CHAPTER 12

SCIENTIFIC AND TECHNICAL ADVANCES, AND POLITICAL, ECONOMIC AND SOCIAL DEVELOPMENTS FROM THE EARLY MODERN AGE UNTIL THE PRESENT

The Promotion and Resistance to Universal Rationalism

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12.1. Advances in Science and Technology from the 17th through the 18th Centuries.

12.1.1. From the Age of Faith Towards the Age of Reason. In Chapter 11, we characterized the medieval mindset and ethos as mnemonic/compulsive from a neuropsychological perspective (see also Chapter 9, Fig. 9-44, Table 9-2). In this Chapter and the following Chapter 13, we will describe the modern mindset and ethos shifting toward the rational/calculating. The prototypical medieval person was credulous and docile, religious and conservative. The prototypical modern person is critical and independent, secular and progressive. The Middle Age was a faith-based traditional epoch in the history of Western civilization. The Modern Age is science-based and innovative. But calling the modern period the Age of Reason is only a broad generalization. As we have previously argued, the mnemonic mindset adopted in the Middle Ages was only one of the contributing factors that formed the ethos of medieval civilization. In sharp contrast to the original ideals of Christianity, medieval society was not egalitarian, peaceful and fair but hierarchical, militant, and discriminatory. Within the framework of the religious medieval order, belligerent and acquisitive people sought power and wealth. They maintained their privileges by creating a hierarchic social order where they lived in luxury at the expense of the peasants that they ruled. The peasants undoubtedly resented their subordination and humiliation but they had no political power and not even a basic education to change their social status. While the religious ideals that permeated all aspects of medieval life succeeded in modifying *human behavior* relative to the pagan past, it could not eradicate the inborn dispositions of *human nature*. The Christian message of the heavenly rewards of altruism reinforced human prosocial emotions—love, altruism and empathy—and elevated the moral standards of those who were temperamentally predisposed to be compassionate and benevolent. However, preaching and indoctrination could not eradicate human antisocial emotions—hatred, greed and callousness—and therefore those with egotistical impulses or aggressive dispositions became predatory and intolerant. In spite of the strong religious influence during the Middle Ages, man's evolutionary neurobiological origins set limits to his plasticity and malleability.

Our Age of Reason is a complex historical epoch. The medieval social and political order was gradually abandoned due largely to the rationalism of the Scientific Revolution, and the Industrial Revolution. Great scientific advances contributed to a better understanding of the world we live in. The invention of ever more effective machines and tools, and the utilization of novel energy resources have improved our lives. Medical advances have improved our health and lengthened our life expectancy. However, all these technological accomplishments have failed to create a rationally administered social and political order that was put forth by the Enlightenment. To this day, rational means are used to achieve irrational ends in many aspects of our daily life. The rich are still allowed to exploit the poor. There is widespread social and ethnic discrimination. Political conflicts often result in destructive wars. We shall argue that the admixture of continuous rational advances in technilogy and persistent irrationalism in social interactions can be explained by the dynamics of human nature.

The Distinction Between Universal and Selective Rationalism. Rationalism, more specifically empirical rationalism, is the belief that the best way to resolve a theoretical issue or solve a practical problem is to gather all the relevant evidence and use logical reasoning to make a judgment or plan an appropriate action. "Universal rationalism" is an extension of that belief, the ideology that *all* issues—scientific or technical, social or political, religious or personal—can be (and ought to be) solved by gathering data and making logical inferences, irrespective whether we like or dislike what those inferences dictates us to do. "Selective rationalism," in contrast, is based on a cost-benefit analysis, accepting the dictates of reason when that is easy or advantageous to follow but not when it is difficult or disadvantageous. We shall argue that notwithstanding great advances, the modern mindset still retains the character of selective rationalism.

The limits of the rational mindset. To think and act rationally is not always easy and it may fail even if we commit ourselves to be reasonable. First, we may not think or act rationally because our reasoning power is unable to inhibit our tendency to make judgments and solve problems emotionally or habitually. Second, our reasoning may be flawed either because our knowledge of the facts may be inadequate or our inferences may not be logical. Third, our reasoning may be biased by our special interests and, fourth, it may serve a short-term rather than a long-term solution to the problem we are facing. In general, we tend to think and act rationally when that does not conflict with our personal interests and cultural prejudices. If the scientific evidence we read about in a physics textbook convinces us that the earth revolves around the sun, we readily reject the old idea (and our sense impression) that the earth is stationary and the sun revolves around it. However, if the astronomical evidence also demands that we reject the old notion that what appears to be the sky "above" is the site of "heaven" where God and the angels dwell and the abode of the righteous—instead of a vast space occupied by physical entities like stars and galaxies—we are liable to reject that rational inference if we have been taught to believe in a heavenly sphere above the earth. The existence of heaven has become a comforting and cherished belief of the faithful and reason is powerless to destroy that conviction.

The limits of the rational ethos. A review of the history of Western civilization from the 17th century to the present indicates that it was an admixture of rational advances in some domains and resistance to the demands of rationality in others. The great scientific discoveries, the epitome of the immense power of empirical rationalism, fostered a technological revolution which led to great increases in food production, finding new energy resources, and manufacturing new labor-saving devices and conveniences. However, the increase in the quantity and variety of goods produced did not lead to the improvement of the standard of living of the great masses of people who produced them. The typical entrepreneur during the Industrial Revolution used every means available to him to accumulate private wealth by exploiting his workers—not a progressive long-term rational strategy. That greed was bound to lead to mass frustration and suffering, social disorder, and political upheaval. The same short-term greed was used by explorers and colonizers who settled in lands owned by indigenous peoples. Instead of cooperating with the natives, the colonizers drove the natives off their lands, enslaved them, and in some cases exterminated them. The thinkers of the Enlightenment came up with rational ideas about how to replace the old social order with new governments that were based on checks and balances to prevent tyranny and foster individual freedom and self determination. But those holding power resisted these changes and sought to retain their power by autocratic means. It took generations—punctuated by political conflicts, social turmoil, regional wars, and two world wars—before our Western civilization appears to be heading towards the establishment of a more rational social and political order.

In this chapter, we will review the scientific and technological advances together with the economic, social and political transformations that transpired in the Western world from the 17th century to the present. We begin with a brief survey of the great scientific and technological advances from the 17th through the 18th centuries as manifestations of evolving rationalism, together with the contributions of the intellectuals of the Enlightenment towards a rational political and social discourse, but one that ended in the disaster of the first French Revolution at the end of the 18th century. We follow that with a brief description of continuing advances in science and technology through the 19th century that were coupled with a change in social organization but the persistence of political conflicts in the form of bloody revolutions and counter-revolutions, and wars between nations. That irrationalism culminated in the tumultuous political history of the first half of the 20th century with the First World War, the rise of dictatorships in the Interwar Period, and the most devastating of all wars in human history, the Second World War. Insanity continued during the decades of the Cold War when the contestants threatened each other with the latest and most hazardous of technical inventions, nuclear warheads mounted on ballistic and guided missiles. On a more positive note, we will also argue that thanks to ongoing political, scientific and technical advances—particularly the spread of democracy, international peace movements, economic and social globalization, and a revolution in communication—humanity appears to be embarking on a rational path that in time could lead to domestic harmony and international peace. We will provide a detailed mindset and ethos analysis of the dynamics of the Modern Age in Chapter 13.

12.1.2. The Scientific Revolution of the 17th Century. A major event that heralded the rise of the "Age of Reason" was the rapid development of science in the 17th century. Science, of course, was not an altogether new enterprise—intelligent men and women have made observations and drew reasonable conclusions from what they observed since the beginnings of the evolution of *Homo sapiens*. The novelty was the introduction of the *scientific method* that led to the programmatic rejection of beliefs, myths and dogmas as the fountains of knowledge. Scientific knowledge was based on systematic observation, experimentation and quantification. Logical reasoning was used to interpret what has been discovered and to make predictions to confirm, modify or refute those interpretations.

ANCIENT SCIENCE. Science began as a distinctive human enterprise when primitive man sought to predict future events by trying to calculate the temporal course of important events. Collectors realized that different fruits and berries ripened at different times, and hunters realized that there were seasonal regularities in the migration of herds. Land cultivators had to predict the right time when to plant seed and when to expect the inundation of rivers or the coming of the wet season. To predict such events, people discovered that the phases of the moon were a reliable way to measure the passage of weeks and months. To measure the passage of years was a more difficult task because a year is not directly related to the phases of the moon. It was not until systematic observations were made of the solstices of the sun that astronomers of Babylonia and Egypt were able determine the duration of a year in days. But they also discovered that the estimate of 365 days in a year was not an exact one and set out to find ways to keep the calendar in line with the passing seasons by recording the cycles of regular celestial phenomena. Claudius Ptolemy, a Greco-Roman scientist of Alexandria, summarized in his book, what became known as the *Almagest*, the results of a thorough mapping of the starry sky by generations of astronomers. Ptolemy also offered an elaborate but erroneous theory of the movements of the planets around the stationary earth. Although science was not much appreciated during the Middle Ages, Ptolemy's work remained popular because astronomy changed into astrology, an esoteric cult that assumed an intimate relationship between planetary movements and earthly events.

FROM THE GEOCENTRIC TO THE HELIOCENTRIC WORLD. For medieval man there were two worlds, heaven and earth. As described by Dante in his *Divine Comedy*, the stars and planets were not physical bodies but crystalline entities attached to ethereal spheres, all of which rotated around the earth, the center of the universe. The earth, God's most important creation, was a physical body where man was assigned temporary residence with the obligation to worship Him, and where the cosmic drama of sin and salvation transpired. The mathematician Nicolaus Copernicus, in his *De revolutionibus orbium caelestium* published in 1543, challenged Ptolemy's geocentric theory of the universe because in order to accurately account for the changing position of the planets over time, that theory had to postulate the existence of as many as eighty rotating spheres around the earth (Butterfield, 1949; Mason, 1962). After extensive calculations, relying primarily on Ptolemy's data, Copernicus found that by abandoning the idea that the heavenly bodies rotate around the earth, and assuming that the earth and the planets rotate around the sun (as was originally proposed by Aristarchus of Samos in the 3rd century BCE) the number of required cycles, epicycles and eccentrics could be reduced to thirty-four. Copernicus retained all the other components of the Ptolemaic system, including the idea that all celestial motions are circular and uniform. Copernicus' main effort was to provide a simpler mathematical account of the celestial spheres; he refrained from stating that the planets were, like the earth, physical bodies.

The Adoption of the Inductive Scientific Method. An early advocate of scientific research was the statesman Francis Bacon (1561-1626). The *Proficience and Advancement of Learning*, published in 1605, was an earlier popular exposition of his views; the *Novum Organum (New Instrument)*, published in 1620, presented his more mature ideas. Bacon argued against false premises used in reasoning, what he called "idols", and was particularly opposed to the deductive method, the formulation of scientific principles on the basis of logical reasoning rather than observation, or induction. As he wrote:

> The syllogisms consist of propositions, propositions consist of words, words are symbols of notions. Therefore if the notions themselves … are confused and over hastily abstracted from the facts, there can be no firmness in the superstructure. Our only hope therefore lies in a true induction.
>
> (Bacon, 1939; aphorism xiii, p. 30)

Moreover, for Bacon, science was more than an intellectual enterprise; it was a tool in man's armature to control the forces of nature for the betterment of the human condition. To accomplish that, Bacon advocated the establishment of a systematic scientific method and the public support of scientific research.

While Bacon advocated the inductive method, the derivation of general principles from observations, René Descartes (1596-1650) advocated the deductive method, the derivation of all knowledge from general principles. For him the purpose of observation and experiment was not so much to acquire new knowledge but to confirm the validity of logical inferences and mathematical calculations. Descartes considered spatial extension the fundamental property of matter and, as the founder of analytical geometry he sought to construct a unified theory of the universe. His grand aim was, as he explained in his *Discourse on Method* (Descartes, 1955a), to deduce from a few fundamental principles the fundamental nature of matter, the dynamics of planetary movements, and the material basis of the soul. But that approach was not promising. Descartes came up with such untenable notions as the vortex theory of the revolution of the planets; he rejected the new evidence that the heart functioned as a pump; and he came up with idea that the pineal gland was the seat of the soul. While Descartes' program of explaining everything in mechanistic terms was a radical break with the prevailing scholastic system of natural philosophy, most experimental scientists opted to follow Bacon's inductive method.

Inspired by Bacon's ideas, a small group of English scientists began to meet in the 1640s to discuss the research they were engaged in, which became in 1660 a formal institution with a charter, known as the Royal Society. The Society's motto was: *Nullius in verba* ("take nobody's word for it"). Robert Hooke was the Society's first head; later Isaac Newton became its president. In addition to regular meetings, in which members of the society presented their research findings and discussed their ideas, the Royal Society began to publish books, such as Hooke's *Micrographia* and Newton's *Principia*, as well as journal articles ('Letters') submitted by scientists from abroad, such as Marcello Malphigi from Italy and Anton van Leeuwenhoek from the Netherlands. What was called "natural philosophy," the lighthearted enterprise of gentlemen of leisure, began to change into a rigorous professional occupation with strict procedures, what later became known as the Scientific Method.

The Scientific Revolution: The New Astronomy and Physics. The major figures who initiated the scientific revolution were Johannes Kepler, Galileo Galilei and Isaac Newton. What they accomplished was the formulation of a radically new conception of the nature of the physical world.

KEPLER'S LAWS OF PLANETARY MOTION. The Copernican heliocentric theory aroused little interest for half a century and the great astronomer, Tycho Brahe (1546-1671), actually rejected it. It was the contribution of three 17th century pioneering scientists that established the validity of the heliocentric theory: Kepler, Galileo and Newton. It was Johannes Kepler who first presented solid support for the heliocentric theory in his *Mysterium cosmographicum*, published in 1597. Using the accurate data of Tycho Brahe and considering the intricate apparent motion of Mars, Kepler discovered that by assuming that the orbit of Mars around the sun is elliptical rather than circular, and that its speed is variable, he could give a perfect account of its apparent movements. In 1609, Kepler made public his first and second laws of planetary motion. Kepler's first law stated that the planets move in elliptical orbits (rather than circular ones), one focus of which is occupied by the sun. His second law stated that the line drawn from the sun to a planet sweeps over equal areas in equal times (Fig. 12-1). That law implied that a planet moves faster on its elliptical orbit when closer to the sun, and slower when farther from it. Kepler's third law, enunciated in 1618 (the inverse square law), stated that the square of the time that it takes a planet to complete its orbit is proportional to the cube of its distance from the sun. Apart from providing a greatly simplified and more accurate account of the planets' orbits, Kepler's cosmology extended the operation of physical principles to the sky. The heavenly spheres became solid bodies like the earth, obeying mechanical laws. Kepler hypothesized that the sun exerts some physical influence on the planets, including the earth, but he could not specify what that force might be.

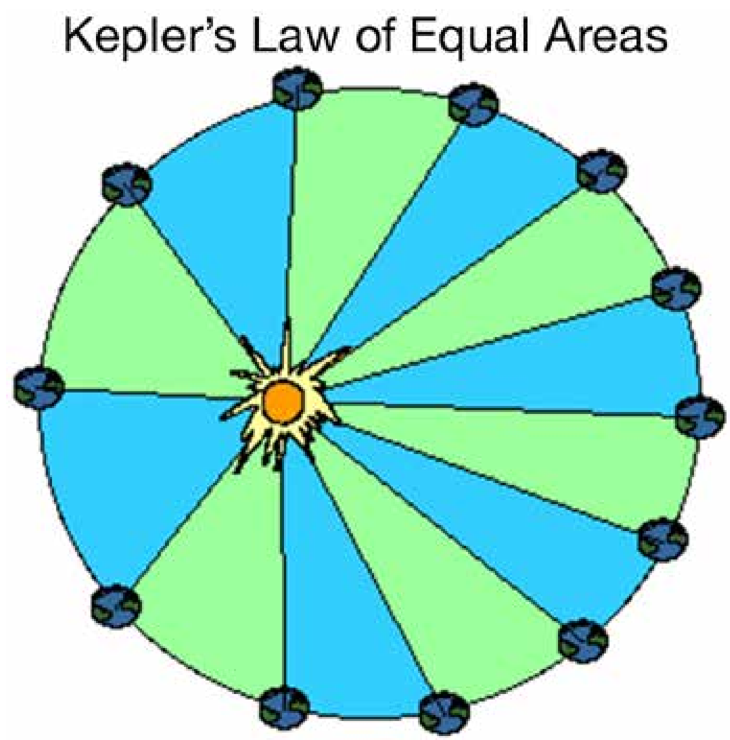


Fig. 12-1. Kepler's law of equal areas. A planet moving around its elliptical orbit around the sun moves faster when closer to the sun and slower when farther from it, sweeping equal areas in equal length of time. (Physicsclassroom.com)

GALILEO'S NEW PHYSICS. In his *Dialogue Concerning the Two Chief Systems of the World, the Ptolemaic and the Copernican* (published in 1632) and the *Discourses on Two New Sciences* (published in 1638), Galileo Galilei went beyond popularizing the theory of the geocentric universe by coupling it with the new physics. Galileo challenged the teleological physics of Aristotle according to which there two kinds of movements, natural and forced. Natural movement was exemplified when a heavy body "seeking" its proper place moved toward the earth and a light body, "seeking" its proper place, moves toward the sky. To keep a heavy body moving on the ground on the ground, it is necessary to apply steady force. To explain the flight of an arrow trough the air, it was assumed that it is driven by airflow produced at the rear and is drawn by the vacuum in front of it ("nature abhors a vacuum"). But that raised an insoluble problem: if force has to be continually applied to keep a heavy body in motion, what force keeps the planets moving endlessly around their orbits?

Galileo believed that to discover the causes of natural events, requires scientific experimentation and he performed simple experiments and sought to provide mathematical formulae to account for his findings. Observing the course of projectiles and experimenting with rolling bodies, he theorized, contrary to Aristotle, that once a body is in motion, it will keep moving unless stopped by some external force (Fig. 12-2). This came to be known as the law of inertia, the resistance of moving bodies to change in their velocity. Hence, the steady motion of a body, like a planet in empty space does not require any explanation, only changes in its speed or direction. Recording the periodicity of a swinging pendulum, Galileo discovered that that is independent of its amplitude and proportional to the square root of its length. He suggested that a pendulum could be the regulator of a weight-driven clock, which

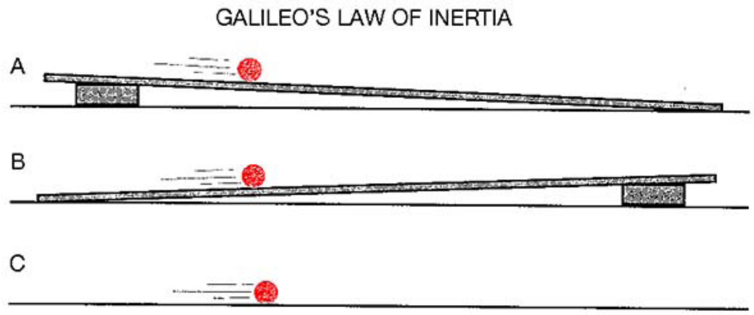


Fig. 12-2. Galileo's law of inertia. A smooth ball on a smooth surface speeds up rolling down (a) and slows down rolling up (b). Hence the ball should keep rolling forever on a perfectly smooth and level surface (c). (Aether.lbl.gov)

was put into practice by Christian Huygens (1629-1695). Galileo designed a simple telescope and discovered, among others, the phases of Venus and the moons of Jupiter. Most importantly, Galileo popularized the new rational principle that the validity of presumed facts (the premises of logical conclusions) depend not on authority (biblical or philosophical) but experimental evidence.

NEWTON'S THEORY OF UNIVERSAL GRAVITY. The final synthesis of terrestrial and celestial physics was the accomplishment of Isaac Newton, which he summarized in his *Philosophiae Naturalis Principia Mathematica*, published in 1687. In addition to using the data and ideas of Copernicus, Kepler and Galileo, Newton must have been influenced by the works of William Gilbert (1544-1603) and Alphonse Borelli (1608-1678). Gilbert determined in his experiments with magnetism that the magnetic force exerted by a loadstone on a piece of iron increased with its size and that the attraction between the two was mutual. He also found that a spherical loadstone revolved when placed in a magnetic field. Based on these findings, Gilbert hypothesized that the earth was a gigantic magnet and holds the universe together with its magnetic force. This view was obviously untenable but it may have given Newton the idea that another force, gravity, could have a similar effect through space without mechanical contact. Borelli suggested in 1665 that the elliptical orbit of a planet is due to the balance of opposing forces, the centripetal force of the sun's gravity attracting the planet and the centrifugal force of its velocity keeping it from falling into the sun.

Newton may be credited with two major achievements, one conceptual, the other, mathematical. Conceptually, Newton discovered that it is one and the same force, universal gravity, that the earth exerts on falling bodies, the moon on the tides of the seas, the earth on the moon, and the sun exerts on the earth and all the other planets to stay in their orbits. Mathematically, Newton was able to carry out the calculations that accounted for the gravitational pull of the mass of the earth on falling bodies, and the gravitational pull of the sun on the planets to account for their motion in accordance with Kepler's third law. Newton reformulated that law to the effect that the attraction between two large bodies is proportional to the product of their masses divided by the square of their distance from each other. Newton's critics, like Leibniz and Huygens, questioned how two solid objects separated by a vast distance devoid of a medium could exert a mechanical influence on one another. Newton did not have an answer and declined to offer any hypotheses. He wrote:

> Hitherto I have not been able to discover the cause … of gravity … and I frame no hypotheses … To us it is enough that gravity does really exist, and act according to laws which we have

> explained, and abundantly serves to account for all the motions of the celestial bodies, and of our sea.
>
> (Newton, 1946, Book 3, p. 547)

Early Experiments in Physics. The experimental tools used by scientists of the 17th century were simple and of two kinds, those that magnify or modify what we perceive visually, and those that allow us to discover phenomena that we cannot directly perceive with our senses. We have referred already to Galileo's use of a low-powered telescope to magnify the view of celestial bodies. A landmark discovery was Newton's demonstration, by using prisms and lenses that what appears to be the white ray of the sun is a composite of rays of different colors (Fig. 12-3). The rays of different colors (as we now know of different wavelengths), Newton argued, are refracted by different amounts as they pass through a prism, and he showed that passing them through an inverted prism, the rays could be recomposed.

THE SPECTRAL COMPOSITION
OF WHITE LIGHT

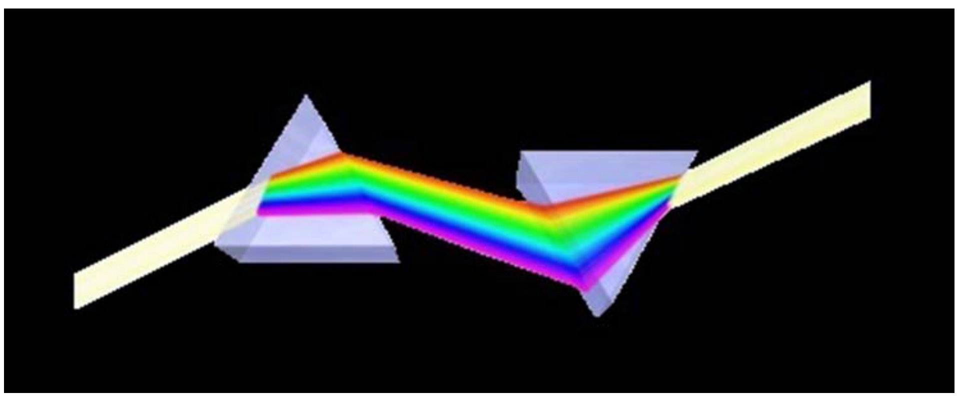


Fig. 12-3.
Modern rendering of Newton's demonstration of the spectral composition of white light.
(Thestargarden.co.uk)

THE DISCOVERY OF ATMOSPHERIC PRESSURE. An early discovery was the power of atmospheric pressure (Hempel, 1966; (Bedini and de Solla Price, 1967). Suction pumps to draw water from a well were in use before he 17th century. They consisted of a barrel and a piston; when the piston was raised, water filed the vacated space. (The explanation offered for this phenomenon was Aristotle's dictum that "nature abhors vacuum.") It was also known that water could not be lifted with this method higher than 34 feet. Evangelista Torricelli (1608-1647) hypothesized that the rise of water in an evacuated cylinder is due to atmospheric pressure and, therefore, the weight of the air on the ground must be equivalent to 34 feet of water. If so, Torricelli reasoned, atmospheric pressure should force mercury in an evacuated cylinder 34/14 feet (about 2½ feet) because its specific gravity is about 14 times that of water. To verify this hypothesis, Torricelli filled a tube with mercury, inverted the tube and placed it into a mercury-well. The mercury swiftly dropped in the tube and then, as predicted, stopped at about 2½ feet (Fig. 12-4). Blaise Pascal (1623-1662), the mathematician, reasoned that if atmospheric pressure keeps the mercury column at a particular height, the column should decrease at higher altitudes. At Pascal's instigation, Florin Perier took a barometer up a mountain. The mercury column dropped the higher up he got. Otto von Guericke (1602-1686), who invented a vacuum pump, made a dramatic demonstration of the immense power of atmospheric pressure. He harnessed eight horses on each side of two apposed bronze hemispheres from which the air has been evacuated. The horses could not pull the hemispheres apart until a cock was opened to break the vacuum (Fig. 12-5). Guericke's vacuum pump was soon improved by Robert Hooke and Robert Boyle, and has since become a standard item in scientific laboratories. Guericke also described a frictional electrostatic machine but at that time instruments were not available to study this mysterious electric force. Such simple tools enabled scientist to discover unknown facts about the physical world.

Beginnings of Biology. In addition to the great advances in astronomy and physics, there were also noteworthy advances in the 17th century in two areas of biology, gross anatomy and microscopy.

THE MERCURY BAROMETER

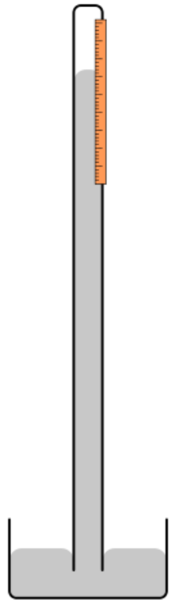


Fig. 12-4. The device Torricelli used to measure atmospheric pressure. (Mercurybarometer.svg)

DEMONSTRATION OF ATMOSPHERIC PRESSURE

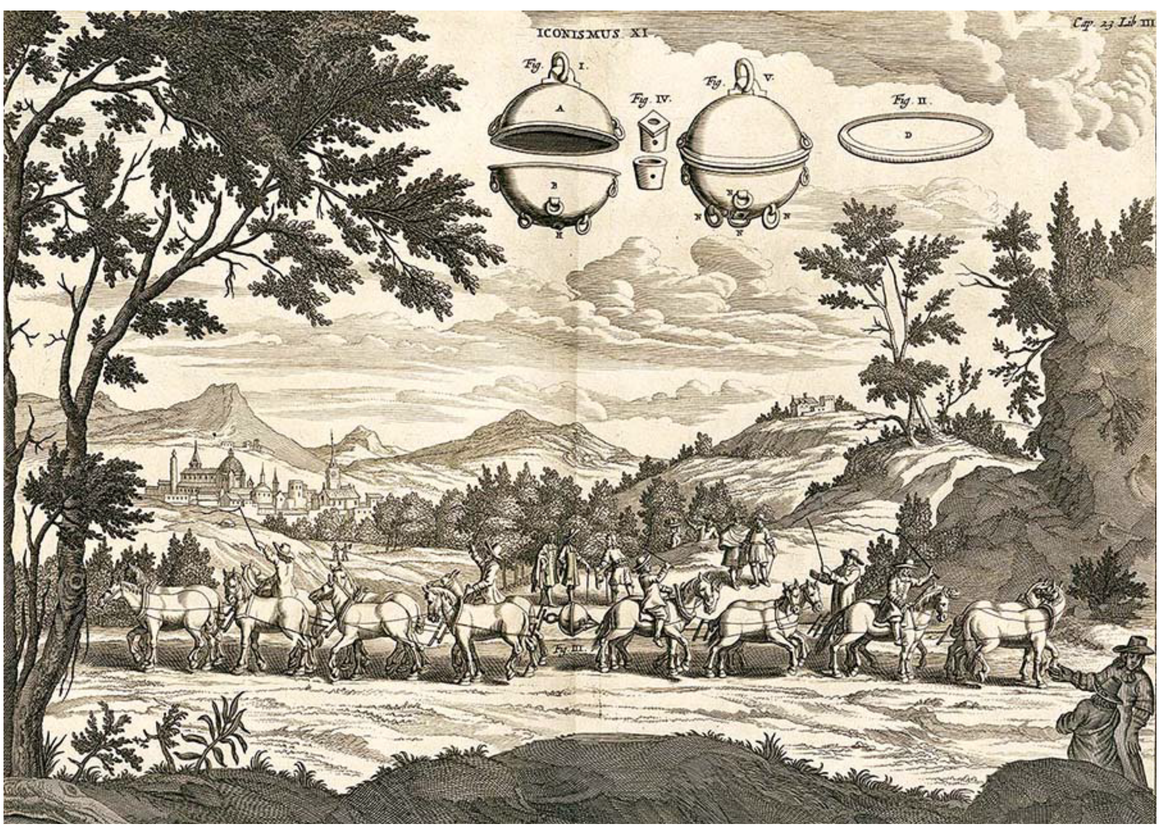


Fig. 12-5. The demonstration of the power of atmospheric pressure by von Guericke. (Magdeburg.jpg)

EARLY GROSS ANATOMY. Modern anatomy began with the publication of *De Humanis Corporis Fabrica* by Andreas Vesalius in the mid-16th century. This work with its high-quality illustrations consisted of seven volumes: the first dealt with the skeletal system; the second with the muscular system; the third with the vascular system; the fifth and the sixth with the viscera; and the seventh with the eye and the brain (Fig. 12-6). These volumes appeared about the same time as Copernicus' book and, like it, represented a break with established tradition. Instead of relying on the texts of ancient authorities, Vesalius undertook the painstaking dissection of cadavers and re-examined in great detail the structure of every part of the human body. Initially, Vesalius' work was appreciated only in Italy but by the 17th century most European medical schools adopted his empirical method.

VESALIUS' ILLUSTRATION OF THE HUMAN BRAIN

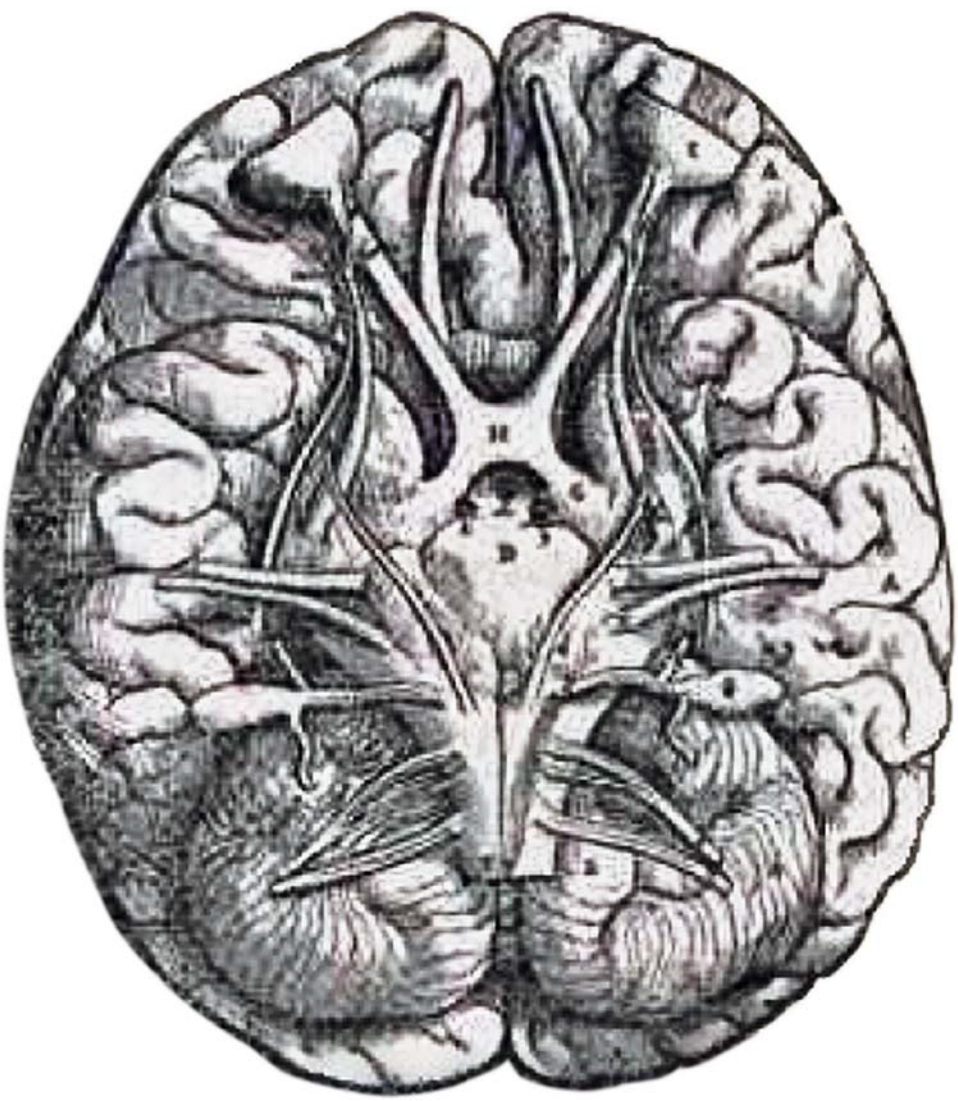


Fig. 12-6. Illustration by Vesalius of the ventral aspect of the human brain, with the retina and cranial nerves. (Wikipedia: AndreasVesalius.jpg)

EARLY MICROSCOPY. The great pioneer of the microscopic examination of living organisms and tissues was the amateur scientist Anton van Leeuwenhoek (1632-1723). Fabricating simple microscopes (Fig. 12-7), Leeuwenhoek discovered a new world of living things not visible to the naked eye: protozoa, rotifers, bacteria, and sperm of animals and man. He also identified single nerve fibers in nerve bundles (Fig. 12-8), and thought he could see their hollow core, which, according to tradition, he interpreted as the conduit for the "animal spirit" of nerves (Clarke and O'Malley, 1968). (What he actually demonstrated were nerve fibers surrounded by a myelin sheath.) Another early contributor to microscopy was Robert Hooke (1635-1702) who first illustrated the cellular organization of organic tissue (Fig. 12-9). (What he actually demonstrated were cell walls.) Subsequently, others made similar observations in plant tissues but they did not realize the significance of their discovery.

There was a controversy in the 17th century between two views of embryonic development. The "epigeneticists," following Aristotle, believed that embryonic development consists of the successive unfolding of potentials inherent in the undifferentiated ovum. In contrast, the "preformationists" believed that the ovum or sperm contained a miniature of the adult organism; hence development consists of little more than growth. Supporting that, the early microscopists, including Leeuwenhoek and Malphigi, claimed that they could recognize a little chick in the egg before incubation, and a "homunculus" in the human sperm. This miscomprehension had the unfortunate consequence of discouraging the study of embryonic development for a

LEEUWENHOEK'S MICROSCOPE

LEEUWENHOEK'S ILLUSTRATION OF A NERVE BUNDLE

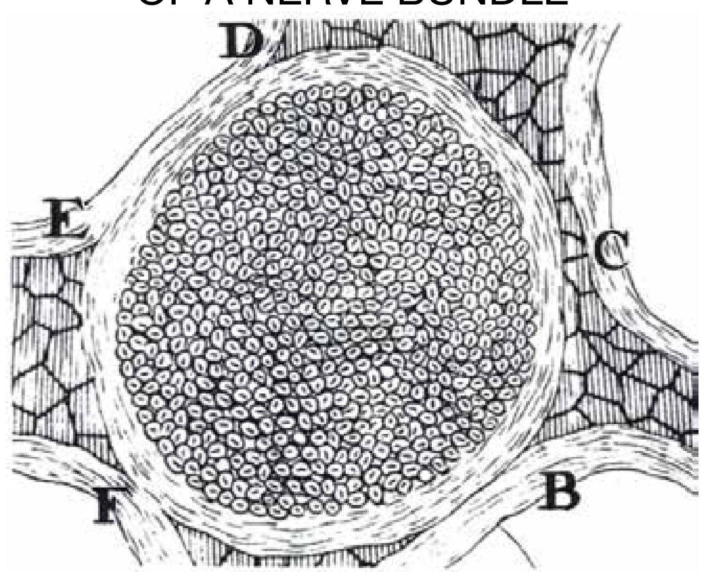


Fig. 12-8. Leeuwenhoek's drawing of nerve fibers within a nerve bundle, as visualized with his primitive microscope. (After Ochs, 2004)

Fig. 12-7. Replica of Leeuwenhoek's microscope. (Leeuwenhoekmicroscope.png)

CELLULAR ORGANIZATION
OF PLANT TISSUE

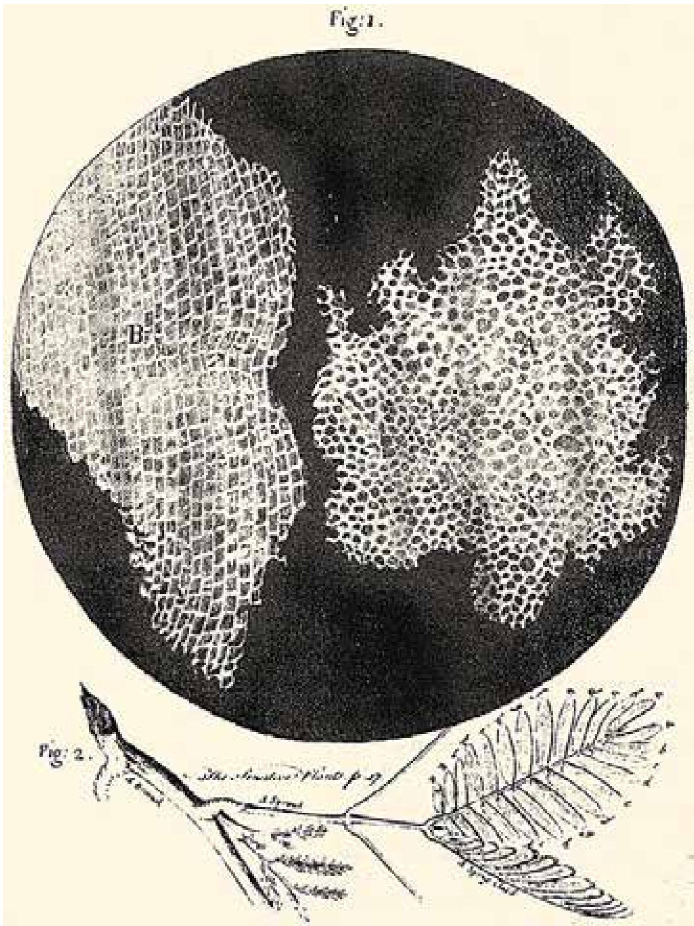


Fig. 12-9. Robert Hooke's illustration of the cellular composition of plant tissue. (RobertHookeMicrographia1665.jpg)

long time. If the organism is already present fully developed in the germ, what is there to be gained by attempting to record its progressive enlargement? William Harvey in his *Exercitationes de Generatione Animalium*, published in 1651, confirmed that a miniature chick is not present in the egg. Harvey studied the onset of embryonic development in deer during the rutting season and found that embryonic development begins with an ovum attached to the uterine wall. From that he drew the generalization that embryonic development always begins in mammals with the implantation of a fertilized egg.

The microscopes used by these 17th century pioneers were simple instruments and difficult to use. The poor quality of the glass, the chromatic and spherical aberrations of the lenses, and the inadequate machining of the screws, made microscopy a difficult art. Eustachio Divini (1620-1695) and Guiseppi Campani (1635-1715) fabricated the first compound microscopes; but these were still rudimentary instruments. Because of this, and the poor preservation of the organic specimens, microscopy did not become a powerful tool of biological research until the 19th century.

12.1.3. Expanding Horizons: Exploration and Colonization. The beginning of the Modern Age was characterized not only by great scientific advances but also by a change from the medieval sedentary, docile and provincial life style of peasants and landlords to the mobile, adventurous and cosmopolitan life style of traders, conquerors and colonizers.

The Age of Exploration. Commerce between West and East was controlled during the Middle Ages by several Italian city-states along the Mediterranean and the Adriatic. Trading spices, silk, and fine textiles originating in the Far East, and incense, drugs and slaves originating in Africa made some of the Italian republics, such as Venice and Genoa, extremely prosperous. But the rise of the Ottoman Empire and the Turkish occupation of Constantinople in 1453 made this trade route difficult. This provided the opportunity for Portuguese sailors to explore a new route to Asia. Early in the 15th century, Portuguese sailors in the service of Henry the Navigator—who increasingly used the caravel (Fig. 12-10) that was better suited to sail windward than most other ships—discovered Madeira in the Atlantic Ocean. That was followed in the succeeding decades by settlements established on the islands of the Azores and Cape Verde. Concurrently, Portuguese sailors also explored the Atlantic coast of Africa. Diogo Cão reached the Congo River in 1842, Bartolomew Diaz sailed around the Cape of Good Hope in 1488, and Vasco da Gama reached India by 1498. This opened up a direct trade route to the Far East. Portuguese sailors reached the Spice Islands in 1512, and by 1522 Ferdinand Magellan circumnavigated the globe (Fig. 12-11).

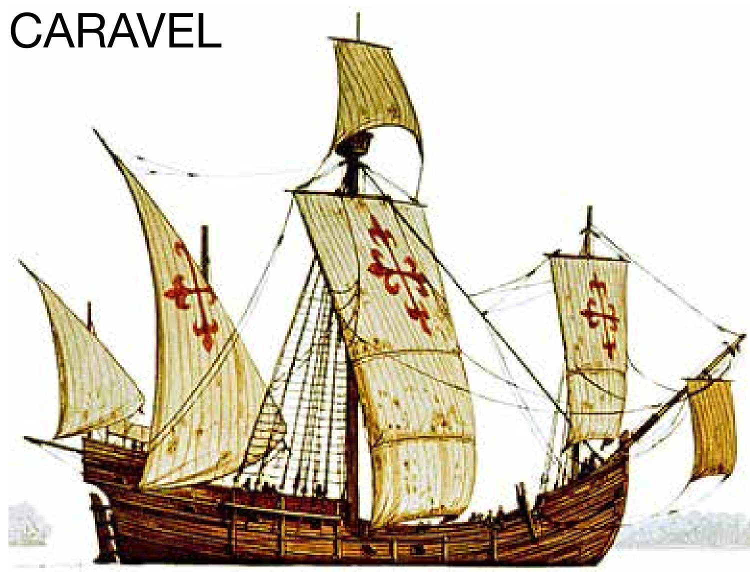


Fig. 12-10. Caravel used by the Western explorers and colonizers. (Nautarch.tamu.edu)

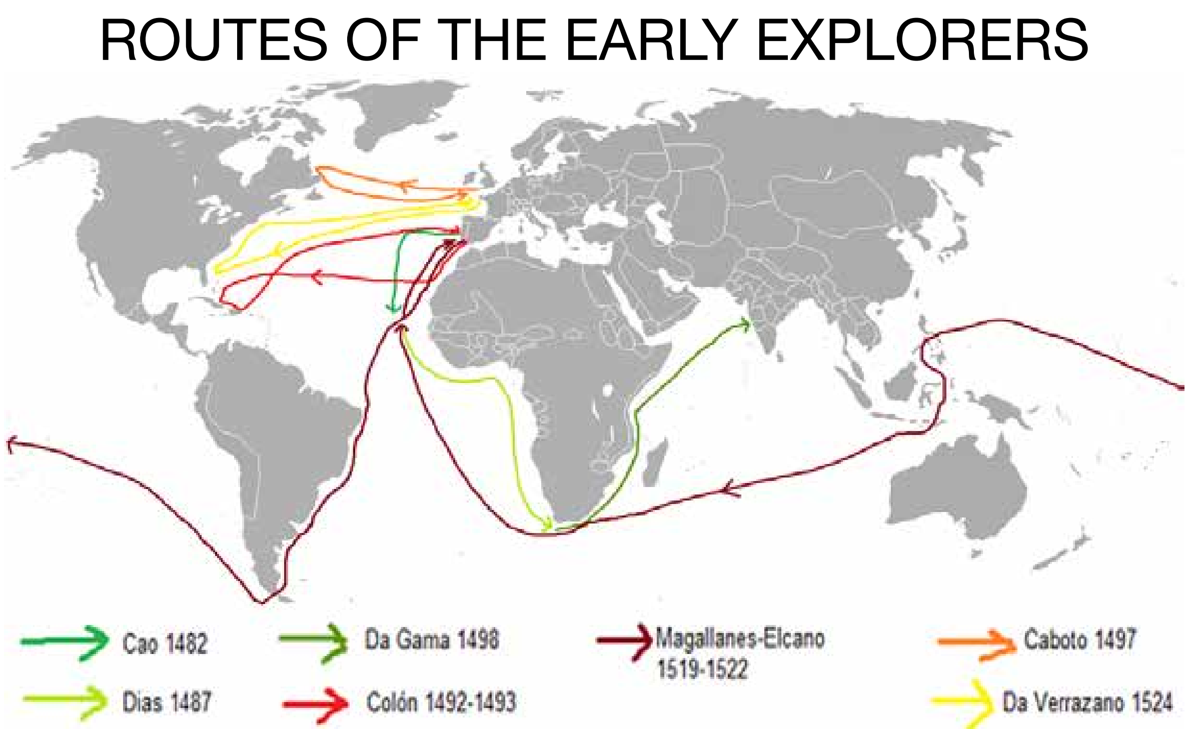


Fig. 12-11. The routes followed by the early explorers across the Atlantic and the Pacific Oceans. (Explos.png)

Another possible route to India was crossing the Atlantic westward. Christopher Columbus undertook that in the service of the Spanish monarchy. This led in 1492 to the discovery of America by Europeans. In his first voyage, Columbus sighted the Bahamas and landed in Cuba and Santa Domingo. In subsequent voyages he discovered the Caribbean Islands and Central America, all along believing that he reached India by the western route. Wasting little time, the English, the French, and the Dutch soon entered the race of exploration. In 1497, an English expedition led by the Venetian John Cabot began to explore North America, hoping to find the Northwestern Passage to India. In 1525, Giovanni da Verrazano, in the service of France, explored the coast from South Carolina to Newfoundland, and in 1534 Jacques Cartier sailed inland along the St. Lawrence River. Henry Hudson, sailing for the East India Company, explored the Hudson River in 1609. By the early 17th century, the great centers of commerce shifted from the Mediterranean to the Atlantic with the establishment of the Dutch East India Company in Amsterdam (Fig. 12-12) and the (British) East India Company in London. Hundreds of ships left Antwerp, Amsterdam and London with spices, chinaware, textiles and other luxury goods destined to reach different harbors in Europe.

The Age of Colonization. The initial purpose of Western exploration of the globe was to find new trade routes to Asia, bypassing the Mediterranean and the Mideast under Ottoman rule.

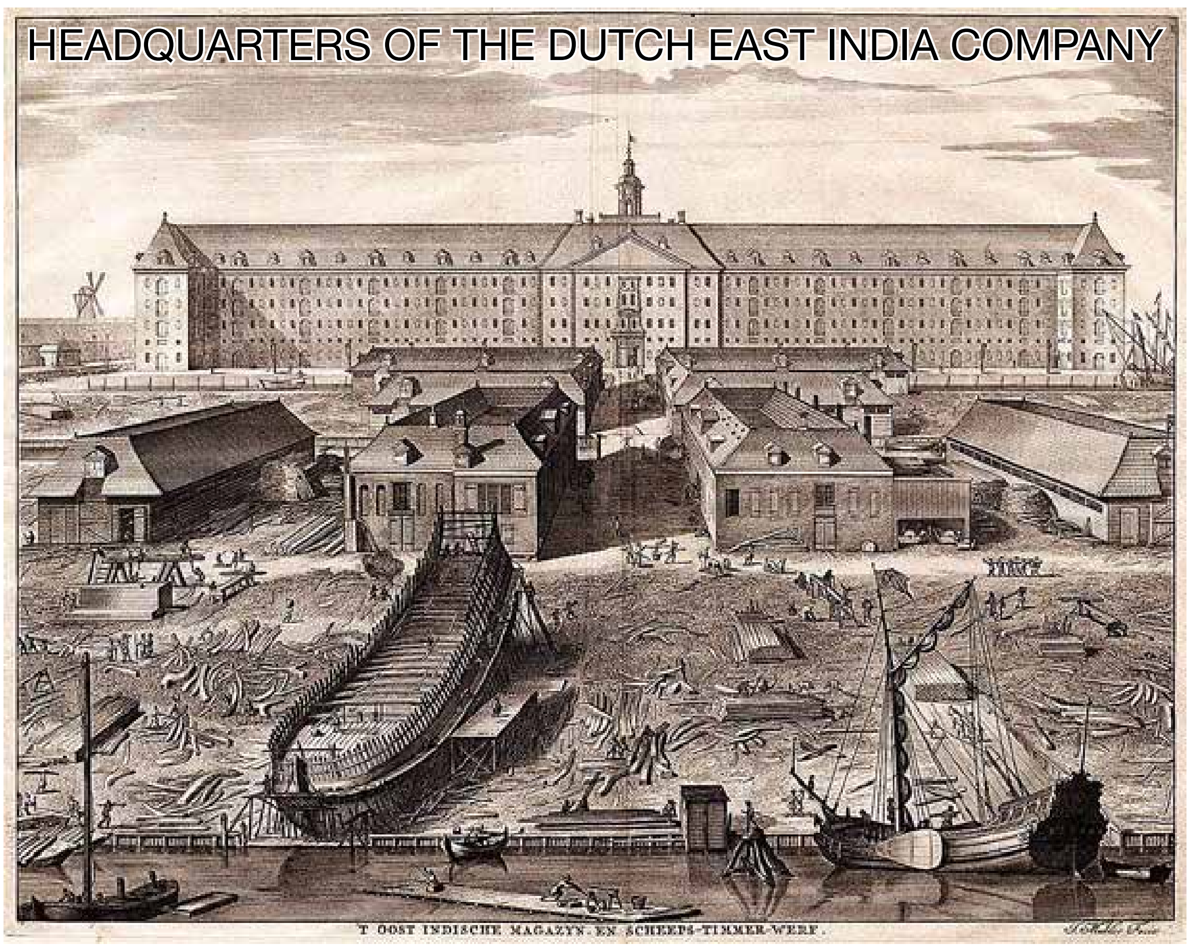


Fig. 12-12. Headquarter and warehouses of the Dutch East India Company in Amsterdam. (Voc.jpg)

Conquerors, settlers, and missionaries then followed the traders. The Spanish conquistadores discovered the gold treasures of the Aztecs, Mayas and Incas of South America, and then the silver mines of Potosí in what is now Bolivia. Natives were initially forced to work in the mines but they were decimated by harsh conditions and epidemics. African slaves were imported in large numbers to do the work. Importantly, the settling of South America by the Portuguese and the Spanish was motivated not only by economic considerations but also the zeal of Catholic missionaries to spread their creed to the heathens. Many Protestants from Britain and France, in contrast, settled in North America to escape religious persecution at home. As the lands were appropriated from the natives, large estates were established to produce goods, such as sugar, tobacco and cotton that were in great demand in Europe.

