CHAPTER 20

The Agricultural and Industrial Revolution

TIME LINE

1712	The Newcomen steam engine is used to pump water from a coal mine
1733	John Kay invents the flying shuttle
1764	James Hargreaves invents the spinning jenny
1769	Richard Arkwright patents the water frame
	James Watt patents a more efficient version of the Newcomen steam engine
1779	Samuel Crompton perfects the spinning mule
1784	Arthur Young establishes the *Annals of Agriculture*
1785	Edmund Cartwright patents a power loom
1793	Eli Whitney invents the cotton gin
1807	Robert Fulton's steamboat, the *Clermont,* goes into service on the Hudson River
1830	George Stephenson's locomotive, the *Rocket,* operates successfully on the Liverpool to Manchester railroad
1834	Cyrus McCormick patents the reaper Samuel E B. Morse invents the telegraph
1840	Samuel Cunard begins regular transatlantic steamship passenger service Great Britain inaugurates the penny post
1856	Henry Bessemer develops the Bessemer converter
1859	The first commercially successful oil well is drilled in Pennsylvania
1866	The Siemens brothers develop the open-hearth process of steelmaking
1876	Cyrus Field lays the first successful transatlantic cable
1876	Alexander Graham Bell invents the telephone
1879	Thomas A. Edison invents the incandescent light bulb
1892	Rudolf Diesel patents the diesel engine
1899	Guglielmo Marconi transmits a wireless message across the English Channel
1903	The Wright brothers make the first successful airplane flights

The agricultural and industrial revolutions brought immense changes to the economy of Europe and ultimately, the world.

During the eighteenth and nineteenth centuries. the pace of the agricultural revolution quickened. The development of scientific agriculture. the introduction of new crops. the enclosure of agricultural land. and increasing mechanization expanded agricultural production and ended the specter of famine in Europe. Fewer

farm workers were needed to produce food for Europe's growing population. and surplus agricultural labor migrated to the new industrial towns to find employment in the factories.

The industrial revolution. which began in Great Britain in the late eighteenth century. involved a number of elements. including the invention of power-driven machinery. the introduction of the factory system. and advances in the production of coal and iron and eventually. steel. In addition. the expansion of banking and credit facilities and the broader application of the principle of limited liability to business organization helped promote the process of industrialization. The industrial revolution was both accompanied and encouraged by contemporaneous revolutions in transportation and communications.

The Agricultural Revolution

The industrial revolution was preceded and accompanied by a revolution in agriculture. in which Great Britain led the way. as it would later do in the industrial revolution.

The Development of Scientific Agriculture

During the seventeenth and eighteenth centuries, science and technology were increasingly applied to British agriculture.

Influence of Tull and Townshend

Around 1700, Jethro Tull (1674-1741) developed a device that planted seeds in neat rows. Tull's seed drill replaced the less efficient method of scattering the seed. Viscount Townshend (1725-1767), an eighteenth-century aristocrat and statesman, urged Britain's farmers to plant clover, which would nourish the soil, and to practice crop rotation. Townshend also advocated the growing of turnips, which would both enrich the soil and provide food for livestock during the winter months. Townshend was such a fervent promoter of turnips that he gained the nickname "Turnip" Townshend. The increased cultivation of turnips ended the need for the mass slaughter of livestock at the onset of winter, and fresh meat gradually replaced salted meat in the British diet during the winter months.

Advances in Livestock and Agricultural Techniques

Later in the eighteenth century, Robert Bakewell (1725-1795) introduced the scientific breeding of cattle and sheep, while Arthur Young (1741-1820) became an effective publicist for the new methods of scientific agriculture, founding the periodical *Annals of Agriculture* in 1784.

Early in the nineteenth century, German agricultural scientists succeeded in extracting sugar from beets. The cultivation of sugar beets soon ended Europe's dependence on imported cane sugar. A few years later, Justus von Liebig (1803-1873) and other German chemists developed chemical fertilizers.

Inventions of Farm Machinery

The invention of the reaper, patented by Cyrus McCormick (1809- 1884), an American, in 1834, represented a major step forward in the application of technology to agriculture. The combine, a harvesting machine that threshed the grain as it was reaped, was developed later in the nineteenth century.

New Crops

Scientific and technological advances in agriculture were accompanied by the introduction of new crops. The potato, which originated in the Western Hemisphere, had become the basic foodstuff of Ireland by the mid-eighteenth century, although many continental Europeans continued to believe that potatoes were poisonous. During the eighteenth century, peas and new varieties of beans were introduced into Great Britain from the Netherlands.

