Manchester, the First Industrial City
The first cotton mills, built on the banks of the River Irwell in northern England, transformed Manchester from a country town into a booming industrial city. The use of chemicals to bleach and dye the cloth and the introduction of steam engines in the early nineteenth century to power the spinning and weaving machines made Manchester, for a time, the most polluted city on earth. (The Royal Collection ©2006 Her Majesty Queen Elizabeth II)

- What caused the Industrial Revolution?
- What were the key innovations that increased productivity and drove industrialization?
- What was the impact of these changes on the society and environment of the industrializing countries?
- How did the Industrial Revolution influence the rise of new economic and political ideas?
- How did the Industrial Revolution affect the relations between the industrialized and the nonindustrialized parts of the world?
Manchester was just a small town in northern England in the early eighteenth century. A hundred years later, it had turned into the fastest-growing city in history. To contemporaries who visited the city, it was both a marvel and a horror. In the inner city, cotton mills and other factories were interspersed with workers' housing, built as cheaply as possible. Here is how the economist Nassau Senior described these workers' quarters:

But when I went through their habitations . . . my only wonder was that tolerable health could be maintained by the inmates of such houses. These towns . . . have been erected by small speculators with an utter disregard to everything except immediate profit . . . In one place we saw a whole street following the course of a ditch, in order to have deeper cellars (cellars for people, not for lumber) without the expense of excavation. Not a house in this street escaped cholera. And, generally speaking . . . the streets are unpaved, with a dunghill or a pond in
the middle; the houses built back to back, without ventilation or drainage, and whole families occupy each a corner of a cellar or of a garret.  

Not everyone deplored the living conditions in the new industrial city. Friedrich Engels, one of the foremost critics of industrial capitalism, recounts a meeting with a well-to-do citizen:

One day I walked with one of these middle-class gentlemen into Manchester. I spoke to him about the disgraceful unhealthy slums and drew his attention to the disgusting condition of that part of the town in which the factory workers lived. I declared that I had never seen so badly built a town in my life. He listened patiently and at the corner of the street at which we parted company, he remarked: "And yet there is a great deal of money made here. Good morning, Sir."

Manchester's rise as a large, industrial city was a result of what historians call the Industrial Revolution, the most profound and wrenching transformation in human life since the development of agriculture 10,000 years earlier. The Industrial Revolution made it possible for increasing numbers of people (including those in Manchester) to lead longer, healthier, richer, and more productive lives than could have been possible before.

This revolution involved dramatic innovations in manufacturing, mining, transportation, and communications and equally rapid changes in society and commerce. New relationships between social groups created an environment that was conducive to technical innovation and economic growth. New technologies and new social and economic arrangements allowed the industrializing countries—first Britain, then western Europe and the United States—to unleash massive increases in production and productivity, exploit the world's natural resources as never before, and transform the environment and human life in unprecedented ways.

The distribution of power and wealth generated by the Industrial Revolution was very uneven, for industrialization widened the gap between rich and poor. The people who owned and controlled the innovations amassed wealth and power over nature and over other people. While some of them lived lives of spectacular luxury, workers, including children, worked long hours in dangerous factories and lived crowded together in unsanitary tenements.

The effect of the Industrial Revolution around the world was also very uneven. The first countries to industrialize grew rich and powerful. In Egypt and India, the economic and military power of the European countries stifled the tentative beginnings of industrialization. Regions that had little or no industry were easily taken advantage of. The disparity between the industrial and the developing countries that exists today has its origins in the early nineteenth century.

**CAUSES OF THE INDUSTRIAL REVOLUTION**

What caused the Industrial Revolution, and why did it begin in England in the late eighteenth century? These are two of the great questions of history. The basic preconditions of this momentous event seem to have been economic development propelled by population growth, an agricultural revolution, the expansion of trade, and an openness to innovation.

**Population Growth**

The population of Europe rose in the eighteenth century—slowly at first, faster after 1780, then even faster in the early nineteenth century. The fastest growth took place in England and Wales. Population there rose from 5.5 million in 1688 to 9 million in 1801 and 18 million by 1851—increases never before experienced in European history.

The growth of population resulted from more widespread resistance to disease and more reliable food supplies, thanks to the new crops that originated in the Americas (see Chapter 17). More dependable food supplies and better job opportunities led people to marry at earlier ages and have more children. A high birthrate meant a large percentage of children in the general population. In the early nineteenth century some 40 percent of the population of Britain was under fifteen years of age. This high proportion of youths explains both the vitality of the British people in that period and the widespread use of child labor. People also migrated at an unprecedented rate—from the countryside to the cities, from Ireland to England, and, more
generally, from Europe to the Americas. Thanks to immigration, the population of the United States rose from 4 million in 1791 to 9.6 million in 1820 and 31.5 million in 1860—faster growth than in any other part of the world at the time.

The Agricultural Revolution

Innovations in manufacturing could only have taken place alongside a simultaneous revolution in farming that provided food for city dwellers and forced poorer peasants off the land. This agricultural revolution had begun long before the eighteenth century. One important aspect was the acceptance of the potato, introduced from South America in the sixteenth century. In the cool and humid regions of Europe from Ireland to Russia, potatoes yielded two or three times more food per acre than did the wheat, rye, and oats they replaced. Maize (American corn) was grown across Europe from northern Iberia to the Balkans. Turnips, legumes, and clover did not deplete the soil and could be fed to cattle, which were sources of milk and meat. Manure from cattle in turn fertilized the soil for other crops.

The security of small-scale tenant farmers and sharecroppers depended on traditional methods and rural customs such as collecting plants left over in the fields after the harvest, pasturing their animals on common village lands, and gathering firewood in common woods. Only prosperous landowners with secure titles to their land could afford to bear the risk of trying new methods and new crops. Rich landowners therefore “enclosed” the land—that is, consolidated their holdings—and got Parliament to give them title to the commons that in the past had been open to all. Once in control of the land, they could drain and improve the soil, breed better livestock, and introduce crop rotation. This “enclosure movement”

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<tr>
<th>Year</th>
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<tbody>
<tr>
<td>1702-1712</td>
<td>Thomas Newcomen builds first steam engine</td>
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<tr>
<td>1759</td>
<td>Josiah Wedgwood opens pottery factory</td>
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<tr>
<td>1764</td>
<td>Spinning jenny</td>
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<td>1769</td>
<td>Richard Arkwright’s water frame; James Watt patents steam engine</td>
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<tr>
<td>1779</td>
<td>First iron bridge</td>
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<td>1780</td>
<td>Boulton and Watt sell steam engines; Samuel Crompton’s mule</td>
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<tr>
<td>1793</td>
<td>Eli Whitney’s cotton gin</td>
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<tr>
<td>1800</td>
<td>Alessandro Volta’s battery</td>
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<td>1807</td>
<td>Robert Fulton’s North River</td>
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<td>1820s</td>
<td>Construction of Erie Canal</td>
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<td>1829</td>
<td>Rocket, first prize-winning locomotive</td>
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<td>1837</td>
<td>Wheatstone and Cooke’s telegraph</td>
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<td>1838</td>
<td>First ships steam across the Atlantic</td>
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<td>1840</td>
<td>Nemesis sails to China</td>
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<td>1843</td>
<td>Samuel Morse’s Baltimore-to-Washington telegraph</td>
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<td>1851</td>
<td>Crystal Palace opens in London</td>
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<th>Year</th>
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<tr>
<td>1776</td>
<td>Adam Smith’s Wealth of Nations</td>
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<td>1776-1783</td>
<td>American Revolution</td>
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<td>1789-1799</td>
<td>French Revolution</td>
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<td>1792</td>
<td>Mary Wollstonecraft’s A Vindication of the Rights of Woman</td>
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<td>1804-1815</td>
<td>Napoleonic Wars</td>
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<td>1820s</td>
<td>U.S. cotton industry begins</td>
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<td>1833</td>
<td>Factory Act in Britain</td>
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<td>1834</td>
<td>German Zollverein; Robert Owen’s Grand National Consolidated Trade Union</td>
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<td>1846</td>
<td>Repeal of British Corn Laws</td>
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<td>1847-1848</td>
<td>Irish famine</td>
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<tr>
<td>1848</td>
<td>Collapse of Chartist movement; revolutions in Europe</td>
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<tr>
<td>1854</td>
<td>First cotton mill in India</td>
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turned tenants and sharecroppers into landless farm laborers. Many moved to the cities to seek work; others became homeless migrants and vagrants; and still others emigrated to Canada, Australia, and the United States.

