

Industrial Revolution

From Wikipedia, the free encyclopedia



A [Watt steam engine](#). The [steam engine](#) propelled the Industrial Revolution in Britain and the world

The **Industrial Revolution** was a major shift of [technological](#), [socioeconomic](#), and [cultural](#) conditions in the late [18th](#) and early [19th century](#). It began in [Britain](#) and spread throughout the world. During that time, an economy based on manual labour was replaced by one dominated by industry and the manufacture of [machinery](#). It began 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) and powered machinery (mainly in [textile manufacturing](#)) underpinned the dramatic increases in production capacity.^[1] 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 period of time covered by the Industrial Revolution varies with different historians. [Eric Hobsbawm](#) held that it 'broke out' in the 1780s and was not fully felt until the 1830s or 1840s,^[2] while [T.S. Ashton](#) held that it occurred roughly between 1760 and 1830.^[3]

The effects spread throughout Western Europe and North America during the 19th century, eventually affecting most of the world. The impact of this change on society was enormous.^[4]

The first Industrial Revolution 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 nineteenth century with the [internal combustion engine](#) and [electrical power generation](#).

It has been argued that [GDP](#) per capita was much more stable and progressed at a much slower rate until the Industrial Revolution and the emergence of the modern [capitalist](#) economy, and that it has since increased rapidly in capitalist countries.^[5]

Some twentieth 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 not a true description of what took place. This is still a subject of debate amongst historians.^{[6][7]}

Nomenclature

The term *Industrial Revolution* applied to technological change was common in the 1830s. [Louis-Auguste Blanqui](#) in 1837 spoke 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".

In his 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.*

Credit for popularising the term may be given to [Arnold Toynbee](#), whose lectures given in 1881 gave a detailed account of the process.

Causes

The causes of the Industrial Revolution were complex and remain a topic for debate, with some historians seeing the Revolution as 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, therefore 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.

Technological innovation was the heart of the industrial revolution and the key enabling technology was the invention and improvement of the [steam engine](#).^[8]

[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 standardized [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 center a church with bell ringing at regular intervals as being necessary precursors to a greater synchronization 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.^[9]

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 industrialization appear clearly in the history of the steam engine, the key enabling technology. The patent system rewards inventors by, e.g, allowing [James Watt](#) to monopolize the production of the first steam engines, thereby enabling 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 rewarding inventors^[10]. Watt's monopoly may have prevented [William Murdoch](#) or [Jonathan Hornblower](#) from introducing improved steam engines into the marketplace thereby retarding the industrial revolution by up to 20 years.

Causes for occurrence in Europe

See also: [China and the Industrial Revolution](#)

One question of active interest to historians is why the Industrial Revolution started in 18th century Europe and not in other parts of the world in the 18th century, particularly [China](#) and [India](#), or at other times like in [Classical Antiquity](#), which had developed a primitive [steam engine](#) by the 1st century in Roman Egypt. ^{[11][12]} Numerous factors have been suggested, including ecology, government, and culture. [Benjamin Elman](#) argues that China was in a [high level equilibrium trap](#) in which the non-industrial methods were efficient enough to prevent use of industrial methods with high costs of capital. [Kenneth Pomeranz](#), in the *Great Divergence*, argues that Europe and China were remarkably similar in 1700, and that the crucial differences which created the Industrial Revolution in Europe were sources of coal near manufacturing centres, and raw materials such as food and wood from the New World, which allowed Europe to expand economically in a way that China could not. ^[13]

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^[14]) whereas China, by comparison, had only 450 dollars. Also, the average [interest rate](#) was about 5% in Britain and over 30% in China, which illustrates how capital was much more abundant in Britain; capital that was available for investment.

Some historians such as [David Landes](#)^[15] 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](#)). The key difference between these belief systems was that those from Europe focused on the individual, while Chinese beliefs centered around relationships between people. The family unit was more important than the individual for the large majority of Chinese history, and this may have played a role in why the Industrial Revolution took much longer to occur in China. There was the additional difference as to whether people looked backwards to a reputedly glorious past for answers to their questions or looked hopefully to the future. Furthermore, Western European peoples had experienced the [Renaissance](#) and [Reformation](#); other parts of the world had not had a similar intellectual breakout, a condition that holds true even into the 21st century.

Regarding [India](#), the Marxist historian [Rajani Palme Dutt](#) has been quoted as saying, "The capital to finance the Industrial Revolution in India instead went into financing the Industrial Revolution in England."^[16] 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 technical innovation was non-existent. The vast amounts of wealth were stored away in palace treasuries, and as such, were easily moved to Britain.

Causes for occurrence in Britain



 [Coalbrookdale](#) at night, 1801 :
Artist: [Philip Jakob Louthembourg the Younger](#)

The debate about the start of the Industrial Revolution also concerns the massive lead that 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 slavery provided only 5% of the British national income during the years of the Industrial Revolution.^[17]

Alternatively, the greater liberalisation of trade from a large merchant base may have allowed Britain to produce and utilise 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](#)^[18]). 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 (when 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 largely destroyed as a significant source of resistance to modernization, and the landed upper classes developed commercial interests that made them pioneers in removing obstacles to the growth of capitalism.^[19]

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.¹ The existence of this class is often linked to the [Protestant work ethic](#) (see [Max Weber](#)) and the particular status of dissenting Protestant sects, such as the [Quakers](#), [Baptists](#) 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.

