UNIT 26 TECHNOLOGICAL REVOLUTION: COMMUNICATIONS AND MEDICAL

Structure

26.1 INTRODUCTION

The term 'Industrial Revolution' does not imply a singular transformation from a pre- to a post-industrial society. Industrial and technological changes had been proceeding for several centuries prior to the 18th. There was, however, a faster tempo in the rate of growth and a markedly global character to the Industrial Revolution, which, although it occurred first in Britain, spread to continental Europe and North America and radically altered the socio-economic life of the colonised world as well. Technological development during the European Middle Ages had been slow. In the succeeding period change was associated with profound social and institutional upheavals. The emergence of the nation-state, the Protestant Reformation, the Renaissance and its accompanying scientific revolution, and the expansion of European colonialism were all linked to developing technology. Thus, imperial expansion was made possible by advances in seafaring, navigational technology and new firepower. The new printing presses of the Reformation helped disseminate all points of view, its intellectual ferment stimulated scientific and technological innovation. Many of the inventors and scientists of the period were Protestants.

This Unit will examine some of the major technological innovations that happened during the course of the last three centuries. In particular it would focus on technological discoveries made in the fields of electricity, communications and medical sciences. Since the pace of changes accelerated tremendously in the 20th century, the changes in the last century will be discussed separately. Apart from discussing the technological changes, the Unit would also examine the factors that motivated and propelled these changes and their profound influences on human life.

26.2 POWER TECHNOLOGY AND STEAM

An outstanding feature of the Industrial Revolution was the advance in power technology. At the beginning of this period, the major sources of power available were animate energy and the power of wind and water, the only exception being the atmospheric steam engines that had been installed for pumping purposes, mainly in coal mines. The use of steam power was exceptional and remained so for most industrial purposes until well into the 19th century. Steam did not simply replace other sources of power: it transformed them. The same sort of scientific enquiry that led to the development of the steam engine was also applied to the traditional sources of inanimate energy, with the result that both waterwheels and windmills were improved in design and efficiency. Numerous engineers contributed to the refinement of waterwheel construction, and by the middle of the 19th century new designs increased the speed of the waterwheel and prepared the way for the emergence of the water turbine.

The revolution in communications had a great deal to do with the development of steam-driven power and locomotion. Scientists, such as Robert Boyle of England (who worked on atmospheric pressure), Otto von Guericke (the vacuum), and Denis Papin (pressure vessels), developed the science of steam power. Technologists Thomas Savery and Thomas Newcomen were pioneers of steam engines. Savery's apparatus condensed steam in a vessel, to create a partial vacuum. The first commercially successful steam engine, was invented by Newcomen. Newcomen's engines were heavy fuel consumers, useful mainly in the British coalfields where they kept deep mines clear of water and fulfilled a pressing need of 18th century British industry. Water power and wind power would now gradually be replaced by a mechanism with tremendous potential. Its most important application, the steam railway engine, would (in tandem with modern metallurgy) transform the basis of transport and communications the world over.

Steam became the characteristic power source of the British Industrial Revolution. Little development took place in the Newcomen atmospheric engine until James Watt patented a separate condenser in 1769, but from that point onward the steam engine underwent continuous improvements. Watt's condenser separated the two actions of heating the cylinder with hot steam and cooling it to condense the steam for every stroke of the engine. By keeping the cylinder permanently hot and the condenser permanently cold, a great economy could be effected. The Birmingham industrialist Matthew Boulton, helped convert the idea into a commercial success. Between 1775 and 1800, the Boulton and Watt partnership produced some 500 engines, which despite their high cost were eagerly acquired by the tin-mining industrialists of Cornwall and other power users who needed a reliable source of energy. Boulton and Watt introduced many important refinements, by converting the engine from a single-acting into a double-acting machine that could be applied to rotary motion. The rotary action engine was adopted by British textile manufacturer Sir Richard Arkwright for use in a cotton mill, Many other industries followed in exploring the possibilities of steam power, and it soon became widely used.

The Cornish engineer Richard Trevithick introduced higher steam pressures in 1802, and the American engineer Oliver Evans built the first high-pressure steam engine in the United States at the same time. High-pressure steam engines became popular in America. Trevithick made the first successful steam locomotive for a tram in South Wales in 1804. (The age of the railways had to wait for the permanent way and locomotives). Another consequence of high-pressure steam was the practice of compounding, of using the steam twice or more at descending pressures before it was finally condensed or exhausted. The technique was first applied by Arthur Woolf, a Cornish mining engineer.