British advances in agriculture won only gradual acceptance on the European continent. Nevertheless, the agricultural revolution ultimately made it possible for Europe to feed its growing population.

The Enclosure Movement

The agricultural revolution in Great Britain was accompanied by an intensification of the enclosure movement, which had begun during the sixteenth century. Enclosure involved the efforts of landowning aristocrats and country gentry to enclose common land by building fences and stone walls and planting hedges, thereby ending the medieval practice of providing free access to grazing lands and woodlands. By the early years of the nineteenth century, almost all of England's agriculturally useful land had been enclosed. While peasants were supposed to receive their fair share of the enclosed land, they were often cheated in practice.

The enclosure movement resulted in an increase in the number of large and medium-sized farms, as well as an increase in the production of food and other agricultural products. At the same time, many peasants were reduced to the status of impoverished farm laborers. A growing number of these displaced peasants migrated to the industrial towns to find employment in factories.

The Industrial Revolution

Although the precise reasons for Great Britain's leadership in the industrial revolution cannot be fully explained, several elements helped make that role possible. First of all, Great Britain possessed ample resources of coal and iron, which were basic necessities for modem industry. In addition, British merchants had become wealthy as a consequence of their activities during the commercial revolution and thus had capital available for investment in the new industries. The British could also apply their mercantile experience to sell the products of their industries in the world market. Furthermore, the British government adopted policies designed to promote the interests of the country's merchants and industrialists.

The Cotton Textile Industry

The British cotton textile industry, centered in the area of Lancashire and its major industrial town, Manchester, was the first to experience the application of power-driven machinery on a wide scale.

Invention of Machinery

In 1733, John Kay (1704-1764), a Lancashire weaver, invented the **flying shuttle**, which enabled one weaver, rather than two, to operate a loom. In the mid-1760s, James Hargreaves (d. 1778) invented a spinning machine that he called the **spinning jenny**. in honor of his wife. Although the spinning jenny made it possible for a single worker to spin a number of threads simultaneously, the thread produced was relatively weak.

The **water frame**, patented by Richard Arkwright (1732-1792) in 1769, produced a stronger thread, although it was coarser than that made by the spinning jenny.

In 1779, Samuel Crompton (1753-1827) perfected a spinning machine called the **mule**, which combined the best features of the spinning jenny and the water frame and produced thread that was both fine and strong.

The first **power loom** was patented by Edmund Cartwright (1743- 1823) in 1785.

As the new textile machinery was placed in wider use, the demand for raw cotton grew. The problem of removing the seeds from the cotton, however, made it difficult to meet the demand. Then, in 1793, the American Eli Whitney (1765-1825) invented the **cotton gin**, an effective device for removing the seeds from the cotton fiber. The cotton textile industry benefited from other inventions as well. Mechanical engineers studied the techniques used by watchmakers and developed **precision parts** that increased the operational efficiency of the new machines. The next step involved the

development of **standardized. interchangeable parts** for industrial machinery. Eli Whitney, who operated an arms factory in Connecticut, made important contributions to this development.

In the 1780s, a **rolling press** was introduced for the printing of textiles. replacing the hand-operated plates that had previously been used.

French Technology

French inventors made significant contributions to the cotton textile industry. Count Berthollet (1748-1822). a chemist. developed a process for using chlorine to bleach cloth that reduced the time required for bleaching cloth from months to hours. Joseph-Marie Jacquard (1752-1834) developed a power loom capable of weaving intricate patterns.

The Factory System

The introduction of larger and more complex industrial machinery gradually resulted in the construction of factories. which replaced small workshops and cottage-based industries.

In England. some workers blamed machine industry for their low wages and unemployment. Between 1811 and 1816. angry mobs of workers assaulted factories and smashed machines. These Luddites, as they were known. were named for Ned Ludd, who had destroyed machinery a generation earlier.

Development of the Steam Engine

The invention and perfection of the steam engine provided a dependable and efficient source of power for the new industrial machinery.

About 1700, Thomas Savery, an English inventor, built a practical steam pump. A few years later, Thomas Newcomen (1663-1729) built a steam engine that was first used in 1712 to pump water from a coal mine. Although it was wasteful of fuel, the Newcomen steam engine met a need, and by 1760 about one hundred Newcomen engines were operating in Great Britain.

In 1769, James Watt (1736-1819) patented a more efficient version of the Newcomen engine. Watt's steam engine required substantially less fuel.

While most of the early steam engines were used to pump water, by 1800 several hundred steam engines powered machinery in cotton textile mills and other factories.

Coal, Iron, and Steel

The interrelationship among the steam engine, coal mining, and iron production was a central aspect of the early industrial revolution.

