
Printing, paper and reading

Movable type printing press (1440s)

Invented by Johannes Gutenberg. His great innovation was not the printing itself, but instead of using readily-carved plates as before, he used separate letters (*types*) from which the printing plates for pages were made up. This meant the types were recyclable and a page cast could be made up far faster than with readily-carved plates.

Paper (13th)

Invented in China, transmitted through Islamic Spain to Europe in the 13th century where the papermaking processes were mechanized by water-powered mills and paper presses



Reading Saint Peter with eyeglasses (1466)

Spectacles (1280s)

European innovation. Florence, Italy. Convex lenses, of help only to the far-sighted. Concave lenses were not developed prior to the 15th century.

Watermark (1282)

Medieval innovation to mark paper products and to discourage counterfeiting. First introduced in Bologna, Italy.

Science and learning

Arabic Numerals (13th c.)

First recorded mention in Europe 976, first widely published in 1202 by Fibonacci with his *Liber Abaci*.

University

The first medieval universities were founded between the 11th and 13th century leading to a rise in literacy and learning. By 1500, the institution had spread throughout most of Europe and played a key role in the Scientific Revolution. Today, the educational concept and institution has been globally adopted.

First international banking system

The first international banking system was created by the Knights Templar to help prvide them with finatial support while they tried to protect the crusader states in the middle east. It also helped pilgrimes in many ways including taking there valuables, then giving them a sealed document containing the items worth. The pilgrims then travaled to the holy land and gave the document to one of the many Templar stations in crusader held cities where they would reseave the same worth of items. Sevices like this made the pilgrimes less atractive targets to the many bandits that roamed the holy land.

Textile industry and garments

Functional button (13th)

Buttons with buttonholes used to fasten or close garment, being the most convenient method before the introduction of the zipper, appear in the 13th century Germany as indigenous innovation. Became soon widespread with the rise of snug-fitting clothing.

Horizontal loom (11th)

Horizontal and operated by foot-treadles, faster and more efficient.

Silk (6th)

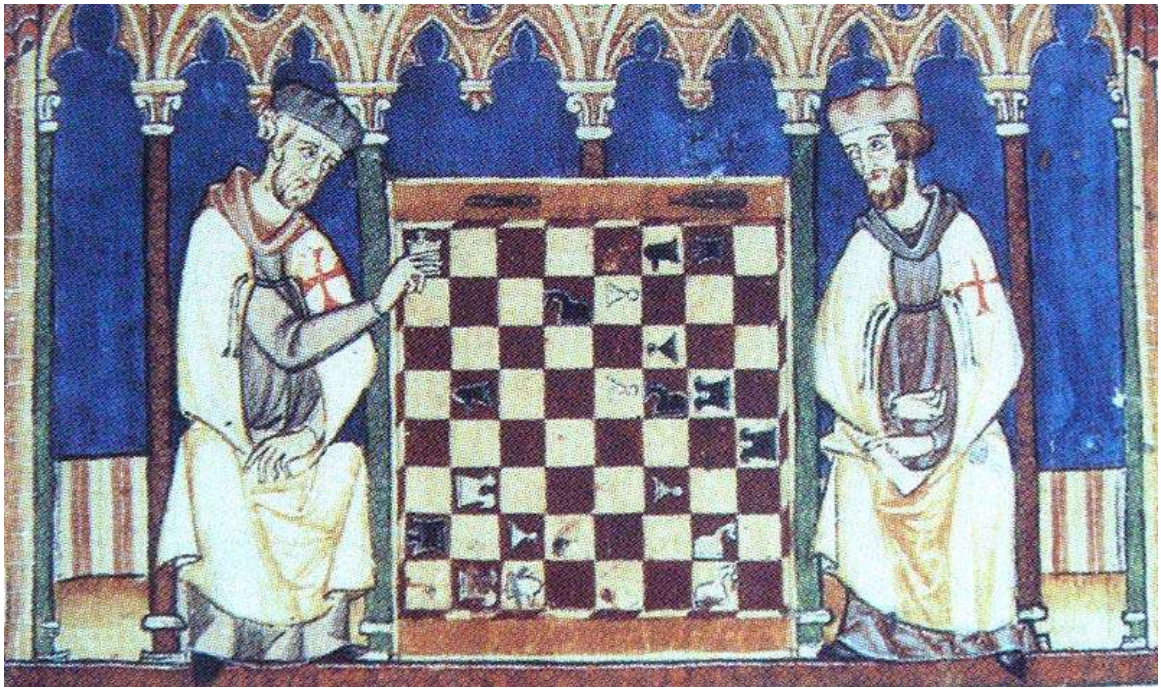
Manufacture of silk began in Eastern Europe in the 6th, in Western Europe in the 11th or 12th centuries. Imported over the Silk Road since antiquity. Technnology of "silk

throwing" mastered in Tuscany in the 13th century. The silk works used waterpower and some regard these as the first mechanized textile mills.

Spinning wheel (13th)

Brought to Europe probably from India.

Miscellaneous



Knights Templar playing chess, *Libro de los juegos* (1283)

Chess (1450)

The earliest predecessors of the game originated in 6th century AD India and spread via Persia and the Muslim world to Europe. Here the game evolved into its current form in the 15th century.

Forest glass (ca. 1000)

Type of glass which uses wood ash and sand as the main raw materials and is characterised by a variety of greenish-yellow colours.

Grindstones (834)

Rough stone, usually sandstone, used to sharpen iron. The first rotary grindstone (turned with a leveraged handle) occurs in the *Utrecht Psalter*, illustrated between 816 and 834. According to Hägermann, the pen drawing is a copy of a late antique manuscript. A

second crank which was mounted on the other end of the axle is depicted in the *Luttrell Psalter* from around 1340.

Liquor (12th)

Alcohol distillation by way of Islamic alchemists, initially used as medicinal elixir. Popular remedy for the Black Death during the 14th century; "national" drinks like vodka, gin, brandy come into form.

Mirrors (1180)

First mention of "glass" mirror in 1180 by Alexander Neckham who said "Take away the lead which is behind the glass and there will be no image of the one looking in."

Illustrated surgical atlas (1345)

Guido da Vigevano (ca. 1280−1349) was the first author to add illustrations to his anatomical descriptions. His *Anathomia* provides pictures of neuroanatomical structures and techniques such as the dissection of the head by means of trephination, and depictions of the meninges, cerebrum, and spinal cord.

Quarantine (1377)

Initially a 40-day-period, the Quarantine was introduced by the Republic of Ragusa as measure of disease prevention related to the Black Death. Later adopted by Venice from where the practice spread all around in Europe.

Rat traps (1170s)

First mention of a rat trap in the medieval romance *Yvain, the Knight of the Lion* by Chrétien de Troyes.

Soap (9th)

Soap came into widespread European use in the 9th century in semi-liquid form, with hard soap perfected by the Arabs in the 12th century.

Military technologies

Armor

Jousting armor commissioned by Maximilian I in 1494

Plate armour (14th, late)

Apex of pre-industrial personal armour in terms of body protection and metallurgical skills involved. Large and complete full plates of armour appear by the end of the 14th century.

Cavalry

Arched saddle (1050s)

Enabled mounted knights to wield lance underarm and prevent the charge turning into an unintentional pole-vault. This innovation gave birth to true shock cavalry, enabling the knights to charge on full gallop, thus exceeding the shock value of the cataphracts.

Spurs (11th)

Invented by the Normans, appearing at the same time as cantled saddle. Enabled the knight to control his horse with his feet instead of hands, replacing the whip and leaving his arms free. Rowel spurs familiar from cowboy films were already known in the 13th century. Gilded spurs were the ultimate symbol of the knighthood - even today someone is said to "earn his spurs" by proving his or her worthiness.

Stirrup (6th)

Invented by the steppe nomads in what is today Mongolia and northern China in the 4th century and transmitted west. Appeared in Byzantium in the 6th, in the Carolingian Empire in the 8th century. Allowed mounted knight to wield sword and strike from a distance leading to a great advantage for mounted cavalry.

Gunpowder weapons

Cannon (1324)

Cannons are first recorded in Europe at the siege of Metz in 1324. In 1350 Petrarch wrote "these instruments which discharge balls of metal with most tremendous noise and flashes of fire...were a few years ago very rare and were viewed with greatest astonishment and admiration, but now they are become as common and familiar as any other kinds of arms."

Corned gunpowder (14th, late)

First practiced in Western Europe, corning the black powder allowed for more powerful and faster ignition of cannon. Also facilitated storage and transportation to operational area, thus constituting a crucial step in the evolution of gunpowder warfare.

Scottish bombard Mons Meg

Supergun (14th, late)

Extant examples include the wrought-iron Pumhart von Steyr, Dulle Griet and Mons Meg as well as the cast-bronze Faule Mette and Faule Grete (all 15th century).

Mechanical artillery

Counterweight trebuchet (12th)

Powered solely by the force of gravity, these catapults revolutionized medieval siege warfare and construction of fortifications by hurling huge stones unprecedented distances. Originating somewhere in the eastern Mediterranean basin, counterweight trebuchets were introduced in the Crusader states by the 1120s, Byzantium by the 1130s and in the Latin West by the second half of the century.

Missile weapons

Longbow with massed, disciplined archery (13th)

Having a high rate of fire and penetration power, the longbow contributed to the eventual demise of the medieval knight class. Used particularly by the English to great effect against the French cavalry during the Hundred Years' War (1337-1453).

Steel crossbow (14th, late)

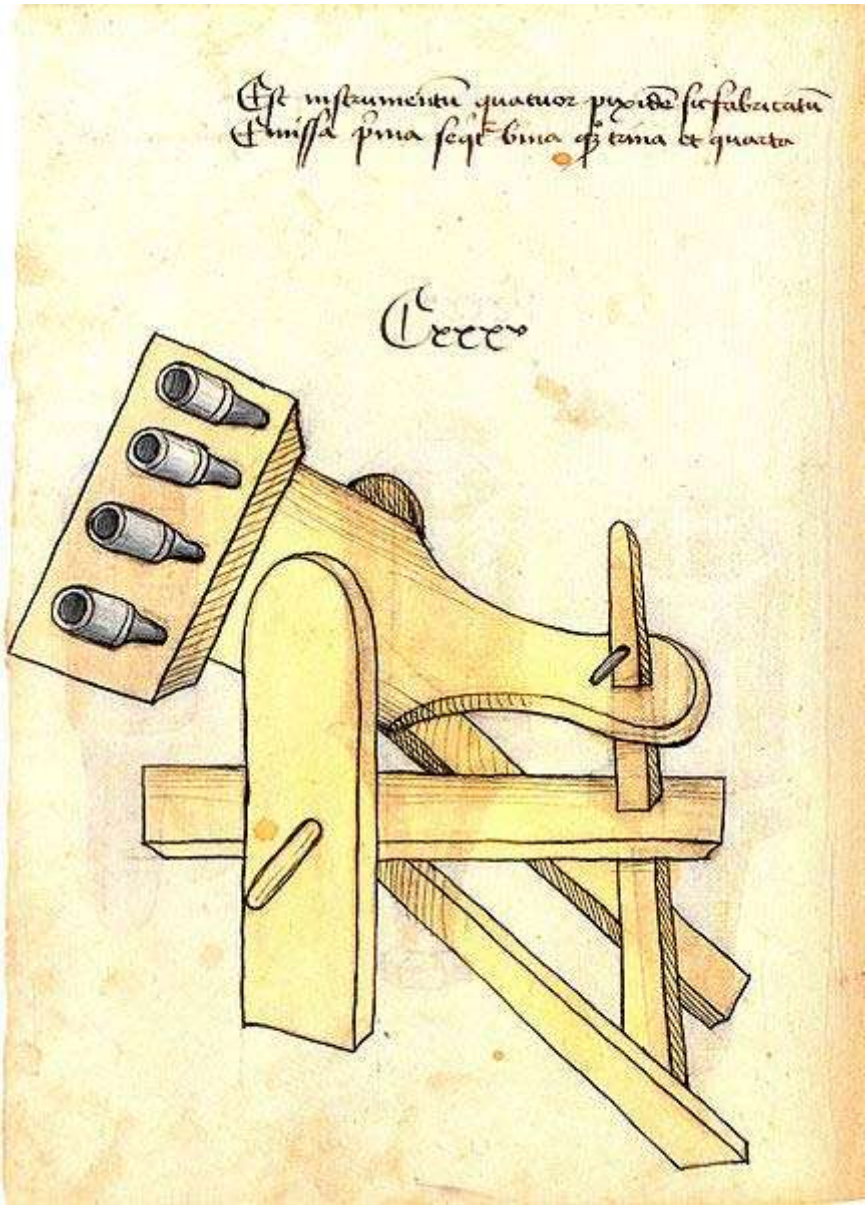
European innovation. Came with several different cocking aids to enhance draw power, making the weapons also the first hand-held mechanical crossbows.

Miscellaneous

Combined arms tactics (1333)

The battle of Halidon Hill 1333 was the first battle where intentional and disciplined combined arms infantry tactics were employed. The English men-at-arms dismounted aside the archers, combining thus the staying power of super-heavy infantry and striking power of their two-handed weapons with the missiles and mobility of the archers. Combining dismounted knights and men-at-arms with archers was the archetypal Western Medieval battle tactics until the battle of Flodden 1513 and final emergence of firearms.

Cranked rack-and-pinion device for cocking a crossbow (ca. 1493)



Organ gun in the *Bellifortis* (ca. 1405)

Renaissance technology

In the 15th century, the pace of technical advancements quickens with such diverse innovations like the printing press, linear perspectivity, patent law, double shell domes or bastions.