In eastern Europe, as in Britain, large estates predominated, and aristocratic landowners used such improvements to increase their wealth and political influence. In western Europe enclosure was hampered by the fact that the law gave secure property rights to numerous small farmers.

Trade and Inventiveness

In most of Europe the increasing demand that accompanied the growth of population was met by increasing production in traditional ways. Roads were improved so stagecoaches could travel faster. Royal manufacturers trained additional craftsmen to produce fine china, silks, and carpets by hand. In rural areas much production was carried out through cottage industries. Merchants delivered fibers, leather, and other raw materials to craftspeople (often farmers in the off-season) and picked up the finished products. The growth of the population and food supply was accompanied by the growth of trade. Most of it was local trade in traditional goods and services, but a growing share came from far away.

In the course of the eighteenth century, Europeans developed a craving for sweet foods. Sugar from Caribbean slave plantations became the most profitable item in international trade. Even people of modest means began drinking tea, coffee, and cocoa at home and eating pastries and candies. These habits in turn stimulated the demand for porcelain cups and other dinnerware. More and more people also wore clothes of silk or cotton imported from Asia.

Stimulated by the demands of an emerging consumer society, scientific discoveries, commercial enterprise, and technical skills became closely connected. Technology and innovation fascinated educated people throughout Europe and eastern North America. The French Encyclopédie contained thousands of articles and illustrations of crafts and manufacturing (see Diversity and Dominance: Adam Smith and the Division of Labor). The French and British governments sent expeditions around the world to collect plants that could profitably be grown in their colonies. They also offered prizes to anyone who could find a method of determining the longitude of a ship at sea to avoid the shipwrecks that had cost the lives of thousands of sailors. The American Benjamin Franklin, like many others, experimented with electricity. In France, the Montgolfier brothers invented a hot-air balloon. Claude Chappe created the first semaphore telegraph. French artillery officers proposed making guns with interchangeable parts. The American Eli Whitney and his associate John Hall invented machine tools, that is, machines capable of making other machines. These machines greatly increased the productivity of manufacturing.

**Britain and Continental Europe**

Economic growth was evident throughout the North Atlantic area, yet industrialization did not take place everywhere at once. To understand why, we must look at the peculiar role of Great Britain. Britain enjoyed a rising standard of living during the eighteenth century, thanks to good harvests, a growing population, and a booming overseas trade. Britain was the world’s leading exporter of tools, guns, hardware, clocks, and other craft goods (see Map 22.1). Its mining and metal industries employed engineers willing to experiment with new ideas. It had the largest merchant marine and produced more ships, naval supplies, and navigation instruments than other countries.

Until the mid-eighteenth century the British were better known for their cheap imitations than for their innovations or quality products. But they put inventions into practice more quickly than other people, as the engineer John F. C. Young, a parliamentary committee in 1829: “The prevailing talent of English and Scotch people is to apply new ideas to use and to bring such applications to perfection, but they do not imagine as much as foreigners.”

Before 1789 Britain also had a more fluid society than did the rest of Europe. The English royal court was less ostentatious, its aristocracy was less powerful, and the lines separating the social classes were not as sharply drawn as in Europe. Political power was not as centralized as on the European continent, and the government employed fewer bureaucrats and officials. Members of the gentry, and even some aristocrats, married into merchant families. Intermarriage among the families of petty merchants, yeoman farmers, and town craftsmen was common. Guilds, which resisted innovation, were relatively weak. Ancestry remained important, but wealth also commanded respect. A businessman with enough money could buy a landed estate, a seat in Parliament, and the social status that accompanied them.

At a time when transportation by land was very costly, Great Britain had good water transportation thanks to its

Chappe (SHAPP)
In the eighteenth century, the economies of continental Europe also underwent a dynamic expansion, thanks to the efforts of individual entrepreneurs and investors. Yet growth was still hampered by high transportation costs, misguided government regulations, and rigid social structures. The Low Countries were laced with canals, but the terrain elsewhere in Europe made canal building costly and difficult. The ruling monarchies made some attempts to import British techniques and organize factory production, but they all foundered for lack of markets or management skills. From 1789 to 1815 Europe was scarred by revolutions and wars. Although war created opportunities for suppliers of weapons, uniforms, and horses produced by traditional methods, the interruption of trade between Britain and continental Europe slowed the diffusion of new techniques, and the insecurity of countries at war discouraged businessmen from investing in factories and machinery.

The political revolutions swept away the restrictions of the old regimes. After 1815 the economies of Western Europe were ready to begin industrializing. Industrialization took hold in Belgium and northern France, as businessmen visited Britain to observe the changes and spy out industrial secrets. In spite of British laws forbidding the emigration of skilled workers and the export of textile machinery, many workers slipped through. By the 1820s several thousand Britons were at work on the continent of Europe setting up machines, training workers in the new methods, and even starting their own businesses.

Acutely aware of Britain's head start and the need to stimulate their own industries, European governments took action. They created technical schools. They eliminated internal tariff barriers, tolls, and other hindrances to trade. They encouraged the formation of joint-stock companies and banks to channel private savings into industrial investments. On the European continent, as in Britain, cotton cloth was the first industry. The mills of France, Belgium, and the German states served local markets but could not compete abroad with the more advanced British industry. By 1830 the political climate in western Europe was as favorable to business as Britain's had been a half-century earlier.

Abundant coal and iron-ore deposits determined the concentration of industries in a swath of territories running from northern France through Belgium and the Ruhr district of western Germany to Silesia in Prussia (now part of Poland). By the 1850s France, Belgium, and the German states were in the midst of an industrial boom like that of Britain, based on iron, cotton, steam engines, and railroads.
Adam Smith and the Division of Labor

Adam Smith (1723–1790), a Scottish social philosopher, is famous for one book, An Inquiry into the Nature and Causes of the Wealth of Nations, which was first published in 1776 and has been reprinted many times and translated into many languages. It was the first work to explain the economy of a nation as a system. In it, Smith criticized the notion, common in the eighteenth century, that a nation's wealth was synonymous with the amount of gold and silver in the government's coffers. Instead, he defined wealth as the amount of goods and services produced by a nation's people. By this definition, labor and its products are an essential element in a nation's prosperity.

In the passage that follows, Smith discusses the increase in productivity (to use a modern term) that results from dividing a craft into separate tasks, each of which is performed over and over by one worker. He contrasts two methods of making pins. In one, a team of workers divided up the job of making pins and produced a great many every day; in the other, pin workers "wrought separately and independently" and produced very few pins per day. It is clear that the division of labor produces more pins per worker per day. But who benefits? Left unsaid is that a pin factory had to be owned and operated by a manufacturer who hired workers and assigned a task to each one. Thus did industrialization reduce the diversity of self-employed craftsmen by replacing them with a system of dominance.

The illustration shows a pin-maker's workshop in late-eighteenth-century France. Each worker is performing a specific task on a few pins at once, and all the energy comes from human muscles. These are the characteristics of a proto-industrial workshop.

To take an example, therefore, from a very trifling manufacture—but one in which the division of labour has been very often taken notice of—the trade of the pin-maker: a workman not educated to this business (which the division of labour has rendered a distinct trade), nor acquainted with the use of machinery employed in it (to the invention of which the same division of labour has probably given occasion), could scarce, perhaps, with his utmost industry, make one pin in a day, and certainly could not make twenty. But in the way in which this business is now carried on, not only the whole work is a peculiar trade, but it is divided into a number of branches, of which the greater part are likewise peculiar trades. One man draws out the wire, another straightens it, a third cuts it, a fourth points it, a fifth grinds it at the top for receiving the head; to make the head requires two or three distinct operations, to put it on, is a peculiar business, to whiten the pins is another; it is even a trade by itself to put them into the paper; and the important business of making a pin is, in this manner, divided into about eighteen distinct operations, which, in some manufactories, are all performed by distinct hands, though in others the same man will sometimes perform two or three of them. I have seen a small manufactury of this kind where ten men only were employed; and where some of them, consequently, performed two or three distinct operations. But though they were very poor, and therefore but indifferently accommodated with the necessary machinery, they could, when they exerted themselves, make among them about twelve pounds of pins in a day.
A Pin-Maker’s Workshop  The man in the middle (Fig. 2) is pulling wire off a spindle (G) and through a series of posts. This ensures that the wire will be perfectly straight. The worker seated on the lower right (Fig. 3) takes the long pieces of straightened wire and cuts them into shorter lengths. The man in the lower left-hand corner (Fig. 5) sharpens twelve to fifteen wires at a time by holding them against a grindstone turned by the worker in Fig. 6. The men in Figs. 4 and 7 put the finishing touches on the points. Other operations—such as forming the wire to the proper thickness, cleaning and coating it with tin, and attaching the heads—are depicted in other engravings in the same encyclopedia.  (Division of Rare and Manuscript Collections, Cornell University Library)

There are in a pound upwards of four thousand pins of a middling size. Those ten persons, therefore, could make among them upwards of forty-eight thousand pins in a day. Each person, therefore, making a tenth part of forty-eight thousand pins, might be considered as making four thousand eight hundred pins a day. But if they had all wrought separately and independently, and without any of them having been educated to this peculiar business, they certainly could not each of them have made twenty, perhaps not one pin in a day; that is, certainly, not the two hundred and fortieth, perhaps not the four thousand eight hundredth part of what they are at present capable of performing, in consequence of a proper division and combination of their different operations.