Colonialism was a new development in modern Europe as nations with growing firepower began to compete with one another in claiming ownership of the lands of militarily and economically less developed non-Europeans, typically "colored" people, whom the Europeans came to treat as inferior human beings. This was the beginning of Western Imperialism. In the late 16th century South America was divided by a papal bull, and later by treaties, into Spanish and Portuguese domains. In the ensuing two centuries England, France and Netherland also turned into colonial empires, occupying lands in North America, Africa, Asia, and the South Pacific (Fig. 12-13). (Other colonial powers, expanding on land, were Turkey and Russia.) Colonies served three utilitarian ends: they were a source of cheap labor and raw materials; they provided land for the landless and a place to ship convicts; and they were potential markets for mass-produced industrial products. Colonies were also a source of pride in countries that increasingly became more and more nationalistic. That rivalry among colonial powers created hostilities that greatly contributed to battles between Spain, Britain and France, and later to the outbreak of the First World War.

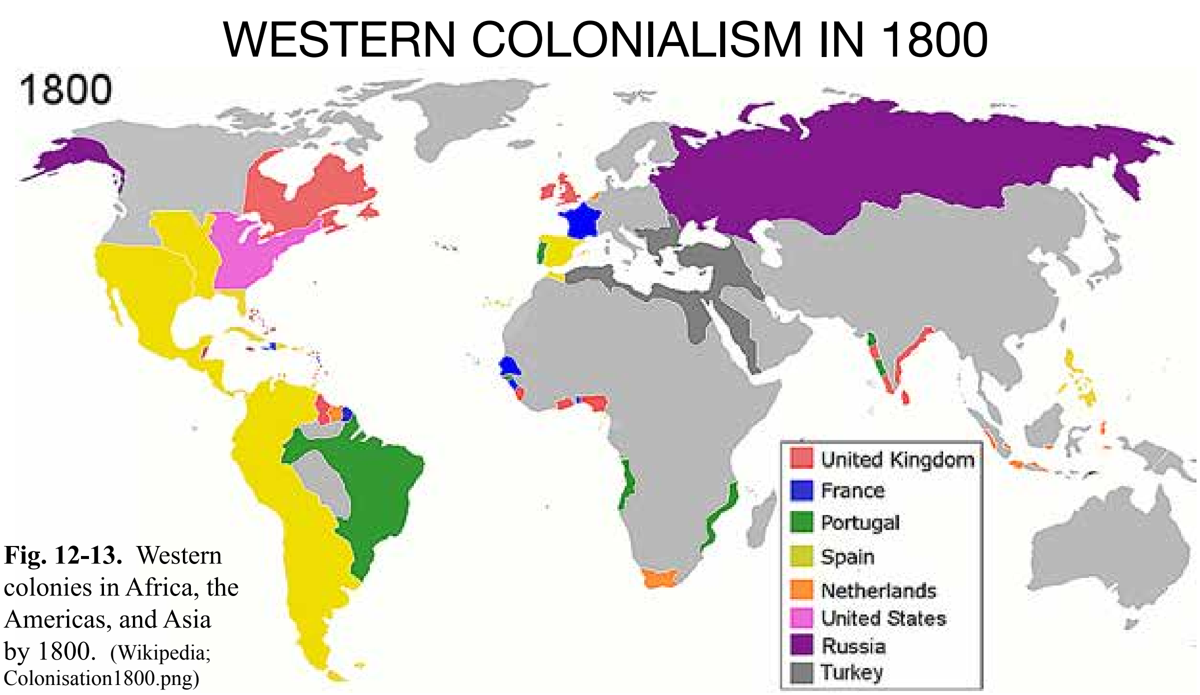


Fig. 12-13. Western colonies in Africa, the Americas, and Asia by 1800. (Wikipedia; Colonisation1800.png)

12.1.4. Scientific Advances in the 18th Century. After the great discoveries made in the 17th century with simple scientific devices, progress in astronomy and physics slowed down for a while because further advances required improved scientific instruments, something that was not accomplished until the second half of the 18th century in association with the Industrial Revolution. Then, as more and more sensitive instruments were invented, it was discovered that the natural world is fundamentally different from what our unaided senses provide.

Advances in Physics and Astronomy. Although the ancient Greeks knew that when amber (*elektron*) is rubbed it attracted other objects, that observation did not receive further consideration. William Gilbert, in his *De Magnete* published in 1600, noted the difference between magnetic attraction, which acted only on iron, and electric attraction, which acted on many objects (Mason, 1962). Gilbert also noted that, in addition to amber, a variety of other objects (such as glass, wax, and precious stones) also had this attractive power when rubbed. In the mid-17th century Robert Boyle carried out some studies on electricity and Otto von Guericke described a simple device to generate electricity. That was followed in the mid-18th century by the invention of the Leyden jar by Pieter van Musschenbroek and Andreas Cunaeus. This device stored static electricity and delivered a brief shock (discharged) when touched (Fig. 12-14). Benjamin Franklin demonstrated in 1752, using a flying kite, that lightning was an electric discharge from the clouds.

DISCOVERY OF THE LEYDEN JAR

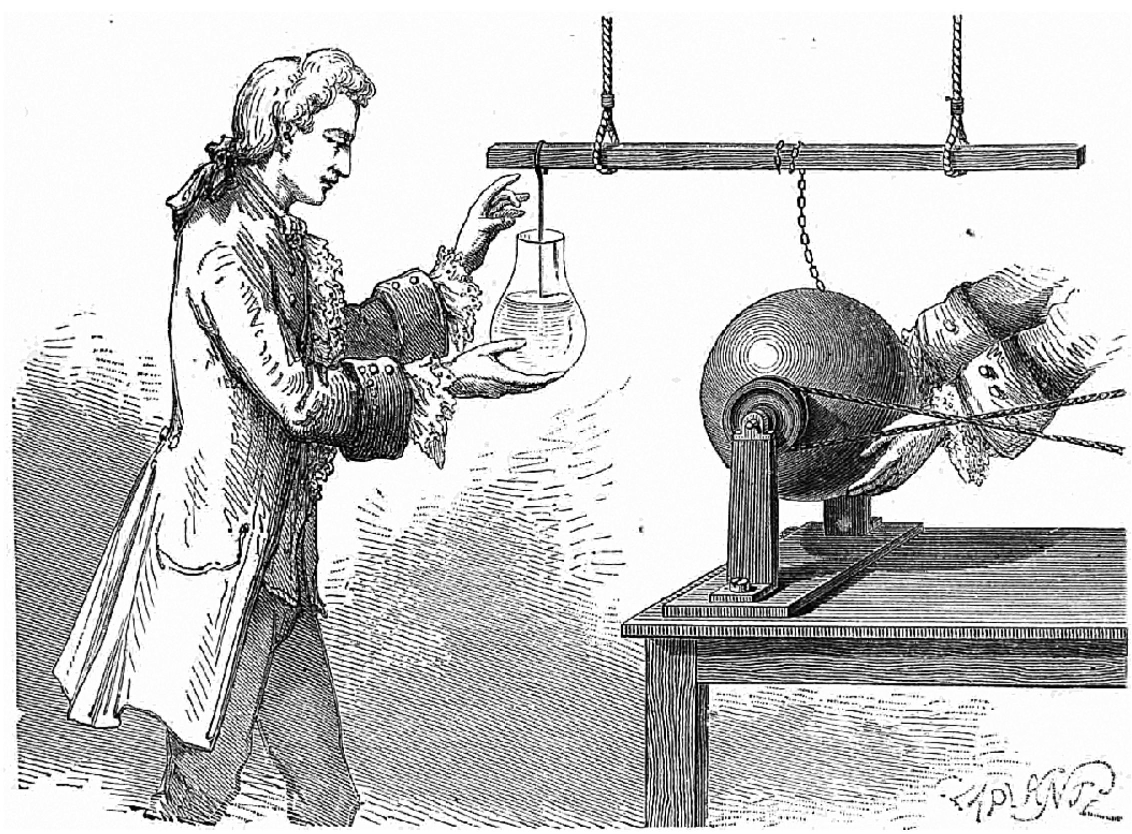


Fig. 12-14. Transferring electricity generated by rubbing a rotating glass sphere with the hands into a jar filled with water. (Wikipedia; Leydenjar.png)

Advances in Astronomy. Newton and others wondered why there is no change in the apparent position of the stars (parallax) as the earth reaches semiannually opposite points along its elliptical path. They inferred that, unlike the planets, the stars must be situated at such immense distances from the earth that the parallax is too small to be measured with available instruments. Early in the 18th century, Edmund Halley discovered that three bright stars—Sirius, Arcturus and Aldebaran—differed appreciably from their positions recorded by the Greek astronomer, Hipparchus (Whitrow, 1959). Halley suggested that these stars must have moved at right angles to the line of sight with respect to the other stars in the course of the elapsed two millennia. This was the first indication that the fixed stars may be mobile.

Advances in Chemistry. Humans have used chemistry ever since the invention of cooking and baking to change the properties of edible substances, and developed techniques to extract substances, such as sulfur, gypsum and lime, by heating certain chemicals, and improving the quality of metals by producing alloys (Toulmin and Goodfield, 1962; Multhauf, 1967). There have also been persistent efforts during the Middle Ages to transform base metals into silver and gold, and create an elixir of life—an undertaking that was known by its Arabic name as *alchemy*. But these efforts were based on superstition and magic not rationally guided scientific theories.

FOUNDATION OF MODERN CHEMISTRY IN THE 18TH CENTURY. It was widely accepted up to the early 18th century that there are four elementary substances—earth, water, air and fire—as described by Aristotle. But by the middle of the century it was established that none of these are elementary substances, and fire is not a substance at all. What was broadly called earth is an extremely heterogeneous collection of *solids*; water is only one kind of *liquid* among many others; and air is only one kind of *gas.* The study of gases was begun when Stephen Hale described a technique in 1727 of studying the properties of different gases that were produced in a retort by bubbling them into a container filled with water. In 1753, Joseph Black established that "fixed air," now known as carbon dioxide, differs from ordinary atmospheric air in that it does not support combustion. Black established that this gas is generated in many processes: when charcoal is burnt; in fermentation; and when air is exhaled from the lungs. In 1766, Henry Cavendish discovered another gas, "inflammable air," which we now know as hydrogen. In the next two decades, Joseph Priestley identified "vitiated air" (nitrogen), "nitrous air" (NO), and "dephlogisticated nitrous air" (NO_2). Of greatest significance was the independent discovery by Joseph Priestley, Karl Wilhelm Scheele and Antoine-Lavoisier of "eminently respirable air," in which a candle burnt more brightly and in which a mouse survived longer than in ordinary air. Lavoisier named that gaseous substance oxygen.

The understanding of the chemistry of gases was hampered for some time by the "phlogiston" theory of fire and the "calcination" of metals (Butterfield, 1949; Mason, 1962). The Aristotelian tradition was that fire is a substance released when objects burn. According to that theory, when burning wood turns into ash phlogiston was released, and when calx (rusted metal) was heated in the presence of charcoal, the phlogiston of the charcoal entered the metal and restored the metal to its original state. Lavoisier reinterpreted the available data by postulating that burning of a substance or its rusting is due to its combination with oxygen (oxidation). In his *Traité Élémentaire de Chimie*, published in 1789, Lavoisier distinguished between simple substances, what we now call elements, and compounds produced by the combination of these elements. As he and others have shown, water is a compound of hydrogen and oxygen. He also recognized that the same substance (not only water) exists in three states depending on its temperature, as a gas, as a liquid and as a solid. Lavoisier postulated that while matter may undergo transformations, it is not destructible. That theory was the foundation of quantitative chemistry.

Early physiology. The first major work in physiology was William Harvey's *Exercitatio Anatomica de Motu Cordis et Sanguinis in Animalibus*, which appeared in 1628. In this book, Harvey summarized his observations that lead to his discovery that the heart was a pumping mechanism responsible for blood circulation throughout the body. His discovery was based on procedures that did not require special instruments: he relied on the comparative study of the heart in a great variety of species from fish to man, and on vivisection. Harvey was able to trace the flow of blood away from the heart through the arteries and back by the veins. The demonstration of the closure of this circuit by way of capillaries between the arteries and the veins required the use of a microscope. This was the discovery of Marcello Malphigi in 1661 (Caullery, 1966).

A great advocate of the mechanistic approach to the functioning of the body was Descartes, as described in his La *Description du Corps Humaine*, published in 1667. Although aware of Harvey's work, Descartes still argued that the heart was a pump that produces the "animal spirit" that flows from the sense organs through the nervous system to the skeletal muscles to produce movement. Descartes formulated an early concept of reflex function, believing that contracting muscles expand as the "animal spirit" enters into them. A pioneer of the scientific analysis of the mechanical action of muscles was Giovanni Borelli (1608-1697), as described in his book, *De Motu Animalium*. Borelli analyzed the mechanics and geometry of muscles at joints; the reciprocal action of antagonistic muscles; the nature of muscle tonus; the postural support of the body; and the various forms of locomotion. He distinguished between skeletal muscles that produce external movements and the muscles of the heart and viscera that produce internal movements. Borelli rejected the idea that "animal spirit" enters the muscle when it contracts, since no bubbles left the slit muscle submerged in water during contraction. Then Francis Glisson (1597-1677) and Jan Swammerdam (1607-1680) showed that muscular contraction is not associated with expansion, as there is no rise in water level when submerged muscles contract. Nicolas Steno's (1638-1686) microscopic observations revealed that muscle is made up of contractile fibers and these, in turn, of fine fibrils. Albrecht von Haller (1707-1772) summarized in his eight-volume *Elementa Physiologiae Corporis Humani,* the vast amount of information that became available by the mid-18th century about the functions of the body's different organs and organ systems. He distinguished between the "sensibility" of nerves to stimulation and the "irritability" of muscles when they shorten during contraction. However, this was still an age before electrical recordings of nerve impulse propagation and muscle contraction were possible. Hence, Haller was not in a position to offer a satisfactory explanation of the vast amount of physiological information accumulated by his predecessors and contemporaries.

LINNAEAUS' TAXONOMY. Aristotle described about 520 animal species and formulated the concept of "scale of nature." Dioscorides of Alexandria (1st century CE) described about 600 edible and medicinal plants (Lanham, 1968). This genuine scientific effort was somewhat compromised by Pliny's (23-79 CE) Natural History, which was further corrupted by the popular herbals and bestiaries written during the Middle Ages. An improved botanical encyclopedia published in the 16th century was Otto Brunfels' *Herbarium Vivae Icones*, and Conrad Gesner's five-volume zoological encyclopedia, *Historia Animalium*. Modern taxonomy was the creation of Carl Linneaus. In the first edition of his *Systema Naturae*, published in 1735, Linnaeus distinguished between species, genus, order, and class as hierarchic scales in the classification of living beings. And in his *Species Plantarum*, published in 1753, Linnaeus introduced the binomial nomenclature for the scientific naming of species. The taxonomic system described in the tenth edition of his *Systema Naturae*, published in 1758, is to this day the standard for the classification of plants and animals.

12.1.5. The Beginning of the Industrial Revolution: Invention of the Steam Engine. The Industrial Revolution that started in England in the middle of the 18th century was an intensification of the technological, economic and social developments that began in the West by the late Middle Age. The growing reliance on experimentation and logical reasoning to solve practical problems, inspired by the Scientific Revolution, led to the use of hitherto neglected energy resources and the invention of new machines. Among aspects of the Industrial Revolution were the following. (i) A shift in the production of goods from small cottage industries to large factories with workers specializing in different tasks. (ii) The invention of machines powered by new energy resources, first the steam engine, followed later by electrical motors, and then the combustion engine burning fossil fuels. (iii) An intensification of the migration of people from the countryside to cities, which became transformed into busy metropolises with a large proletarian population. This period is justly called a "revolution" because it drastically transformed the way the majority of the people worked and lived. However, it was not a short-lived event, like political revolutions but one that continues unabated to this day. It has been the application of reason and accumulating knowledge to generate more and more goods and improve people's standard of living.

INVENTION OF THE STEAM ENGINE. Before the Industrial Revolution, raw muscle power was a major source of energy to perform work. That was provided by peasant laborers, oxen and horses. Windmills and the waterwheel were also used in some areas, but wind was inconsistent and the number of suitable rivers was limited. There was great demand for alternate energy resources. Attempts were made to use steam as an energy source by the end of the 17th century, but it was not until the early 18th century, when Thomas Newcomen introduced his reciprocating steam engine, that steam became a useful source of industrial power (Derry and Williams, 1960; Kranzberg and Pursell, 1967). Newcomen's ingenious engine was a complex science-based invention (Fig. 12-15). It was composed of a boiler, a piston and valves, and its reciprocating action depended on the operation of two physical forces, steam power and atmospheric pressure. In the first cycle, steam power opened the steam valve to the cylinder and the steam pushed the piston up. The partial vacuum created in the cylinder opened the water valve and as the steam became condensed atmospheric pressure pushed the piston down, and that automatically started the new cycle. Newcomen's engine was particularly suited to provide

NEWCOMEN'S STEAM ENGINE

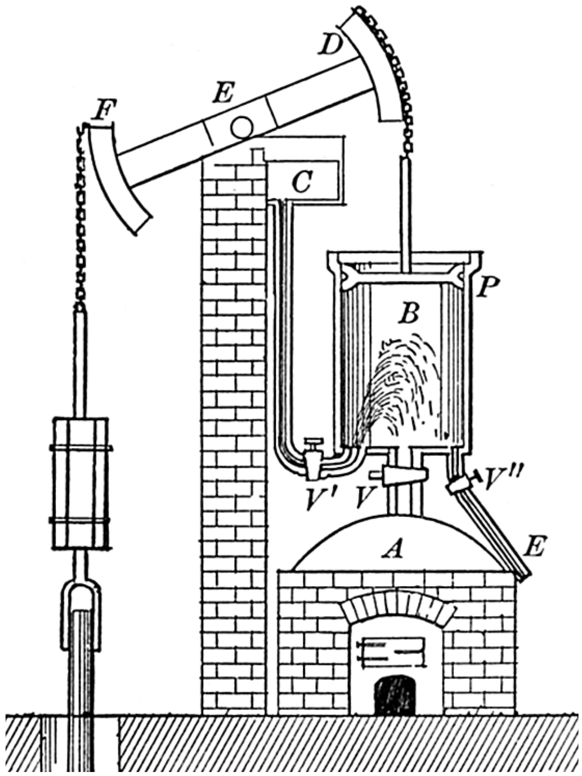


Fig. 12-15. Newcomen's atmospheric steam engine; early 18th century. (Newcomen6325.png)

WATT'S DOUBLE-ACTING STEAM ENGINE

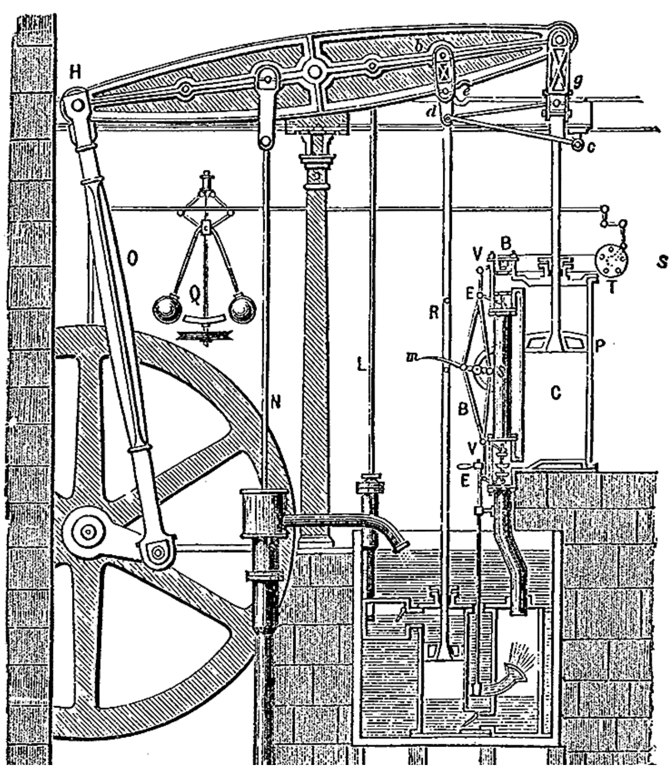


Fig. 12-16. James Watt's improved double-acting steam engine, with a feedback device that regulated engine speed. (SteamEngineBoulton&Watt1784.png)

power for vertical lift pumps and was used mainly to drain mines.

James Watt made the next great improvement in the design of the steam engine during the 1750s (Fig. 12-16) and his "double acting" elaborate mechanism remained essentially unchanged into the 20th century. Among Watt's many important contributions were (a) the separation of the boiler and the condenser; (b) a design for the alternating entry of steam at both ends of the piston; and (c) the insertion of a speed governor. The major advantage of having a separate boiler and condenser was that it dispensed with the need to reheat the steam after each stroke, which resulted in greater thermal efficiency and greater speed. The advantage of two steam ports was that the reciprocating action could now easily be turned into a rotary one and the cylinder no longer had to be vertically positioned. Finally, the governor was an ingenious new idea, a feedback device that allowed the self-regulation of the engine's speed. Watt's steam engine could easily be adapted to drive any machine, and the use of steam engines became more and more widespread in industry and agriculture.

In summary, the scientific advances that took place from the beginning of the 17th to the end of the 18th century profoundly changed Western man's conception of the universe and the nature of physical matter; the colonization of hitherto unknown lands expanded his conception of the size of the globe and its diversity and potentials; and the creation of an industry using steam power drastically changed the economic system. The scientific advances proved the merits of critical thinking and inquisitiveness over traditional thinking and slavish acceptance of authority. The new discoveries and inventions contributed to a greater appreciation of the merits of individual effort and free enterprise, and respect for man's rational powers. Naturally, the social and political order was also beginning to change drastically but that followed a far more complex trajectory. The appliances, tools and machines produced in large quantities raised the standard of living of the upper and middle classes. However, it had initially a disastrous effect on the living conditions of the expanding working class. Serfs and peasants moving in large numbers to the cities to earn money were made to work in many factories for endless hours a day under conditions that decreased rather than increased their quality of life. And where indigenous workers were in short supply, particularly where raw materials were produced in large quantities to meet the demands of the industries, employers turned to slaves captured in Africa to work on their plantations. The frustration and restlessness of these oppressed and exploited masses contributed to the tumultuous social and political history of the developing nations throughout much of this period.

12.2. Political and Social Developments in the 17th and 18th Centuries, and the Age of Enlightenment

12.2.1. Political Developments: From Autocracies to Constitutional Governments. The traditional medieval political order—characterized by divine kingship, local rule by feudal lords, and coercive mind-control by the ecclesiastical authorities—was beginning to disintegrate in some of the more advanced countries of Western Europe during the 17th century. The religious conflict between Catholics and Protestants, such as the Thirty Years' War (1618-1648), weakened the political and moral influence of the papacy and strengthened the hands of monarchs seeking to become the autocrats of their nation states. And monarchs threatened by the ongoing changes began to use various practical-rational means to strengthen their rule. These included the establishment of an elaborate bureaucratic system ran by professional government officials; reorganization of the taxation system in an effort to create a solvent treasury; building roads, bridges and harbors to improve communication, travel and transportation; and maintaining a well-equipped standing army for defense and offense. The change from decentralized feudal order to a centralized autocratic one was not an easy undertaking and took different forms in the different states. The government of Catholic-dominated France became far more absolutist than did Protestant-dominated Britain, and national unification altogether failed to take place in Italy and Germany for several centuries.

From Autocracies to Constitutional Governments. The formation of sovereign Western nation-states started during the Middle Ages as royal dynasties began to stabilize their rule over territories inhabited by a heterogeneous population that, at that time, could not be considered members of a distinct nationality. The religious allegiance of most people was to something much broader than the dynastic domain, namely the universal Church. Their social allegiance was to something much narrower than the kingdom, namely, the ruling feudal lord and the town authorities where they resided. However, those allegiances changed as the power of ecclesiastical authorities declined during protracted religious wars. Monarchs began to strengthen their rule by weakening the power of feudal nobles, establishing a central bureaucracy financed through taxation, formulating a unified system of law and justice, and building a standing army to enforce their autocratic rule. Below we examine what transpired in two of the most advanced countries of Europe, England and France, where after protracted struggles the absolutist governments changed into constitutional governments.

Absolutism is an ancient form of government with an autocrat—king or tyrant—claiming unlimited personal authority to govern a subject population. The pharaohs of Egypt were such absolutist rulers and so were the emperors of Rome. The standard justification of authoritarianism in the early civilizations was the myth that the autocrat was not acting on his own behalf as an individual but was either an agent of a god charged to carry out his will, or a descendant of a god, or a god himself. The medieval and early modern monarchs, being Christians, could not claim divine descent but asserted that they ruled by "divine right," a claim that was usually supported by the clergy. Constitutionalism is an altogether different form of government. It also has ancient analogs in those tribal societies where chiefs were selected by a council of elders and elected by popular acclamation. The idea of a constitutional government is that the ruler governs by the consent of the people and on their behalf relying on traditional laws or laws enacted by a legislative body. The ruler must, in principle, obey the laws of his nation or forfeit the legal right to rule. Constitutionalism has been tried in democratic Athens and republican Rome, but it did not endure in either place.

The Development of Constitutional Monarchy in England. The Norman kings exercised greater authority during the 11th and the 12th century over the provincial feudal lords in England than did the kings of France. But the English kings occasionally called upon the Great Council of nobles (dukes, earls and lords) and prelates (bishops and abbots) to assemble, particularly whenever they needed their help in raising taxes to finance a war. The Council later became known as the Parliament.

THE MAGNA CARTA: THE KINGS AND NOBLES. The first attempt to establish a constitutional government in the Middle Ages was the written charter, the Magna Carta (Macauley, 1979). Composed by the lords (peers) of England, it obligated the monarch (King John) in 1215 to grant them a series of rights (originally 61 clauses) that he must not violate. An important clause was: "No Freeman shall be taken or imprisoned, or be disseized of his Freehold, or Liberties … but by lawful judgment of his Peers, or by the Law of the land." While the king rejected and the pope annulled the charter, it endured as a document and was alternatingly reissued and revoked in the succeeding centuries as the nobles, and later commoners, struggled against royal absolutism. By the late 13th century, "knights of the shire" (landed gentry representing their counties) and "burgesses" (lawyers and rich merchants representing their towns) came to serve in an assembly, known as the Parliament. The commoners were initially treated as "petitioners and suitors" and were unable to play a role in making important political decisions. The nobles and commoners met separately during the 14th century, and the two chambers came to be known as the House of Lords and the House of Commons. By the 15th century, males owning substantial freeholds also became eligible to vote; however, they constituted a very small proportion of the population.

By the time of the establishment of the Tudor dynasty, England had a well-established governmental organization but Henry VIII and Elizabeth I still had autocratic powers to enforce their own will. Henry (reign: 1509-1547) was able to separate the Church of England from the Roman Catholic Church. As a tyrant, he could use his political power to have two of his wives and anyone opposing him—prelates, nobles and government officials—put to death. When Elizabeth I was elected queen (reign: 1558-1603), the treasury, partly due to the confiscation of clerical lands, was solvent again and her reign was associated with the ascendancy of England as a maritime power. Elizabeth I strengthened the navy and encouraged her sailors to prey on Spanish ships that carried gold and silver from South America across the Atlantic. The destruction of the Spanish Armada by her navy in 1588 opened the seas to the British to engage in trade, and later, establish their colonies. The prosperity of the Elizabethan period was associated with the flowering of the arts, such as the literature of Shakespeare, Christopher Marlow, John Donne and Ben Jonson.

THE PARLIAMENT: THE RISE OF COMMONERS. The Stuarts who followed the Tudors remained autocratic rulers. James I (reign: 1603-1625), who insisted that he was God's "lieutenant upon earth," dissolved Parliament and ruled without it for ten years. So did Charles I (reign: 1625-1649). However, times were changing and that led to a Civil War between the armies of the royalists and the commoners. Following the latter's victory, Charles I was executed; the House of Lords was abolished; and the chief of the commoners' army, Oliver Cromwell, ruled England as a military dictator from 1649 until his death in 1658. Soon thereafter the regime collapsed, and Charles II, who returned to England in 1660, dissolved the Parliament. But parliament was restored after his death, and then Charles's successor, James II, was overthrown and William and Mary became the monarchs. In 1688, parliament enacted a new Coronation Oath that compelled the monarchs to: "solemnly promise and swear to govern the people … according to the statutes of the parliament agreed on, and the laws and customs of the same" (Williams, 1960, p. 37). In 1689, William and Mary agreed to the Bill of Rights enacted by parliament. Among others, it prohibited the monarch's interference with the law and with elections; required the consent of parliament to increase taxes; guaranteed freedom of speech; established an independent judiciary; and outlawed "cruel and unusual punishment." The subsequent Act of Toleration allowed freedom of worship by religious dissenters and freedom of the press. The occasion has been referred to as the Glorious Revolution, the establishment of an enduring constitutional government in England with minimal bloodshed.

THE FORMATION OF POLITICAL PARTIES: TORIES AND WHIGS. The political union of the kingdoms of England and Scotland was officially established when their parliaments merged in 1707. In 1801, Ireland was forced to join the union and sent delegates to London. That union, under English dominance, played a major role in gradually turning the United Kingdom into the largest colonial and industrial powers of the globe. By the early 19th century, the monarchy was stabilized but political decisions were increasingly made by the parliament, with the head of the winning party becoming the prime minister and forming a government. The two major parties that formed were the Tories and the Whigs. The terms were originally derogatory, applied to factions favoring different successors to the throne, but in time came to be applied to two opposing political parties. During the Civil War, the Tories supported the king and the Whigs supported the parliament. After the Restoration, the Tories came to defend the privileges of the rural landowners, were in favor of state control of the economy (mercantilism), and remained loyal supporters of the established Church of England. The Whigs, in contrast, supported the interests of the growing burgher class, were in favor of free trade, were tolerant of the Protestant puritans and dissenters, and advocated the expansion of the franchise to all male citizens who owned property. The kings initially oscillated in supporting one or the other party but in time came to accept the one that won an election. Eventually, the Tories came to represent those inclined toward conservatism and maintenance of the status quo and the more progressive reformists became known as the Liberals.

From the Absolutist Monarchy to the First Republic in France. France was a feudal country during the Middle Ages without a powerful monarchy, and the English repeatedly occupied Normandy, Brittany and other territories (Price, 2005). It was during second half of the 15th century, under the reign of Louis XI, that the central government resumed its control of France and efforts were made to establish a unified nation. But then, the reconstruction of France was interrupted by the bloody wars between Catholics and Protestants (Huguenots). Protestantism entered France during the early 16th century but the government began to persecute them by the middle of the century. By the 1560s and 1570s thousands of Protestants were massacred in Paris and the countryside, and the religious wars did not end until 1598, when the Bourbon king Henry IV (originally a Protestant who converted to Catholicism) ended the religious wars. Henry IV declared himself the absolute ruler of the French state and justified his edicts by the ideology of *reason d'état*. When Henry IV granted religious toleration to Protestants throughout France (the Edict of Nantes, 1598) it was done for "reasons of the state." Two Catholic prelates, Cardinal Richelieu and Cardinal Mazarin, were instrumental in turning France into the most powerful autocratic and reactionary state of Western Europe during the 17th century.

GROWTH OF THE FRENCH ABSOLUTIST MONARCHY. Richelieu began his career as a bishop but then turned to politics. He became a cardinal in 1616 and chief minister of Louis XIII in 1624, and remained in that position until his death in 1642. Richelieu was instrumental in transforming France from a feudal state into a modern bureaucratic state by replacing the *seigneurs* with *governeurs* and *intendants* (the kings representatives) to administer the *généralités* (provinces). Although a great patron of the arts, Richelieu censored the press, employed spies to report on his enemies, and persecuted them. A merciless individual, he personally led the siege of the Huguenots in La Rochelle, defeating them in 1629. To finance his expansionist wars, Richelieu imposed new taxes on the peasants and crushed their rebellion. He saw to it that his protégé, Cardinal Mazarin, succeeded him as chief minister and continued his reactionary policies. Disliked by the populace, open violence erupted in Paris, known as the Fronde, but Mazarin succeeded in crushing the rebellion and remained in his office until his death in 1661.

Royal absolutism reached its zenith during the long reign of Louis XIV, which lasted from 1643 until his death in 1715. Louis succeeded in embodying the entire governmental organization of France in his own person (Cobban, 1963; Popkin, 2000). The Estates-General were no longer summoned; there was no national assembly to discuss matters and advise the king; and political meetings by the people were outlawed. By now, the elaborate French government had departmental councils headed by ministers and secretaries, but the king, who presided over the councils, could override their decisions or dismiss them at will. The king could reject any court judgment by his power of *justice retenue*, and summon or imprison anyone by a *lettre de cachet* that could not be repealed. To control the nobility, Louis built an immense palatial complex in an elaborate garden setting at Versailles, away from the disorder of Paris, creating luxurious facilities for celebrations and entertainment (Fig. 12-17). The palace also contained apartments for the nobles (the palace complex contained 2300 rooms) who were coerced to serve in various capacities as members of his court.

Decline of the absolute monarchy. The authority of the absolutist monarchy progressively declined during the 18th century, terminating in the revolution of 1789 (Durant and Durant, 1967). The causes of that decline were multiple, important among them were the government's inability to put the state's finances in order; the inept leadership during the Regency and the reigns of Louis XV and Louis XVI; the rising power of the bourgeoisie; the rebellion of the poor

HALL OF MIRRORS, VERSAILLES

Fig. 12-17. Luxurious hall in the Versailles Palace. (ChateauVersaillesGaleriedesGlaces.jpg)

and hungry, and the agitation of the intellectuals, known as the *philosophes*. The government's attempt to bring about tax reforms to increase its revenues was resisted both by the nobility and the bourgeoisie, and increasingly the regional *parlements*, hitherto regional institutions that rallied behind the king, became centers of dissidence. The shift in wealth from the great country estates to the cities, brought about by the expansion of commerce and industry, strengthened the demands of the prosperous middle class. The relentless ridicule by writers, playwrights and journalists of the conduct by nobles, the hypocrisy of the clergy, the suppression of free speech, and outcries against prevailing social injustices greatly undermined the credibility and moral authority of the monarchy. The *parlements* that existed in France's major cities were initially law courts and executive bodies that enforced royal decrees and regulations, headed by rich lawyers with hereditary rights to their offices, the *noblesse de robe*. These regional institutions had the traditional right to issue *remonstrances*, but the king could overrule them and exile its members. However, as the parlements became more powerful, some of its member began to advocate constitutionalism and demand political reform. Echoing Montesquieu, the parlement of Toulouse declared in 1763 that the law depends on the "free consent of the nation," and echoing Rousseau, the parlement of Rennes proclaimed in 1788 that, "man is born free, that originally men are equal; these are truths that have no need of proof" (Cobban, 1963, vol. 1, p. 130). The language of the remonstrances began to change, with the term *sujects* often replaced by *citoyens*, and *pays* by *nation*.

Louis XVI suspended the parlements in 1788 but their popularity was such that riots broke out in the provinces. In response, the king summoned the Assembly of the States-General in 1789, a deliberative body that had not met since 1614. Traditionally, the Assembly of the States-General was composed of three Estates: the clergy (First Estate), the nobility (Second Estate), and the commoners (Third Estate). Louis XVI decreed that the Third Estate should have double representation to equal the number of the two other Estates combined. All tax-paying males were eligible to vote to select deputies of the Third Estate. About half of the deputies were lawyers; the others were businessmen, professionals and a small percentage represented the peasantry. The States-General assembled in Versailles in May 1789. Some of the more liberal prelates and nobles joined the Third Estate in demanding political reforms. About a month after their first meeting, the Third Estate declared that it constituted a new institution, the *Assemblée Nationale*, with the plan to transform the absolutist monarchy into a constitutional monarchy. The Assembly took over municipal powers in Paris and began to work on the Constitution. At the same time, crowds began gathering in Paris to resist the troops called in to maintain order. In July of 1789, orators at the *Palais Royal* called the people to arms. The *Invalides* was raided on July 14 by a large mob seeking arms and subsequently the Bastille was stormed. The Revolution started.

THE FRENCH REVOLUTION. On August 26, 1789 the National Assembly accepted the "Declaration of the Rights of Man and of the Citizen," which, as a proposed social contract, transferred sovereignty from the monarchy to the people. Its third paragraph reads:

> The principle of all sovereignty resides essentially in the nation; nobody nor individual may exercise any authority which does not proceed directly from the nation.
>
> (Quoted from Hayes, 1960, p. 51)

Church property was confiscated, the hereditary judiciary was abolished, and a new flag (the *tricolor*) and national anthem (*Marseillaise*) were adopted. Under pressure from the armed revolutionaries, the Assembly passed a series of measures in 1791 to eradicate persisting class distinctions, abolish all wars of conquest, and establish a compulsory national educational system. But these rational plans could not be executed because by this time revolutionary France was at war with most of Europe and the Reign of Terror began at home. In 1792, the radical Convention and the Paris Commune replaced the Assembly. Among the first acts of the Convention was the abolition of the monarchy and Louis XVI was executed in January of 1793. A revolutionary tribunal was set up to judge counter-revolutionaries and the Committee of Public Safety began the summary guillotining of "traitors." But in spite of the terror at home, the revolutionary government was able to assemble a formidable army and the allied nations were beaten at several fronts. The ideal of international peace turned into a nationalistic war. As one of the leaders of the revolution, Danton, proclaimed:

> When the fatherland is in danger, no one can refuse his service without being declared infamous and a traitor to the fatherland. Pronounce the death penalty for every citizen who refuses to march, or who directly or indirectly opposes the measures taken for public safety.
> (Quoted from Kohn, 1965, p. 28)

The French army units were composed of "patriots," who fought under the leadership of young generals, with some of them inspired by the ideals of the Revolution. The Reign of Terror came to an end at home in 1794 when Maximilien de Robespierre, the leader of the Convention, together with many of his followers, were beheaded. By the middle of 1795 the Convention was dissolved and replaced by the Directory. Its First Consul, the general Napoleon Bonaparte, soon became successful in establishing his dictatorship and ended what later became known as the First Republic. Napoleon declared himself the Emperor of France and the would-be ruler of Europe with papal blessings. Although initially successful, his rule lasted only a decade; the Holy Roman Empire could no longer be restored in the changed Western world.

12.2.2. Social Developments: The Victims of Colonization and the Industrial Revolution. Most of the explorers and settlers of overseas territories were not scientists or naturalists, motivated to find out what the unknown world was like. Rather, they were an admixture of conquerors and merchants, missionaries and pilgrims, and poor people looking for cultivable land. Monarchs commissioned expeditions, hoping to enrich their treasury with gold and silver. Financiers supported seafaring as a commercial undertaking with the promise of money to be made. The Catholic Church was supporting colonization because it was committed to convert the heathens and expand papal influence; and persecuted Protestants were seeking to establish settlements where they could practice their faith free of governmental interference or ecclesiastical censure. However, indirectly they were beneficiaries of the Scientific Revolution and the rising rationalism because it was their technical, organizational and educational superiority that allowed them to defeat, subjugate and exploit the indigenous people whose lands they occupied. Correspondingly, the industrialists used the new technologies of the Industrial Revolution to build factories to produce goods in large quantities. But they were not benefactors bent on employing more and more people and sharing the profits with them. Rather, they were ingenious and astute people who made laborers work endless hours for as little money as possible to increase their profits and those of their investors. The result of this development was multifold. It led to the horrors of colonialism, the slave trade, the development of slums in industrial cities, and the intensification of conflicts among the social classes.

EXPLOITATION OF THE NATIVES OF THE COLONIES. By the end of the 18th century the Spanish laid claim to much of the lower half of North America and the western half of South America, while the Portuguese claimed the latter's eastern portion (Fig. 12-13). The British claimed the northeastern part of North America (they just lost their colonies in what became the independent United States) as well as coastal areas in Africa and India and some islands in the Caribbean and the South Pacific. (The colonial expansion of the Russians and Turks was mainly through land-based territorial expansion.) The principal political motive behind the establishment of colonies was the exploitation of the material and human resources of countries that could not resist the firepower of the invaders (Davis, 1953). The Spanish conquistadores were initially after the treasures of the Aztecs, Mayas and Incas, but as these were exhausted they turned to force the natives to work in the silver mines of Potosì. Due to the mistreatment of the natives, but above all their lack of immunity to European diseases (smallpox, influenza, measles), the indigenous population was decimated. As an example, the native population of Hispaniola was reduced from 250,000 to 15,000 after two decades of Spanish rule. The Spanish administrators, missionaries and soldiers who followed the conquistadores, mostly impoverished nobles, were given title to large tracts of land on which they established haciendas. Because relatively few farmer families from the Iberian Peninsula settled in the Americas, there was considerable interbreeding with the converted natives, creating a mixed mestizo population. By the late 17th century, because of shortage of manpower, both the Spanish and the Portuguese turned to the importation of African slaves. The Spanish and Portuguese justified their conquest as their religious duty to convert the heathens to Catholicism. The pattern of colonization of North America by the English was different. The colonists (pilgrims) of New England were mostly farmers who looked for new land to settle where they could form their own puritanical Protestant communities, free from government interference. They did not seek to convert the natives to their religion or establish close relationships with them. Rather the natives were driven off the land that was their hunting ground and the pioneers tried to cultivate the land themselves. The pattern of colonization was somewhat different in the southern states where landowners turned to the production of tobacco and cotton on a large scale for export to Europe. In need of a large labor force, they tried to use indentured servants but soon turned to the importation of slaves from Africa.

ENSLAVEMENT OF BLACK AFRICANS. The use of human beings as slaves has a long history. Slaves were the foundation of the economy of many archaic societies and of ancient Greece and Rome. The enslavement of Christians was eventually outlawed in Europe during the Middle Ages. However, slave trade was widespread in Africa, and in the 17th century, due to demand for cheap labor in the Americas, Europeans began to purchase and transport slaves in large numbers from Africa, known as the Atlantic Slave Trade (Klein, 2010). Africans caught in slave raids were chained and marched to embarkation centers on the Atlantic coast (Fig. 12-18). From there they were shipped to the Americas in large cargo ships that were designed to hold as many of them as possible (Fig. 12-19). Death rate on the ships during passage over the Atlantic was as high as 50 percent, due to crowding, unsanitary conditions and maltreatment

THE SLAVE TRADE

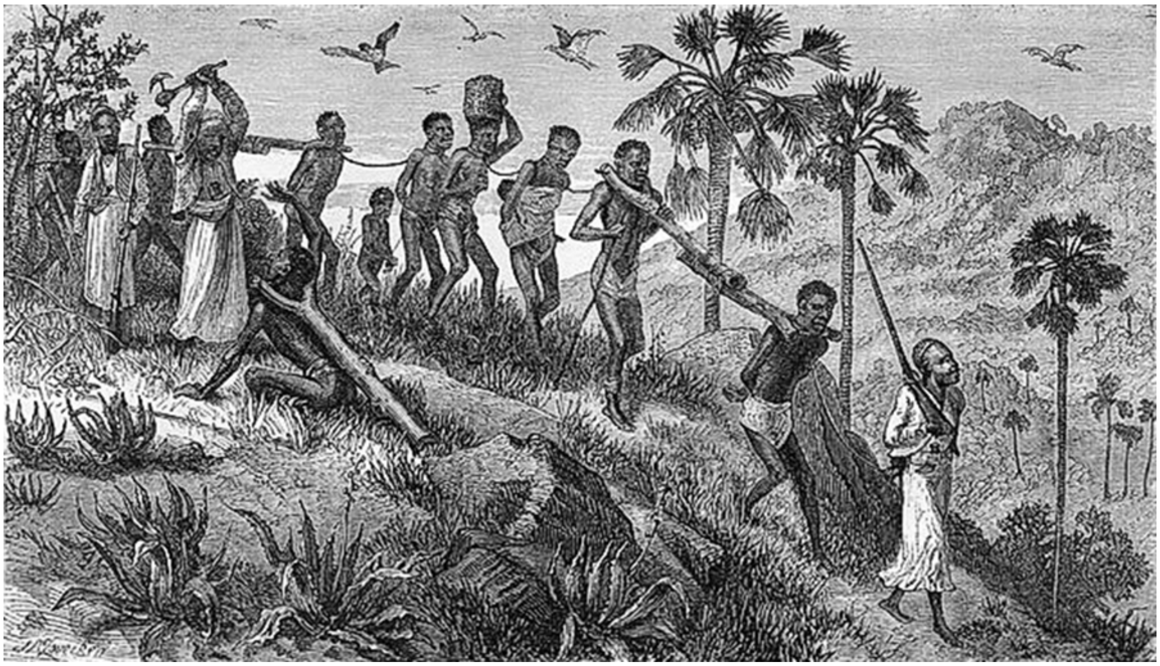


Fig. 12-18. Guards and traders with chained captives marching to the east coat of Africa for shipment and sale in the Americas as slaves. (SlavesRuvuma.jpg)

but up to 12 million African slaves, according to current estimates, reached the Americas between 1540 and 1850.

The slaves were treated in the Americas as chattel, with none of the legal rights of subjects or citizens. They could be bought and sold, abused with impunity, and were denied freedom of movement. An estimated 645,000 African slaves were brought to the colonial states of North America that later formed the early United States. Although the U. S. guarantees all its citizens equal human rights ("all men are created equal"), those did not apply to the dark-skinned Africans. Upon arrival, like cattle, the slaves were sold to the highest bidders (Fig. 12-20) and their owners could use them as they saw fit (Fig. 12-21). Women were used as house slaves or worked on the fields; the men had to do all the hard work on the plantation. Slavery became a legal institution in the southern states, and the children of slaves, a precious commodity whether sired by Africans or Europeans, became themselves slaves. There were abolitionists who objected to the barbarous institution of slavery both abroad and in the United States. Denmark, which had been active in the slave trade, was the first to ban slavery in 1792 and the British abolished the slave trade in 1807. However, the cheap labor by slaves became very important about this time to the southern states of the United States. They became the leading world producers of cotton and tobacco, and slavery persisted much longer there. (That was not the case in the industrializing northern states where slave labor represented little economic advantage.)

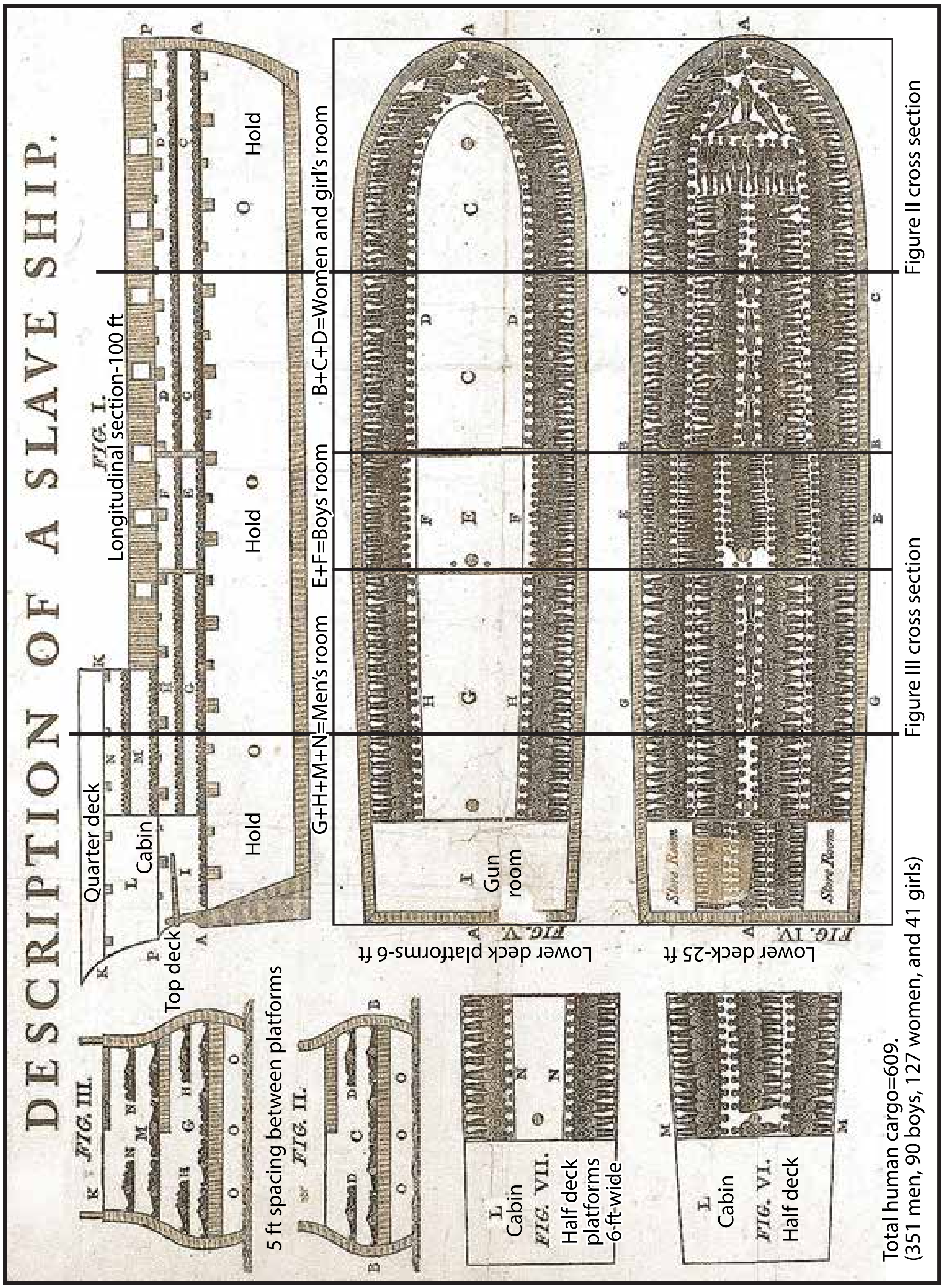
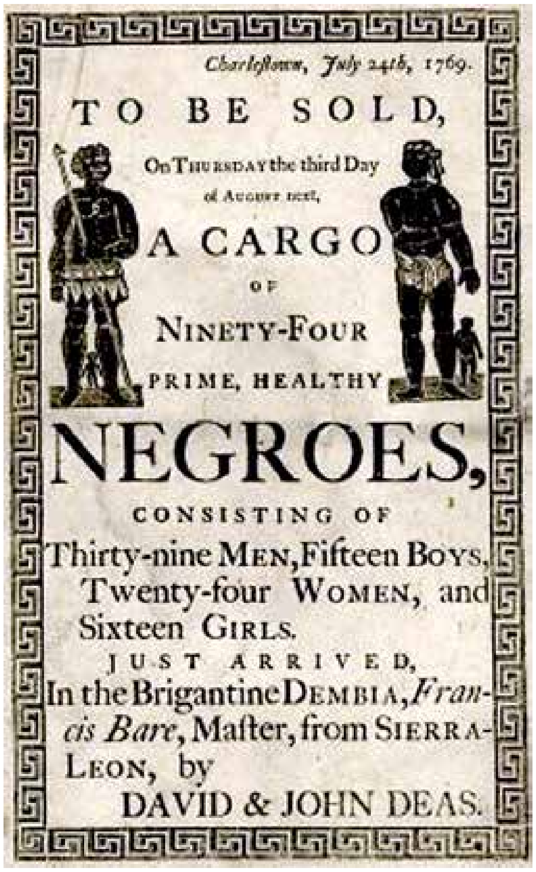


Fig. 12-19. A scale drawing of the slave ship, *Brooks* (1/8 inch=1 foot [ft]). Packing density of the human cargo chained to the various decks and platforms is approximate because fewer than 609 individuals are drawn; the real density is greater. (Slightly modified from the British Library. http://www.bl.uk/learning/timeline/large106661.html)

ADVERTISING A SLAVE AUCTION



Charlestown, July 24th, 1769.