Chapter- 7

Technology Tree

The **technology tree** or **tech tree** is an hierarchical visual representation of the possible sequences of upgrades a player can take, by means of research. The diagram is tree-shaped in the sense that it branches at certain intervals, allowing the player to choose one sequence or another. Typically, at the beginning of a session of a strategy game, a player may only have a few options for technologies to research. Each technology that a player researches will open up more options, but may or may not, depending on the computer game the player is playing, close off the paths to other options. The tech tree is the representation of all possible paths of research a player can take.

A player who is engaged in research activities is said to be "teching up," "going up the tech tree," or "moving up the tech tree." Analysis of a tech tree can lead players to memorize and use specific build orders.

Types of tech tree

Prerequisites for technology advances

In many real-time strategy (RTS) games, the player needs particular buildings in order to research specific techs or build specific advanced units (*StarCraft*, *Age of Empires*, *Total Annihilation*). In many turn-based strategy (TBS) games the prerequisite is one or more lower-level technologies, with no dependency on specific buildings (*Master of Orion* series, *Civilization* series, *Space Empires* series).

Complexity

The structures of tech trees vary quite widely. In the simplest cases (e.g. *Master of Orion*) there are several completely separate research areas and one could research all the way up to the highest level in one area without researching other areas (although this would often be suicidal). In the most complex cases (e.g. *Civilization*) every technology above the starting level has more than one prerequisite and one has to research most of the lower-level technologies in order to research any of the top-level technologies. And there are many possibilities between these two extremes, for example in *Space Empires* researching to a specified level in one field may enable the player both to research to a

higher level in that field *and* to start research in a new field which was previously not available.

Major 4X games like *Civilization* and *Master of Orion* have a much larger technology tree than most other strategy games; as an extreme example, *Space Empires III* has over 200 technologies.

Are all technologies available?

Some RTSs make different techs available to different races / cultures (especially *StarCraft*; but many RTSs have special units or buildings for different cultures, e.g. *Age of Empires* expansion pack and later versions, *Red Alert 2*). Most TBSs make all technologies available to all cultures (e.g. *Civilization*). *Master of Orion* (original version) is a complex special case in this respect: the full tree is the same for all; but in each game each player gets a random subset of the full tech tree that depends on which race was selected.

Balance between civilian and military techs

In many RTS games tech advances are almost exclusively military (e.g. *StarCraft*). But in most TBS and some RTS games the research and production costs of top-end military techs are so high that you have to build up your economy and your research productivity first (RTS - *Age of Empires* and *Empire Earth*, where one of the most significant costs is going up an epoch; TBS - the *Civilization* series and *Master of Orion* series).

What happens after researching everything

In many games there's nothing useful to do and the player may scrap research centers to save maintenance costs and/or devote the resources to something else (*Space Empires* series).

In the *Civilization* series researching "future technologies" increases a player's score. It also raises the health and the happiness in the empire. One of the last few technologies enables a "wonder" project, space exploration, that in turn triggers a race for technological victory. In the *Galactic Civilizations* series (no relation) the final technology solves the nature of existence, and *is* victory.

In the *Master of Orion* series more advanced research reduces the size and cost of spaceship components, and "hyper-advanced" research in areas which have military applications therefore enables players to build more high-tech weapons into a given ship size and at lower production cost.

In *Rise of Nations*, the final four technologies result in such an advantage that the game will likely end quickly. Also, the "knowledge" resource needed to research is also used late in the game to produce cruise missiles and nuclear weapons.

History

The tech tree was originally designed for Civilization (board game) by Francis Tresham (game designer) that was released in 1980 by Avalon Hill.

Tech trees started showing up in turn-based strategy games around 1990, where Mega Lo Mania had a system of research levels/epochs that allowed the deployment of better units and defenses. *Civilization* (1991) was probably the first game to feature the same basic structure of tech trees seen in games today. 1992's *Dune II* is another example of an early game featuring tech trees.

Chapter- 8

Industrial Revolution

A Watt steam engine, the steam engine fuelled primarily by coal that propelled the Industrial Revolution in Great Britain and the world.

The **Industrial Revolution** was a period from the 18th to the 19th century where major changes in agriculture, manufacturing, mining, transportation, and technology had a profound effect on the socioeconomic and cultural conditions of the times. It began in the United Kingdom, then subsequently spread throughout Europe, North America, and eventually the world.

The Industrial Revolution marks a major turning point in human history; almost every aspect of daily life was influenced in some way. Most notably, average income and

population began to exhibit unprecedented sustained growth. In the two centuries following 1800, the world's average per capita income increased over 10-fold, while the world's population increased over 6-fold. In the words of Nobel Prize winning Robert E. Lucas, Jr., "For the first time in history, the living standards of the masses of ordinary people have begun to undergo sustained growth. ... Nothing remotely like this economic behavior has happened before."

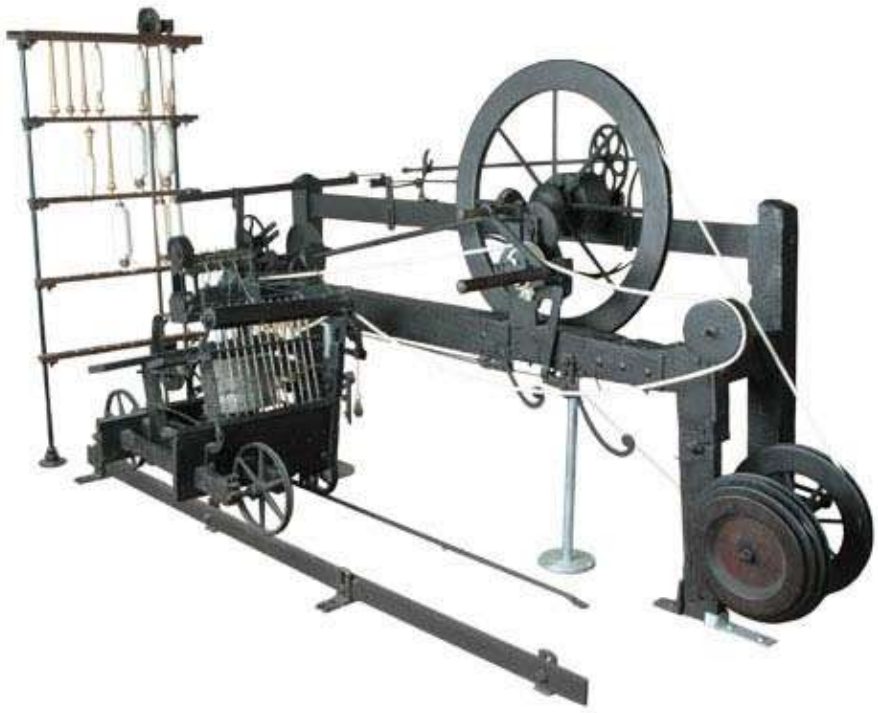
Starting in the later part of the 18th century, there began a transition in parts of Great Britain's previously manual labour and draft-animal–based economy towards machine-based manufacturing. It started with the mechanisation of the textile industries, the development of iron-making techniques and the increased use of refined coal. Trade expansion was enabled by the introduction of canals, improved roads and railways.

The introduction of steam power fuelled primarily by coal, wider utilisation of water wheels and powered machinery (mainly in textile manufacturing) underpinned the dramatic increases in production capacity. The development of all-metal machine tools in the first two decades of the 19th century facilitated the manufacture of more production machines for manufacturing in other industries. The effects spread throughout Western Europe and North America during the 19th century, eventually affecting most of the world, a process that continues as industrialisation. The impact of this change on society was enormous.

The first Industrial Revolution, which began in the 18th century, merged into the Second Industrial Revolution around 1850, when technological and economic progress gained momentum with the development of steam-powered ships, railways, and later in the 19th century with the internal combustion engine and electrical power generation. The period of time covered by the Industrial Revolution varies with different historians. Eric Hobsbawm held that it 'broke out' in Britain in the 1780s and was not fully felt until the 1830s or 1840s, while T. S. Ashton held that it occurred roughly between 1760 and 1830.

Some 20th century historians such as John Clapham and Nicholas Crafts have argued that the process of economic and social change took place gradually and the term *revolution* is a misnomer. This is still a subject of debate among historians. GDP per capita was broadly stable before the Industrial Revolution and the emergence of the modern capitalist economy. The Industrial Revolution began an era of per-capita economic growth in capitalist economies. Economic historians are in agreement that the onset of the Industrial Revolution is the most important event in the history of humanity since the domestication of animals and plants.

Innovations



The only surviving example of a Spinning Mule built by the inventor Samuel Crompton

The commencement of the Industrial Revolution is closely linked to a small number of innovations, made in the second half of the 18th century:

- **Textiles –** Cotton spinning using Richard Arkwright's water frame, James Hargreaves's Spinning Jenny, and Samuel Crompton's Spinning Mule (a combination of the Spinning Jenny and the Water Frame). This was patented in 1769 and so came out of patent in 1783. The end of the patent was rapidly followed by the erection of many cotton mills. Similar technology was subsequently applied to spinning worsted yarn for various textiles and flax for linen.
- **Steam power –** The improved steam engine invented by James Watt and patented in 1775 was initially mainly used for pumping out mines, but from the 1780s was applied to power machines. This enabled rapid development of efficient semi-automated factories on a previously unimaginable scale in places where waterpower was not available.
- **Iron making –** In the Iron industry, coke was finally applied to all stages of iron smelting, replacing charcoal. This had been achieved much earlier for lead and copper as well as for producing pig iron in a blast furnace, but the second stage in the production of bar iron depended on the use of potting and stamping (for which a patent expired in 1786) or puddling (patented by Henry Cort in 1783 and 1784).

These represent three 'leading sectors', in which there were key innovations, which allowed the economic take off by which the Industrial Revolution is usually defined. This is not to belittle many other inventions, particularly in the textile industry. Without some earlier ones, such as the spinning jenny and flying shuttle in the textile industry and the smelting of pig iron with coke, these achievements might have been impossible. Later inventions such as the power loom and Richard Trevithick's high pressure steam engine were also important in the growing industrialisation of Britain. The application of steam engines to powering cotton mills and ironworks enabled these to be built in places that were most convenient because other resources were available, rather than where there was water to power a watermill.

In the textile sector, such mills became the model for the organisation of human labour in factories, epitomised by Cottonopolis, the name given to the vast collection of cotton mills, factories and administration offices based in Manchester. The assembly line system greatly improved efficiency, both in this and other industries. With a series of men trained to do a single task on a product, then having it moved along to the next worker, the number of finished goods also rose significantly.

Also important was the 1756 rediscovery of concrete (based on hydraulic lime mortar) by the British engineer John Smeaton, which had been lost for 1300 years.

Transfer of knowledge

A Philosopher Lecturing on the Orrery (ca. 1766) Informal philosophical societies spread scientific advances

Knowledge of innovation was spread by several means. Workers who were trained in the technique might move to another employer or might be poached. A common method was for someone to make a study tour, gathering information where he could. During the whole of the Industrial Revolution and for the century before, all European countries and America engaged in study-touring; some nations, like Sweden and France, even trained civil servants or technicians to undertake it as a matter of state policy. In other countries, notably Britain and America, this practice was carried out by individual manufacturers anxious to improve their own methods. Study tours were common then, as now, as was the keeping of travel diaries. Records made by industrialists and technicians of the period are an incomparable source of information about their methods.

Another means for the spread of innovation was by the network of informal philosophical societies, like the Lunar Society of Birmingham, in which members met to discuss 'natural philosophy' (*i.e.* science) and often its application to manufacturing. The Lunar Society flourished from 1765 to 1809, and it has been said of them, "They were, if you like, the revolutionary committee of that most far reaching of all the eighteenth century revolutions, the Industrial Revolution". Other such societies published volumes of proceedings and transactions. For example, the London-based Royal Society of Arts published an illustrated volume of new inventions, as well as papers about them in its annual *Transactions*.

There were publications describing technology. Encyclopaedias such as Harris's *Lexicon Technicum* (1704) and Abraham Rees's *Cyclopaedia* (1802–1819) contain much of value. *Cyclopaedia* contains an enormous amount of information about the science and technology of the first half of the Industrial Revolution, very well illustrated by fine engravings. Foreign printed sources such as the *Descriptions des Arts et Métiers* and Diderot's *Encyclopédie* explained foreign methods with fine engraved plates.

Periodical publications about manufacturing and technology began to appear in the last decade of the 18th century, and many regularly included notice of the latest patents. Foreign periodicals, such as the Annales des Mines, published accounts of travels made by French engineers who observed British methods on study tours.

Technological developments in Britain

Textile manufacture

Model of the spinning jenny in a museum in Wuppertal, Germany. The spinning jenny was one of the innovations that started the revolution

In the early 18th century, British textile manufacture was based on wool which was processed by individual artisans, doing the spinning and weaving on their own premises. This system is called a cottage industry. Flax and cotton were also used for fine materials, but the processing was difficult because of the pre-processing needed, and thus goods in these materials made only a small proportion of the output.

Use of the spinning wheel and hand loom restricted the production capacity of the industry, but incremental advances increased productivity to the extent that manufactured cotton goods became the dominant British export by the early decades of the 19th century. India was displaced as the premier supplier of cotton goods.