Innovations

The commencement of the Industrial Revolution is closely linked to a small number of innovations, made between in the second half of the [18th century](#):

- **Textiles** - [Cotton spinning](#) using [Richard Arkwright's 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](#) 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 founding** - 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 [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 [mill](#).

In the textile sector, such mills became the model for the organization 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.

Transfer of knowledge

Knowledge of new 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".^[20] 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 Dr 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.

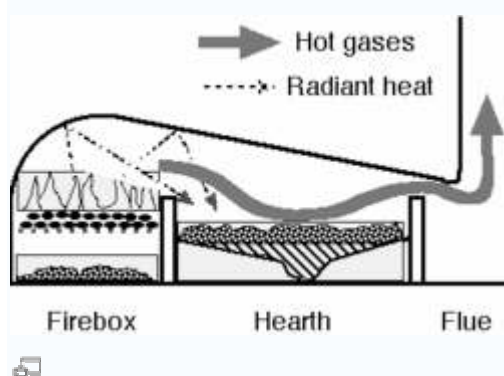
Periodical publications about manufacturing and technology began to appear in the last decade of the 18th century, and many regularly included notice of the latest patents. Foreign periodicals, such as the [Annales des Mines](#), published accounts of travels made by French engineers who observed British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

Industry in Britain

Mining

[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](#) 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.

Metallurgy



Reverberatory Furnace

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 sulfur) 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 [Iron Bridge](#) in 1778 by [Abraham Darby III](#).

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.

Chemicals

The large scale production of chemicals was an important development during the Industrial Revolution. The first of these was the production of [sulfuric 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 a few pounds at a time, he was able to make a hundred pounds (45 kg) or so at a time in each of the chambers.

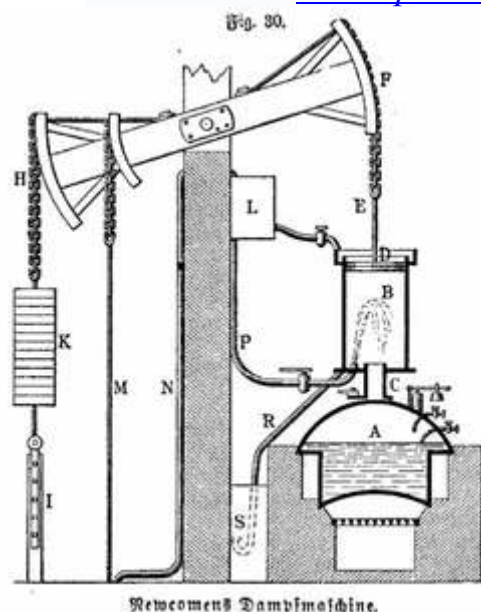
The production of an [alkali](#) on a large scale became an important goal as well, and [Nicolas Leblanc](#) succeeded in 1791 in introducing a method for the production of [sodium carbonate](#). The [Leblanc process](#) was a reaction of sulfuric acid with sodium chloride to give sodium sulfate and hydrochloric acid. The sodium sulfate was heated with limestone (calcium carbonate) and coal to give a mixture of sodium carbonate and calcium sulfide. Adding water separated the soluble sodium carbonate from the calcium sulfide. The process produced a large amount of pollution (the hydrochloric acid was initially vented to the air, and calcium sulfide was a useless waste product). Nonetheless, this synthetic [soda ash](#) proved economical compared that produce from burning certain plants ([barilla](#)) or from [kelp](#), which were the previously dominant sources of soda ash,^[21] 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 sulfuric 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](#), revolutionized 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.

Steam power

Main article: [Steam power during the Industrial Revolution](#)



Newcomen's atmospheric steam engine

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 industrial use of steam power started with [Thomas Savery](#) in 1698. He constructed and patented in London the first engine, which he called the "Miner's Friend" since he intended it to pump water from mines. This machine used steam at 8 to 10 atmospheres (120-150 [psi](#)) and did not use a piston and cylinder, but applied the steam pressure directly on to the surface of water in a cylinder to force it along an outlet pipe. It also used condensed steam to produce a partial vacuum to suck water into the cylinder. It generated about one [horsepower](#) (hp). It was used as a low-lift water pump in a few mines and numerous water works, but it was not a

success since it was limited in the height it could raise water and was prone to boiler explosions.

The first successful machine was the [atmospheric engine](#), a low performance steam engine invented by [Thomas Newcomen](#) in 1712. Newcomen apparently conceived his machine quite independently of Savery. His engines used a piston and cylinder, and it operated with steam just above atmospheric pressure which was used to produce a partial vacuum in the cylinder when condensed by jets of cold water. The vacuum sucked a piston into the cylinder which moved under pressure from the atmosphere. The engine produced a succession of power strokes which could work a pump but could not drive a rotating wheel. They were successfully put to use for pumping out mines in Britain, with the engine on the surface working a pump at the bottom of the mine by a long connecting rod. These were large machines, requiring a lot of capital to build, but produced about 5 hp. They were inefficient, but when located where coal was cheap at pit heads, they were usefully employed in pumping water from mines. They opened up a great expansion in coal mining by allowing mines to go deeper. Despite using a lot of fuel, Newcomen engines continued to be used in the coalfields until the early decades of the nineteenth century because they were reliable and easy to maintain.