A demand for power to generate electricity stimulated new thinking about the steam engine in the 1880s. The problem was that of achieving a sufficiently high rotational speed for the dynamos. Full success in achieving a high-speed engine depended on the steam turbine, a major technological innovation invented by Sir Charles Parsons in 1884. By passing steam through the blades of a series of rotors of gradually increasing size (to allow for the expansion of the steam) the energy of the steam was converted to very rapid circular motion, which was ideal for generating electricity. This method still provides a major source of electric power. Even the most modern nuclear power plants use steam turbines because technology has not yet solved the problem of transforming nuclear energy directly into electricity. In marine propulsion, too, the steam turbine remains an important source of power despite competition from the internal-combustion engine.

26.3 COMMUNICATIONS: TRANSPORT

The sea was the greatest commercial highway, stimulating technological changes in sailing ships. These came in various forms, Elizabethan galleons with maneuverability and firepower, Dutch fishing vessels with spacious hulls and shallow draft, and the fast clippers of the East India companies. Reliable navigation demanded better instruments. The quadrant was improved upon by the octant, which then developed into the modern sextant. The construction of clocks that could keep accurate time helped sailors determine how far east or west of Greenwich the ship lay (longitude). The British Board of Longitude awarded a prize in 1763 to John Harrison for a chronometer that fulfilled all the requirements. Transport provides an example of a revolution within the Industrial Revolution, so complete were the changes in the period 1750-1900. The first improvements in Britain came in roads and canals in the second half of the 18th century. A network of hard-surfaced roads was built in France in the 17th and early 18th centuries and copied in Germany. Pierre Trééseaguet of France improved road construction in the late 18th century by separating the hard-stone wearing surface from the rubble substrata and providing ample drainage. By the beginning of the 19th century, British engineers were innovating in road and canal-building techniques, with J.L. McAdam's inexpensive and long-wearing road surface of compacted stones and Thomas Telford's canals. The outstanding innovation in transport, however, was the application of steam power.

26.3.1 Steam Locomotives

First was the evolution of the railroad: the combination of the steam locomotive and a permanent travel way of metal rails. Experiments in the first quarter of the 19th century culminated in the Stockton & Darlington Railway, opened in 1825. The Liverpool and Manchester Railway opened in 1830, and was the first railway service with freight and passenger traffic relying entirely on the steam locomotive. It was designed by George Stephenson, and its locomotives the work of Stephenson and his son Robert. The first locomotive was called the Rocket. The opening of the Liverpool- Manchester line was the inauguration of the Railway Era, which continued until World War I. During this time railways were built across all countries and continents, opening up vast areas to the markets of industrial society. Locomotives increased rapidly in size and power, but the essential principles remained those established by the Stephensons : horizontal cylinders mounted beneath a multi-tubular boiler with a firebox at the rear and a tender carrying supplies of water and fuel. Meanwhile, the construction of the permanent way underwent an improvement borrowd from preceding tramroads: wrought-iron, and eventually steel rails replaced the cast-iron rails. Very soon, a well-aligned track with easy gradients and substantial supporting civil-engineering works became a common place.

26.3.2 Steam Shipping

The other major application transformed marine transport. The initial attempts to use a steam engine to power a boat were made on the Seine River in France in 1775, and experimental steamships were built by William Symington in Britain at the turn of the 19th century. The first commercial success in steam propulsion for a ship, was that of the American Robert Fulton, whose paddle steamer the "North River Steamboat," commonly known as the Clermont after its first overnight port, plied between New York and Albany in 1807, equipped with a Boulton and Watt engine. A similar engine was installed in the Glasgow-built Comet, put in service on the Clyde in 1812 and which was the first successful steamship in Europe.

All early steamships were paddle-driven, and all were small vessels suitable only for ferry and packet duties because it was long thought that the large fuel requirements of a steamship would preclude long-distance cargo carrying. The further development of the steamship was thus delayed until the 1830s, when I.K. Brunel began work on the problems of steamship construction. His three great steamships each marked a leap forward in technique. The Great Western (launched 1837), was the first steamship built specifically for oceanic service in the North steam shipAtlantic, and demonstrated that the proportion of space required for fuel decreased as the total volume of the ship increased. The Great Britain (launched 1843) was the first large iron ship in the world and the first to be screw-propelled; and was in service until as late as 1970. The Great Eastern (launched 1858), with a displacement of 18,918 tons, was the largest ship built in the 19th century. By the end of the century, steamships were well on the way to displacing the sailing ship on all the main trade routes of the world.

