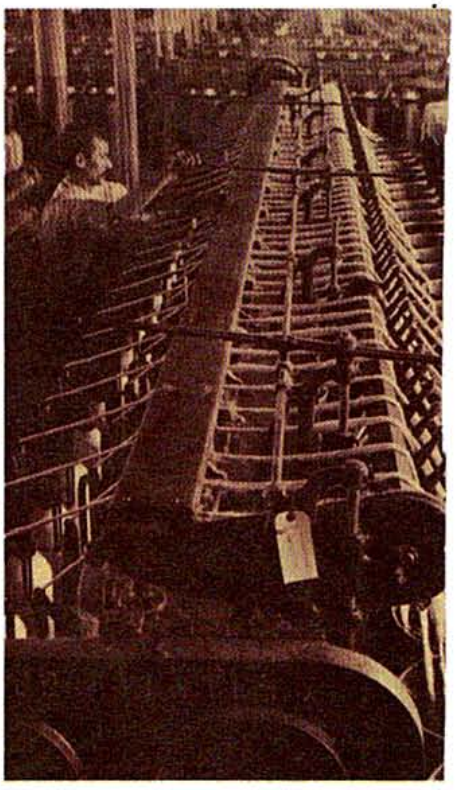
CHAPTER 21

The Industrial Revolution, Science, and the Arts



CHAPTER 21 1700–1900

During the 19th century, Western civilization underwent tremendous changes. They were sparked by developments in industry so far-reaching as to be termed an Industrial Revolution. Textile manufacturing provided a dramatic example. In the late 18th century, a home weaver (in a painting at left by Van Gogh) worked many hours to produce a single bolt of cloth. A century later, a factory employee operating a bank of machines could make fifty times as much cloth.

Not all the great changes of the 19th century took place at the barricades, on the battlefield, or around the conference table. While violent revolutions, military conflicts, and political rearrangements occupied the center of the stage, powerful forces were quietly at work behind the scenes transforming the very nature of western civilization.

One of the most important single figures in this transformation was a Scottish instrument maker named James Watt. In 1763 a fellow faculty member at the University of Glasgow asked him to repair a model steam engine. Watt, good Scotsman that he was, noticed that the engine wasted a great deal of fuel. He discussed the matter with several professors at the university, but no one could think of any practical solution. For months Watt pondered the problem. Even after he hit upon a solution in 1765, it took him four years to iron out the technical difficulties before he could finally take out a patent on his greatly improved steam engine.

The adoption of this invention by the workaday world had far-reaching consequences. The efficient steam engine was destined to limit or replace traditional energy sources—horses, oxen, the water mill, and human muscle power. By 1819, when James Watt died, machines powered by his device were supplanting hand tools in much of British industry, and goods produced in factories were competing with articles made in the home. Industrialization spread to the rest of western Europe during the 19th century and across the seas to the United States and Japan.

The advance of industrialism was accompanied by new discoveries in science and medicine. Scientific progress not only made life healthier and more comfortable, but also changed men's ideas about their origins, their development, and their relations to one another. Literature, art, music, and architecture reflected the profound changes of the 19th century in a burst of creative activity.

This chapter tells how:

1. **The Industrial Revolution began in England.**
2. **The development of technology spurred industrial growth.**
3. **Science and medicine progressed rapidly.**
4. **The arts displayed great vigor.**

1 The Industrial Revolution began in England

There was a time when historians viewed the industrialization that began in the late 18th century as *the* Industrial Revolution. It was interpreted as a "cataclysm followed by a catastrophe"—that is, as the sudden appearance of new machines that transformed production, created the factory system, and resulted in the cruel exploitation of men, women, and children. All of these things were supposed to have happened within a few decades.

It is now known that this picture is grossly exaggerated. The essence of the so-called Industrial Revolution was the process by which power-driven machinery came to take the place of hand tools in the manufacture of various goods. As such, it is a movement that had no precise beginning and has not yet ended. Many new inventions appeared in the 18th and 19th centuries, but not suddenly. They were preceded by centuries of trial-and-error experimentation in many countries. The search for new machines and new sources of power to run them still continues. Nuclear energy and atomic reactors are only examples from the latest stage of a continuous development.

Still, the idea of an Industrial Revolution is a useful one because it signifies that

in a relatively short period of time—about two centuries—there occurred an exceedingly rapid acceleration of economic growth. This dramatic speed-up was first seen in England between about 1760 and 1830. It did not become evident in Germany until the 1860's, in the United States until the 1870's, and in Russia until the 1890's. Many areas of the world have yet to experience an industrial revolution.

Several conditions favored industrialization. In 18th-century England, a number of factors combined to produce a favorable setting for industrial development.

One important factor was a supply of natural resources. England was fortunate in possessing rich deposits of coal and iron. Short, swift rivers furnished the water power to keep machines whirring, and ample harbors helped in shipping the products of British industry around the world. Native wool and cotton from the colonies provided the raw materials for a flourishing textile industry.

Another condition aiding industrialization was a large labor force. A phenomenal increase doubled the population of Great Britain in the 18th century. Because of improvements in sanitation and hospital care and advances in medicine, the death rate was reduced. New methods of farming required fewer people to produce food; thus many farm laborers were free to take up other kinds of work. Because the British were leaders in developing mechanical inventions and in training people to use them, their labor force was skilled and well educated compared to its counterpart on the Continent.

Resources and an ample labor supply were organized by businessmen who supplied capital, bought the new machines, and built the new factories. For centuries, Englishmen had been accumulating capital from farming, handicrafts, and overseas trade. They had invested in joint-stock companies. Successful businessmen and landowners reinvested their profits to an even more marked degree after 1750. The men who developed business enterprises provided the equipment which the army of new workers needed.

Businessmen would not have made goods unless there was a demand for them. In Britain it sprang from several sources. The rapid rise in population created an enormous need for food, clothing, and housing. Colonies abroad provided additional incentives for increased production. The Napoleonic wars of the late 18th and early 19th centuries spurred demand for home-grown foodstuffs and iron and steel products.

The government of 18th-century England encouraged the growth of industrialism. During the 17th century, trade was sluggish and the English government felt that any radical business changes would endanger the economy. It closely regulated businesses, taxed profits heavily, and opposed any inventions that threatened to throw people out of work.

In the 18th century, however, markets expanded and foreign and domestic trade increased rapidly. Many restrictions were relaxed, taxes on profits were reduced, and the manufacture of new machines was actually encouraged. The English Parliament stimulated economic growth by permitting far-reaching changes in the landholding system, authorizing the building of roads and canals, and issuing patents to protect the work of inventors. The British navy safeguarded merchantmen around the globe, while at home an efficient legal system kept the roads free of bandits and assured justice for businessmen in the courts.

British society was relatively mobile—that is, a poor man who worked hard and saved his money might rise to wealth and arrange for his daughter to marry into the gentry or the nobility. This circumstance helped encourage enterprise because it

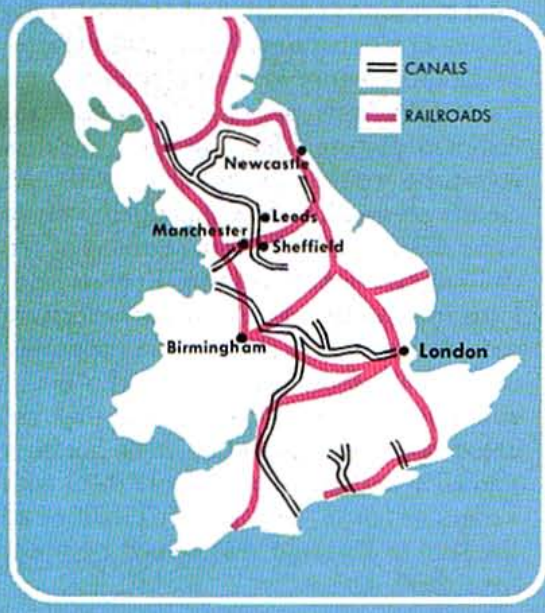
The Industrial Revolution in Europe during the 18th and 19th centuries may be better understood by noting the locations of European coal fields, iron ore deposits, and avenues of transportation. The combination of these geographic factors helped to provide a favorable environment for the growth of the Industrial Revolution.