By 1729, when Newcomen died, his engines had spread to France, [Germany](#), [Austria](#), [Hungary](#) and [Sweden](#). A total of 110 are known to have been built by 1733 when the patent expired, of which 14 were abroad. A total of 1,454 engines had been built by 1800.

Its working was fundamentally unchanged until James Watt succeeded in making his [Watt steam engine](#) in 1769, which incorporated a series of improvements, especially the separate steam condenser chamber. This improved engine efficiency by about a factor of five saving 75% on coal costs. The Watt steam engine's ability to drive rotary machinery also meant it could be used to drive a factory or mill directly. They were commercially very successful, and by 1800, the firm [Boulton & Watt](#) had constructed 496 engines, with 164 acting as pumps, 24 serving [blast furnaces](#), and 308 to power mill machinery. Most of the engines generated between 5 to 10 hp.

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](#), which was built within a stone or brick engine-house, but around that time various patterns of portable (readily removable engines, but not on wheels) engines were developed, such as the [table engine](#).


[Richard Trevithick](#), a Cornish blacksmith, began to use high pressure steam with improved boilers in 1799. This allowed engines to be 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 had many improvements by a host of inventors and engineers.

Textile manufacture

Main article: [Textile manufacture during the Industrial Revolution](#)



 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](#) and John Wyatt of Birmingham patented the [Roller Spinning machine](#) and the [flyer-and-bobbin](#) system for drawing wool to a more even thickness. 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](#); fifty spindles turned on five of Paul and Wyatt's machines proving more successful than their first Mill and operated until 1764. Lewis Paul also invented the hand driven [carding](#) machine. 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](#) and [Samuel Crompton](#), although this came about under great suspicion after a fire at [Daniel Bourn](#)'s factory in [Leominster](#) which specifically used Paul and Wyatt's spindles. Borne produced a similar patent in the same year. 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 Higs](#) 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](#), then [water power](#) and finally steam power — which made cotton manufacture a mechanized industry.

Factories



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

Industrialisation also led to the creation of the [factory](#). Arguably the first was [John Lombe's water-powered silk mill](#) at [Derby](#) was 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 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 powered by water and built to serve local needs. Later each mill would have its own steam engine and a tall chimney to give an efficient draft through its boiler.

The transition to industrialisation was not wholly smooth. For example, a group of English workers known as [Luddites](#) formed to protest against industrialisation and sometimes [sabotaged](#) factories. One of the earliest reformers of factory conditions was [Robert Owen](#).

In other industries the transition to factory production followed a slightly different course. In 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.

Machine tools

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 [William 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.

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 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.

Gaslighting

Another major industry of the later industrial revolution was [gaslighting](#). It consisted of the large scale gasification of coal in furnaces, the purification of the gas (removal of sulphur, ammonium, and heavy hydrocarbons), and its storage and distribution. The first gaslighting utilities were established in London between 1812-20. They soon became one of the major consumers of coal in the UK. Gaslighting had in impact on social and industrial organization 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 street could be lighted on a larger scale than before.

Transport in Britain

Main article: [Transport during the Industrial Revolution](#)

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.

Navigable rivers

Main article: [List of rivers of United Kingdom](#)

All the major rivers of the United Kingdom were made more navigable during the Industrial Revolution. 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](#). 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.

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 major international seaports such as London, Bristol, and Liverpool, were the means by which raw materials such as cotton might be imported and finished goods exported. Transporting goods onwards within Britain by sea was common during the whole of the Industrial Revolution and only fell away with the growth of the railways at the end of the period.

Canals

Main article: [History of the British canal system](#)

Canals began to be built in the late eighteenth century to link the major manufacturing centres in the Midlands and north with seaports and with London, at that time the largest manufacturing centre in the country. Canals were the first technology to allow bulk materials to be easily transported across 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 organization 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 horses. Stage coaches transported rich people. The less wealthy walked or paid to ride on a carriers cart.

Railways

Main article: [History of rail transport in Great Britain](#)

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 [Liverpool and Manchester](#) and [Stockton and Darlington](#) Railways of the late 1820s. The 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.

Industrial Revolution elsewhere

America

Main article: [United States technological and industrial history](#)

As in Britain, the United States originally used water power to run its factories, 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. However, the raw materials (cotton) came from the [Southern United States](#). It was not until after the [American Civil War](#) in the 1860s that steam-powered manufacturing overtook water-powered manufacturing, allowing the industry to fully spread across the nation.

[Samuel Slater](#) (1768–1835) is popularly known as the founder of the American cotton industry. As a boy apprentice in Derbyshire, England he learnt 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 started [Slater's mill](#) at

[Pawtucket, Rhode Island](#), in 1793 and went on to own thirteen textile mills.^[22]

While on a trip to England in 1810, [Newburyport, Massachusetts](#) 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 memorized 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 first cotton-to-cloth textile mill at [Waltham, Massachusetts](#). 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](#), utilizing 5.6 miles of canals and ten thousand horsepower delivered by the [Merrimack River](#), is considered the 'Cradle 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 labor.