26.4 ELECTRICITY

The pioneering work in the development of electricity as a source of power had been done by an international collection of scientists including Benjamin Franklin of Pennsylvania, Alessandro Volta of the University of Pavia, Italy, and Michael Faraday of Britain. The latter demonstrated the nature of the relationship between electricity and magnetism in 1831, and his experiments provided the point of departure for the mechanical generation of electric current, previously available only from chemical reactions and the utilization of such current in electric motors. Both the mechanical generator and the motor depend on the rotation of a continuous coil of conducting wire between the poles of a strong magnet. Both generators and motors underwent substantial development in the middle decades of the 19th century. In particular, French, German, Belgian, and Swiss engineers evolved the most satisfactory forms of armature (the coil of wire) and produced the dynamo, which made the large-scale generation of electricity commercially feasible.

Continental Europe and North America rapidly developed markets for electricity. In the United States Thomas Edison invented the carbon-filament lamp for domestic illumination. The success of the carbon-filament lamp did not mean the supersession of gas lighting. Coal gas had been used for lighting in Cornwall, in 1792, and in Birmingham in 1798. Gas lighting was adopted by firms and towns all over Britain in the first half of the 19th century. Under competition from electric lighting the quality of gas lighting was improved, and remained popular until the middle of the 20th century. Lighting alone could not provide an economical market for electricity because century. Lighting alone could not provide an economical market for electricity because its use was confined to the hours of darkness. The popularity of urban electric tramways and the adoption of electric traction on subway systems such as the London Underground coincided with the widespread construction of generating equipment in the late 1880s and 1890s. The subsequent spread of this form of energy is one of the most remarkable technological success stories of the 20th century, but most of the basic techniques of generation, distribution, and utilization had been mastered by the end of the 19th century.

26.5 COMMUNICATIONS: IDEAS, WORDS, IMAGES

Communications were equally transformed in the 19th century. The steam engine helped to mechanize and thus to speed up the processes of papermaking and printing. In the latter case the acceleration was achieved by the introduction of the high-speed rotary press and the Linotype machine for casting type and setting it in justified lines (i.e., with even right-hand margins). Printing had to undergo a technological revolution comparable to the 15th-century invention of movable type to be able to supply the greatly increasing market for the printed word. (On the increasing demand for the printed word, see 25.2 of the previous Unit). Another important process that was to make a vital contribution to modern printing was discovered in the 19th century: photography. The first photograph was taken in 1826 or 1827 by the French physicist J.N. Niepce, using a pewter plate coated with bitumen. Daguerre and Fox Talbot adopted silver compounds to give light sensitivity. By the 1890s George Eastman in the United States was manufacturing cameras and celluloid photographic film and the first experiments with the cinema were beginning to attract attention.

Telegraphs and Telephones

The great innovations in communications technology, however, derived from electricity, and were propelled rapidly into usage by a combination of business and military motivations. The first was the electric telegraph, invented or at least made into a practical proposition for use on the developing British railway system by two British inventors, Sir William Cooke and Sir Charles Wheatstone, who collaborated on the work and took out a joint patent in 1837. The same year, the American inventor Samuel F.B. Morse patented and devised the signalling code that bore his name and was subsequently adopted all over the world. The first public telegraph line opened from Baltimore to Washington in 1844. Within a decade, telegraph lines had sprung up in the USA and Europe, and in 1848, Julius Reuter partnered Bernhard Wolff to open the first news agency in Germany. By the 1860 is, the continents of the world were linked telegraphically by transoceanic cables, and the main political and commercial centres were brought into instantaneous communication. Rapid communication eroded parochial and national barriers, telegraph treaties and unions were formed, and the International Telegraph Union (formed in 1865) in Paris, soon grew into the International Bureau of Telegraph Communication - the world's first permanent international organisation, established in Vienna, in 1868.

To be truly effective internationally however, telegraph cables needed insulation in order to cross the seas and oceans. One of the most successful inventors of insulation was an English doctor in the East India Company's Bengal Army, and chemistry professor at the Calcutta Medical College. In 1838 he suspended 22 kilometres of wire on bamboo poles, with the last 3 kilometres under the surface of the Hoogly river. This was the first underwater circuit, but went unnoticed in Europe. However, experimentation was taking place elsewhere, with the rapid spread of the telegraph. France and Britain were linked in 1850, and lines across the Mediterranean laid, with partial success through the next two decades. (France was particularly interested in establishing stable links with its Algerian colony in North Africa). The Crimean War, wherein France and Britain were pitted against Tsarist Russia, was the first one conducted with long-distance contact between armies and command headquarters. This could prove to be a mixed blessing for local commanders who could be subjected to long-distance meddling by political leaders as well. In India, the recently installed telegraph played a major role in colonial-imperial communications in the Revolt of 1857.