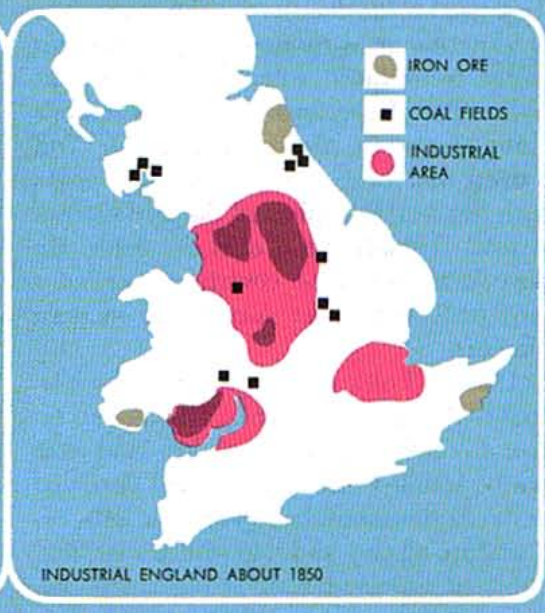
In northern and north-central England, for example, great industrial cities such as Newcastle, Manchester, Sheffield, and Birmingham grew up around sources of coal and iron and transportation facilities. Coal was necessary in the manufacture of iron and steel, and was also used to provide power for industrial machinery. Since coal is bulky and costly to transport from mines to factories, many industrial centers were built near coal fields to reduce shipping costs.

Some iron ore and other raw materials, however, had to be transported from ocean ports or from inland areas to the centers of industry, and manufactured products had to be shipped to domestic and overseas markets. Thus, a low-cost system of transportation was needed to link port cities such as Liverpool and London with the industrial cities. To meet this need, canals and, later, railroads were constructed. By 1830 England had more than 3000 miles of canals. By 1850 the country was served by more than 6600 miles of railroads. (In proportion to population, England had more than twice the railroad mileage of any country in Europe.) In that same year England produced half of all the iron in the world. The favorable location of its coal and iron resources and transportation facilities had important consequences. England was able to gain an early lead in industrialization.

France and Germany also had resources which favored the development of industry. Both countries possessed extensive deposits of coal and iron ore, which were linked by a network of rivers, canals, and railroads. These two countries became the industrial leaders in continental Europe.

Certain other European countries lacked one or more of the resources which favored the growth of industry. It is an important geographic fact that there is almost no coal in the Mediterranean region of Europe. This circumstance helps to explain why Mediterranean countries such as Spain and Italy failed to achieve the degree of industrialization experienced by England, France, and Germany in the 18th and 19th centuries.





INDUSTRIAL ENGLAND ABOUT 1850

gave opportunities for talented men to better themselves. Another encouraging factor was the example set by the upper classes. Some noblemen spent their lives at creative labor on their land; the Duke of Bridgewater built one of the first modern canals in England. Even George III loved to inspect his estate in high boots and thought of himself as a "farmer king." The upper classes had long engaged in trade. Only the eldest son of a noble line became noble, and since the younger sons often turned to business, working lost its social stigma.

A revolution in agriculture preceded that in industry. The 18th century witnessed an enormous increase in food production, an increase so rapid that it has sometimes been termed an Agrarian Revolution. This development consisted of two broad, interrelated movements. One was a series of technical improvements in methods of farming; the other represented changes in the system of landholding. England led the way in both.

Early in the 18th century, Englishmen began seeking ways in which to increase the efficiency of their farms. Most of them were well-to-do landlords who were free to experiment with new and sometimes costly techniques. Among the first was Jethro Tull. Experimenting on his father's estate early in the 18th century, Tull proved that he could obtain larger crops with less seed if he planted the seed in rows instead of scattering it over the fields. He devised a mechanical contrivance called a seed drill, the direct ancestor of modern planters.

One of Tull's contemporaries was Viscount Charles Townshend, who had an estate in Norfolk. Much of his land was sandy. Using a technique he had observed in the Netherlands, he treated the soil with a mixture of clay and lime called marl and obtained excellent results. Instead of letting fields lie fallow regularly, he worked out a four-phase rotation system by adding turnips and clover to the traditional crops of wheat and barley. Planting clover improved the soil by transferring nitrogen from the air to the ground (although this chemical action was not understood at the time) and since turnips required constant hoeing, cultivating them killed weeds and kept the soil loose. (Townshend became such an advocate of using turnips that he was nicknamed "Turnip" Townshend.) Another advantage of clover and turnips was that they could be stored and fed to livestock during the winter. Fewer animals had to be slaughtered in the fall and, as a consequence, there was an increase in their numbers.

The quality of livestock, however, was still inferior. A farmer named Robert Bakewell improved the size and health of his animals through careful selection and inbreeding. Thanks to his work and that of other men, England tripled its meat supply in the 18th century and gave the world such famous breeds as Shorthorn, Hereford, and Devon cattle, Leicester sheep, and Berkshire hogs.

The second basic element in the agricultural revolution consisted of changes in the system of landholding. Most English farms in the 18th century were composed of strips leased to tenants and open fields used for common pasture. Farming as a business enterprise could not be conducted efficiently on small, widely separated plots of ground. Nor could the small farmers afford drills or expensive fertilizers. English landlords were anxious to reap the benefits from a rise in farm prices and from an increasing demand for food. Landlords, who dominated Parliament, secured laws that enabled them to consolidate their holdings into compact farms and enclose them with hedges or fences. By the 1870's, half of all the land in England was owned by fewer than 2500 persons.

The enclosure movement made agriculture more efficient and stimulated productivity. It created social problems, however. Tenant farmers were forced to give up their rights to the land they worked. Many were compensated for their losses, but others received nothing and became either paupers or agricultural laborers. The small farmers of England, its "bold peasantry," decreased in number. A large new class of wage earners arose. Long before the coming of the factory, there existed in England as nowhere else a source of mobile labor ready to move where jobs were available and wages attractive.

Section Review

1. Explain the meaning of the term Industrial Revolution as it applied to a period beginning in the late 18th century.
2. What conditions favored rapid industrialization in 18th-century England?
3. Describe the contributions of Tull, Townshend, and Bakewell to the Agrarian Revolution.
4. What was the enclosure movement? How did it affect the Agrarian Revolution? the Industrial Revolution?

2 The development of technology spurred industrial growth

Economic growth is a seamless web; all parts of the process fit together. In 18th-century England, several conditions favored rapid industrializatioin. Changes in agriculture freed laborers from farms and simultaneously produced additional food to sustain them as urban workers. Against this background, a series of new inventions helped transform economic life.

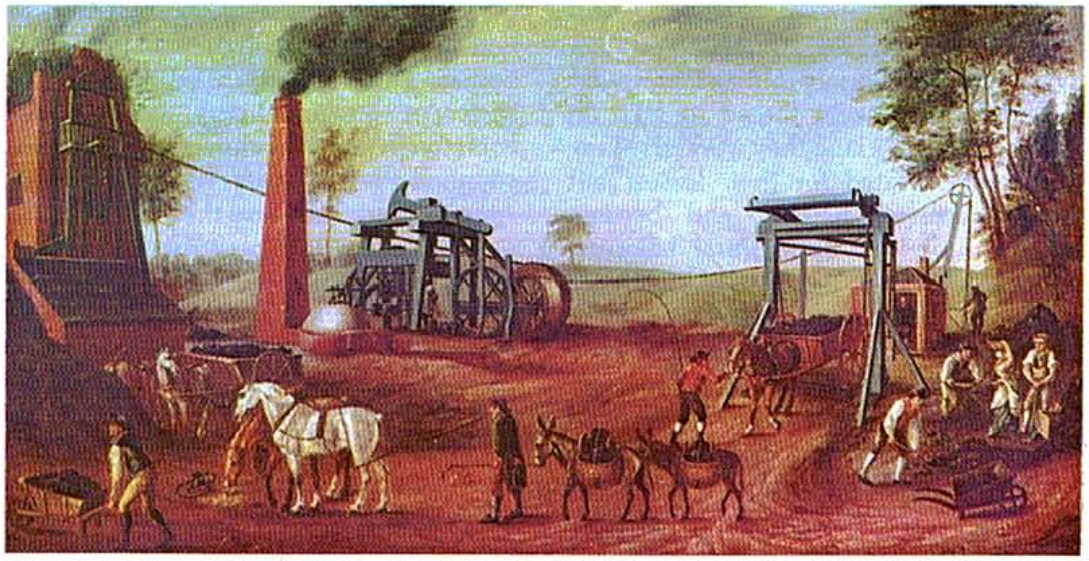
The industrialization of the textile industry helped create the factory system. Most industry prior to the late 18th century —with the exception of mining, shipbuilding, and sugar refining—was carried on with hand tools in small shops or in people's homes. This method, called the *domestic system* or cottage industry, was especially common in textile manufacture. Managers supplied the raw materials, and workers spun the yarn and wove the cloth at home.