QUESTIONS FOR ANALYSIS

1. Why does dividing the job of pin-making into ten or more operations result in the production of more pins per worker? How much more productive are these workers than if each one made complete pins from start to finish?

2. How closely does the picture of a pin-maker’s workshop illustrate Smith’s verbal description?

3. What disadvantage would there be to working in a pin factory where the job was divided as in Smith’s example, compared to making entire pins from start to finish?

4. What other examples can you think of, from Adam Smith’s day or from more recent times, of the advantages of the division of labor?

THE TECHNOLOGICAL REVOLUTION

Five innovations spurred industrialization: (1) mass production through the division of labor, (2) new machines and mechanization, (3) a great increase in the manufacture of iron, (4) the steam engine and the changes it made possible in industry and transportation, and (5) the electric telegraph. China had achieved the first three of these during the Song dynasty (960–1279), but it had not developed the steam engine or electricity. The continued success of Western industrialization depended heavily on these new forms of energy.

Mass Production: Pottery

The pottery industry offers a good example of mass production, the making of many identical items by breaking the process into simple repetitive tasks. East Asian potters had long known how to make fine glazed porcelain, or “china,” but the high cost of transporting it to Europe before the mid-eighteenth century meant that only the wealthy could afford fine Chinese porcelain. Middle-class people used pewter tableware, and the poor ate from wooden or earthenware bowls. Several royal manufactures—Meissen* in Saxony, Delft in Holland, and Sévres* in France—produced exquisite handmade products for the courts and aristocracy, but their products were much too expensive for mass consumption. Meanwhile, more and more Europeans acquired a taste for Chinese tea as well as for cocoa and coffee, and they wanted porcelain that would not spoil the flavor of hot beverages. This demand created opportunities for inventive entrepreneurs.

Like other countries, Britain had many small pottery workshops where craftsmen made a few plates and cups at a time. Much of this activity took place in a part of the Midlands that possessed good clay, coal for firing, and lead for glazing. There Josiah Wedgwood, the son of a potter, started his own pottery business in 1759. He had a scientific bent and invented the pyrometer, a device to measure the extremely high temperatures that are found in kilns during the firing of pottery, for which he was elected a member of the Royal Society. Today the name Wedgwood is associated with expensive, highly decorated china. But Wedgwood’s most important contribution lay in producing ordinary porcelain cheaply by means of the division of labor (see Diversity and Dominance: Adam Smith and the Division of Labor).

Wedge wood subdivided the work into highly specialized and repetitive tasks, such as unloading the clay, mixing it, pressing flat pieces, dipping the pieces in glaze, putting handles on cups, packing kilns, and carrying things from one part of his plant to another. To prevent interruptions in production, he instituted strict discipline among his workers. He substituted the use of molds for the potter’s wheel wherever possible, a change that not only saved labor but also created identical plates and bowls that could be stacked. He invested in toll roads and canals so that special pottery clay found in southwestern England could be economically shipped to his factories in the Midlands.

*Meissen (my-zen)  Sévres (sey-ruh)
Wedgwood’s interest in applying technology to manufacturing was sparked by his membership in the Lunar Society, a group of businessmen, scientists, and craftsmen that met each month when the moon was full to discuss the practical application of knowledge. In 1782 the naturalist Erasmus Darwin encouraged him to purchase a steam engine from Boulton and Watt, the firm founded by two other members of the society. The engine that Wedgwood bought to mix clay and grind flint was one of the first to be installed in a factory.

These were radical departures from the age-old methods of craftsmanship. But the division of labor and new machinery allowed Wedgwood to lower the cost of his products while improving their quality, and to offer his wares for sale at lower prices. His factory grew far larger than his competitors’ factories and employed several hundred workers. His salesmen traveled throughout England touting his goods, and his products were sold on the European continent as well.

The cotton industry, the largest industry in this period, illustrates the role of mechanization, the use of machines to do work previously done by hand. Cotton cloth had long been the most common fabric in China, India, and the Middle East, where it was spun and woven by hand. The cotton plant did not grow in Europe, but the cloth was so much cooler, softer, and cleaner than wool that wealthy Europeans developed a liking for the costly import. When the powerful English woolen industry persuaded Parliament to forbid the import of cotton cloth into England, that prohibition stimulated attempts to import cotton fiber and make the cloth locally. Here was an opportunity for enterprising inventors to reduce costs with labor-saving machinery.

To turn inventions into successful businesses, inventors had to link up with entrepreneurs or become businessmen themselves. Making a working prototype often took years, even decades, and many inventions led to dead ends. History remembers those who were successful, but even they struggled against great odds.

Beginning in the 1760s a series of inventions revolutionized the spinning of cotton thread. The first was the spinning jenny, invented in 1764, which mechanically drew out the cotton fibers and twisted them into thread. The jenny was simple, cheap to build, and easy for one person to operate. Early models spun six or seven threads at once, later ones up to eighty. The thread, however, was soft and irregular and could be used only in combination with linen, a strong yarn derived from the flax plant.

In 1769 Richard Arkwright invented another spinning machine, the water frame, which produced thread strong enough to be used without linen. Arkwright was both a gifted inventor and a successful businessman. His machine was larger and more complex than the jenny and required a source of power such as a water wheel, hence the name “water frame.” To obtain the necessary energy he installed dozens of machines in a building next to a fast-flowing river. The resemblance to a flour mill gave such enterprises the name cotton mill.

In 1785 Samuel Crompton patented a machine that combined the best features of the jenny and the water frame. This device, called a mule, produced a strong thread that was thin enough to be used to make a better type of cotton cloth called muslin. The mule could make a finer, more even thread than could any human being, and at a lower cost. At last British industry could undersell high-quality handmade cotton cloth from India, and British cotton output increased tenfold between 1770 and 1790.

The boom in thread production and the soaring demand for cloth created bottlenecks in weaving, stimulating inventors to mechanize the rest of textile manufacturing. The first power loom was introduced in 1784 but was not perfected until after 1815. Other inventions of the period included carding machines, chlorine bleach, and cylindrical presses to print designs on fabric. By the 1830s large English textile mills powered by steam engines were performing all the steps necessary to turn raw cotton into printed cloth. This was a far cry from the cottage industries of the previous century.

Mechanization offered two advantages: (1) increased productivity for the manufacturer and (2) lower prices for the consumer. Whereas in India it took five hundred hours to spin a pound of cotton, the mule of 1790 could do so in three person-hours, and the self-acting mule—an improved version introduced in 1830—required only eighty minutes. Cotton mills needed very few skilled workers, and managers often hired children to tend the spinning machines. The same was true of power looms, which gradually replaced handloom weaving: the number of power looms rose from 2,400 in 1813 to 500,000 by 1850. Meanwhile, the price of cloth fell by 90 percent between 1782 and 1812 and kept on dropping.

The industrialization of Britain made cotton America’s most valuable crop. In the 1790s most of Britain’s cotton came from India, as the United States produced a mere 750 tons (729 metric tons), mostly from South Carolina. In 1793 the American Eli Whitney patented his cotton gin, a simple device that separated the bolls or seedpods from the fiber and made cotton growing economical. This invention permitted the spread of cotton farming into Georgia, then into Alabama, Mississippi,
and Louisiana, and finally as far west as Texas. By the late 1850s the southern states were producing a million tons of cotton a year, five-sixths of the world’s total.

With the help of British craftsmen who introduced jennies, mules, and power looms, Americans developed their own cotton industry in the 1820s. By 1840 the United States had twelve hundred cotton mills, two-thirds of them in New England, that served the booming domestic market.