See Also: [History of Lowell, Massachusetts](#)

Continental Europe

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. Harsh working conditions were prevalent long before the industrial revolution took place as well. 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.^[23]

Child labour

The Industrial Revolution led to a population increase. Industrial workers were better paid than those in agriculture. With more money, women ate better, had healthier babies, who were themselves better fed. Death rates declined, and the distribution of age in the population became more

youthful. There was limited opportunity for education, and children were expected to work. Employers also liked that they could pay a child less than an adult.

[Child labour](#) had existed before the Industrial Revolution, but with the increase in population and education it became more visible. Before the passing of laws protecting children, many were forced to work in terrible conditions for much lower pay than their elders.

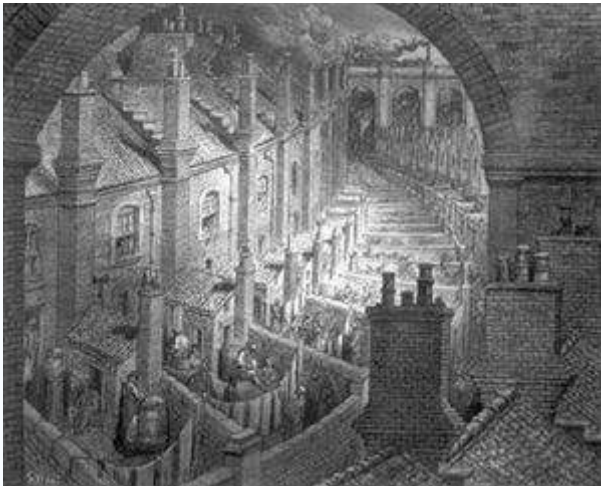



A young "drawer" pulling a coal tub up a mine shaft

Reports were written detailing some of the abuses, particularly in the coal mines^[3] and textile factories^[4] and these helped to popularize 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. 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 up to the 20th century.

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. [Cliffe Castle](#), [Keighley](#), is a good example of how the newly rich chose to live. This is a large home modelled loosely on a castle with towers and garden walls. The home is very large and was surrounded by a massive garden, the estate itself stretching for a number of miles. Cliffe Castle is now open to the public as a museum.

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 disease 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. [Dickens'](#) novels perhaps best illustrate this - even some government officials were horrified by what they saw. Strikes and riots by workers were also relatively common. [\[5\]](#)

Luddites

Main article: [Luddite](#)

The rapid industrialisation of the English economy cost many craft workers their jobs. The textile industry in particular industrialized early, and many weavers 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 had to take drastic measures to protect industry.

Organization of labour

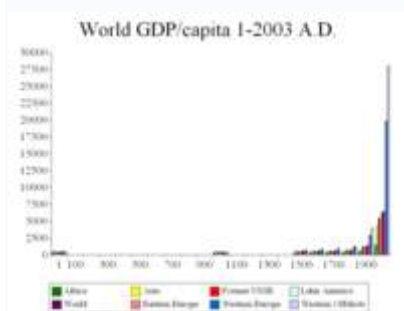
See also [Labor history](#)

The Industrial Revolution concentrated labour into mills, factories and mines, thus facilitating the organization of [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 suffer 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.

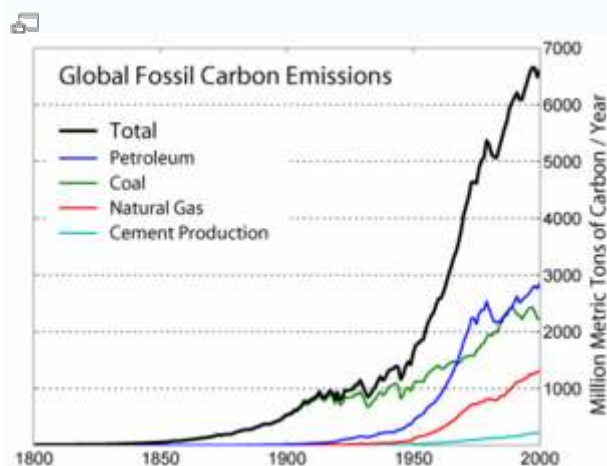
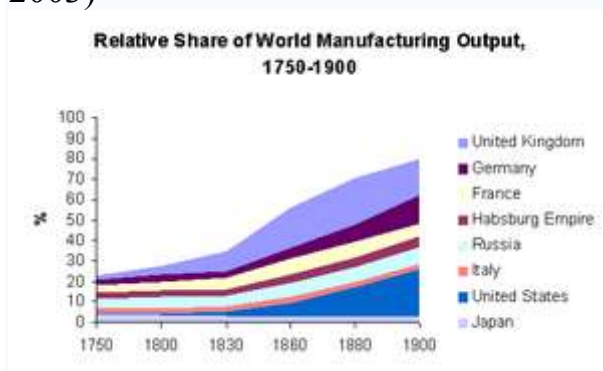
The main method the unions used to effect change was [strike action](#). Strikes were painful events for both sides, the unions and the management. In England, the [Combination Act](#) forbade workers to form any kind of trade union from 1799 until its repeal in 1824. Even after this, unions were still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

In 1842, a [General Strike](#) involving cotton workers and colliers and organized through the [Chartist](#) movement stopped production across Great Britain.^[24]

Other effects



World [GDP](#)/capita changed very little for most of human history before the industrial revolution. (The empty areas mean no data, not very low levels. There are data for the years 1, 1000, 1500, 1600, 1700, 1820, 1900, and 2003)



Roughly exponential increase in carbon dioxide emissions from fossil fuels, driven by increasing energy demands since the Industrial Revolution (See [global warming](#))

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.^[25] Besides, there was a significant increase in worker wages during the period 1813-1913.^{[26][27][28]}

Intellectual paradigms and criticism

Capitalism

Main article: [Capitalism](#)

The advent of [The 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 is that industrialisation have increased wealth for all, as evidenced by raising life expectancy, reduced working hours, and no work for children and the elderly.