The telegraph system also played an important part in the opening up of the American West by providing rapid aid in the maintenance of law and order. The telegraph was followed by the telephone, invented by Alexander Graham Bell in 1876 and adopted quickly for short-range oral communication in American cities and at a slower pace in Europe. Meanwhile theoretical work on the electromagnetic properties of light and other radiation was beginning to produce experimental results, and the possibilities of wireless telegraphy began to be explored. By the end of the nineteenth century, Guglielmo Marconi had transmitted long-distance messages over many miles and was preparing the apparatus with which he made the first transatlantic radio communication on December 1901. The world was being drawn inexorably into a closer community.

26.6 DEVELOPMENTS IN MODERN MEDICINES

The development and use of the compound microscope (invented slightly earlier, in Holland) was the work of Galileo (1564-1642). He was the first to insist upon the value of measurement in science and in medicine, replacing guesswork with accuracy. **The view of the French philosopher Renéé Descartes (1596-1650) that the human body is a machine and that it functions mechanically had its repercussions in medical thought**. One group adopting this explanation viewed life as a series of chemical processes, and were called iatrochemists. Santorio Santorio, working at Padua, was an exponent of this view and a pioneer investigator of metabolism. Another Italian, who developed the idea was Giovanni Borelli, a mathematics professor at Pisa University, who gave his attention to the mechanics of the human body and the laws that govern its movements. The discovery of the circulation of the blood based on precise observation and scrupulous reasoning was a landmark of medical progress. In 1628 William Harvey, who studied at Cambridge University and then at Padua, published his classic book *Concerning the Motion of the Heart and Blood*. Following the method described by the philosopher Francis Bacon, he drew the truth from experience and not from authority. Meanwhile, in the 18th century, medical education grew, and prominent schools functioned at Leiden (Holland), Padua (Italy), and Edinburgh (Scotland). In 18th-century London, Scottish doctors were the leaders in surgery and obstetrics. William Smellie's *Treatise on the Theory and Practice of Midwifery*, published in 1752-64, placed midwifery on a sound scientific footing and helped to establish obstetrics as a recognized medical discipline. It contained the first systematic discussion on the safe use of obstetrical forceps, which have saved countless lives. The science of modern pathology also had its beginnings in this century. Giovanni Morgagni, of Padua, in 1761 published his massive work *The Seats and Causes of Diseases Investigated by Anatomy*, based on 700 postmortem examinations.

A highly significant medical advance was vaccination. The often fatal disease smallpox, was widely prevalent. Inoculation, which had been practised in the East, was popularized in England in 1721-22 by Lady Mary Montagu, who had seen it practised in Turkey. In 1796 Edward Jenner, a country practitioner began inoculations with cowpox (the bovine form of the disease).This procedure - vaccination - has been responsible for eradicating the disease. Public health received more attention during the 18th century, with population statistics, health legislation and hospitals. In Paris, Philippe Pinel initiated reforms in the care of the mentally ill, discarding the notion that insanity was caused by demon possession. Conditions improved for sailors and soldiers. James Lind, a British naval surgeon from Edinburgh, recommended citrus juices to prevent scurvy. In 1752 the Scotsman John Pringle, published his *Observations on the Diseases of the Army.* His suggestion in 1743 that military hospitals be regarded as sanctuaries eventually led to the establishment of the Red Cross organization in 1864.

By the beginning of the 19th century, the structure of the human body was almost fully known, due to new methods of microscopy and of injections. The understanding of physiological processes was rapidly elucidated, especially in Germany, where physiology became established as a distinct science under the guidance of Johannes Müüller, a professor at the University of Berlin. France's brilliant physiologist Claude Bernard, made important discoveries based on carefully planned experiments. He clarified the role of the pancreas, revealed the presence of glycogen in the liver, and explained the functioning of the blood vessels. His work, *An Introduction to the Study of Experimental Medicine* (1865) is still studied.

The great medical advance of the 19th century was the demonstration that certain diseases and surgical infections were caused by minute living organisms. This discovery changed the face of pathology and the practice of surgery. A pioneer in the parasitic theory of infection was Agostino Bassi of Italy, who showed that a disease of silkworms was caused by a fungus that could be destroyed by chemical agents. The main credit for establishing bacteriology goes to the French chemist Louis Pasteur (1822-95), who proved that the fermentation of wine and the souring of milk are caused by living microorganisms. His work led to the pasteurization of milk and solved problems of animal and human diseases. He employed inoculations to prevent anthrax in sheep and cattle, chicken cholera in fowl, and finally rabies in humans and dogs. From Pasteur were derived concepts that led to the antiseptic principle in surgery. In 1865 Lister, a surgeon at Glasgow University, began using carbolic acid as a disinfectant. His pioneering work led to more refined techniques of sterilizing the surgical environment. An important development in tropical medicine (and of great consequence to colonial projects of conquest) was the extraction of quinine from the cinchona bark by the French chemists Pierre Peletier and Joseph Caventou in 1820. This made it possible to treat the malaria, one of the most dreaded of all diseases especially in the 'Orient'. It was only in 1897 that the anopheles mosquito was identified as the vector of malaria.