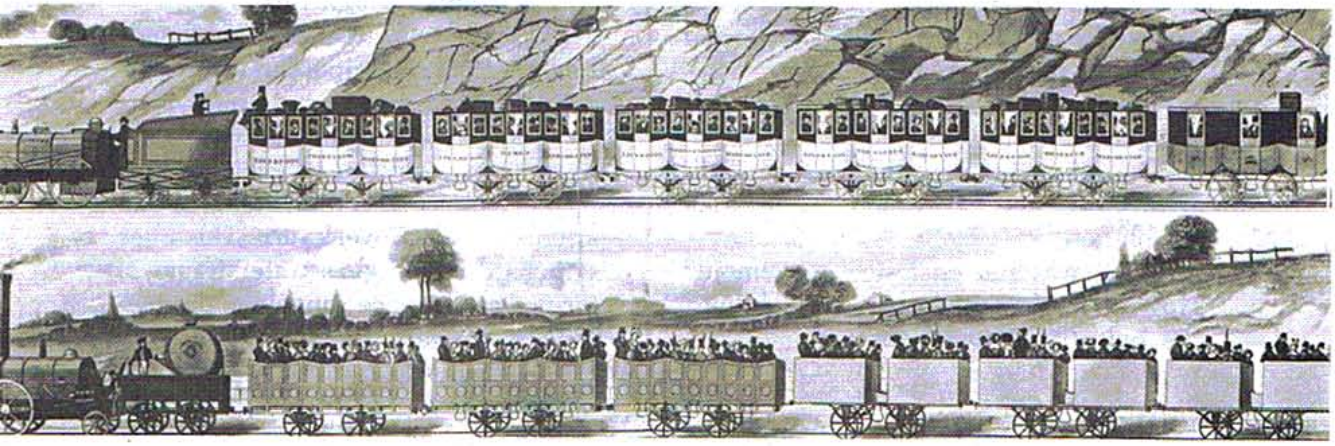
Early in the 18th century, the demand for cotton cloth from new city dwellers and from markets abroad became so great that old methods of production could not keep pace. In 1733 an English weaver named John Kay developed a "flying shuttle," which cut weaving time in half. Within a few years, his invention was widely adopted all over the land. This development created a new problem: spinners could not supply enough yarn.

For several years no solution was found, and then in 1769 two important inventions were patented. One was James Hargreaves' mechanized spinning wheel, the spinning jenny, which used eight bobbins instead of one; its chief drawback was that it produced a rather weak yarn. The other was Richard Arkwright's water frame, a water-powered device capable of producing fine, strong yarn. By 1779 a jenny spinner named Samuel Crompton found a way to combine the best features of both spinning jenny and water frame into a single machine. His "spinning mule" made excellent yarn that was the envy of his fellow spinners. At first the mule was driven by water power, but by 1830 it was adapted to steam.

These inventions ended the "famine in yarn" and for awhile transferred the bottleneck back to the weavers. A fortune awaited anyone who could devise a faster loom. In 1785 Edmund Cartwright patented a successful power loom, and by 1800 it was widely adopted throughout England.

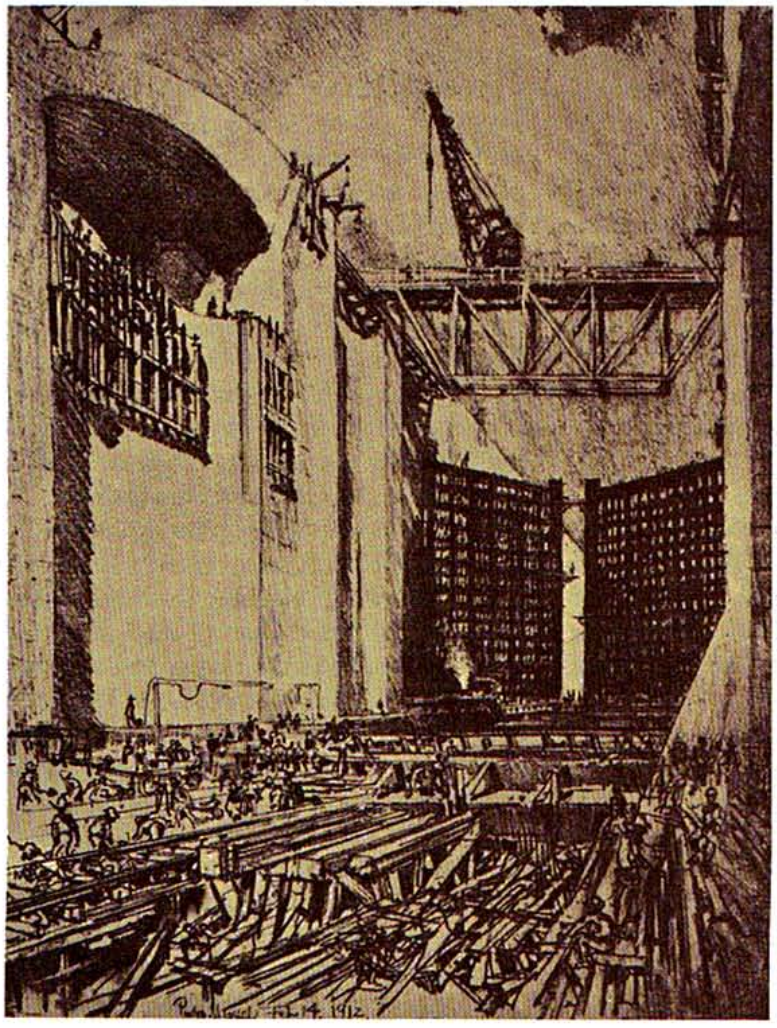
The new machines were used primarily in making cotton cloth. Supplies of raw cotton were limited because cleaning seeds from the cotton bolls took a long time.





Changes in Technology

Hardly an industry or occupation was untouched by the technological advances of the Industrial Revolution. At an English coal mine of the 18th century, top left, a Newcomen engine in the rear lifts loads of ore from mine shafts at left and right while workers collect the coal in wheelbarrows. The railroad industry itself was a product of the Industrial Revolution. A drawing of the Liverpool and Manchester Railway, middle left, compares the luxury of first-class coaches (above) to open third-class cars (below). Virginia farmers and their slaves gather to witness a demonstration of the McCormick reaper, bottom left. In a single day, such a machine could harvest six times as much grain as a man with a scythe. The scene below, drawn in 1912, depicts workers constructing one of the giant locks of the Panama Canal. Among man's most notable engineering achievements, the canal opened in 1914 and cut in half the sailing distance from New York to San Francisco. To the right is the munitions plant of the great Krupp steelworks in Germany. Alfred Krupp inherited a mill employing only four workers in 1848. He introduced the steam engine and enlarged his operations so that over 16 thousand men were employed by 1873. His method of casting steel was a family secret for years.



When a New Englander, Eli Whitney, went to Georgia in 1793 and learned of the problem facing Southern planters, he built a machine in ten days that could clean cotton as fast as fifty men working by hand. Whitney's cotton gin made possible a fifty-fold increase in the American cotton crop within twenty years. By 1820 cotton led all exports from the southern United States; in addition, it was the chief import of Great Britain.