Coal

The steam engine was used not only to pump water out of coal mines but also to power ventilating fans that pushed fresh air into the mines, making it possible for the miners to work longer hours underground. Coal mining also benefited from the invention of the safety lamp, in which an oil flame burned behind a metal screen, reducing the danger presented by dangerous gases in the mines. These technological innovations led to a tremendous increase in British coal production.

Iron

The increased production of coal provided the fuel needed to power the growing number of steam engines. These steam engines, in turn, were also applied to the production of iron. The steam engine was an essential part of the blast furnace, which produced a purer and stronger iron. This stronger iron, in turn, made possible the manufacture of more efficient steam engines.

Steel

Even the best quality of iron lacked the strength and flexibility of steel, which is iron whose carbon content has been reduced by a process of intense heating. In the early nineteenth century, it was possible to manufacture steel, but it involved a costly process that was economically justifiable only in special circumstances.

In 1856, Henry Bessemer (1813-1898), an English inventor, developed the Bessemer converter, the first efficient method for the mass production of steel. At about the same time, an American inventor, William Kelly (1811-1888), developed a similar process.

A decade later, in 1866, William Siemens (1823-1883), a German-born inventor living in England, and his brother, Ernst Werner von Siemens (1816-1892), developed the open-hearth process of steelmaking. As a result of these inventions, the steel industry experienced a rapid growth.

The Revolution in Transportation

Roads and Canals

The revolution in transportation began with improvements in road construction and the expansion of canal systems. About 1815, John McAdam (1756-1836), a Scotsman, developed a durable road surface made of crushed stones cemented by stone dust and water. These macadam roads, as they were known, represented a marked improvement over the dirt roads then generally in use. Extensive canal systems were built in both Europe and America. In 1869, the great Suez Canal, linking the Mediterranean Sea with the Indian Ocean by way of the Red Sea, was opened to shipping.

Railroads

The development of the steam engine and improvements in the quality of iron led to the creation of railroads. For several generations, horse-drawn carts, operating on wooden rails, had been used to move coal and iron. During the eighteenth century, iron replaced wood for both the rails and the wheels of the carts. The next step was to develop a steam-powered locomotive to pull the carts. George Stephenson (1781-1848), a British inventor, was the first to develop an economically successful locomotive. In 1825, a Stephenson locomotive was put into operation on the world's first real railroad, running some forty miles from the coal fields around Darlington in northern England to the port of Stockton. In 1830, Stephenson's famous locomotive, the *Rocket*. demonstrated its speed on the new Liverpool to Manchester railway, running twelve miles in fifty-three minutes.

A great boom in railroad construction began. In 1830, only a few miles of railroads were in operation. By 1870, European railway mileage totaled almost 900,000.

Steamships

Steam power was also applied to water transportation. In 1807, Robert Fulton (1765-1815), an American, introduced the first economically successful steamship, the *Clermont*, which operated on the Hudson River between New York City and Albany. In 1816, the first steamship crossed the English Channel, and three years later the *Savannah*, an American sailing ship equipped with auxiliary steam power, crossed the Atlantic in twenty-nine days. In 1833, the *Royal William,* a Canadian vessel, became the first ship powered entirely by steam to cross the Atlantic in a voyage taking twenty days.

In 1840, Samuel Cunard (1787-1865), a Canadian, inaugurated regular passenger service by steamship from the English port of Liverpool to Boston. The marine steam engine was still relatively inefficient, and the coal required for the voyage occupied about half the available space on the ship. While the cost of transporting passengers by steamship could be justified economically, freight continued to be carried by sailing ship. By the 1860s, a more efficient marine steam engine had been developed, while the screw propeller replaced the paddle wheel. Steamships soon operated on the seaways of the world, and the days of the great sailing ships came to an end.

Electricity and Petroleum

During most of the nineteenth century, the steam engine provided power for the industrial revolution. Gradually, however, a series of inventors made improvements in the electrical generator developed by Michael Faraday (179]-1867) in]831. Nikola Tesla (1856--1943), an Austrian-born immigrant to the United States, developed a method for the long-distance transmission of electric power.

Thomas A. Edison (1847-1931)

In 1879, the American genius Edison developed the first successful incandescent electric light bulb. (Edison also invented the phonograph and the movie projector.) In 1882, he designed a plan for the construction of central electric power stations. The major urban centers of America and Europe soon became electrified, and electric light replaced kerosene and gas lighting. Electricity was used increasingly to power industrial machinery.