Marxism

Main article: [Marxism](#)

Marxism is essentially a reaction to the Industrial Revolution.^[29] 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](#).

Romantic Movement

Main article: [Romanticism](#)

Concurrent with the Industrial Revolution there developed an intellectual and artistic hostility towards the new industrialisation 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](#), [Byron](#) and [Percy Bysshe Shelley](#). The movement stressed the importance of "nature" in art and language, in contrast to the 'monstrous' machines and factories. In Blake's words they were the, "*Dark satanic mills*" of his poem *And did those feet in ancient time*. [Mary Shelley](#)'s short story *Frankenstein* reflected a concern about the possibly two-edged nature of scientific progress.

Second Industrial Revolution

Main article: [Second Industrial Revolution](#)

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 characterize a "Second Industrial Revolution", beginning around 1850. This second Industrial Revolution gradually grew to include the [chemical industries](#), [petroleum](#) refining and distribution, [electrical industries](#), and, in the twentieth 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.

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](#).

Notes and References

1. [^] Business and Economics. *Leading Issues in Economic Development*, Oxford University Press US. [ISBN 0-19-511589-9](#) [Read it](#)
2. [^] Eric Hobsbawm, *The Age of Revolution: Europe 1789–1848*, Weidenfeld & Nicolson Ltd. [ISBN 0-349-10484-0](#)
3. [^] Joseph E Inikori. *Africans and the Industrial Revolution in England*, Cambridge University Press. [ISBN 0-521-01079-9](#) [Read it](#)
4. [^] Russell Brown, Lester. *Eco-Economy*, James & James / Earthscan. [ISBN 1-85383-904-3](#) [Read it](#)
5. [^] Federal Reserve Bank of Minneapolis [\[1\]](#) Accessed 13 November 2006.

6. [^ Rehabilitating the Industrial Revolution](#) Maxine Berg, Pat Hudson, *Economic History Review*, New Series, Vol. 45, No. 1 (Feb., 1992), pp. 24-50 doi:10.2307/2598327
7. [^ Rehabilitating the Industrial Revolution](#) by Julie Lorenzen , Central Michigan University. Accessed November 2006
8. [^](#) Hudson, Pat. *The Industrial Revolution*, Oxford University Press US. [ISBN 0-7131-6531-6](#) [Read it](#)
9. [^](#) Deane, Phyliss. *The First Industrial Revolution*, Cambridge University Press. [ISBN 0-521-29609-9](#) [Read it](#)
10. [^](#) Eric Schiff, *Industrialization without national patents: the Netherlands, 1869-1912; Switzerland, 1850-1907*, Princeton University Press, 1971.
11. [^ Why No Industrial Revolution in Ancient Greece?](#) J. Bradford DeLong, Professor of Economics, University of California at Berkeley , September 20, 2002. Accessed January 2007.
12. [^ The Origins of the Industrial Revolution in England](#) | The History Guide, Steven Kreis, October 11, 2006 - Accessed January 2007
13. [^](#) Immanuel Chung-Yueh Hsu. *The Rise of Modern China*, Oxford University Press US. [ISBN 0-19-512504-5](#) [Read it](#)
14. [^ Cobb-Douglas in pre-modern Europe1 - Simulating early modern growthPDF](#) (254 [KiB](#)) Jan Luiten van Zanden, International Institute of Social History/University of Utrecht. May 2005. Accessed January 2007
15. [^](#) Landes, David (1999) *Wealth And Poverty Of Nations* pub WW Norton, [ISBN 0393318885](#)
16. [^ South Asian History](#) -Pages from the history of the Indian subcontinent: British rule and the legacy of colonization. Rajni-Palme Dutt *India Today* (Indian Edition published 1947); Accessed January 2007
17. [^ http://www.digitalhistory.uh.edu/historyonline/con_economic.cfm](#) Was slavery the engine of economic growth? Digital History
18. [^](#) The Royal Navy itself may have contributed to Britain's industrial growth. Among the first complex industrial manufacturing processes to arise in Britain were those that produced material for British warships. For instance, the average warship of the period used roughly 1000 pulley fittings. With a fleet as large as the Royal Navy, and with these fittings needing to be replaced ever 4 to 5 years, this created a great demand which encouraged industrial expansion. The industrial manufacture of rope can also be see as a similar factor.
19. [^ Barrington Moore, Jr.](#), *Social Origins of Dictatorship and Democracy: Lord and Peasant in the Making of the Modern World*, pp. 29-30, Boston, Beacon Press, 1966.