With the introduction of mechanical power, employers found it more economical to group expensive machines together in factories close to convenient sources of power. This arrangement saved time and money, for instead of carrying material to the workers, manufacturers had the workers come to them. Employers could also make certain that their workers observed regular hours and did not waste raw materials. By centralizing production through the so-called factory system, employers could control the quality of goods more effectively and be assured of a steadier rate of production. They could also take advantage of new techniques such as mass production—that is, production in standard sizes and large numbers—which required a division of labor not possible in the domestic system.

Iron and steel manufacture was improved. Building many new mechanical devices required increased amounts of iron. The supply seemed limited, however, because most smelting was done with charcoal, which was not only slow and costly, but was also depleting English forests. In 1735 Abraham Darby began smelting ore with coke instead of charcoal; because of his success, the iron industry shifted from forest areas to the coal regions. In the 1780's Henry Cort, a contractor for the British navy, found that by "puddling," or stirring, molten iron with long rods in a furnace, he could quickly burn off many impurities and produce a large amount of wrought iron. He also developed a system of passing hot iron through heavy rollers, squeezing out further impurities and producing iron sheets that could be used for boiler plate and armor.

The manufacture of steel—stronger and generally more useful than iron—was aided by Sir Henry Bessemer, who in 1856 introduced a process for burning off impurities in molten iron to make steel. Ten years later another Englishman, Sir William Siemens, and a Frenchman, Pierre Émile Martin, developed a successful open-hearth furnace for smelting iron. Their system was widely adopted because it could make a greater range of steels.

Such technical advances made possible abundant supplies of cheap iron and steel, without which modern mechanized civilization would be impossible. Great steel centers grew up in areas blessed with stores of coal and iron ore, such as northern England, the Ruhr valley in Germany, and the Pittsburgh area in Pennsylvania. As iron and steel became more available, they were utilized to make machines of increasing size and complexity. In the sparsely populated western United States, for example, farmers were helped by machines developed to take advantage of plentiful rich soil. Cyrus McCormick demonstrated a horse-drawn reaper for grain in the 1830's. Hiram and John Pitts invented a threshing and winnowing machine in 1837. John Deere constructed an all-steel plow in 1847. In the 1880's the reaper and thresher were combined in a single machine, the combine. These mechanical improvements in farming helped open up the vast plains of America and, later, of Europe.

Transportation became faster and cheaper. In this field, as in farming, the early 18th century presented a picture little different from that of the Middle Ages. Roads were bad and travel by horse-

back or stagecoach was slow and uncomfortable. Some improvements were made when private companies began building roads in the early 18th century. Stone was used to pave these so-called toll roads. They were also called turnpikes because they were blocked by pikes, or gates, that were turned aside upon payment of a fee. As late as 1760, however, it still took two weeks to travel the 400 miles from London to Edinburgh. Greater advancements resulted after 1770 with the work of two Scottish engineers, Thomas Telford and John McAdam. Both advocated better drainage of roads and the use of layers of crushed rock; McAdam's economical method, known as macadamizing, became the basis for all modern road building.

Waterways also underwent change. Rivers were dredged to make them more easily navigable and in 1761 one of the first modern canals was dug. Built by the Duke of Bridgewater to link some of his coal mines with the city of Manchester, this seven-mile waterway was so successful that the price of coal in Manchester dropped over 80 per cent. A canal-building craze resulted. By 1830 England had one of the best inland waterway systems in the Western world. The mania spread to other countries, particularly the United States, where the Erie Canal was completed by the year 1825.

Meanwhile, there had appeared the steam engine. Building on experimentation of the 17th century, an English ironmonger named Thomas Newcomen invented a steam engine. From about 1705 onward, Newcomen engines were widely employed for pumping water out of mines. It was a model of one of these that James Watt was asked to repair in 1763. His new engine, patented in 1769, was over four times as efficient as its predecessor. After Watt found a way to adapt it to rotary motion in 1781, it could be used for purposes other than pumping water.

In the mid-1700's, iron rails—over which donkeys pulled carts—were in common use around English coal mines. It occurred to Richard Trevithick, an English mining engineer, that a steam engine on wheels would be more efficient than animal power. Trevithick built two such engines in the early 1800's, but they were used only at mines. In 1825 another mining engineer, George Stephenson, succeeded in constructing a locomotive that could do the work of forty teams of horses. When a group of businessmen decided to build a railway between Liverpool and Manchester, they offered a prize for the best locomotive. In a competition held in 1829, Stephenson won with his *Rocket,* which pulled a train thirty-one miles at an average speed of fourteen miles an hour. Stephenson's achievement set off a railroad building boom in England that reached its peak in the 1840's. By 1850 the most important routes were built and freight trains operated regularly. Western Europe and the United States began building railroads in the mid-1800's, and had almost completed their rail networks before the century was over.

The steam engine also had a drastic effect on water transportation. Robert Fulton, an American inventor, bought an engine from the firm of James Watt for use on a ship. In 1807 his *Clermont* steamed 150 miles from New York City up the Hudson River to Albany in only thirty-two hours. Fulton's was not the first steamboat, but it was the first to be a practical and financial success. In the next few decades steamboats came into common use on island waterways and short coastal journeys.

Ocean voyages presented more formidable problems. Until about 1880, the maritime world remained predominantly one of wind and sail. A good supply of wood from the Americas and, after the 1830's, the use of iron hulls, kept construction costs so low that sailing vessels could offer very low

rates. In 1838 a British ship, the *Sirius*, crossed from Liverpool to New York entirely under steam in eighteen days. By 1850 oceangoing steamships were firmly established in mail and passenger traffic because of their speed and regularity. Only after such inventions as the screw propeller, however, did steamships begin to displace sailing vessels for carrying cargo.

All the improvements in transportation reduced shipping costs, brought town and country within easy reach of one another, and knit nations more closely together.

Capitalism changed. The mercantile capitalism of the Commercial Revolution had been based essentially on trade and commerce. As industrialism grew in the 18th century, capitalism adapted to new kinds of enterprises. Called *industrial capitalism*, it was usually based on small companies managed directly by their owners (either one man or a group of partners).

Some industries, however, required extremely large amounts of capital because the equipment needed was so expensive. This was especially true of railroads and iron and steel manufacture. Since no one individual could supply this capital, some form of joint enterprise was necessary. The joint-stock companies that had come into existence during the Commercial Revolution had generally been confined to the field of overseas trade and colonization; they were also strictly limited by government charters. During the 19th century, there evolved a more flexible organization, the *corporation*. Unlike the joint-stock company, it was recognized legally as a distinct being, and so was able to own property, bring and defend suits at law, and maintain a continuous existence despite changes in shareholders or directors.

By the end of the 19th century, corporations had become the usual form of organization in the business world. They were managed not by their owners but by salaried executives who used other persons' money. The role of banks and financiers became increasingly important because of the large amounts of capital needed; thus the economic organization of the period after 1850 is known as *finance capitalism*.

Section Review

1. Summarize the chief steps in the mechanization of the English textile industry.
2. Explain why the introduction of mechanization led to the factory system.
3. What developments made iron and steel cheaper and more abundant? Show by example how increased use of iron and steel led to increased mechanization.
4. Describe some of the improvements in transportation that took place during the 18th and 19th centuries. How did these improvements affect society?
5. How did capitalism change as the pace of industrialization increased?

3 Science and medicine progressed rapidly

An increased willingness to adopt new ways of doing things helped spur the growth of industrialism; it also led to remarkable advances in science and medicine. In the 19th century, the great majority of Europeans became more science-minded than ever before. They were confident that science was the key that would unlock nature's secrets and open the door to limitless material progress.

Chemists and physicists made important discoveries. Chemistry was put on a new footing with the work of John Dalton, an English schoolteacher of the early 19th century. Dalton, like the Greek philosopher Democritus, believed that all matter is composed of invisible particles called atoms. He theorized further that all the atoms of any one chemical element are

alike and differ in weight from those of any other. Dalton said that in chemical compounds, atoms combined into units (now called molecules), and he devised a type of chemical formula to describe them. During the next fifty years, chemists discovered more elements and refined their methods of combining them. In 1869 a Russian, Dmitri Mendelyeev, drew up the Periodic Table, in which he classified in families all known elements (at that time sixty-two were known) according to their atomic weights. This classification enabled him to indicate gaps where other elements might be—and later were—found, and to describe these elements in advance with remarkable accuracy.