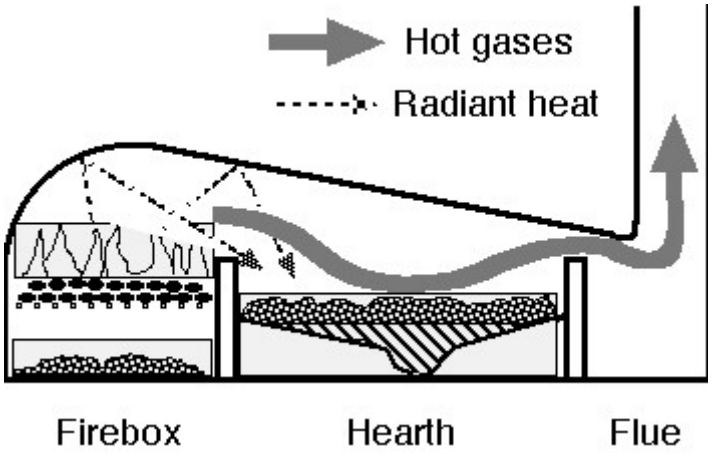
Lewis Paul patented the Roller Spinning machine and the flyer-and-bobbin system for drawing wool to a more even thickness, developed with the help of John Wyatt in Birmingham. Paul and Wyatt opened a mill in Birmingham which used their new rolling machine powered by a donkey. In 1743, a factory was opened in Northampton with fifty spindles on each of five of Paul and Wyatt's machines. This operated until about 1764. A similar mill was built by Daniel Bourn in Leominster, but this burnt down. Both Lewis Paul and Daniel Bourn patented carding machines in 1748. Using two sets of rollers that travelled at different speeds, it was later used in the first cotton spinning mill. Lewis's invention was later developed and improved by Richard Arkwright in his water frame and Samuel Crompton in his spinning mule.

Other inventors increased the efficiency of the individual steps of spinning (carding, twisting and spinning, and rolling) so that the supply of yarn increased greatly, which fed a weaving industry that was advancing with improvements to shuttles and the loom or 'frame'. The output of an individual labourer increased dramatically, with the effect that the new machines were seen as a threat to employment, and early innovators were attacked and their inventions destroyed.

To capitalise upon these advances, it took a class of entrepreneurs, of which the most famous is Richard Arkwright. He is credited with a list of inventions, but these were actually developed by people such as Thomas Highs and John Kay; Arkwright nurtured the inventors, patented the ideas, financed the initiatives, and protected the machines. He created the cotton mill which brought the production processes together in a factory, and he developed the use of power—first horse power and then water power—which made cotton manufacture a mechanised industry. Before long steam power was applied to drive textile machinery.

Metallurgy

Coalbrookdale by Night, 1801, Philipp Jakob Loutherbourg the Younger
Blast furnaces light the iron making town of Coalbrookdale



The Reverberatory Furnace could produce wrought iron using mined coal. The burning coal remained separate from the iron ore and so did not contaminate the iron with impurities like sulphur. This opened the way to increased iron production.

The major change in the metal industries during the era of the Industrial Revolution was the replacement of organic fuels based on wood with fossil fuel based on coal. Much of this happened somewhat before the Industrial Revolution, based on innovations by Sir Clement Clerke and others from 1678, using coal reverberatory furnaces known as cupolas. These were operated by the flames, which contained carbon monoxide, playing on the ore and reducing the oxide to metal. This has the advantage that impurities (such as sulphur) in the coal do not migrate into the metal. This technology was applied to lead from 1678 and to copper from 1687. It was also applied to iron foundry work in the 1690s, but in this case the reverberatory furnace was known as an air furnace. The foundry cupola is a different (and later) innovation.

This was followed by Abraham Darby, who made great strides using coke to fuel his blast furnaces at Coalbrookdale in 1709. However, the coke pig iron he made was used mostly for the production of cast iron goods such as pots and kettles. He had the advantage over his rivals in that his pots, cast by his patented process, were thinner and cheaper than theirs. Coke pig iron was hardly used to produce bar iron in forges until the mid 1750s, when his son Abraham Darby II built Horsehay and Ketley furnaces (not far from Coalbrookdale). By then, coke pig iron was cheaper than charcoal pig iron.

Bar iron for smiths to forge into consumer goods was still made in finery forges, as it long had been. However, new processes were adopted in the ensuing years. The first is referred to today as potting and stamping, but this was superseded by Henry Cort's puddling process. From 1785, perhaps because the improved version of potting and stamping was about to come out of patent, a great expansion in the output of the British iron industry began. The new processes did not depend on the use of charcoal at all and were therefore not limited by charcoal sources.

Up to that time, British iron manufacturers had used considerable amounts of imported iron to supplement native supplies. This came principally from Sweden from the mid-17th century and later also from Russia from the end of the 1720s. However, from 1785, imports decreased because of the new iron making technology, and Britain became an exporter of bar iron as well as manufactured wrought iron consumer goods.

Since iron was becoming cheaper and more plentiful, it also became a major structural material following the building of the innovative The Iron Bridge in 1778 by Abraham Darby III.

The Iron Bridge, Shropshire, England

An improvement was made in the production of steel, which was an expensive commodity and used only where iron would not do, such as for the cutting edge of tools and for springs. Benjamin Huntsman developed his crucible steel technique in the 1740s. The raw material for this was blister steel, made by the cementation process.

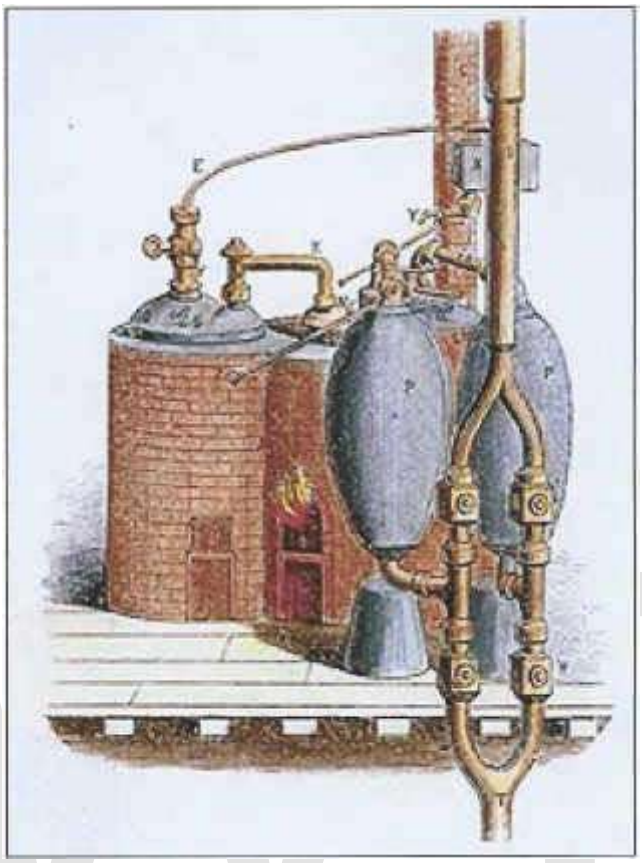
The supply of cheaper iron and steel aided the development of boilers and steam engines, and eventually railways. Improvements in machine tools allowed better working of iron and steel and further boosted the industrial growth of Britain.

Mining

Men working their own coal mines. Early 1900s, USA

Coal mining in Britain, particularly in South Wales started early. Before the steam engine, pits were often shallow bell pits following a seam of coal along the surface, which were abandoned as the coal was extracted. In other cases, if the geology was favourable, the coal was mined by means of an adit or drift mine driven into the side of a hill. Shaft mining was done in some areas, but the limiting factor was the problem of removing water. It could be done by hauling buckets of water up the shaft or to a sough (a tunnel driven into a hill to drain a mine). In either case, the water had to be discharged into a stream or ditch at a level where it could flow away by gravity. The introduction of the steam engine greatly facilitated the removal of water and enabled shafts to be made deeper, enabling more coal to be extracted. These were developments that had begun before the Industrial Revolution, but the adoption of James Watt's more efficient steam engine from the 1770s reduced the fuel costs of engines, making mines more profitable. Coal mining was very dangerous owing to the presence of firedamp in many coal seams. Some degree of safety was provided by the safety lamp which was invented in 1816 by Sir Humphry Davy and independently by George Stephenson. However, the lamps proved a false dawn because they became unsafe very quickly and provided a weak light. Firedamp explosions continued, often setting off coal dust explosions, so casualties grew during the entire 19th century. Conditions of work were very poor, with a high casualty rate from rock falls.

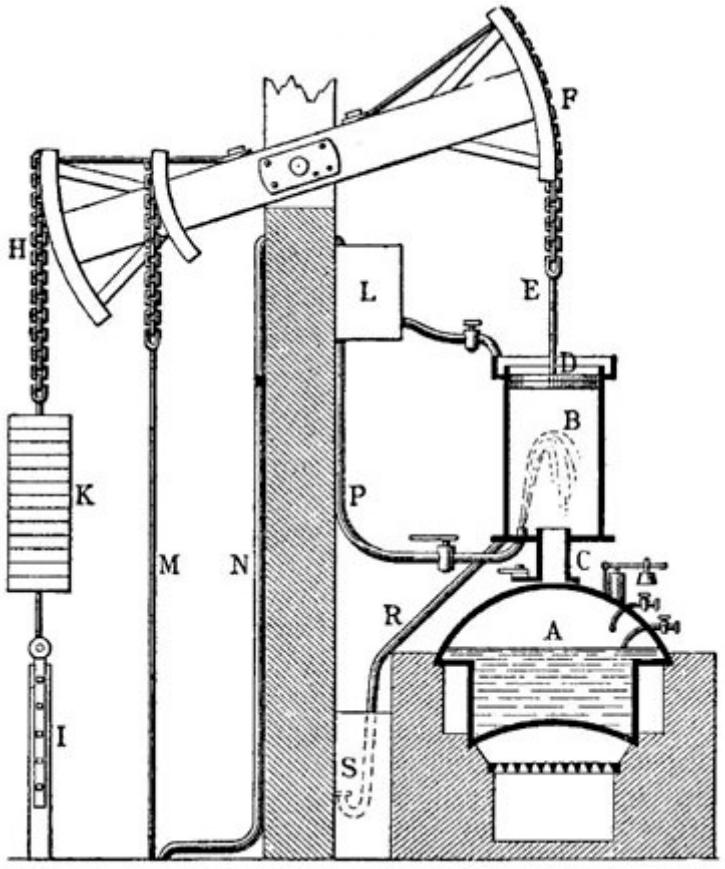
Steam power



The 1698 *Savery Engine* – the world's first commercially useful steam engine: built by Thomas Savery

The development of the stationary steam engine was an essential early element of the Industrial Revolution; however, for most of the period of the Industrial Revolution, the majority of industries still relied on wind and water power as well as horse- and man-power for driving small machines.

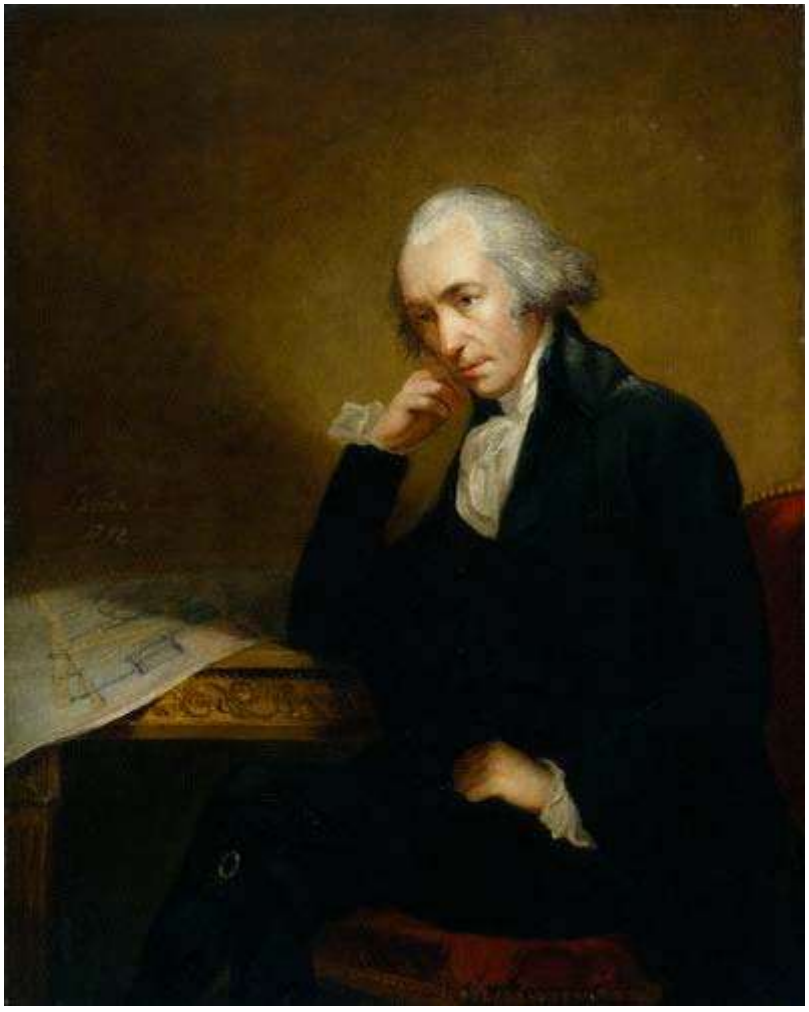
The first real attempt at industrial use of steam power was due to Thomas Savery in 1698. He constructed and patented in London a low-lift combined vacuum and pressure water pump, that generated about one horsepower (hp) and was used in numerous water works and tried in a few mines (hence its "brand name", *The Miner's Friend*), but it was not a success since it was limited in pumping height and prone to boiler explosions.



Newcomen's steam powered atmospheric engine was the first practical engine. Subsequent steam engines were to power the Industrial Revolution

The first safe and successful steam power plant was introduced by Thomas Newcomen before 1712. Newcomen apparently conceived the Newcomen steam engine quite independently of Savery, but as the latter had taken out a very wide-ranging patent, Newcomen and his associates were obliged to come to an arrangement with him, marketing the engine until 1733 under a joint patent. Newcomen's engine appears to have been based on Papin's experiments carried out 30 years earlier, and employed a piston and cylinder, one end of which was open to the atmosphere above the piston. Steam just above atmospheric pressure (all that the boiler could stand) was introduced into the lower half of the cylinder beneath the piston during the gravity-induced upstroke; the steam was then condensed by a jet of cold water injected into the steam space to produce a partial vacuum; the pressure differential between the atmosphere and the vacuum on either side of the piston displaced it downwards into the cylinder, raising the opposite end of a rocking beam to which was attached a gang of gravity-actuated reciprocating force pumps housed in the mineshaft. The engine's downward power stroke raised the pump, priming it and preparing the pumping stroke. At first the phases were controlled by hand, but within ten years an escapement mechanism had been devised worked by a vertical *plug tree* suspended from the rocking beam which rendered the engine self-acting.