**The Iron Industry**

Iron making also was transformed during the Industrial Revolution. Throughout Eurasia and Africa, iron had been in use for thousands of years for tools, swords and other weapons, and household items such as knives, pots, hinges, and locks. In the eleventh century, during the Song period, Chinese forges had produced cast iron in large quantities. Production declined after the Song, but iron continued to be common and inexpensive in China. Wherever iron was produced, however, deforestation eventually drove up the cost of charcoal (used for smelting) and restricted output. Furthermore, iron had to be repeatedly heated and hammered to drive out impurities, a difficult and costly process. Because of limited wood supplies and the high cost of skilled labor, iron was a rare and valuable metal outside China before the eighteenth century.

A first breakthrough occurred in 1709 when Abraham Darby discovered that coke (coal from which the impurities have been cooked out) could be used in place of charcoal. The resulting metal was of lower quality than charcoal-smelted iron but much cheaper to produce, for coal was plentiful. Just as importantly, in 1784 Henry Cort found a way to remove some of the impurities in coke-iron by puddling—stirring the molten iron with long rods. Cort’s process made it possible to turn high-sulfur English coal into coke to produce wrought iron (a soft and malleable form of iron) very cheaply. By 1790 four-fifths of Britain’s iron was made with coke, while other countries still used charcoal. Coke-iron was cheaper and less destructive of forests, and it allowed a great expansion in the size of individual blast furnaces, substantially reducing the cost of iron. There seemed almost no limit to the quantity of iron that could be produced with coke. Britain’s iron production began rising fast, from 17,000 tons in 1740 to 3 million tons in 1844, as much as in the rest of the world put together.

In turn, there seemed no limit to the amount of iron that an industrializing society would purchase or to the novel applications for this cheap and useful material. In 1779 the iron manufacturer Abraham Darby III (grandson of the first Abraham Darby) built a bridge of iron across the Severn River. In 1851 Londoners marveled at the Crystal Palace, a huge greenhouse made entirely of iron and glass and large enough to enclose the tallest trees.

The availability of cheap iron made the mass production of objects such as guns, hardware, and tools appealing. However, fitting together the parts of these products required a great deal of labor. To reduce labor costs, manufacturers turned to the idea of interchangeable parts. This idea originated in the eighteenth century when French army officers attempted, without success, to persuade gun makers to produce precisely identical parts. Craftsmen continued to use traditional methods to make gun parts that had to be fitted together by hand. By the mid-nineteenth century, however,
interchangeable-parts manufacturing had been adopted in the manufacture of firearms, farm equipment, and sewing machines. At the Crystal Palace exhibition of 1851, Europeans called it the "American system of manufactures." In the next hundred years the use of machinery to mass-produce consumer items was to become the hallmark of American industry.

The Steam Engine

In the history of the world, there had been a number of periods of great technological inventiveness and economic growth. But in all previous cases, the dynamism eventually faltered for various reasons, such as the Mongol invasions that overthrew the Song dynasty in China and the Abbasid Caliphate (750–1258) in the Middle East.

The Industrial Revolution that began in the eighteenth century, in contrast, has never slowed down but has instead only accelerated. One reason has been increased interactions between scientists, technicians, and businessmen. Another has been access to an inexhaustible source of cheap energy, namely fossil fuels.

The first machine to transform fossil fuel into mechanical energy was the steam engine, a substitute for human and animal power as well as for wind and water power. Although the mechanization of manufacturing was very important, the steam engine was what set the Industrial Revolution apart from all previous periods of growth and innovation.

Before the eighteenth century, many activities had been limited by the lack of energy. For example, deep mines filled with water faster than horses could pump it out. Scientists understood the concept of atmospheric pressure and had created experimental devices to turn heat into motion, but they had not found a way to put those devices to practical use. Then, between 1702 and 1712 Thomas Newcomen developed the first practical steam engine, a crude but effective device. One engine could pump water out of mines as fast as four horses, and it could run day and night without getting tired.

The Newcomen engine's voracious appetite for fuel mattered little in coal mines, where fuel was cheap, but it made the engine too costly for other uses. In 1764 James Watt, a maker of scientific instruments at Glasgow University in Scotland, was asked to repair the university's model Newcomen engine. Watt realized that the engine wasted fuel because the cylinder had to be alternately heated and cooled. He developed a separate condenser—a vessel into which the steam was allowed to escape after it had done its work, leaving the cylinder always hot and the condenser always cold. Watt patented his idea in 1769. He enlisted the help of the iron manufacturer Matthew Boulton to turn his invention into a commercial

Transatlantic Steamship Race
In 1838, two ships equipped with steam engines, the Sirius and the Great Western, steamed from England to New York. Although the Sirius left a few days earlier, the Great Western—shown here arriving in New York harbor—almost caught up with it, arriving just four hours after the Sirius. This race inaugurated regular transatlantic steamship service. (Courtesy of the Mariners' Museum, Newport News, VA)
product. Their first engines were sold to pump water out of copper and tin mines, where fuel was too costly for Newcomen engines. In 1781 Watt invented the sun-and-planet gear, which turned the back-and-forth action of the piston into rotary motion. This allowed steam engines to power machinery in flour and cotton mills, pottery manufactures, and other industries. Watt's steam engine was the most celebrated invention of the eighteenth century. Because there seemed almost no limit to the amount of coal in the ground, steam-generated energy appeared to be an inexhaustible source of power, and steam engines could be used where animal, wind, and water power were lacking.

Inspired by the success of Watt's engine, inventors in France in 1783, in the United States in 1787, and in England in 1788 put steam engines on boats. The need to travel great distances in the United States explains why the first commercially successful steamboat was Robert Fulton's North River, which steamed up and down the Hudson River between New York City and Albany, New York, in 1807.

Soon steamboats were launched on other American rivers, especially the Ohio and the Mississippi, gateways to the Midwest. In the 1820s the Erie Canal linked the Atlantic seaboard with the Great Lakes and opened Ohio, Indiana, and Illinois to European settlement. Steamboats proliferated west of the Appalachian Mountains; by 1830 some three hundred plied the Mississippi and its tributaries. To counter the competition from New York State, Pennsylvania built a thousand miles of canals by 1840. The United States was fast becoming a nation that moved by water.

Ongoing steam-powered ships were much more difficult to build than river boats, for the first steam engines used so much coal that no ship could carry more than a few days' supply. The Savannah, which crossed the Atlantic in 1819, was a sailing ship with an auxiliary steam engine that was used for only ninety hours of its twenty-nine-day trip. Engineers soon developed more efficient engines, and in 1838 two steamers, the Great Western and the Sirius, crossed the Atlantic on steam power alone. Elsewhere, sailing ships held their own until late in the century. World trade was growing so fast that there was enough business for ships of every kind.

**Railroads**

On land as on water, the problem was not imagining uses for steam-powered vehicles but building ones that worked, for steam engines were too heavy and weak to pull any weight. After Watt's patent expired in 1800, inventors experimented with lighter, more powerful high-pressure engines—an idea Watt had rejected as too dangerous. In 1804 the engineer Richard Trevithick built an engine that consumed twelve times less coal than Newcomen's and three times less than Watt's. With it, he built several steam-powered vehicles able to travel on roads or rails.

By the 1820s England had many railways on which horses pulled heavy wagons. On one of them, the Stockton and Darlington Railway, chief engineer George Stephenson began using steam locomotives in 1825. Four years later the owners of the Liverpool and Manchester Railway organized a contest between steam-powered locomotives and horse-drawn wagons. Stephenson and his son Robert easily won the contest with their locomotive Rocket, which pulled a 20-ton train at up to 30 miles (48 kilometers) per hour. After that triumph, a railroad-building mania that lasted for twenty years swept Britain. The first lines linked towns and mines with the nearest harbor or waterway. In the late 1830s passenger traffic soared, and entrepreneurs built lines between the major cities and then to small towns as well. Railroads were far cheaper, faster, and more comfortable than stagecoaches, and millions of people got in the habit of traveling.

In the United States entrepreneurs built railroads as quickly and cheaply as possible with an eye to fast profits, not long-term durability. By the 1840s, 6,000 miles
Map 22.2 Industrialization in Europe, ca. 1850 In 1850 industrialization was in its early stages on the European continent. The first industrial regions were comparatively close to England and possessed rich coal deposits: Belgium and the Ruhr district of Germany. Politics determined the location of railroads. Notice the star-shaped French network of rail lines emanating from Paris and the lines linking the different parts of the German Confederation.