TO BE SOLD,

On THURSDAY the third Day of AUGUST next,

A CARGO OF NINETY-FOUR PRIME, HEALTHY NEGROES,

CONSISTING OF

Thirty-nine MEN, Fifteen BOYS, Twenty-four WOMEN, and Sixteen GIRLS.

JUST ARRIVED,

In the Brigantine DEMBIA, *Francis Bare*, Master, from SIERRA-LEON, by

DAVID & JOHN DEAS.

Fig. 12-20. A handbill advertising the sale of newly landed slaves in South Carolina in 1769. (Wikipedia; SlaveAuctionAd.jpg)

PLANTATION SLAVES

Fig. 12-21. African slaves processing tobacco on a Virginia plantation, ca. 1670. (TobaccoCultivation.jpg)

Exploitation of the Proletariat. During the medieval period the landed nobles took advantage of the landless peasants and serfs by having them toil on their estates and appropriate much of what they produced. As wealth began to shift from the landowners to those engaging in commerce and industry, it was the wealthy burghers of commercial and industrial enterprises who turned to the exploitation of the masses, and the social order began to change drastically. During the Middle Ages, the landless peasants had very little money but could feed themselves by cultivating a small plot of land around their houses where they grew vegetables and fed some domestic animals to supplement their diet. The villagers may also have collected berries and fruits in season and trapped some wild animals in the surrounding forests. However, as the peasants moved to the city to earn money, they found themselves in a built-up environment, without a garden or nearby forests, and no other way to feed their family but sell their labor in exchange for wages and working conditions dictated by their employers (Thompson, 1964; Daunton, 1995).

CONDITION OF THE WORKING PEOPLE IN ENGLAND. The average laborer's wage in the late 18th and early 19th centuries was just sufficient to feed the family and rent a single-room apartment in a tenement to call his home (Ashton, 1985; Williamson, 1985). Laborers employed in English factories worked up to 14-16 hours a day (with a 1-hour break for lunch) six days a week. To supplement the family's income, family's sent their children to work at an early age, who received a fraction of what adults were paid. Most of the factories were dark, noisy and dirty, and devoid of any safety devices. Because demand for housing was considerable in the rapidly expanding cities, speculators erected crowded tenements (Fig. 12-22), with no gardens and only a small area for outdoor toilets, often cesspits. Families with up to 6-9 members lived in one room under unsanitary conditions with no running water or bathing facilities. There were typically no sewers and all wastes were thrown outside, which were periodically collected by "night-men" and thrown into a nearby river, such as the Thames.

HOUSING FOR WORKING-CLASS LONDONERS

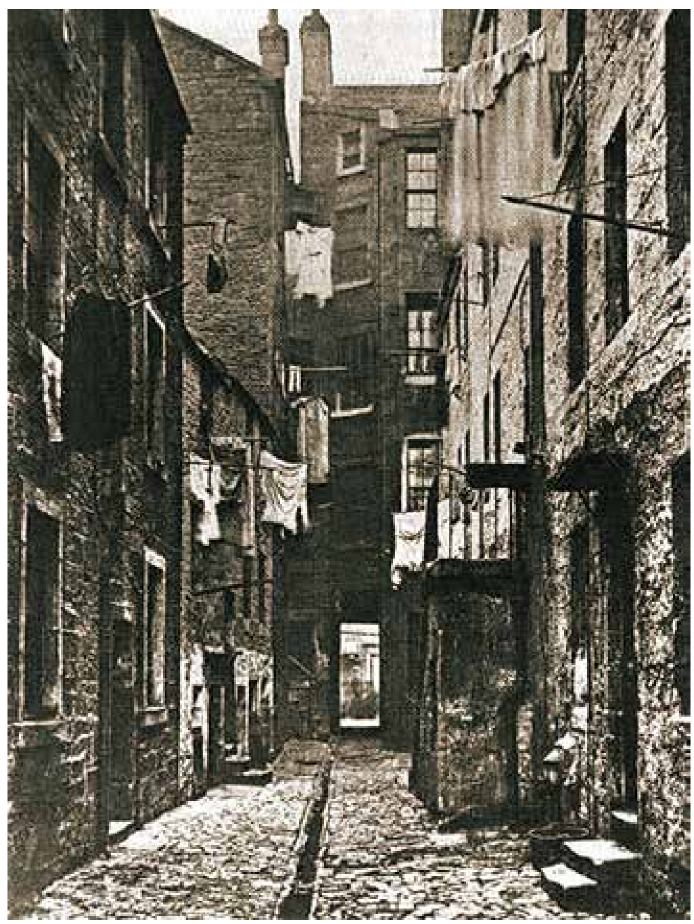


Fig. 12-22. Crowded working class tenements, with open sewer. Late 18th century and early 19th century London. (Wikipedia; Regency London)

CONDITION OF THE WORKING PEOPLE IN FRANCE. The social and economic system prevailing in France during the 17th and 18th centuries was designed to maintain the privileged status and wealth of the nobility with total disregard for the welfare of the peasants in the countryside and the laboring class in cities (Heywood, 1995; Price, 2005). The nobility was exempt from taxation and many of them received sinecures and pensions from the government. Financiers and revenue agents who advanced loans to the government (*ferme générale*) were allowed to enrich themselves by heavily taxing all commoners. The contractors who supplied goods for construction projects, wars and oversees enterprises, also enriched themselves and by buying estates, purchasing titular offices or marrying into the nobility, these entrepreneurs could become members of the nobility. The Catholic Church, whose leadership (cardinals and bishops) were mostly members of the nobility, supported the system. The Church ran the schools and provided some social services, such as administering hospitals and maintaining charitable organizations to aid the poor. But most peasants, farm laborers and city workers lived under wretched conditions and the great famines of 1693-94 and 1709-10 devastated their number, leading to a population decline. As La Bruyere wrote in his *Les Caractéres*:

> We see certain wild animals, male and female, scattered about the countryside … deeply tanned by the sun, bound to the soil, which they dig and till with unconquerable persistence: they have, as it were, an articulate voice, and when they rise to their feet, they show a human face; and they are in fact men. At night they withdraw into dens, where they live on black bread, water and roots: they spare other men the labor of sowing, plowing, and harvesting in order to live.
>
> (Quoted from Havens, 1955, p. 15)

The letter Fénelon wrote to Louis XIV (but opted not to deliver) attests to the accuracy of this condition of the peasants (Havens, 1955, p.16). A farm laborer earned on the average eight or nine cents a day, and a weaver fifteen cents, when a pound of wheat cost about one cent. The aggrandizement of the king, the privileges of the nobility, the endless foreign wars, and the severe taxation that impoverished peasants and laborers were justified as the necessary means to finance the exalted state. When Louis XIV died in 1718, the French nation was economically exhausted and its treasury insolvent. The reform of the system advocated by some enlightened intellectuals, were not heeded by the government. The improvements that began at the end of the century and came about in the next century were gained by violent revolutions.

12.2.3. Intellectual Developments: The British, French, and American Enlightenment. It was during the 17th and 18th centuries that a new type of intellectual and philosopher began a critique of the old social and political order by offering new views about the origins of human society, the nature of man, and of man's legal entitlements and moral obligations (Becker, 1932; Cassirer, 1955; Gay, 1969; Dupré, 2004). We briefly describe below three of these developments, known respectively as the British, French and American Enlightenment. These three intellectual movements had a profound and enduring influence on the social and political advance of modern Western civilization.

The Philosophers of the British Enlightenment. Following Hobbes, who still defended the old social order, the most influential philosophers of the British Enlightenment were Locke, Hume and Adam Smith.

HOBBES. Thomas Hobbes, who was on the royalist side during the English Civil War, argued in his *Leviathan* (published in 1651) that men in a "state of nature" are selfish and violent but who, at some stage of their history, made a "social contract" to elect a monarch to rule over them and enforce social order and peace. According to Hobbes, men, by natural disposition, are endowed with an insatiable power drive:

> I put for a general inclination of all mankind, a perpetual and restless desire of power after power that ceaseth only in death. And the cause of this, is not always that a man hopes for a more intensive delight than he has already attained to … but because he cannot assure the power and means to live well, which he hath present, without the acquisition of more.
>
> (Hobbes, *Leviathan*, chapter 2)

Without an autocratic sovereign, Hobbes wrote, when

> men live without a common power to keep them all in awe, they are in that condition which is called war … every man against every man … In such condition, there is no place for industry … no arts; no letters; no society, and which is worst of all, continual fear, and danger of violent death; and the life of man solitary, poor, nasty, brutish and short.
>
> (Hobbes, *Leviathan*, chapter 13)
>
> The only way to erect such a common power … is, to confer all their power and strength upon one man, or upon one assembly of men, that may reduce all their wills … unto one will … This is more than consent, or concord; it is a real unity of them all …This done, the multitude so united in one person, is called a *Commonwealth*.
>
> (Hobbes, *Leviathan*, chapter 17)

Royal absolutism was thus justified as a rational political order because it was in the best interest of both the warring individuals and their society.

JOHN LOCKE. In contrast to Hobbes, John Locke, postulated that aboriginal men were rational and peaceful beings who came to recognize that they could better defend their freedom collectively rather than individually and, accordingly, made a social contract to that effect. The loss of human freedom was due, Locke argued, to the unchecked political power of autocrats and their government. Hence, to prevent tyranny, Locke argued in his *Essay on Civil Government*, published in 1690, for the separation of the powers of legislators and executives. As he wrote:

> because it may be too great a temptation … for the same persons, who have the power to make laws, to have also in their hands the power to execute them … to their own private advantage … Therefore, in well ordered commonwealths … the legislative power is put into the hands of divers persons …
>
> (Locke, 1965, chapter. XII, sect. 143)

Interestingly, Locke, a pioneer of the British Enlightenment, also argued that, in addition to assuring life and liberty, it is the obligation of civil government to safeguard private property. It seems that Locke assumed that men of means—propertied gentlemen with an education and a sense of moral responsibility—would be the best guardians of a civil society:

> The state of nature has a law … and reason, which is that law, teaches all mankind who will but consult it, that, being all equal and independent, no one ought to harm the other in his life, health, liberty or possessions.
>
> (Locke, 1939, p. 405)

DAVID HUME. In contrast to Hobbes and Locke, David Hume in his essay *Of the Original Contract*, published in 1748, rejected social contract theory as a historic fiction, the false idea that people ever consented to be governed by rulers.

> Were you to ask the far greatest part of the nation, whether they had ever consented to the authority of their rulers, or promised to obey them, they would be inclined to think very strangely of you.
>
> (Quoted from Levin, 1973; p. 261)

According to Hume, both social organization and government are institutions that were imposed on people by rulers who used coercive means, and people submitted to them due to their powerlessness rather than to free choice.

ADAM SMITH. Another influential social and economic philosopher of the British Enlightenment was Adam Smith. In his *Theory of Moral Sentiments* (published in 1759) and *The Wealth of Nations* (published in 1776), Smith recognized two principal motives of human behavior, self-interest and sympathy for others. The former, Smith maintained, inclines people to advance their own interest, the latter to assist others. He wrote that, on the one hand,

> It is not from the benevolence of the butcher, the brewer, or the baker that we expect our dinner, but from their regard to their own interests.
>
> (*Wealth of Nations*, Book I, chapter II, paragraph 12)

But, on the other hand,

> How selfish soever man may be supposed, there are evidently some principles in his nature, which interest him in the fortunes of others, and render their happiness necessary to him, though he derives nothing from it, except the pleasure of seeing it. Of this kind is pity or compassion, the emotion we feel for the misery of others.
>
> (*Theory of Moral Sentiments*, Part I, chapter 1, paragraph 1)

And Smith applied, far less convincingly, the same argument for the attitude of the rich who

> consume little more than the poor, and in spite of their natural selfishness and rapacity … divide with the poor the produce of all their improvements. They are led by an invisible hand to make nearly the same distribution of the necessities of life, which would have been made, had the earth been divided into equal portions among all of its inhabitants, and thus without intending it, without knowing it, advance the interest of the society, and afford means to the multiplication of the species.
>
> (*Theory of Moral Sentiments*, Part IV, Chapter 1, paragraph 10)

In contrast to the medieval belief that man is evil (a born sinner), Smith recognized man's dual affective disposition, what in current parlance we know as the asocial (egotistical) and prosocial (altruistic) emotions. However, Smith retained the medieval tradition of invoking a supernatural agency, what he called the "invisible hand," that turns the selfishness of the individual into the welfare of society. (This was expressed earlier by Bernard Mandeville, in his *Fable of the Bees*, published in 1723, as "private vices" turning into "public benefits.") Smith opposed the government-controlled mercantilism still current in his days in favor of a free-enterprise (laissez faire) capitalistic system. Let each individual use his capital and labor as he sees fit, and the shrewd and industrious will contribute more to the betterment of the human condition than government regulations. He argued that competition is bound to lower the prices of goods and promote commercial expansion. However, although Smith was aware that without governmental control industrialists might exploit workers to reduce prices and form cartels or monopolies to fix prices, he failed to offer remedies to achieve social fairness.

The reduced role of the government in the management of economic affairs, advocated by the liberal philosophers of the British Enlightenment, undoubtedly facilitated the immense growth of technology and commerce during the Industrial Revolution, and the prosperity of the middle class. However, it failed to produce a "commonwealth." The social conditions that developed in England by the end of the 18th and during the early 19th century (sweat shops, child labor, unsafe factories and mines, long working hours, slums, the spread of diseases, etc.) proved that the idea that the "invisible hand" will ensure that the selfish interests of individual's will benefit the population was unrealistic. Social and political developments proved that the pecuniary industrialists and financiers could no more be trusted to respect the legitimate rights of those without power—the city proletariat and the natives of colonies—than the landowners of the feudal age could be trusted in treating fairly the subjugated peasantry.

The Philosophes of the French Enlightenment. Among the most influential intellectuals of the French Enlightenment were Montesquieu, Voltaire, Diderot and Rousseau.

MONTESQUIEU. A pioneer of the French Enlightenment, Montesquieu, started his career as a public official but later turned to literature and social philosophy (Pangle, 1973). In his satirical *Persian Letters* (published in 1721), Montesquieu had two fictitious Oriental travellers describe the absurdities of contemporary French society. In his subsequent history of the Roman Empire (1734), Montesquieu argued that rather than the actions of individual politicians, changing material and social conditions played a pivotal role in Rome's rise and fall. And in his magnum opus, *De l'Esprit des Lois*, published in 1748, he analyzed in detail the different forms of governments that have existed throughout history and their advantages and shortcomings (Montesquieu, 1949). Although a member of the nobility, Montesquieu was a liberal and argued that the function of good government is to assure the liberty of all its citizens. He defined liberty as a rational principle of living under a system of laws that allows each individual as much freedom of action as possible provided that those actions do not interfere with the freedom of others. And because those who yield political power over others tend to abuse it, it is essential that the different branches of government—the legislative, the judicial and the executive—are separated and balance each other. The legislature, he proposed, should be composed of two houses, one representing the interests of the nobles and the rich, the other the interests of the commoners and the poor; the courts of justice should be independent of the legislature; and the legislature should exercise control of the executive branch.

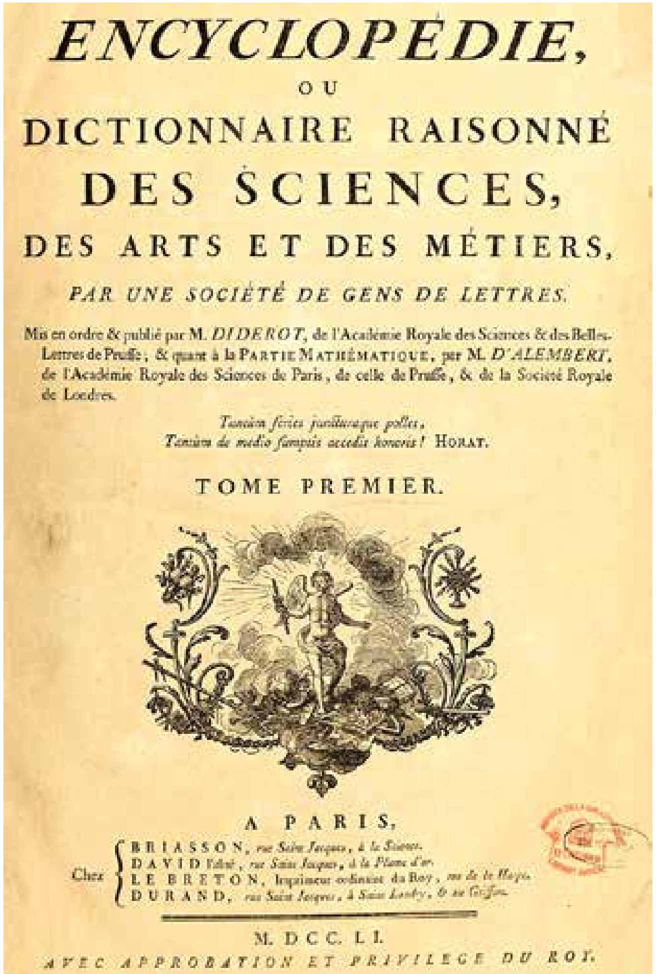
Locke, Hume, Adam Smith, and Montesquieu described their ideas how to build a better society in books designed for academics, educated professionals and political leaders. And they sought to reform the prevailing social order not overthrow it. In contrast Voltaire, Diderot and Rousseau were political and educational activists who wrote popular works for the public at large and had clearly the intent of abolishing the old order, the *Ancien régime*.

VOLTAIRE. The penname of François-Marie Arouet, Voltaire (1694-1778) was a prolific writer who wrote poems, plays, novels, essays and polemical pamphlets, as well as popular historical and scientific books, and thousands of letters (Besterman, 1969). He was an outspoken opponent of the abuses of those in power—royalty, nobility and the Catholic clergy—and his battle cry was *écrasez l'infâme* (crush the infamous). His witty and sharp criticism was directed against religious intolerance, social discrimination and the unfair practices of the justice system. Popular with the public, he was imprisoned several times by the authorities, and sailed as an exile to England. While there for several years, he studied the scientific works of Newton and the philosophical works of Locke, and popularized those after his return to France. To escape harassment and imprisonment, he moved to Geneva and later settled in a *château* in France near the Swiss border. Voltaire did not believe in democracy, as he did not trust the judgment of the uneducated masses, but thought that enlightened and benevolent monarchs might be able to create a good society. He befriended and corresponded with Frederick the Great of Prussia and Catherine the Great of Russia but was disappointed in their rule. Later in his life he became resigned that the world and society cannot be improved. In his satire, *Candide* (published in 1759), he said the best way to live is to "cultivate our garden." When he returned to Paris in old age, the populace lined the streets, greeting him as the great hero. When he died, the National Assembly buried him in the Panthéon as the forerunner of the French Revolution.

DENIS DIDEROT. Like Voltaire, Denis Diderot was a prolific author. He wrote plays, essays, novels and popular philosophical works, and early in his career was briefly imprisoned on charges of sedition because of his criticism of the Catholic Church. He was released after he signed a letter to refrain from criticizing religion in the future. Thereafter, he undertook the monumental task of editing the *Encyclopédie, ou Dictionnaire Raisonné des Sciences, des Arts et des Métiers* (Fig. 12-23). The first volume of the Encyclopedia (with the assistance of D'Alembert) appeared in 1751, in which Diderot stated that the comprehensive knowledge of the different sciences and trades, to be presented in the forthcoming volumes, will "change men's common way of thinking." The courts suspended publication of the Encyclopedia because it contained criticism of the prevailing social order, and its publication was outlawed in 1759. However, the volumes were printed and distributed clandestinely. Diderot spent over 20 years editing the articles submitted by more than a hundred professionals to the 28 volumes of the Encyclopedia, and himself contributed hundreds of articles to it. The articles in the Encyclopedia contained cross-references for further information on any given subject and contained 2,900 plates, many of them of very high quality. By 1789 over 25,000 copies of the Encyclopedia were sold. Diderot gained little financially from that sale and he received no formal recognition for his effort from the political or academic authorities (although he received financial support from Catherine the Great of Russia). The Encyclopedia reflected the rationalist spirit of the French Enlightenment and was one of its greatest tangible accomplishments.

JACQUES ROUSSEAU. Jean Jacques Rousseau began his literary career after he left Geneva and settled in Paris where he joined the circle of the *philosophes*, Voltaire and Diderot. Like them, he wrote plays, novels and books on social-philosophical subjects, and contributed articles to the Encyclopedia, particularly on the subject of music (Dent, 2005; Bertram 2010). But unlike Voltaire and Diderot, who were empirical rationalists and favored science, Rousseau was a romantic opposed to science and advocated a return to the simpler life of earlier times, which

DIDEROT'S ENCYCLOPEDIA



ENCYCLOPÉDIE,
OU
DICTIONNAIRE RAISONNÉ
DES SCIENCES,
DES ARTS ET DES MÉTIERS,
PAR UNE SOCIÉTÉ DE GENS DE LETTRES.

Mis en ordre & publié par M. DIDEROT, de l'Académie Royale des Sciences & des Belles-Lettres de Prusse; & quant à la PARTIE MATHÉMATIQUE, par M. D'ALEMBERT, de l'Académie Royale des Sciences de Paris, de celle de Prusse, & de la Société Royale de Londres.

Tantùm series juncturaque pollet,
Tantùm de medio sumptis accedit honoris! HORAT.

TOME PREMIER.

A PARIS,
Chez BRIASSON, rue Saint Jacques, à la Science.
DAVID l'aîné, rue Saint Jacques, à la Plume d'or.
LE BRETON, Imprimeur ordinaire du Roy, rue de la Harpe.
DURAND, rue Saint Jacques, à Saint Landry, & au Griffon.

M. DCC. LI.
AVEC APPROBATION ET PRIVILEGE DU ROY.

Fig. 12-23. Title page of the fist volume of Diderot's "Encyclopedia of the Sciences, Arts and Crafts."
(Wikipedia; ENC1-NA5.jpg)

he imagined to have been happier than the age in which he lived. Rousseau was more of a radical than Voltaire and Diderot, and in some sense can be considered a founder of the Counter-Enlightenment that developed into the anti-rationalist Romantic movement of the 19th century.

Rousseau acquired fame in Paris when, in 1750, he won the first prize in a competition sponsored by the *Académie de Dijon* for his essay entitled *Discours sur les Sciences et les Arts*. Referred to as the *First Discourse*, Rousseau argued that science was a factor in contributing to the moral degeneration of modern man. As he wrote:

> Astronomy was born from superstition; eloquence from ambition, hate, flattery, and falsehood; geometry from avarice, physics from vain curiosity; all, even moral philosophy, from human pride.
> (*First Discourse*, vol. 1, p. 12)

Rousseau argued that rational advances enabled governments to more effectively suppress the freedom of the individual, and while science has made the life of the individual easier and more comfortable, it did not improve him morally. He elaborated on this theme in his *Discourse on Inequality*, published in 1755, where he put forward the myth that became known as the "noble savage." According to Rousseau's fantasy, natural man was noble before he was corrupted by society. He was of gentle disposition, led an innocent life, and maintained peaceful relations with his neighbors. Man became evil when he joined society and claimed the right to private property:

> The first man who, having fenced in a piece of land, said "This is mine," and found people naïve enough to believe him, that man was the true founder of civil society. From how many crimes, wars, and murders, from how many horrors and misfortunes might not any one have saved mankind, by pulling up the stakes, or filling up the ditch, and crying to his fellows: Beware of listening to this impostor; you are undone if you once forget that the fruits of the earth belong to us all, and the earth itself to nobody.
> (*Discourse on Inequality,* 1754, p.)

The *Social Contract* (published in 1762) begins with the dramatic statement, "Man is born free, and everywhere he is chains." Neither of these assertions is factually correct. Man is born as a helpless infant, dependent on the altruism of others for survival, typically the mother; and when he is weaned he tends to display traits aimed at establishing his independence but cannot survive without adult assistance for some time. Society does limit his freedom of action by not yielding to his will but that does not induce the juvenile and adult to lead a solitary life. With no respect for the scientific method, Rousseau's Romantic idea that man was corrupted by society lacked empirical support. The anthropological evidence that was already available in his days indicated that people living in primitive societies are not peaceful or morally superior to civilized modern people. While primitive nomads possess little property, they do claim territorial rights to the land they use for collecting and hunting and fight to defend it. Rousseau social philosophy was inconsistent. On the one hand, in his *Émile* he advocated freedom of the individual; on the other hand, in his *Social Contract* he insisted that the individual must act in accordance with a fictitious moral force that he called the "General Will." And while he advocated religious tolerance, he insisted that in his reformed society all must assent to the state's religion and dissidents should be exiled or put to death. Rousseau's opposition to the prevailing unfair and corrupt social order had great appeal to the French people and after his death, his remains were interred by the National Assembly in the *Panthéon* of Paris as the hero of the Revolution.

The American Enlightenment and Revolution. The American Enlightenment was an intellectual movement embraced by politicians who sought to free themselves from Britain's rule of the North American colonies (Cooke, 1993). Through the 17th and 18th centuries European colonists, most of them from Britain, settled in the fertile area that stretched along the Atlantic coast from Florida in the south (ruled by Spain) to Canada in the north to a depth of about 200 miles inland (Fig. 12-24). Some of the early British settlers were refugees who sought to escape religious harassment and persecution at home, but most of them were members of government-chartered companies that shipped landless and impoverished people to the New World with the aim of establishing agricultural settlements and trading centers there. After initial failures and hardships, the settlers' economy began to expand when tobacco, and later rice and cotton, came to be produced in increasing quantities for export to Europe in large estates worked by indentured servants and black slaves. By the mid-18th century there were 13 colonies with a population of about two-and-a half million people living in sizable towns and smaller villages. A British governor typically headed each colony, with daily affairs regulated by a locally elected legislative body. The British looked upon the American colonies as a source of raw materials and a market for finished goods as well as a source of revenue though taxation. Particularly that latter burden led to agitation by some American politicians for liberation from British rule.

Social and political conditions were altogether different in the American colonies than in Europe, and the liberation movement was not directed against prevailing domestic social and economic conditions but rather against arbitrary British rule (Wood, 2005; Allison, 2011). Starting in 1765, the citizens of the Massachusetts's colony began to protest against the imposition of taxes by the British Parliament "without representation," and that led to an open violation of British law in Boston Harbor in 1773. Following punitive measures by the

BRITAIN'S AMERICAN COLONIES

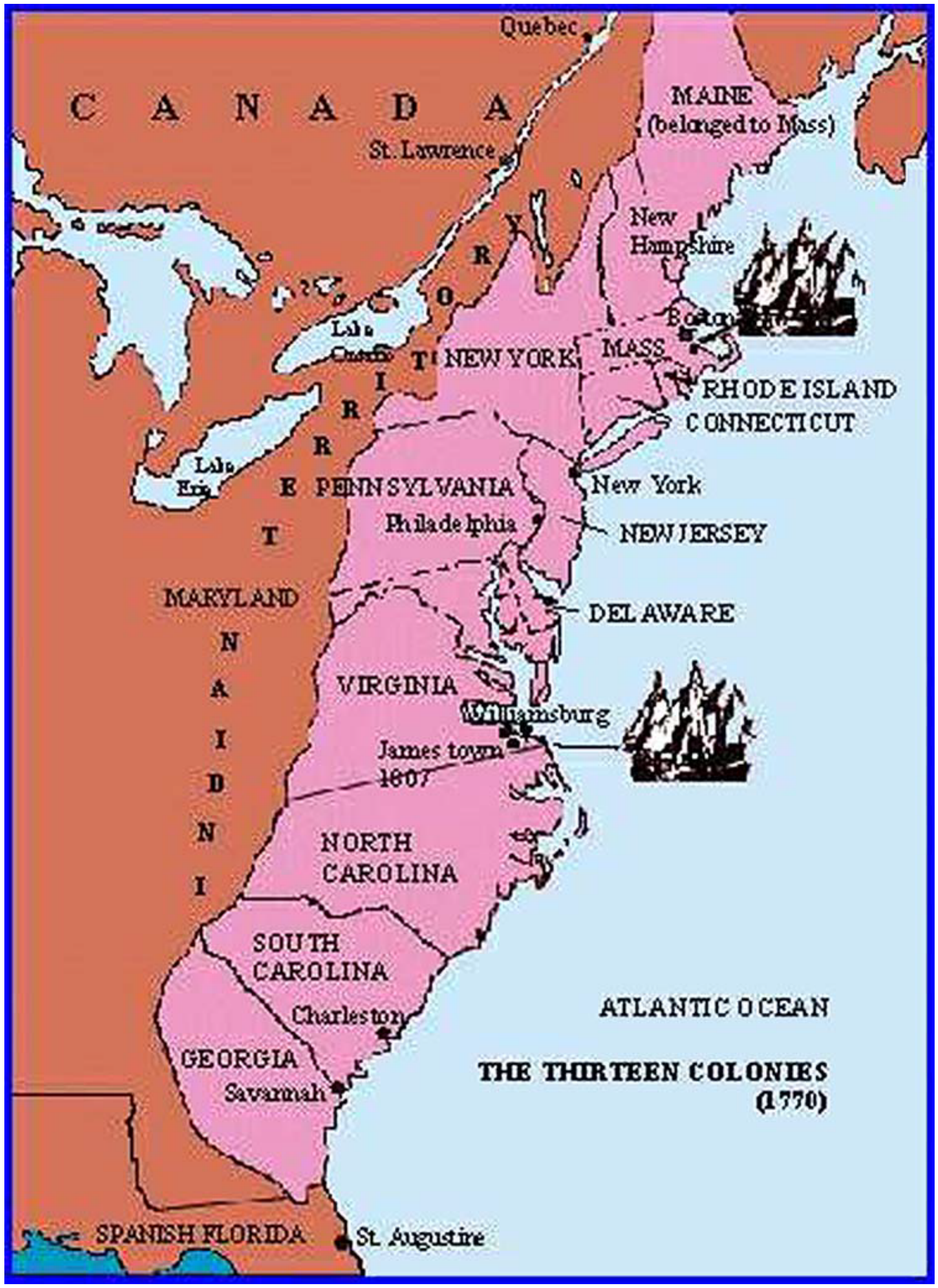


Fig. 12-24. The 13 American colonies towards the late 18th century. (Google: Early American settlements)

British, the delegates of the colonies met in the First Colonial Congress in Philadelphia to petition the king to redress their grievances and to plan future actions, such as forming militias in the case of British military action. Indeed, the British landed a military force to subdue the insurrection, and that led to the Revolutionary Wars of 1775-1783.

The leaders of the growing independence movement that spread to all the colonies were educated individuals, such as Thomas Jefferson, James Madison, John Jay, Alexander

Hamilton, and Benjamin Franklin, who used the new social philosophy to justify their insurrection and turn the colonies into independent states. Thomas Jefferson composed the United States Declaration of Independence, a unique political document that clearly spelled out the Enlightenment's ideal of a liberal political and social order. The Declaration stated:

> When in the Course of human events, it becomes necessary for one people to dissolve the political bands which have connected them with another … a decent respect to the opinions of mankind requires that they should declare the causes which impel them to the separation. ...
> We hold these Truths to be self-evident, that all men are created equal, that they are endowed by their Creator with certain unalienable Rights, that among these are Life, Liberty and the pursuit of Happiness. …That whenever any Form of Government becomes destructive of these ends, it is the Right of the People to alter or to abolish it, and to institute new Government, laying its foundation on such principles and organizing its powers in such form, as to them shall seem most likely to effect their Safety and Happiness. ...
> We, therefore … by Authority of the good People of these Colonies, solemnly publish and declare, That these United Colonies are, and of Right ought to be Free and Independent States
> .

The Second Continental Congress of the 13 colonies unanimously approved the United States Declaration of Independence on July 4, 1776.

In the ensuing military encounters, the British were routed from Boston, but occupied New York. After several successes and failures, the military position of the American revolutionaries greatly improved when French forces joined the war in 1778. The Revolutionary War ended when the British capitulated in 1781. In the Paris Peace Treaty of 1783, the United States took possession of much of North America east of the Mississippi River and south of the Great Lakes. The British kept Canada, and Spain kept Florida. After the Revolutionary War ended there was a period of prosperity. However, the country lacked unity because there was no strong central government or a national bank, and the states operated independently under the Articles of the Continental Congress. There were no financial resources to pay debts owed to foreign governments and banks, and to redeem the promissory notes to its citizens who supplied goods and services to the government. These political and economic problems led to a debate between two factions, the "Federalists" and the "Republicans" advocating "states-rights." The debate was publicized in the Federalist Papers, anonymously written by John Jay, James Madison and Alexander Hamilton. In 1787, delegates of the States met at a Constitutional Convention in Philadelphia and began a debate how to produce a stronger union by balancing the interests of the different States and ensuring "checks and balances" to prevent the Federal government becoming tyrannical.

The Republicans, powerful in the South and led by Thomas Jefferson and James Madison, envisaged a country whose strength would come from the promotion of agriculture. The Federalists, strong in the North and led by Alexander Hamilton, envisaged a country whose economic strength would come from industry and commerce. A Convention in Philadelphia in 1787 drew up the articles of the Constitution of the United States, which was ratified by all states in 1789. The Preamble to the Articles of the Constitution began on the lofty note:

> We the People of the United States, in Order to form a more perfect Union, establish Justice, insure domestic Tranquility, provide for common defence, promote the general Welfare,

> and secure the Blessings of Liberty to ourselves and Prosperity, do ordain and establish this Constitution for the United States of America.

Supplementing the Constitution, Congress passed the Bill of Rights with 12 Amendments in 1791, much of it written by James Madison. The adoption of these Constitutional documents contributed to the establishment of a greatly strengthened United States with a President at its head and an independent Legislature and Judiciary. In contrast to the British bicameral Parliament with a House of Lords and a House of Commons, in the American bicameral Congress the Senate was designed to represent the states' interests, independent of their size or population, and the House of Representatives was to represent the interests of the majority of the voting population in the different districts of the states. The Constitution granted considerable powers to the President in external and military affairs (but subject to "advice and consent" by Congress) and Congress was granted the power of taxation and finances, using a method of "checks and balances" to prevent the President from assuming dictatorial powers. The Bank of the United States was organized to pay off the debts of the nation and the states, and stabilize the financial infrastructure of the U. S. by creating a uniform system of taxation. George Washington, the commander of the Revolutionary forces rather than a member of a political party, was elected the first president of the United States. After serving two 4-years terms in office, Washington returned to private life in 1797. The national capital was moved from New York to Philadelphia, and then to the city of Washington in 1800.

The subsequent history of the United States indicates that its citizens were unable to realize the lofty ideals of the Constitution. The United States, much like several other imperialist Western countries, embarked on an expansionist policy and the powerful and rich sought to exploit the defenseless and the poor. The territory of the United States progressively expanded in the ensuing years, after the purchase of territories claimed by France (the Louisiana Purchase in 1803) as far west as the Rocky Mountains and later to the Pacific Coast. The natives of North America were decimated and their lands were confiscated. Those who resisted were forcibly evicted by the US army or killed. The enslaved colored people of Africa were bought and sold, exploited and denied all civil rights. The expansionism created a mentality characterized by rugged individualism and violence. And, instead of "tranquility," there was endless class struggle between the privileged minority who sought to amass undue wealth in the name of individual "freedom," and the exploited majority who wanted a greater share in the bounties of the land in the name of "equality." Nonetheless, both the letter and the spirit of the Constitution prevailed and the United States has remained for over two centuries a democratic Republic seeking to reconcile the ideals of freedom and equality.

12.3. Advances in Science and Technology, and Social and Political Conflicts from the Early 19th Century until World War I.

12.3.1. Scientific Advances from the 19th Century to World War I. The major advance during this period in physics was the intensive study of electricity and electromagnetism, the discovery of x-rays, and of radioactivity. The discovery of galaxies was an important accomplishment in astronomy. Advances in the life sciences included Darwin's theory of evolution, the discovery of the role of bacteria and viruses in diseases, which led to procedures improving public sanitation; improvements in food production and processing that resulted in improvements in the standard of living; and advances in medicine and pharmacology that led to the lengthening life expectancy.

Advances in Physics and Astronomy. Early in the 19th century Alessandro Volta discovered bimetallic electricity by demonstrating that a pair of zinc and silver plates separated by a weak acid in a flask was a good source of continuously flowing electric current. When Giovanni Aldini stretched a wire across the Bay of Calais and connected it to a battery, he found that metals conduct electricity at a great speed. Soon thereafter it was discovered that cable conduction is only one form of electrical propagation; electricity, much like magnetism, is also propagated across space without a visible medium. Hans Christian Ørsted, using a pile of voltaic plates, found in 1820 that a wire carrying an electric current will rotate around a magnetic pole and, conversely, a magnet will rotate around a stationary wire carrying electric current. This was the first demonstration of an interrelationship between electricity and magnetism. A decade later, Michael Faraday assembled a device consisting of an inducing magnet, coils of wire, and a copper disc rotated manually, to produce a steady follow of direct electric current (Fig. 12-25). Faraday's demonstrations led to the invention of the dynamo that converts mechanical energy into electricity and of the electric motor that converts electrical energy into rotary motion.

FARADAY'S ELECTROMAGNETIC GENERATOR

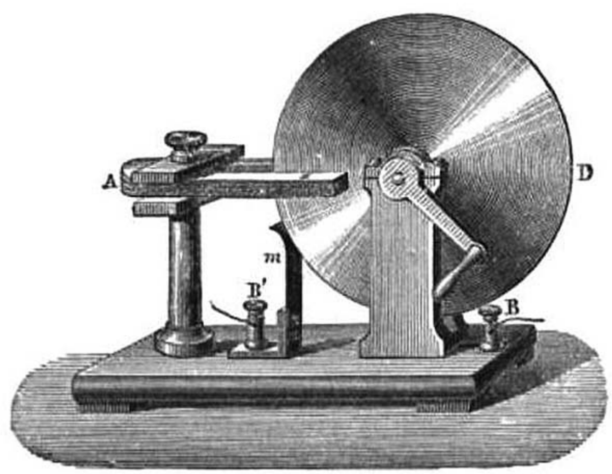


Fig. 12-25. An electromagnetic generator. Similar to the one invented by Michael Faraday in 1831. (FaradayDiskGenerator.jpg)

In contrast to Newton's corpuscular theory of light, Christian Huygens proposed the wave theory of light in the 17th century. Huygens assumed that there is a medium called ether that is uniformly dispersed through space and light consisted of waves propagated through this medium. Most scientists favored Newton's theory. Early in the 19th century Thomas Young revived the wave theory to account for his demonstration of the polarization of light. He proposed that these waves were vibrations propagated transversely across the direction of light rays. That led to the development of the field theory of electromagnetic radiation by James Clerk Maxwell in the mid-19th century (Hesse, 1967). A mathematical physicist, Maxwell formulated a set of equations that unified electricity, magnetism and visible light as aspects of the same force, the propagation of electromagnetic waves across space at immense speed. Heinrich Hertz experimentally confirmed this theory in the late 1880s by showing that electromagnetic waves could be reflected, diffracted and polarized like visible light and

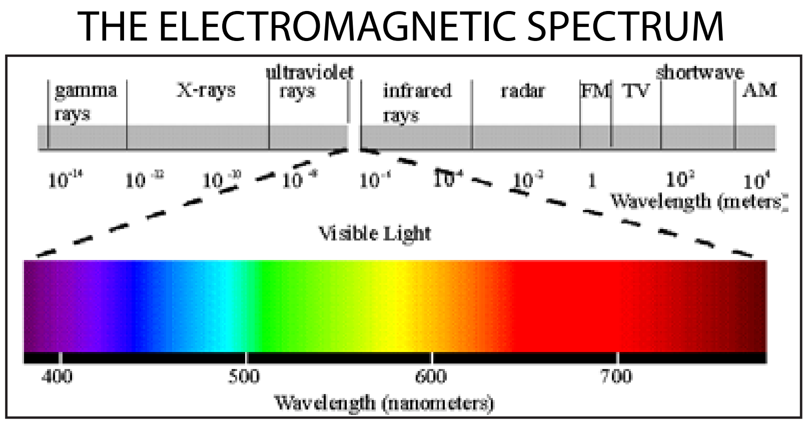


Fig. 12-26. Modern rendering of the electromagnetic spectrum, from the highest to the lowest radiation frequencies. (Google: Images of electromagnetic spectrum)

travelled in a straight line at the same speed. Recent studies have established that in a vacuum that speed is 299,792,458 meters/second. Wilhelm Roentgen discovered the existence of x-rays in 1895. As we now know, the spectrum of electromagnetic radiation ranges from the very short wavelength of gamma rays to the very long wavelengths of radio waves, with the spectrum of visible light ranging between the invisible ultraviolet and infrared rays (Fig. 12-26). This scientific research led in the 20th century to the development of wireless broadcasting.

Henri Becquerel discovered in 1896 that uranium salts emitted radiation that resembled x-rays in their penetrating properties and Marie Curie demonstrated that the element uranium was the source of that radiation. She later discovered three other radioactive elements, thorium, polonium and radium. This seminal research showed that atoms were not indivisible as previously thought and it contributed to the later discovery of the subatomic composition of atoms.

Advances in Astronomy. Thomas Wright suggested in the mid-18th century that the Milky Way consists of millions of stars and has the shape of a flattened disc (Roberts, 1972). The philosopher Immanuel Kant speculated that the hazy nebulae that had been currently discovered were similar to the Milky Way, consisting of an immense number of stars. He also suggested that the nebulae have a flattened shape because they are rotating. Kant's speculations were supported by the subsequent observations of William Herschel (1738-1822) with his reflecting telescope. Herschel was able to estimate the size of the Milky Way and concluded that the sun, as a member of that galaxy, was situated near its center. He also found that some of the nebulae could be resolved into constituent stars. Over a century later, Friedrich Wilhelm Bessel had established that over a period of 300 years, a faint star known as 61 Cygni has moved across the sky a distance equivalent to the diameter of the moon. Soon several other astronomers, using improved telescopes, undertook to measure the distances of other stars, a task that became easier after the introduction of photography. The cosmos was evidently far larger than was earlier believed.

Advances in Chemistry. The modern concept of matter began with the atomic theory of chemical compounds proposed by John Dalton in his *New System of Chemical Philosophy*, published in 1808. Dalton and others studied the relative weights of elements that combine to form different compounds and found that the proportions were always the same. To explain this constancy, Dalton made several assumptions. First, that the different elements are composed of atoms and that there are as many different kinds of atoms as there are elements. Second, all atoms of a particular element have the same weight. Third, all molecules of a particular compound contain the same proportion of constituent atoms. Dalton drew up the first table of atomic weights relative to hydrogen as unity, and the table of atomic weights compiled by Jöns Jacob Berzelius two decades later are close to the one in use today. To investigate the formation of molecules, Berzelius and others began to study the effect of electric currents on chemical reactions. They found that in the ensued chemical decomposition (electrolysis), some elements gathered near the negative pole (cathode), others near the positive pole (anode). A simple demonstration of this is the electrolysis of water, with hydrogen forming gas bubbles near the cathode, and oxygen near the anode (Fig. 12-27). From these observations it was concluded that the mutual attraction of atoms to form molecules is due to their electric charges (valences) when ionized. In 1869 Dimitri Mendeleev formulated the periodic law of elements by listing the then-known elements into rows of eight according to their atomic weights. So arranged the elements in the different columns display many similar chemical properties. The subsequent discovery of many more elements have led to new periodic tables but the idea of periodicity has not been abandoned.

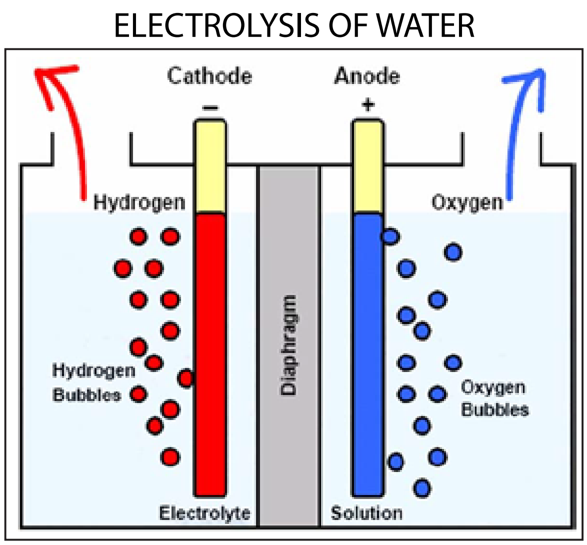


Fig. 12-27. Dissociation of water molecules (H_2O) into charged (ionized) hydrogen and oxygen atoms. (Google: Electrolysis of water)

Advances in Biology. Among the advances in biology between the 17th and 18th centuries have been the following discoveries: organisms are composed of microscopic cells; nerve conduction and muscle contraction are electric phenomena; the evolutionary origin of species; the formulation of the basic laws of genetic inheritance; and the groundwork was laid for the later development of the science of biochemistry.

THE CELL THEORY. We described earlier Robert Hooke's observation of the cellular organization of plant tissue. It was Matthias Jacob Schleiden who, in an article published in 1838, concluded that the cell was the elementary unit of plants (Caullery, 1966). In the next year, Theodor Schwann extended this generalization to animals. Both Schleiden and Schwann realized the significance of the cell nucleus and its role in cell division. Jan Evangelista Purkinje coined the term protoplasm, and in 1854 Max Schultze defined the cell as a "small mass of protoplasm containing a nucleus." In 1855, Rudolf Virchow coined the developmental concept, "*Omnis cellula e cellula,*" every cell derives from another cell.

However, to confirm that all animal tissues have a cellular organization proved to be difficult. For instance, the central nervous system appeared to be composed of two distinct elements, cells and fibers. But that issue was partly resolved when Otto Deiters (1834-1863) showed that some large neurons have fibrous processes, what are now called dendrites and an axon (Fig. 12-28) and Camillo Golgi, using a novel cell preparation technique, was able to demonstrate that the nerve cell body and its fibrous processes are a single structural unit. Confirming that, Wilhelm His obtained evidence in the late 19th century for the outgrowth of nerve fibers from primitive cell bodies during embryonic development. Finally, Ramón y Cajal demonstrated at the turn of the century that different dendritic configurations distinguish different types of neurons; that there is structural discontinuity between single neurons; and inferred that the dendrites were the input ends of neurons and the axon their output end (Fig. 12-29). Cajal's "neuron doctrine" became the morphological foundation of modern neurobiology.