The most famous contribution by the United States to medical progress at this period was the introduction of general anesthesia, a procedure that not only liberated the patient from pain and enabled the surgeon to perform more extensive operations. There were many claimants for priority, some used nitrous oxide gas, and others ether. But it was William Morton who, on October 16, 1846, in Boston, first demonstrated the use of ether as a general anesthetic. General anesthesia soon became prevalent in surgery. In November 1847 chloroform was tried with complete success, and soon it was preferred to ether and became the anesthetic of choice.

Preventive medicine was considered as important as the cure of disease. The 20th century witnessed the evolution of national health services. (We may pay attention, in passing to Ivan Ilich's observation that the two most significant safeguards for public health have been sanitation and clean water supply). Spectacular advances in diagnosis and treatment followed the discovery of X rays by Wilhelm Röötgen, in 1895, and of radium by Pierre and Marie Curie in 1898. Before the turn of the century, too, the new field of psychiatry had been opened up by Sigmund Freud. The increase in scientific knowledge during the 19th century radically altered and expanded medical practice, and led to the establishment of public and professional bodies to govern the standards for medical training and practice.

26.7 TECHNOLOGY IN THE 20th CENTURY

Recent history of technology is notoriously difficult to write, because of the mass of material and the problem of distinguishing the significant from the insignificant among events that have virtually the power of contemporary experience. In respect to the recent history of technology, however, one fact stands out clearly: despite the immense achievements of technology by 1900, the following decades witnessed more advance over a wide range of activities than the whole of previously recorded history. The airplane, the rocket and interplanetary probes, electronics, atomic power, antibiotics, insecticides, and a host of new materials have all been invented and developed to create an unparalleled social situation, full of possibilities and dangers, which would have been virtually unimaginable before the present century.

In venturing to interpret the events of the 20th century it will be convenient to separate the years before 1945 from those that followed. The years 1900 to 1945 were dominated by the two world wars, while those since 1945 have been preoccupied by the need to avoid another major war. The dividing point is one of outstanding social and technological significance: the detonation of the first atomic bomb at Alamogordo, N.M., in July 1945.

There have been profound political changes in the 20th century related to technological capacity and leadership. It may be an exaggeration to regard the 20th century as "the American century," but the rise of the United States as a superstate has been sufficiently rapid and dramatic to excuse the hyperbole. It has been a rise based upon tremendous natural resources exploited to secure increased productivity through widespread industrialization, and the success of the United States in achieving this objective has been tested and demonstrated in the two world wars. Technological leadership passed from Britain and the European nations to the United States in the course of these wars. This is not to say that the springs of innovation went dry in Europe: many important inventions of the 20th century originated there. But it has been the United States that has had the capacity to assimilate innovations and to take full advantage from them at times when other nations have been deficient in one or other of the vital social resources without which a brilliant invention cannot be converted into a commercial success. **As with Britain in the Industrial Revolution, the technological vitality of the United States in the 20th century has been demonstrated less by any particular innovations than by its ability to adopt new ideas from whatever source they come.**

The two world wars were themselves the most important instruments of technological as well as political change in the 20th century. The rapid evolution of the airplane is a striking illustration of this process, while the appearance of the tank in the first conflict and of the atomic bomb in the second show the same signs of response to an urgent military stimulus. It has been said that World War I was a chemists' war, on the basis of the immense importance of high explosives and poison gas. In other respects the two wars hastened the development of technology by extending the institutional apparatus for the encouragement of innovation by both the state and private industry. This process went further in some countries than in others, but no major belligerent nation could resist entirely the need to support and coordinate its scientific-technological effort. **The wars were thus responsible for speeding the transformation from "little science," with research still largely restricted to small-scale efforts by a few isolated scientists, to "big science," with the emphasis on large research teams sponsored by governments and corporations, working collectively on the development and application of new techniques**. While the extent of this transformation must not be overstated, and recent research has tended to stress the continuing need for the independent inventor at least in the stimulation of innovation, there can be little doubt that the change in the scale of technological enterprises has had far-reaching consequences. It has been one of the most momentous transformations of the 20th century, for it has altered the quality of industrial and social organization. In the process it has assured technology, for the first time in its long history, a position of importance and even honour in social esteem.