20. [^] [The Lunar Society](#) at Moreabout, the website of the *Birmingham Jewellery Quarter* guide, Bob Miles.
21. [^] Clow, Archibald and Clow, Nan L. (1952). *Chemical Revolution*, (Ayer Co Pub, June 1952), pp. 65-90. [ISBN 0-8369-1909-2](#).
22. [^] Encyclopædia Britannica (1998): *Samuel Slater*
23. [^] R.M. Hartwell, *The Industrial Revolution and Economic Growth*, Methuen and Co., 1971, page 339-341 [ISBN 0-416-19500-8](#)
24. [^] [General Strike 1842](#) From chartists.net, Accessed 13 November 2006.
25. [^] Mabel C. Buer, *Health, Wealth and Population in the Early Days of the Industrial Revolution*, London: George Routledge & Sons, 1926, page 30 [ISBN 0-415-38218-1](#)
26. [^] [ScienceDirect - Explorations in Economic History: Trends in Real Wages in Britain, 1750-1913](#) from www.sciencedirect.com, downloaded 17 July 2006.
27. [^] [Industrial Revolution and the Standard of Living](#) From www.econlib.org, downloaded 17 July 2006.
28. [^] R.M. Hartwell, *The Rising Standard of Living in England, 1800-1850*, *Economic History Review*, 1963, page 398 [ISBN 0-631-18071-0](#)
29. [^] [Karl Marx: Communist as Religious Eschatologist](#)

Bibliography

General

- [Ashton, Thomas S.](#), *The Industrial Revolution (1760-1830)*, Oxford University Press, 1948, [ISBN 0195002520](#) [online edition](#)
- Berlanstein; Lenard R. *The Industrial Revolution and work in nineteenth-century Europe* Routledge, 1992 [online edition](#)
- Bernal, John Desmond, *Science and Industry in the Nineteenth Century*, Bloomington: Indiana University Press, 1970.
- J. H. Clapham; *An Economic History of Modern Britain: The Early Railway Age, 1820-1850*. Cambridge University Press, 1926 [online edition](#)
- M. J. Daunton; *Progress and Poverty: An Economic and Social History of Britain, 1700-1850*, Oxford University Press, 1995 [online edition](#)
- Derry, Thomas Kingston and Trevor I. Williams, *A Short History of Technology: From the Earliest Times to A.D. 1900*, New York : Dover Publications, 1993.
- Hughes, Thomas Parke. *Development of Western Technology Since 1500* (1980)

- Kranzberg, Melvin and Carroll W. Pursell, Jr. eds. *Technology in Western civilization*, Oxford University Press, 1967.
- David S. Landes. *The Wealth and Poverty of Nations: Why Some Are So Rich and Some So Poor* (1999)
- Lines, Clifford, *Companion to the Industrial Revolution*, London, New York etc., Facts on File, 1990, [ISBN 0-8160-2157-0](#)
- Mokyr; Joel. *The British Industrial Revolution: An Economic Perspective* (1999) [online edition](#)
- More; Charles. *Understanding the Industrial Revolution* (2000) [online edition](#)
- Sidney Pollard; *Peaceful Conquest: The Industrialization of Europe, 1760-1970* Oxford University Press, 1981 [online edition](#)
- Usher; Abbott Payson. *An Introduction to the Industrial History of England* (1920) [online edition](#)

Social and Political Impact

- Graeme Gill; "Farm to Factory: A Reinterpretation of the Soviet Industrial Revolution, " *Economic Record*, Vol. 80, 2004 [online edition](#)
- [Hayek, Friedrich A.](#), *Capitalism and the Historians*, The University of Chicago Press, 1963, [ISBN 0-226-32072-3](#)
- [Hobsbawm, Eric J.](#), *Industry and Empire: From 1750 to the Present Day*, W. W. Norton, 1999.
- Smelser; Neil J. *Social Change in the Industrial Revolution: An Application of Theory to the British Cotton Industry* University of Chicago Press, 1959 [online edition](#)
- Stearns; Peter N. *The Industrial Revolution in World History* Westview Press, 1998 [online version](#)
- Thompson, E. P., *The Making of the English Working Class*, London: Penguin Books, 1980.

Causes

- [Landes, David S.](#), *The Unbound Prometheus: Technical Change and Industrial Development in Western Europe from 1750 to the Present* 2nd ed. New York: Cambridge University Press, 2003
- Paul Mantoux, *The Industrial Revolution in the Eighteenth Century*, First English translation 1928, revised edition 1961 [online edition](#)
- Dunham; Arthur Louis. *The Industrial Revolution in France, 1815-1848* Exposition Press, 1955 [online edition](#)

Local Studies

- Constance McLaughlin Green, *Holyoke, Massachusetts: A Case History of the Industrial Revolution in America* Yale University Press, 1939 [online edition](#)
- Herbert Kisch, *From Domestic Manufacture to Industrial Revolution The Case of the Rhineland Textile Districts*. Oxford US, 1989 [online edition](#)
- B. Trinder, *The Industrial Revolution in Shropshire* (3rd edn, 2000).