Important discoveries in physics helped establish the close relationships among electricity, magnetism, heat, and light. In 1800 Alessandro Volta of Italy, working on the principle that electric current can be produced by chemical action, made one of the first batteries. Hans Christian Oersted of Denmark discovered electromagnetism in 1820 when he found that current flowing through a wire would move a compass needle lying parallel to it. Further investigation of the connections between electricity and magnetism were carried on by an English scientist, Michael Faraday. In 1831 he showed that electric current could be produced by moving a wire through the lines of force of a magnetic field. Faraday's discovery, the first dynamo, was the basis for the electric generator.

Faraday's experiments inspired the Scottish scientist James Clerk Maxwell, who in the 1860's formulated exact mathematical equations to explain them. Maxwell theorized that light too was electromagnetic in nature. Using Maxwell's equations, physicists demonstrated the existence of other electromagnetic waves. It soon became clear that not only electric current and visible light, but also radiant heat and other invisible kinds of radiation were all electromagnetic waves of different lengths. In 1885 Heinrich Hertz of Germany proved the existence and measured the velocity of what were later called radio waves. Another German, Wilhelm Roentgen, in 1895 discovered rays that could penetrate solid substances; he called them X rays. In searching for similar rays, Pierre and Marie Curie of France isolated the element radium in 1898. Their discovery of this radioactive element was a milestone in the new field of atomic physics that was to revolutionize 20th-century science.

Increased scientific knowledge stimulated inventions. Many of the discoveries of pure science helped to solve problems posed by industrialism. During the 19th century, chemists analyzed nearly 70 thousand chemical compounds and developed portland cement, vulcanized rubber, synthetic dyes, nitroglycerin explosives, and celluloid. A German scientist, Justus von Liebig, discovered in the 1840's that the chemical composition of the soil had a direct bearing on plant life. His discovery explained why Townshend's rotation plan had worked, and opened the door to the development of commercial fertilizers.

Building on the work of Faraday and others, inventors improved electric generators so that they would provide steady supplies of electricity at a reasonable cost. The first electric motors were constructed in the 1870's, and it soon became possible to use electricity to propel trolley cars, trains, and ships. Engineers quickly adapted electric motors to power machines in factories.

In 1832 Samuel F. B. Morse of the United States made the first electric telegraph. Another American, Alexander Graham Bell, patented the telephone in 1876, and a fellow-countryman, Thomas A. Edison, developed the first practical electric light in 1879. A young Italian, Guglielmo Marconi, developed a wireless

telegraph which was put into operation across the English Channel in 1898; three years later, messages were transmitted across the Atlantic. All these inventions linked together the new world-wide economy and aided the growth of cities.

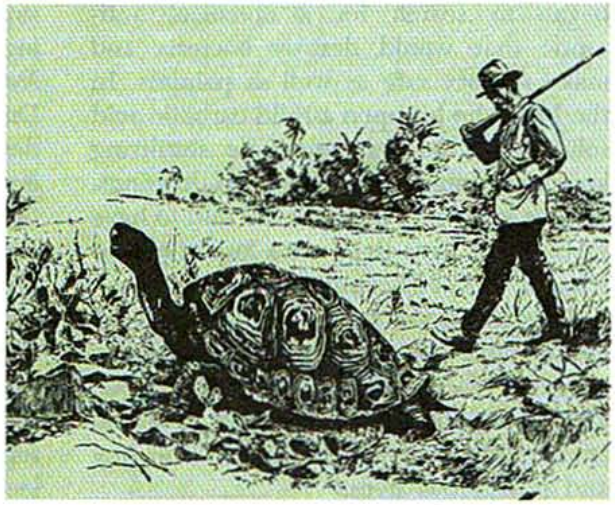
Other advances tapped rich natural resources as new sources of power. Fuel gas, although known since ancient times, was first manufactured and given a practical application in the late 18th century, when English and French scientists experimented with it for lighting. London, in 1807, became the first city to light streets with gas. As its use grew more widespread, natural gas reserves in America and Europe proved of great value. Another resource, petroleum, gave rise to a new industry in the middle 1800's, with the United States soon taking the lead. At first petroleum was in demand chiefly for lubrication and as a source of kerosene. In the 1860's and 1870's, however, scientists in France, Germany, and Austria began building internal combustion engines, the more advanced of which used gasoline for fuel. From then on, this by-product of petroleum became its most important use. As these engines were made lighter, the foundation was laid for the development of the automobile. Another type of internal combustion machine, the Diesel engine, was patented in 1892. It was designed to run on fuel oils instead of gasoline and found wide use in ships and locomotives, for though the engines were heavier than gasoline engines, they operated more cheaply.

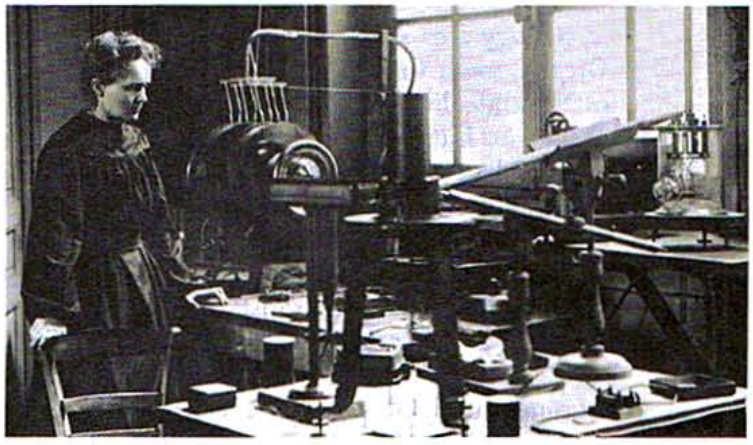
Medical research lengthened the human life span. Modern medicine advanced greatly with the work of an English physician, Edward Jenner, who developed vaccination as a preventive against smallpox, for centuries a dread and often fatal disease. In 1796 he inoculated a boy with the virus of cowpox (a mild disease related to smallpox). When the boy was later inoculated with smallpox, he did not fall ill.

The field of surgery benefited from new developments in chemistry. Until the mid-19th century, surgeons operated on patients who shrieked with pain as they were held down by force. In the 1840's several Americans experimented successfully with various anesthetics; in 1846 W. T. G. Morton, a Boston dentist, publicly demonstrated the value of ether during an operation at Massachusetts General Hospital. News of this event prompted experiments by Sir James Simpson, an English professor of medicine at the University of Edinburgh, who discovered chloroform. The use of anesthetics resulted in painless surgery, and also made it possible to perform medical research on living animals.

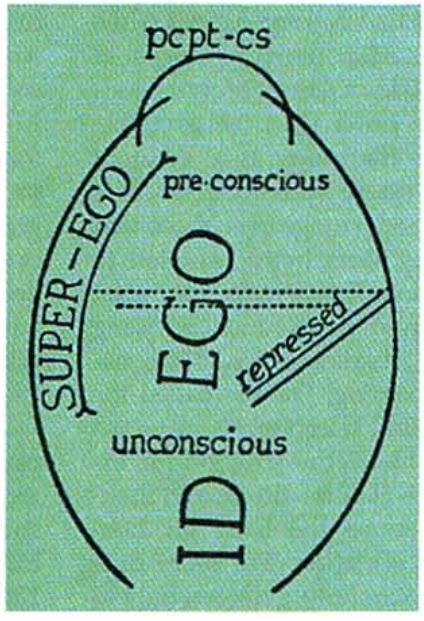
Although operations grew less fearsome, they were still very often fatal. Infection was quite common because sterilization was unknown. Surgeons wore their operating coats for years without washing them. One problem was that the cause of infection was not understood. It was a great French scientist, Louis Pasteur, who proved conclusively that infectious diseases are caused by microscopic organisms. In the 1850's, Pasteur began a study of fermentation and, finding that it was caused by certain bacteria, invented a heating process (later named pasteurization) to retard it. In the 1870's Pasteur worked with another scientist, Robert Koch of Germany, in studying the infectious disease anthrax. Koch isolated the organism that caused the disease, and Pasteur in 1881 developed a vaccine to prevent it. Pasteur went on to investigate rabies; in 1885 he successfully inoculated a little boy who had been bitten by a mad dog. Koch meanwhile discovered the individual organisms that caused eleven diseases, including tuberculosis and cholera.