A number of Newcomen engines were successfully put to use in Britain for draining hitherto unworkable deep mines, with the engine on the surface; these were large machines, requiring a lot of capital to build, and produced about 5 hp (3.7 kW). They were extremely inefficient by modern standards, but when located where coal was cheap at pit heads, opened up a great expansion in coal mining by allowing mines to go deeper. Despite their disadvantages, Newcomen engines were reliable and easy to maintain and continued to be used in the coalfields until the early decades of the 19th century. By 1729, when Newcomen died, his engines had spread (first) to Hungary in 1722, Germany, Austria, and Sweden. A total of 110 are known to have been built by 1733 when the joint patent expired, of which 14 were abroad. In the 1770s, the engineer John Smeaton built some very large examples and introduced a number of improvements. A total of 1,454 engines had been built by 1800.



James Watt

A fundamental change in working principles was brought about by James Watt. In close collaboration with Matthew Boulton, he had succeeded by 1778 in perfecting his steam engine, which incorporated a series of radical improvements, notably the closing off of

the upper part of the cylinder thereby making the low pressure steam drive the top of the piston instead of the atmosphere, use of a steam jacket and the celebrated separate steam condenser chamber. All this meant that a more constant temperature could be maintained in the cylinder and that engine efficiency no longer varied according to atmospheric conditions. These improvements increased engine efficiency by a factor of about five, saving 75% on coal costs.

Nor could the atmospheric engine be easily adapted to drive a rotating wheel, although Wasborough and Pickard did succeed in doing so towards 1780. However by 1783 the more economical Watt steam engine had been fully developed into a double-acting rotative type, which meant that it could be used to directly drive the rotary machinery of a factory or mill. Both of Watt's basic engine types were commercially very successful, and by 1800, the firm Boulton & Watt had constructed 496 engines, with 164 driving reciprocating pumps, 24 serving blast furnaces, and 308 powering mill machinery; most of the engines generated from 5 to 10 hp (7.5 kW).

The development of machine tools, such as the lathe, planing and shaping machines powered by these engines, enabled all the metal parts of the engines to be easily and accurately cut and in turn made it possible to build larger and more powerful engines.

Until about 1800, the most common pattern of steam engine was the beam engine, built as an integral part of a stone or brick engine-house, but soon various patterns of self-contained portative engines (readily removable, but not on wheels) were developed, such as the table engine. Towards the turn of the 19th century, the Cornish engineer Richard Trevithick, and the American, Oliver Evans began to construct higher pressure non-condensing steam engines, exhausting against the atmosphere. This allowed an engine and boiler to be combined into a single unit compact enough to be used on mobile road and rail locomotives and steam boats.

In the early 19th century after the expiration of Watt's patent, the steam engine underwent many improvements by a host of inventors and engineers.

Chemicals

The Thames Tunnel (opened 1843)
Cement was used in the world's first underwater tunnel

The large scale production of chemicals was an important development during the Industrial Revolution. The first of these was the production of sulphuric acid by the lead chamber process invented by the Englishman John Roebuck (James Watt's first partner) in 1746. He was able to greatly increase the scale of the manufacture by replacing the relatively expensive glass vessels formerly used with larger, less expensive chambers made of riveted sheets of lead. Instead of making a small amount each time, he was able to make around 100 pounds (50 kg) in each of the chambers, at least a tenfold increase.

The production of an alkali on a large scale became an important goal as well, and Nicolas Leblanc succeeded in 1791 in introducing a method for the production of sodium carbonate. The Leblanc process was a reaction of sulphuric acid with sodium chloride to give sodium sulphate and hydrochloric acid. The sodium sulphate was heated with limestone (calcium carbonate) and coal to give a mixture of sodium carbonate and calcium sulphide. Adding water separated the soluble sodium carbonate from the calcium sulphide. The process produced a large amount of pollution (the hydrochloric acid was initially vented to the air, and calcium sulphide was a useless waste product). Nonetheless, this synthetic soda ash proved economical compared to that from burning specific plants (barilla) or from kelp, which were the previously dominant sources of soda ash, and also to potash (potassium carbonate) derived from hardwood ashes.

These two chemicals were very important because they enabled the introduction of a host of other inventions, replacing many small-scale operations with more cost-effective and controllable processes. Sodium carbonate had many uses in the glass, textile, soap, and

paper industries. Early uses for sulphuric acid included pickling (removing rust) iron and steel, and for bleaching cloth.

The development of bleaching powder (calcium hypochlorite) by Scottish chemist Charles Tennant in about 1800, based on the discoveries of French chemist Claude Louis Berthollet, revolutionised the bleaching processes in the textile industry by dramatically reducing the time required (from months to days) for the traditional process then in use, which required repeated exposure to the sun in bleach fields after soaking the textiles with alkali or sour milk. Tennant's factory at St Rollox, North Glasgow, became the largest chemical plant in the world.

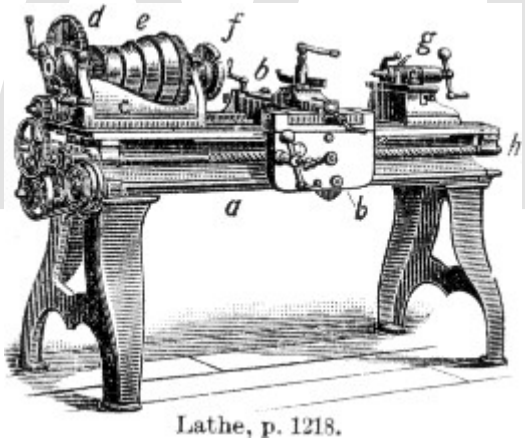
In 1824 Joseph Aspdin, a British bricklayer turned builder, patented a chemical process for making portland cement which was an important advance in the building trades. This process involves sintering a mixture of clay and limestone to about 1,400 °C (2,552 °F), then grinding it into a fine powder which is then mixed with water, sand and gravel to produce concrete. Portland cement was used by the famous English engineer Marc Isambard Brunel several years later when constructing the Thames Tunnel. Cement was used on a large scale in the construction of the London sewerage system a generation later.

Machine tools

Sir Joseph Whitworth

The Industrial Revolution could not have developed without machine tools, for they enabled manufacturing machines to be made. They have their origins in the tools developed in the 18th century by makers of clocks and watches and scientific instrument makers to enable them to batch-produce small mechanisms. The mechanical parts of early textile machines were sometimes called 'clock work' because of the metal spindles and gears they incorporated. The manufacture of textile machines drew craftsmen from these trades and is the origin of the modern engineering industry.

Machines were built by various craftsmen—carpenters made wooden framings, and smiths and turners made metal parts. A good example of how machine tools changed manufacturing took place in Birmingham, England, in 1830. The invention of a new machine by Joseph Gillott, William Mitchell and James Stephen Perry allowed mass manufacture of robust, cheap steel pen nibs; the process had been laborious and expensive. Because of the difficulty of manipulating metal and the lack of machine tools, the use of metal was kept to a minimum. Wood framing had the disadvantage of changing dimensions with temperature and humidity, and the various joints tended to rack (work loose) over time. As the Industrial Revolution progressed, machines with metal frames became more common, but they required machine tools to make them economically. Before the advent of machine tools, metal was worked manually using the basic hand tools of hammers, files, scrapers, saws and chisels. Small metal parts were readily made by this means, but for large machine parts, production was very laborious and costly.



Lathe, p. 1218.

A lathe from 1911, a machine tool able to shape parts (usually metal)for other machines

Apart from workshop lathes used by craftsmen, the first large machine tool was the cylinder boring machine used for boring the large-diameter cylinders on early steam engines. The planing machine, the slotting machine and the shaping machine were developed in the first decades of the 19th century. Although the milling machine was invented at this time, it was not developed as a serious workshop tool until during the Second Industrial Revolution.

Military production, as well, had a hand in the development of machine tools. Henry Maudslay, who trained a school of machine tool makers early in the 19th century, was employed at the Royal Arsenal, Woolwich, as a young man where he would have seen

the large horse-driven wooden machines for cannon boring made and worked by the Verbruggans. He later worked for Joseph Bramah on the production of metal locks, and soon after he began working on his own. He was engaged to build the machinery for making ships' pulley blocks for the Royal Navy in the Portsmouth Block Mills. These were all metal and were the first machines for mass production and making components with a degree of interchangeability. The lessons Maudslay learned about the need for stability and precision he adapted to the development of machine tools, and in his workshops he trained a generation of men to build on his work, such as Richard Roberts, Joseph Clement and Joseph Whitworth.

James Fox of Derby had a healthy export trade in machine tools for the first third of the century, as did Matthew Murray of Leeds. Roberts was a maker of high-quality machine tools and a pioneer of the use of jigs and gauges for precision workshop measurement.

Gas lighting

Another major industry of the later Industrial Revolution was gas lighting. Though others made a similar innovation elsewhere, the large scale introduction of this was the work of William Murdoch, an employee of Boulton and Watt, the Birmingham steam engine pioneers. The process consisted of the large scale gasification of coal in furnaces, the purification of the gas (removal of sulphur, ammonia, and heavy hydrocarbons), and its storage and distribution. The first gas lighting utilities were established in London between 1812-20. They soon became one of the major consumers of coal in the UK. Gas lighting had an impact on social and industrial organisation because it allowed factories and stores to remain open longer than with tallow candles or oil. Its introduction allowed night life to flourish in cities and towns as interiors and streets could be lighted on a larger scale than before.

Glass making

The Crystal Palace held the Great Exhibition of 1851

A new method of producing glass, known as the cylinder process, was developed in Europe during the early 19th century. In 1832, this process was used by the Chance Brothers to create sheet glass. They became the leading producers of window and plate glass. This advancement allowed for larger panes of glass to be created without interruption, thus freeing up the space planning in interiors as well as the fenestration of buildings. The Crystal Palace is the supreme example of the use of sheet glass in a new and innovative structure.

Paper machine

A machine for making a continuous sheet of paper on a loop of wire fabric was patented in 1798 by Nicholas Louis Robert who worked for Saint-Léger Didot family in France. The paper machine is known as a Fourdrinier after the financers, brothers Sealy and Henry Fourdrinier, who were stationers in London. Although greatly imoproved and with many variations, the Fourdriner machine is the predominant means of paper production today.

Effects on agriculture

The invention of machinery played a big part in driving forward the British Agricultural Revolution. Agricultural improvement began in the centuries before the Industrial

revolution got going and it may have played a part in freeing up labour from the land to work in the new industrial mills of the 18th century. As the revolution in industry progressed a succession of machines became available which increased food production with ever fewer labourers.

Jethro Tull's seed drill invented in 1701 was a mechanical seeder which distributed seeds efficiently across a plot of land. Joseph Foljambe's Rotherham plough of 1730, was the first commercially successful iron plough. Andrew Meikle's threshing machine of 1784 was the final straw for many farm labourers, and led to the 1830 agricultural rebellion of the Swing Riots.

Transport in Britain

At the beginning of the Industrial Revolution, inland transport was by navigable rivers and roads, with coastal vessels employed to move heavy goods by sea. Railways or wagon ways were used for conveying coal to rivers for further shipment, but canals had not yet been constructed. Animals supplied all of the motive power on land, with sails providing the motive power on the sea.

The Industrial Revolution improved Britain's transport infrastructure with a turnpike road network, a canal and waterway network, and a railway network. Raw materials and finished products could be moved more quickly and cheaply than before. Improved transportation also allowed new ideas to spread quickly.

Coastal sail

Sailing vessels had long been used for moving goods round the British coast. The trade transporting coal to London from Newcastle had begun in medieval times. The transport of goods coastwise by sea within Britain was common during the Industrial Revolution, as for centuries before. This became less important with the growth of the railways at the end of the period.

Navigable rivers

All the major rivers of the United Kingdom were navigable during the Industrial Revolution. Some were anciently navigable, notably the Severn, Thames, and Trent. Some were improved, or had navigation extended upstream, but usually in the period before the Industrial Revolution, rather than during it.

The Severn, in particular, was used for the movement of goods to the Midlands which had been imported into Bristol from abroad, and for the export of goods from centres of production in Shropshire (such as iron goods from Coalbrookdale) and the Black Country. Transport was by way of trows—small sailing vessels which could pass the various shallows and bridges in the river. The trows could navigate the Bristol Channel to the South Wales ports and Somerset ports, such as Bridgwater and even as far as France.

Canals

Pontcysyllte Aqueduct, Llangollen, Wales

Canals began to be built in the late 18th century to link the major manufacturing centres in the Midlands and north with seaports and with London, at that time itself the largest manufacturing centre in the country. Canals were the first technology to allow bulk materials to be easily transported across the country. A single canal horse could pull a load dozens of times larger than a cart at a faster pace. By the 1820s, a national network was in existence. Canal construction served as a model for the organisation and methods later used to construct the railways. They were eventually largely superseded as profitable commercial enterprises by the spread of the railways from the 1840s on.