LARGE NEURON WITH DENDRITES AND AXON

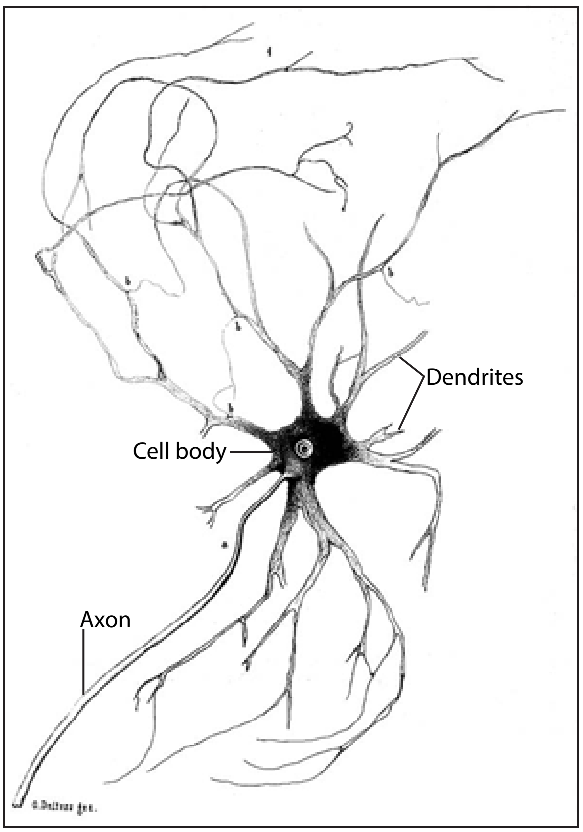


Fig. 12-28. Deiters's illustration of a large nerve cell with its protoplasmic dendrites and its axon. (DeitersNerveCell.jpg)

CAJAL'S DRAWING OF A PURKINJE CELL

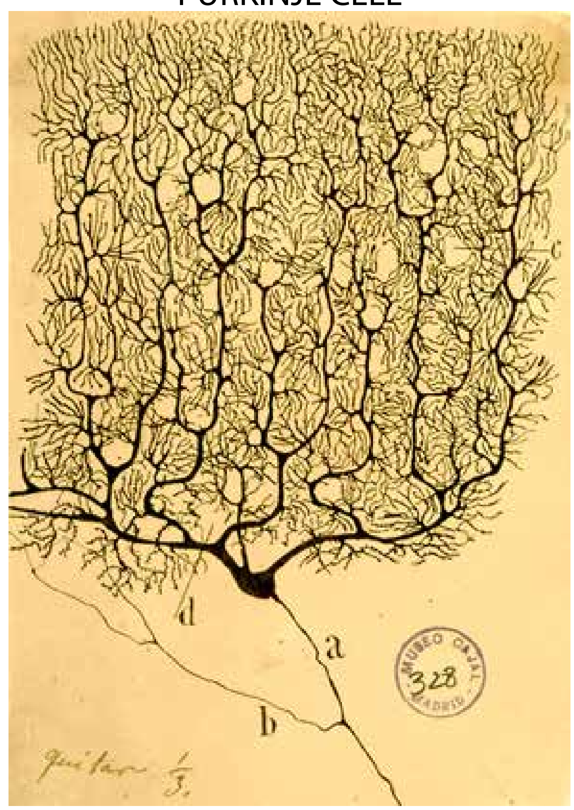


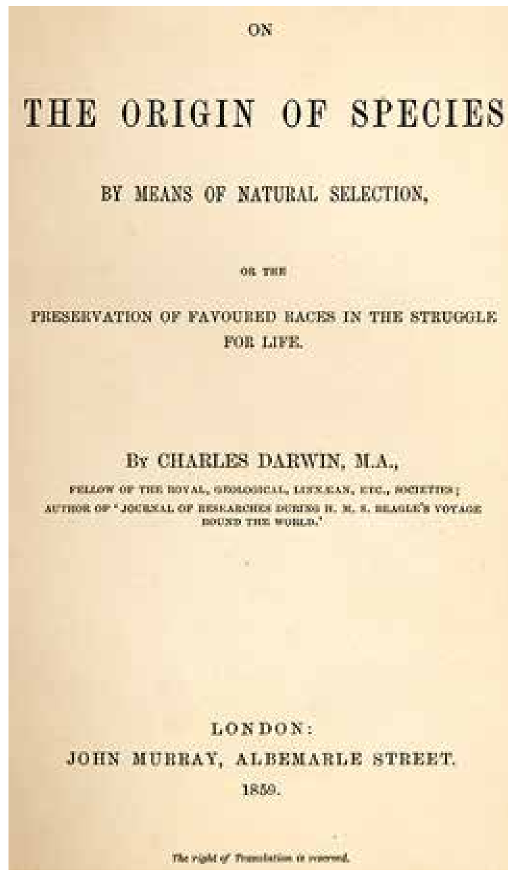
Fig. 12-29. The Purkinje cell of the cerebellar cortex with its elaborate dendritic branches. Abbreviations: d, dendrites; a, axon; b, recurrent axon collateral. (Museo Cajal)

Advances in physiology. The introduction of reliable electrical generators, like the Leyden jar and batteries, and the invention of electrical recording instruments, like the galvanometer, turned physiology from a descriptive science of tissues and cells (morphology) into an experimental science of organic functions (physiology). This is illustrated by the discovery of the role of electricity in the conduction of nerve signals and in the initiation of muscle contraction. Lepoldo Caldani demonstrated in the mid-18th century that electric stimulation of a nerve in experimental animals produces muscle contraction (Brazier, 1959, 1984). The subsequent confirmation of that by Luigi Galvani and Alessandro Volta, and added experiments by them, led to the discovery of what became known as "animal electricity." In his *Essai sur les Phénoménes Electriques des Animaux*, published in 1840, Carlo Mateucci reported that when a muscle contracts in response to nerve stimulation, current flows between its interior and exposed surface. Emil du Bois-Reymond confirmed that a few years later, as described in his *Untersuchungen über thierische Elektricität*, and supplemented that with the observation that electric current also flows in the stimulated nerve. This was the discovery of the electrical nature of nerve conduction. In 1850, Hermann von Helmholtz, using an ingenious electric circuit, was able to measure the speed of nerve conduction; it proved to be very slow when compared with electrical conduction by a metallic wire. By the end of the century, Julius Bernstein, using an improved recording technique, demonstrated that the surface of the nerve becomes negative as current flows, deducing from that that the nerve "action potential" was an ionic process.

THE REFLEX ARC. In his *An Essay on the Vital and Other Involuntary Motions of the Animal*, published in 1751, Robert Whytt reported that nerve stimulation in the decapitated frog ceased to produce leg contraction if the spinal cord was destroyed with a hot needle. Charles Bell, in his book *Idea of a New Anatomy of the Brain*, published in 1811, described an experiment in which he sought to determine the functions of the two peripheral branches of the spinal cord, the ventral and dorsal nerve roots. When he cut the ventral root, nerve stimulation no longer elicited limb movement; however, stimulation of the ventral nerve peripherally still produced muscle contraction. It was finally François Magendie who established experimentally that the function of the dorsal nerve is sensory (afferent), that of the ventral nerve is motor (efferent), and that the spinal cord is the central component of this neural circuit. This was the foundation of the concept of the "reflex arc" as a mechanism of involuntary movement. Towards the end of the 19th century, Charles Sherrington summarized his extensive studies of the properties of reflexes in his *Integrative Action of the Nervous System* (published in 1904). Sherrington discovered that the central organization of reflexes in the spinal cord is based on neural excitation and inhibition: the former leading to the contraction of the innervated muscle, the latter to is relaxation. He also demonstrated that interaction between local (intrasegmental) and distant (intersegmental) reflexes are responsible for the coordinated limb movements that produce quadruped locomotion. This was the discovery of a basic mechanism of involuntary animal locomotion.

STUDIES OF BRAIN FUNCTION. Physiologists also began to study the functions of different components of the brain in experimental birds and mammals. Luigi Rolando reported in 1809 that removal (ablation) of the cerebellum produced motor abnormalities. François Magendie demonstrated later that the operated animals' handicap was not strictly motor in nature but due to their inability to maintain their postural balance. The subsequent studies by Luigi Luciani, as reported in his *Il Cerveletto* in 1891, confirmed this conclusion and added further details about the role of the cerebellum in the coordination of motor activity. Ablation of the cerebral cortex proved to be a more difficult task, as the early investigators could not keep the operated animals alive. Friedrich Goltz succeeded in that and reported that the decorticated dog showed elevated emotional reactivity and "psychic blindness," confirming the hypothesis that the cerebral cortex mediates higher mental functions. Another approach to the study cerebral functions was electrical stimulation. It was in 1870 that Gustav Fritsch and Eduard Hitzig identified the motor cortex and demonstrated that stimulation of discrete points produced movements in different body parts. This was the beginning of a concerted effort by neurophysiologists to construct "maps" of the functional organization of the cerebral cortex.

DARWIN'S ORIGIN OF SPECIES TITLE PAGE



ON

THE ORIGIN OF SPECIES

BY MEANS OF NATURAL SELECTION,

OR THE

PRESERVATION OF FAVOURED RACES IN THE STRUGGLE FOR LIFE.

BY CHARLES DARWIN, M.A.,

FELLOW OF THE ROYAL, GEOLOGICAL, LINNÆAN, ETC., SOCIETIES;
AUTHOR OF 'JOURNAL OF RESEARCHES DURING H. M. S. BEAGLE'S VOYAGE ROUND THE WORLD.'

LONDON:
JOHN MURRAY, ALBEMARLE STREET.
1859.

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Fig. 12-30. The title page of Darwin's "The Origin of Species." (Wikipedia)

THE THEORY OF ORGANIC EVOLUTION. The biological theory with the greatest scientific and cultural impact was the one proposed by Charles Darwin in his books *On the Origin of Species*, published in 1859 (Fig. 12-30), and *The Descent of Man* published in 1871. It is noteworthy that Darwin's theory of evolution was a revolutionary proposition only in the context of the Western tradition because of the explicit biblical assertion that God created man separately from animals and in his own image. This contrasted with the widely held tradition in many primitive societies of an affinity between animals and man. The first 19th century biologist who advocated the theory of evolution was Jean Baptiste Lamarck. In the volumes of his *Histoire Naturelle das Animaux sans Vertébres*, published between 1815 and 1822, Lamarck proposed that individual survival favors the modification of organs and abilities and that these acquired adaptations become the inherited properties of the new species. His contemporaries, such as the comparative anatomist and paleontologist, Georges Cuvier, rejected Lamarck's theory. Darwin worked on his theory for about a quarter of a century before publishing his first book on evolution. His theory was based: (i) on the emerging empirical evidence for the great antiquity of life on earth, and (ii) the evidence for the heritability of changes in the traits produced in domesticated animals by selective breeding. And he combined these facts with some empirically based inferences: (iii) that animals "struggle for survival," and that (iv) under changing environmental conditions "natural selection" would favor (v) "the survival of the fittest. Unfit old species are liable to go extinct and be replaced by better adapted new species.

Darwin's theory produced an immediate controversy. From a scientific perspective, Darwin could not adequately deal with the issue how the newly formed species traits are transmitted and stabilized by inheritance. More importantly Darwin's theory contradicted not only the biblical Creation story but it also denied the uniqueness of man in the cosmic order. However, emerging evidence began to support his theory of the animal origins of *Homo sapiens*. The primitive skull of Neanderthal man was discovered in 1868, suggesting that human beings have existed before and gone extinct, and Heinrich Haeckel's idea of a "missing link" from apes to man led to the discovery by Eugéne Dubois of *Pithecanthropus* in Java in 1891—an ancestral form of primitive man with a small skull, now classified as *Homo erectus* (Fig. 12-31).

RESTORED JAVA "APE MAN"

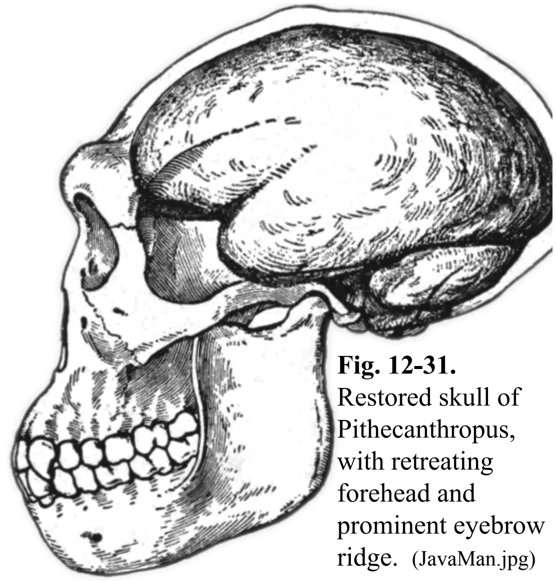

Fig. 12-31. Restored skull of Pithecanthropus, with retreating forehead and prominent eyebrow ridge. (JavaMan.jpg)

PRINCIPLES OF GENETICS. The clarification of the nature and principles of inherited variations, an important component of evolution theory, had to await the discovery of the contributions of cell division to sexual propagation and the development of the science of genetics. It was known by the mid-19th century that cell division (mitosis) is preceded by the duplication and splitting of the chromosomes of the cell nucleus. In 1875, Oscar Hertwig discovered that the fertilization of an ovum by a sperm involves the union of their nuclei, indicating that the nucleus played a major role in the morphogenesis of organisms. Soon thereafter, August Weismann and others discovered that while ordinary cells are diploid (contain a duplicate set of chromosomes) the ovum and sperm are haploid (contain only one set of chromosomes). When the sperm fertilizes the ovum, the union of their nuclei results in the restoration of the duplicate set of chromosomes, one set coming from the male parent, the other from the female parent.

Independently of these discoveries, Gregor Mendel published a paper, *Versuche über Pflanzenhybriden* (Research on Plant Hybrids), in the obscure journal of the Natural Historical Society of Brünn (Brno) in 1866, giving an account of the results of his breeding experiments. Mendel crossed pea plants (*Pisum sativum*) with different traits and quantified the traits passed on by the hybrids to their offspring. When Mendel bred a plant with yellow pea with another of yellow pea, the offspring were all yellow. When he bred a green pea with another green pea, the offspring were all green. When he crossbred a yellow pea with a green pea, the offspring of the first generation were all yellow. And then when he bred the hybrid yellow peas, he repeatedly got a ratio of three yellow peas to one green pea, while the breeding of the hybrid green peas produced all green peas (Fig. 12-32). To explain these results, Mendel postulated that inherited traits are the product of two "factors", one passed on by the male parent, the other by the female parent. If these two hereditary factors are identical all the offspring will be alike. However, if the two are different, the dominant trait will mask the expression of the recessive trait in the first generation but may reappear in the next generation. On the basis of his results, Mendel formulated two principles of heredity, which were later called the law of segregation and the law of independent assortment. The law of segregation states that of the two genes for every trait, each parent passes on only one to its offspring. The law of independent assortment states that each trait is passed on independently and randomly, hence inheritance in a population is statistically predictable.

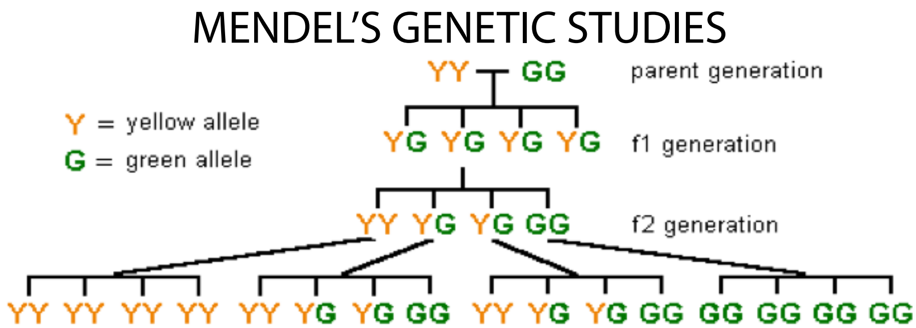

Fig. 12-32. Gregor Mendel's seminal experiment of the transmission of a simple genetic trait through three generations. (Anthropalomar.edu)

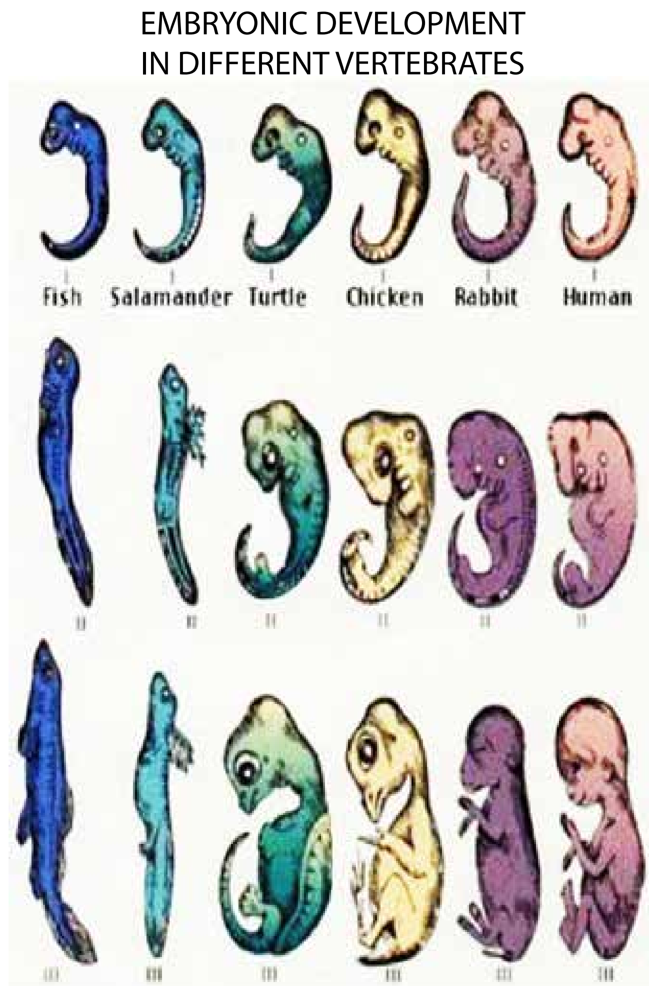

Fig. 12-33. Illustration of Ernst Haeckel's evolituonary theory of embryonic development. (Recapitulation; users.rcn.com)

ADVANCES IN EMBRYOLOGY. Descriptive embryological research began in 1816 when Heinrich Christian Pander published his thesis on the formation of three germ layers during the early development of the chick embryo. In 1855, Remak named them endoderm, mesoderm and ectoderm. Remak suggested that the endoderm gives rise to the digestive and glandular systems; the mesoderm to the muscular, skeletal and excretory systems; and the ectoderm to the skin and nervous system. (We have argued in Chapter 2 [see Fig. 2-34] that the ectoderm gives rise in vertebrates to a fourth germ layer, the neuroepithelium.) In his *Über Entwicklungsgeschichte der Thiere*, published in 1827, Karl Ernst von Baer traced embryonic development to its beginnings when he identified the ovum in the Graafian follicle. Baer offered the generalization that during early embryonic development all vertebrates look similar but as development proceeds their divergent fate becomes more and more evident. General organic features develop before specific ones, and features common to a whole class of animals develop before those characterizing a specific group. For instance, the limb buds form before they differentiate and turn into limbs, wing or flipper. This observation acquired particular significance when Darwin published his *Origin of Species*, as it led to the Ernst Haeckel's dictum of "ontogeny recapitulates phylogeny" (Fig. 12-33). Although we now know that "recapitulation" is not an ironclad law, it is an important aspect of the complex mechanism of embryonic development.

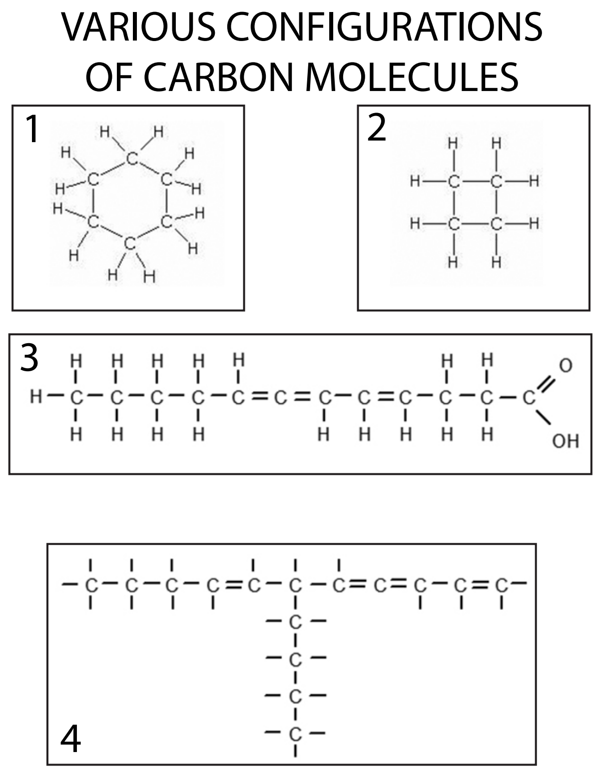

Fig. 12-34. Carbon compounds forming rings, chains and branches. (Google: carbon molecules)

BEGINNINGS OF BIOCHEMISTRY. Biochemistry is concerned with the chemical composition of different tissues, their synthesis and metabolism. Early in the 19th century it was widely believed that the synthesis of organic substances was due to vital rather than physical forces. The synthesis of urea in 1828 by Friedrich Wöhler was the first indication that that may not be the case. An important biochemical discovery was that all organic molecules are carbon-based, an element with four valence bonds that easily forms compounds with itself and many other elements (hydrogen, oxygen, nitrogen, phosphorus, etc.) in the shape of rings, chains and branches (Fig. 12-34). By 1842, when Justus von Liebig's published his textbook, *Animal Chemistry*, it was already known that both plant and animal tissues contain three major classes of organic substances, carbohydrates, lipids (fats), and proteins. Liebig described the differences between the metabolism of plants and animals. Plants (autotrophs) require only light, carbon dioxide, water and some minerals to produce their organic ingredients. In contrast, animals (heterotrophs) require many substances synthesized by plants for their survival. In 1897, Eduard Buchner extracted a substance called zymase from crushed yeast cells and found that it promoted the fermentation of sugar into alcohol in a cell-free system. Buchner proposed that every chemical reaction within the body is guided by a protein catalyst, or enzyme. By the end of the 19th century the structure and composition of carbohydrates, lipids and proteins were beginning to be determined. Emil Fischer established around the turn of the century that a given kind of protein yielded a constant ratio of amino acids, from which he inferred that proteins have an invariant composition much like other molecules. Fischer developed a technique to break up proteins into their amino acid constituents and then rejoin them as dipeptides, tripeptides and polypeptides.

ARCHEOLOGICAL AND ANTHROPOLOGICAL DISCOVERIES. Primitive stone implements and weapons, fragments of pottery and other antique artifacts were collected for some time in Europe, but it was not until the 19th century that their significance as records of human technological evolution came to be appreciated (Boule and Vallois, 1957; Tattersall, 1995; Klein, 1999). In 1836, the museum curator Christian Thomsen proposed in his *Guide to Scandinavian Antiquities* that there was a succession of three prehistoric epochs in man's tool-making evolution, what he called the Stone, the Bronze and the Iron Ages. Jaques Boucher de Perthes in his *Antiquités Celtiques et Antédeluviennes*, published In 1847, described the results of his excavation of ancient artifacts in combination with the bones of some extinct animals. Archeology was established as the science of prehistory, and the work of archeologists produced a growing body of evidence in support of the cultural, particularly technological evolution of mankind.

The theory of human evolution also received support from the wealth of ethnological descriptions that were initially gathered by missionaries and administrators in the Americas, Africa, the Pacific islands, and Australia. The earlier anecdotal and often sensationalist descriptions of the curious customs, beliefs and lifestyle of the natives were turned by anthropologists into a theory of the stages of the putative cultural evolution of mankind. As we have described in some detail earlier (Chapter 9, section 9.1.2), Lewis Henry Morgan, in his *Ancient Society*, published in 1877, proposed that mankind passed through three evolutionary epochs, from "savagery" to "barbarism," followed by "civilization" (Morgan, 1964). Savagery was associated with the life of nomadic hunters and gatherers who used simple Old Stone Age (Paleolithic) implements; barbarism referred to the life of sedentary villagers of the New Stone Age (the Neolithic) who domesticated plants and animals; and civilization was the culture of the urban peoples of the Bronze and Iron Ages who used greatly improved tools and implements to exploit available resources.

Advances in Medicine and Public Sanitation. In 1774 there was an outbreak of smallpox epidemic in Chester, England. A statistical study suggested that the incidence of death was higher among those who did not previously have the disease than among those who did (Singer and Underwood, 1962). There was also prevailing belief among country people that individuals who had been affected by cowpox were protected against smallpox (Fig. 12-35). To experimentally test the validity of this belief Edward Jenner, vaccinated people with a cowpox extract and confirmed that, indeed, the procedure provided protection against smallpox. By the 19th century, physicians throughout the Western world soon adopted inoculation against smallpox as a remedial procedure. Ignác Semmelweiss first documented the importance of cleanliness in obstetric wards in the mid-19th century. He demonstrated that puerperal fever, often lethal, could be reduced when physicians washed their hands in chlorinated lime between deliveries. Although ignored initially, eventually Pasteur's microbiological research convinced surgeons of the importance of a sterile environment in the surgery. A pioneer of aseptic surgery was Joseph Lister towards the end of the 19th century. He insisted on surgeons washing their hands and wearing rubber gloves and gauze masks in the operating room, of sterilizing surgical instruments with carbolic acid, and using the same to swab wounds and dressing them to prevent infections.

Fig. 12-35. The hand of a girl infected with cowpox. (Illustration by Edward Jenner; Wellcome Library)

PREVENTION OF CHOLERA EPIDEMICS. The rapid growth of cities during the Industrial Revolution, with consequent crowding of great masses of people in slums under unsanitary conditions (Fig. 12-22), created an acute public health problem (Singer ad Underwood, 1962). In London, thousands of houses had no drainage, and hundreds of streets were full of cesspools. Where there were sewers they were open ditches that emptied into the polluted Thames River. Many people got their drinking water from polluted wells or the river, and in the 1740s about 75 percent of the children died before the age of five. Although there was a decline in infant mortality in the subsequent decades, epidemics were frequent until the mid-19th century. For instance, there were outbreaks of cholera in London in 1832, 1849, 1854 and 1866 that killed thousands of people. The prevailing miasmatic theory attributed cholera, diphtheria, typhoid fever and other epidemic diseases to vapors of putrid substances ("bad smells"). John Snow, a physician, discovered that a cholera epidemic in Soho in 1854 was due to people drinking contaminated water from a nearby public water pump. The sanitary measures and health legislation that were introduced improved health conditions during the second half of the century. Deaths per 1000 of population per year dropped in England from 21.9 in mid-century to 17 in 1901 and the population increased from 21.9 to 30.9 million during that period.

DISCOVERY OF MICROBES. The efficacy of inoculation and sanitary measures in preventing infectious diseases came to be understood when Louis Pasteur developed the germ theory of fermentation and disease. In a series of experiments, summarized in 1861 under the title *Mémoire sur les Corpuscles Organisees qui Existent dans l'Atmosphère,* Pasteur postulated that putrefaction and fermentation is produced by airborne microorganisms that multiply at high rate in certain media, and he established that these microbes can be destroyed by heating provided that proper precautions are taken to maintain sterility. This discovery was first applied to control diseases in the silkworm and beer industry. Subsequently Pasteur showed that virulence of anthrax could be attenuated in sheep by extract of these bacilli, and that the injection of rabies bacilli saved the life of a small boy bitten by a rabid dog. Another pioneer of microbiology was Robert Koch who cultured these microbes in pure form to determine their life cycle and growth requirements. In 1878 Koch identified bacteria that infect wounds, in 1882 he identified the tubercle bacillus, and in 1883 the vibrio of cholera. By the end of the century the microbes causing many more diseases were identified: the bubonic plague, typhoid fever, diphtheria, gonorrhea, pneumonia, meningitis, gangrene, botulism, syphilis, and whooping cough. However, neither the identity nor the nature of these microbes was known for decades. In 1888, Pierre Paul Roux and Alexander Emile Yersin found that after they had filtered the broth containing diphtheria bacillus, the fluid devoid of organisms remained as virulent as the original broth. From this they inferred that substances produced by the bacillus, called toxins, cause death. Complementing that finding, Emil Adolf von Behring and Shibasaburo Kitasato established that by injecting an animal with sublethal doses of tetanus toxins, it developed immunity to tetanus. Finally, Paul Ehrlich proposed at the turn of the century that a chemical process between toxin and antitoxin produces immunity.

12.3.2. Advances in Technology During the 19th Century. While the inventors and entrepreneurs of the 19th century were inspired by science, most of them were not formally educated either in science or engineering. For instance, the inventors of the steam engine had little understanding of the principles of thermodynamics; indeed, they could not have received much help from scientists since those principles have not been worked out until after the major innovations in the design of steam engines have been accomplished. That situation began to change in the fourth quarter of the 19th century, when manufacturers and inventors began to turn to experimental and theoretical scientists to solve technical problems. As this development took place, technical colleges were established throughout the Western world and industry and governments set up research laboratories employing trained scientists and engineers. That new rational trend of technology being explicitly guided by scientific research, gave rise to a new burst of the Industrial Revolution.

From the Steam Engine to Electricity and the Combustion Engine. As we noted earlier, steam engines were developed early in the 18th century and were beginning to be installed to supply power for mining and industry. By the early 19th century they were widely used in all large plants and they were also beginning to be used for transportation and travel on land and sea. Then by the mid-19th century electricity came into use, first for information transmission and later to supply power to an endless variety of devices. Following that, the combustion engine was beginning to be used by the turn of the century to propel automobiles, airplanes and other devices. The pace of technological development increased.

THE EXTENSIVE AND MULTIPLE USES SE OF STEAM POWER. By the early 19th century the less efficient steam engines contained in brick buildings (Fig. 12-15) were replaced with more efficient and powerful high-pressure boilers. Steam engines became more widespread in industry to move belts, wheels and gears that drove various machines (Fig. 12-36). While textile manufacture was initially a cottage industry, the mechanization of spinning and weaving allowed manufacturers to employ a large work force in a single factory, greatly increasing the volume of production. The introduction of power equipment allowed miners to extract coal from seams at greater and greater depth, thus meeting the growing energy demand for steam power in the proliferating industries. The annual production of coal in Britain in the early 18th century was about 3 million tons; that increased to 30 million tons by 1830 (Griffin, 2010). In combination with advances in metallurgy, such as chemical and magnetic separation techniques and improved metal working techniques, the volume of metal tools and machine production greatly increased and became much cheaper (Smith, 1967a). The shaping of wrought iron was improved with the introduction of steam hammers and metallurgy was greatly advanced when Henry Bessemer discovered a process whereby steel could be produced cheaply in the molten

STEAM-POWERED TEXTILE FACTORY

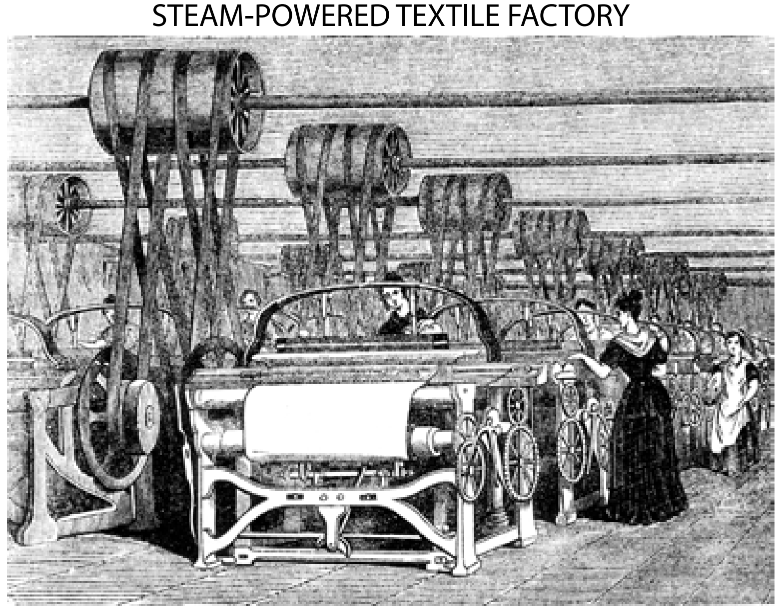

Fig. 12-36. A series of belt-coupled weaving machines driven by steam engines in a textile factory. (Globalprep. wikispace)

state (Smith, 1967b). As engineers began to produce more and more complex machines, a machine tool industry developed that supplied stronger, more enduring and better fitting wheels, gears, shafts and frames (Ferguson, 1967).

THE USE OF STEAM POWER FOR LOCOMOTIVES AND STEAMSHIPS. Richard Trevithick built the first serviceable steam locomotive running on rails in England in 1804, and the first railroad line was put into operation in 1825, using a locomotive designed by George Stephenson (Fig. 12-37A). There were 51 miles of railroad tracks in England in 1829 and by 1858 over 10,000 miles. By the mid-19th century, railroads connected distant cities in several industrially developing nations in Europe and in the United States (Burlingame, 1967). The locomotives built by the turn of the century became larger, more powerful and faster, carrying people and transporting goods (Fig. 12-37B). Of comparable importance to the railroad in making travel easier and promoting commerce and industry was the introduction of steamships (Ferguson, 1967). Robert Fulton's steamboat, using paddlewheels, first sailed on the Hudson River from New York to Albany and back in 1800. By 1811, a steamboat was in service on the Mississippi River. A steamboat supported by sails, the *Savannah*, crossed the Atlantic in 1819; in 1820 a true iron steamship was built for service between Paris and London. The first ship to use a screw propeller, the *Great Eastern*, was launched in 1858. By the mid-19th century, the extensive network of railroads, riverboats and seagoing iron ships made a veritable revolution in transportation by moving large number of people and goods over long distances cheaply, reliably and rapidly.

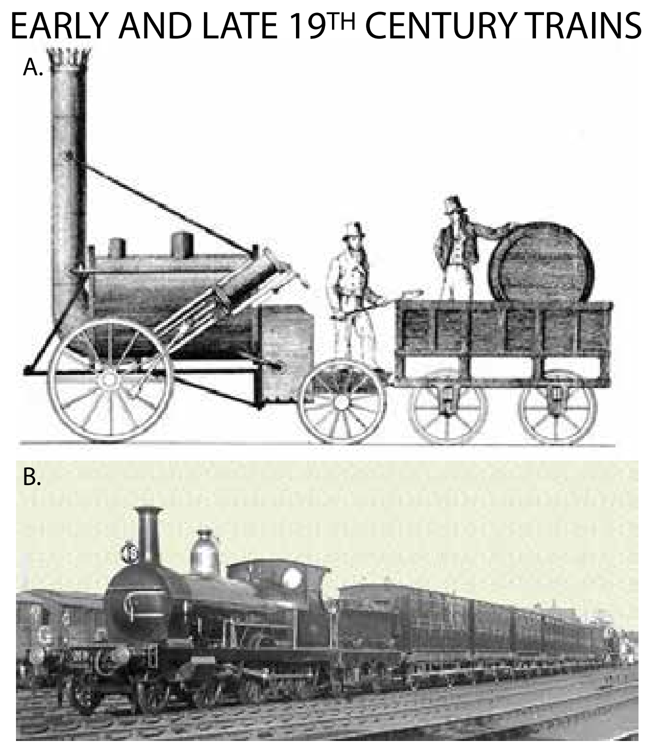

Fig. 12-37. A. Stephenson's steam locomotive of the early 19th century. **B**. A late-19th century steam locomotive with railroad cars. (Foggieloan.co.UK)

INVENTION OF THE TELEGRAPH AND THE TELEPHONE. The first important use of electricity was in long-distance communication (Dibner, 1967a). In the late 18th century, an optical system of signaling was developed in France, using semaphores placed at high points, spaced about 15 miles part. With this method, messages could be transmitted over a distance of 150 miles in about 15 minutes. This system could not be depended upon in mist, rain or a storm. By the 1830s several devices became available for electrical signaling over long-distances. Of these, the telegraph designed in 1845 by Samuel Morse became widely adopted (Fig. 12-38). This system used a key that allowed the composition of a message in a code of dots and dashes that could be instantly transmitted over hundreds of miles in the form of short and

TELEGRAPH KEY

Fig. 12-38. Morse key for transmission of telegraphs. (Greatsouthbay.com)

long electric pulses that energized a magnet at the receiver end of the line, where it produced legible marks on a moving tape. By 1860 an apparatus was available that would print up to 60 words per minute. The first cable across the Atlantic Ocean between North America and Europe was set up in 1858, reducing the time for the delivery of a message from about 10 days to a few minutes. In 1913 Western Union developed multiplexing, a technique that allowed the transmission of up to eight messages (four in each direction) over a single wire. (By 1936 as many as 72 messages could be transmitted over a single wire simultaneously.)

The next invention of comparable importance in revolutionizing human communication was the telephone, the electrical transmission of human voice over long distances (Fig. 12-39). Several inventors were involved in producing different devices in the 1860s and 1870s; it was the apparatus developed by Alexander Graham Bell in 1876 that became the forerunner of the modern telephone. The early telephones were set up in pairs for communication between two parties (Dibner, 1967b). But as telephones became more widespread, central switchboards were established to interconnect a growing number of subscribers in a given locality. Soon telephone cables were set up for long distance communication between cities, and then distant countries.

DIAGRAM SHOWING HOW THE TELEPHONE WORKS

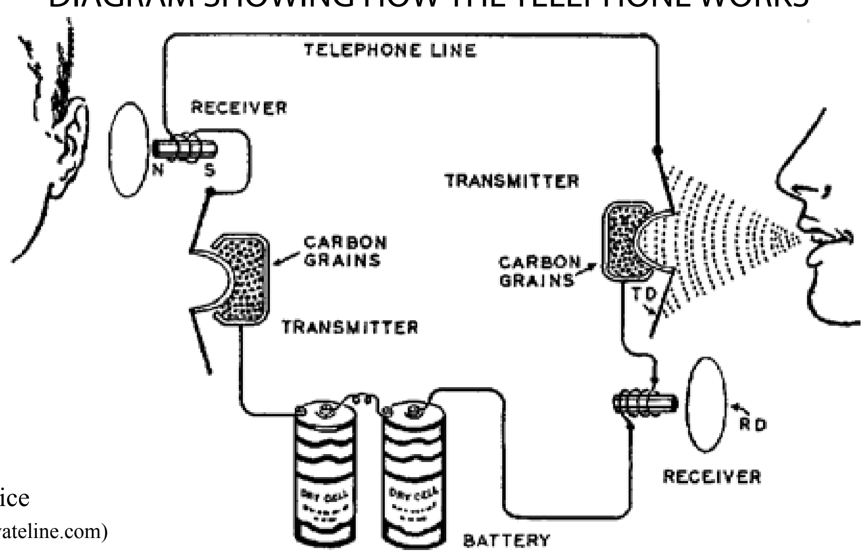

Fig. 12-39. Early design for voice transmission by telephone. (Privateline.com)

INVENTION OF ELECTRIC DYNAMOS AND MOTORS. Electric power did not challenge steam power as a major source of energy until the late 19th century (Sharlin, 1967). Batteries were the initial source of electric power, but they had their limitations: they supplied a limited amount of current and they were inconvenient because the acid into which the metal plates were dipped dried out and corroded the metals. In 1856, William Siemens replaced Faraday's rotating disc (Fig. 12-25) with the drum armature to produce the modern dynamo. In 1879 Edison developed a power station and a cable network that could supply energy for electric bulbs in shops and homes. Gradually, powerful dynamos were developed that could reliably supply energy not only to homes but also to industry. The rapid adoption of electricity was aided by using alternating current instead of direct current and high-voltage transmission lines over long distances to avoid appreciable loss of energy. The introduction of the small electric motor proved very beneficial. While the use of steam power required a large plant and a complicated system of belts and pulleys to operate a machine, a small electric motor connected to a power line could be turned on and off at will. By the end of the 19th century, newly built factories were electrified and electric motors were beginning to be used in streetcars.

INVENTION OF COMBUSTION ENGINES. By the middle of the 19th century, many inventors were engaged in assembling combustion-based engines for industrial use in small plants and for carriages but few of them were practicable (Bryant, 1967). The first breakthrough came in 1876 when Nicolaus August Otto used a compressed chemical mixture that could be ignited to drive a four-stroke single cylinder engine. The improved Otto-Langen engine immediately became popular in small machine shops, printing presses, pumping stations, and the like (Fig. 12-40). The internal combustion engine was not only smaller, but far more efficient than the steam engine because no energy is lost in the boiler and much less energy is wasted during idling. It is also more convenient because it lends itself for intermittent use, as it can be started or stopped at an instant. But it took two more decades before a reliable electric-spark ignition system was developed and the carburetor was invented to mix air and gasoline.

AN EARLY COMBUSTION ENGINE

Fig. 12-40. The Otto-Langen combustion engine. (Google images)

THE PRODUCTION OF AUTOMOBILES AND AIRPLANES. Once relatively light engines were developed, it became feasible to use them for horseless carriages. Karl Benz and Gottlieb Daimler of Germany did much of the pioneering work to create a reliable automobile running on gasoline, and the Mercedes built in 1901 was essentially a modern automobile with a 35 horsepower engine, capable of speeds over 50 miles an hour (Fig. 12-41). Most of the early automobiles were built in small shops and were owned by prosperous people because they were expensive. The popular era of automobiles, which affected all aspects of modern life, was due to the establishment of large manufacturing companies. One of the largest of these, the Ford Motor Company founded by Henry Ford, put on the market its Model T vehicle in 1908, expressly designed "for the great multitude." By 1914, the annual production of cars reached one million in the United States. In the ensuing decades further improvements were made in the design of automobiles, such as electric starting and automatic transmission, which made driving convenient for women as well as men.

MERCEDES BENZ AUTO IN 1901

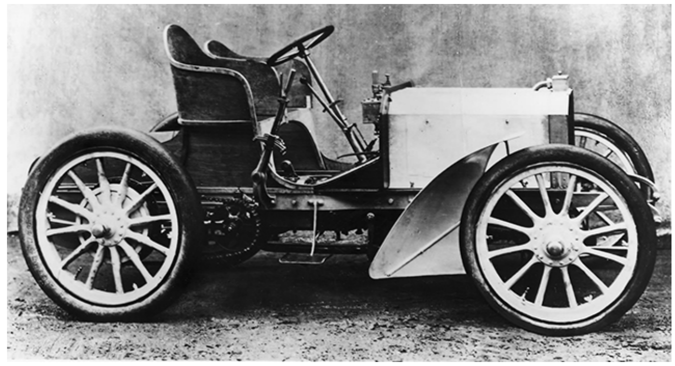

Fig. 12-41. A modern automobile built by Benz and Daimler in 1901. (Emercedesbenz.com)

BLÉRIOT'S MONOPLANE

Fig. 12-42. One of Blériot's maneuverable airplanes. (BleriotThulin2.jpg)

The first heavier-than-air flying machine was Orville and Wilbur Wright's 12-horsepower biplane that became airborne in in 1903 for 59 seconds, covering a distance of 852 feet (Smith, 1967). The first maneuverable airplanes were designed Louis Blériot (Fig. 12-42), who succeeded in flying across the English Channel in 1909. Similar feats were accomplished soon thereafter by other aviation pioneers. The realization of the airplanes' military potential induced many governments to facilitate their improvement before and during World War I. When Charles Lindbergh flew his plane across the Atlantic Ocean, aviation's great future became evident to all. Gradually the planes made of cloth, wood and guy-wire were transformed into streamlined flying machines with cantilevered wings without external bracing, retractable landing gear, and sleek aluminum bodies.

THE ESTABLISHMENT OF INDUSTRIAL LABORATORIES. In the 1870s, German dye manufacturing and pharmaceutical companies set up laboratories and employed university graduates to carry out applied chemical research. In the same year the German government established a department for the coordination of science and technology, the *Physikalische-Technische Reichsanstalt*, and the *Kaiser Wilhelm Gesellschaft* a little later. These innovations proved to be very successful and within a short time Germany became the world leader in several industries. This symbiotic relationship between science and industry was followed in the United States, mostly pioneered by inventors and the business community rather than the government (Lewis, 1976). In 1876, Thomas Alva Edison set up a research laboratory in Menlo Park, New Jersey, to develop incandescent light bulbs. To accomplish that, Edison employed a large staff to solve several technical problems, including the production of vacuum bulbs and high resistance filaments, improved dynamos and voltage regulators, and also a complex electrical distribution system, Decades later, in the research laboratory set up by the General Electric Company in Schenectady, New York, physicists and mathematicians started to work not only on problems of immediate interest to the company but studied a broad range of basic electrical phenomena of potential practical interest. Early in the 20th century, several governments set up laboratories to design standards and test the quality of industrial goods produced. The National Physical Laboratory was established in England in 1900, and the United States National Bureau of Standards in 1901. This trend was augmented during World War I, with the Department of Scientific and Industrial Research set up in England in 1915, and the National Research Council in the United States in 1916.

12.3.3. Economic, Political and Social Conflicts from the Early 19th Century until World War I. During the 19th century the Western world underwent a drastic economic transformation as its primarily agricultural and rural economy became increasingly industrial and urban. Paralleling that, the social order began to change from one dominated by monarchs, nobles and prelates to one influenced by wealthy financiers and merchants, and educated professionals. And increasingly parliamentary representatives of the bourgeoisie came to exert more and more influence on legislation and government. More slowly, the masses of working class people began to assert themselves and the unions representing them began to assume a role in improving working conditions and playing a role in the management of public affairs. Initially, social and political developments were quite different in Britain and the European Continent. With a longer tradition of political democracy and having become quite prosperous, Britain underwent a slow but relatively smooth political and social transformation. In contrast, there was a strong reaction to the Enlightenment and the French Revolution in France, Germany and Austria, leading to a veritable "culture war" between royalists and conservatives, on the one hand, and republicans and socialists, on the other hand.

The Enlightenment's ideals of liberty and equality was perceived by Europe's monarchs and aristocrats during the 19th century as a threat to their time-honored social and political privileges. Financiers, industrialists, and merchants viewed the growing power of the exploited proletariat as a threat to their wealth and influence. As predominantly agricultural nations became increasingly more industrialized, they competed among themselves for sources of raw materials and markets, which led to international conflicts. That conflict triggered an armaments race among Europe's nations and the formation of defensive and offensive alliances. We consider briefly below how these domestic conflicts and foreign entanglements played out in Britain, France and the German-speaking nations of Austria and Germany, four leading culture areas with different social conditions and antecedent histories.

British Economic, Social and Political Developments. Possessing ample sources of raw materials from its colonies (India, Canada, Australia, New Zealand, parts of Africa, and many other smaller lands) and ruling the seas, the British industrial economy and its infrastructure grew considerably during the 19th century (Williams, 2004). Beginning with a few railroad lines in the 1820s, virtually all British towns had rail service by the end of the 1840s. Britain also had the largest merchant marine with regular services to many ports of the world. Cheap coal from local mines supplied energy to the steam engines used by factories and Britain became the largest producer of textiles, metal tools, and machines. Imports of raw materials nearly doubled between the mid 18th and mid 19th centuries, and exports of finished products tripled (Crafts 1985). Associated with these economic advances, London and some other cities expanded immensely, becoming inhabited by a growing population of prosperous artisans and merchants, as well as masses of industrial laborers. The economic system of mercantilism and the exploitation of the working class needed to be changed but that was slow in coming because the government was still dominated by the landowning nobility favoring protectionism and the industrialists wanting cheap labor. For instance, as late as 1815, the Corn Laws were enacted to prohibit the importation of cheap wheat from the colonies. There was political pressure to yield to the demands of the bourgeoisie to promote their commercial interests and factory workers began to demand an improvement of their working and living conditions. However, although wages doubled between the 1770s and the 1870s that was coupled with an increase in living costs; hence the improvement in the working people's standard of living was modest (Feinstein, 1998).

While the French Revolution frightened the landowners of Britain, it inspired her reformers (Evans, 1994). Initially, successive Tory (conservative) governments used political repression to silence the reformers but by the early 1830s demand for social and political reform grew considerably. The election of 1831 gave the Whigs (progressives) the majority of votes and their succeeding governments began to introduce important political and social reforms. The Reform Act of 1832 gave voting rights to many who did not qualify earlier, although it still denied that to working class people who earned far less than what was stipulated. Legislation in 1833 forbade the employment of children under 9 years of age in textile factories and limited the working hours of children under 13 to 48 hours a week. The Factory Act 1844 reduced the hours that children under 13 could work a day to 6.5 hours and that of women to 12 hours a day. The Chartrist movement demanded manhood suffrage, secret ballots, the abolition of property qualifications for membership in Parliament, and pay for MPs (so that poor people could run for office), and equal electoral districts, the elimination of "rotten boroughs" and "pocket boroughs" that sent unelected people with privileged connections to Parliament.

THE VICTORIAN PERIOD. British social and industrial development and colonial expansion peaked during the long rule of Queen Victoria (1837-1901). The population of England doubled from 16.8 million in 1851 to 30.5 million in 1901, and about 15 million from the British Isles settled in the United States, Canada, Australia and New Zealand, or went to serve in the scattered colonies as soldiers and administrators (Burton, 2001; Williams, 2004). London's population of 2.7 million in 1851 increased to 6.6 million by 1901. Constituting about 2 percent of the word population, Britain controlled 45 percent of the world's industrial output. Factories mass-produced cotton shirts and fine woolen cloth, fine steel cutlery and china, as well as light and heavy machinery, and ships distributed these products widely all over the world. Britain also became the center of worldwide banking and insurance. Busy entrepreneurs used their wealth to build comfortable houses. By 1850, schools were built to educate children, and education was made compulsory. Prosperous cities built public parks and sports facilities. Libraries and museums were built that were open to all the public. Greatly improved living conditions reduced infectious illnesses, and improved health services led to a decrease in mortality. (After the cholera epidemics of 1848 and 1853 there was no further outbreaks during the rest of the century.)

However, prosperity did not reach all within the British Empire. The government did little to alleviate the Irish potato famine that began in 1844, and colonial administrators ruthlessly suppressed the Indian mutiny in 1857. Living conditions of the working class at home was also slow in improving, and much of the improvement was attributable to the efforts of the newly forming trade unions. The International Workingmen's Association was formed in 1864 and in 1867 voting rights were extended to male members of the working class who paid taxes. Parliament passed the Trade Union Act in 1871, giving unions the legal status of social institutions, and in 1884 voting rights were extended to agricultural workers. Initially the British unions were limited to skilled workers but unskilled laborers were beginning to form unions beginning by the 1880s. Still, it was not until the successful strike of dockworkers and gas workers in 1889 that the trade unions became a political force. In 1900, the Labor Party was formed and two of its members were elected to the House of Commons. The party won 29 parliamentary seats in the 1906 election and 42 seats in the 1910 election.

Socialist movements in France and Germany did inspire the British labor movement. However, while the French and German worker's parties were Marxist-oriented, the British Labor movement became far more moderate. Its aim was to advance the living conditions, social status and political power of working class people through parliamentary action rather than through the dictatorship of the proletariat. The British Labor Party was ideologically affiliated with the Fabian Society that was founded in London in 1884 by a group of intellectuals advocating social and cultural reforms by democratic means.