Profiting from the new germ theory of disease, Joseph Lister, an English surgeon,





Scientists had a great impact on 19th-century intellectual life. Above left, Pasteur records experimental data on rabbits. Darwin gathered a wealth of evidence for his theories; above right, he observes a giant tortoise. Madame Curie, right, stands in her laboratory. Freud and a diagram of the psychological system he devised are shown below. Unconscious impulses arising from the id are modified by the ego (conscious self) and the superego (like the conscience).



began to search for a chemical antiseptic that would destroy bacteria and make surgery safe as well as painless. In the 1860's he hit upon a mild carbolic acid solution as the best agent for sterilizing hands, instruments, wounds, and dressings. Lister's antiseptic methods are said to have saved more lives than were lost in all the wars of the 19th century.

Like the development of modern agriculture and industry, these discoveries in medicine increased mankind's life span and made possible the growth of urban communities where men could live healthy and prosperous lives.

Biology was revolutionized. In ancient Greece, some thinkers had held that the earth and living organisms were not changeless but had developed from simple to complex forms through a process of evolution. Several 19th-century scientists advocated the idea of continuous development and change from past to present, but no one could explain satisfactorily how the evolutionary process worked in nature.

Charles Darwin, an English naturalist, became interested in why there was such a great variety of plants and animals, and why some types had become extinct while others lived on. After much reading and study, he reasoned as follows: Most animals tend to increase faster than the available food supply, so that there is a constant struggle for existence. Those that survived must have some advantage over those that perished, making them better adapted to their environment. Hence only the fittest survived and lived to produce offspring with the same characteristics. This, nature's way of choosing, Darwin called the principle of natural selection.

These three ideas—the struggle for existence, the survival of the fittest, and natural selection—became the basis for Darwin's theory of evolution. For more than twenty years he carefully gathered data to support it, and in 1859 published his findings in *The Origin of Species by Means of Natural Selection.* The implications of Darwin's theory were that all living things developed through evolution, that they all evolved from simpler forms over eons of time, and that they probably had a common ancestor. In *The Descent of Man* (1871), Darwin theorized that human beings and apes were probably descended from a common ancestor.

Like the heliocentric theory of the 16th century, Darwin's theory of evolution had repercussions throughout European intellectual life. The churches in particular were aroused by it, for Darwin's theory seemed to contradict the Biblical account of creation. For half a century a heated controversy raged between the defenders and opponents of Darwinism. Eventually, however, many persons, including churchmen, came to feel that science dealt with certain aspects of human life and religion with others. Thus, they concluded that no real conflict existed between Darwinism and Christianity.

Another objection to Darwin's theory was that it did not sufficiently explain how characteristics were actually passed on from one generation to another. Pioneering work in the field of heredity was done by an Austrian monk named Gregor Mendel. After careful experiments with plants, he found that inherited characteristics are carried by minute particles (now called genes). Although Mendel's laws of heredity did not receive wide recognition when first formulated in the 1860's, they were later regarded as the foundation of the science of genetics.

Psychology became a science. Modern psychology, the science of human behavior, grew from the work of physicians who studied men's conscious experiences, especially the operation of the senses. In the 1890's a Russian, Ivan Pavlov, went much

further. In a series of experiments, he gave food to a dog while ringing a bell. Food and bell became so closely linked that the dog eventually watered at the mouth when a bell was rung, even if no food were present. Pavlov's experiments with dogs influenced scientists' attitudes toward human beings. Many of them took the view that a person's reason was not responsible for his or her actions, but that many human responses were the result of mechanical reactions to stimuli.

Most important of all was the work of a Viennese physician, Sigmund Freud. He believed that people often act in response to unconscious needs and desires. In the 1890s, he devised psychoanalysis as a method of revealing unconscious motives and developed a complex theory to explain how they worked. By making people aware of the powerful emotional impulses that determine their behavior, Freud provided new insights in understanding human beings and new methods for treating mental illness.

Section Review

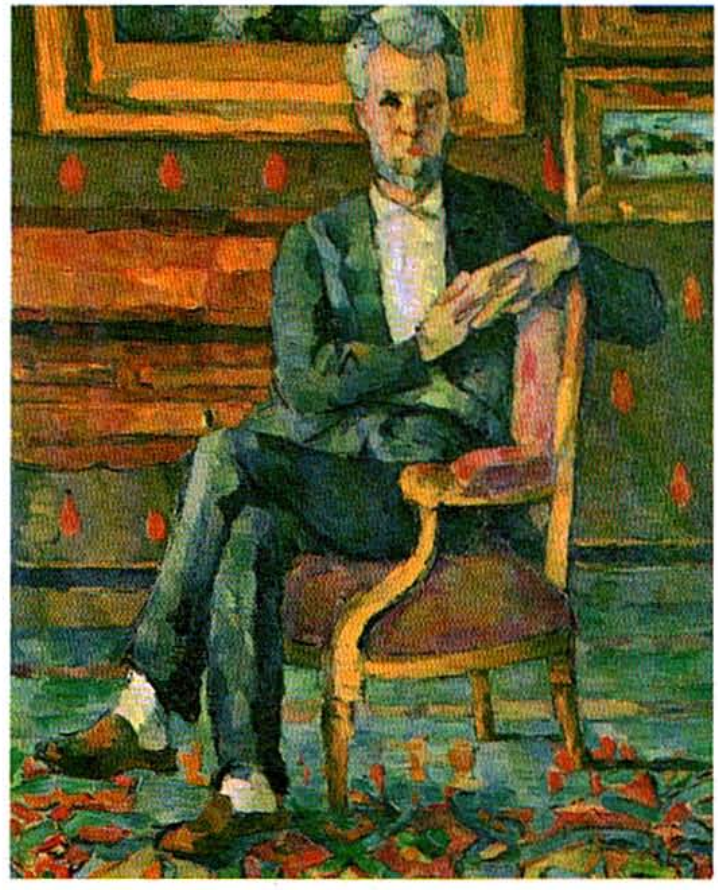
1. What contribution to chemistry was made by Dalton? by Mendelyeev?
2. Describe at least six discoveries in physics that were made in the course of the 19th century.
3. What were some of the practical inventions in transportation, communication, heating, and lighting that resulted from important scientific discoveries of the 19th century?
4. What advances in medical research during the 19th century helped to lengthen the human life span?
5. Explain the basic principles of Charles Darwin's theory of evolution. What additional contribution in biology was made by Gregor Mendel?
6. Describe briefly the work of Ivan Pavlov and Sigmund Freud in the field of psychology.

4 The arts displayed great vigor

The 19th century was a period of tremendous activity in the world of literature and the fine arts. Here, too, the impact of industrialism was evident. Some writers and artists deliberately turned their backs on the confusion and bustle of contemporary life in favor of fantasy, the exotic, or the past. Others tried to understand and describe the forces that were changing society. As the middle class grew in size and influence, it became increasingly important as an audience for creative works. Artists, writers, and musicians were no longer dependent on the patronage of the wealthy for their support. As a result, they enjoyed greater freedom to express their own ideas in a variety of different art forms.

Romanticism dominated the early 19th century. Toward the end of the 18th century, there developed a reaction against the excessive emphasis on reason that characterized the Enlightenment. Several artists and thinkers adopted a different outlook, called *romanticism;* a forerunner of the movement was Jean Jacques Rousseau, a French social philosopher. Romantics argued that man must take account of emotion, intuition, and imagination. Feelings of love and responses to beauty and religion, they said, could not be explained exclusively in rational terms. As artists, romantics wished to free themselves from rigid neoclassical forms and models, which had allowed little scope for personal feelings. They believed above all that art must reflect the artist as a distinct and unique expression of his own being. Romanticism also represented a reaction against the ugliness and materialism of an increasingly industrial society.