(10,000 kilometers) of track connected and radiated westward from Boston, New York, Philadelphia, and Baltimore. The boom of the 1840s was dwarfed by the mania of the 1850s, when 21,000 miles (34,000 kilometers) of new track were laid, much of it westward across the Appalachians to Memphis, St. Louis, and Chicago. After 1856 the trip from New York to Chicago, which had once taken three weeks by boat and on horseback, could be made in forty-eight hours. More than anything else, it was the railroads that opened up the Midwest, turning the vast prairie into wheat fields and pasture for cattle to feed the industrial cities of the eastern United States.

Railways also triggered the industrialization of Europe (see Map 22.2). Belgium, independent since 1830, quickly copied the British railways. Because France and Prussia planned and supervised their railroad construction from the start, construction was delayed in those countries until the mid-1840s. When it began, however, it had an even greater impact than in Britain, for it not only satisfied the long-standing need for transportation but also stimulated the iron, machinery, and construction industries.

Communication over Wires

After the Italian scientist Alessandro Volta invented the battery in 1800, making it possible to produce an electric current, many inventors tried to apply electricity to
communication. The first practical electric telegraph systems were developed almost simultaneously in England and America. In 1837 in England Charles Wheatstone and William Cooke introduced a five-wire telegraph that remained in use until the early twentieth century. That same year, the American Samuel Morse introduced a code of dots and dashes that could be transmitted with a single wire; in 1843 he erected a telegraph line between Washington and Baltimore.

The railroad companies were among the first users of the new electric telegraph. They allowed telegraph companies to string wires along the tracks in exchange for the right to send telegrams from station to station announcing the departure and arrival of trains. Such messages made railroads much safer as well as more efficient.

By the late 1840s telegraph wires were being strung throughout the eastern United States and western Europe. In 1851 the first submarine telegraph cable was laid across the English Channel from England to France; it was the beginning of a network that eventually connected the entire globe. The world was rapidly shrinking, to the applause of Europeans and Americans for whom speed was a clear measure of progress. No longer were communications limited to the speed of a sailing ship, a galloping horse, or a fast-moving train.

THE IMPACT OF THE EARLY
INDUSTRIAL REVOLUTION

The Industrial Revolution led to profound changes in society, politics, and the economy. At first, the changes were local. While some people became wealthy and built beautiful mansions, others lived in squalid neighborhoods with polluted water and smoke-filled air. By the mid-nineteenth century, the worst local effects were being alleviated and cities became cleaner and healthier. Replacing them were more complex problems on a national scale: business cycles, labor conflicts, and the transformation of entire regions into industrial landscapes. At the international and global level, industrialization empowered the nations of western Europe and North America at the expense of the rest of the world.

The New Industrial Cities

The most dramatic environmental changes brought about by industrialization occurred in the towns. Never before had towns grown so fast. London, one of the largest cities in Europe in 1700 with 500,000 inhabitants, grew to 959,000 by 1800 and to 2,363,000 by 1850; it was then the largest city the world had ever known. Smaller towns grew even faster. Manchester, a town of 20,000 in 1758, reached 400,000 a century later; a twofold increase. Liverpool grew sixfold in sixty years, from 82,000 in 1801 to 472,000 in 1861. New York City, already 100,000 strong in 1815, reached 600,000 (including Brooklyn) in 1850. European cities also grew, but more slowly; their fastest growth occurred after 1850 with increasing industrialization. In some areas, towns merged and formed megalopolises, such as Greater London, the English Midlands, central Belgium, and the Ruhr district of western Germany.

Industrialization made some people very prosperous. A great deal of this new wealth went into the building of fine homes, churches, museums, and theaters in wealthy neighborhoods in London, Berlin, and New York. Much of the beauty of London dates from the time of the Industrial Revolution. Yet, by all accounts, the industrial cities grew much too fast, and much of the growth occurred in the poorest neighborhoods. As poor migrants streamed in from the countryside, developers built cheap, shoddy row houses for them to rent. These tenements were dangerously overcrowded. Often, several families had to live in one small room.

Sudden population growth, overcrowding, and inadequate municipal services conspired to make urban problems more serious than in earlier times. Town dwellers recently arrived from the country brought country ways with them. People threw their sewage and trash out the windows to be washed down the gutters in the streets. The poor kept pigs and chickens; the rich kept horses; and pedestrians stepped into the street at their own risk. Factories and workers' housing were mixed together. Air pollution from burning coal, a problem since the sixteenth century, got steadily worse. Londoners in particular breathed dense and noxious coal smoke. People drank water drawn from wells and rivers contaminated by sewage and industrial runoff. The River Irwell, which ran through Manchester, was, in the words of one visitor, "considerably less a river than a flood of liquid manure." 3

"Every day that I live," wrote an American visitor to Manchester, "I thank Heaven that I am not a poor man with a family in England." 4 In his poem "Milton," William Blake (1757–1827) expressed the revulsion of sensitive people at the spoliation of England's "mountains green" and "pleasant pastures":

And did the Countenance Divine
Shine forth upon our clouded hills?
And was Jerusalem builded here
Among these dark Satanic Mills?

Railroads invaded the towns, bringing noise and smoke into densely populated neighborhoods. Railroad
industrial cities. Steamships brought cholera from India, causing great epidemics that struck poor neighborhoods especially hard. In the 1850s, when the average life expectancy in England was forty years, it was only twenty-four years in Manchester, and around seventeen years in Manchester’s poorest neighborhoods, because of high rates of infant mortality. Observers of nineteenth-century industrial cities documented the horrors of slum life in vivid detail. Their shocking reports led to municipal reforms, such as garbage removal, water and sewage systems, and parks and schools. These measures began to alleviate the ills of urban life after the mid-nineteenth century.

**Rural Environments**

Long before the Industrial Revolution began, practically no wilderness areas were left in Britain and very few in western Europe. Almost every piece of land was covered with fields, forests, or pastures shaped by human activity, or by towns; yet humans continued to alter the environment. The most serious problem was deforestation. As they had been doing for centuries, people cut timber to build ships and houses, to heat homes, and to manufacture bricks, iron, glass, beer, bread, and many other items.

Americans transformed their environment even faster than Europeans. In North America, the Canadian and American governments seized land from the Indians and made it available at low cost to white farmers and logging companies. After shipbuilding and construction had depleted the British forests in the early nineteenth century, Britain relied heavily on imports of Canadian lumber. East of the Appalachian Mountains, settlers viewed forests not as a valuable resource but as a hindrance to development. In their haste to “open up the wilderness,” pioneers felled trees and burned them, built houses and abandoned them, and moved on. The cultivation of cotton in the southern United States was especially harmful. Planters cut down forests, grew cotton for a few years until it depleted the soil, then moved west, abandoning the land to scrub pines. This was slash-and-burn agriculture on an industrial scale.

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**Interactive Map: Territorial Growth of the United States**

At that time, America seemed immune to human depredations. Americans thought of nature as an obstacle to be overcome and dominated. This mindset persisted long after the entire continent was occupied and the environment truly endangered.
An Industrial Canal  In the late eighteenth and early nineteenth centuries, before railroads were introduced, many canals were constructed in England so that barges could transport heavy materials cheaply, such as coal for industrial works and steam engines, stone and bricks for buildings, and clay for pottery works. Canals such as this one, which ran alongside Josiah Wedgwood’s famous Etruria china factory, contributed greatly to Britain’s industrial development. (The Art Archive)

Paradoxically, in some ways industrialization relieved pressures on the environment in Europe. Raw materials once grown on the land—such as wood, hay, and wool—were replaced by materials found underground, like iron ore and coal, or obtained overseas, like cotton. While Russia, Sweden, the United States, and other forested countries continued to smelt iron with charcoal, the British and western Europeans substituted coke made from coal. As the population increased and land grew scarcer, the cost of growing feed for horses rose, creating incentives to find new, less land-hungry means of transportation. Likewise, as iron became cheaper and wood more expensive, ships and many other objects formerly made of wood began to be made of iron.

To contemporaries, the most obvious changes in rural life were brought about by the new transportation systems. In the eighteenth century France had a national network of quality roads, which Napoleon extended into Italy and Germany. In Britain local governments’ neglect of the roads that served long-distance traffic led to the formation of private enterprises—“Turnpike Trusts”—that built numerous toll roads. For heavy goods, horse-drawn wagons were costly even on good roads because of the need to feed the horses. The growing volume of heavy freight triggered canal-building booms in Britain, France, and the Low Countries in the late eighteenth century. Some canals, like the duke of Bridgewater’s canal in England, connected coal mines to towns or navigable rivers. Others linked navigable rivers and created national transportation networks.