26.7.1 Industry and Innovations

There have been technological innovations of great significance in many aspects of industrial production during the 20th century. It is worth observing, in the first place, that the basic matter of industrial organization has become one of self-conscious innovation, with organizations setting out to increase their productivity by improved techniques. Methods of work study, first systematically examined in the United States at the end of the 19th century, were widely applied in U.S. and European industrial organizations in the first half of the 20th century. These evolved rapidly into scientific management and the modern studies of industrial administration, organization and method, and particular managerial techniques. The object of these exercises has been to make industry more efficient and thus to increase productivity and profits, and there can be no doubt that they have been remarkably successful. Without this superior industrial organization it would not have been possible to convert the comparatively small workshops of the 19th century into the giant engineering establishments of the 20th with their mass-production and assembly-line techniques. The rationalization of production, so characteristic of industry in the 20th century, may thus be legitimately regarded as the result of the application of new techniques that form part of the history of technology since 1900.

26.7.2 Improvements in Iron and Steel

Another field of industrial innovation in the 20th century has been the production of new materials. As far as volume of consumption goes, man still lives in the Iron Age, with the utilization of iron exceeding that of any other material. But this dominance of iron has been modified in three ways:

- by the skill of metallurgists in alloying iron with other metals;
- by the spread of materials such as glass and concrete in building; and
- by the appearance and widespread use of entirely new materials, particularly plastics.

Alloys had already begun to become important in the iron and steel industry in the 19th century (apart from steel itself, which is an alloy of iron and carbon); self-hardening tungsten steel had been first produced in 1868, and manganese steel, possessing toughness rather than hardness, in 1887. Manganese steel is also nonmagnetic; this fact suggests great possibilities for this steel in the electric-power industry. In the 20th century steel alloys multiplied. Silicon steel was found to be useful because, in contrast to manganese steel, it is highly magnetic. In 1913 the first stainless steels were made in England by alloying steel with chromium, and the Krupp works in Germany produced stainless steel in 1914. The importance of a nickel-chromium alloy in the development of the gas-turbine engine in the 1930s has already been noted. Many other alloys also came into widespread use for specialized purposes.

26.7.3 Modern Medicine and Pharmaceuticals

An even more dramatic result of the growth in chemical knowledge has been the expansion of the modern pharmaceutical industry. The science of pharmacy emerged slowly from the traditional empiricism of the herbalist, but by the end of the 19th century there had been some solid achievements in the analysis of existing drugs and in the preparation of new ones. The discovery in 1856 of the first aniline dye had been occasioned by a vain attempt to synthesize quinine from coal-tar derivatives. Greater success came in the following decades with the production of the first synthetic anti-fever drugs and pain-killing compounds, culminating in 1899 in the conversion of salicylic acid into acetylsalicylic acid (aspirin), which is still the most widely used drug. Progress was being made simultaneously with sulfonal hypnotics and barbiturate drugs, and early in the 20th century Paul Ehrlich of Germany successfully developed an organic compound containing arsenic which was effective against syphilis. This discovery, made in 1910, was the first to overwhelm an invading microorganism without offending the host. In 1935 the discovery that Prontosil, a red dye developed by the German synthetic-dyestuff industry, was an effective drug against streptococcal infections (leading to blood poisoning) introduced the important sulfa drugs. Alexander Fleming's discovery of penicillin in 1928 was not immediately followed up, because it proved very difficult to isolate the drug in a stable form. But World War II gave a fresh urgency to research in this field, and commercial production of penicillin, the first of the antibiotics, began in 1941. These drugs prevented the growth of pathogenic organisms. All these pharmaceutical advances demonstrate an intimate relationship with chemical technology.

In 1901, for the United Kingdom the expectation of life at birth was 48 years for males and 51.6 years for females. By the 1980s life expectancy had reached 71.4 years for males and 77.2 years for females. With the exception of diseases such as cancer and AIDS, attention has become focused on morbidity rather than mortality, and the emphasis has changed from keeping people alive to keeping them fit. The rapid progress of medicine was reinforced by improvements in communication between scientists. And although specialization increased, teamwork became the norm. In the first half of the century, the emphasis was on combating infection, but landmarks were also attained in endocrinology and nutrition. Following World War II, new discoveries in biochemistry and physiology led to more precise diagnostic tests and therapies; and spectacular advances in biomedical engineering enabled the physician and surgeon to probe into the structures and functions of the body by noninvasive imaging techniques like ultrasound (sonar), computerized axial tomography (CAT), and nuclear magnetic resonance (NMR). With each new scientific development, medical practices of just a few years earlier became obsolete.