French Economic, Social and Political Developments. The collapse of the First Republic and the interlude of the Napoleonic era did not mean that the French Revolution altogether failed to transform the political and social landscape of France (Cobban, 1963; Popkin, 2000; Price, 2005). The commoners of France, hitherto *subjects* of monarchs became in principle *citizens* of the nation. Napoleon's defeat of the Austrian and Russian armies at Ulm in 1805, and the Prussian army at Jena in 1806, and the occupation of Spain and Portugal in 1807, became sources of great national pride. Although rigged, Napoleon held elections in 1799, 1802, and 1805, and as long as he was militarily successful, he could claim the enthusiastic support of a large segment of the French population. And even though the causes of discord among the social classes were not reduced during Napoleon's rule, the military actions were rationalized as serving the people's best interest. When military defeat came, the new spirit of populist nationalism was not extinguished, and the restored monarchy of the Bourbon dynasty retained many of Napoleon's reforms.

The Bourbon kings of France, who ruled France from 1814 until 1830 (with a hundred day interval in 1805 during Napoleon's return) were officially constitutional rulers. The Charter of 1814 established a bicameral government, with a hereditary Chamber of Peers and a popularly elected Chamber of Deputies. However, political discord continued. The Bourbon kings sought to exercise as much autocratic control as they could, while the different political parties representing different interest groups—conservative royalists, liberal royalists, and republicans—endlessly fought each other for political influence and gain. Economic difficulties and the people's rising discontent led to an uprising in 1830 and the Bourbon dynasty was replaced by the more liberal Louis Philippe, of the House of Orléans, known as the

"Citizen King." During his reign, as stipulated by the Charter of 1830, the power of the urban bourgeoisie increased considerably relative to the landowning nobility but the conditions of the working people failed to improve. The revolutionary ideals of equality and fraternity were not forgotten and the frustration of the working class people led to protest marches and the eruption of riots early in 1848. As the angry mass converged on the royal palace, Louis Philippe fled the country. The revolutionaries erected barricades throughout Paris, but the military restored order. Among those seeking a seat in the Chamber of Deputies in the ensuing elections, and one who later declared his candidacy for the Presidency, was Louis Bonaparte, the nephew of Napoleon. By overwhelming popular vote he was elected President of the Second Republic. Then, in a coup d'état in 1851, Louis Bonaparte declared himself the Emperor of France as Napoleon III.

Napoleon III proved to be an effective administrator. He was instrumental in supporting Hausmann, the architect, who turned Paris into a modern metropolis with broad avenues and public parks. He modernized France's infrastructure by building roads, bridges, railway lines, canals, aqueduct and harbors. Napoleon also promoted commerce, education and science, and was a patron of the arts. However, there were unresolved conflicts between the royalists and nobles, who dominated the army, and between the wealthy and the very poor. Napoleon III's rule ended in 1870 when, opposing the unification of Germany, the French army went to war against the Prussians. In a series of battles the French were defeated, and France lost Alsace and Lorraine to Germany. These events ended royal rule in France forever.

Following the French defeat, the Third Republic began with the uprising of the Communards and the erection of barricades (Fig. 12-43). The Communards turned over Church property to the State, outlawed the teaching of religion in schools, and advocated gender equality for women (Sowerwine, 2009). But by mid-1871 all the barricades were removed by the military and thousands of the rebels were killed or exiled. In the ensuing decades France recovered economically and militarily in association with the colonies that were established in North Africa, Madagascar, Indonesia, and Polynesia. However, the parliamentary governments that formed were not stable due to the endless bickering among three political parties and factions: the conservative royalists led by the landed nobility, who sought to retain their traditional privileges; the bourgeois republicans who sought to promote their commercial interests; and the radical socialists who opposed the capitalist system and sought to create a new social order. In 1880, the French Workers Party was formed and a decade later the Revolutionary Socialist Workers Party. The parties split further later as their leaders could not agree on goals and tactics, in particular in their attitude towards the French government's imperialism

PARIS BARRICADES, 1871

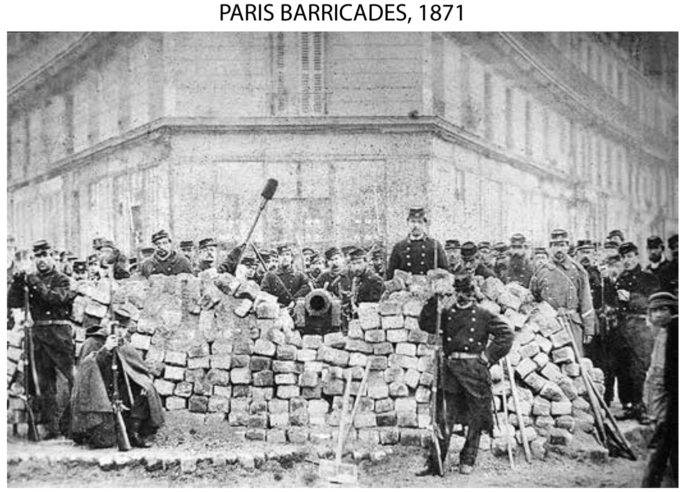

Fig. 12-43. A barricade set up by soldiers joining the Communards in Paris. (BarricadeCommuneParis1871.jpg)

and militarism. The Dreyfus affair that began in 1894 pitted the conservative royalists against the progressive liberals and gradually French public opinion shifted more and more toward the left, and the socialists joined the liberals in the governments of the early 1900s. However, unlike the British, who developed a tradition of compromise, the French public and politicians remained confrontational.

Economic, Social and Political Developments in Austria and Germany. The ideals of freedom and equality disseminated by the French Revolution inspired a liberating movement during the early 19th century throughout Europe. To contain that trend, the monarchs of Europe reacted with measures that included tightening political control at home and the forming "Holy Alliances." That latter began with the Congress of Vienna in 1815 that led to the formation the Triple Alliance by Austria, Prussia and Austria (Jarrett, 2013).

POLITICAL DEVELOPMENTS IN AUSTRIA. A major player in the royalist reaction against the liberalization and secularization of Europe was Clemens von Metternich, the foreign minister and later chancellor of the Austrian Empire from 1821 until 1848. A champion of autocratic royal rule and traditional values, Metternich was determined to halt the effort of liberals to introduce constitutional reforms in Austria, and sought to crush the demand of Hungarians, Poles, Czechs, Slovaks, Serbs, Croatians and others for autonomy within the multinational Austrian Empire. To halt the liberalization of Austria, Metternich used censorship of the press, outlawed political gatherings, and employed a network of spies to report on the activities of his opponents. And to organize unity among the great European monarchies—Austria, Russia, Prussia, France and England—against the rising nationalistic and liberal movements, Metternich was busy forming and maintaining a political and military alliance among them. Initially successful, Metternich's diplomatic efforts failed when revolutions broke out throughout much of Europe. Inspired by the 1848 revolution in France, popular revolts broke out against autocratic rule in the same year in Austria, Hungary, Croatia and Romania, Denmark, Prussia and various German states, and in the Italian states of Milan, Venice, Turin and Rome. Initially successful in some states, the revolution was soon suppressed everywhere. However, the revolutions were not without political gains, and the old social order began to change. The lot of peasants improved in the subsequent decades in Austria and Prussia; serfdom was abolished in Russia in 1861; and a political compromise was reached between Austria and Hungary in 1867. Throughout Europe, as a consequence of increasing industrialization and urbanization, and the spreading liberal ideals, parliamentary reforms were introduced that facilitated Europe's slow movement toward democratization.

GERMAN POLITICAL DEVELOPMENTS. While initially many Germans welcomed Napoleon as a liberator, and contributed over 100,000 soldiers to the invasion of Russia, his defeat ended the progressives' and nationalists' effort to establish a unified Germany for a while. With its fragmentation into so many states, the German Confederacy created by the Congress of Vienna in 1815 did not become a sovereign entity that could play a role in the political affairs of Europe for several decades (Holborn, 1962). The Custom Treaty (*Zollverein*) of 1833, designed to promote the free movement of goods between the different states (soon to be crisscrossed by railway lines) was the first step towards German unification. However, both Austria and France opposed unification because of their fear that Germany will to turn into a world power. The rivalry between Austria and Prussia as to who will dominate the future unified Germany, led to a war between the two nations in 1866. The Prussians were victorious. In 1870, the Prussians were again victorious in the war with France and occupied Paris in 1871. As a consequence of Prussia's military victories, the rulers of German states that gathered in Versailles in 1871 proclaimed King Wilhelm of Prussia the Emperor (Kaiser) of the unified Germany.

Although living under the autocratic rule of a prince or a king was an established German tradition, there was a growing urban population of burghers, professionals and intellectuals who wanted a constitutional Germany. Inspired by the February 1848 revolution in Paris, there were uprisings in March 1848 in several German cities –Mannheim, Frankfurt, Dresden, Berlin, and others—demanding constitutional reforms. The uprisings were swiftly put down by the Austrians and Prussians. But the effort continued and in 1861, reformers formed the United Progress Party. Offshoots of that political organization—the right-wing National Liberal Party and the left-wing Liberal Union—were established later. By 1884, the Liberal Union sent over 100 delegates to the *Reichstag* in 1884, opposing the prevailing "pseudo-constitutionalism" and militarism of Germany. Opposing the liberals were the Socialists supported by a growing working class constituency. The Social Democratic Workers Party of Germany was founded in 1875. Although banned for several years, 35 party members were elected to the *Reichstag* in 1890, and in the elections of 1912 the socialists became the largest single party in Germany. However, notwithstanding the Liberal and Socialist opposition, the government of the new Germany remained an autocratic and conservative system under Prussian dominance

The mastermind of German unification was Otto von Bismarck, a conservative Prussian nobleman, who started his career as the head of the Prussian government in 1862 and became the Chancellor of unified Germany in 1871 (Abrams, 1995; Mommsen, 1995; Feuchtwanger, 2001). A firm supporter of the monarchy and an able politician, Bismarck combined *Realpolitik* with Prussian military tradition, determined to solve the new Germany's political problems by a combination of diplomacy and "iron and blood." Bismarck treated the defeated Austrians leniently to ensure their future cooperation. His policies led to a German-Austrian military alliance in 1879. Through intensive diplomatic efforts, he created peace in Europe for several decades by fostering a "balance of powers." To assure social order on the domestic front, Bismarck was instrumental in extending voting rights to all adult male citizens of Germany. He supported business and received the allegiance of the magnates of industry and commerce. In order to weaken the power of the socialists, he instituted the first welfare nation in the world by establishing an insurance system for the working class that included accident, health and old-age coverage. However, Bismarck saw to it that the liberal and social party delegates sent to the *Reichstag* had limited political power. The management of governmental affairs remained in the hands of the old nobility. Bismarck's firm but rational control of the German government came to an end when Wilhelm II became the Kaiser in 1888. In contrast to his predecessors, the Kaiser decided to take control of running the German government himself. Abandoning Bismarck's diplomatic approach, Wilhelm embarked on a "new course," an aggressive strategy that, among others, sought to challenge the rule of the seas by Britain. Bismarck resigned in 1890, and Kaiser Wilhelm's bellicose rule greatly contributed to the outbreak of World War in 1914.

GERMAN ECONOMIC, SOCIAL AND POLITICAL DEVELOPMENTS. The German states were less advanced industrially in the early 19th century than England or France. Industrial development began slowly with the *Zollverein* of 1834, and turned rapidly into an "economic miracle" after unification. British engineers began to build rail lines in the German states in the 1840s, and by the 1850s passenger and freight trains crisscrossed all of Germany. Large industrial centers arose in several regions by the 1860s, in particular the Ruhr area, and by the end of the 19th century the German economy became the largest in Europe. However, the admixture of Germany's original social backwardness and rapid industrialization, had profound political consequences. The middle class had little political power because unification was achieved through military power and aristocratic Prussian authoritarianism. Unlike Britain, Germany did not have a powerful parliamentary system, and the Germans did not acquire a strong democratic tradition. And because the German states (unlike Britain and France) had no colonies, the united militaristic Germany tried to rectify that by building a navy and joining other European nations in a "scramble" to acquire overseas colonies and "protectorates." However, that effort produced little economic gain. The colonies that Germany acquired in East Africa, and a few islands in the South Pacific, had minimal economic significance and the German navy (except for its fleet of submarines) never came to match that of Britain or France.

In competing with Britain and France, the only advantage Germany had was its Prussian-dominated well-trained and well-equipped army. After unification, all able-bodied young Germans were conscripted to serve in the armed forces for several years and then remained in the reserves until middle age. In 1874, the German army had 420,000 regular servicemen and 1.3 million reservists. By 1897, the regular army grew to 545,000 and the reservists to 3.4 million. German militarization led to an arms race throughout Europe, with all the other countries also increasing their military strength. By the end of the century, Austria had 2.4 million reservists, France 3.4 million, and Russia 4.0 million. The maintenance of armies is an immense economic burden except when victorious wars expand territories, get booty, and reparations. Germany set out to become a Great Power, by going to war on two fronts, against the French and British in the West and the Russians in the east. It was an irrational undertaking enthusiastically supported by a population imbued with a nationalistic and militaristic ethos.

12.3.4. Social Developments in the 19th Century: Beneficiaries and Casualties. The advances in science and technology contributed to the improvement of the living conditions of a considerable segment of the population. Middle class people with an adequate income came to live in well-built residences with spacious rooms, supplied with conveniences like indoor plumbing and toilet facilities. They had year-round access to a reliable food supply as well as to some imported luxury items, such as tea, coffee and sugar. They could purchase relatively inexpensive garments designed for the changing seasons, and had access to comfortable conveyances for travel and transportation. Schools and academic facilities allowed families to send their children to acquire higher education and thus provide them with the opportunity to get ahead in an expanding economy. However, the new age produced many casualties: in particular, the city proletariat, the native people of the colonies, and the African slaves.

PROGRESSIVE IMPROVEMENTS IN THE STANDARD OF LIVING. During the 19th century, technological advances in the production, preservation and distribution of nutrients has resulted in the virtual elimination of food shortages during peacetime in most economically advanced and well-ordered nations, eliminating famines that plagued people in earlier times. In Britain between 1720 and 1840, wheat production per acre increased from about 19 bushels to 30 bushels. The repeal of the Corn Laws in 1840 and the importation of wheat from abroad further increased the availability of flour (Overton, 1966; Kingsbury, 2009). By 1875 most towns passed building regulations that specified the minimum size of rooms, the size of windows for ventilation, and installing safe ovens in kitchens (Harper, 1985). Middle class people came to live in sturdily built houses with comfortable furniture. Thanks to the mass production of garments, shoes, and the like, people were adequately clothed. Increasingly the roads and sidewalks in towns became paved and were lit at night by gas lamps and, by the turn of the century, with electric light. To enable people to commute to work, trolleys were installed in larger towns and they could take trains to visit relatives out of town or go to the seashore on weekends.

SPREAD OF LITERACY. Education was mostly limited during the Middle Ages to the nobility and those aiming to become clergymen or officials (Cook, 1974). Most schools were attached to churches and monasteries, the teachers were priests or monks, and the language of instruction was Latin. Students preparing for the professions—government, law, medicine—received a basic education in secular subjects but religious indoctrination was what the teachers emphasized. The introduction of the printing press and the Reformation changed that. In the 17th century Jan Amos Comenius, bishop of a Protestant sect and a religious refugee, was one of the pioneers of educational reform. Comenius argued for the use of the local vernacular rather than Latin as the language of teaching; that instead of learning by drill and memorization teachers should use concepts geared to the educational level of the student; and textbooks should be illustrated and written in a style that makes learning easy. He insisted that education should be available to all, including women. In the 18th century, Johann Heinrich Pestalozzi introduced the idea that instead of regimenting children in an effort to turn them into docile adults, they should be given the opportunity to develop their natural aptitudes. Early in the 19th century, Friedrich Wilhelm Froebel established kindergartens for the young, and Maria Montessori developed an educational program geared to what she considered natural stages in children's intellectual development.

By the mid-19th century governments began funding elementary education for all, employing qualified educators to teach children reading, writing and arithmetic (Gillard, 2011). By the late 19th century, public education was instituted by governments in most European countries and in time became compulsory. In advanced countries, like France, only a small percentage of the population was illiterate by the end of the century (Fig. 12-44). However, most of the public schools did not adopt the liberal ideals of the pioneers of the educational movement but used teaching as a means to turn the young into good citizens of the state and preparing them for their station in society. Those expected to become productive members of the working class got a primary education and learned to read and write and some basic general knowledge. Those prepared to become technicians, businessmen, and clerical workers—members of the middle class—received a secondary education, in what was in some places known as grammar schools. Secondary education included some basic science, mathematics, and a modicum of humanistic disciplines, such as literature and history. Students were disciplined and graded on the basis of formal competitive examinations. Finally, those prepared to become professionals,

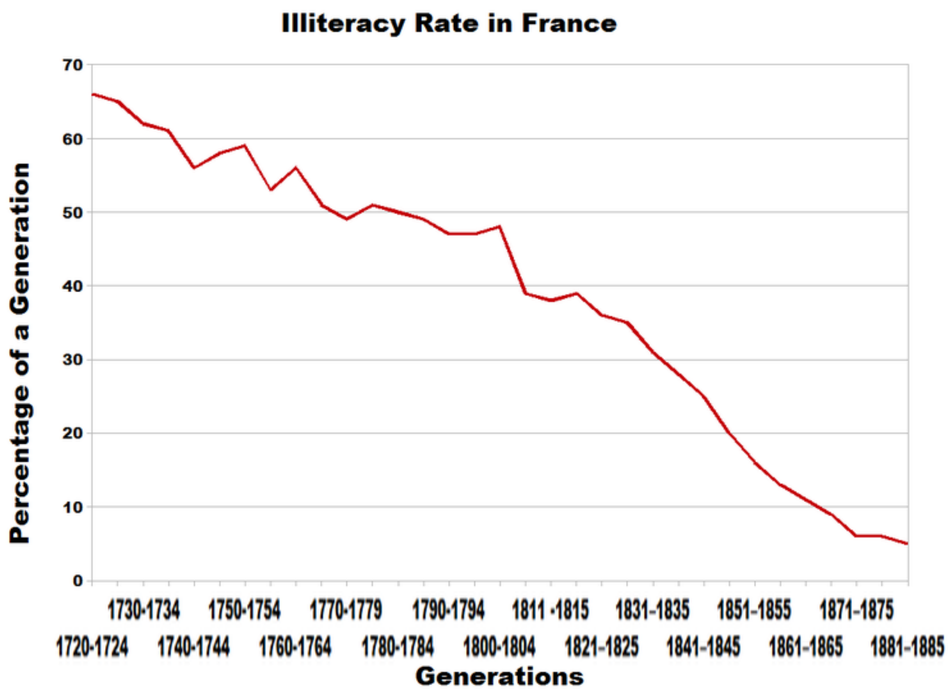

Fig. 12-44. Illiteracy rate in France as a function of 5-year long generations. (IlliteracyFrance.png)

such as physicians, engineers, teachers and lawyers, and those selected to become members of the ruling elite, like government bureaucrats and military officers, received a college education. By the end of the 19th century some universities became research institutions where professors, in addition to teaching, also engaged in scientific research.

LENGTHENED LIFE EXPECTANCY. An important outcome of the scientific and industrial revolutions—one attributable to improvements in nutrition, public hygiene, and health care—has been the steady growth in human life expectancy. Life expectancy can be calculated statistically as the probability of survival from birth onward, or from any chosen age during adulthood as a measure of increased longevity. Because birth, infancy and childhood were the most vulnerable periods in the past, it has been estimated that life expectancy in hunter-gatherer societies from birth was 33 years; however, among those who have reached the age of 15 life expectancy was as high as 54 years (Kaplan et al., 2000). Life expectancy, so calculated, has not improved until modern times. During the 17th century, more than two-thirds of children in England died before the age of four, and male life expectancy was as low as 35 years (Buer, 1926). But the percentage of children who died in London before the age of five decreased from 74.4 percent in 1730-1749 to 31.8 percent by 1810-1829, and life expectancy increased in Britain to 48 years by the end of the 19th century. This increase was mainly attributable to a reduction of early-age mortality because life expectancy calculated from the age of 20 (longevity) did not begin to increase appreciably until the turn of the century (Fig. 12-45). Increase in life expectancy was a progressive trend that accelerated during the 20th century. During the latter period mortality rate among children under 5 years of age was reduced in England to 8 per 1000 live births (World Bank, 2013) and male life expectancy in England increased regionally between 74 and 83 per cent (UK Office of National Statistics, 2013). The increased longevity was due to improved childcare and living conditions, as reflected in the progressive increase in the height of British males within one hundred years (Fig. 12-

46). It is interesting in this context that statistical studies indicate a small but significant positive correlation between height and IQ measures (Wilson et al., 1986; Sundet et al., 2005; Silventoinen et al., 2006) and neocortical gray matter volume (Taki et al. 2012).

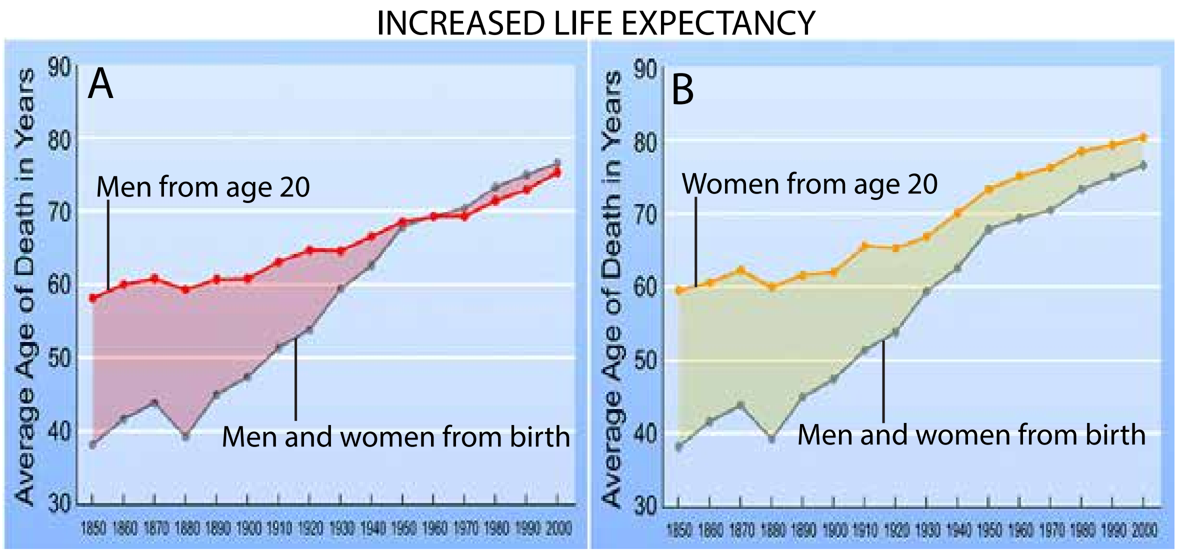

Fig. 12-45. Growth in life expectancy between 1850 and 2000 in men (**A**) and women (**B**), calculated from birth and from age 20. (MappingHistory.uoregon.edu)

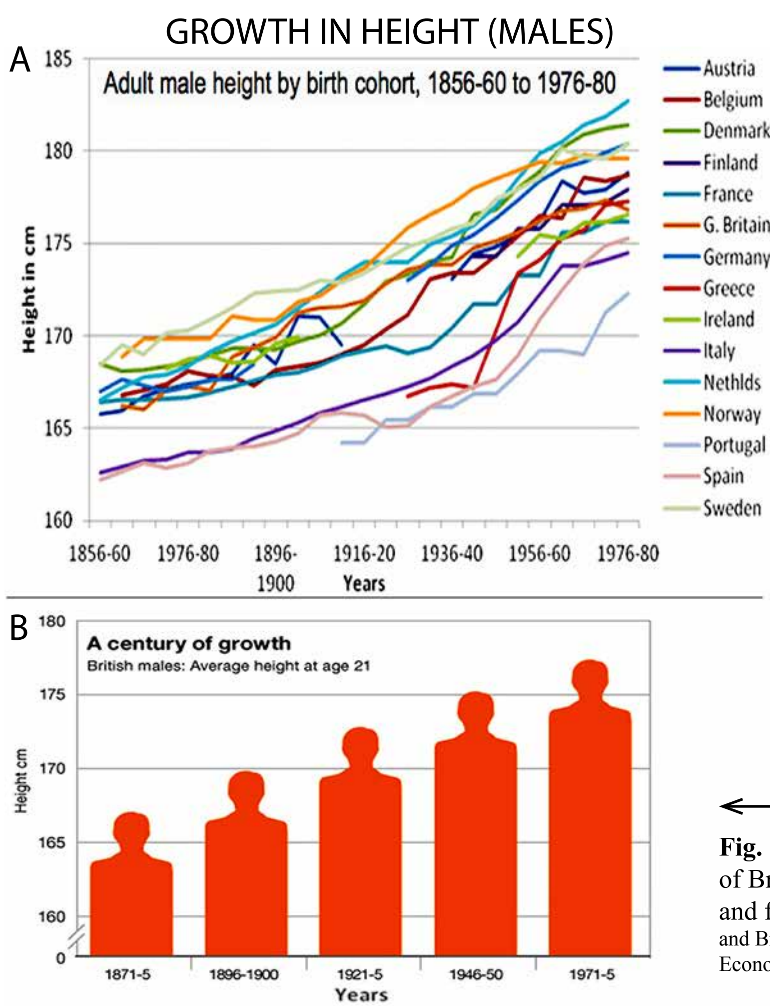

Fig. 12-46. Increase in the average height of British males from 1861 to 1915 (**A**), and from 1871 to 1971 (**B**). (**A**. From Hatton and Bray, 2010; **B**. From Hattonet al.,, 2013 Oxford Economic Papers)

CASUALTIES OF THE MODERN AGE. Science and technology are sources of economic and military power, and those with an edge over others—whether individuals, social groups or nations—can turn that to their own advantage. The rich can take advantage of the poor, the shrewd can befuddle the gullible, and those with more powerful weapons can subdue those lacking them. As we noted earlier, the Industrial Revolution created a city proletariat that lived under dire conditions that continued for several generations through much of the 19th century. Poor men and women were compelled to toil for long hours in unsafe factories and live in crowded and unsanitary tenements. To supplement their meager wages, poor families had to send their children to work in factories and mines instead of sending them to school. The settlers in the colonies destroyed the cultures of the people they subdued and decimated them. And to have enough hands to work the land, the settlers relied greatly on people captured in Africa to become slaves. The need for cheap raw materials and the growing market for goods caused fierce competition between industrialized nations. That competition led to imperialism, and that led to the devastating First World war.

12.4. Advances in Science and Technology, and the Regression to Savagery during the First Half of the 20th Century.

12.4.1. Advances in the Physical Sciences: New Concepts of Matter, Energy and the Universe. It is a historical paradox that the irrational political developments that led to the two World Wars was also the period characterized by great advances in science and technology. These enterprises were based on the fullest exercise of fact-finding and logical reasoning. It was during the second half of the 20th century that new insights were gained about the fundamental properties of matter and energy, of the nature of the universe, as well as the nature and properties of living organisms.

NEW CONCEPTS OF MATTER AND ENERGY. At the turn of the century, the discoveries of radioactivity by Henri Becquerel, of several radioactive elements by Marie and Pierre Curie, and of the electron by Joseph John Thomson led to the realization that, contrary to earlier views, atoms are divisible substances composed of subatomic particles (Mason, 1962; Foot, 2004). Ernest Rutherford studied the properties of the electric discharge that pass from the negative plate (the cathode) to the positive plate (the anode). These negative cathode rays are deflected in an electromagnetic field and are equal in electric strength to the positively charged hydrogen ions that travel in the opposite direction in the cathode ray tube. The mass of the negative particles, later named electrons, was estimated to be about 1/2000th of the mass of the positively charged hydrogen ions, which later became known as protons. Based on this evidence, Rutherford and others proposed that atoms consist of a positively charged nucleus of protons and negatively charged electrons. It also became established by that time that in addition to stable atoms there are unstable isotopes that decay in time and emit one of three types of radiation: alpha (protons), beta (electrons) and gamma (high-energy electromagnetic waves). In Niels Bohr's 1913 planetary model of atoms, electrons were assumed to be rotating in fixed shells around the nucleus and when they jumped from one orbit to another they emitted or absorbed photons (Fig. 12-47). Then physicists discovered that the nucleus was a structure composed not only of protons but also of other subatomic particles. In 1932, James Chadwick discovered a particle much like the proton but without a charge, the neutron, and Carl David Anderson discovered

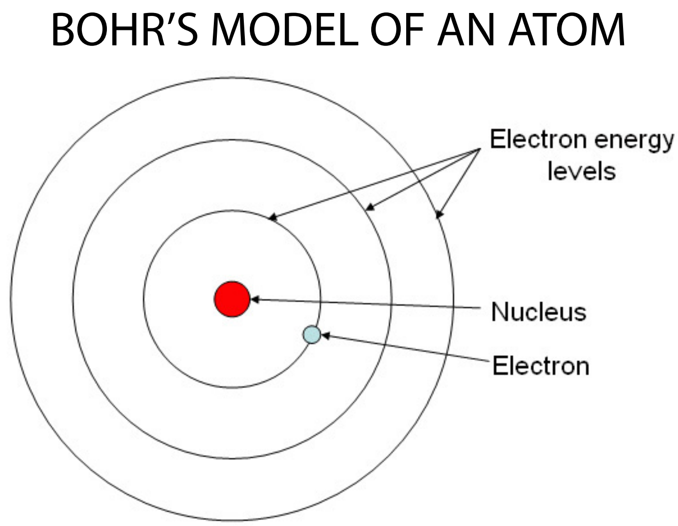

Fig. 12-47. Bohr's model of an atom with a positively charged nucleus and orbiting electron changing shells by absorbing or emitting a quantum of light. (Google)

a particle much like the electron but with a positive charge, the positron. A few years later the muon was discovered with about 200 times the mass of an electron. In the modified model of the atom, the nucleus was conceptualized as composed of protons and neutrons, most of them in a stable configuration but some (their isotopes) unstable. In the three forms of hydrogen, for instance, two are stable but the third, tritium with one proton and two neutrons, is unstable and emits beta particles.

QUANTUM PHYSICS. Max Planck postulated in 1900 that electromagnetic radiation consists of fixed packets, or quanta, of energy. This led to Albert Einstein's subsequent proposition that light, as photons, has both wave and particle properties and, more generally, that matter and energy are convertible physical entities. According to Einstein's simple equation, when matter is transformed into energy the released force is the product of the mass and velocity of light squared ($E=mc^2$; where E is energy, m the transformed mass, and c the velocity of light). Newton's classical physics, which adequately accounts for the matter/energy relationship of large bodies, has been supplemented by quantum mechanics, as formulated by Werner Heisenberg, Max Born, Erwin Schrödinger and others, to account for the properties and behavior of atoms and subatomic particles. Electrons, for instance, are no longer conceptualized as particles at a particular location at a given time but as oscillating three-dimensional "clouds" that spin, change their shape and inclination, and have other unusual properties that do not exist in the macroscopic world. In 1938, Otto Hahn and Fritz Strassmann succeeded in splitting atoms by bombardment with neutrons and found that the lost mass is converted into energy in the form of atomic particles and high-energy radiation, particularly neutrons and gamma rays. This suggested that it should be possible to use neutrons released by radioactive materials to split more atoms and produce a chain reaction. In 1941, Glenn Seaborg discovered a process to create a heavy element, plutonium, which could easily be split by neutrons to release more neutrons. The first chain reaction was achieved by Enrico Fermi in 1942, and the immense power of nuclear fission was demonstrated when two atomic bombs were exploded over Hiroshima and Nagasaki in 1945.

THE MESSIER 81 GALAXY

Fig. 12-48. Spiral galaxy, Messier 81, in the constellation Ursa Major. (Nationalgeographic.com)

NEW VIEW OF THE UNIVERSE. As we noted earlier, in the 19th century William Herschel identified the Milky Way as a galaxy and inferred that the sun is one of its stars. In 1918, Harlow Shapley estimated that the diameter of the Milky Way is about 100,000 light years and that the sun is about 50,000 light years from its center. Later it was established that the Milky Way contains about 1 billion stars, that it rotates at a high speed but it may take 200 million years for it to complete a single revolution (Roberts, 1972). One of the closest galaxies, Andromeda was estimated to be 2 million light years from earth, and Messier 81 (Fig. 12-48) about 12 million light years away. By 1936, Edwin Hubble was able to explore the universe to a distance of 500 million light years and estimated that within that horizon there are 100 million galaxies. Subsequent estimates extended the size of the Milky Way (an average galaxy) to 1 million light years. Newton's gravitational theory that the universe is stable and finite in size was challenged in the early 20th century as astronomers found shifts in the spectral lines from different stars and galaxies toward longer or shorter wavelengths (the Doppler effect). William Huggins inferred from the red shift in the spectrum from Syrius that it was receding from the solar system, and Vesto Slipher found the same in the spectra of several galaxies. This gave rise to the new concept of an expanding rather than a stable universe.

12.4.2. Advances in Technology: Modern Automobiles, Airplanes and Synthetic Materials. The landscape of industrial cities and living conditions changed during the first half of the twentieth century due to rapid technological advances. Among these were the mass production of more reliable and cheaper automobiles; the use of faster trains, particularly those pulled by electric or diesel engines; the increased production of such labor-saving devices as refrigerators, washing machines and vacuum cleaners; and the proliferation of such conveniences as telephones, radios, grammophones, and cameras. These technical advances were facilitated by the invention and increasing use of synthetic materials (Kranzberg and Pursell, 1967; McNeil, 1990). Much of the countryside throughout the Western world became electrified, and the expanding cities began to build high-rise buildings with elevators and central heating.

ADVANCES IN TRAVEL AND COMMUNICATION. Public transportation was increasingly supplemented after World War I by private automobiles. The Ford Motor Company, which was established after the turn of the century, sold 15 million Model T cars in the United States by 1927. The proliferation of automobiles required resurfacing dirt roads and building of new ones. Demand greatly increased for gasoline, rubber, gas stations, and motels. As soon as the telephone became widely adopted, serious problems arose that had to be solved. One of these was the distortion of sound by the attenuation of the transmitted electric signals over long distances; another was the difficulty of manually switching the increasing number of incoming and outgoing calls at central stations; still another was how to transmit the many calls over limited trunk lines. In the 1910s, electron tubes were put to use as amplifiers and repeaters, greatly improving the quality of signal transmission over long distances. In the 1920s, an innovation switched calls at local exchanges automatically by activating relays with dialing signals. At the same time multiplexing was developed, and one line was used for the concurrent transmission of several calls.

After World War I, "wireless telegraphy" came of age as the invention of amplifying vacuum tubes revolutionized radio transmission and reception. Wireless communication over long distances is based on the scientific discovery that electromagnetic radiation spreads in straight line from its source at the speed of light (about 300,000 kilometers per second). In 1901, Guglielmo Marconi used a spark generator, an antenna and a sensitive radiation detector to transmit a Morse code signal by radio wave across the Atlantic, from Newfoundland to England. This was the beginning of the development of wireless communication. While spark generators produce discontinuous waves that are suitable for telegraphy, it was the production of oscillating radio signals by electron tubes that made possible the transmission of transduced sound signals. The first transmission of the human voice across the Atlantic took place in 1915, and commercial radio technology rapidly developed after World War I. During the 1920s and 1930s, radio broadcasting became a widespread medium for the dissemination of news, entertainment, education and propaganda. Regular radio broadcasting was introduced in many cities by the early 1930s. Frequency-modulated (FM) transmission, which reduces static interference, came into use before World War II. Although air travel had not yet become common during the first half of the 20th century, considerable advances were made during this period in developing reliable airplanes.

ADVANCES IN CHEMICAL ENGINEERING. Physical and organic chemistry as a basis of industrial technology began in the 19th century but its rapid development took place in the 20th century

(Morrison, 1937; Perry and Green, 1984). The chemical industry came to produce two kinds of man-made materials in large quantities: (i) those made by reprocessing natural substances, and (ii) those synthetically produced from simple chemical precursors. The inorganic chemicals that came to be produced in large quantities to meet diverse industrial needs included sulfuric, phosphoric and nitric acids; ammonia, chlorine and sodium hydroxide; and gaseous oxygen and nitrogen. Raw materials of organic origin, such as petroleum and natural gas, were used to produce such chemicals as benzene, phenol and ethylene (aromatic hydrocarbons) and methane, ethane and propane (aliphatic hydrocarbons). The latter substances were converted into a great variety of consumer products by various chemical processes. The end products of aromatic hydrocarbons include gasoline, solvents, dyes, oils, plastics, styrene, and nylon; and the end products of aliphatic hydrocarbons include weed killers and a variety of synthetic materials.

THE PRODUCTION OF SYNTHETIC MATERIALS. The first commercially successful plastic was bakelite, produced by Leo Baekaland from phenol and formaldehyde in 1910. A few years later, polyvinyl was introduced, followed in the 1920s by acrylates and polystyrene. The industrial and consumer uses of the relatively cheap and mass produced plastics have become endless. Among others, they are used in the construction industry for insulating wires and cables, as building panels, protective coatings and roofing, floor coverings, water ducts and drainage pipes, fuel tanks and containers for corrosive materials. Examples of its domestic uses are kitchen utensils and containers, tabletops, waterproof wrappings, and toys. Related to plastics are resins, the basic ingredients of paints, varnishes and lacquers for the preservation and decoration of surfaces. Another man-made material that has found widespread use in modern life is synthetic rubber. Synthetic rubbers of a great variety (like acrylonitrile, polyisoprene and silicone rubber) are in many applications replacing natural rubber.

The production of man-made fibers and the mechanization of garment manufacture illustrate how research in chemistry has contributed to the development of an immense industry and a change in lifestyle. Clothing in the past was made of natural fibers like wool, flax, hemp, cotton and silk. The fibers were spun into yarns, the yarn was woven into blankets or into lengths of fabric that were cut and tailored into garments. Most of these steps were carried out a at home or by tailors or seamstresses in small shops. After the invention of spinning and weaving machines the production of textiles became an industrial enterprise. Large apparel factories began to emerge, particularly in the United States, at the end of the 19th century. By the early 20th century, cellulose extracted from wood was converted into such man-made fibers as rayon and acetate. Continuing research led to the discovery that simple carbon compounds with strong polar chemical bonds (monomers) can be converted into long filamentous compounds (polymers). The first of these, developed by the Du Pont Company has been marketed as nylon. Nylon has many favorable properties, among them unusual strength, ability to recover from deformation, and high abrasion resistance. It is widely used not only for knit and woven fabrics but also for making carpets, ropes, nets and many other consumer and industrial goods. Nylon was followed by a large number of synthetic polymers suitable for the production of textile fibers, such as polyesters, polyvinyl and polyurethanes. These fibers differ in such properties as texture, moisture absorption, heat conduction and wrinkle resistance, and are selectively used where one or the other of these properties offer special advantages. Blending these synthetic fibers with natural fibers has become common practice in the textile industry. Another development was the mechanization of the tailoring process. The industry employs textile engineers, designers, laborers and marketing specialists to produce comfortable and fashionable garments in large quantities at a relatively low cost. Machines that automatically follow the design patterns cut large batches of fabric and sewing machines perform such tasks semi-automatically as buttonholing, sewing buttons, stitching, pleating and the like.

12.4.3. Advances in the Life Sciences during the Early 20th Century. Mendel's pioneering work remained unknown to most scientists until the beginning of the 20th century (Allen, 1975). Wilhelm Johannsen coined the term "gene" in 1909 as the putative material unit of hereditary transmission, and distinguished between "phenotype" and "genotype." In this new view, organisms do not pass on to their progeny the traits themselves but a genetic disposition (genotype) that may or may not become overtly expressed (phenotype) in the next generation depending whether that gene is dominant or recessive. William Bateson called the two homologous forms of each gene "alleles." Cells with identical alleles for a particular genotype came to be called "homozygotes," and cells with different alleles "heterozygotes." Later it was established that many phenotypic traits are the product of several rather than just one gene. Modern genetics has had the effect of the strengthening Darwin's theory of evolution and is a cornerstone of cellular and molecular biology.

Advances in Genetics and Embryology. The botanist, Hugo de Vries found at the turn of the century that both in the wild and in his garden new varieties of primroses (*Oenothera lamarckiana*) appeared spontaneously. He attributed these random changes in genetic inheritance to "mutations," and proposed that new species are formed not by slow and subtle modifications, as Darwin and others have thought, but by sudden and drastic transformations. This idea was supported by the experimental studies of Hermann Muller in the 1920s, who used x-ray irradiation and other means to induce genetic changes in the fruitfly *Drosophila melongaster*. He demonstrated that the various mutations thus produced were passed on to the next generation. Beginning with the publication of Ronald Fisher's *The Genetical Theory of Natural Selection* in 1930, and followed by Theodosius Dobzhansky's *Genetics and the Origin of Species* in 1937, evolutionary theory became closely associated with genetics.

MOLECULAR GENETICS. The integration of Mendelian genetics, cell theory, and molecular biology began in the first decade of the 20th century with the work of Thomas Hunt Morgan. Morgan, who studied trait transmission in *Drosophila*, reasoned that if the Mendelian factors are material units strung along the chromosomes, than it should be possible to locate their position and construct a chromosomal map of the hypothetical genes. He chose several pairs of traits that are linked in inheritance, assuming that they were on the same chromosomes, and inferred whether the genes were closer together or farther apart along that chain on the basis of the frequency of "crossing over" when the chromosome broke. However, while Morgan and his students succeeded in producing chromosomal maps, that did not clarify either the molecular identity or mode of action of genes. Archibald Garrod's work, suggested in his *Inborn Errors of Metabolism*, published in 1909, that enzymes were involved in the transmission of genetic traits. He studied the family history of several metabolic abnormalities in his patients, such as phenylketonuria, and found that these ailments are inherited as Mendelian traits. George

Beadle and Edward Tatum began the experimental investigation of the link between genes and enzymes in the slime mold, *Neurospora* in the 1930s. They irradiated normal slime mold spores to produce mutants and found that those with specific nutritional disorders had abnormalities in the biochemical pathway of that nutrient. Because an enzyme (a protein with catalytic properties) controls each step in a biochemical pathway, Beadle and Tatum proposed the "one gene-one enzyme" hypothesis.

EXPERIMENTAL EMBRYOLOGY. The microscopic analysis of embryonic development began in the 1850s. That work established that embryonic growth begins with the cellular division (cleavage) of the fertilized ovum and the formation of a clump of cells known as the blastomere. Wilhelm Roux, as reported in his *Über die Entwicklungsmechanik der Organismen* (1890), found that when he destroyed one cell in the two-cell stage of the frog blastomere with a hot needle, the undamaged cell continued to develop for a while and formed half an embryo. This gave rise to the mechanistic (mosaic) theory of embryonic development. Hans Driesch carried out essentially the same experiment but used a different species, the sea urchin, to separate the two-cell blastomere. In contrast to Roux, Driesch found that each cell formed a miniature but full embryo. Driesch used his results to argue in his lectures on *The Science and Philosophy of Organisms* (1908) for a teleological (holistic) theory of embryonic development. Later research has shown species differences and stage differences in the potency of germ cells, ranging from: totipotemcy, a proliferating cell able to form a full embryo; to pluripotency, the ability to form a multi-tissue component of the embryo; to oligopotency, the ability limited to form a particular type of tissue; and unipotency, the ability restricted to produce a single cell type.

Embryonic research was advanced by Hans Spemann's studies of the development of the eye in the early 20th century. The vertebrate eye is formed of two germinal components: the optic cup, which is the evagination of the forebrain and becomes the retina; and the overlying ectoderm which becomes the lens. Spemann found that removal of the optic cup region in the frog embryo prevented formation of the lens and, conversely, the transplantation of the optic cup tissue to another area of the body, led there to the formation of a lens. Spemann concluded from these findings that the optic cup has the potential to trigger lens differentiation from any ectodermal tissue and is therefore the "inducer" of lens development under normal conditions. In a subsequent experiment on slalmander embryos, Spemann and Ilse Mangold investigated the effects of transplantation of a piece of the blastopore lip from a donor embryo into another region of a host embryo. The blastopore lip forms after the spheroid blastula changes into the gastrula by invagination, and it subsequently becomes the neural tube, the germinal source of the central nervous system. Spemann and Mangold used two species of salamanders (one pigmented, the other albino) and found that a piece taken from the blastopore lip of one and transplanted into the other led first to the development of an extra notochord, followed by the development of a second nervous system and to a two-headed salamander (Fig. 12-49). Spemann called the blastopore region the "organizer" of embryonic development. However, while the Spemann-Mangold experiment established the importance of cell-to-cell interaction in morphogenesis, their broad concept of an organizer has been abandoned recently and replaced by ongoing investigations of the complex role of a cascade of signaling molecules in the pattering of embryonic development.

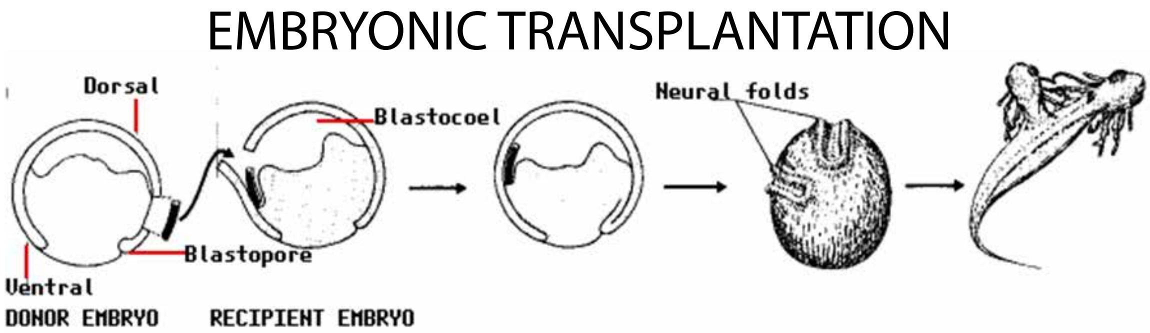

Fig. 12-49. The Spemann-Mangold experiment of transplantation of the blastopore lip of the embryo that produces a two-headed salamander. (Users.rcn.com)

Advances in Molecular Biology. The great accomplishments of biochemists of the early 20th century, among them Albert Szentgyörgyi and Hans Adolf Krebs, was the elucidation of the complex series of reactions (known as the Krebs cycle) that all aerobic organisms use as a source of metabolic energy (Fig. 12-50). In that catabolic cycle (referred to as aerobic respiration, a form of slow organic combustion) energy-rich glucose is transformed through enzymatic action, and with the aid of energy-transfer molecules (ATP/ADP, NAD/NDH), into donor molecules that provide metabolic energy to drive a variety of energy-demanding organic processes, such as the conduction of nerve signals. That catabolic cycle ends with carbon dioxide as a waste product, and the anabolic (regenerative) cycle resumes by absorbing water as a source of oxygen.

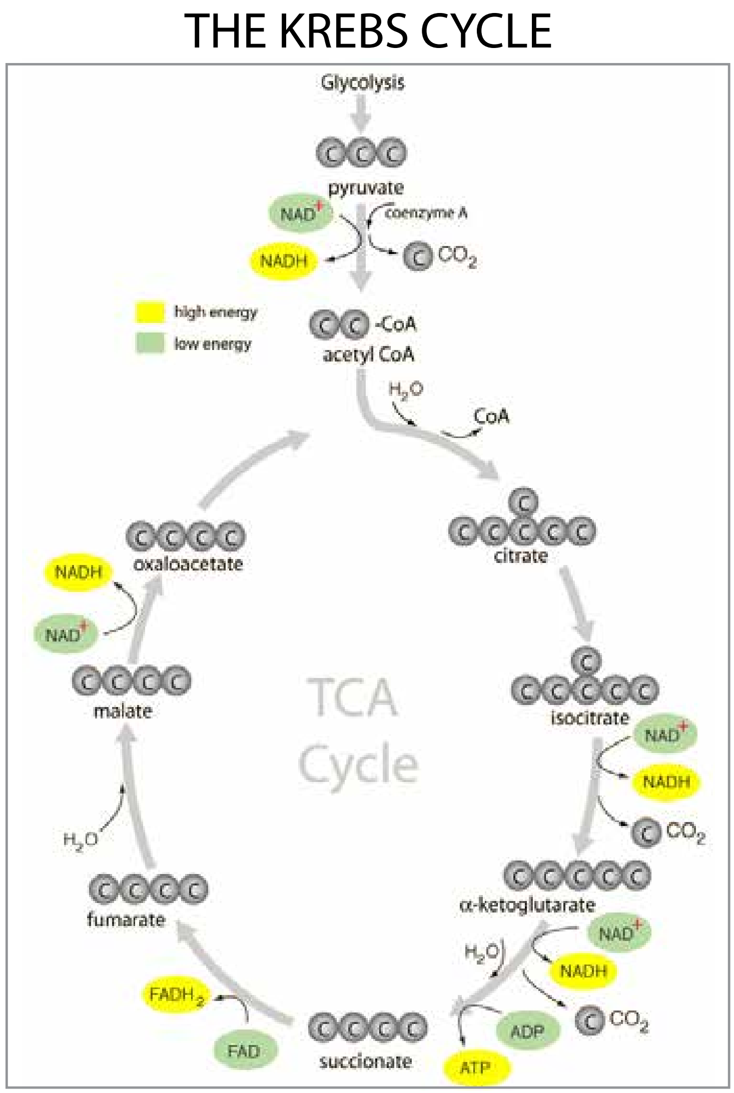

Fig. 12-50. The complex Krebs cycle, which uses carbohydrates to produce aerobic energy, and regenerates by absorbing water as an oxygen donor. (Google)

12.4.4. The Return to Savagery: The First World War, 1914-1918. While scientists, engineers and technicians—as creative and productive rational individuals—were making great contributions to the improvement of standard of living, the rulers of Europe—following affective impulse and ingrained tradition—were engaged in the irrational pursuit of making preparations to go to war. Instead of using rational means—trade negotiations, diplomacy, and the necessary compromises—to remedy their grievances and resolve conflicts of interest, they continued to use the atavistic irrational methods to resolve conflicts through destruction and killing. Aided by the great technological advances of the new age, each side was determined to achieve its political ends by using the most powerful weapons they could get in order to defeat their enemies, no matter what that cost to themselves in waste of resources, personal suffering and loss of lives. The outcome of that irrational policy became one of the greatest disasters that befell humankind in modern times.