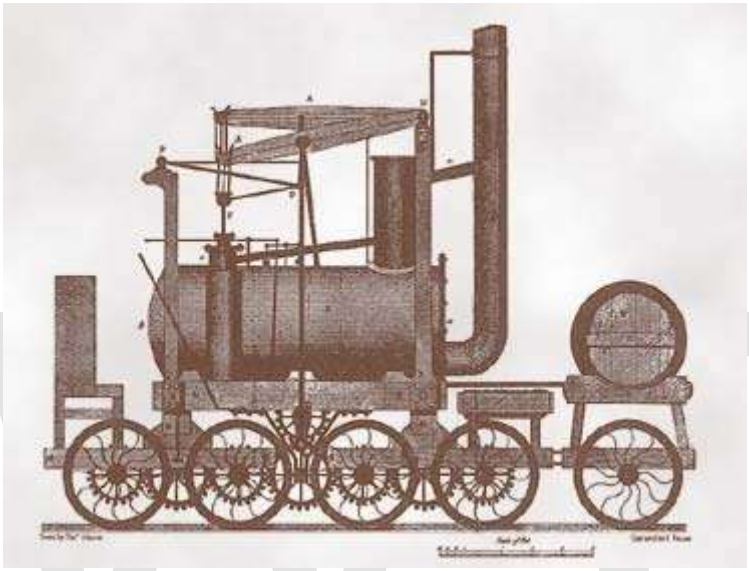
Britain's canal network, together with its surviving mill buildings, is one of the most enduring features of the early Industrial Revolution to be seen in Britain.

Roads

Much of the original British road system was poorly maintained by thousands of local parishes, but from the 1720s (and occasionally earlier) turnpike trusts were set up to charge tolls and maintain some roads. Increasing numbers of main roads were turnpiked from the 1750s to the extent that almost every main road in England and Wales was the

responsibility of some turnpike trust. New engineered roads were built by John Metcalf, Thomas Telford and John Macadam. The major turnpikes radiated from London and were the means by which the Royal Mail was able to reach the rest of the country. Heavy goods transport on these roads was by means of slow, broad wheeled, carts hauled by teams of horses. Lighter goods were conveyed by smaller carts or by teams of pack horse. Stage coaches carried the rich, and the less wealthy could pay to ride on carriers carts.

Railways



Puffing Billy, an early railway steam locomotive, constructed in 1813-1814 for colliery work.

Wagonways for moving coal in the mining areas had started in the 17th century and were often associated with canal or river systems for the further movement of coal. These were all horse drawn or relied on gravity, with a stationary steam engine to haul the wagons back to the top of the incline. The first applications of the steam locomotive were on wagon or plate ways (as they were then often called from the cast iron plates used). Horse-drawn public railways did not begin until the early years of the 19th century. Steam-hauled public railways began with the Stockton and Darlington Railway in 1825 and the Liverpool and Manchester Railway in 1830. Construction of major railways connecting the larger cities and towns began in the 1830s but only gained momentum at the very end of the first Industrial Revolution.

After many of the workers had completed the railways, they did not return to their rural lifestyles but instead remained in the cities, providing additional workers for the factories.

Railways helped Britain's trade enormously, providing a quick and easy way of transport and an easy way to transport mail and news.

Social effects

In terms of social structure, the Industrial Revolution witnessed the triumph of a middle class of industrialists and businessmen over a landed class of nobility and gentry.

Ordinary working people found increased opportunities for employment in the new mills and factories, but these were often under strict working conditions with long hours of labour dominated by a pace set by machines. However, harsh working conditions were prevalent long before the Industrial Revolution took place. Pre-industrial society was very static and often cruel—child labour, dirty living conditions, and long working hours were just as prevalent before the Industrial Revolution.

Factories and urbanisation

Manchester, England ("Cottonopolis"), pictured in 1840, showing the mass of factory chimneys

Industrialisation led to the creation of the factory. Arguably the first was John Lombe's water-powered silk mill at Derby, operational by 1721. However, the rise of the factory came somewhat later when cotton spinning was mechanised.

The factory system was largely responsible for the rise of the modern city, as large numbers of workers migrated into the cities in search of employment in the factories. Nowhere was this better illustrated than the mills and associated industries of

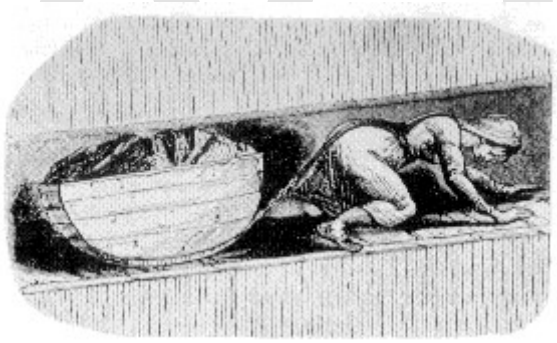
Manchester, nicknamed "Cottonopolis", and arguably the world's first industrial city. For much of the 19th century, production was done in small mills, which were typically water-powered and built to serve local needs. Later each factory would have its own steam engine and a chimney to give an efficient draft through its boiler.

The transition to industrialisation was not without difficulty. For example, a group of English workers known as Luddites formed to protest against industrialisation and sometimes sabotaged factories.

In other industries the transition to factory production was not so divisive. Some industrialists themselves tried to improve factory and living conditions for their workers. One of the earliest such reformers was Robert Owen, known for his pioneering efforts in improving conditions for workers at the New Lanark mills, and often regarded as one of the key thinkers of the early socialist movement.

By 1746, an integrated brass mill was working at Warmley near Bristol. Raw material went in at one end, was smelted into brass and was turned into pans, pins, wire, and other goods. Housing was provided for workers on site. Josiah Wedgwood and Matthew Boulton were other prominent early industrialists, who employed the factory system.

Child labour



A young "drawer" pulling a coal tub along a mine gallery

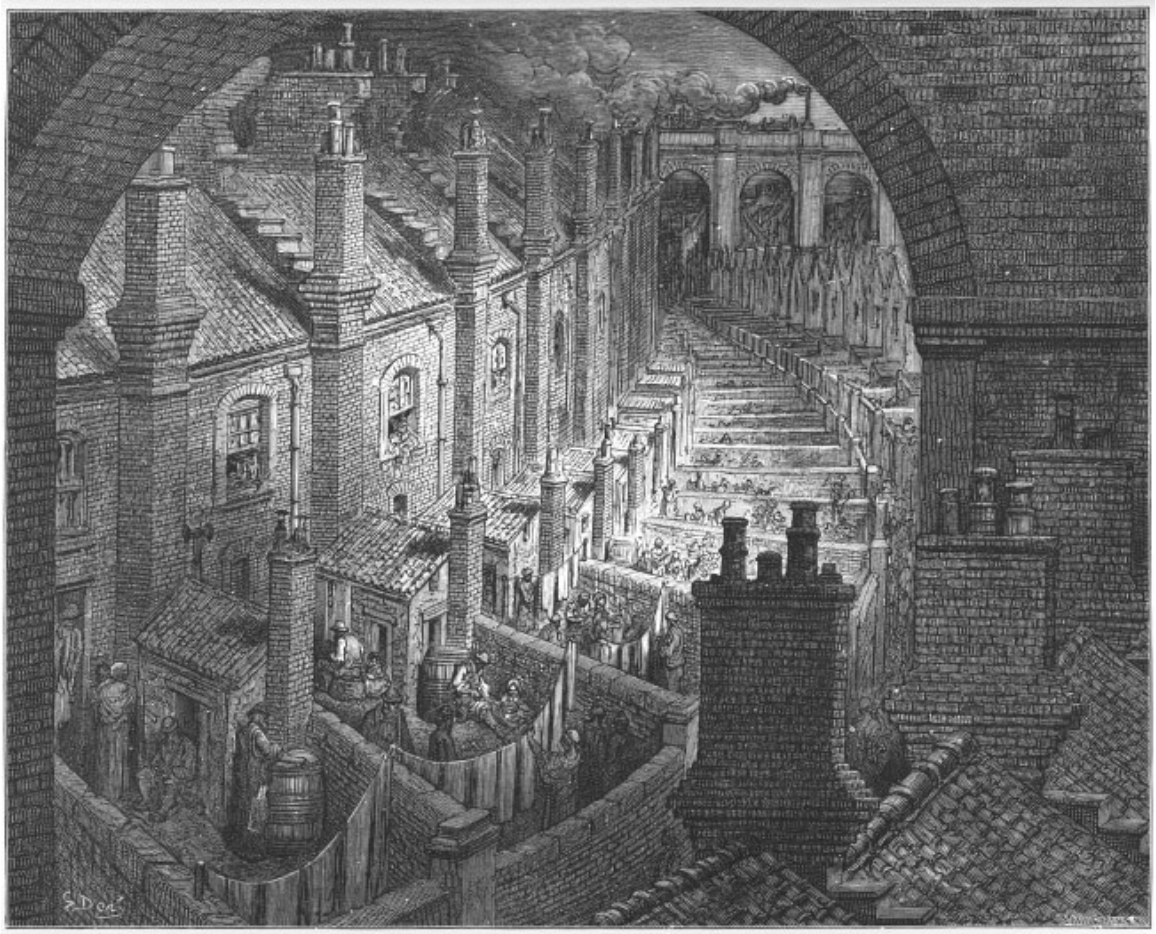
The Industrial Revolution led to a population increase, but the chances of surviving childhood did not improve throughout the Industrial Revolution (although *infant* mortality rates were reduced markedly). There was still limited opportunity for education, and children were expected to work. Employers could pay a child less than an adult even though their productivity was comparable; there was no need for strength to operate an industrial machine, and since the industrial system was completely new there were no experienced adult labourers. This made child labour the labour of choice for manufacturing in the early phases of the Industrial Revolution between the 18th and 19th centuries. In England and Scotland in 1788, two-thirds of the workers in 143 water-powered cotton mills were described as children.

Child labour had existed before the Industrial Revolution, but with the increase in population and education it became more visible. Many children were forced to work in relatively bad conditions for much lower pay than their elders, 10-20% of an adult male's wage. Children as young as four were employed. Beatings and long hours were common, with some child coal miners working from 4 am until 5 pm. Conditions were dangerous, with some children killed when they dozed off and fell into the path of the carts, while others died from gas explosions. Many children developed lung cancer and other diseases and died before the age of 25. Workhouses would sell orphans and abandoned children as "pauper apprentices", working without wages for board and lodging. Those who ran away would be whipped and returned to their masters, with some masters shackling them to prevent escape. Children employed as "scavengers" by cotton mills would climb under machinery to pick up cotton, working 14 hours a day, six days a week. Some lost hands or limbs, others were crushed under the machines, and some were decapitated. Young girls worked at match factories, where phosphorous fumes would cause many to develop phossy jaw. Children employed at glassworks were regularly burned and blinded, and those working at potteries were vulnerable to poisonous clay dust.

Reports were written detailing some of the abuses, particularly in the coal mines and textile factories and these helped to popularise the children's plight. The public outcry, especially among the upper and middle classes, helped stir change in the young workers' welfare.

Politicians and the government tried to limit child labour by law, but factory owners resisted; some felt that they were aiding the poor by giving their children money to buy food to avoid starvation, and others simply welcomed the cheap labour. In 1833 and 1844, the first general laws against child labour, the Factory Acts, were passed in England: Children younger than nine were not allowed to work, children were not permitted to work at night, and the work day of youth under the age of 18 was limited to twelve hours. Factory inspectors supervised the execution of the law, however, their scarcity made enforcement difficult. About ten years later, the employment of children and women in mining was forbidden. These laws decreased the number of child labourers; however, child labour remained in Europe and the United States up to the 20th century. By 1900, there were 1.7 million child labourers reported in American industry under the age of fifteen.

Housing



Over London by Rail Gustave Doré c. 1870. Shows the densely populated and polluted environments created in the new industrial cities

Living conditions during the Industrial Revolution varied from the splendour of the homes of the owners to the squalor of the lives of the workers. Poor people lived in very small houses in cramped streets. These homes would share toilet facilities, have open sewers and would be at risk of damp. Disease was spread through a contaminated water supply. Conditions did improve during the 19th century as public health acts were introduced covering things such as sewage, hygiene and making some boundaries upon the construction of homes. Not everybody lived in homes like these. The Industrial Revolution created a larger middle class of professionals such as lawyers and doctors. The conditions for the poor improved over the course of the 19th century because of government and local plans which led to cities becoming cleaner places, but life had not been easy for the poor before industrialisation. However, as a result of the Revolution, huge numbers of the working class died due to diseases spreading through the cramped living conditions. Chest diseases from the mines, cholera from polluted water and typhoid

were also extremely common, as was smallpox. Accidents in factories with child and female workers were regular. Strikes and riots by workers were also relatively common.

A description of housing of the mill workers in England in 1844 was given by Fredrick Engels.

Luddites

The Leader of the luddites, engraving of 1812

The rapid industrialisation of the English economy cost many craft workers their jobs. The movement started first with lace and hosiery workers near Nottingham and spread to other areas of the textile industry owing to early industrialisation. Many weavers also found themselves suddenly unemployed since they could no longer compete with machines which only required relatively limited (and unskilled) labour to produce more cloth than a single weaver. Many such unemployed workers, weavers and others, turned their animosity towards the machines that had taken their jobs and began destroying factories and machinery. These attackers became known as Luddites, supposedly followers of Ned Ludd, a folklore figure. The first attacks of the Luddite movement began in 1811. The Luddites rapidly gained popularity, and the British government took drastic measures using the militia or army to protect industry. Those rioters who were caught were tried and hanged, or transported for life.

Unrest continued in other sectors as they industrialised, such as agricultural labourers in the 1830s, when large parts of southern Britain were affected by the Captain Swing disturbances. Threshing machines were a particular target, and rick burning was a popular activity. However the riots led to the first formation of trade unions, and further pressure for reform.

Organisation of labour

The Great Chartist Meeting on Kennington Common, 1848

The Industrial Revolution concentrated labour into mills, factories and mines, thus facilitating the organisation of *combinations* or trade unions to help advance the interests of working people. The power of a union could demand better terms by withdrawing all labour and causing a consequent cessation of production. Employers had to decide between giving in to the union demands at a cost to themselves or suffering the cost of the lost production. Skilled workers were hard to replace, and these were the first groups to successfully advance their conditions through this kind of bargaining.

