

The Industrial Revolution

The Industrial Revolution, which took place from the 18th to 19th centuries, was a period during which predominantly agrarian, rural societies in Europe and America became industrial and urban. Prior to the Industrial Revolution, which began in Britain in the late 1700s, manufacturing was often done in people's homes, using hand tools or basic machines. Industrialization marked a shift to powered, special-purpose machinery, factories and mass production. The iron and textile industries, along with the development of the steam engine, played central roles in the Industrial Revolution, which also saw improved systems of transportation, communication and banking. While industrialization brought about an increased volume and variety of manufactured goods and an improved standard of living for some, it also resulted in often grim employment and living conditions for the poor and working classes.

The Industrial Revolution was the transition to new manufacturing processes in the period from about 1760 to sometime between 1820 and 1840. This transition included going from hand production methods to machines, new chemical manufacturing and iron production processes, improved efficiency of water power, the increasing use of steam power, the development of machine tools and the rise of the factory system. Textiles were the dominant industry of the Industrial Revolution in terms of employment, value of output and capital invested; the textile industry was also the first to use modern production methods. The Industrial Revolution began in Great Britain and most of the important technological innovations were British.

BRITAIN: BIRTHPLACE OF THE INDUSTRIAL REVOLUTION

Before the advent of the Industrial Revolution, most people resided in small, rural communities where their daily existences revolved around farming. Life for the average person was difficult, as incomes were meager, and malnourishment and disease were common. People produced the bulk of their own food, clothing, furniture and tools. Most manufacturing was done in homes or small, rural shops, using hand tools or simple machines. As demand for British goods increased, merchants needed more cost-effective methods of production, which led to the rise of mechanization and the factory system.

Impact of Industrial Revolution (Technological, Social & Intellectual)

Textiles – Mechanized cotton spinning powered by steam or water greatly increased the output of a worker. The power loom increased the output of a worker by a factor of over 40. The cotton gin increased productivity of removing seed from cotton by a factor of 50. Large gains in productivity also occurred in spinning and weaving of wool and linen, but they were not as great as in cotton.

Steam power – The efficiency of steam engines increased so that they used between one-fifth and one-tenth as much fuel. The adaptation of stationary steam engines to rotary motion made them suitable for industrial uses. The high pressure engine had a high power to weight ratio, making it suitable for transportation. Steam power underwent a rapid expansion after 1800.

Iron making – The substitution of coke for charcoal greatly lowered the fuel cost for pig iron and wrought iron production. Using coke also allowed larger blast furnaces, resulting in economies of scale. The cast iron blowing cylinder was first used in 1760. It was later improved by making it double acting, which allowed higher furnace temperatures. The puddling process produced a structural grade iron at a lower cost than the finery forge. The rolling mill was fifteen times faster than hammering wrought iron. Hot blast (1828) greatly increased fuel efficiency in iron production in the following decades.

Metallurgy

A major change in the metal industries during the era of the Industrial Revolution was the replacement of wood and other bio-fuels with coal. For a given amount of heat, coal required much less labour to mine than cutting wood and converting it to charcoal, and coal was more abundant than wood.

Steam power

The development of the stationary steam engine was an important element of the Industrial Revolution; however, for most of the period of the Industrial Revolution, the majority of industrial power was supplied by water and wind. In Britain by 1800 an estimated 10,000 horsepower was being supplied by steam. By 1815 steam power had grown to 210,000 hp. Small power requirements continued to be provided by animal and human muscle until the late 19th century.

Machine tools

The Industrial Revolution created a demand for metal parts used in machinery. This led to the development of several machine tools for cutting metal parts. 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.

Chemicals

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.

Cement

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.

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 and 1820. They soon became one of the major consumers of coal in the UK. Gas lighting had an 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 streets could be lighted on a larger scale than before.

Glass making

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 financiers, brothers Sealy and Henry Fourdrinier, who were stationers in London. Although greatly improved and with many variations, the Fourdrinier machine is the predominant means of paper production today.

The method of continuous production demonstrated by the paper machine influenced the development of continuous rolling of iron and later steel and other continuous production processes.

Agriculture

The British Agricultural Revolution is considered one of the causes of the Industrial Revolution because improved agricultural productivity freed up workers to work in other sectors of the economy. Industrial technologies that affected farming included the seed drill, the Dutch plough, which contained iron parts, and the threshing machine.

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 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).

Transportation

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. Wagon ways were used for conveying coal to rivers for further shipment, but canals had not yet been widely constructed. Animals supplied all of the motive power on land, with sails providing the motive power on the sea. The first horse railways were introduced toward the end of the 18th century, with steam locomotives being introduced in the early decades of the 19th century.

Factory system

Prior to the Industrial Revolution most of the workforce was employed in agriculture, either as self-employed farmers as land owners or tenants, or as landless agricultural laborers. By the time of the Industrial Revolution the putting-out system whereby farmers and townspeople produced goods in their homes, often described as *cottage industry*. Typical putting out system goods included spinning and weaving. Merchant capitalist provided the raw materials, typically paid workers by the piece, and were responsible for the sale of the goods. Embezzlement of supplies by workers and poor quality were common problems. The logistical effort in procuring and distributing raw materials and picking up finished goods were also limitations of the putting out system.

Standards of living

The effects on living conditions the industrial revolution have been very controversial, and were hotly debated by economic and social historians from the 1950s to the 1980s. 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. During 1813–1913, there was a significant increase in worker wages.

Food and nutrition

Chronic hunger and malnutrition were the norm for the majority of the population of the world including Britain and France, until the late 19th century. Until about 1750, in large part due to malnutrition, life expectancy in France was about 35 years, and only slightly higher in Britain. The US population of the time was adequately fed, much taller on average and had life expectancy of 45–50 years.

Housing

In *The Condition of the Working Class in England* in 1844 Friedrich Engels described backstreet sections of Manchester and other mill towns, where people lived in crude shanties and shacks, some not completely enclosed, some with dirt floors. These shantytowns had narrow walkways between irregularly shaped lots and dwellings. There were no sanitary facilities. Population density was extremely high. Eight to ten unrelated mill workers often shared a room, often with no furniture, and slept on a pile of straw or sawdust. Toilet facilities were shared if they existed. Disease spread through a contaminated water supply. Also, people were at risk of developing pathologies due to persistent dampness.

Clothing and consumer goods

Consumers benefited from falling prices for clothing and household articles such as cast iron cooking utensils, and in the following decades, stoves for cooking and space heating.

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 1850 and, by 1901, had nearly doubled again to 30.5 million. Improved conditions led to the population of Britain increasing from 10 million to 40 million in the 1800s. Europe's population increased from about 100 million in 1700 to 400 million by 1900.

Social structure and working conditions

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. As late as the year 1900, most industrial workers in the United States still worked a 10-hour day (12 hours in the steel industry), yet earned from 20% to 40% less than the minimum deemed necessary for a decent life. 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

Industrialisation led to the creation of the factory. Arguably the first highly mechanised was John Lombe's water-powered silk mill at Derby, operational by 1721. Lombe learned silk thread manufacturing by taking a job in Italy and acting as an industrial spy; however, since the silk industry there was a closely guarded secret, the state of the industry there is unknown. Because Lombe's factory was not successful and there was no follow through, the rise of the modern factory dates to somewhat later when cotton spinning was mechanised.

Child labour

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.^{[84][85]} 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.

Luddites

The rapid industrialisation of the English economy cost many craft workers their jobs. The movement started first with lace and hosieryworkers 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.

Organisation of labour

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.

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 Scottish economist 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, associated with 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.