THE ANTECEDENTS OF THE FIRST WORLD WAR. The unification of Germany altered the geopolitical power balance of Europe and led to the formation of new military alliances (Taylor, 1954; Henig, 2002). The French, defeated by the Prussians in 1871 and losing Alsace-Lorraine began to ally themselves with the British against the Germans. An example of that was the building of the Suez Canal. Initially a French undertaking, the project turned into a joint British-French enterprise in 1875, beginning their cooperation in creating an easy route to their colonies. That alliance was formalized in 1904 as the Entente Cordiale, which ended almost a thousand years of intermittent warfare between France and England. The French also formed an alliance with the Russians in 1894 against militant Germany, and the British did the same in 1904—what came to be known as the Triple Entente. Germany, in turn, formed a military alliance with Austria-Hungary in 1879, and the two of them formed an alliance with Italy in 1882, which became known as the Central Powers (Fig. 12-51). An acute problem that these two alliances

EUROPEAN ALLIANCES, 1914

Fig. 12-51. The Central Powers and the Triple Entente at the outbreak of World War I. (MapEuropeAlliances1914-en.svg)

faced after the turn of the century was the political disorder in the Balkans, recently freed from Turkish rule. Particularly restless was Austria-Hungary, a multiethnic empire in Eastern Europe that ruled over Slavic peoples in the north (Czechs, Slovaks, Poles and Ukranians), in the south (Slovenians, Serbs, Croatians, and Bosnians), and Romanians in the east.

By the end of the 19th century and the beginning of the 20th century, Britain and France were the most prosperous countries of Europe, due partly to their control of overseas colonies, their access to cheap sources of raw materials, and their markets for manufactured goods. Industrialized Germany felt disadvantaged on the world stage. To rectify that, Germany began to scramble for colonies and challenged the British for naval supremacy. The socialists of Germany, who made large gains in the 1912 election, advocated peace but the government of Germany was still dominated by the nobles of Prussia (the Junkers) who used nationalistic propaganda to prepare the nation for war. There were influential people in France who sought revenge after their earlier defeat by the Prussians and while England had no interest in going to war, it proceeded to strengthen its navy. The Austro-Hungarians were also preparing to go to war against Serbia, to prevent Slav resurgence in the Balkans supported by the Russians. Threatened by Germany and Austria-Hungary, Imperial Russia embarked on a modernization of its military towards the end of 1912, and the German and Austrian alliance decided to go to war with Russia before it became more powerful.

THE OUTBREAK OF THE FIRST WORLD WAR. The murder of the Austrian Archduke and his wife by an assassin acting on his own on June 28 1914, was not the *cause* that led to the First World War but served as an *excuse* for the alliance of the Central Powers to solve their escalating conflict with the Triple Entente Cordiale by military means. On July 23, 1914, the Austro-Hungarian government delivered an ultimatum to the government of Serbia, and on the next day (without waiting for a Serbian response) Germany declared its support of that ultimatum. World War I started as a local conflict in the Balkans that did not have to involve any of the other outside powers. But within two weeks the leading nations of Europe were in a state of war. On July 25, the Serbs mobilized their army, and on July 28 Austria-Hungary declared war on Serbia. The mobilization of Russia was ordered on July 30th. Germany mobilized on August 1, declaring war on Russia, and on August 3, declaring war on France. The next day the German army crossed into neutral Belgium and Luxembourg in preparation for the invasion of France. On August 4, Britain declared war on Germany, and on August 6 Austria-Hungary declared war on Russia. Then the war zone was extended from Europe to the rest of the world as Turkey and Japan joined the Central Powers, and members of the British Commonwealth, Australia, New Zeeland and Canada, and later the United States of America, joined the Triple Entente.

THE PROTRACTED WAR. The military leaders of Germany anticipated that having an ingenious military strategy of invading France (Fig. 12-52) and superior firepower, the war would end in 1914 before Christmas. Instead of attacking France at their shared border, German troops invaded Belgium and Luxembourg, and captured the city of Liège by August 15. By early September German forces penetrated deep into northeastern France, and were about 35 miles from Paris. However, a counterattack by French and British troops halted the advance and forced the Germans to retreat. Early in August, Russian troops invaded East Prussia and Poland but German and Austro-Hungarian forces stopped them. One of the problems that the

THE SCHLIEFFEN PLAN

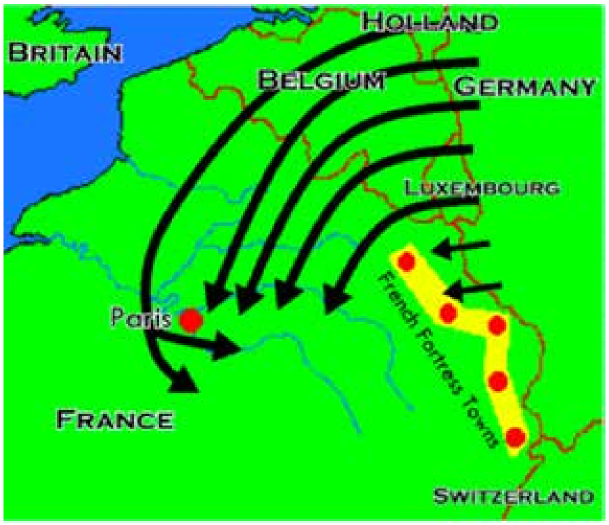

Fig. 12-52. The German military plan to occupy France. (Google: Schlieffen plan)

FIGHTING IN WORLD WAR I

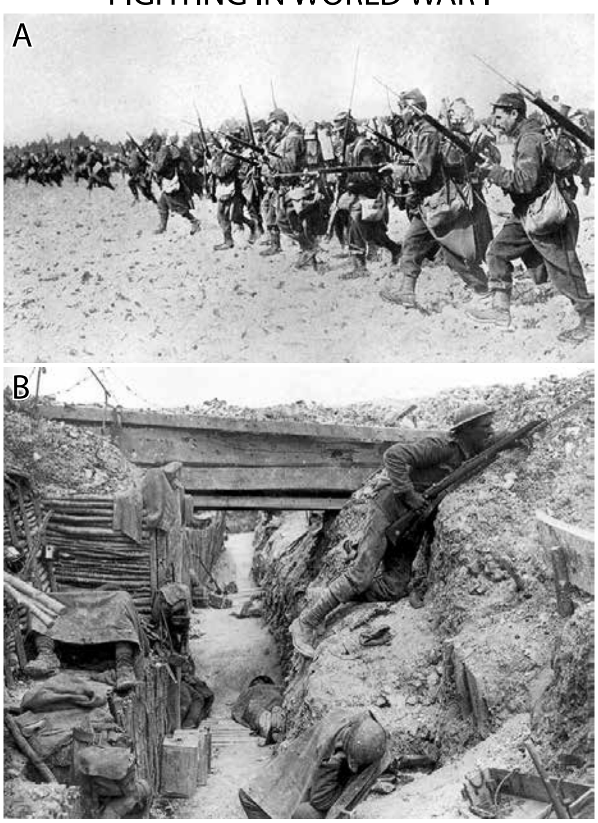

Fig. 12-53. A. Bayonet charge by French soldiers against a German line. **B.** German defensive trench line. (**A**. FrenchBayonetCharge.jpg. **B**. Google: Trench warfare)

Germans faced was that they had to fight on two fronts, the west and east. The same was true of the Austro-Hungarians who had to fight the Serbs in the south and the Russians in the north. Neither side being able to crush the other, the combatants began digging trenches along the entire war zone, defended by barbed wire, machine guns and artillery fire (Fig. 12-53B). There were repeated attempts on both sides to break through these defense lines by sacrificing an immense number of soldiers (Fig. 12-53A); however, none of these were successful.

Germany was not prepared for a long war. Its economy was dependent on imports of raw materials and food. But the war zones and the British blockade of German ports cut these off. Food rationing began in 1915 and increasingly cheap *ersatz* materials came to replace quality goods. Instead of suing for armistice, the Germans introduced poison gas in the spring of 1915 in an attempt to change the stalemate, which was soon adopted by the Allies. Initially chlorine was released in the war zone, followed by firing shells filled with phosgene and mustard gas into the trenches. Chemical warfare produced many casualties but did not change the stalemate. The same applied to the increased use of warplanes for strafing and bombing; the introduction of tanks by the Allies; and the intensification of submarine activity at sea by the Germans. The fierce Battle of Verdun during 1916 ended with over 750,000 French and German casualties but no substantial gain for either side. After the Germans sank several American merchant ships, the United States declared war on Germany in 1917. The Russians mounted several offensives during the war but failed to break through the German defense lines. That failure and deteriorating economic conditions at home led to the Russian Revolution of 1917, which ended the monarchy. After the Soviets replaced the provisional government, an armistice was reached with Germany in December 1917. That freed the German troops tied down in the east and led to a major German offensive in July 1918, the second Battle of the Marne. However, the attack was repulsed. Deteriorating conditions on the battlefields, the economy in ruins, and unrest and uprisings at home forced the German military to capitulate and sign an armistice treaty with the Allies in November 1918. The same happened to Austria-Hungary. The conglomerate Empire that ruled over different nationalities—Czechs, Slovaks, Poles, Romanians, Croats and Bosnians—began to fall apart in 1918 as many of the nationals declared their independence. By the end of 1918 the Austro-Hungarian monarchy collapsed.

THE PEACE TREATIES. In January 1918, the President of the United States, Woodrow Wilson, proposed a list of points how to establish "peace without victory" in the world (Henig, 1995). It included ethnicity as the guiding principle in the redrawing of national boundaries and established the League of Nations to arbitrate international disputes. When towards the end of 1919 the German delegation came to sign the peace treaty in Versailles, some of them believed that Woodrow Wilson's plan would serve as a guideline. Instead, the treaty that the Germans were forced to sign included a "war guilt clause" to justify their severe punishment. Germany had to pay severe reparations and lost Alsace-Lorraine to France; West Prussia and Upper Silesia were transferred to Poland; and it lost all of its colonies. The redrawing of the boundaries in this and subsequent treaties led to the formation of new nations in the east and the truncation of others. For instance, Czechoslovakia was formed with a multiethnic population of Czechs, Slovaks, Germans, Hungarians, Ukrainians and Poles, while Hungary lost a large proportion of its ethnic (Magyar) population not only to Czechoslovakia but also to Romania and the new kingdom that later became Yugoslavia. The vengeance used in the treatment of Germany and in changing the national boundaries of Eastern Europe, and the threat posed by the communist order in Russia created a geopolitical conundrum that was worse than what existed before the war. The Hohenzollern, Hapsburg and Romanov dynasties were abolished forever but instead of forming democratic republics most of the adversely affected countries ultimately became ultra-nationalistic dictatorships seeking revenge.

12.4.5. The Social and Political Conflicts of the Interwar Period: 1919-1939. The First World War devastated both the vanquished and the victors. Of the 60 million soldiers engaged in the war between 1914 and 1918 on the two sides, 9 million died and 21 million were permanently disabled or wounded. Instead of learning a lesson about the irrationality of social conflict and warfare and the desirability of a fair national and international order that could lead to an enduring peace, the widespread frustration produced by the economic hardships and the sense of injustices led to two decades of social upheaval throughout much of Europe that inevitably led to the Second World War (Carr, 1945).

From the Weimar Republic to the Rise of Nazi Germany. The Allies maintained the blockade of German harbors between the armistice in November 1918 and the signing of the Versailles peace treaty in June 1919. That blockade and the reparations that the Weimar Republic was forced to pay to France and Belgium led to Germany's economic collapse in 1921 and the hyperinflation of the German currency. In 1922 the Reparations Committee declared Germany in default and French and Belgian troops occupied the Ruhr region. The Germans could not defend their territory because the peace agreement outlawed them to have a large army and heavy military equipment. Inflation wiped out the savings of the German middle class, and economic collapse led to severe unemployment. Economic conditions improved by 1924, partly due to the Dawes Plan that made U.S. banks render large loans to Germany. However, in 1929 the Great Depression in the U.S. led to the withdrawal of those loans and that resulted again in economic decline and a severe unemployment. Notwithstanding the dire economic conditions, the Weimar period was characterized by an outburst of creativity in the physical and social sciences, literature and theater, representative art (Fig. 12-54A) and architecture (Fig. 12-54B). Conservatives responded to much of this experimentation, and the excesses of Weimar culture, as "decadent," contrary to traditional German values (Gay, 1968).

HITLER'S RISE TO POWER. The conviction was widespread in Germany that the war of 1914-1918 was not lost in the battlefield but that the nation was "stabbed in the back" by traitors—Socialists, Communists and Jews (Shirer, 1960; Burleigh, 2000; Evans, 2005). As an indication of the dissatisfaction with the democratic government and the social and political disorder of the early 1920s, the people opted to elect the former head of the army, Paul von Hindenburg, as the country's President in 1925. And increasingly more and more Germans lined up behind Adolf Hitler, a demagogue who repudiated the Versailles Peace Treaty, harangued against Communists and Jews, and advocated Germany's rearmament. A corporal during the First World War, Hitler started his political career as an agitator of the German Worker's Party (DAP), which later changed into the National Socialist

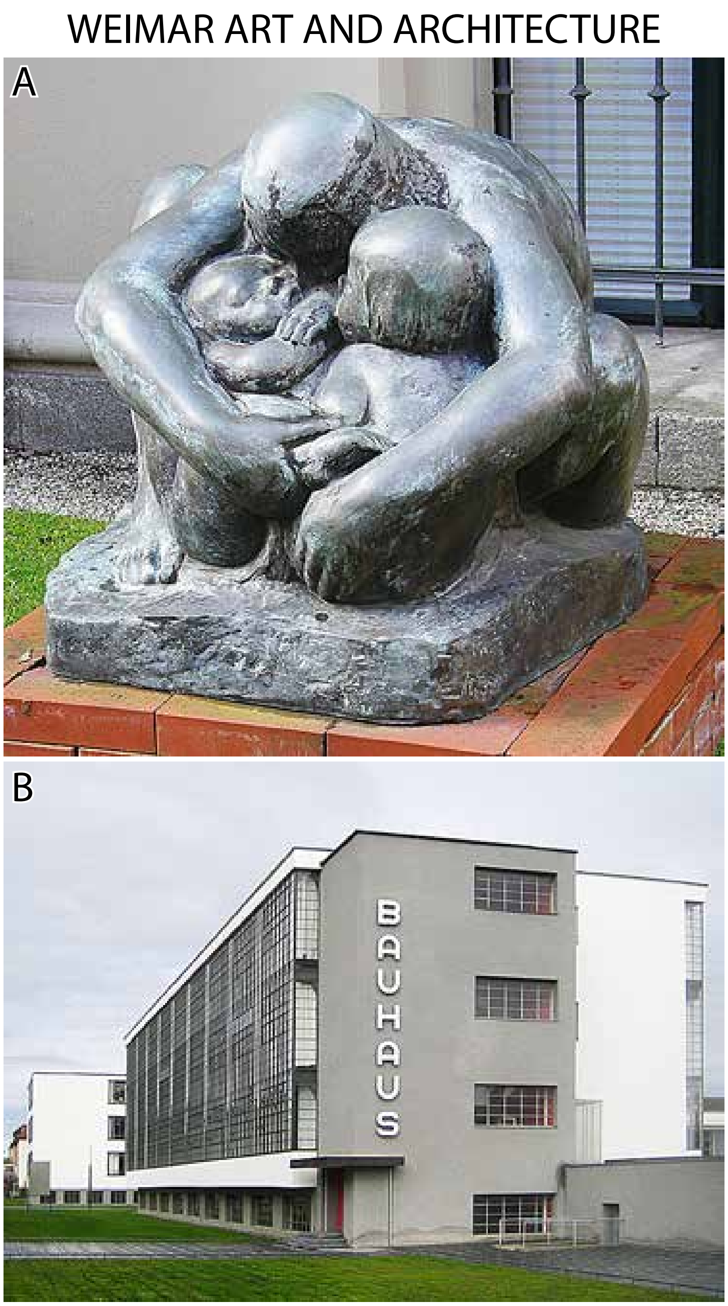

Fig. 12-54. A. Mother with twins, by Käthe Kollwitz. Portrayal of human compassion. **B.** Building by Walter Gropius. Promotion of pragmatism in architecture. (**A**. Mutter mit Zwillingen.jpg. **B**. Wikipedia:Bauhaus.jpg)

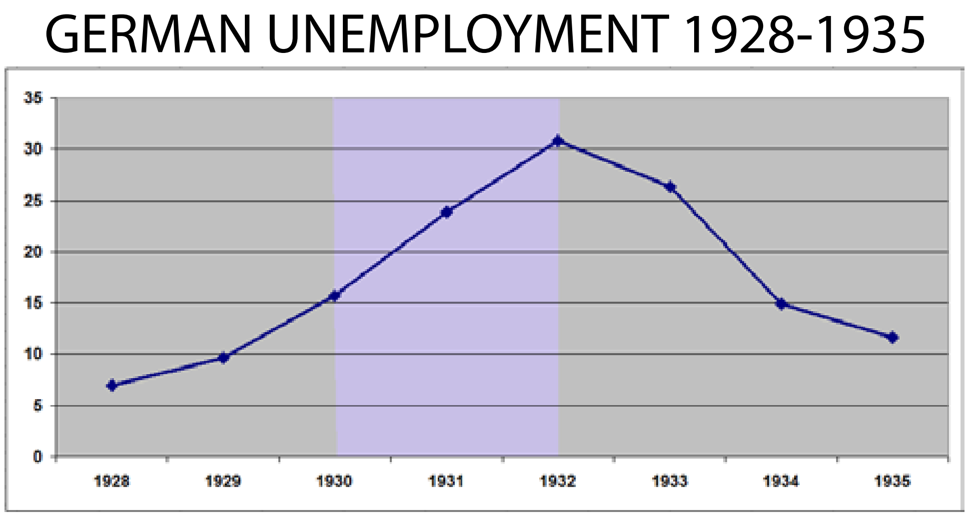

Fig. 12-55. The rise and fall of German unemployment, 1928-1935. (Arbeitslosenquote1928bis1935.png)

Workers (Nazi) Party. Hitler soon gained notoriety for his rowdy speeches in the beer halls of Munich, supported by brawlers. In 1923 Hitler organized an aborted *Putsch* to overthrow the government. He was arrested and sentenced to five years in prison, but was pardoned after serving less than one year. The Nazi's political advance was initially slow, with only 12 seats in the *Reichstag* in 1928. However, following the stock market crash in the United States in 1929, and the subsequent collapse of the German economy that led to massive unemployment (Fig. 12-55), the Nazis gained 107 seats by 1930, and 288 seats by 1933 (the largest number of seats in the Reichstag of all parties). Consequently, Hindenburg appointed Hitler as the Chancellor of Germany. Following a fire in the *Reichstag*, which was blamed on the Communists, civil liberties were suspended. After Hindenburg's death in 1934, Hitler declared himself the *Führer* (leader) of Germany. The Communists were imprisoned; the social democratic and liberal parties were banned; the trade unions were dissolved and its leaders sent into concentration camps. Hitler also had some of his adversaries in his party liquidated.

Due largely to the acceleration of rearmament, the German economy rapidly recovered and unemployment fell from six million in 1932 to one million by 1936. Germany withdrew from the League of Nations in 1933, and by 1935 the *Wehrmacht* had 600,000 troops, six times larger than permitted by the Versailles Treaty. Germany reoccupied the Rhineland in 1936, and sent troops to aid the fascist General Franco in Spain. Early in 1938, Hitler declared the *Anschluss* (unification) of Austria with Germany, and late in the same year, with the approbation of Chamberlain of Britain and Daladier of France in the Munich Agreement, annexed the German-speaking *Sudetenland* of Czechoslovakia. Under Hitler's dictatorial rule, aided by his dedicated party members, virulent party propaganda, and the strong-arm tactics of paratroopers—initially the brown-shirt *Sturmabteilung* (SA) and later the uniformed *Schutzstaffel* (SS) and of the secret service (*Gestapo*)—Germany's political and social order changed drastically. The parliamentary system was abolished, liberal books were burned, education was turned into Nazi propaganda, and laws were introduced to deprive Jews of their political and social rights. That was followed by the terrorization of Jews by breaking the shop windows of Jewish merchants (*Kristalnacht*) and the burning of synagogues (Fig. 12-56). Anti-Semitism, a monomania of Hitler and many of his cohorts, was designed to force Germany's Jews to leave the country, partly in order to confiscate their property and reward Nazis and partly to restore Germany's "Aryan" racial purity.

BERLIN SYNAGOGUE AFTER KRISTALLNACHT

Fig. 12-56. Interior of a Berlin synagogue, after its state-sponsored torching. (Kristalnacht.jpg)

PRELUDE TO THE SECOND WORLD WAR. Hitler's determination to rearm Germany was justified by his plan to occupy the Soviet Union. The *Drang nach Osten,* the push toward the Slavic East, was a motto of 19th century German imperialism, and that could now be ideologically justified by the necessity to terminate the ostensibly Jewish-led Bolshevik menace. More pragmatically, Germany's shortage of arable land and grain could be remedied by occupying the "bread basket" of the Ukraine, and by appropriating the oil fields of the Black Sea and the Caucasus and thus end the gasoline shortage of German industry. It is possible that from the outset, Hitler also planned to occupy France to gain access to the English Channel and thus be in a position to harass the British navy. (Indeed, when France was occupied in 1940, the latter regions were turned into a German military zone.) However, it is unlikely that Hitler had plans to attack England or go to war with the United States but rather to turn Eastern Europe into a system of German colonies. And because many right-wing politicians in Western Europe and the U.S. welcomed the termination of Communist rule in Russia, there was initially little Western opposition to halt German rearmament.

The Rise of Interwar Fascist States. Before the First World War there was throughout Europe a movement toward the formation of constitutional governments and political democratization. But most of them, with the exception of Britain, France, the Scandinavian countries and Czechoslovakia, became nationalistic or fascist dictatorships during the Interwar Period. Benito Mussolini initiated that movement in Italy.

INTERWAR ITALY. The independent Italian States came under foreign domination after the Renaissance, successively ruled by the conservative Spanish monarchy (from 1559 to 1713) and the Austrian monarchy (from 1713 to 1796). Following the French Revolution, Italy was ruled by Napoleon until 1814 when, blessed by the Congress of Vienna, the unification of Italy (*Risorgimento*) began, aided by such revolutionaries as Giuseppe Mazzini and Giuseppe Garibaldi. Italy became a constitutional monarchy in 1861 with an elected parliament. The liberalization of Italy continued through the early 20th century. Italy joined the First World War on the Allies side but disappointed by its treatment at the Paris Peace Conference in 1919, a Fascists movement formed under the leadership of Benito Mussolini. Initially a small party, aided by paramilitary “black shirts,” the Fascists began to attack communists and socialists and took charge of several cities. In 1922, Mussolini organized the “March on Rome” and, in order to avoid bloodshed, the king appointed him as the prime minister of an Italian coalition government in 1923. Initially collaborating with the other parties, Mussolini used strong-armed intimidation techniques and in 1926 declared himself *Il Duce*, the dictator of Italy. Over the years, to pacify the Catholic Church, Mussolini recognized it as a sovereign state (confined to the Vatican), allied Italy with Fascist Germany and militant Japan, and embarked on its aggressive expansionist policy by colonizing Libya, waging war in Ethiopia, and occupying Albania.

INTERWAR SPAIN. During the 16th and 17th centuries Spain was ruled by a branch of the Hapsburg monarchy and was the most powerful empire in Europe. Occupying or dominating several European countries, its treasury enriched by the gold and silver ferried from the New World by its large navy, Spain became immensely rich. Art and literature flourished, creating a Golden Age (*Siglo de Oro)*. However, due to the firm protectionist control of the economy by the monarchy and the landed aristocracy, and the persisting power of the ultra-conservative Church, neither the Industrial Revolution nor the Enlightenment succeeded to take a hold in Spain during the 18th century. Following the Battle of Trafalgar in 1808, when the British navy destroyed the Spanish Armada, Spain started to decline. And during the 19th century, as Spain began to lose its overseas colonies and political influence in Europe, revolutionary movements arose at home. However, Spain remained substantially an absolutist monarchy, now ruled by a new Bourbon dynasty. Not being involved in the First World War, Spain prospered for a while early in the 20th century but the economy collapsed in 1931 and a Republic was formed. But due to the persisting influence of the Church, and support received from fascist Italy and Nazi Germany, the nationalists led by Francisco Franco defeated the Republicans and instituted a dictatorial rule of a fascist (Phalange) party. Communists and socialists were executed and liberals were exiled or silenced.

INTERWAR EASTERN EUROPE. The economic Great Depression that started in the U.S. and spread to Europe led to the abandonment of parliamentary democracies throughout much of

Eastern Europe. In 1929, the Social Democratic Kingdom of Serbs, Croats and Slovenes changed into the dictatorship of Yugoslavia, when King Alexander abolished the Constitution and assumed his personal autocracy. Hungary, ruled since 1919 by Miklós Horthy as the regent with dictatorial powers, moved farther to fascism when Gyula Gömbös, a leader of the "white terror" against Communist rule in 1919, became the prime minister of Hungary in 1932. Gömbös signed treaties with Mussolini and Hitler and began the persecution of Jews. Greater Romania (*România Mare*), which through the unification of Wallachia, Transylvania, Bukovina and Bessarabia, became a liberal constitutional monarchy in 1918, turned into a royal dictatorship in 1938 and joined the Axis powers in 1940.

The Interwar Democratic States. It mat not have been accidental that the countries of Europe that had little experience with parliamentary government and were dominated by the conservative Catholic or Orthodox Churches—Spain, Portugal, Italy, Austria, Hungary, Yugoslavia, Romania—reverted to autocracies. And, in contrast, those with longer experience with constitutional governance and/or a more progressive Protestant tradition—Britain, Sweden, Norway, Holland, Denmark, Belgium, and Czechoslovakia—remained democratic. An exception to this generalization has been the anticlerical Catholic France, which remained democratic until occupied by Germany.

Interwar France. Before World War I, France was politically unstable due to the hostility between the conservatives, who agitated for war with Germany to revenge the defeat during the Franco-Prussian war, and the socialists who favored peace. Following the assassination of their leader, Jean Jaurès, the socialists rallied behind the flag when the war started in 1914. While due to hardships at home, the French began to oppose the war by 1917, the militaristic spirit was rekindled when France emerged victorious in 1918, and in the election of 1919 the French sent many more conservative delegates to the Chamber of Deputies than socialists. The tide turned when due to the tardiness of economic recovery, the socialists became more popular again. In the 1920s the socialists and conservatives alternated in forming unstable coalition governments. By the 1930s the nation became more and more radicalized and two powerful opposing factions formed, the fascist *Action Française* and the socialist *Front Populaire*. In 1936 the socialist, Léon Blum, became the prime minister but he failed to improve the economy or bring about a national reconciliation and his government fell in 1938. While the German army was aggressively preparing for war, the French military adopted a defensive posture. When France declared war on Germany in 1939 to honor its military alliance with Poland, France waited until it was attacked by Germany and failed to launch an effective resistance.

Interwar Britain. From being the largest investor in the world during the second half of the 19th century, the First World War turned Britain into a debtor nation (Fig. 12-57). The war necessitated borrowing money from the United States and other countries to finance the procurement of armaments and essential goods. Interest payments after the war came to constitute 40 percent of all government spending. The shortage of manpower after the war emboldened miners and railway workers to strike and they gained concessions. Due to increased labor costs and taxation, British industry became less and less commercially competitive. In 1921 unemployment reached its highest point (11.3 percent) since records were kept in England. The Commonwealth nations—Australia, Canada, New Zealand—became more independent

BRITISH PUBLIC DEBT DURING THE 20TH CENTURY

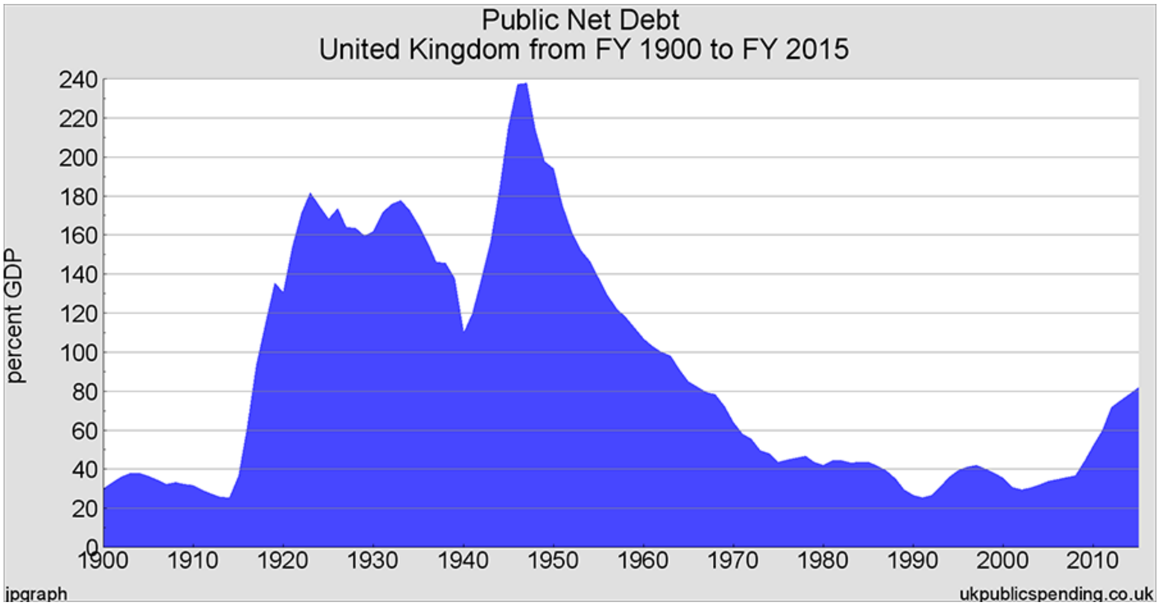

Fig. 12-57. The growth of British national debt that began with World War I, and was sustained throughout the Interwar Period, rose again at the outbreak of World War II. (Ukpublicspending.co.uk)

politically and financially. Several of the colonies that were an economic resource before the war, such as India, became a liability. Garrisons were withdrawn from Ireland in 1921 and the Irish were granted independence in 1922 (except for several northern counties). The British left Mesopotamia in 1921, which became the kingdom of Iraq, and Egypt became independent in 1922. Ramsay Macdonald became the first Labor prime minister in 1924, reflecting the changing political situation. With all these problems, the British desired peace in Europe and, accordingly, sought appeasement with Germany. The British-German naval agreement in 1935 allowed Germany to increase its naval forces, and in 1938 Neville Chamberlain signed an agreement with Adolf Hitler that allowed the annexation of the ethnic German Sudetenland of Czechoslovakia. And when the Nazis occupied Czechoslovakia in the spring of 1939, the British failed to go to the aid of that unique democratic republic in Eastern Europe.

The Interwar Soviet Union. The most drastic political, economic and cultural transformation that any country has undergone after World War I was Imperial Russia (Nove, 1993; McCauley, 2007). The October Revolution of 1917 brought the autocratic rule of the Romanov dynasty to an end as the Bolsheviks under Vladimir Lenin's leadership overthrew the short-lived provisional government. The Soviets established a Federation of Russian, Ukrainian, Belorussian and Trans-Caucasian Republics. The Civil War that ensued (aided by foreign, including U.S. troops) ended in 1921, with the Bolshevik Red Army defeating the royalist White Army. Lenin and Leon Trotsky called for a world revolution in the name of the "international proletariat," as envisaged by Karl Marx. However, that failed to materialize. Following Lenin's death early in 1924, Joseph Stalin succeeded in consolidating his autocratic power as the head of the party, the government and the army. Leon Trotsky was expelled from the Communist Party, exiled and later killed, and Stalin, a ruthless dictator, adopted the idea of "socialism in one country." The drastic plan involved the collectivization of agriculture and the rapid industrialization of the Soviet Union. The agricultural collectivization was a failure. There was a severe famine between 1929 and 1932, due mostly to poor planning and the resistance of the landholding farmers (kulaks) to collectivization. However, industrialization (formulated as a series of centrally orchestrated Five Year Plans) was successful, leading to a substantial increase in industrial output and an average annual economic growth rate of 18 percent. For instance, coal production increased from 35 million tons per year in 1928 to 64 million tons by 1932, and to 127 tons by 1937. Pig iron production rose from 1928 to 1932 from 3.3 million to 6.2 million tons per year, and by 1937 to 14.5 million tons.

The economic and political transformation of the Soviet Union was achieved through drastic control of the workers' output and the terrorization of the population. There were no free trade unions and separation of powers between the Communist Party, the Politburo, and the Judiciary. The kulaks were put into forced labor camps administered by the Soviet secret service (GPU, later NKVD), or were exiled to Siberia, or summarily executed. The same fate befell political dissenters and those accused of "counterrevolutionary crimes." Disregarding all human rights principles, Soviet terrorism reached its peak during the great purges of 1937-1938. High-ranking members of the party and government, and a many as 30,000 military officers were "liquidated." Some of the accused received show trials but most of them were summarily convicted. According to the NKVD's own account, 681,692 people were shot during the 1937-1938 purge. Estimates vary, but as many as 6-7 million individuals may have been exiled to Siberia between 1929 and 1963, and as many as 14 million sent to the forced labor camps, known as the Gulag. The forced labor system served several purposes: a means of terrorizing the population; enslaving those considered enemies of the regime; and using the convicts as cheap labor (Fig. 12-58). The convicts cleared forests, built roads and canals, or worked in mines. Millions died under the harsh conditions of Siberian winters and starvation. But some of the convicts were freed after serving their sentence and the settlements they formed turned into new industrial cities.

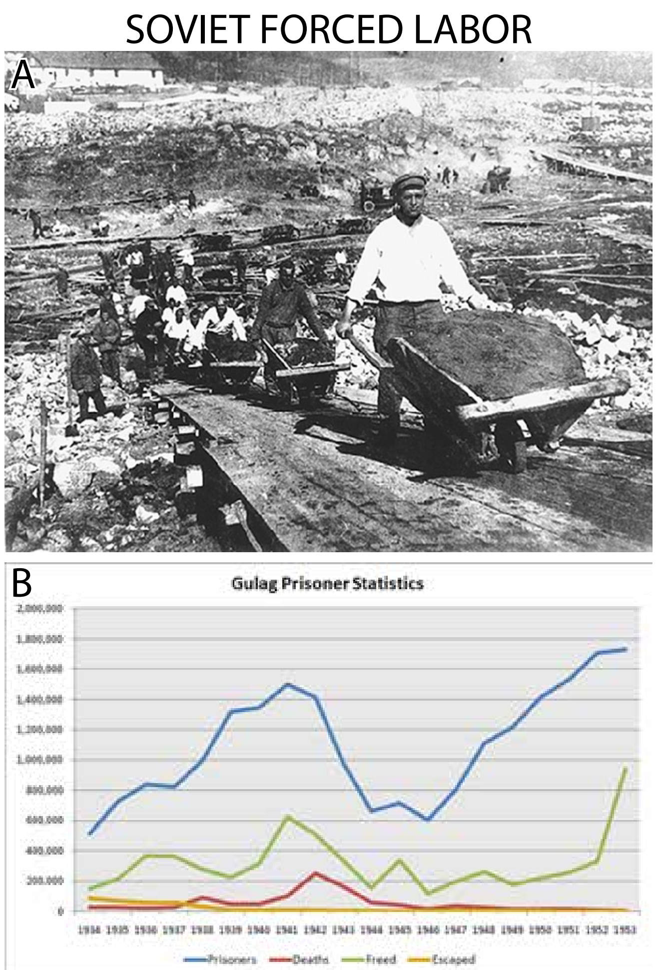

Fig. 12-58. **A**. Road construction by Gulag convicts. **B**. Statistics of the fate of convicts, 1934-1953. (**A**. Gulaghistory.org. **B**. GulagPrisonerStats.png)

While the Soviet government initially sought to ally itself with France and Britain, the latter's failure to resist German aggression in the late

1930's induced Stalin to establish a nonaggression treaty with the Nazis. Stalin was aware that Hitler was planning to invade the Soviet Union to get grain from the Ukraine and oil from the Caucasus but he needed several years to strengthen the army and complete its reorganization. That proved to be a miscalculation as the *Wehrmacht* invaded Russia much earlier than Stalin anticipated.

The Interwar United States. U.S. involvement in world affairs was minimal in the 19th century as it passed through a period of domestic turbulence (Stokes, 2002; Carnes and Garraty, 2011). The election of Abraham Lincoln as President in 1860 led to the secession of seven (later eleven) slave-holding states from the Union, the founding of the Confederacy, and Civil War. While the Union victory in 1865 led to the abolition of slavery, the social and legal discrimination of black people continued in the south, where economic development languished for decades. In contrast, the northern states thrived, due partly to the influx of millions of migrants from Europe, fleeing poverty and discrimination there. The U.S. became a world economic power by the end of the 19th century but remained essentially isolationist on the world scene. That ended when the U.S. joined the First World War in 1917. Before that war ended, President Woodrow Wilson proposed an international treaty designed to create "world peace without victory." His "Fourteen Point" program, delivered to the U.S. Congress in 1918, included guaranteeing self-determination to all nationalities, substantial arms reduction, open trade, freedom of the seas, and the formation of an international forum of arbitration, the League of Nations. However, Wilson was opposed at the Paris peace conference of 1919 by Georges Clemenceau, the Premier of France, who insisted on the humiliation of Germany and the imposition of heavy reparation payments. Nor did Wilson get the support of the U.S. Congress. The League of Nations did get established—at the beginning with 42 members and by 1930 with 60 members—but the U.S. never joined it.

FROM ECONOMIC PROSPERITY TO DEPRESSION. While the First World War devastated much of Europe, the economy of the U.S. was not adversely affected. Although there was a brief period of unemployment as war production ended and the soldiers were demobilized, the economy recovered when industry turned to the mass production of automobiles and such new devices as telephones, radios, vacuum cleaners, toasters and refrigerators. But U.S. economic expansion and prosperity ended abruptly with the New York Stock Exchange market crash in October 1929 (Cravens, 2009). The expansion of the U.S. economy was largely fueled by capital that came from the sale of company stocks to investors. Investors could buy stocks with as low a cash deposit as 10 percent of its nominal value, and stock prices quadrupled in value between 1920 and 1929. Contributing to the prosperity was also the fact that Wall Street bankers became moneylenders to many enterprises abroad. Than the economic bubble burst as the inflated stock prices began to fall in 1929 and in a panic people ran to withdraw their investments from the banks. As the Republican government, committed to the gold standard, failed to respond to the crisis by lending money to the banks at a lowered interest rate, over 1600 of the banks went bankrupt. The stock market crash triggered the Great Depression, with 20,000 businesses going bankrupt and over 20 percent of the population losing their jobs by 1932 (Fig. 12-59). The U.S. economic depression lasted a decade and had a disastrous effect on economic and political developments in the U.S. and the rest of the industrial world.

U.S. UNEMPLOYMENT SPIKE
DURING THE GREAT DEPRESSION

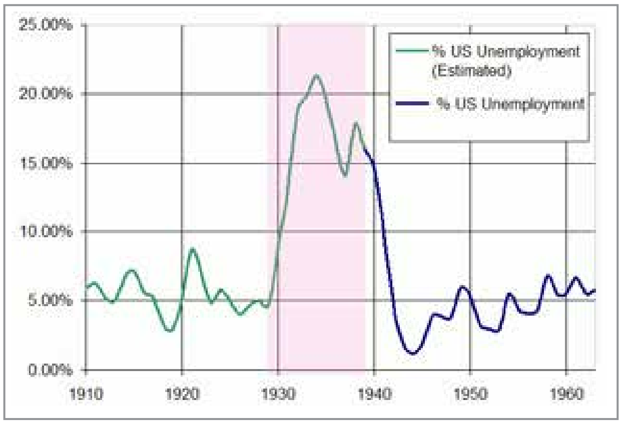

Fig. 12-59. U.S. unemployment rate during the Great Depression. (Google)

POVERTY DURING THE GREAT DEPRESSION

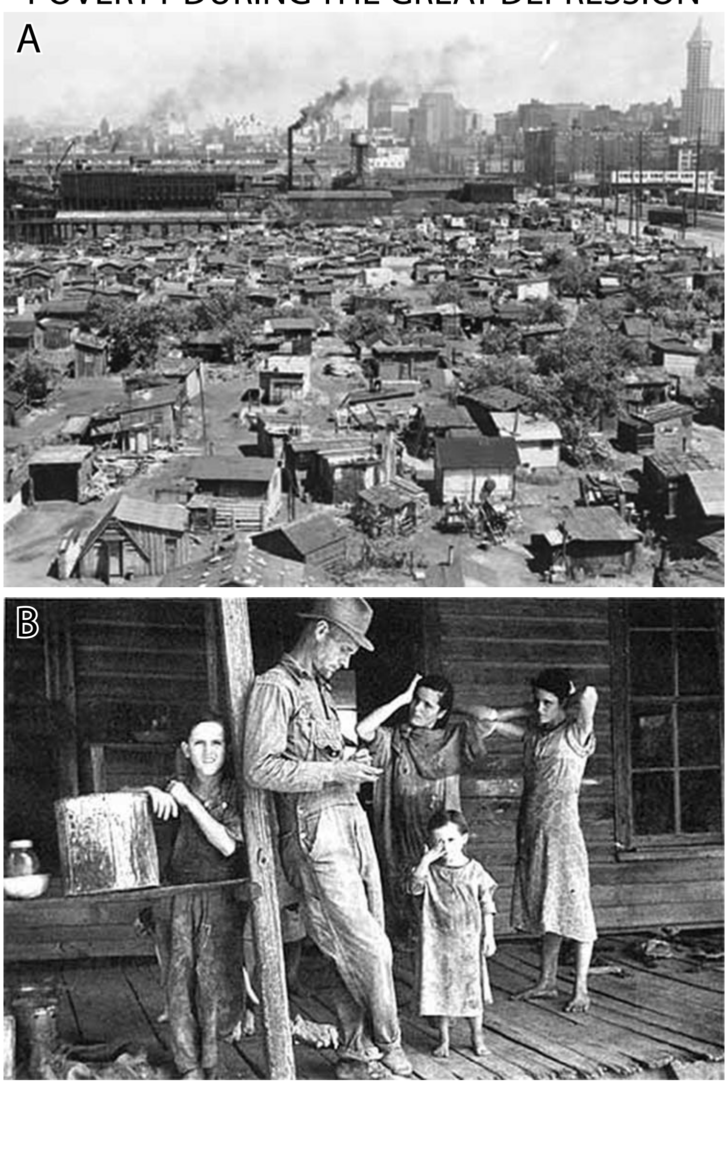

Fig. 12-60. **A**. Homeless shantytown in Seattle, Washington, in 1937. **B**. Impoverished farmer with his family. (**A**. Nansemondriverworks.com. **B**. Chn.gmu.edu)

THE NEW ECONOMY. As a consequence of the stock market crash, the prosperous U.S. turned into a nation with widespread poverty (Fig. 12-60). There were no social safeguards in place in the laissez-faire economic system. There was no Federal unemployment insurance. The government did not spend money to temporarily create of public jobs. There was no plan to lend money to farmers or small businessmen at low-interest rates to foster economic development. In 1933, the democrat Franklin Delano Roosevelt became the President. He introduced a series of social and economic reforms that began to modify the laissez-fare capitalist system to one regulated by the government. Increasing deficit spending, the reform popularly called the New Deal, created jobs for several million people in public works projects; allowed workers to form unions to engage in collective bargaining; established a modest social security system for retired and disabled workers; subsidized farmers to reduce crop production, and thus reverse the falling price of grains; and introduced legislation to protect consumers and regulate trading on the Stock Market. Roosevelt also began to change U.S. foreign policy but faced opposition by those who favored the continuation of isolationism. As Hitler began his war mongering, the U.S. Congress passed the Neutrality Acts in 1936 and 1937, which prohibited giving economic aid or selling arms to combatant nations. When France and Britain declared war on Germany in September 1939, Roosevelt assured the nation that the U.S. will stay out of the war. In fact, he began to support the Allies by supplying them with armaments in the "Cash and Carry" program of 1940 and the "Lend-Lease" program of 1941. After Japan attacked Pearl Harbor in December 1941, the United States joined the Allies' war against the Axis powers. With war production increasing greatly and with 10 million civilians joining the military, unemployment was virtually ended.

12.4.6. The Escalation of Savagery: The Second World War, 1939-1945. On September 1, 1939, Germany invaded Poland (Burleigh, 2000; Evans, 2008). To achieve that, the Nazis formed a treaty with the Soviets to partition Poland into a German- and a Soviet-occupied territory (the Molotov-Ribbentrop pact). In response to that military action Britain and France, although inadequately prepared, declared war on Germany on September 3, 1939. Using the *Blitzkrieg* (lightning war) strategy—which involved the concentration of airpower, artillery and tanks along a narrow front to break through and get behind enemy lines—the *Wehrmacht* rapidly overcame Polish resistance. Indeed, Polish resistance became futile when the Soviets began the invasion of Poland from the east on September 7. The campaigns ended by early October when the Nazis and Communists divided and annexed all of Poland. However, the French and British did not initiate any military activity, with the exception of some naval engagements.

THE INVASION OF FRANCE. The Germans, using the same *Blitzkrieg* technique that they used in Poland, began the attack of the Allies on the Western front by invading Denmark and Norway in April 1940. The Danes put up little resistance but the Norwegians, who did, capitulated about one month later and the Germans entered Oslo and established there a puppet government of collaborators. Then, early in May 1940, German mechanized divisions supported by aircraft occupied Belgium and Luxembourg, and moving through the Ardennes Forest began the invasion of France. The British expeditionary force facing annihilation was evacuated in Dunkirk early in June. (The *Wehrmacht* could have prevented that but Hitler ordered it to halt fire). The French failed to put up effective resistance and the Germans occupied undefended

Paris on June 14, 1940. The French sued for armistice and, according to its terms, the Germans occupied the north and west of France and the rest came to be administered by the far-right Vichy government.

THE BATTLE FOR BRITAIN. Hitler did not want a war on two fronts and in July 1940 announced publicly his desire to establish peace with Britain, provided it agreed to the unconditional German domination of Europe. Winston Churchill rejected the offer, whereupon Hitler ordered the *Luftwaffe* to start the aerial *Blitz* of England. Early in September waves of bombers, accompanied by fighter planes, attacked British airfields and infrastructure. Seeking to terrorize the population, and thus force Britain to surrender, that was followed by the bombing of city centers throughout Britain (Fig. 12-61). Aerial bombardment continued until the end of April 1941, which killed over 40,000 civilians and injured 139,000 but failed to break British

Fig. 12-61. **A**. German aerial bombing of London. **B**. Destruction produced by bombing of Liverpool. (Wikipedia)

morale. The improvement of British air defenses resulted in the gradual loss of German air superiority (the *Luftwaffe* lost over 2,500 aircraft and over 5000 airmen in that *Blitz*), which led Hitler to halt the aerial offensive in May 1941. Failing to subdue Britain, Hitler turned to execute his original plan of invading the Soviet Union, and get the needed supply of grain and oil before the Russians could improve their defenses.

INVASION OF THE SOVIET UNION. In preparation for invading the Soviet Union, Hitler induced Hungary, Romania and Slovakia to join the Axis alliance, and invaded Yugoslavia early in April 1940. Although offering resistance, Yugoslavia capitulated by mid-April. Then the Germans occupied Greece and the island of Crete by October 1940. The *Wehrmacht* then started to prepare the invasion of the Soviet Union, which was scheduled for the spring of 1941, in direct violation of the German-Soviet 10-year nonaggression pact. Behind schedule, massive German army units—with about 3 million personnel, 3,000 tanks, 7,000 artillery pieces, and 2,500 aircraft—began the invasion of the Soviet Union along a 1,800-mile front on June 22, 1941. This was the largest invasion force in recorded history with armies in East Prussia invading the Baltic countries, those in Poland invading Belorussia, and those in Hungary and Romania invading the Ukraine (Fig. 12-62). The strategy was again a *Blitzkrieg*, with *Panzer* divisions

Fig. 12-62. The rapid advance of the Wehrmacht into the Soviet Union between July and December 1941. (EasternFront1941.jpg)

aided by overwhelming aerial support punching holes in defense lines and encircling large Soviet military units. By early September, German forces had "liberated" the Baltic countries and occupied Belorussia and the Ukraine, the cities of Novgorod, Smolensk, and Krasnograd in Russia, and reached the outskirts of Leningrad. By early December they occupied Orel and Kharkov and reached the outskirts of Moscow. Millions of Soviet soldiers were taken captive, and killing units under the command of the SS that followed the fighting troops were given the task to control the occupied lands. They engaged in mass killings of prisoners of war, communist functionaries and Jews, and terrorized the population (Fig. 12-63).

GERMAN WAR ATROCITIES

Fig. 12-63. Mass murder of Jewish civilians in the occupied territory by German military personnel. (Wikipedia: Eastern front, 1941)

COLLAPSE OF THE GERMAN BLITZKRIEG. In spite of its great military superiority, the *Wehrmacht* failed to accomplish its mission of forcing the Soviet Union to surrender before the winter. During the autumn of 1941, the Soviets transferred well-equipped troops from Mongolia and Siberia to Moscow, and with this reinforcement attacked the exhausted and freezing German troops, forcing them to withdraw from the vicinity of Moscow early in January 1942. The German *Blitzkrieg* failed because despite their heavy losses, the retreating Soviet troops burned crops, destroyed bridges, and evacuated factories to the Urals where they were swiftly put back into production. The Soviet troops that escaped the encirclements turned into partisans that harassed the German occupiers and damaged their supply lines. German casualties in personnel and materiel was enormous and the soldiers of the *Wehrmacht* were not equipped to fight in the winter cold and move effectively during the spring thaw. The armies had to wait until the summer of 1942 to resume their offensive, now directed towards the south and southeast, with the aim of reaching the oil fields inthe Caucasus.