In literature, there was a great diversity of themes as writers let their imaginations roam freely. One was a stress on liberty. A



Painting of the 19th Century was dominated by French artists. Claude Monet was an outstanding impressionist. In his painting of a park scene entitled "The Frog Pond," left, the shimmering water almost seems to move. One reason for this vibrancy is that the colors, instead of being blended on the canvas, are "mixed" in the viewer's eye. Another notable impressionist was Edgar Degas. In his painting of two laundresses, below left, he has caught a fleeting moment at the ironing table. Paul Cézanne, a post-impressionist, was more interested in exploring three-dimensional reality than in portraying surface effects. Bands of rich color create a feeling of depth in his portrait of a friend, Victor Chocquet, shown at right.

German movement known as *Sturm und Drang* (Storm and Stress) glorified individualism and defiance of authority. Its members included Johann Friedrich von Schiller, whose drama *William Tell* dealt with the Swiss struggle for freedom; and Johann Wolfgang von Goethe, author of the epic drama of human striving, *Faust* (Part I, 1808; Part II, 1833). A spirit of rebellion also characterized two great English poets, Lord Byron and Percy Bysshe Shelley.

Another aspect of the Romantic Movement, a belief in beauty as a fundamental standard superior to ethical ones, is best exemplified in the work of another English poet, John Keats. Two famous lines from his poem, *Ode on a Grecian Urn*, express this attitude:

> "Beauty is truth, truth beauty,"—that is all
> Ye know on earth, and all ye need to know.

An important romantic theme was nature, treated not as the orderly, mechanical system pictured by 18th-century thinkers, but as having a mystical beauty, especially in its wild state. The English poet William Wordsworth discarded the artificial poetic expressions of neoclassic writers and used instead what he termed the "very language of men" to express his love of nature. Wordsworth and other romantics, following Rousseau's example, regarded primitive men—and the common people at home—as noble and virtuous because they were unspoiled by the artificialities of civilization. Thus, romantics developed a great interest in myths, fairy tales, and folk

songs. Some of the great collections of this material, such as the folk tales of the Grimm brothers, are products of the Romantic Movement.

Believing as they did in the inadequacy of reason, some romantics turned for inspiration to dreams, fantasies, and the supernatural. Examples of this approach are *Rime of the Ancient Mariner* (1797) by Samuel Taylor Coleridge, an Englishman, and the poetry of the American Edgar Allan Poe. Interest in the exotic also led the romanticists into rediscovering the Middle Ages, shunned by 18th-century thinkers as barbaric. The romantics regarded the medieval period as the golden age of chivalry, justice, romance, and adventure. Such feelings are reflected in the novels of Sir Walter Scott of Scotland and Victor Hugo of France.

Painting, like literature, reflected romantic attitudes. Eugène Delacroix of France, a master of color, painted exotic scenes as well as subjects inspired by the political revolts of the 1820s and 1830s. The painters of England, like its poets, found inspiration in nature. The work of John Constable and J. M. W. Turner had a fresh, dramatic quality considered revolutionary by the other landscape painters of the time.

Architecture exhibited the influence of romanticism primarily as a renewed interest in the Gothic style of the Middle Ages. In France and Germany much work was done in restoring medieval buildings that had fallen into decay. In England, when the old Westminster Palace burned down in 1834, new Parliament buildings were constructed completely in Gothic style. Churches, houses, and public buildings bristled with pointed arches, flying buttresses, and turrets.

Romanticism in music, as in the other arts, represented a break with tradition. Composers expanded 18th-century forms to make them more varied and expressive; for example, the symphony became much longer and more complex. Technical improvements also broadened the range of musical expression. The orchestra grew in size, and many instruments were made easier to playq1. The harpsichord was replaced by the piano, which had greater flexibility. All of these changes are evident in the music of Ludwig van Beethoven, whose great symphonies and chamber music served as a bridge between classicism and romanticism.

Romantic composers used music to portray personal emotions. The hundreds of songs written by Franz Schubert covered a wide range of lyric expression. Other trends that characterized romantic music were the use of folk themes and the importance of the virtuoso performer. Both trends are evident in the careers of two composer-pianists: Frédéric Chopin of Poland and Franz Liszt of Hungary.

Later movements reacted against romanticism. By the mid-19th century, the exaggerations of some romantic art stimulated a reaction against its principles. Much of it had become merely sentimental and, in an age that admired *Realpolitik*, its otherworldliness seemed out of date. Romanticism did not disappear completely, but it was no longer the dominant tone of the arts.

In literature, the reaction against romanticism frequently took the form of *realism*. Realists, like the romantics, were aware of the harsh social conditions of their times. But while romantics sought escape from them, realists wanted to present life as it actually existed. In avoiding romantic idealism, realists tended to stress the sordid aspects of life and to emphasize the evils of society. Even the English poet Alfred, Lord Tennyson, while predominantly a romantic, expressed in some of his work the troubled attitudes of his contemporaries toward their changing world.

One group of literary realists wanted to stimulate public awareness of various problems, educating their readers as well as entertaining them. One of the greatest of these was the Englishman Charles Dickens. Although he was romantic enough to enliven his novels with sentiment, whimsy, and melodrama, he was also a severe social critic who portrayed the poor and downtrodden to call attention to needed reforms. *Oliver Twist* (1837–1839) depicted the abuses of children in workhouses and slums; *Nicholas Nickleby* (1838–1839) and *David Copperfield* (1849–1850) exposed the injustices of education; and *Bleak House* (1852–1853) dealt with the social evils of the legal system. In France, Honoré de Balzac wrote a panoramic series of over ninety novels, *The Human Comedy,* which presented a searching picture of lower- and middle-class French life. Many of his novels attacked greed and social climbing.

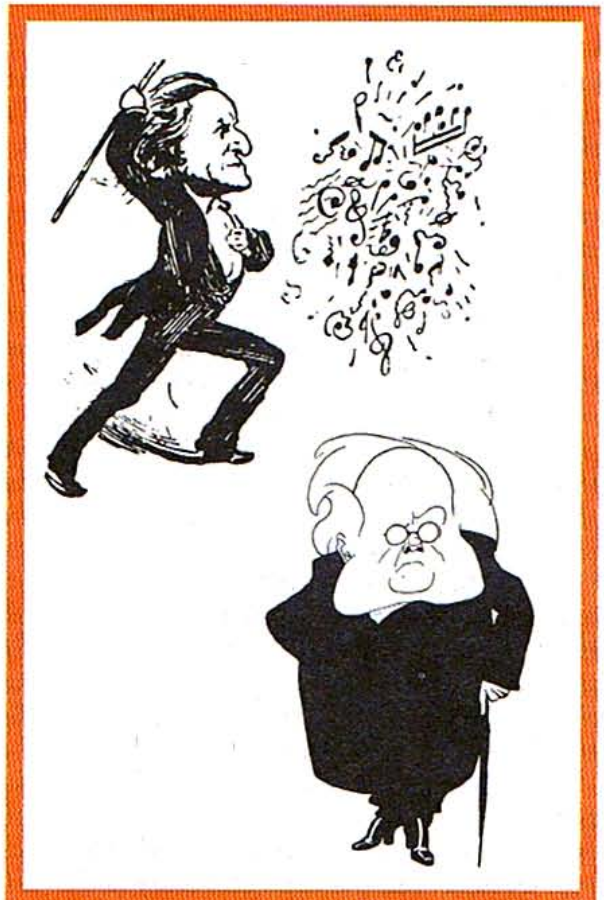
Mark Twain described with humorous accuracy life in the American Midwest and on the frontier. At the same time his writings underscored the evils of slavery and other social injustices. A Norwegian, Henrik Ibsen, developed a new form of realistic drama through which he presented many problems previously considered too controversial to discuss in public. In his best-known play, *A Doll's House* (1879), he attacked loveless marriage as immoral.