Canals were marvels of construction, with deep cuts, tunnels, and even aqueducts that carried barges over rivers. They also were a sort of school where engineers learned skills they were able to apply to the next great transportation system: the railroads. They laid track across rolling country by cutting deeply into hillsides and erecting daringly long bridges of stone and iron across valleys. Lesser lines snaked their way to small towns hidden in remote valleys. Soon, clanking trains pulled by puffing, smoke-belching locomotives were invading long-isolated districts.

Thus, in the century after industrialization began, the landscape of industrializing countries was transformed more rapidly than ever before. But the ecological changes, like the technological and economic changes that caused them, were only beginning.

Working Conditions

Industrialization offered new opportunities to the enterprising. Carpenters, metalworkers, and machinists were in great demand. Since industrial machines were fairly simple, some workers became engineers or went into business for themselves. The boldest in England moved to the European continent, the Americas, or India, using their skills to establish new industries.

The successful, however, were a minority. Most industrial jobs were unskilled, repetitive, and boring. Factory work did not vary with the seasons or the time of day but began and ended by the clock. Factories used the invention of gas lighting to expand the working day past sunset (see Environment and Technology: Gas Lighting). Workdays were long; there were few breaks; and foremen
Gas Lighting

Before the nineteenth century, the night was a dangerous time to be out. Oil lamps and candles made of tallow or beeswax were too expensive for everyday use. Some hardy souls—like the engine designer James Watt, the pottery manufacturer Josiah Wedgwood, the chemist Joseph Priestley, the iron manufacturer Matthew Boulton, and the naturalist Erasmus Darwin—called themselves the Lunar Society because they only met on nights when there was a full moon so they could find their way home in the dark. Almost everyone else went to bed at sundown and got up at dawn.

There was a big demand for better lighting. For the managers of cotton mills and other industrial establishments, daylight hours were too short, especially in the winter months; they knew that they could keep running after sunset if they had light, but lanterns and candles were costly and dangerous. Wealthy people wanted to light up their homes. Businesses and government offices also needed light. The demand inspired inventors to look for new ways to produce light.

In France, the engineer Philippe Lebon knew that heating wood to make charcoal let off a flammable gas. In the 1790s he was able to channel this gas through pipes to illuminate a home and garden. In Britain, William Murdoch, an engineer who worked for the steam engine manufacturers Boulton and Watt, extracted gas released in the process of heating coal to make coke and used it to light up a house. Moving from these experiments to commercial applications was a long and complicated process, however. Coal gas was smelly and explosive and full of impurities that gave off toxic fumes and smoke when it burned. Engineers had to learn ways to extract the gas efficiently, make strong pipes that did not leak, and market the product. In 1806 a German immigrant to England, Frederick Albert Winsor, founded the National Light and Heat Company to produce and distribute gas in London. By 1816, London had 26 miles of gas mains bringing gas to several neighborhoods. That same year, Baltimore became the first American city to install gas mains and streetlights. In the following decades, engineers developed ways of removing the impurities from the gas to make it safer and cleaner. They also invented meters to measure the amount of gas consumed and burners that produced a brighter light. As a result of these improvements, the cost of gas dropped to less than a third that of oil lamps of equivalent lighting power. From the 1840s until the early twentieth century, gaslights were installed in homes, businesses, and factories and even along streets in the major cities of Europe and America.

The results were astonishing and delighted city dwellers. Mills and factories could operate on two eight- to ten-hour shifts instead of one long dawn-to-dusk shift. Businesses stayed open late. Theaters gave evening performances. And people could now walk the streets safely. Evening illumination also contributed to the tremendous increase in adult education, as working people attended classes after work. Sales of books soared, in part because the increasing number of people with gaslights in their homes could stay up late reading. The brightly lit cities attracted migrants from the still-dark countryside. Long before electricity, gas lighting had banished the terrors of the night.
watched constantly. Workers who performed one simple task over and over had little sense of achievement or connection to the final product. Industrial accidents were common and could ruin a family. Unlike even the poorest preindustrial farmer or artisan, factory workers had no control over their tools, jobs, or working hours.

Industrial work had a major impact on women and family life. Working-class women— that is, those who could not afford servants—had always worked, but mostly within the family: spinning and weaving, sewing hats and clothes, preparing food, washing, and doing a myriad other household chores. In rural areas, women also did farmwork, especially caring for gardens and small animals, as well as helping during the planting and harvesting seasons. With industrialization, however, their work was removed from the home. Women workers were concentrated in textile mills, partly because of ancient traditions, partly because textile work required less strength than metalworking, construction, or hauling. On average, women earned one-third to one-half as much as men. The economist Andrew Ure wrote in 1835: “It is in fact the constant aim and tendency of every improvement in machinery to supersede human labour altogether or to diminish its cost, by substituting the Industry of women and children for that of men.” Young unmarried women worked to support themselves or to save for marriage. Married women took factory jobs when their husbands were unable to support the family. Mothers of infants faced a hard choice: whether to leave their babies with wet nurses at great expense and danger or bring them to the factory and keep them drugged. Rather than working together as family units, husbands and wives increasingly worked in different places.

In the early years of industrialization, even where factory work was available, it was never the main occupation of working women. Most young women who sought paid employment became domestic servants in spite of the low pay, drudgery, and risk of sexual abuse by male employers. Women with small children tried hard to find work they could do at home, such as laundry, sewing, embroidery, millinery, or taking in lodgers.

Even with both parents working, poor families found it hard to make ends meet. As in preindustrial societies, parents thought children should contribute to their upkeep as soon as they were able to. The first generation of workers brought children as young as five or six with them to the factories and mines; they had little choice, since there were no public schools or day-care centers. Employers encouraged the practice and even hired orphans. They preferred children because they were cheaper and more docile than adults and were better able to tie broken threads or crawl under machines to sweep the dust.

In Arkwright’s cotton mills two-thirds of the workers were children. In another mill 17 percent were under ten years of age, and 53 percent were between ten and seventeen; they worked fourteen to sixteen hours a day and were beaten if they made mistakes or fell asleep. Mine operators used children to pull coal carts along the low passageways from the coal face to the mine shaft. In the mid-nineteenth century, when the British government began restricting child labor, mill owners increasingly recruited adult immigrants from Ireland.
American industry began on a somewhat different note than the British. In the early nineteenth century Americans still remembered their revolutionary ideals. When Francis Cabot Lowell built a cotton mill in Massachusetts, he hired the unmarried daughters of New England farmers, promising them decent wages and housing in dormitories under careful moral supervision. Other manufacturers eager to combine profits with morality followed his example. Soon the profit motive won out, and manufacturers imposed longer hours, harsher working conditions, and lower wages. The young women protested: "As our fathers resisted with blood the lordly avarice of the British ministry, so we, their daughters, never will wear the yoke which has been prepared for us."

When they went on strike, the mill owners replaced them with Irish immigrant women willing to accept lower pay and worse conditions.

While the cotton boom enriched planters, merchants, and manufacturers, African-Americans paid for it with their freedom. In the 1790s, 700,000 slaves of African descent lived in the United States. The rising demand for cotton and the British and American prohibition of the African slave trade in 1808 caused an increase in the price of slaves. As the "Cotton Kingdom" expanded, the number of slaves rose through natural increase and the reluctance of slave owners to free their slaves. By 1830 there were 3.2 million slaves in the United States, 60 percent of whom grew cotton. Similarly, Europe's and North America's surging demand for tea and coffee prolonged slavery in the sugar plantations of the West Indies and caused it to spread to the coffee-growing regions of southern Brazil. In the British West Indies slavery was abolished in 1833, but elsewhere in the Americas it persisted for another thirty to fifty years.

Slavery was not, as white American southerners maintained, a "peculiar institution"—a consequence of "biological" differences, biblical injunctions, or African traditions. Slavery was just as much part and parcel of the Industrial Revolution as child labor in Britain, the clothes that people wore, and the beverages they drank.

Changes in Society

Industrialization accentuated the polarization of society and income disparities. In his novel *Sybil*, or, *The Two Nations*, the British politician Benjamin Disraeli (1804–1881) spoke of "two nations between whom there is no intercourse and no sympathy, who are as ignorant of each other's habits, thoughts, and feelings as if they were dwellers in different zones, or inhabitants of different planets... the rich and the poor."

In Britain the worst-off were those who clung to an obsolete skill or craft. The cotton-spinning boom of the 1790s briefly brought prosperity to weavers. Their high wages and low productivity, however, induced inventors to develop power looms. As a result, by 1811 the wages of handloom weavers had fallen by a third; by 1832, by two-thirds. Even by working longer hours, they could not escape destitution.