GERMAN DEFEAT ON THE EASTERN FRONT. Desperately short of gasoline, the major purpose of the 1942 German military campaign was to reach the oilfields of the Caucasus. The offensive began late in June and initially army units advanced rapidly southward, occupying cities along the Don River by mid-July. However, stiff Soviet resistance and counterattacks slowed the advance by early autumn, and it was winter when the Germans reached Stalingrad on the Volga and the Caucasus farther south. The *Wehrmacht* failed to reach the rich oilfields and the months-long Battle of Stalingrad, the bloodiest of the entire war, ended in the encirclement of an entire German army unit, which surrendered to the Soviets on February 2, 1943. The German army thereafter retreated from the Caucasus and the Soviets retook the cities of Kharkov and Kursk by mid-February, 1943. In a subsequent counteroffensive, the Germans reoccupied Kharkov and Kursk and made intensive preparation to break through the Soviet defenses. About one-third of the German military might was concentrated in the Kursk area, involving over 750,000 soldiers and close to 2,500 tanks, including the latest models. But the Soviets amassed more soldiers and more tanks, and the Germans failed to break through the Soviet defenses. This was the last German offensive on the Eastern front. Henceforth, the Soviet Army relentlessly moved westward and German units could only engage in rear-guard defensive actions. By the end of 1943, the Soviets liberated most of Russia; by the end of 1944 they liberated Belorussia and the Ukraine, and occupied eastern Poland, Bulgaria and Romania, and much of Hungary (Fig. 12-64). The offensive to occupy central Germany began in the spring of 1945 and the encirclement of Berlin was completed by April. The Battle for

SOVIET ADVANCES 1943-1945

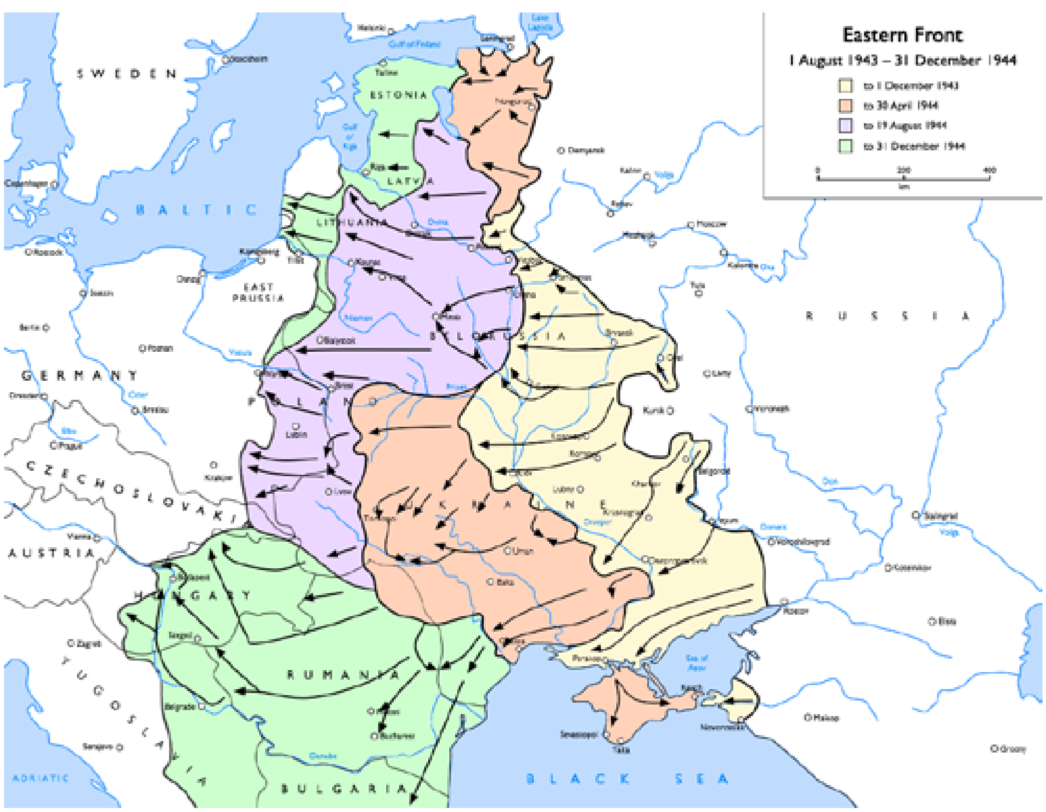

Fig. 12-64. Soviet counteroffensive and occupation of European countries in 1943 and 1944. (Wikipedia: Eastern front, 1943-1944)

Berlin ended after Hitler committed suicide and the city was occupied by the Soviets on May 2, 1945. The German army surrendered to the Soviets on May 9, two days after it has already surrendered to the Allies on the Western front.

CASUALTIES AND NAZI ATROCITIES IN THE EAST. World War II was the deadliest military confrontation in human history (Krivosheev, 1997; Overmans, 2000). German military casualties have been estimated between 4.3 to 5.3 million dead on the Eastern Front. Allied bombings killed 437,000 civilians, 300,000 Germans were victims of Nazi racial and religious persecution, and 22,000 people died during the Battle of Berlin. Total war-related deaths in the Soviet Union may have been as high as 30.5 million. About 10.6 million Soviet soldiers were killed or missing in action; 3.6 million died of starvation and disease in POW camps; and 400,000 partisans lost their lives in fights. Soviet civilian deaths totaled 15.9 million, which included those killed in reprisals, those that died in concentration camps, and those that died due to famine or disease. An estimated 1.2 million people died during the Siege of Leningrad; most of them of starvation.

Jews were among the prime targets of Nazi atrocities (Hilberg, 2003; Rees, 2005). In November 1939, the Jews of Warsaw were herded into a ghetto. After invading the Soviet Union, the German special task forces began the indiscriminate killing of Jews living in the villages and towns. The implementation of the "final solution" began in 1942 as extermination centers were established at such sites as Belzec, Majdanek and Treblinka where the victims were killed in gas chambers and then, after removal of their hair, glasses, jewelry and gold teeth, they were incinerated One of the most notorious camps was in Auschwitz, where as late as April-June 1944, 437,000 Hungarian Jews were brought to the camp (Fig. 12-65). The young, the aged and all those considered unfit for hard labor were gassed and incinerated. An estimated 1.5 million people perished in Auschwitz, most of them Jews but also Poles, Russians, Gypsies, and others. The Nazis lost the war but succeeded in exterminating about 6 million Jews, about two-thirds of Europe's Jewish population.

HUNGARIAN JEWS ARRIVE IN AUSCHWITZ

Fig. 12-65. Arrival of innocent Hungarian Jews at the Auschwitz extermination camp, 1944. (BudesarchivBildAuschwitzKZ.jpg)

THE DEFEAT OF GERMANY ON THE WESTERN FRONT. The British air force began to bomb German dockyards, rail depots, dams, bridges, and town centers early in 1942. The air raids intensified when he U.S. Air Force joined the British in the relentless targeting of industrial and residential areas all over Germany and reduced several cities into rubble (Fig.12-66). The Germans shot down many of the bombers but the air raids produced severe damage to industry, hampered the logistics of troop movement and transportation, and began to break down civilian morale. The bombing of German cities continued until 1945. One of them, Dresden, was bombed by the Allies with high explosive bombs and incendiary devices in February 1945, which produced a firestorm that destroyed 90 percent of the city center and killed about 25,000 civilians.

The first military engagement by the Allies with the Axis powers began in North Africa in 1940, which ended with their victory in 1942. Units of the British and American invasion forces that assembled in Tunisia occupied the island of Sicily in July 1943 and that was followed, early in September, by troops landing in southern Italy. Benito Mussolini, the fascist dictator, was deposed and the Italian army surrendered to the Allied forces. German army units stationed in Italy, in contrast, put up a stiff resistance but by early October 1943 the Allies entered Naples. Then the invasion got bogged down and Rome did not fall until June 5, 1944, and German forces in northern Italy did not surrender until May 1945.

Fig. 12-66. Destruction of the German city of Cologne, after years of relentless bombing. (Koeln1945.jpg)

On June 6 1944, units of a large Allied force that were assembled in Britain landed on the beaches of Normandy, France (Fig. 12-67). The initial contingent consisted of 156,000 troops carried by 3000 ships and another 24,000 soldiers parachuting from the air (Beevor, 2009). More troops landed on the successive days and weeks, the Armada reaching about a million soldiers by July. This was the largest amphibious expedition in world history. By the end of the month, after a period of intense fighting, Allied troops were in control of Normandy and French troops liberated Paris on August 25, 1944. Aachen in Germany was occupied in October but then, in December 1944, the Germans began their winter counteroffensive in the Ardennes forests of Belgium known as the *Wacht am Rhein* (Watch on the Rhine) or the Battle of the Bulge in which both sides suffered severe losses. The invasion of Germany was resumed in March 1945, as the Rhine was crossed at several points and the occupation of much of northern and western Germany was accomplished in April. On May 7, 1945, the German forces surrendered to the Allies. The Allies suffered severe casualties on the Western Front between in 1944-1945, with 750,000 soldiers dead or wounded.

NORMANDY INVASION, 1944

Fig. 12-67. Allied troops landing on a Normandy beach, June 1944. (Oldsaltblog.com)

12.5. Advances in Science and Technology, the Cold War, and the Rapidly Changing Contemporary Social Order.

12.5.1. Advances in the Physical and the Life Sciences. The importance of scientific and technical research was clearly recognized during World War II as the combatants competed with each other to produce ever more powerful weapons and other means to gain military advantage. It was at the beginning of the war that penicillin (although discovered earlier) was developed as the most powerful antibacterial agent; it was during the war that radar was developed to detect the approach of enemy aircraft and radio navigation was improved to fly under conditions of limited visibility; that synthetic oil and rubber was produced on a large scale to make up for shortages; the forerunners of computers were developed to intercept enemy communication; jet engine and rockets were introduced as improved flying machines; and controlled nuclear fission was achieved to produce the most powerful weapon ever used (Fig. 12-68). Nuclear energy has also become a major source of industrial energy. Then the decades after the end of World War II witnessed an immense acceleration of scientific discoveries and technical innovations as governments recognized not only the military but also the economic advantages accruing from large-scale financing of "research and development."

FIRST NUCLEAR TEST EXPLOSION JULY 16,1945

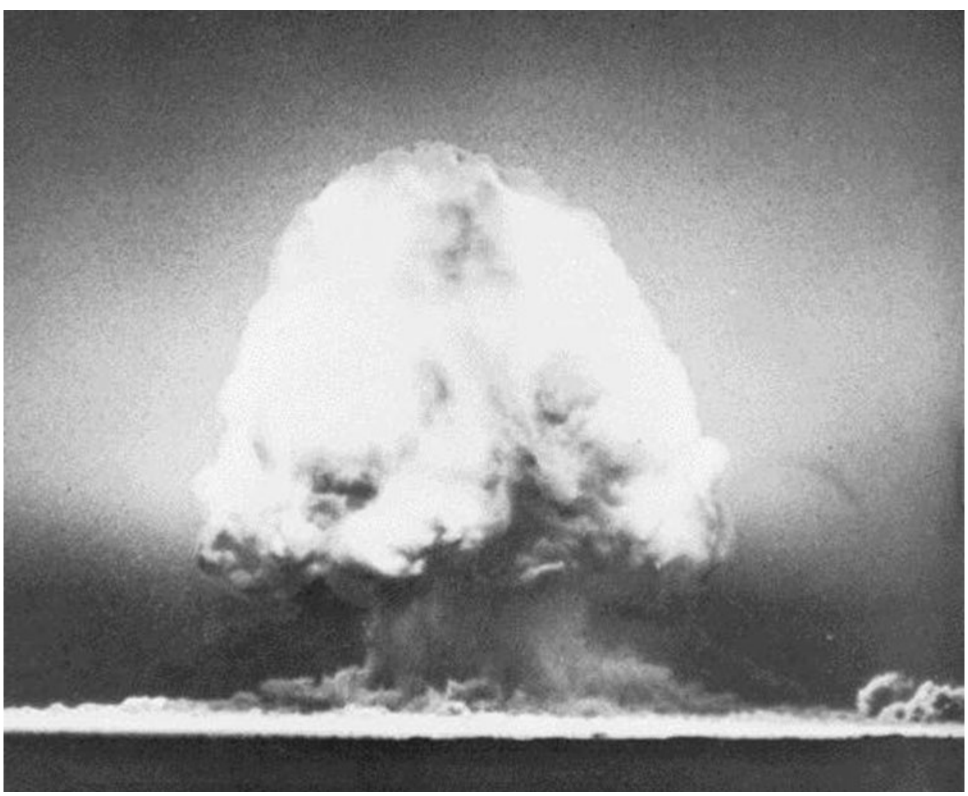

Fig. 12-68. The first explosion of a nuclear device in New Mexico, July 16, 1945.
(TrinityExplosionatLosAlamos.tif)

Advances in the Physical Sciences. Among the several advances in physics after the end of World War II were the creation and isolation of trans-uranium elements and discoveries in nuclear physics gained in collision experiments with ever more powerful particle accelerators (McClellan and Dorn, 2006). To account for the many subatomic particles discovered—as distinguished by their mass, charge and spin—the earlier model of atoms has been replaced with more elaborate new models, such as the "standard model" that posits the existence of six quarks, six leptons, three gauge bosons, and eight gluons. In addition to the electromagnetic force that keeps electrons in their orbit around the nucleus, other strong and weak forces have been postulated to exist which hold the subatomic particles together within the nucleus.

Earlier research by Hubble and others led to the theory that the universe is expanding at an enormous speed. More recent research with new instruments—radio, infrared, ultraviolet, x-ray and gamma ray telescopes, and the Hubble space telescope (Fig. 12-69)—have revealed the existence of a multitude of different types of stars and galaxies, some exploding, others contracting. There are quasars with massive cores; extremely dense pulsars with powerful magnetic forces; and galaxies with black holes, so dense that light cannot escape from them. The evidence for the rate of expansion of the universe led to the Big Bang theory, according to which the universe came into existence 13.7 billion years ago. It began as a small, immensely compact and hot entity that expanded into an increasingly larger, less dense and colder universe. Initially, so the theory goes, the universe consisted only of subatomic particles, but gradually lighter atoms and than heavier atoms formed, then the gases solidified into stars and the stars formed galaxies. With these centrifugal forces in operation, how can gravitational forces hold the universe together? It has been postulated that much of the universe consists of "dark matter" that does not emit light but exerts a powerful gravitational centripetal force and of "dark energy" which accounts for the centrifugal force of the expansion. However, the existence of this dark matter and dark energy has never been experimentally demonstrated. Whatever future research may reveal about the origin of the universe, it remains a fact that its immense size and age are beyond what we, as earthly beings, have considered "big" or "old." The same applies to what we know about matter and energy with their miniscule size and strange properties. Among other advances in astronomy of great importance, are those that have come from the space probes that have been flying past the planets and those that have landed on Mars with the strong suggestion that in the distant past it may have harbored living organisms. Important in that context is the recent discovery of planets that rotate around distant stars, with perhaps some of them supporting living organisms.

Advances in the Life Sciences. The widespread use of several new biochemical techniques contributed the great advances in the study of organic processes by the mid-20th century: the ultracentrifuge, paper chromatography, x-ray crystallography, and the labeling of chemicals with radioactive isotopes to follow their metabolic transformations. The ultracentrifuge allows the separation of various molecules by spinning them in solution at very high speeds. Pioneering that technique in 1925, Theodor Svedberg was able to determine the molecular weight of different proteins and found that they were much heavier than previously assumed. Paper chromatography allows the isolation and measurement of small amounts of dissolved proteins on the basis of their diffusion patterns. By the mid-1940s, Frederick Sanger and his associates succeeded in determining the complete amino sequence of insulin.

THE HUBBLE TELESCOPE
AND
ITS EXTREME DEEP VIEW
OF SPACE

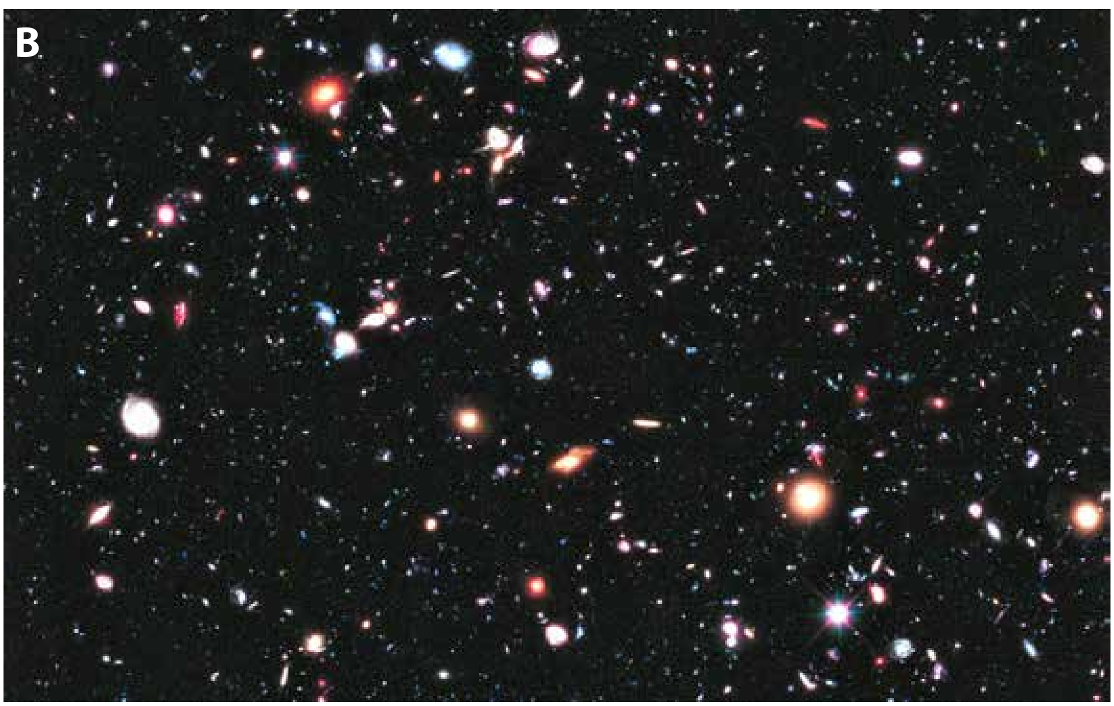

Fig. 12-69. A. The Hubble space telescope in orbit. **B**. Multitude of galaxies in deep space. (**A**. Socialmediaseo.net. **B**. NASA)

MOLECULAR BIOLOGY. It was established by the 1950s that genes produce phenotypic traits by way of biochemical processes involving enzymes. Subsequent research modified the "one gene-one enzyme" hypothesis in the sense that genes specify the amino acid and polypeptide composition and configuration of proteins, such as polypeptides and amino acids. For instance, Linus Pauling showed in 1949 that the genetic disorder, sickle cell anemia, is associated with altered hemoglobin in the red blood cells of affected patients, and in 1957 Vernon Ingram demonstrated that that disorder is caused by the mutational replacement of a single amino acid by another. Although initially it was assumed that the genes were nucleoproteins, it was later found they were nucleic acids. Nucleic acids were discovered by Friedrich Mischer in 1896 and by the 1930s it was known that, much like proteins, they were polymers with a complex structure. Nucleic acids are composed of four bases, adenine and guanine (purines), and cytosine and either thymine or uracil (pyrimidines). Oswald Avery, working with bacteria provided the first line of evidence implicating nucleic acids in genetic transmission. Alfred Hershey and Martha Chase followed that work in the early 1950s by labeling the nucleic acids of bacteriophage viruses with radioactive phosphorus and their protein coat with radioactive sulfur. Hershey and Chase found that when bacteriophages infected bacteria (replicating themselves at the host's expense) only the nucleic acids penetrated the cell, the protein coat was left outside. These and related experiments established that nucleic acids are self-replicating macromolecules and they are able to transform the amino acids of the host tissue into proteins of their own kind. Thus the bacteriophage nucleic acids met the two fundamental biochemical requirements of the putative genetic material: autocatalysis (self-replication) and heterocatalysis (production of proteins). The next step in deciphering the function of DNA was the discovery that strands of this macromolecule serve as a codes for the preservation, replication and transmission of genetic information.

In 1953, James Watson and Francis Crick, using biochemical data and the crystallographic work of Rosalind Franklin, published their model of DNA as a double helix. In this model, the DNA of chromosomes consists of two helices wound around each other like spiral ladders (Fig. 12-70). The rungs of the ladder consists of varied sequence of nuclear bases (nucleotides) in such a way that adenine (A) is always linked with thymine (T), and guanine (G) with cytosine (C). Replication of DNA is achieved by each strand acting as a template for assembling the proper sequence of its counterpart. Within a decade not only the main features of DNA replication but also the transcription of that information to RNA has been worked out. DNA with a particular nucleotide sequence assembles on its surface a complementary copy of RNA, aided by an enzyme known as RNA polymerase. The next step, translation, usually takes place in the cytoplasm where the RNA nucleotide sequence is read off to specify the sequence of amino acids to produce polypeptides and proteins. There are three types of RNA—messenger, ribosomal and transfer—each with a specific function in the translation process. For each of the twenty amino acids in the sequence of a polypeptide chain or protein, there are several triplet codes, known as codons. For instance, one of the codons for phenylalanine is UUU, for leucine CUU, and for alanine GAU. There are also codons for punctuation marks and for the proper reading of the RNA code. The nucleotides are analogous to the letters of a book, single genes to paragraphs, and chromosomes to the chapters of the book. But unlike human languages, the genetic code is universal, indicating that it became permanently fixed as quite early as life evolved on this planet.

MOLECULAR GENETICS. The aim of molecular genetics is to explain organic processes—in particular genetic inheritance and morphological development—in terms of the structural and functional properties of bioactive macromolecules. An important discovery has been that a class of so-called homeobox (*Hox*) genes play an important role in the regulation of embryonic development. As regulatory factors of genetic transcription, Hox genes specify the antero-

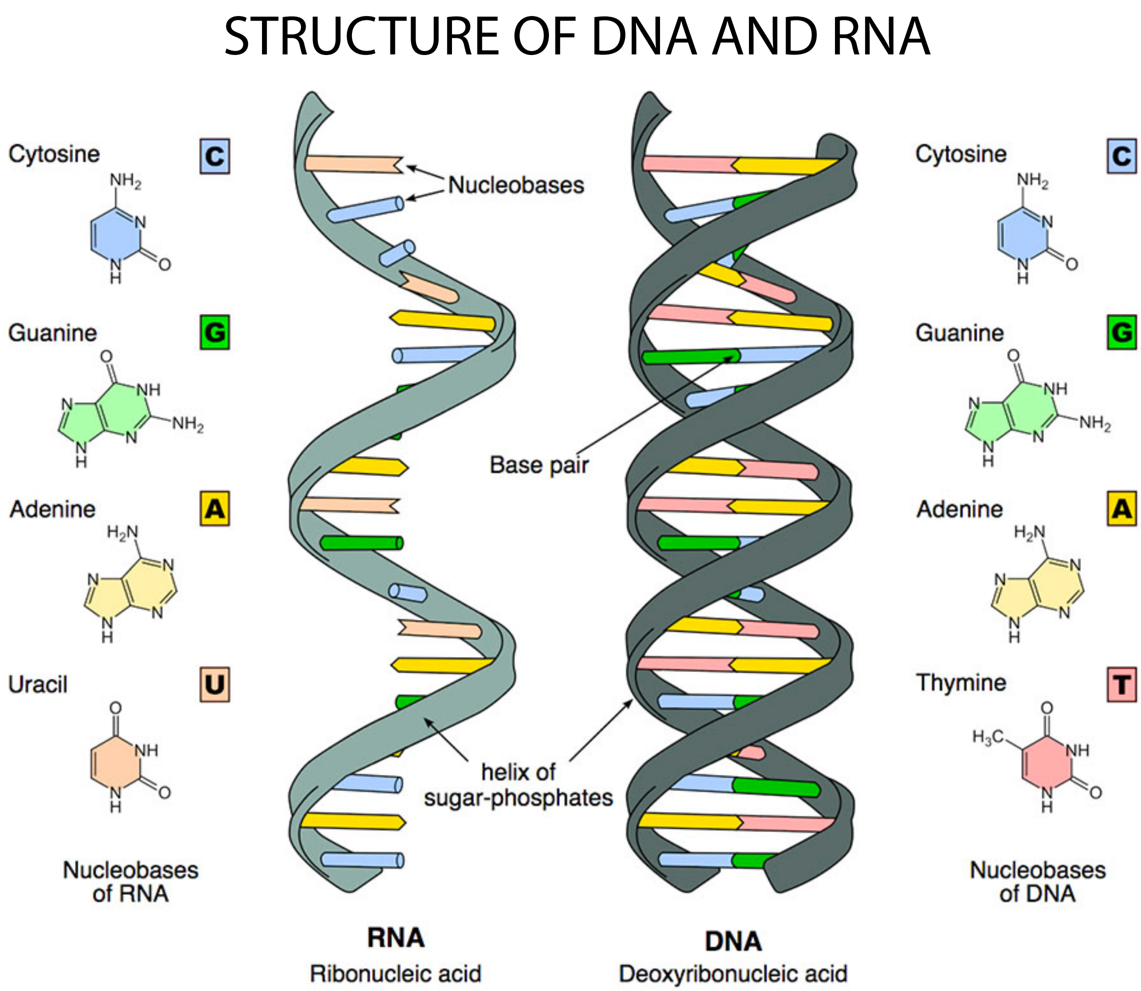

Fig. 12-70. Nuclear bases, and helical structure of DNA and RNA. (Wikipedia)

posterior axis of the body, its segmentation, and the development of distinct body members, such as limbs and their component parts. Regulation of morphogenesis by *Hox* genes is extremely complex and involves cascades of other genes and their products, and reciprocal interaction through facilitation and inhibition of gene expression. There are also other signaling molecules that synchronize the diversification of peripheral sensory systems, such as nostrils, eyes and ears, with the development of central nervous mechanisms controlling them. For instance, various *Pax* (paired box) proteins have been implicated in lens formation and the development of different neuronal elements of the retina and the brain.

FROM LIGHT MICROSCOPY TO ELECTRON MICROSCOPY. Modern research using transmission and scanning electron microscopy has led to the characterization of many bacteria and viruses. Bacteria are prokaryotic microorganisms (cells without nuclei) with a great variety of morphologies and functional properties. Many are part of the ecosystem involved in the recycling of nutrients; others cause diseases, such as bubonic plague, cholera, syphilis, anthrax and leprosy. (We have described the morphology and behavior of *E. coli* in Chapter 2, Figure 2-1.) Bacteria can be destroyed with antibiotics, such as penicillin. The viruses, in contrast, are not true organisms. They typically consist of nucleic acids encased in a protein coat that needs the metabolic apparatus of the host cell they invade to multiply. Viruses infect plants and animals as well as bacteria (bacteriophages). Viruses cause such diseases as influenza, herpes, measles, and mumps (Fig. 12-71).

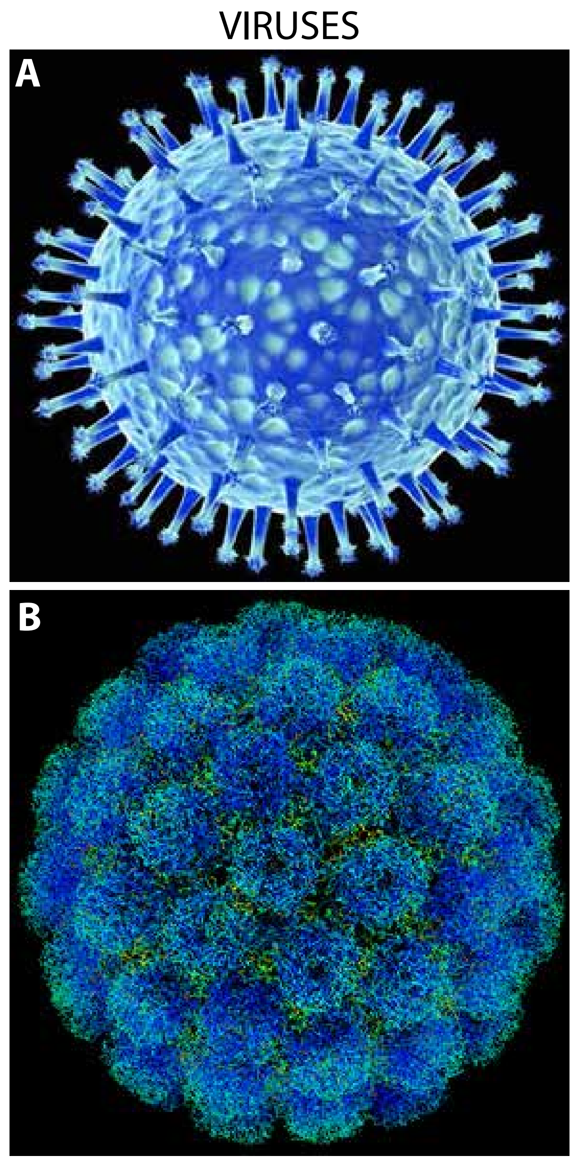

Fig. 12-71. Electron micrographs of (**A**) bird flu, and (**B**) human papilloma virus. (**A**, theguardian.con. **B**. envikipedia.org)

ADVANCES IN BIOCHEMISTRY. By the mid-1940s, Frederick Sanger and his associates succeeded in determining the complete amino sequence of insulin. And by the 1960s, using crystallography, Max Ferdinand Perutz and John Kendrew were able to work out the three-dimensional structure of two related proteins, hemoglobin (the oxygen-carrying molecule of red blood cells) and myoglobin (the oxygen binding molecule of muscle cells). A contemporary rendering of the subunits of a hemoglobin molecule is illustrated in Figure 12-72.

12.5.2. Technological Advances in Engineering, Communication, Computation, Automation, and Transportation. There have been advances in all fields of engineering in the contemporary world, marked by an increase in the use of machines in all aspects of daily life, increased demand for and exploitation of energy resources, and reliance on computer controlled logistics and automation in producing and distributing goods.

Advances in Mining, Electrical and Nuclear Engineering. The increase in the use of machines and the population explosion has necessitated an intensified search for, production and use of energy resources. The consequences have been both beneficial and harmful.

COAL MINING. Early in the 20th century the main energy source of electricity was coal (Netschert, 1967). Coal was burned in a boiler and the steam generated was used to rotate the blades of a turbine to produce electricity. Coal mining still depended on the old laborious technique of tunneling with pick and shovel, blasting the coal out of place, and loading the coal into small rail cars pulled by people or mules. The average coal miner in the U.S. produced three tons of coal per day. The mechanization of coal mining began slowly in the following decades. A coal miner's daily production rose to 6.3 tons by the mid-1940s, and to 13.7 tons by the mid-1960s. Modern mines that use a machine with large rotating steel drums furnished

THE STRUCTURE OF HEMOGLOBIN

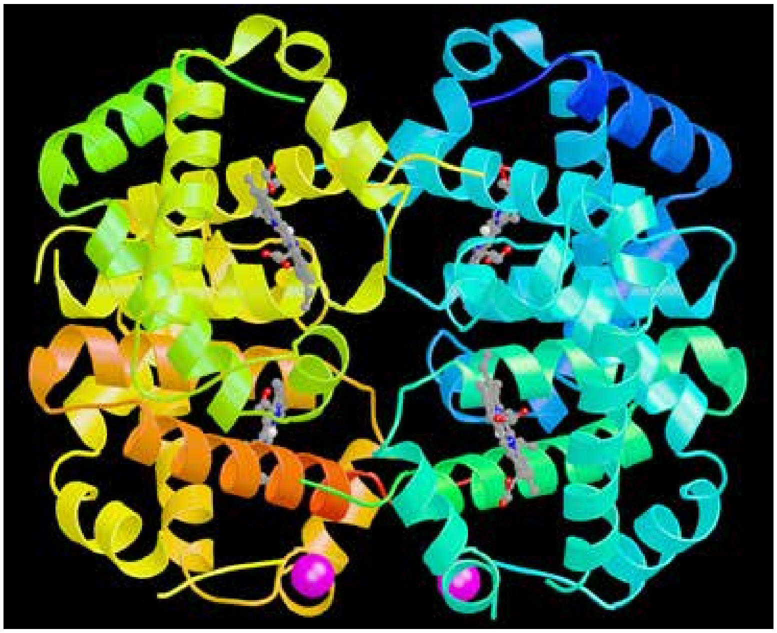

Fig. 12-72. Model of a hemoglobin protein molecule. The curled colored units are two α subunits and two β subunits. Gray: four flat iron-containing heme groups embedded in each of the four subunits are sites of oxygen binding. (biodavidson.edu)

with tungsten carbide teeth can scrape as much as five tons of coal in one minute. Conveyor belts then move the coal to trains. Where strip mining was feasible, production rose in the United States to nearly 30 tons per man/day. In some regions a practice known as "mountain-top removal" (Fig. 12-73) are enabling a small team of men to produce immense quantities of coal, replacing miners, changing the landscape and adversely affecting the local ecology (Palmer et al., 2010).

MINING BY MOUNTAINTOP REMOVAL

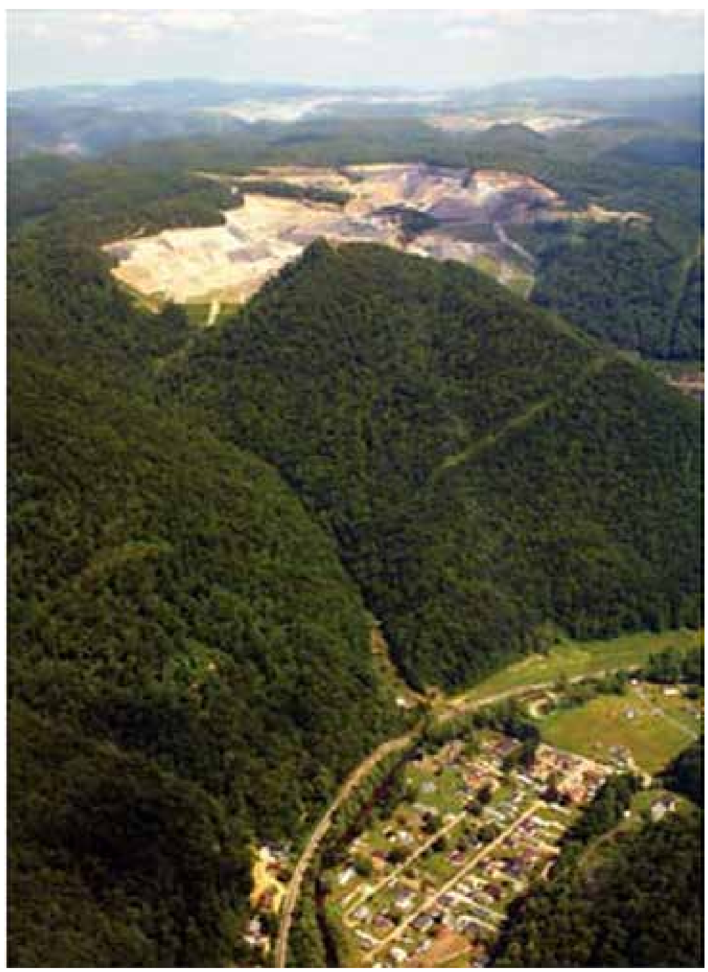

Fig. 12-73. Repeated flooding inundated this small town in Virginia after the commencement of a nearby "mountaintop removal" for mining coal. (Erik Reece, orion. magazine.org)

The efficiency and capacity of producing electricity has also increased. In 1902 seven pounds of coal were needed to produce one kilowatt-hour; by the mid-1960s the same amount was obtained from 0.86 pounds of coal. While in the first decade of the century a large electric station had the capacity to generate 25,000 kilowatts, this increased to over 200,000 kilowatts by 1930. Large current stations generate thousands of megawatts. Methods were also developed gradually to distribute high voltage electric power over long distances by using step up transformers for high voltage transmission over long distances and using step down transformers for local distribution (Fig. 12-74). Early in the 20th century, power lines could carry a maximum of 110,000 volts over 100-200 miles; this was increased to over 280,000 volts in the 1930s; and by the 1960s interconnected lines in the United Stars conveyed up to one million volts. A new development has been the creation of computerized grid systems that distribute electric energy generated in diverse power stations over an entire state, country or several countries.

OIL AND GAS EXTRACTION AND UTILIZATION. The widespread use of combustion engines stimulated an intensified search for finding underground fossil fuel reserves. Initially the search was largely a random enterprise and exploratory drilling was done with inefficient cable tools. The technique of hydraulic rotary drilling was introduced at the beginning of the 20th century and

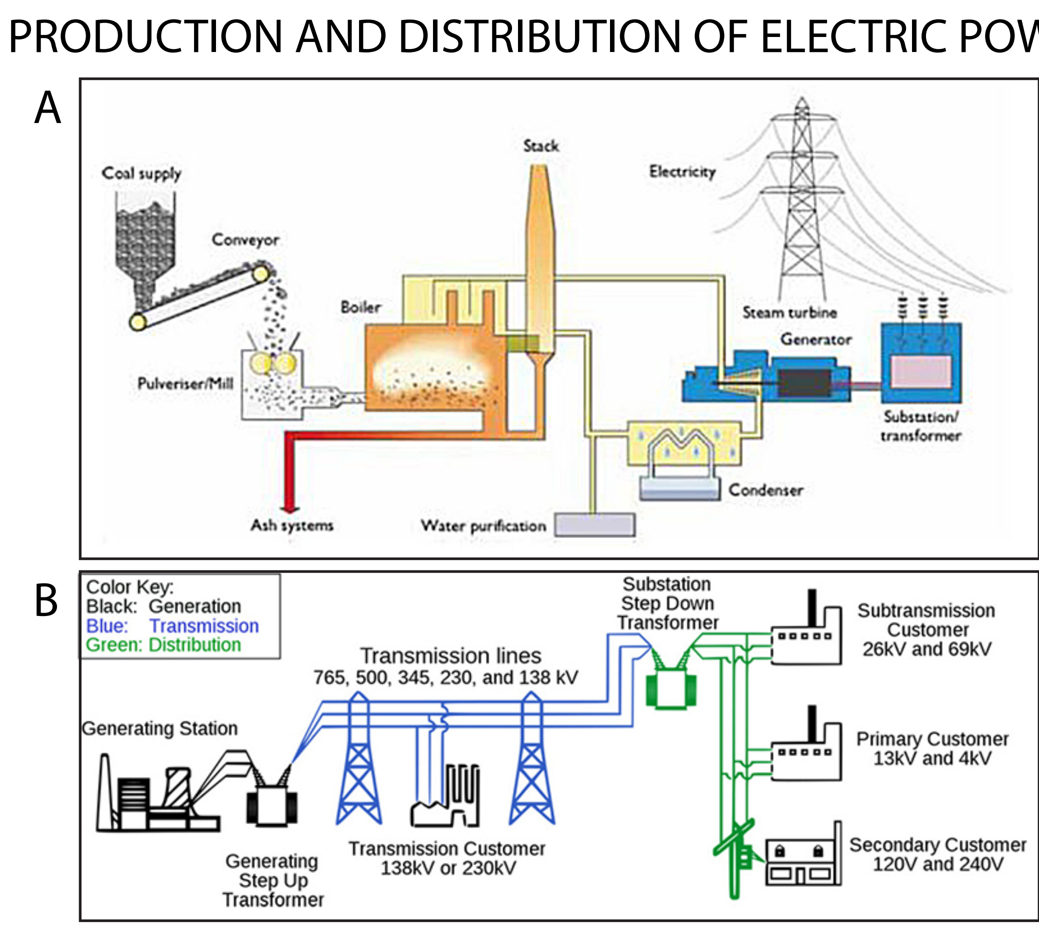

Fig. 12-74. The use of coal in producing electricity (**A**) and its distribution (**B**) over large areas. (ElectricityGrid. Svg)

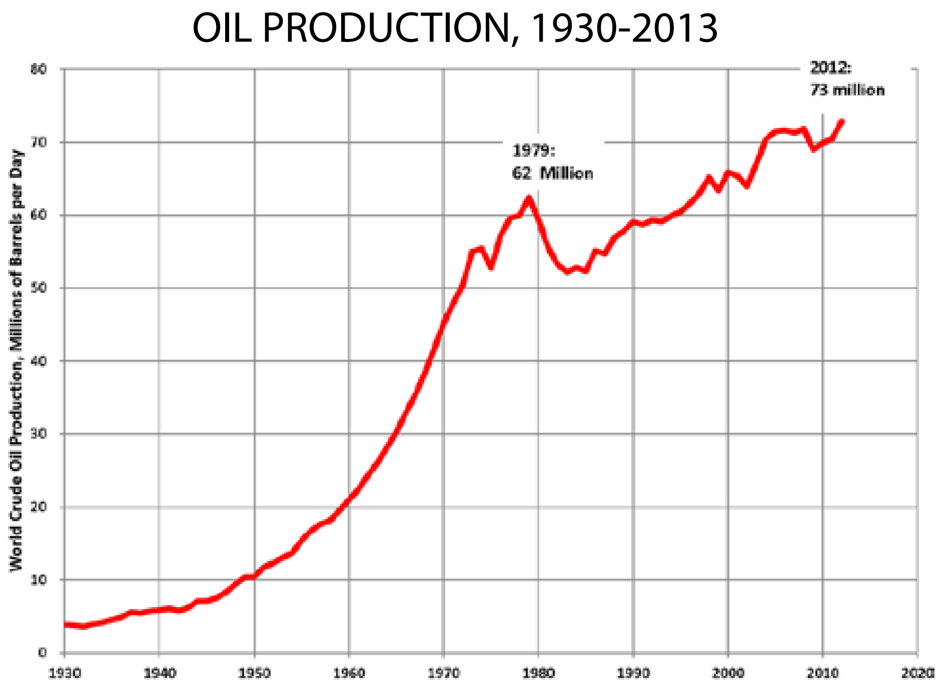

Fig. 12-75. Accelerated growth in worldwide oil production since the end of World War II. (Wikipedia: World oil production)

later such scientific aids as seismology, gravimetry and magnetometry were beginning to be applied to find petroleum fields throughout the world (Yergin, 1990; Yeomans, 2004). Various techniques—distillation, and thermal and catalytic cracking—were gradually developed to separate kerosene, gasoline and lubricating oil from crude petroleum. Initially, gasoline used by automobiles was the principal product of petroleum but progressively it acquired significance as the raw material of the expanding petrochemical industry. Breaking apart or recombining such hydrocarbon molecules as benzene, ethylene, methane and paraffin from petroleum crude also gave new products—plastics, fertilizers, pesticides, and solvents. The growth of oil production has accelerated in the second half of this century but may be peaking (Fig. 12-75). Because oil fields with large reserves are few on the planet, the transportation of oil has become a major challenge. Large pipelines now cross national boundaries, and immense tankers ply the seas to move crude oil, the lifeblood of technological civilization, from wells to refining and distribution centers. Another fossil fuel, natural gas, initially had limited use for heating and lighting, and was conveyed from storage containers to local consumers by small caliber pipes joined by screw couplings. In the ensuing decades, large diameter, seamless pipes were laid down across continents to reach consumers at distant locations. Late in the 1950s a technique was introduced to store natural gas in liquefied form and transport it across seas in special tankers.

NUCLEAR ENERGY. Coal remains one of the major sources of energy use for residential and industrial needs. However, there are deleterious consequences from burning coal and polluting the atmosphere with carbon dioxide—mainly the increase in global warming (Hansen et al., 2006). Eventually, oil and gas reserves will be exhausted. In addition, there are geopolitical considerations about extracting oil from politically unstable countries in the Middle East. Because of these realities, there has been an ongoing search for alternative energy resources for over half a century. A promising source since the end of World War II has been atomic energy created by nuclear fission. The harnessing of fission energy through controlled chain reaction is accomplished by embedding the radioactive fuel in graphite or water to absorb the energy of the released neutrons and use the heat so generated to drive turbines to produce electricity (Fig. 12-76). There are currently over 500 nuclear power plants in operation or under construction in the world, generating about 13.5 percent of the globe's electricity. Unlike fossil fuel power plants, the only substance leaving the cooling towers of nuclear power plants is water vapor, thus it does not pollute the air and increase global warming. France obtains over 75 percent of its electricity from nuclear energy, and changing from an electricity importer through the 1970s, it has become the world's largest electricity exporter. However, the problem of storing the spent radioactive fuel rods has not yet been satisfactorily solved and the danger of nuclear accidents was demonstrated in the meltdown of the Chernobyl plant in the Ukraine and the disaster of the Fukushima plant in Japan. Hence the search has been intensified to find additional alternate sources of energy, such as wind turbines, photovoltaic panels and biofuels.

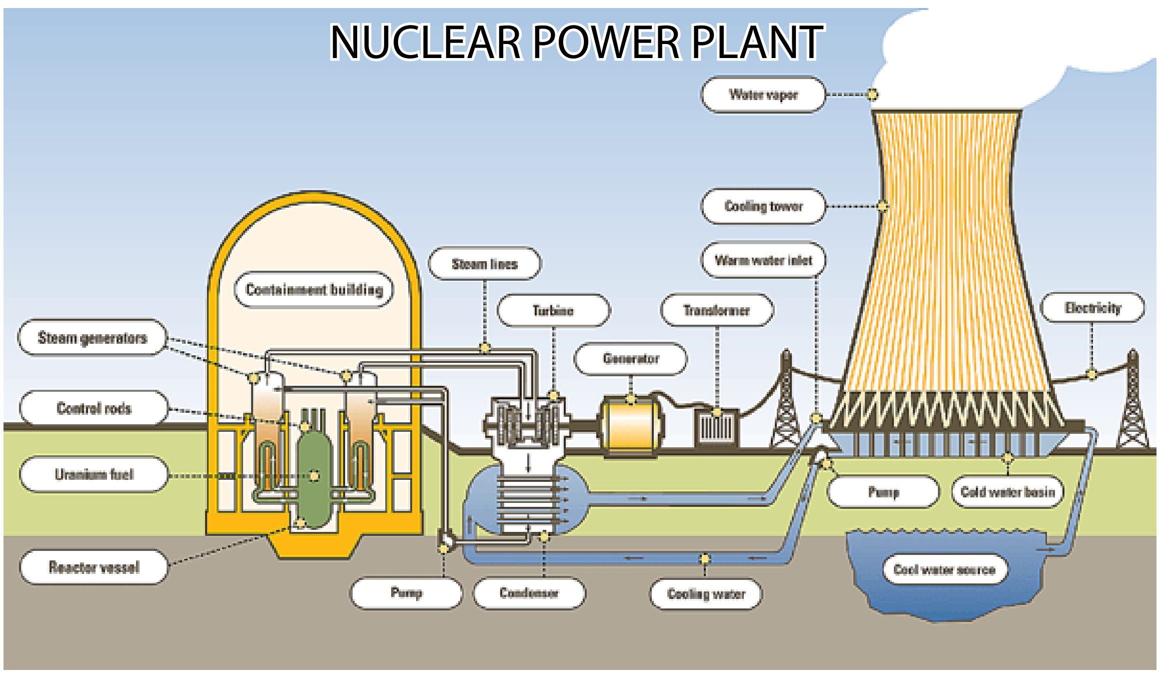

Fig. 12-76. Design of a nuclear facility that generates electricity. (45nucleatplants.com)

Advances in Electronic Engineering. In the 1950s microwave relay towers were built on the ground to carry telephone and television signals, and in the 1960s orbiting satellites were established to facilitate transcontinental signal transmission. Gradually, stationary telephones were supplemented (and partially replaced) by pocket size satellite and cell phones that can be carried anywhere while walking, driving in a car, or flying in an airplane.

TELEVISION. An important development in the second half of the 20th century was the supplementation of radio broadcast by television, the transmission of images by means of radio waves over long distances. Two discoveries led to the implementation of television. One was the observation in the late 19th century that selenium changes its electrical conductivity under illumination, which led to the development of the photocell that transforms light into electric current. The other was the invention of the cathode ray tube (CRT), which allows the transformation of electricity into light. Paul Nipkow obtained a patent in 1884 for the first design of a television system. Nipkow used a rotating disc with apertures to scan a visual pattern, which fell in sequence on a photocell. Then the sequence of the modulated electric pulses was converted back into corresponding light intensities by a lamp that was visible through a rotating disc similar to the one used for scanning. The resolution obtained with this mechanical-optical device was not satisfactory for commercial purposes. John Baird designed the prototype of the modern television in 1926, and the first public television broadcasting took place in London in 1937. Based on the earlier demonstration that an electron beam deflected in a magnetic field can be made visible in a CRT fitted with a fluorescent screen, the magnetic field in both the video camera and the receiver was made to scan the visual field line-by-line rapidly and repetitively in a pattern called a raster. High visual resolution was achieved by up to 300,000 spots (pixels) and up 25 to 30 scans per second. For color television, three electron guns and three different phosphors were used that emit red, green and blue light, respectively. Because of the heavy weight of the CRT, they have been largely replaced by other technologies recently, such as liquid crystal display (LCD) and plasma display (PDP). The latter are lighter, compact, and use far less electricity.

ELECTRONIC DATA PROCESSING. The first "computers" were interactive calculating machines, the oldest of which is the abacus. Mechanical calculating machines based on an assembly of gears were first experimented with in the 17th century. These were greatly improved by the late-19th century and were used in commerce and industry for simple repetitive arithmetic calculations and record keeping. Early in the 20th century these hand-operated machines were changed into electrically driven devices for faster operation and more complex calculations. By the early 1940s electromechanical computers came into use that accepted data from punched cards as input, used electromagnetic relays as switching devices for data processing, and provided output to an electric typewriter. The first electronic computer was introduced in the mid-1940s, using vacuum tubes instead of electromagnetic relays, and thus speeding up calculations thousands of times. The computers that were introduced in the 1960s replaced the vacuum tubes with solid-state transistors—crystalline semiconductors, like germanium or silicon—that were infiltrated with minute amounts of impurities to modify the conduction of electrical charges. The diodes used allow current flow only in one direction; resistors reduce current flow; capacitors store electric charge; and inductors allow DC current flow but block AC current. Instead of wires connecting the components, circuits were printed on one or both sides of an insulated board by a photoengraving process, reducing the lines of the circuit to 5-10 microns (0.001 millimeter). These circuits were assembled to perform specific computations.

The core of contemporary computers is a central processing unit or CPU. The CPU is a single integrated microprocessor that accepts binary digital data (0 and 1 sequences) as an input, uses digital (Boolean) logic for data processing, has a memory bank for information storage, and provides a digital output. It is composed of millions of tiny transistors, resistors and diodes (some smaller than one micrometer) that carry out millions of sequential operations in one second. Smaller than a penny, the CPU is placed on a motherboard and serves as a relay center for all the functions that a computer may be used for (Fig. 12-77). Among its functional components is an address bus which directs the task at hand to the computer's memory; a data bus which retrieves and moves the memory; and read and write lines that instruct the memory to move in place (fetch, decode, execute). While the earliest electronic computers using vacuum tubes may have filled a whole room, computers range now from desktops, laptops to those that fit into the palm of one's hand.