The main method the unions used to effect change was strike action. Many strikes were painful events for both sides, the unions and the management. In England, the Combination Act forbade workers to form any kind of trade union from 1799 until its repeal in 1824. Even after this, unions were still severely restricted.

In 1832, the year of the Reform Act which extended the vote in England but did not grant universal suffrage, six men from Tolpuddle in Dorset founded the Friendly Society of Agricultural Labourers to protest against the gradual lowering of wages in the 1830s. They refused to work for less than 10 shillings a week, although by this time wages had been reduced to seven shillings a week and were due to be further reduced to six shillings. In 1834 James Frampton, a local landowner, wrote to the Prime Minister, Lord Melbourne, to complain about the union, invoking an obscure law from 1797 prohibiting people from swearing oaths to each other, which the members of the Friendly Society had done. James Brine, James Hammett, George Loveless, George's brother James Loveless, George's brother in-law Thomas Standfield, and Thomas's son John Standfield were arrested, found guilty, and transported to Australia. They became known as the Tolpuddle martyrs. In the 1830s and 1840s the Chartist movement was the first large scale organised working class political movement which campaigned for political equality and social justice. Its *Charter* of reforms received over three million signatures but was rejected by Parliament without consideration.

Working people also formed friendly societies and co-operative societies as mutual support groups against times of economic hardship. Enlightened industrialists, such as Robert Owen also supported these organisations to improve the conditions of the working class.

Unions slowly overcame the legal restrictions on the right to strike. In 1842, a General Strike involving cotton workers and colliers was organised through the Chartist movement which stopped production across Great Britain.

Eventually effective political organisation for working people was achieved through the trades unions who, after the extensions of the franchise in 1867 and 1885, began to support socialist political parties that later merged to became the British Labour Party.

Standards of living

The history of the change of living conditions during the industrial revolution has been very controversial, and was the topic that from the 1950s to the 1980s caused most heated debate among economic and social historians. A series of 1950s essays by Henry Phelps Brown and Sheila V. Hopkins later set the academic consensus that the bulk of the population, that was at the bottom of the social ladder, suffered severe reductions in their living standards.

Chronic hunger and malnutrition were the norm for the majority of the population of the world including England and France, until the latter part of the 19th century. Until about 1750, in large part due to malnutrition, life expectancy in France was about 35 years, and only slightly higher in England. The U.S. population of the time was adequately fed, were much taller and had life expectancies of 45–50 years. A vivid description of living standards of the mill workers in England in 1844 was given by Fredrick Engels.

During the period 1813-1913 there was a significant increase in worker wages.

Population increase

According to Robert Hughes in *The Fatal Shore*, the population of England and Wales, which had remained steady at 6 million from 1700 to 1740, rose dramatically after 1740. The population of England had more than doubled from 8.3 million in 1801 to 16.8 million in 1851 and, by 1901, had nearly doubled again to 30.5 million. As living conditions and health care improved during the 19th century, Britain's population doubled every 50 years. Europe's population doubled during the 18th century, from roughly 100 million to almost 200 million, and doubled again during the 19th century, to around 400 million.

Other effects

The application of steam power to the industrial processes of printing supported a massive expansion of newspaper and popular book publishing, which reinforced rising literacy and demands for mass political participation.

During the Industrial Revolution, the life expectancy of children increased dramatically. The percentage of the children born in London who died before the age of five decreased from 74.5% in 1730–1749 to 31.8% in 1810–1829.

The growth of modern industry from the late 18th century onward led to massive urbanisation and the rise of new great cities, first in Europe and then in other regions, as new opportunities brought huge numbers of migrants from rural communities into urban areas. In 1800, only 3% of the world's population lived in cities, a figure that has risen to nearly 50% at the beginning of the 21st century. In 1717 Manchester was merely a market town of 10,000 people, but by 1911 it had a population of 2.3 million.

The greatest killer in the cities was tuberculosis (TB). By the late 19th century, 70 to 90% of the urban populations of Europe and North America were infected with *M. tuberculosis*, and about 40% of working-class deaths in cities were from TB.

Continental Europe

The Industrial Revolution on Continental Europe came a little later than in Great Britain. In many industries, this involved the application of technology developed in Britain in new places. Often the technology was purchased from Britain or British engineers and entrepreneurs moved abroad in search of new opportunities. By 1809 part of the Ruhr Valley in Westphalia was called 'Miniature England' because of its similarities to the industrial areas of England. The German, Russian and Belgian governments all provided state funding to the new industries. In some cases (such as iron), the different availability of resources locally meant that only some aspects of the British technology were adopted.

Wallonia, Belgium

Lifts on Canal du Centre (1888 - 1917) near La Louvière, Wallonia

Workers' housing at Bois-du-Luc (1838-1853) in La Louvière

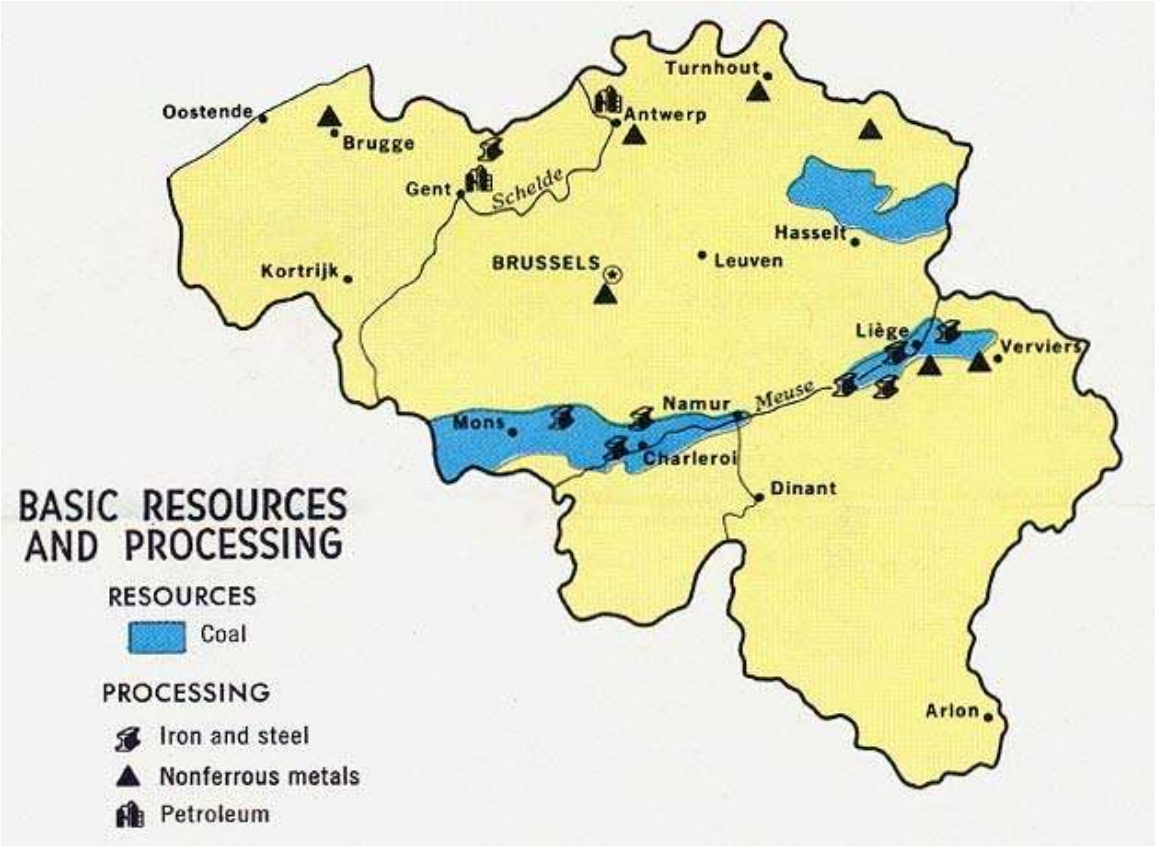
Renowned for its coal and steel, Wallonia has experienced strong industrial growth since the Middle Ages. For many years, heavy industry was the driving force behind the region's economy. Indeed, Wallonia was the birthplace of the industrial revolution on continental Europe:

Before railway construction on the Continent demanded huge quantities of maleable iron mainly for rails, for which low quality iron sufficed, Wallonia was the only Continental region to follow the British model successfully. Since the middle of the 1820s, numerous works comprising coke blast furnaces as well as puddling and rolling mills were built in the coal mining areas around Liège and Charleroi. Excelling all others, John Cockerill's factories at Seraing integrated all stages of production, from engineering to the supply of raw materials, as early as 1825.

Wallonia came to be regarded as an example of the radical evolution of industrial expansion. Thanks to coal (the French word "houille" was coined in Wallonia), the region geared up to become the 2nd industrial power in the world after England. But it is also pointed out by many researchers, with its *Sillon industriel*, 'Especially in the Haine, Sambre and Meuse valleys, between the Borinage and Liège, (...) there was a huge industrial development based on coal-mining and iron-making...'. Philippe Raxhon wrote about the period after 1830: "It was not propaganda but a reality the Walloon regions were becoming the second industrial power all over the world after England." "The sole industrial centre outside the collieries and blast furnaces of Walloon was the old cloth making town of Ghent." Michel De Coster, Professor at the Université de Liège wrote

also: "The historians and the economists say that Belgium was the second industrial power of the world, in proportion to its population and its territory (...) But this rank is the one of Wallonia where the coal-mines, the blast furnaces, the iron and zinc factories, the wool industry, the glass industry, the weapons industry... were concentrated"

Demographic effects



Wallonia's Sillon industriel (the blue area in the north is not in Wallonia)

Gallow frame of the *Crachet* in Frameries IN Wallonia's French *Châssis à molettes* or *Belfleur* (French *Chevalement*

Wallonia was also the birthplace of a strong Socialist party and strong trade-unions in a particular sociological landscape. At the left, the *Sillon industriel*, which runs from Mons in the west, to Verviers in the east (except part of North Flanders, in another period of the industrial revolution, after 1920). Even if Wallonia is the second industrial country after England, the effect of the industrial revolution there was very different. In 'Breaking stereotypes', Muriel Neven and Isabelle Devious say:

The industrial revolution changed a mainly rural society into an urban one, but with a strong contrast between northern and southern Belgium. During the Middle Ages and the Early Modern Period, Flanders was characterised by the presence of large urban centres (...) at the beginning of the nineteenth century this region (Flanders), with an urbanisation degree of more than 30 per cent, remained one of the most urbanised in the world. By comparison, this proportion reached only 17 per cent in Wallonia, barely 10 per cent in most West European countries, 16 per cent in France and 25 per cent in England. Nineteenth century industrialisation did not affect the traditional urban infrastructure, except in Ghent (...) Also, in Wallonia the traditional urban network was largely unaffected by the industrialisation process, even though the proportion of city-dwellers rose from 17 to 45 per cent between 1831 and 1910. Especially in the Haine, Sambre and Meuse valleys, between the Borinage and Liège, where there was a huge industrial

development based on coal-mining and iron-making, urbanisation was rapid. During these eighty years the number of municipalities with more than 5,000 inhabitants increased from only 21 to more than one hundred, concentrating nearly half of the Walloon population in this region. Nevertheless, industrialisation remained quite traditional in the sense that it did not lead to the growth of modern and large urban centres, but to a conurbation of industrial villages and towns developed around a coal-mine or a factory. Communication routes between these small centres only became populated later and created a much less dense urban morphology than, for instance, the area around Liège where the old town was there to direct migratory flows.

France

The industrial revolution in France was a particular process for it did not correspond to the main model followed by other countries. Notably, most French historians argue that France did not go through a clear *take-off*. Instead, France's economic growth and industrialisation process was slow and steady along the 18th and 19th centuries. However, some stages were identified by Maurice Lévy-Leboyer :

- French Revolution and Napoleonic wars (1789–1815),
- industrialisation, along with Britain (1815–1860),
- economic slowdown (1860–1905),
- renewal of the growth after 1905.

United States

Slater's Mill

The United States originally used horse-powered machinery to power its earliest factories, but eventually switched to water power, with the consequence that industrialisation was essentially limited to New England and the rest of the Northeastern United States, where fast-moving rivers were located. Horse-drawn production proved to be economically challenging and a more difficult alternative to the newer water-powered production lines. However, the raw materials (cotton) came from the Southern United States. It was not until after the Civil War in the 1860s that steam-powered manufacturing overtook water-powered manufacturing, allowing the industry to fully spread across the nation.

Thomas Somers and the Cabot Brothers founded the Beverly Cotton Manufactory in 1787, the first cotton mill in America, the largest cotton mill of its era, and a significant milestone in the research and development of cotton mills in the future. This cotton mill was designed to utilise horse-powered production, however the operators quickly learned that the economic stability of their horse-drawn platform was unstable, and had fiscal issues for years after it was built. Despite the losses, the Manufactory served as a

playground of innovation, both in turning a large amount of cotton, but also developing the water-powered milling structure used in Slater's Mill.

Bethlehem Steel, founded in 1857, was once the second-largest manufacturer of steel in the United States; its Bethlehem, Pennsylvania, location has been transformed into a casino.

Samuel Slater (1768–1835) is the founder of the Slater Mill. As a boy apprentice in Derbyshire, England, he learned of the new techniques in the textile industry and defied laws against the emigration of skilled workers by leaving for New York in 1789, hoping to make money with his knowledge. Slater founded Slater's Mill at Pawtucket, Rhode Island, in 1793. He went on to own thirteen textile mills. Daniel Day established a wool carding mill in the Blackstone Valley at Uxbridge, Massachusetts in 1809, the third woollen mill established in the U.S. (The first was in Hartford, Connecticut, and the second at Watertown, Massachusetts.) The John H. Chafee Blackstone River Valley National Heritage Corridor retraces the history of "America's Hardest-Working River', the Blackstone. The Blackstone River and its tributaries, which cover more than 45 miles (72 km) from Worcester to Providence, was the birthplace of America's Industrial Revolution. At its peak over 1100 mills operated in this valley, including Slater's mill, and with it the earliest beginnings of America's Industrial and Technological Development.