Other realistic writers particularly excelled in portraying character. In *Madame Bovary* (1857), Gustave Flaubert of France described with objectivity the downfall of a weak woman obsessed by romantic love. Russia produced two great novelists whose work shows penetrating psychological insight—Feodor Dostoevski, who wrote *Crime and Punishment* (1866) and Leo Tolstoy, author of *War and Peace* (1862–1869) and *Anna Karenina* (1875–1877).

In England, William Makepeace Thackeray wrote with detachment about human foibles and created unforgettable characters in his *Vanity Fair* (1847–1848). A similar interest in character—although with more emphasis on traditional moral values—motivated the work of the woman novelist George Eliot. Subtle analysis of human personality through poetry was the great achievement of Robert Browning in his "dramatic monologues" such as "My Last Duchess" and "Fra Lippo Lippi."

Another group of writers, the naturalists, tried to be as objective as scientists in describing a "slice of life." They felt that writers should tell their stories without comment or any expression of their own emotions. The outstanding representative of this school was the French novelist Émile Zola, who wrote about various members of a family in books that are almost clinical case histories.

In painting, realism had its spokesman in Gustave Courbet, the son of a French peasant. He believed in painting people and places as they were, and once remarked that he did not paint angels because he had never seen one. Courbet, by inspiring other painters to break with the romantic tradition, helped stimulate a movement known as *impressionism.* The impressionists developed new techniques for depicting light and color on canvas and tried to present an impression of a scene at a given moment, undistorted by subjective feelings. Famous painters in this style—all of whom were Frenchmen—included Claude Monet, Edgar Degas, and Auguste Renoir. Impressionism, however, by emphasizing fleeting moments, brought its own reaction. Paul Cézanne of France, a leader of the post-impressionist school, concentrated on the elements of space and solidity. A Dutch artist, Vincent van Gogh, used vivid colors and bold outlines to convey his heightened emotions about people and places.



Creative Personalities brought new and often controversial ideas to the literature and music of the 19th century. Lord Byron of England, above, rebelled against conventional social standards and became a symbol of the poet in revolt. The German composer Richard Wagner is cartooned above right, conducting amid a welter of bruised notes. One critic called his music an "inflated display of noise and extravagance." Playwright Henrik Ibsen of Norway, center right, also drew indignant criticism. His "problem plays" were designed to provoke thought rather than entertain. The realistic novelist Leo Tolstoy, lower right, hated inequality and believed that everyone should earn his living by physical labor. In his later years, he renounced his Russian title and worked in the fields among the peasants.

Architecture felt the impact of a realistic approach as architects abandoned Gothic imitations in favor of more original styles. One reason for the change was a variety of new structural materials such as steel, reinforced concrete, and stronger glass. In the United States, Louis Sullivan developed the doctrine of *functionalism*, based on the principle that buildings must be constructed to suit their functions. A modern bank, he said, should not look like a Greek temple, nor a warehouse like a medieval castle. Sullivan was a pioneer builder of skyscrapers, which combined new materials and new designs.

Music in the late 19th century reflected various trends. The German composer, Johannes Brahms, continued the romantic tradition in his symphonies, as did the Italian Giuseppe Verdi, who composed such great operas as *Rigoletto*, *La Traviata*, and *Aida*. Strong nationalist feeling inspired the work of Richard Wagner of Germany. Using Germanic folklore as the basis of his "music dramas," he integrated plot, poetry, music, and stagecraft to create a unified impact. Russia produced an entire school of nationalist composers, including Modest Moussorgsky and Nikolay Rimski-Korsakov, who drew upon Russian folk themes in their compositions. More romantic was Peter Tschaikowsky, whose gift for melody made his works among the most popular of all classical compositions. The French composer Claude Debussy, like the impressionists in painting, used unusual techniques to gain brilliant, shimmering effects.

Section Review

1. What were the chief characteristics of romanticism? Show, with specific examples, how they were reflected in literature.
2. How was romanticism expressed in painting? architecture? music?
3. Describe the following movements: literary realism; naturalism; impressionism; functionalism.

Chapter 21 A Review

Section 1

The Industrial Revolution, a dramatic speed-up in Western economic life, consisted of a vast number of interrelated discoveries, inventions, and processes. It began in England, where conditions were particularly favorable. The development of industrialism was aided by an Agrarian Revolution, which increased food production and freed laborers from farms to swell the urban labor force.

Section 2

Economic life was changed by a series of developments in technology. In a pivotal industry, that of textiles in England, a rapid shift from hand to machine methods stimulated the factory system in this and other fields. Of special significance were innovations in iron and steel manufacture and mechanized farming. Improvements in transportation—better roads, networks of canals and railroads, and the displacement of sailing vessels by steamships—knit regions more closely together. Capitalism itself adapted to new conditions; old methods of business organization were replaced by industrial and, later, by finance capitalism.

Section 3

Meanwhile, the scientific spirit flowered to produce an ever increasing stream of new discoveries that broadened people's knowledge of the world. Beginning with the work of Dalton, a chain of developments in chemistry and physics wrought profound changes within a few decades. Inventors like Morse, Bell, Edison, and Marconi made contributions in the field of communications that further united the world. Scientists found and exploited new power sources, such as gas and oil. In medicine, one of

the greatest advances was Pasteur's germ theory of disease, which aided in the conquest of such age-old enemies as rabies and tuberculosis. Knowledge of new chemicals helped in developing painless surgery and antiseptics. The theories of Darwin, Mendel, and Freud opened up entire new fields of scientific investigation.

Section 4

The dynamic changes of the period were naturally reflected in literature and the other arts. The ordered neoclassicism of the Age of Reason gave way to romanticism, which pervaded most of the arts until the mid-1800s. As the century progressed, it brought a bewildering variety of forms and movements—among them the literary realism of Dickens, Flaubert, and Zola; the shimmering impressionistic painting of Monet and Renoir; the functional architecture of men like Sullivan; and the nationalism of such composers as Wagner and Moussorgsky.

The Time

Indicate the period in which each invention, discovery, or book listed below appeared.

(a) 1751-1800
(b) 1801-1850
(c) 1851-1900

1. Coleridge's *Rime of the Ancient Mariner*
2. Deere's all-steel plow
3. Stephenson's *Rocket*
4. Edison's electric light
5. Fulton's *Clermont*
6. Pasteur's anthrax vaccine
7. Morse's telegraph
8. Flaubert's *Madame Bovary*
9. Watt's steam engine
10. Hargreaves' spinning jenny
11. Bessemer's steel-making process
12. Dickens' *Oliver Twist*
13. Faraday's dynamo
14. Darwin's *The Origin of Species by Means of Natural Selection*

The People

1. What contribution did each of the following people make to his or her field?

AGRICULTURE

Tull	Townshend	Bakewell
Deere		

IRON AND STEEL PRODUCTION

Darby	Siemens	Bessemer

COMMUNICATION

Morse	Bell	Marconi

MEDICINE

Lister	Koch	Pasteur

CHEMISTRY AND PHYSICS

Hertz	the Curies	Liebig
Mendelyeev	Faraday	Roentgen
		Volta

BIOLOGY AND PSYCHOLOGY

Darwin	Mendel	Pavlov	Freud

2. Classify the following writers as romanticists, realists, or naturalists.

Dickens	Keats	Flaubert
Schiller	Ibsen	Browning
Balzac	Wordsworth	Coleridge
Goethe	Grimm brothers	Hugo
Twain	Zolá	Thackeray

3. Which of the following painters were romanticists? realists? impressionists? post-impressionists?

Delacroix	Courbet	Constable
Cézanne	Renoir	Monet

Key Historical Terms

1. What was the *domestic system?*
2. Explain the terms *industrial capitalism* and *finance capitalism.*
3. What is a *corporation?*

4. Define each of the following terms and give an example to illustrate the trend in literature or the arts that it represents: *romanticism, realism, naturalism, impressionism, functionalism.*

Questions for Critical Thinking

1. Why did the Industrial Revolution begin in England and not in Germany or Russia?

2. What ideas and attitudes are revealed in the literature, art, architecture, and music of the 19th century?