26.7.4 The Human Genome Project

This scientific effort to analyze the DNA of human beings and of several lower types of organisms began in the United States in 1990 under the sponsorship of the U.S. Department of Energy and the National Institutes of Health and was completed in 2003. Related programmes were begun in several other countries in coordination with the American programme. Every cell of an organism has a set of chromosomes containing the heritable genetic material that directs its development - i.e., its genome.

The genetic material of chromosomes is DNA. Project goals were to identify all the approximately 30,000 genes in human DNA, determine the sequences of the three billion chemical base pairs that make up human DNA, store this information in databases, improve tools for data analysis, transfer related technologies to the private sector, and address the ethical, legal, and social issues that may arise.

Human genome projects undertaken concurrently in Japan, the United Kingdom, Italy, France, and Russia are coordinated with the American effort through the Human Genome Organization, whose members include scientists from throughout the world. The potential utility of the Human Genome Project is immense. The information gathered will serve as the basic reference for research in human biology and medicine and will provide fundamental insights into the genetic basis of human disease. The new technologies developed in the course of the project will be applicable in numerous other fields of biomedical endeavour. Though the HGP is finished, analyses of the data will continue for many years.

26.7.5 Twentieth Century Communications

The spectacular transport revolution of the 20th century has been accompanied by a communications revolution quite as dramatic, although technologically springing from different roots. In part, well-established media of communication like printing have participated in this revolution, although most of the significant changes—such as the typewriter, the Linotype, and the high-speed power-driven rotary press—were achievements of the 19th century. Photography was also a proved and familiar technique by the end of the 19th century, but cinematography was new and did not become generally available until after World War I, when it became enormously popular.

The real novelties in communications in the 20th century came in electronics. The scientific examination of the relationship between light waves and electromagnetic waves had already revealed the possibility of transmitting electromagnetic signals between widely separated points, and on Dec. 12, 1901, Guglielmo Marconi succeeded in transmitting the first wireless message across the Atlantic. Early equipment was crude, but within a few years striking progress was made in improving the means of transmitting and receiving coded messages. This was essentially a development from the carbon-filament electric light bulb. In 1883 Edison had found that in these lamps a current flowed between the filament and a nearby test electrode, called the plate, if the electric potential of the plate was positive with respect to the filament. This current, called the Edison effect, was later identified as a stream of electrons radiated by the hot filament. In 1904, Sir John Ambrose Fleming of Britain discovered that by placing a metal cylinder around the filament in the bulb and by connecting the cylinder (the plate) to a third terminal, a current could be rectified so that it could be detected by a telephone receiver. Fleming's device was known as the diode, and two years later, in 1906, Lee De Forest of the United States made the significant improvement that became known as the triode by introducing a third electrode (the grid) between the filament and the plate. The outstanding feature of this refinement was its ability to amplify a signal. Its application made possible by the 1920s the widespread introduction of live-voice broadcasting in Europe and America, with a consequent boom in the production of radio receivers and other equipment.

This, however, was only one of the results derived from the application of the thermionic valve. The idea of harnessing the flow of electrons was applied in the electron microscope, radar (a detection device depending on the capacity of some radio waves to be reflected by solid objects), the electronic computer, and in the cathode-ray tube of the television set. The first experiments in the transmission of pictures had been greeted with ridicule. Working on his own in Britain, John Logie Baird in the 1920s demonstrated a mechanical scanner able to convert an image into a series of electronic impulses that could then be reassembled on a viewing screen as a pattern of light and shade. Baird's system, however, was rejected in favour of electronic scanning, developed in the United States by Philo Farnsworth and Vladimir Zworykin with the powerful backing of the Radio Corporation of America. Their equipment operated much more rapidly and gave a more satisfactory image. By the outbreak of World War II, television services were being introduced in several nations, although the war suspended their extension for a decade. The emergence of television as a universal medium of mass communication is therefore a phenomenon of the postwar years. But already by 1945 the cinema and the radio had demonstrated their power in communicating news, propaganda, commercial advertisements, and entertainment.