The Use of Oil for Power

The first commercially important oil well was drilled in Pennsylvania in 1859, and petroleum gradually began to be used instead of coal to power steam engines. In 1892, Rudolf Diesel (1858-1913), a German inventor, patented an engine that burned oil directly in its cylinders to produce power, instead of using it to make steam. Diesel engines were far more efficient than coal-burning steam engines, although they did not come into widespread use until after World War I.

The Automobile

The use of petroleum to power motor vehicles began in the 1880s, when the German inventor Gottlieb Daimler (1834-1900) used a gasoline motor to power a bicycle, thereby creating the first motorcycle. (Bicycles had come into widespread use in Europe during the 1870s.) Motorcycles did not come into general use, however, until after 1900. One of Daimler's associates used a gasoline engine in the world's first automobile, a vehicle with the engine in front, a clutch, gears, and a drive shaft. In 1885, Karl Friedrich Benz (1844-1929), another German inventor, developed a water-cooled internal combustion engine with electric ignition. During the 1890s, gasoline-driven trucks and buses appeared, and passenger cars soon followed.

Aviation

Aviation traces its origins back to the late eighteenth century, when the hot-air balloon was invented in France, but more than a century passed before aviation made further progress. In 1900, Count Ferdinand von Zeppelin (1838-1917), a German, built the first efficient dirigible, a powered balloon.

Others were experimenting with the possibility of flight with a craft that was heavier than air. In Germany, Otto Lilienthal (1848-1896) and his brother, Gustav (1849-1933), experimented with gliders. At Kitty Hawk, North Carolina, in December 1903, Wilbur (1867-1912) and Orville Wright (1871-1948) made the first successful flights in an airplane. Prior to World War I, however, the airplane was still in the early stages of its development.

The Revolution in Communications

Innovations introduced during the nineteenth century made rapid long-distance communication possible for the first time in human history.

The Telegraph

In 1836, Samuel F. B. Morse (1791-1872), an American, invented the telegraph and eight years later, in 1844, sent a message from Washington to Baltimore. In 1851, a telegraph cable was laid beneath the English Channel linking Great Britain with the continent. In 1866, soon after the end of the American Civil War, Cyrus Field (1819-1892), an American, laid the first successful transatlantic cable joining the United States and Great Britain.

Mail Delivery

In 1840, Great Britain introduced the penny post, creating the first modern postal system. The Universal Postal Union was established in 1874 to regulate the international delivery of mail.

The Telephone

In 1876, Alexander Graham Bell (1847-1922), an American, invented the telephone, and the Bell Telephone Co. was founded the following year. In 1884, telephone service began between New York and Boston, and by the 1890s, a telephone network was taking shape in Europe.

The Radio

During the 1890s, Guglielmo Marconi (1874-1937), an Italian inventor, began experiments in wireless telegraphy. In 1899, Marconi sent a message across the English Channel and in 1901, across the Atlantic Ocean. Radio, the wireless transmission of voices and music, developed on the eve of World War I, based largely on research undertaken by Sir John A. Fleming (1849-1945), an

Englishman, and Lee de Forest (1873-1961), an American. Regularly scheduled radio broadcasting began in the years following World War I.

Banking, Credit, and Business Organization

During the industrial revolution, there was a great expansion of banking and credit as private banks lent increasing amounts of capital to assist the expansion of industry.

Limited Liability

The joint stock principle, which had earlier been applied to trading companies, soon began to be used for banks and industrial enterprises. Joint stock companies operated on the basis of limited liability. Investors purchased shares of stock in the company, thereby becoming part owners. The investors would share in the profits, if any, in proportion to the amount of stock owned. In the event the enterprise failed, the investors were liable only for the amount they had invested. Creditors of a bankrupt enterprise could not demand additional payments from them. By reducing the investors' risks, the principle of limited liability encouraged investment in new and untried ventures.

The Human Cost of Industrialization

While industrialization promoted the prosperity and wealth of both nations and individuals, the human cost was considerable. During the early stages of the industrial revolution, men, women, and children – many of them under ten years old – worked twelve to eighteen hours a day for very low wages in unsafe and unhealthy factories. The workers and their families lived in crowded slums, without adequate sewage facilities, a safe supply of water, and educational opportunities, and access to health care.

The industrial revolution spread gradually beyond Great Britain to the rest of Europe and North America and ultimately, to other regions of the world. Over the course of a few generations. the industrial revolution brought greater material changes to the lives of human beings than had occurred during all of recorded history up to that time. Industrialization ultimately brought great improvements in the material standard of living to millions of people in the industrialized countries of Europe and America. In the first generation of the industrial revolution. however. miserable conditions prevailed in the factories and slums of the new industrial towns. These conditions brought the problem of poverty into sharp focus. promoting the growth of demands for reform.