Coal, Metallurgy

- R. F. Tylecote, *A history of metallurgy* (2nd edn, 1992).
- P. W. King, 'Sir Clement Clerke and the Adoption of Coal in Metallurgy' *Transactions of Newcomen Society* 73, 33-53.
- P. W. King, 'The production and consumption of iron in early modern England and Wales' *Economic History Review* LVIII (2005), 1-33.
- R. A. Mott, *Henry Cort: the Great Finer* (1983), [ISBN 0-904357-55-4](#)
- A. Birch, *The economic history of the British iron and steel industry 1784 to 1879* (Cass, London 1967)).
- C. K. Hyde, *Technological change and the British iron industry 1700-1870* (Princeton University Press, Princeton NJ 1977).

Machine tools

- Norman Atkinson, *Sir Joseph Whitworth*, 1996, [Sutton Publishing Limited](#) 1996 [ISBN 0-7509-1211-1](#) (hc), [ISBN 0-7509-1648-6](#) (pb)
- John Cantrell and Gillian Cookson, eds., *Henry Maudslay and the Pioneers of the Machine Age*, 2002, Tempus Publishing, Ltd, pb., ([ISBN 0-7524-2766-0](#))
- Rev. Dr. Richard L. Hills, *Life and Inventions of Richard Roberts, 1789-1864*, Landmark Publishing Ltd, 2002, ([ISBN 1-84306-027-2](#))
- Joseph Wickham Roe, *English and American Tool Builders*, Yale University Press, 1916. Rep. Lindsay Publications Inc., Bradley IL., 1987, ([ISBN 0-917914-74-0](#)), (cloth), ([ISBN 0-917914-73-2](#)), paper

Steam power

- Ivor Blashka Hart. *James Watt and the History of Steam Power* (1949)
- Rev. Dr. [Richard L. Hills](#), *James Watt* 3 vol *Vol. 1, His time in Scotland, 1736-1774*; ([ISBN 1-84306-045-0](#)); *Vol. 2, The Years of Toil, 1775-1784*, ([ISBN 1-84306-046-9](#)); *Vol. 3, Triumph through*

Adversity , 1784-1719, Landmark Publishing Ltd, ([ISBN 1-84306-193-7](#))

- [L. T. C. Rolt](#) and J. S. Allen, *The Steam Engine of Thomas Newcomen*, Landmark Publishing Ltd, (1997), ([ISBN 1-901522-44-X](#))
- Vaclav Smil; *Energy in World History*. Westview Press, 1994 [online edition](#)

Transportation

- Pawson, E., *Transport and Economy: the turnpike roads of 18th century England*, 1977.
- Szostak; Rick. *The Role of Transportation in the Industrial Revolution: A Comparison of England and France* McGill-Queens University Press, 1991 [online edition](#)

External links

- [Industrial Revolution](#) at the [Open Directory Project](#) ([suggest site](#))
- [Internet Modern History Sourcebook: Industrial Revolution](#)
- ["The Day the World Took Off" Six part video series from the University of Cambridge tracing the question "Why did the Industrial Revolution begin when and where it did."](#)
- [BBC History Home Page: Industrial Revolution](#)
- [National Museum of Science and Industry website: machines and personalities](#)
- *Industrial Revolution and the Standard of Living* by Clark Nardinelli - the debate over whether standards of living rose or fell
- [An Overview of The Industrial Revolution: Industrial Revolution](#)
- [Factory Workers in the Industrial Revolution](#)
- [Revolutionary Players website](#)

References

1. [^] Business and Economics. *Leading Issues in Economic Development'*, Oxford University Press US. [ISBN 0-19-511589-9](#) [Read it](#)
2. [^] Eric Hobsbawm, *The Age of Revolution: Europe 1789–1848*, Weidenfeld & Nicolson Ltd. [ISBN 0-349-10484-0](#)
3. [^] Joseph E Inikori. *Africans and the Industrial Revolution in England*, Cambridge University Press. [ISBN 0-521-01079-9](#) [Read it](#)
4. [^] Russell Brown, Lester. *Eco-Economy*, James & James / Earthscan. [ISBN 1-85383-904-3](#) [Read it](#)

5. [^ Federal Reserve Bank of Minneapolis \[2\]](#) Accessed 13 November 2006.
6. [^ Rehabilitating the Industrial Revolution](#) Maxine Berg, Pat Hudson, *Economic History Review*, New Series, Vol. 45, No. 1 (Feb., 1992), pp. 24-50 doi:10.2307/2598327
7. [^ Rehabilitating the Industrial Revolution](#) by Julie Lorenzen , Central Michigan University. Accessed November 2006
8. [^ Hudson, Pat. *The Industrial Revolution*, Oxford University Press US. \[ISBN 0-7131-6531-6\]\(#\) \[Read it\]\(#\)](#)
9. [^ Deane, Phyliss. *The First Industrial Revolution*, Cambridge University Press. \[ISBN 0-521-29609-9\]\(#\) \[Read it\]\(#\)](#)
10. [^ Eric Schiff, *Industrialization without national patents: the Netherlands, 1869-1912; Switzerland, 1850-1907*, Princeton University Press, 1971.](#)
11. [^ Why No Industrial Revolution in Ancient Greece?](#) J. Bradford DeLong, Professor of Economics, University of California at Berkeley , September 20, 2002. Accessed January 2007.
12. [^ The Origins of the Industrial Revolution in England](#) | The History Guide, Steven Kreis, October 11, 2006 - Accessed January 2007
13. [^ Immanuel Chung-Yueh Hsu. *The Rise of Modern China*, Oxford University Press US. \[ISBN 0-19-512504-5\]\(#\) \[Read it\]\(#\)](#)
14. [^ Cobb-Douglas in pre-modern Europe1 - Simulating early modern growth](#)[PDF](#) (254 [KiB](#)) Jan Luiten van Zanden, International Institute of Social History/University of Utrecht. May 2005. Accessed January 2007
15. [^ Landes, David \(1999\) *Wealth And Poverty Of Nations* pub WW Norton, \[ISBN 0393318885\]\(#\)](#)
16. [^ South Asian History](#) -Pages from the history of the Indian subcontinent: British rule and the legacy of colonization. Rajni-Palme Dutt *India Today* (Indian Edition published 1947); Accessed January 2007
17. [^ \[http://www.digitalhistory.uh.edu/historyonline/con_economic.cfm\]\(http://www.digitalhistory.uh.edu/historyonline/con_economic.cfm\)](#) Was slavery the engine of economic growth? Digital History
18. [^](#) The Royal Navy itself may have contributed to Britain's industrial growth. Among the first complex industrial manufacturing processes to arise in Britain were those that produced material for British warships. For instance, the average warship of the period used roughly 1000 pulley fittings. With a fleet as large as the Royal Navy, and with these fittings needing to be replaced ever 4 to 5 years, this created a great demand which encouraged industrial expansion. The industrial manufacture of rope can also be see as a similar factor.