In the industrial regions of Britain and continental Europe, the wages and standard of living of factory workers did not decline steadily like those of handloom weavers; they fluctuated wildly. During the war years of 1792 to 1815, the price of food, on which the poor spent most of their income, rose faster than wages. The result was widespread hardship. Then, in the 1820s real wages and public health began to improve. Industrial production grew at over 3 percent a year, pulling the rest of the economy along. Prices fell and wages rose. Even the poor could afford comfortable, washable cotton clothes and underwear.

Improvement, however, was not steady. One reason was the effect of business cycles—recurrent swings from economic hard times to recovery and growth, then back to hard times. When demand fell, businesses contracted or closed, and workers found themselves unemployed. Most had few or no savings, and no government at the time provided unemployment insurance. Hard times returned in the "hungry forties." In 1847-48 the potato crop failed in Ireland. One-quarter of the Irish population died in the resulting famine, and another quarter emigrated to England and North America. On the European continent the negative effects of economic downturns were tempered by the existence of small family farms to which urban workers could return when they were laid off.

Only in the 1850s did the benefits of industrialization—cheaper food, clothing, and utensils—begin to improve workers' standard of living. The real beneficiary of the early Industrial Revolution was the middle class. In Britain landowning gentry and merchants had long shared wealth and influence. In the late eighteenth century a new group arose: entrepreneurs whose money came from manufacturing. Most, like Arkwright and Wedgwood, were the sons of middling shopkeepers, craftsmen, or farmers. Their enterprises were usually self-financed, for little capital was needed to start a cotton-spinning or machine-building business. Many tried and some succeeded, largely by plowing their profits
back into the business. A generation later, in the nineteenth century, some newly rich industrialists bought their way into high society. The same happened in western Europe after 1815.

Before the Industrial Revolution, wives of merchants had often participated in the family business; widows occasionally managed sizable businesses on their own. With industrialization came a "cult of domesticity" to justify removing middle-class women from contact with the business world. Instead, they became responsible for the home, the servants, the education of children, and the family's social life (see Chapter 26). Not all women accepted the change; Mary Wollstonecraft (1759–1797) wrote the first feminist manifest, *Vindication of the Rights of Woman*, in 1792.

Middle-class people who attributed their success, often correctly, to their own efforts and virtues believed in individual responsibility: if some people could succeed through hard work, thrift, and temperance, then those who did not succeed had no one but themselves to blame. Many workers, however, were newly arrived from rural districts and earned too little to save for the long stretches of unemployment they experienced. The squalor and misery of life in factory towns led to a noticeable increase in drunkenness on paydays. While the life of the poor remained hard, the well-to-do attributed their own success to sobriety, industriousness, thrift, and responsibility. The moral position of the middle class mingled condemnation with concern, coupled with feelings of helplessness in the face of terrible social problems, such as drunkenness, prostitution, and child abandonment.

**NEW ECONOMIC AND POLITICAL IDEAS**

Changes as profound as the Industrial Revolution triggered political ferment and ideological conflict. So many other momentous events took place during those years—the American Revolution (1776–1783), the French Revolution (1789–1799), the Napoleonic Wars (1804–1815), the reactions and revolts that periodically swept over Europe after 1815—that we cannot neatly separate out the consequences of industrialization from the rest. But it is clear that by undermining social traditions and causing a growing gap between rich and poor, the Industrial Revolution strengthened the ideas of laissez faire and socialism and sparked workers' protests.

**Laissez Faire and Its Critics**

The most celebrated exponent of *laissez faire* ("let them do") was Adam Smith (1723–1790), a Scottish economist. In *The Wealth of Nations* (1776) Smith argued that if individuals were allowed to seek personal gain, the effect, as though guided by an "invisible hand," would be to increase the general welfare. The government should refrain from interfering in business, except to protect private property; it should even allow duty-free trade with foreign countries. By advocating free-market capitalism, Smith was challenging the prevailing economic doctrine of earlier centuries, mercantilism, which argued that governments should regulate trade in order to maximize their hoard of precious metals (Chapter 18).

Persuaded by Adam Smith's arguments, governments dismantled many of their regulations in the decades after 1815. Britain even lowered its import duties, though other countries kept theirs. Nonetheless, it was obvious that industrialization was not improving the general welfare but was instead causing widespread misery. Two other thinkers, Thomas Malthus (1766–1834) and David Ricardo (1772–1823), attempted to explain the poverty they saw without challenging the basic premises of *laissez faire*. The cause of the workers' plight, Malthus and Ricardo said, was the population boom, which outstripped the food supply and led to falling wages. The workers' poverty, they claimed, was as much a result of "natural law" as the wealth of successful businessmen, and the only way the working class could avoid mass famine was to delay marriage and practice self-restraint and sexual abstinence.

*Laissez faire* provided an ideological justification for a special kind of capitalism: banks, stock markets, and chartered companies allowed investors to obtain profits with reasonable risks but with much less government control and interference than in the past. In particular, removing guild and other restrictions allowed businesses to employ women and children and keep wages low.

Businesspeople in Britain eagerly adopted *laissez faire* ideas that justified their activities and kept the government at bay. But not everyone accepted the grim conclusions of the "dismal science," as economics was then known. The British philosopher Jeremy Bentham (1748–1832) believed that it was possible to maximize "the greatest happiness of the greatest number." If only a Parliament of enlightened reformers would study the social problems of the day and pass appropriate legislation.

The German economist Friedrich List (1789–1846) rejected *laissez faire* and free trade as a British trick "to make the rest of the world, like the Hindus, its serfs in all industrial and commercial relations." To protect their
“infant industries” from British competition, he argued, the German states had to eliminate tariff barriers between them but erect high barriers against imports from Britain. On the European continent, List’s ideas were as influential as those of Smith and Ricardo and led in 1834 to the formation of the Zollverein, a customs union of most of the German states.

Positivists and Utopian Socialists

Bentham optimistically advocated gradual improvements. In contrast, three French social thinkers, moved by sincere concern for the poor, offered a radically new vision of a just civilization. Espousing a philosophy called positivism, the count of Saint-Simon (1760–1825) and his disciple Auguste Comte (1798–1857) argued that the scientific method could solve social as well as technical problems. They recommended that the poor, guided by scientists and artists, form workers’ communities under the protection of benevolent business leaders. These ideas found no following among workers, but they attracted the enthusiastic support of bankers and entrepreneurs, for whom positivism provided a rationale for investing in railroads, canals, and other symbols of modernity. The third French thinker, Charles Fourier (1768–1837), loathed capitalists and imagined an ideal society in which groups of sixteen hundred workers would live in dormitories and work together on the land and in workshops where music, wine, and pastries would soften the hardships of labor. Critics called his ideas utopian socialism, from the Greek word utopia meaning “nowhere.” Fourier’s ideas are now considered a curiosity, but positivism resonates to this day among liberal thinkers, especially in Latin America.

The person who came closest to creating a utopian community was the Englishman Robert Owen (1771–1858), a successful cotton manufacturer who believed that industry could provide prosperity for all. Conscience-stricken by the plight of British workers, Owen took over the management of New Lanark, a mill town south of Glasgow. He improved the housing and added schools, a church, and other amenities. He also testified in Parliament against child labor and for government inspection of working conditions. Although he angered his fellow industrialists, he helped bring about long-overdue reforms.

Protests and Reforms

Workers benefited little from the ideas of these middle-class philosophers. Instead, they resisted the harsh working conditions in their own ways. They changed jobs frequently. They were often absent, especially on Mondays. When they were not closely watched, the quality of their work was likely to be poor.

Periodically, workers rioted or went on strike, especially when food prices were high and when downturns in the business cycle left many unemployed. In some places, craftsmen broke into factories and destroyed the machines that threatened their livelihoods. Such acts of resistance did nothing to change the nature of industrial work. Not until workers learned to act together could they hope to have much influence.

Gradually, workers formed benevolent societies and organizations to demand universal male suffrage and shorter workdays. In 1834 Robert Owen organized the Grand National Consolidated Trade Union to lobby for an eight-hour workday; it quickly gained half a million members but collapsed a few months later in the face of government prosecution of trade-union activities. A new movement called Chartism arose soon thereafter. It was led by the London cabinetmaker William Lovett and the Irish landlord Fergus O’Connor and appealed to miners and industrial workers. It demanded universal male suffrage, equal electoral districts, the secret ballot, salaries for members of Parliament, and annual elections. It gathered 1.3 million signatures on a petition, but Parliament rejected it. Chartism collapsed in 1848, but it left a legacy of labor organizing.