The dominant lines of development continue to be those that were established before or during World War II. In particular, the rapid growth of television services, with their immense influence as media of mass communication, has been built on foundations laid in the 1920s and 1930s, while the universal adoption of radar on ships and airplanes has followed the invention of a device to give early warning of aerial attack. But the development of communications age has produced important innovations. The transistor, so significant for computers and control engineering, has also made a large contribution to communications technology. The establishment of space satellites, considered to be a remote theoretical possibility in the 1940s, had become part of the accepted technological scene in the 1960s, and have played a dramatic part in telephone and television communication as well as in relaying meteorological pictures and data. The development of magnetic tape as a means of recording sound and, more recently, vision, has provided a highly flexible and useful mode of communication. New printing techniques such as photo-typesetting and xerography, have increased the speed of publication. New optical devices such as zoom lenses have increased the power of cameras and prompted corresponding improvements in the quality of film available to the cinema and television. Physical techniques such as the laser (light amplification by stimulated emission of radiation) are making available an immensely powerful means of communication over long distances. The laser also has acquired significance as an important addition to surgical techniques and an instrument of space weaponry. The final communications innovation is the use of electromagnetic waves other than light to explore the structure of the universe by means of the radio telescope and its derivative, the X-ray telescope. This technique was pioneered after World War II and has since become a vital instrument of satellite control and space research. Radio telescopes have also been directed toward the Sun's closest neighbours in space in the hope of detecting electromagnetic signals from other intelligent species in the universe.

26.8 SUMMARY

The story of technological revolutions is, in many ways, a continuing story. New innovations feed on the old ones and make them obsolete. This Unit has traced the story of a whole range of technological breakthroughs—cumulatively called technological revolution—in the field of electricity, communications, and medical sciences. Although technological changes had occurred prior to 18th century, their pace accelerated dramatically after the industrial revolution and they also increasingly acquired a global reach. In the 20^{th} century, however, a few decades were able to achieve levels of technological developments unmatched in the preceding centuries. This technological advance has brought about enormous changes in the socio-economic life of mankind across the globe, and continues to govern and shape human life in a variety of ways.

26.9 EXERCISES

1) Discuss the major breakthrough that occurred in the field of medical sciences both prior to and during the course of the 20^{th} century.

2) Mention some of the major technological developments in communications.

3) How are transport, electricity and telegraph connected to one another?

4) Examine some of the major technological innovations made in the 20^{th} century.

SUGGESTED READINGS FOR THIS BLOCK

Adon E., *Russia: The Tsarist and Soviet Legacy*, London, 1995.

Baker, Keith Michael, *Inventing the French Revolution, Essays on French Political Culture in the Eighteenth Century*, 1990.

Bayly, C.A., *The Birth of the Modern world, 1780 – 1914.*

Cobb R.C., *Reactions to the French Revolution,* 1972.

Daniels R.V., *Red October: The Bolshevik Revolution of 1917*, New York, 1967.

Ellis, John., *The Social History of the Machine Gun,* Pantheon, 1975.

Furet, Francois and Ozanf, Mona (eds), *Critical Dictionary of the French Revolution*, 1989.

Furet, François, *Interpreting the French Revolution.*

Gill, Graven, *Peasants and Government in the Russian Revolution*, London 1979.

Goodwin, Albert, *The French Revolution*, 1953.

Headrick, Daniel R., *The Tentacles of Progress: Technology Transfer in the Age, of Imperialism 1850-1940*, Oxford, 1988.

Headrick, Daniel R., *The Invisible Weapon: Telecommunications and International Politics 1851-1945*, Oxford, 1991.

Headrick, Daniel R., *The Tools of Empire: Technology and European Imperialism in the Nineteenth Century*, Oxford, 1981.

Hobsbawm, E.J., *The Age of Revolution, 1789 - 1848*, New York, 1962.

Jones, Howard, *Steam Engines: An International History*, London, 1973.

Jones, Peter (ed.), *The French Revolution: In Social and Political Perspective*, 1966.

Kaplow, Jiffry (ed.), *New Perspectives on French Revolution*, 1965.

Keep, J.L.H., *The Russian Revolution: A Study in Mass Mobilization*, London, 1976.

Kerr, Ian J., *Building the Railways of the Raj, 1850-1900*, Oxford, 1995.

Kochan, Lionel and Keep John, *The Making of Modern Russia*, London, 1997.

Kumar, Deepak, (ed.), *Science and Empire: Essays in Indian Context*, Delhi, 1991.

Lucas, Colin (ed.), *The French Revolution and the Creation of Modern Political Culture.*

Mcluhan, Marshall, *Understanding Media*, London, 1960.

Mona Ozonf, *Festivals and the French Revolution,* 1988.

Palmer R.R., *The Age of Democratic Revolutions: A Political History of Europe and America 1760 – 1800* (2 Vols), 1989.

Riasanovsky, N.V., *A History of Russia*, Oxford, 1993.

Skocpol, Theda, *States and Social Revolutions: A Comparative Analysis of France, Russia and China*, Cambridge, 1979.

Talmon, J.L., *The Origins of Totalitarian Democracy*.

Watson, Hugh Seton, *The Decline of Imperial Russia*.

Williams, Raymond, *Television*, London, 1972.