While on a trip to England in 1810, Newburyport merchant Francis Cabot Lowell was allowed to tour the British textile factories, but not take notes. Realising the War of 1812

had ruined his import business but that a market for domestic finished cloth was emerging in America, he memorised the design of textile machines, and on his return to the United States, he set up the Boston Manufacturing Company. Lowell and his partners built America's second cotton-to-cloth textile mill at Waltham, Massachusetts, second to the Beverly Cotton Manufactory After his death in 1817, his associates built America's first planned factory town, which they named after him. This enterprise was capitalised in a public stock offering, one of the first uses of it in the United States. Lowell, Massachusetts, utilising 5.6 miles (9.0 km) of canals and ten thousand horsepower delivered by the Merrimack River, is considered by some to be a major contributor to the success of the American Industrial Revolution. The short-lived utopia-like Lowell System was formed, as a direct response to the poor working conditions in Britain. However, by 1850, especially following the Irish Potato Famine, the system had been replaced by poor immigrant labour.

The industrialisation of the watch industry started 1854 also in Waltham, Massachusetts, at the Waltham Watch Company, with the development of machine tools, tools, gauges and assembling methods adapted to the micro precision required for watches.

Japan

In 1871 a group of Japanese politicians known as the Iwakura Mission toured Europe and the USA to learn western ways. The result was a deliberate state led industrialisation policy to prevent Japan from falling behind. The Bank of Japan, founded in 1877, used taxes to fund model steel and textile factories. Education was expanded and Japanese students were sent to study in the west.

Second Industrial Revolution and later evolution

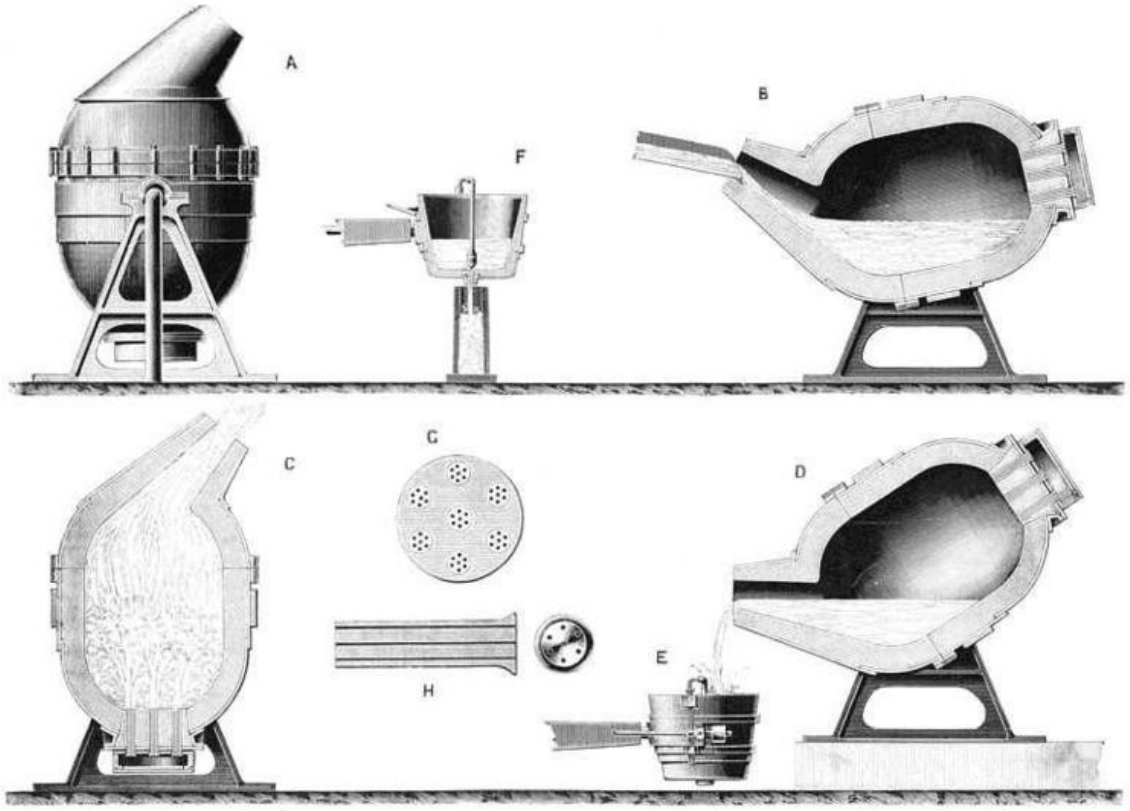


Fig. 43. The First Form of Bessemer Moveable Converter and Ladle

Bessemer converter

The insatiable demand of the railways for more durable rail led to the development of the means to cheaply mass-produce steel. Steel is often cited as the first of several new areas for industrial mass-production, which are said to characterise a "Second Industrial Revolution", beginning around 1850, although a method for mass manufacture of steel was not invented until the 1860s, when Sir Henry Bessemer invented a new furnace which could make wrought iron and steel in large quantities. However, it only became widely available in the 1870s. This second Industrial Revolution gradually grew to include the chemical industries, petroleum refining and distribution, electrical industries, and, in the 20th century, the automotive industries, and was marked by a transition of technological leadership from Britain to the United States and Germany.

The introduction of hydroelectric power generation in the Alps enabled the rapid industrialisation of coal-deprived northern Italy, beginning in the 1890s. The increasing availability of economical petroleum products also reduced the importance of coal and further widened the potential for industrialisation.

Marshall McLuhan analysed the social and cultural impact of the electric age. While the previous age of mechanisation had spread the idea of splitting every process into a sequence, this was ended by the introduction of the instant speed of electricity that brought simultaneity. This imposed the cultural shift from the approach of focusing on "specialised segments of attention" (adopting one particular perspective), to the idea of "instant sensory awareness of the whole", an attention to the "total field", a "sense of the whole pattern". It made evident and prevalent the sense of "form and function as a unity", an "integral idea of structure and configuration". This had major impact in the disciplines of painting (with cubism), physics, poetry, communication and educational theory.

By the 1890s, industrialisation in these areas had created the first giant industrial corporations with burgeoning global interests, as companies like U.S. Steel, General Electric, and Bayer AG joined the railroad companies on the world's stock markets.

Intellectual paradigms and criticism

Capitalism

The advent of the Age of Enlightenment provided an intellectual framework which welcomed the practical application of the growing body of scientific knowledge—a factor evidenced in the systematic development of the steam engine, guided by scientific analysis, and the development of the political and sociological analyses, culminating in Adam Smith's *The Wealth of Nations*. One of the main arguments for capitalism, presented for example in the book *The Improving State of the World*, is that industrialisation increases wealth for all, as evidenced by raised life expectancy, reduced working hours, and no work for children and the elderly.

Socialism

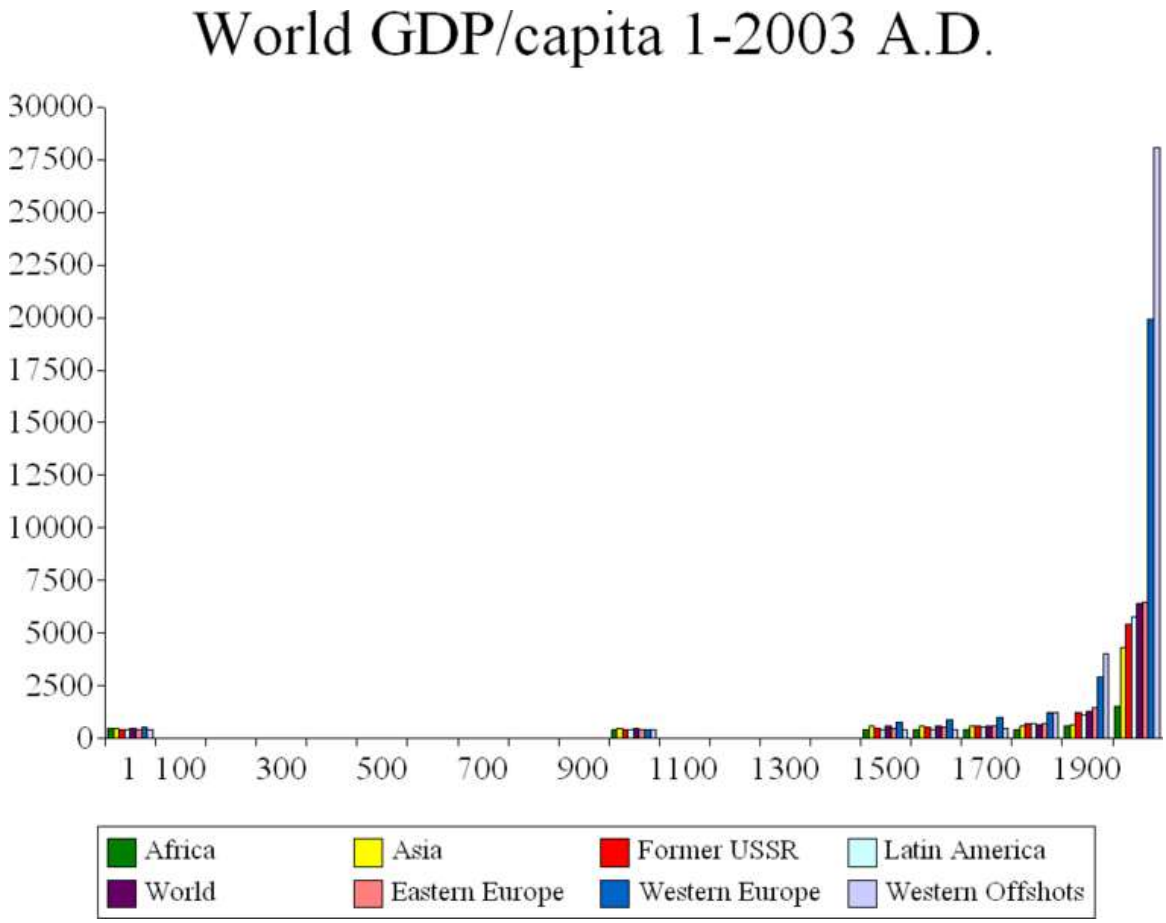
Socialism emerged as a critique of capitalism. Marxism began essentially as a reaction to the Industrial Revolution. According to Karl Marx, industrialisation polarised society into the bourgeoisie (those who own the means of production, the factories and the land) and the much larger proletariat (the working class who actually perform the labour necessary to extract something valuable from the means of production). He saw the industrialisation process as the logical dialectical progression of feudal economic modes, necessary for the full development of capitalism, which he saw as in itself a necessary precursor to the development of socialism and eventually communism.

Romanticism

During the Industrial Revolution an intellectual and artistic hostility towards the new industrialisation developed. This was known as the Romantic movement. Its major exponents in English included the artist and poet William Blake and poets William Wordsworth, Samuel Taylor Coleridge, John Keats, Lord Byron and Percy Bysshe Shelley. The movement stressed the importance of "nature" in art and language, in

contrast to "monstrous" machines and factories; the "Dark satanic mills" of Blake's poem "And did those feet in ancient time". Mary Shelley's novel *Frankenstein* reflected concerns that scientific progress might be two-edged.

Causes



Regional GDP per capita changed very little for most of human history before the Industrial Revolution. (The empty areas mean no data, not very low levels. There is data for the years 1, 1000, 1500, 1600, 1700, 1820, 1900, and 2003)

The causes of the Industrial Revolution were complicated and remain a topic for debate, with some historians believing the Revolution was an outgrowth of social and institutional changes brought by the end of feudalism in Britain after the English Civil War in the 17th century. As national border controls became more effective, the spread of disease was lessened, thereby preventing the epidemics common in previous times. The percentage of children who lived past infancy rose significantly, leading to a larger workforce. The Enclosure movement and the British Agricultural Revolution made food production more efficient and less labour-intensive, forcing the surplus population who could no longer find employment in agriculture into cottage industry, for example weaving, and in the longer term into the cities and the newly developed factories. The

colonial expansion of the 17th century with the accompanying development of international trade, creation of financial markets and accumulation of capital are also cited as factors, as is the scientific revolution of the 17th century.