Eventually, mass movements persuaded political leaders to look into the abuses of industrial life, despite the prevailing laissez-faire philosophy. In the 1820s and 1830s the British Parliament began investigating conditions in factories and mines. The Factory Act of 1833 prohibited the employment of children younger than nine in textile mills. It also limited the working hours of children between the ages of nine and thirteen to eight hours a day and of fourteen- to eighteen-year-olds to twelve hours. The Mines Act of 1842 prohibited the employment of women and boys under age ten underground. Several decades passed before the government appointed enough inspectors to enforce the new laws.

Most important was the struggle over the Corn Laws—tariffs on imported grain. Their repeal in 1846, in the name of “free trade,” was designed to lower the cost of food for workers and thereby allow employers to pay lower wages. A victory for laissez faire, the repeal also represented a victory for the rising class of

Zollverein (TSOLL-feh-rihn) Comte (COMB-tuh)
Fourier (FOOR-yeh) utopian (you-TOE-pe-uhn)
manufacturers and other employers over the conservative landowners who had long dominated politics and whose harvests faced competition from cheaper imported food.

The British learned to seek reform through accommodation. On the European continent, in contrast, the revolutions of 1848 revealed widespread discontent with repressive governments but failed to soften the hardships of industrialization (see Chapter 26).

**THE LIMITS OF INDUSTRIALIZATION OUTSIDE THE WEST**

The spread of the Industrial Revolution in the early nineteenth century transformed the relations of western Europe and North America with the rest of the world. In Egypt and India cheap industrial imports, backed by the power of Great Britain, delayed industrialization for a century or more. China was defeated and humiliated by the products of industrial manufacture. In these three cases, we can discern the outlines of the Western domination that has characterized the history of the world since the late nineteenth century.

Egypt, strongly influenced by European ideas since the French invasion of 1798, began to industrialize in the early nineteenth century. The driving force was its ruler, Muhammad Ali (1769–1849), a man who was to play a major role not only in the history of Egypt but in the Middle East and East Africa as well (see Chapters 24 and 25). He wanted to build up the Egyptian economy and military in order to become less dependent on the Ottoman sultan, his nominal overlord. To do so, he imported advisers and technicians from Europe and built cotton mills, foundries, shipyards, weapons factories, and other industrial enterprises. To pay for all this, he made the peasants grow wheat and cotton, which the government bought at a low price and exported at a profit. He also imposed high tariffs on imported goods in order to force the pace of industrialization.

Muhammad Ali's efforts fell afloat of the British, who did not want a powerful country threatening to interrupt the flow of travelers and mail across Egypt, the shortest route between Europe and India. When Egypt went to war against the Ottoman Empire in 1839, Britain intervened and forced Muhammad Ali to eliminate all import duties in the name of free trade. Unprotected, Egypt's
fledging industries could not compete with the flood of cheap British products. Thereafter, Egypt exported raw cotton, imported manufactured goods, and became, in effect, an economic dependency of Britain.

Until the late eighteenth century, India had been the world's largest producer and exporter of cotton textiles, handmade by skilled spinners and weavers. The British East India Company took over large parts of India just as the Industrial Revolution was beginning in Britain (see Chapter 25 and Map 25.2). It allowed cheap British factory-made yarn and cloth to flood the Indian market duty-free, putting spinners and later handloom weavers out of work. Unlike Britain, India had no factories to which displaced handicraft workers could turn for work. Most of them became landless peasants, eking out a precarious living.

Like other tropical regions, India became an exporter of raw materials and an importer of British industrial goods. To hasten the process, British entrepreneurs and colonial officials introduced railroads into the subcontinent. The construction of India's railroad network began in the mid-1850s, along with coal mining to fuel the locomotives and the installation of telegraph lines to connect the major cities.

Some Indian entrepreneurs saw opportunities in the atmosphere of change that the British created. In 1854 the Bombay merchant Cowasjee Nanabhooy Davar imported an engineer, four skilled workers, and several textile machines from Britain and started India's first textile mill. This was the beginning of India's mechanized cotton industry. Despite many gifted entrepreneurs, India's industrialization proceeded at a snail's pace, for the government was in British hands and the British did nothing to encourage Indian industry.

China's stagnation in the late eighteenth and early nineteenth centuries, at the very time when first Britain and then western Europe and North America were becoming industrialized, has long puzzled historians. China had the resources, both human and natural, to advance technologically and economically, but a conservative elite and a growing population of poor peasants stood in the way of change (see Chapter 20). As a result, when faced with Western industrial technology, China became weaker rather than stronger.

In January 1840 a shipyard in Britain launched a radically new ship. The Nemesis had an iron hull, a flat bottom that allowed it to navigate in shallow waters, and a steam engine to power it upriver and against the wind. In November it arrived off the coast of China, heavily armed. Though ships from Europe had been sailing to China for three hundred years, the Nemesis was the first steam-powered iron gunboat seen in Asian waters. A Chinese observer noted: "Iron is employed to make it strong. The hull is painted black, weaver's shuttle fashion. On each side is a wheel, which by the use of coal fire is made to revolve as fast as a running horse. . . . At the vessel's head is a Marine God, and at the head, stern, and sides are cannon, which give it a terrific appearance. Steam vessels are a wonderful invention of foreigners, and are calculated to offer delight to many." Instead of offering delight, the Nemesis and other steam-powered warships that soon joined it steamed up the Chinese rivers, bombarded forts and cities, and transported troops and supplies from place to place along the coast and up rivers far more quickly than Chinese soldiers could move on foot. With this new weapon, Britain, a small island nation half a world away, was able to defeat the largest and most populated country in the world (see Chapter 24).

The cases of Egypt, India, and China show how the demands of Western nations and the military advantage that industrialization gave them led them to interfere in the internal affairs of nonindustrial societies. As we shall see in Chapter 27, this was the start of a new age of Western dominance.
The Industrial Revolution arose from a combination of factors in European society in the eighteenth and early nineteenth centuries. The population grew, but so did the food supply, thanks to improvements in agriculture. Among upper- and middle-class Europeans, practical subjects like business, science, and technology became fashionable. Great Britain had a particularly fluid society open to talents and enterprise. On the European continent, the revolutions of 1789-1815 swept away the restrictions of the old aristocratic regimes.

A series of technological and organizational innovations transformed the manufacture of many products, reducing their costs and increasing their productivity. New machines, assembled in mills, mass-produced cotton yarn and cloth. Work formerly done by skilled craftsmen was divided into many simple tasks assigned to workers in factories. New techniques made iron cheap and abundant. Steam engines provided power to factories, ships, and railroads. And electricity found its first practical application in telegraphy.

The Industrial Revolution changed people’s lives and the environments in which they lived. Cities grew huge and, for, most of their inhabitants, unsightly and unhealthy. While middle-class women were consigned to caring for the home and children, working-class women and children as well as men were obliged to earn their living in mines and factories. In the industrial cities, social problems such as unemployment, alcoholism, and the abandonment of children became acute. Rural environments were also transformed as roads, canals, and railroads crisscrossed open land.

Some thinkers defended the growing disparities between rich and poor in the name of laissez faire. Governments and businesspeople eagerly adopted many of the free-market capitalist views of Adam Smith. Others, such as positivists and utopian socialists, criticized the injustices caused by industrialization and offered a new vision of just communities. Workers created labor unions, leading political leaders to reexamine the working conditions of factories and mines, especially as they concerned women and children. However, not until the mid-nineteenth century did industrialization begin to raise living standards in the industrialized countries.

The Industrial Revolution changed life not only in the industrializing nations but also around the world because it gave the newly industrial nations of the West new powers to coerce non-Western societies. In particular, Britain smugly took advantage of the Westernization of Egypt and India and turned those countries into producers of raw materials, and British steam-powered gunboats forced China to open its doors to unequal trade.
SUGGESTED READING


The first book to treat industrialization as a global phenomenon is Peter Stearns, The Industrial Revolution in World History (1983); see also Louise Tilly’s important article “Connections” in American Historical Review (February 1994). An important work comparing China and Europe in the eighteenth century is Kenneth Pomeranz, The Great Divergence: Europe, China, and the Making of the Modern World Economy (2000).

NOTES

1. Nassau W. Senior, Letters on the Factory Act, as it affects the cotton manufacture, addressed to the Right Honourable the President of the Board of Trade, 2nd ed. (London: Fellows, 1844), 20.