19. [^] [Barrington Moore, Jr.](#), *Social Origins of Dictatorship and Democracy: Lord and Peasant in the Making of the Modern World*, pp. 29-30, Boston, Beacon Press, 1966.
20. [^] [The Lunar Society](#) at Moreabout, the website of the *Birmingham Jewellery Quarter* guide, Bob Miles.
21. [^] Clow, Archibald and Clow, Nan L. (1952). *Chemical Revolution*, (Ayer Co Pub, June 1952), pp. 65-90. [ISBN 0-8369-1909-2](#).
22. [^] Encyclopædia Britannica (1998): *Samuel Slater*
23. [^] R.M. Hartwell, *The Industrial Revolution and Economic Growth*, Methuen and Co., 1971, page 339-341 [ISBN 0-416-19500-8](#)
24. [^] [General Strike 1842](#) From chartists.net, Accessed 13 November 2006.
25. [^] Mabel C. Buer, *Health, Wealth and Population in the Early Days of the Industrial Revolution*, London: George Routledge & Sons, 1926, page 30 [ISBN 0-415-38218-1](#)
26. [^] [ScienceDirect - Explorations in Economic History: Trends in Real Wages in Britain, 1750-1913](#) from [www.sciencedirect.com](#), downloaded 17 July 2006.
27. [^] [Industrial Revolution and the Standard of Living](#) From [www.econlib.org](#), downloaded 17 July 2006.
28. [^] R.M. Hartwell, *The Rising Standard of Living in England, 1800-1850*, *Economic History Review*, 1963, page 398 [ISBN 0-631-18071-0](#)
29. [^] [Karl Marx: Communist as Religious Eschatologist](#)

Edit	The Industrial Revolution
Themes	Coal , Coal mining , Coke , Cotton , Industry , Invention , Iron , Machinery , Manufacturing , Metallurgy , Sociology , Steam power , Steel , Technology , Textiles , Water power , Workforce
People/ groups	Richard Arkwright , Thomas Boulsover , Matthew Boulton , James Brindley , Isambard Kingdom Brunel , Edmund Cartwright , Henry Cort , Thomas and George Cranege , Samuel Crompton , Abraham Darby I , Abraham Darby II , Abraham Darby III , Francis Egerton, 3rd Duke of Bridgewater , William Fairbairn , James Hargreaves , Thomas Highs , Eaton Hodgkinson , Benjamin Huntsman , Joseph Marie Jacquard , Thomas Johnson (dressing frame) , John Kay (flying shuttle) , John Kay (spinning frame) , Francis Cabot Lowell , Lunar Society , Thomas Newcomen ,

	Robert Owen , Richard Roberts , George Stephenson , Richard Trevithick , John Wyatt	Lewis Paul , Thomas Savery , Robert Stephenson , James Watt	William Radcliffe , John Smeaton , Thomas Telford , John Wilkinson
Places	Abbeydale Industrial Hamlet , Coalbrookdale , Ironbridge , Quarry Bank Mill , Stockton and Darlington Railway	Cromford , New Lanark	Bridgewater Canal , Derwent Valley Mills , Portsmouth Block Mills , Soho Foundry
Invention/ technology	Blast furnace , Dressing frame , Newcomen steam engine , Reverberatory furnace , Spinning jenny , Water frame , Watt steam engine	Canal , Factory , Power loom , Sheffield plate , Steam engine	Cotton mill , Crucible steel , Flying shuttle , Railway , Spinning frame , Stephenson's Rocket
Social impact	Bourgeoisie , operative Movement , Industrial unrest , Luddite	Child labour , Cottage industry , Proletariat	History of the Co-operative Movement , Factory Acts , Rochdale Pioneers
Reference	History of technology , Industrial archaeology , related topics , Timeline of invention , Timeline of steam power	History of the British canal system , List of United Kingdom-related topics , Timeline of clothing and textiles technology , Timeline of materials technology	