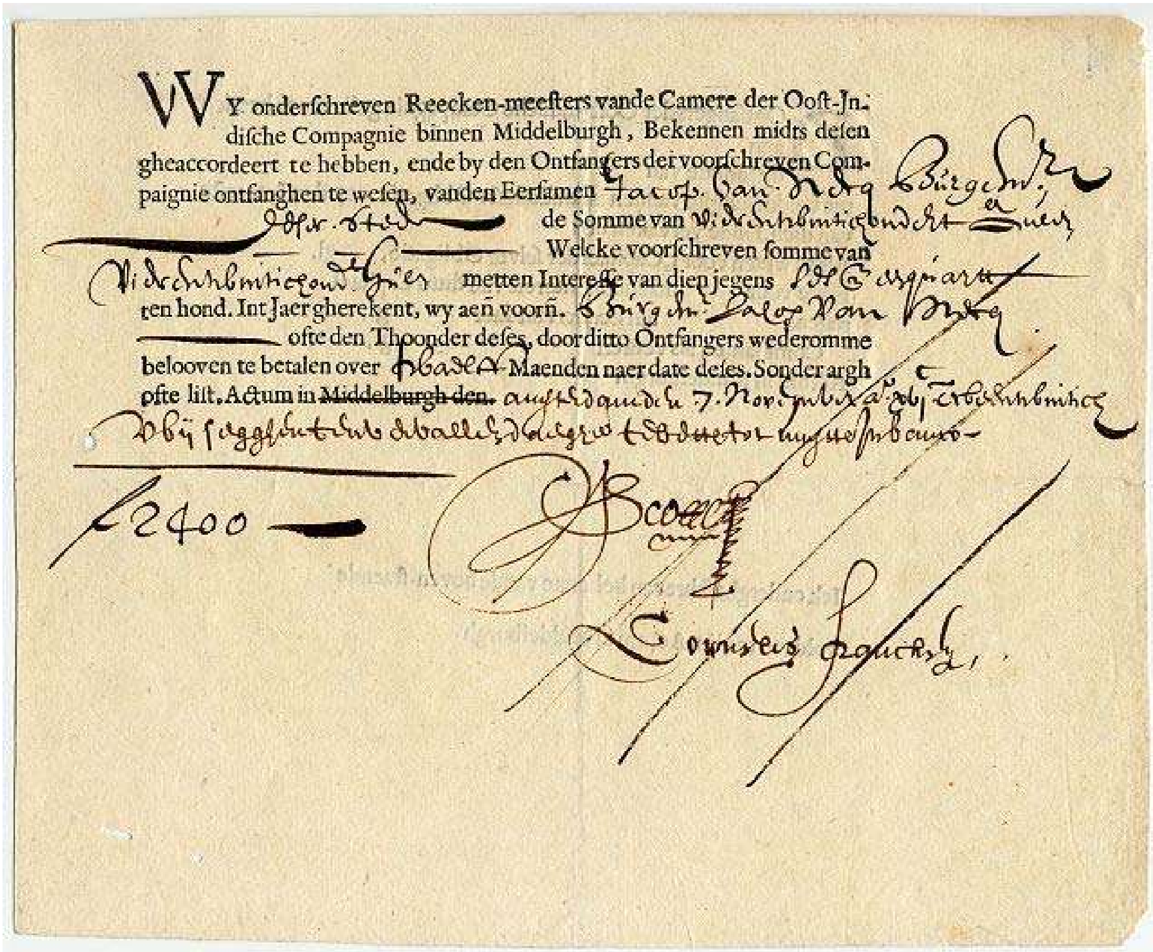
Until the 1980s, it was universally believed by academic historians that technological innovation was the heart of the Industrial Revolution and the key enabling technology was the invention and improvement of the steam engine. However, recent research into the Marketing Era has challenged the traditional, supply-oriented interpretation of the Industrial Revolution.

Lewis Mumford has proposed that the Industrial Revolution had its origins in the Early Middle Ages, much earlier than most estimates. He explains that the model for standardised mass production was the printing press and that "the archetypal model for the industrial era was the clock". He also cites the monastic emphasis on order and time-keeping, as well as the fact that medieval cities had at their centre a church with bell ringing at regular intervals as being necessary precursors to a greater synchronisation necessary for later, more physical, manifestations such as the steam engine.

The presence of a large domestic market should also be considered an important driver of the Industrial Revolution, particularly explaining why it occurred in Britain. In other nations, such as France, markets were split up by local regions, which often imposed tolls and tariffs on goods traded amongst them. Internal tariffs were abolished by Henry VIII of England, they survived in Russia till 1753, 1789 in France and 1839 in Spain.

Governments' grant of limited monopolies to inventors under a developing patent system (the Statute of Monopolies 1623) is considered an influential factor. The effects of patents, both good and ill, on the development of industrialisation are clearly illustrated in the history of the steam engine, the key enabling technology. In return for publicly revealing the workings of an invention the patent system rewarded inventors such as James Watt by allowing them to monopolise the production of the first steam engines, thereby rewarding inventors and increasing the pace of technological development. However monopolies bring with them their own inefficiencies which may counterbalance, or even overbalance, the beneficial effects of publicising ingenuity and rewarding inventors. Watt's monopoly may have prevented other inventors, such as Richard Trevithick, William Murdoch or Jonathan Hornblower, from introducing improved steam engines, thereby retarding the industrial revolution by about 16 years.

Causes for occurrence in Europe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A 1623 Dutch East India Company bond.

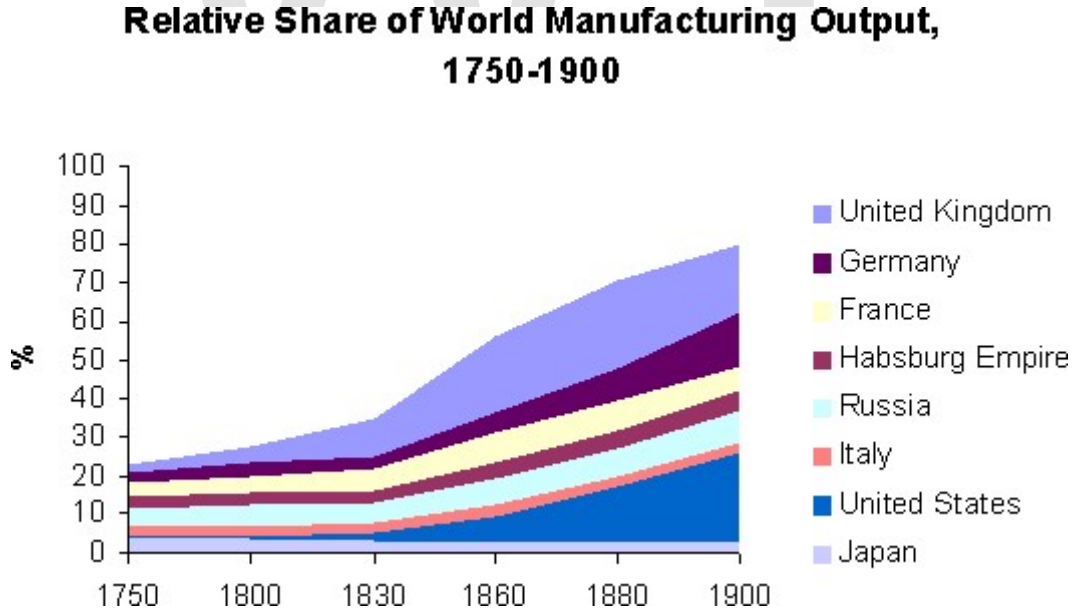
European 17th century colonial expansion, international trade, and creation of financial markets produced a new legal and financial environment, one which supported and enabled 18th century industrial growth.

One question of active interest to historians is why the industrial revolution occurred in Europe and not in other parts of the world in the 18th century, particularly China, India, and the Middle East, or at other times like in Classical Antiquity or the Middle Ages. Numerous factors have been suggested, including education, technological changes, "modern" government, "modern" work attitudes, ecology, and culture. The Age of Enlightenment not only meant a larger educated population but also more modern views on work. However, most historians contest the assertion that Europe and China were roughly equal because modern estimates of per capita income on Western Europe in the late 18th century are of roughly 1,500 dollars in purchasing power parity (and Britain had a per capita income of nearly 2,000 dollars) whereas China, by comparison, had only 450 dollars.

Some historians such as David Landes and Max Weber credit the different belief systems in China and Europe with dictating where the revolution occurred. The religion and beliefs of Europe were largely products of Judaeo-Christianity, and Greek thought. Conversely, Chinese society was founded on men like Confucius, Mencius, Han Feizi (Legalism), Lao Tzu (Taoism), and Buddha (Buddhism). Whereas the Europeans believed that the universe was governed by rational and eternal laws, the East believed that the universe was in constant flux and, for Buddhists and Taoists, not capable of being rationally understood. Other factors include the considerable distance of China's coal deposits, though large, from its cities as well as the then unnavigable Yellow River that connects these deposits to the sea.

Regarding India, the Marxist historian Rajani Palme Dutt said: "The capital to finance the Industrial Revolution in India instead went into financing the Industrial Revolution in England." In contrast to China, India was split up into many competing kingdoms, with the three major ones being the Marathas, Sikhs and the Mughals. In addition, the economy was highly dependent on two sectors—agriculture of subsistence and cotton, and there appears to have been little technical innovation. It is believed that the vast amounts of wealth were largely stored away in palace treasuries by totalitarian monarchs prior to the British take over. Absolutist dynasties in China, India, and the Middle East failed to encourage manufacturing and exports, and expressed little interest in the well-being of their subjects.

Causes for occurrence in Britain



As the Industrial Revolution developed British manufactured output surged ahead of other economies. After the Industrial Revolution, it was overtaken later by the United States.

The debate about the start of the Industrial Revolution also concerns the massive lead that Great Britain had over other countries. Some have stressed the importance of natural or financial resources that Britain received from its many overseas colonies or that profits from the British slave trade between Africa and the Caribbean helped fuel industrial investment. It has been pointed out, however, that slave trade and West Indian plantations provided only 5% of the British national income during the years of the Industrial Revolution. Even though slavery accounted for minimal economic profits in Britain during the Industrial Revolution, Caribbean-based demand accounted for 12% of England's industrial output.

Alternatively, the greater liberalisation of trade from a large merchant base may have allowed Britain to produce and use emerging scientific and technological developments more effectively than countries with stronger monarchies, particularly China and Russia. Britain emerged from the Napoleonic Wars as the only European nation not ravaged by financial plunder and economic collapse, and possessing the only merchant fleet of any useful size (European merchant fleets having been destroyed during the war by the Royal Navy). Britain's extensive exporting cottage industries also ensured markets were already available for many early forms of manufactured goods. The conflict resulted in most British warfare being conducted overseas, reducing the devastating effects of territorial conquest that affected much of Europe. This was further aided by Britain's geographical position—an island separated from the rest of mainland Europe.

Another theory is that Britain was able to succeed in the Industrial Revolution due to the availability of key resources it possessed. It had a dense population for its small geographical size. Enclosure of common land and the related agricultural revolution made a supply of this labour readily available. There was also a local coincidence of natural resources in the North of England, the English Midlands, South Wales and the Scottish Lowlands. Local supplies of coal, iron, lead, copper, tin, limestone and water power, resulted in excellent conditions for the development and expansion of industry. Also, the damp, mild weather conditions of the North West of England provided ideal conditions for the spinning of cotton, providing a natural starting point for the birth of the textiles industry.

The stable political situation in Britain from around 1688, and British society's greater receptiveness to change (compared with other European countries) can also be said to be factors favouring the Industrial Revolution. In large part due to the Enclosure movement, the peasantry was destroyed as a significant source of resistance to industrialisation, and the landed upper classes developed commercial interests that made them pioneers in removing obstacles to the growth of capitalism. (This point is also made in Hilaire Belloc's The Servile State.)

Britain's population grew 280% 1550-1820, while the rest of Western Europe grew 50-80%. 70% of European urbanisation happened in Britain 1750-1800. By 1800, only the Netherlands was more urbanised than Britain. This was only possible because coal, coke, imported cotton, brick and slate had replaced wood, charcoal, flax, peat and thatch. The latter compete with land grown to feed people while mined materials do not. Yet more

land would be freed when chemical fertilisers replaced manure and horse's work was mechanised. A workhorse needs 3 to 5 acres (1.21 to 2.02 ha) for fodder while even early steam engines produced 4 times more mechanical energy.

In 1700 5/6 of coal mined worldwide was in Britain while the Netherlands had none; so despite having Europe's best transport, most urbanised, well paid, literate people and lowest taxes, it failed to industrialise. In the 18th century it was the only European country whose cities and population shrank. Without coal, Britain would have run out of suitable river sites for mills by the 1830s.

Protestant work ethic

Another theory is that the British advance was due to the presence of an entrepreneurial class which believed in progress, technology and hard work. The existence of this class is often linked to the Protestant work ethic and the particular status of the Baptists and the dissenting Protestant sects, such as the Quakers and Presbyterians that had flourished with the English Civil War. Reinforcement of confidence in the rule of law, which followed establishment of the prototype of constitutional monarchy in Britain in the Glorious Revolution of 1688, and the emergence of a stable financial market there based on the management of the national debt by the Bank of England, contributed to the capacity for, and interest in, private financial investment in industrial ventures.

Dissenters found themselves barred or discouraged from almost all public offices, as well as education at England's only two universities at the time (although dissenters were still free to study at Scotland's four universities). When the restoration of the monarchy took place and membership in the official Anglican Church became mandatory due to the Test Act, they thereupon became active in banking, manufacturing and education. The Unitarians, in particular, were very involved in education, by running Dissenting Academies, where, in contrast to the universities of Oxford and Cambridge and schools such as Eton and Harrow, much attention was given to mathematics and the sciences—areas of scholarship vital to the development of manufacturing technologies.

Historians sometimes consider this social factor to be extremely important, along with the nature of the national economies involved. While members of these sects were excluded from certain circles of the government, they were considered fellow Protestants, to a limited extent, by many in the middle class, such as traditional financiers or other businessmen. Given this relative tolerance and the supply of capital, the natural outlet for the more enterprising members of these sects would be to seek new opportunities in the technologies created in the wake of the scientific revolution of the 17th century.

This theory does not explain how the second country to be industrialised-Belgium, was Catholic.

Name history

The earliest use of the term "Industrial Revolution" yet located seems to be a letter of 6 July 1799 by French envoy Louis-Guillaume Otto, announcing that the process had started in his country. In his 1976 book *Keywords: A Vocabulary of Culture and Society*, Raymond Williams states in the entry for "Industry": "The idea of a new social order based on major industrial change was clear in Southey and Owen, between 1811 and 1818, and was implicit as early as Blake in the early 1790s and Wordsworth at the turn of the century." The term *Industrial Revolution* applied to technological change was becoming more common by the late 1830s, as in Louis-Auguste Blanqui description in 1837 of *la révolution industrielle*. Friedrich Engels in *The Condition of the Working Class in England in 1844* spoke of "an industrial revolution, a revolution which at the same time changed the whole of civil society". Credit for popularising the term may be given to Arnold Toynbee, whose lectures given in 1881 gave a detailed account of it.