INTEL MOTHERBOARD FOR A PERSONAL COMPUTER

Fig. 12-77. Motherboard with a CPU (square black object, upper right quadrant). (IntelMotherboard.jpg)

As a mindless machine, or "hardware," a computer cannot function without "software." As noted, the hardware consists of input lines, a memory bank, a CPU, and output lines. The software is a fixed or modifiable program that provides the computer with operating instructions. Special-purpose computers are typically programmed by the manufacturer and need little or no programming by the user. In contrast, general-purpose computers, which can perform a great variety of functions, have to be programmed for the particular application they are used for. Specialists, known as programmers, usually do that for the user. The instructions are usually written by a programmer in a standardized "programming language" that a "compiler" and "assembler" converts into the "machine language" of the computer's CPU. The input may be of the analog or digital type, may come from a human-operated keyboard, a magnetic tape, a compact disc reader, an optical scanner, another computer, or a combination of these or some other elements. In the case of analog input, voltage amplitudes code data magnitudes; in the case of digital input, the data are coded in binary form by switching the current on or off. Because "on" and "off" are the simplest and most stable states in electrical systems, data processing in modern computers is digital. In arithmetic calculations on and off represent 1 and 0; in logical processing "go" and "no-go." Calculations are carried out, using Boolean algebra, with a binary code (base of two) for every decimal number. Logical operations are also based on binary coding of logic elements, known as gates, such as "AND," "OR," "NOT," and "NOR." The gates can be cascaded infinitely to produce more complex logic functions. A microprocessor may contain a hundred million gates. The enduring on and off states of magnetic cores, and corresponding transient states of semiconductors constitute the computer's memory system. Each memory cell, being in an on or off state stores one "bit" of information and this is scanned sequentially or by random access very rapidly. While in operation, computers use a temporary working memory store and are capable of processing millions of stored bits of information, as well as the input from the various sources, in a fraction of a second. The output of a computer is usually displayed on a visual monitor, and may be recorded on paper, or passed on electronically to another computer or a machine that performs some work. Before the computer is turned off, the accumulated and processed data have to be stored on an enduring built-in or auxiliary hard disk.

ELECTRONIC AUTOMATION AND ROBOTICS. Mills driven by a steady stream of water may be said to work automatically because they carry out the task for which they were built over extended periods without human intervention. However, computer-aided automation is much more than that. First, it involves the performance by a machine of a series of sequential operations as determined by a program. Second, it involves correction or modulation of that performance by means of feedback mechanisms. Third, it may also involve the ability to choose among different courses of actions as changing circumstances demand. In 1725, Basile Bouchon invented the punched tape for the automatic selection of needles to produce a preset textile pattern (Bright, 1967). In 1804, Joseph Marie Jaquard used punched cards in his loom to produce cloth with different intricate patterns. By the end of the 19th century, punched cards, tapes or cylinders were used in different industries, and also for census work and for recreational purposes, as in the player piano. Depending on the application, the machine parts used for automation are hooks, levers, gears, cams, valves, and the like. This type of automation made possible the accurate execution of long and highly variable mechanical operations without human intervention, and their modification by changing holes in a tape or by changing tapes.

Perhaps the first device expressly designed for the feedback control of the output of a machine was the "governor" used by James Watt in his steam engine (Fig. 12-16). In that feedback system, a set-point is chosen and that level is maintained by negative feedback: when the output exceeds that level, the energy supply is reduced; when the output is below that level, energy supply is increased. Automation was greatly advanced when electrical circuits and electromagnetic switches were put into use to control the operation of powerful machines. Then automation came of age when human operators watching gauges or reading meters were replaced by various sensing devices—such as photocells, thermocouples, piezoelectric transducers, TV cameras—to automatically control the production process by computers. The culmination of automation was achieved in several industries where "robots" replaced human operators (Fig. 12-78) in such task as welding, riveting, assembling machine parts, painting the finished product and packaging it.

INDUSTRIAL ROBOTS IN AN AUTO ASSEMBLY PLANT

Fig. 12-78. Programmed robots performing mechanical operations previously done manually by laborers. (KUKAIndustrialRobotsIR.jpg)

ADVANCES IN TRANSPORTATION. An illustration of the immense technological advance in just over 100 years is the history of aviation. At the beginning of the 20th century, airplanes were small flying machines that carried a venturesome pilot in an open seat for a short distance (Fig. 12-42). The biggest airplanes of today carry several hundred passengers nonstop across continents and oceans in great comfort and safety (Fig. 12-79). The production of reliable aircrafts began during World War I, and the first commercial flights in the 1920s carried a few passengers over short distances and airmail between select cities. The feasibility of transatlantic flight was proven by the solo flight of Charles Lindbergh in a small plane from New York to Paris in 1927. Advances in aeronautic engineering were made during the 1930s and commercial airlines began to offer scheduled flights in Europe and the U.S. that carried up to a dozen passengers. While the early planes used air-cooled engines with relatively low horsepower and cruising speeds below 200 miles/hour, during World War II liquid-cooled and gas turbine engines were developed and planes with one to four engines could reach 350 miles an hour. After the war, planes were fitted with jet engines that can fly close to the speed of sound or beyond. To fly above the turbulence of weather, pressurized cabins with air conditioning replaced the oxygen masks used for breathing. And to enable planes to take off, navigate and land on schedule under various weather conditions and without visual guidance, complex navigational aids have been installed on land and on board for instrumental guidance of the pilot. By the 1980s, the U.S. airline industry operated over 10,000 domestic departures a day from 3,000 airports, some small, others very large. According to statistics compiled by the International Air Transport Association, people throughout the globe, representing about 44 percent of the world population, took over 3 billion flights in 2013. In addition, 50 million tons of cargo was transported in one year, representing 35 percent of the value of goods traded internationally.

COCKPIT AND CABIN OF A BOEING 777 AIRPLANE

Fig. 12-79. The computerized cockpit (**A**) and comfortable passenger compartment (**B**) of a wide-body jet aircraft. (777Boeing.com)

12.5.3. Advances in Agriculture, Nutrition, Medicine and Pharmacology. The immense increase in food production, which has allowed the great majority of people to be engaged in other occupations, was brought about by several scientific and technological developments, including the mechanization of the farm, the breeding of improved varieties of plants and domesticated animals, and the increased use of fertilizers, herbicides, and pesticides, and improvements in food processing, preservation, packaging and distribution. And that, combined with improved health care led to an accelerated increase in the world population.

Advances in Agriculture and Food Production. Advances in agriculture and food production can be followed by the history of farmers' productivity in the U.S. (Wik, 1967). While early in the 19th century a farmer spent 344 man/hours to obtain 100 bushels of corn, by 1910 that amount could be produced in 147 man/hours, and by 1960 that was reduced to 4 man/hours. In the middle of the 19th century one farmer produced enough food for five people, by the end of the century he could supply food for seven people, and by the 1960s for 30 people. Whereas 70 percent of the population of the U.S. lived on farms at the beginning of the 19th century, today less than five percent work full-time on farms.

MECHANIZATION OF THE FARM. In the mid-19th century, the two-wheeled sulky plow was introduced, which allowed the plowman to ride comfortably instead of plodding behind the horses on foot. A few decades later a harvester drawn by a team of horses allowed the processing of 30 acres of standing grain per day and transferring it into sacks for storage and transportation. The first steam engines for traction, harvesting and threshing appeared in the 1880s, but these were bulky and expensive, far beyond the means of the average farm owner. The thorough mechanization of agriculture began in the decades after the introduction of mass produced gasoline tractors and other farm machinery, such as combines that do the harvesting, thrashing and loading of grain in a single operation (Fig. 12-80). As a consequence, the peasant of yesterday changed into a business-oriented farmer who produces a few choice crops or he is bought out by big agricultural corporations that produce grains on a large industrial scale.

HARVESTING COMBINE

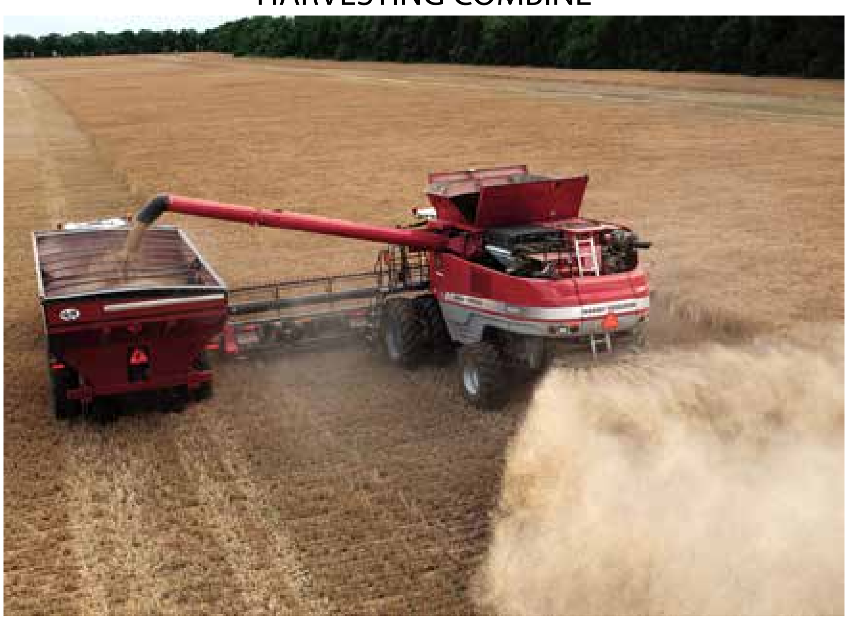

Fig. 12-80. A combine designed for harvesting, threshing, winnowing, and loading grain by a single operator in a large field. (Massey-Ferguson 9500)

CROPDUSTER SPRAYING PESTICIDES

Fig. 12-81. Spraying pesticide over a field by aircraft. (Wikipedia)

USE OF FERTILIZERS, HERBICIDES, AND PESTICIDES. Exhaustion of the land's fertility has been a perennial problem, and so has been the destruction of planted crops by weeds and pests. Early cultivators have discovered that burning a patch of the forest promoted plant growth and that once the land's fertility was exhausted they had to move on and burn another patch of the forest. When the slash-and-burn method was no longer possible as land became precious property, portions of the land were allowed to lay fallow and the growth was plowed under to restore fertility. A more recent supplementary method is to enhance crop yield by using organic fertilizers, such as manure, compost and guano and inorganic ones, such as lime, potash and phosphate rock. Increased understanding of the biochemistry and the metabolic requirements of different plants have led to the widespread use of chemically prepared fertilizers with different proportions of macronutrients, such as nitrogen, phosphorus and potassium, and such micronutrients as boron, chlorine and iron. To eradicate weeds, modern farmers use synthetic herbicides, such as 2,4-Dichlorophenoxyacetic acid introduced in the 1940s, triazine introduced in the 1950s, and glyphosate (Roundup) introduced in the 1970s. The latter is particularly effective when applied to genetically engineered, glyphosate-resistant crops. To rid a multitude of pests that damage crops, a great variety of pesticides are available, which are applied by a variety of means, including dusting by aircraft (Fig. 12-82). However, fertilizers can be a source of groundwater and river pollution, and most pesticides are toxic to livestock and people.

GENETIC ENGINEERING. Farmers have for a long time been engaged in an implicit form of genetic engineering by selectively breeding domesticated animals and planting seeds with desirable traits. Contemporary genetic engineering is based on the direct manipulation of the genetic code of organisms by isolating genes (DNA fragments), cloning them, and inserting them into the genome of selected organisms, such as bacteria, plants, and animals in order to produce particular substances or modify their traits (LeVine, 2006). Examples are insulin and growth hormone produced by genetically modified bacteria; potato engineered to produce higher quality starch; tomato engineered to be redder and have a longer shelf life; crops to be more resistant to pathogens and parasites; and cows to produce more and better quality milk. The benefits of genetic engineering have been enormous; however, the risks of consuming genetically modified nutrients have yet to be determined.

ADVANCES IN FOOD PROCESSING. The mechanization of agriculture and the reduced man-power required for land cultivation led to rural people increasingly moving to towns and cities looking for alternate occupations. This demographic change, coupled with the immense growth in world population, necessitated the development of new techniques for the production, preservation, packaging, distribution and marketing of nutrients. Replacing the old method of preserving a few food items by drying, salting or smoking them, two new methods developed in the second half of the 19th century—canning and refrigeration—increased the year-round availability of perishable seasonal nutrients. Canning, the older method, involves the heat processing and hermetic sealing of a product to prevent its spoilage. Refrigeration was started on a large scale by the mid-19th century by commercial companies using natural ice. By the end of the century, with the introduction of artificial ice—based either on the expansion of compressed air or the evaporation of a volatile liquid—reliance on refrigeration increased, with railroad cars and ships, and later large trucks, carting frozen meat from slaughterhouses to urban processing and distribution centers. Refrigeration moved from industry to the home by the mid-20th century after the introduction of controllable electric or gas refrigerators.

By the mid-1960s in the U.S. about 11 percent of the labor force—more than double of those working on farms—were employed in various branches of the food processing industry (Borgstrom, 1967). That proportion has increased substantially since then as the food industry is producing pre-processed nutrients and pre-cooked meals on a large scale, and as more and more people consume many of their meals in fast-food restaurants. The human diet has changed profoundly as a consequence. Before this new development, non-perishable items, such as bread, cabbage and potato were diet staples throughout much of the year, supplemented by smoked meat or fish where that was available. Periodically, natural or man-made disasters led to food-shortages and famines. Today, aided by refrigeration, rapid transportation and worldwide distribution methods, a great variety of natural and processed foodstuffs are available year-round on the shelves of large supermarkets. The combined result of new techniques of food production, preservation, processing and distribution has been that, contrary to expectations, a food shortage did not develop in economically advanced countries in spite of population growth. Moreover, scientists engaged in nutritional research have determined the daily macro- and micro-nutritional requirements of the individual and many food manufacturers supplement their products with essential amino acids, minerals and vitamins.

However, food abundance and the widespread consumption of high calorie drinks and food, combined with a sedentary lifestyle, have also created epidemic-proportion obesity problems. This is illustrated in the increase in the percentage of overweight children in the U.S. aged 6 to 11 years, and of adolescents aged 12 to 19 years, between 1963 and 2002 (Figure 12-82). There was a threefold increase among the young judged to be obese in about four decades. In adult males aged 20 to 74 years, the prevalence of obesity increased between 1976 and 1994 by 15 percent, and in adult females by 17 percent (Wihbey, 2012). Obesity is a serious health problem as it is closely associated with heart disease, stroke, and type 2-diabetes. According to a recent survey, about 85 percent of people with type 2-diabetes are overweight, and a person diagnosed with diabetes at the age of 50 is liable to live 6 years less than a person with normal weight (American Diabetes Association, Fast Facts, 2013). Interestingly, a relationship has been found in several economically advanced countries between educational level and obesity, the incidence of obesity being much lower in some ethnic populations among those with more years of school attendance (Devaux et al., 2011; Fig. 12-83). This offers the promise that education may halt and possibly reverse the spread of obesity. Indeed, while more than one-third of U.S. adults are currently obese, there has not been any further increase in the prevalence of obesity among children and adults between 2003-2004 and 2011-2012 (Ogden et al., 2014).

INCREASED OVERWEIGHT RATE IN CHILDREN AND ADOLESCENTS, 1963-2002

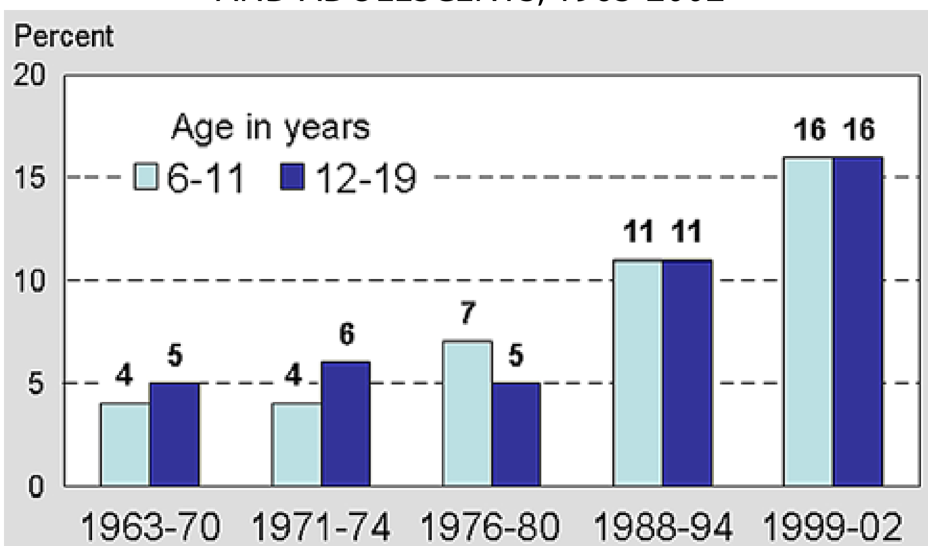

Fig. 12-82. Increase from 1963 to 2002 in the percentage of overweight U. S. children and adolescents in the U.S. (Wikipedia)

RELATIONSHIP BETWEEN OBESITY AND YEARS OF EDUCATION BY ETHNICITY GROUPS IN ENGLAND

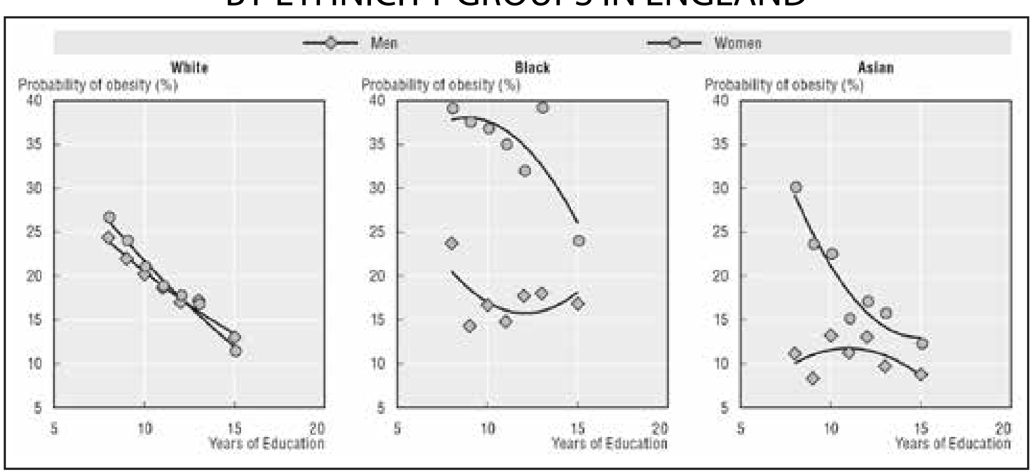

Fig. 12-83. The relationship between years of education and obesity in various ethnic groups in England. (Ogden et al., 2014)

Advances in Medicine and Pharmacology. Until the last quarter of the 19th century, medicine remained a traditional craft mostly practiced by the family doctor. With limited training in anatomy, physiology, pathology and pharmacology his expertise was based mainly on age-old remedies and his personal bedside experience. That changed during the 20th century as medical students came to receive a thorough scientific education, followed by supervised clinical practice and some research. Increasingly, physicians become specialists in some field of medicine. Advances have been particularly pronounced in noninvasive scanning techniques, diagnostic blood tests, surgery and organ transplantation, and the pharmaceutical and immunological treatment of diseases.

SCANNING TECHNIQUES. Wilhelm Röntgen introduced x-irradiation to visualize internal hard tissues, such as bone, in 1895. A great advance in x-ray technology was the introduction in the 1970s of computed tomography (CT), a scanning technique that allows the 3-D reconstruction of compact structures in a patient's body, such as tumors. Another useful scanning method developed by the mid-century was ultrasonography, which allows the visualization of soft internal tissues, including a fetus inside the uterus of pregnant mothers. Widely used more recent scanning techniques include magnetic resonance imaging (MRI) and positron emission tomography (PET). For MRI scanning the patient is rolled into a machine surrounded by powerful magnets that cause atomic nuclei to resonate. That is detected by scanners and is digitally processed to provide detailed anatomical images of the body, including such soft tissues as the brain (Fig. 12-84A). PET scans (Fig. 12-84B) are used to record changes in the level of blood flow in an organ by measuring local changes in positron emission following administration of radioactive oxygen, or changes in the level of metabolic activity by changes in the utilization of the administered radioactive glucose.

DIAGNOSTIC TESTS. Diagnostic tests include chemical analyses of small blood samples from patients and physiological tests of brain, heart, lung, vascular, bladder and other bodily functions. Blood tests are performed in laboratories with swift and reliable automated machines using small blood samples from the patient. These machines can determine the concentration, relative to normal levels, of such inorganic substances as sodium, potassium, and chloride; such organic substances as glucose, cholesterol and triglycerides, the concentration of red and white blood cells, immune system proteins, and the presence of cancer-marking agents.

BRAIN IMAGING WITH MRI AND PET SCANS

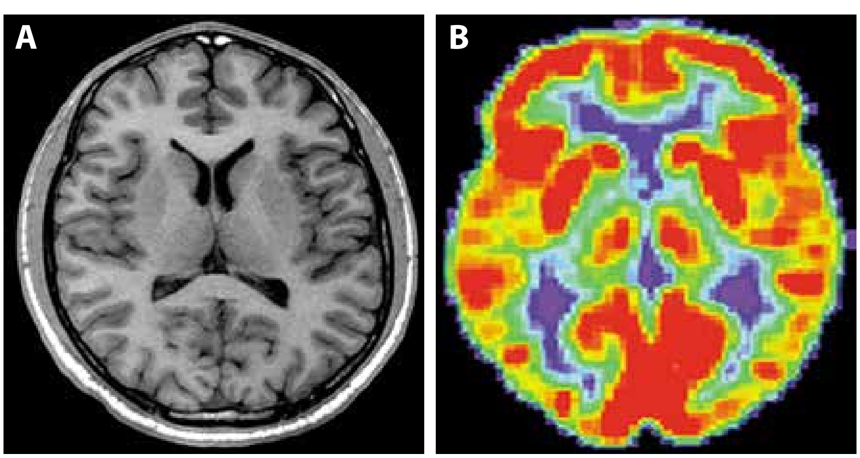

Fig. 12-84. **A**. MRI scan of the anatomy of the head and brain of a subject in the horizontal plane. **B**. PET scan of brain metabolic activity in a subject in the same plane. (**A**. fmrib.ox.ac.uk. **B**. ucair.medutah.edu)

Physiological tests of abnormal organ functions include electroencephalography (EEG) for the brain; electrocardiography (EKG) for the heart, and tests for lung, vascular, urinary and other functions.

MODERN SURGERY. Before the development of modern surgery, operations were largely limited to peripheral body parts, like limb amputations or ablation of superficial tumors. There are reports of alcohol or opium use by ancient physicians to relieve the patient's pain during surgery but surgeons did not regularly use anesthetics. In the battlefield, military surgeons amputated the limbs of soldiers without anesthetics, disregarding their suffering. The anesthetics introduced in the mid-19th century were chloroform, ether, and nitrous oxide, administered by inhalation. Attempts to remedy internal organ pathologies by surgical means were rarely successful. Modern surgery allows the performance delicate operations involving all internal organs and is based on the use (i) of effective and safe anesthetics, (ii) the maintenance of aseptic conditions to prevent infections, and (iii) the prevention of systemic shock during and after the operation.

Complex surgical operations are typically a team effort, including a specialist surgeon (or surgeons), an anesthesiologist, and medical technicians (Fig. 12-85). Local, regional or systemic anesthetics are used to either reduce the patient's pain or render him or her unconscious. The anesthetics are administered by inhalation, intravenously or other routes, and the anesthesiologist monitors and controls the patient's vital functions, such as heart rate and rhythm, blood pressure, breathing, body temperature, and body fluid balance. In developed countries anesthesia-related deaths were recently reduced to 1 death per 10,000 patients (Braz et al., 2009), and in the United States there has been a 97 per cent reduction in deaths attributed to anesthesia since the 1940s (Li et al., 2009). Infection is prevented by rigorous use of aseptic conditions and to prevent stress and shock due to blood and fluid loss during the operation, blood and saline is infused intravenously during and after the operation. Contributing to the success of surgery is the use of antibiotics to prevent post-surgical infections. The combination of these procedures, in association with growing understanding of the physiology and pathology of internal organs, has led to an increasing rate of success in surgical operations involving the heart and lungs, the gastrointestinal system, the urogenital system, as well as the nervous system, including the spinal cord and the brain.

Fig. 12-85. Contemporary operating room with a surgeon, anesthesiologist and technicians. (Corbisimages.com)

BRAIN-CONTROLLED ROBOTIC ARM

Fig. 12-86. Computer controlled robotic arm with fingers, connected by electrodes to the brain of a patient to carry out skilled action by mental volition. (Sciencetech/article2249321)

Among the greatest advances in modern medicine has been organ transplantation, the use of bloodless surgery, and the development of electronically assisted prosthetic devices. Organ transplantation began in the 1950s with the replacement of diseased kidneys taken from a recently deceased donor, followed by liver and pancreas transplants in the 1960s. Successful heart transplantation was achieved by Christiaan Barnard in 1967. Major technical advances since then have lengthened the time that donor organs can be stored with no loss of function and introduction of improved techniques for managing immune rejection (Watson and Dark, 2012). Among other advances in surgery have been the replacement of the scalpel to get inside the body by using laser beams. Eye surgeons use laser to repair tears in the retina, cauterize blood vessels or reshape the cornea to improve vision. Guided by MRI scans, surgeons are experimenting with lasers to remove brain tumors bloodlessly. Another ongoing effort is to develop electronically controlled prosthetic devices. Simple prosthetic devices, such as canes or crutches for the old, wooden legs for amputees, and spectacles for those with poor vision have been used for a long time. More complex contemporary devices are electronic hearing aids for those with auditory impairment and pacemakers for those with abnormal heart functions. And some success has been reported recently in patients supplied with artificial (robotic) legs, arms or hands that, connected by electrodes to the cerebral cortex, he or she can learn to control by sending electrical nerve signals to the device's computer (Fig. 12-86).

THE USE OF ANTIBIOTICS AND ANTIBODIES. The discovery of antibiotics has been the culmination in the use chemical agents in treating bacterial infections. In 1928 Alexander Fleming observed the effect of a strain of mold, *Penicillium*, in inhibiting the growth of staphylococci. A decade later Howard Florey and Ernst Chain developed techniques to isolate penicillin in pure form and produce it on an industrial scale. Penicillin proved effective against bacteria that cause throat infections, pneumonia, spinal meningitis, gangrene, and diphtheria. It proved ineffective against tuberculosis. In 1944, Selman Waksman and colleagues extracted streptomycin from *Streptomycis griseus* to combat that fatal disease. In the ensuing decades many other antibiotics came into use and they effectively control most bacterial diseases. However, antibiotics are not effective against viral diseases. Although, as we noted earlier, immunization against smallpox was known to be effective for some time, its mode of action was not understood. That was accomplished when the immune system of the body was discovered and its properties were clarified. It is a complex humoral system with many elements, most important of which are the large glycoprotein molecules, the antibodies, produced by lymphocytes (white blood cells) that recognize and inactivate a molecular component from foreign agents, known as antigens. (The antibody is analogous to a lock that binds to the antigen, analogous to a key.) An important property of the immune system is that it is adaptive: once antibodies have developed against a specific antigen, those people have immunity to further exposure to that antigen. That is the basis of vaccination to produce immunity. Infectious diseases that have killed millions of people in the past have either been eradicated, such as smallpox; others, such as polio and measles, have been greatly reduced by a worldwide program of vaccination.

THE PRODUCTION OF SYNTHETIC PHARMACEUTICALS. Herbalists have been preparing drugs with real or presumed remedial properties for millennia. The first chemically identified pharmaceuticals were alkaloids—like morphine, strychnine, quinine, atropine, and cocaine—extracted from natural sources in the 19th century. The first synthetic drug, aspirin, was developed in the 1890s by converting salicylic acid into acetylsalicylic acid. It is widely used to this day as an analgesic, fever-reducing and anti-inflammatory agent, and to prevent blood clot formation. The modern era of targeted chemotherapy ("magic bullet") began with Paul Ehrlich's synthetic preparation of a drug known as Salvarsan, which kills the bacteria causing syphilis. As a result of its application, that dreaded human disease has almost been eradicated. Gerhard Domagk began the development of sulfonamide drugs against bacterial agents in the mid-1930s. Ever since, researchers at large pharmaceutical companies have been developing an immense variety of synthetic drugs designed against pathogenic bacteria, protozoa and worms, and a great variety of diseases. Some of them are simple chemicals; others complex ones produced by elaborate processes. Some are administered orally; others intravenously or intramuscularly. There are effective cardiovascular drugs now available that aid the failing heart muscles, promote coronary blood flow, reduce high blood pressure and act as anticoagulants. Drugs that aid the gastrointestinal system include antacids, emetics, and laxatives. Drugs that regulate the reproductive system include synthetic male and female sex hormones and oral contraceptives. There are drugs that ameliorate allergic reactions and support the immune system. Among the drugs that affect the nervous system are analgesics, local and systemic anesthetics, sedatives and psychoactive agents that reduce anxiety and depression, and produce altered states of consciousness.

The Lengthening of Life Expectancy. Due to improved nutrition, hygiene, and preventive and remedial medicine there has been a progressive trend during the 20th century to increase life expectancy. Life expectancy as a statistical measure that may be calculated from the time of birth or from any later age. As we noted earlier (Fig. 12-45) increase in life expectancy has been far more pronounced in the first half of the 20th century when calculated from birth than from the age of 20. That trend has continued until the present. Between 1960 and 2011, a woman's life expectancy from birth increased by 8 years, a man's by close to 10 years (Montez, 2012). A major factor in the initial increase of life expectancy has been the reduction in child mortality. But current developments have also greatly increased longevity in adults. For example in the 10 years between 2000 and 2010, the probability that 65-year-old men will live to be 80 increased from 50+% to 60+%, 65-year-old women from 70+% to nearly 80% (Fig. 12-87A). The probability of reaching 90 years of age increased in men from 12% to 20% (men) and in women from 26% to 34% (Fig. 2-87B).

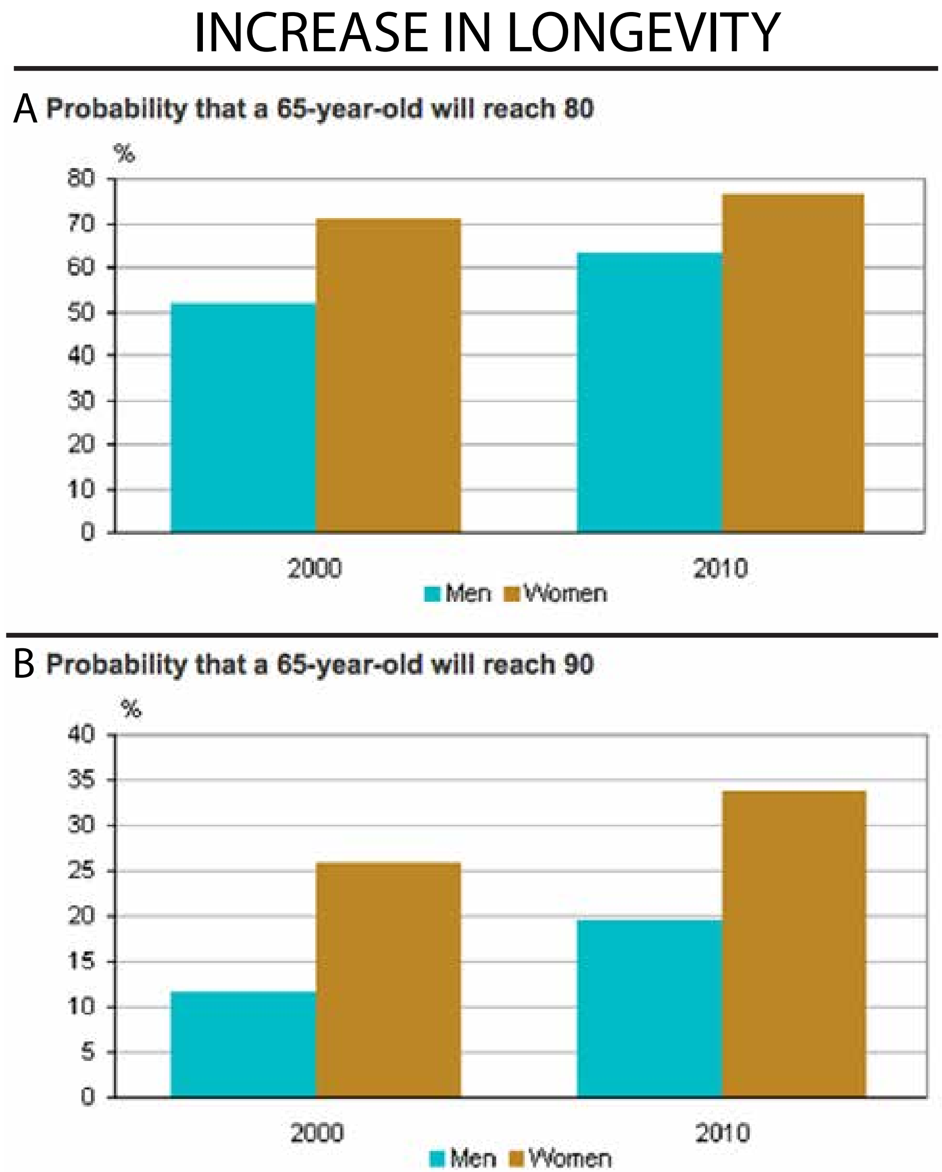

Fig. 12-87. Increases in the probabilities that 65-year old men and women will reach the age of 80 (**A**) or 90 (**B**) between 2000 and 2010 . (Agingstats.gov).

However, this gain in life expectancy has not been universal but is tied to such factors as the economic development of a country and the educational level of a population within a country. In the U.S. there has been a close correlation since the end of World War II between the increase in life expectancy and the gross domestic product (GDP) per capita (Fig. 12-88). And while life expectancy has increased throughout much of the develop d world, there are considerable differences in how long people may expect to live in underdeveloped Asia and Africa (Fig. 12-89).

Undoubtedly better nutrition and improved health care have been contributing factors to the prolongation of life expectancy but another contributing factor appears to be educational achievement (Olshansky et al., 2012; Montez, 2012; Hummer and Hernandez, 2013). Men

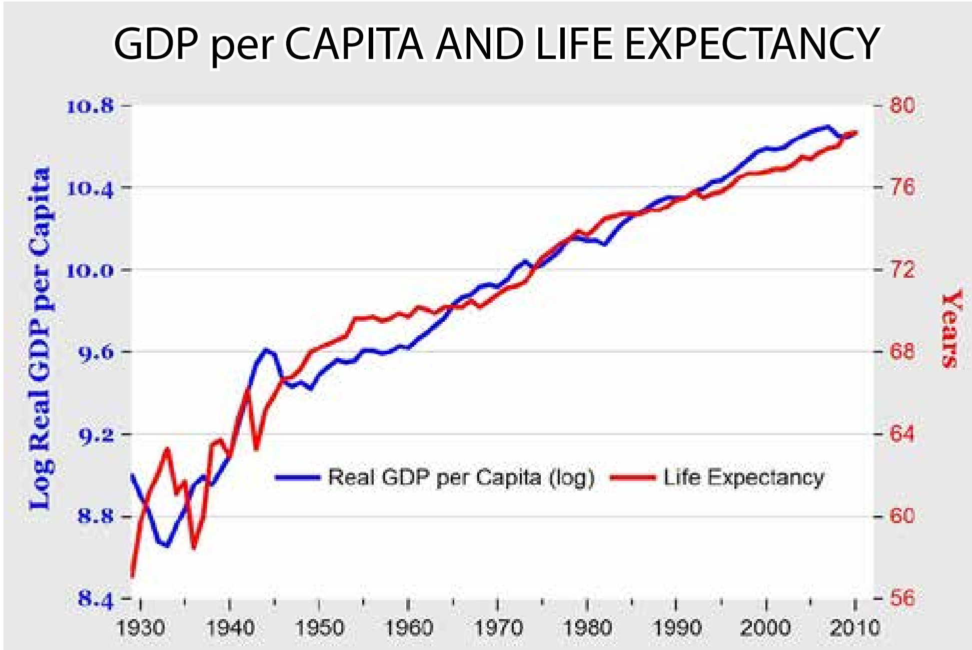

Fig. 12-88. Positive correlation between increase in GDP/capita and lengthening of life expectancy since the end of World War II. (After mjperry.blogspot .com)

REGIONAL DIFFERENCES IN LIFE EXPECTANCY

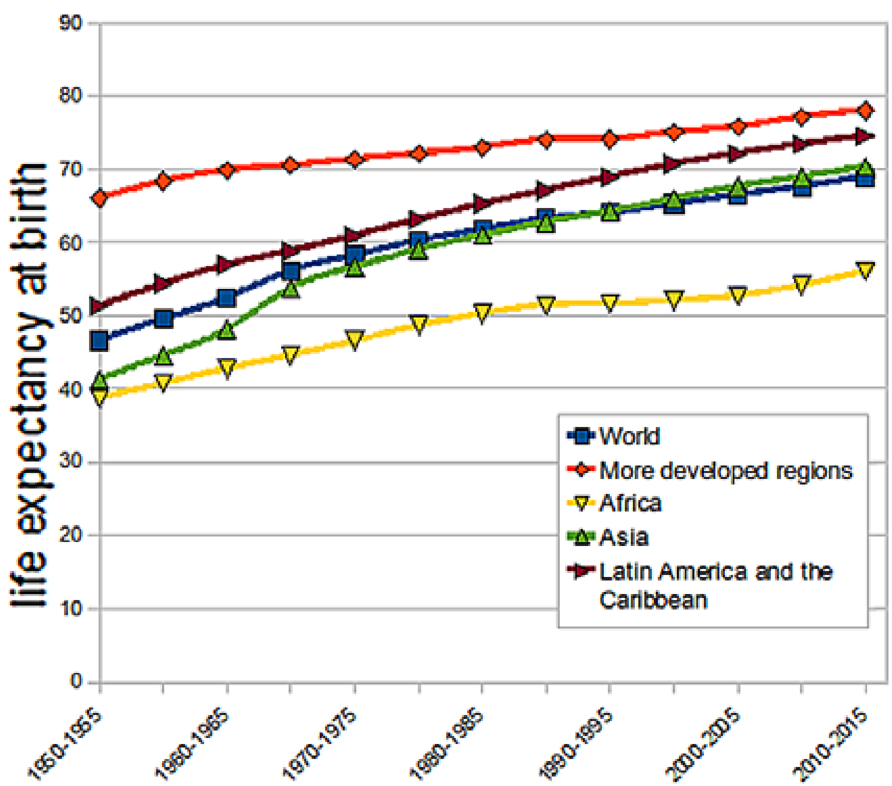

Fig. 12-89. Increase in life expectancy, calculated from birth, in the economically developed and underdeveloped regions of the world. (Wikipedia)

and women aged 25 years without a high school education may expect to live 50 and 44 more years, respectively; life expectancy increases several years if they are high school graduates; and if they have graduate degrees they may expect to live 62 and 60 more years, respectively (Fig. 12-90). The basis of this difference is complex since there is a relationship between educational level and income, the quality of health care one receives, and perhaps also in such personal choices as avoiding smoking and drug use. But broadly speaking, the immense gain in life expectancy may be attributed to three powerful rationally-based modern developments: improvements in the standard of living, advances in public health, and better personal knowledge of how to take good care of oneself.

POSITIVE CORRELATION BETWEEN LIFE EXPECTANCY AND LEVEL OF EDUCATION

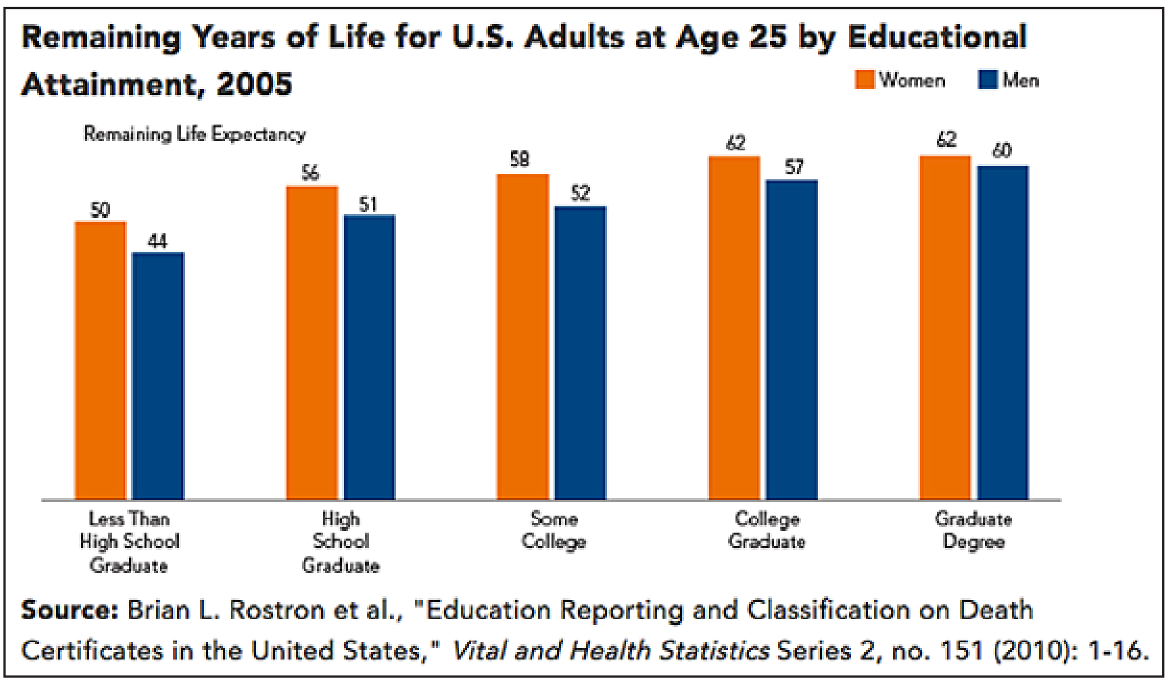

Fig. 12-90. Relationship between years of education and the remaining life expectancy of 25 year-old adults. (Hummer and Hernandez, 2013)

12.5.4. The Cold War and its Aftermath. In sharp contrast to the advances in science, technology and medicine, as manifestations of growing rationalism, the end of World War II was followed by several decades of an irrational political development, the Cold War between the United States and the Soviet Union. Although allied during the war, these two new superpowers with fundamentally different economic and political systems—one capitalistic and democratic, the other communist and dictatorial—were bent upon dominating the world, which led to an open confrontation between them that began in 1947 and lasted until the collapse of the Soviet Union in 1991. While the U.S. and the USSR refrained from directly going to war with one another, they threatened annihilating one another by building a large arsenal of ballistic and guided missiles with nuclear warheads, and openly or clandestinely supported other nations, and factions within nations, to fight one another and join their side. Another conflict that was developing was between the secular and prosperous West and the nationalistic and fundamentalist Mideast. Concurrently, however, there were also some rational social and political developments taking place, such as ongoing efforts to unify the European nations that previously fought one another; the slow transformation of dictatorships into democracies; and the rising prosperity of large segments of the population in the developed nations.

The Cold War and the Collapse of the Soviet Union. The future of Germany and Eastern Europe was the subject of the Yalta conference between Stalin, Churchill and Roosevelt early in 1945, and after Roosevelt's death and the end of World War II, of the Potsdam Conference with the U.S. delegation headed by Truman. Roosevelt was more accommodating ("dovish"), Truman far more confrontational ("hawkish") toward the Soviet Union. Truman informed Stalin of the development of the atomic bomb (detonated a week later over Hiroshima and Nagasaki in Japan), intimating the immense military advantage that the U.S. has acquired relative to the Soviet Union. That may have added to Stalin's fear of U.S. intentions to re-establish a capitalist, free enterprise social order in Europe and his determination to use the power of large Soviet Army to keep East Germany and the eastern block of European nations, as a buffer zone, under Soviet rule.

THE ANTECEDENTS OF THE COLD WAR. An uneasy accommodation took place among the Allies after the World War II, with the Soviets initially allowing democratic elections in the Eastern European countries they occupied. The U.S. and Britain accepted these nations as members of the Soviet sphere of influence (Gaddis, 2005; Wettig, 2008;). However, the communists failed to gain a majority in the free elections. Therefore, the communists abolished political parties by 1948 and established "People's" or "Socialist" Republics in Poland, Bulgaria, Romania, Czechoslovakia, Hungary, Albania and Eastern Germany. To assure one-party rule that obeyed Soviet dictates, the communists set up Soviet-style secret police services, and those who sought to resist or failed to cooperate were intimidated, harassed, jailed or executed. In response to that Soviet action and the rising danger of communism spreading to the West, the U.S. initiated a policy of "containment." That began with the implementation of the Marshall Plan (European Recovery Program) in 1948, providing generous economic assistance to those nations committed to free economic enterprise and a democratic system of government. The explicit purpose was to make Europe prosperous again by modernizing European industry and removing trade barriers; but the Plan also sought to create an anti-Soviet economic block. The Marshall Plan stipulated that most of the funds spent went into purchasing goods from the US and much of it went to rebuilding the participating nations' military. While the Western countries welcomed the Marshall Plan, the Soviets, who were particularly opposed to the rebuilding of the German economy, rejected it and forced Poland and Czechoslovakia to abandon their intent to join the Plan. The first recipients of US aid were Greece and Turkey; two targets of communist expansion that was successfully averted. Then, in the same year, the U.S. government created a unified Department of Defense, the Central Intelligence Agency, and the National Security Council. This was the beginning of the Cold War that was soon escalated and endured for several decades.

THE U.S. AND THE COLD WAR. By 1948, the hostility between the U.S. and the Soviets became a matter of open policy. The U.S. resolution to "contain" Soviet expansion became manifest during the Berlin airlift, which began in 1948, as the Soviets blocked road, rail and canal access to deliver food and essential goods to West Berlin as a way of gaining control of the entire city. The Soviet blockade failed, Berlin was partitioned, and Germany was divided into two nations, the Federal Republic in West Germany and the German Democratic Republic in the East, a Soviet-style dictatorship and police state. In 1949, U.S., Britain, France, and Canada, together with eight other western nations, established a new military alliance, the North Atlantic Treaty Organization (NATO). Military preparedness was combined with a propaganda war (Radio Free Europe, the Voice of America) to foster the demise of communist advances in the member states (such as France and Italy). In 1949, the Soviets detonated an atomic device, and China was taken over by the communists. In response, the U.S. established a military alliance with Japan, Australia, New Zealand, Thailand and the Philippines in the early 1950s. Gradually, the U.S. shifted from containment of communist expansion by economic means to active military involvement. In 1950, the U.S. began military support for France as it battled liberation movements in Indochina led by communists. Also in 1950, U.S. forces were deployed to support the right-wing South Korean government, which came under attack by the communist North Koreans; the Korean war ended with a stalemate in 1953. (The U.S. military retains a substantial presence near the border of the two states to this day.) The Cold War continued after the death of Stalin in 1953. A temporary Soviet "thaw," and several attempts at rapprochement between new Soviet and U.S. administrations failed. A shock to U.S. self-confidence during the Cold War came in 1957, when the Soviets launched the first artificial earth satellite into orbit. Nuclear war became a real threat during the Cuban missile crisis of 1962.

The Soviets and the Cold War. Unlike the U.S., which emerged from World War II unharmed at home and its economy in full recovery from the Great Depression, the USSR was devastated by the war and its economy was in shambles. While there is no evidence that the U.S. leadership had any intention of pre-emptively using atomic weapons against the Soviets, the communist leadership assumed that they would do so. It was evident that, in contrast to the isolationism that the U.S. assumed after World War I, after World War II the U.S. intended to remain a major player in European politics, with the primary aim to make Europe part of the expanding American economy. As hostility between East and West escalated, the Soviets ended multi-party rule in the satellite countries and forced them to adopt harsh Soviet-style communist dictatorial rule. Convinced that a war was imminent, the Soviets concentrated on rebuilding their heavy industry, neglecting their agricultural and private sectors. Daily life remained miserable for the majority of Soviet citizens not only because of continuing food shortages and tardiness in rebuilding the devastated cities, but also because Stalin reintroduced his draconian treatment of anyone suspected of hostility toward communist rule. Contrary to Western expectations, the Soviets detonated an atomic device in 1949 and began a nuclear armament race with the U.S. early in 1950. Facing one another along the "Iron Curtain" with a threatening arsenal of nuclear missiles, each adopted a different strategy to establish its imperialist hegemony. To counter NATO, the Soviets formed a military alliance with Eastern counties under its rule, known as the Warsaw Pact nations. As the latter were reluctant partners, the Soviets used coercive means to keep them in line by stationing military units in their lands and forcing upon them Communist governments that obeyed Soviet instructions.

NUCLEAR PROLIFERATION AND THE SPACE RACE. Ahead of the U.S., the Soviets launched the world's first intercontinental ballistic missile in August 1957, which assured a faster delivery of nuclear devices than by airplanes. That launch directly threatened the U.S. and began the space race between the US and the USSR, each trying to assemble more and more short-and long-range missiles with nuclear warheads. For a period, the Soviets surged ahead of the U.S. in spacecraft technology. In October 1957, they launched Sputnik into orbit around the Earth. Then the Luna spacecraft took pictures of the far side of the moon in 1959, and a Soviet cosmonaut was sent into space in 1961. The space race reached its peak when the U.S. Apollo program successfully landed astronauts on the Moon in 1969. In time it became clear to both the U.S. and Soviet leaders that the nuclear arms race and the race to space were sheer madness. Henceforth, instead of threatening each other with "mutually assured destruction," they began proxy wars. One of the proxy wars was the one fought in Vietnam. U.S. involvement began in 1956 and the war finally ended with U.S. defeat when Saigon fell to the communist Viet-Kong in 1975. It is estimated that 3 million people died in that conflict in which the U.S. used search-and-destroy operations, carpet bombings, and chemical defoliation. Another proxy war was fought in Afghanistan. The Soviets began to deploy forces in 1978 to aid the communist government. To frustrate that attempt and weaken the Soviet Union, the U.S. began to support the Muslim religious fighters (Mujahideen). These fighters, aided by Pakistan, began to harass the Soviet occupying forces to such an extent that the Soviets withdrew from Afghanistan in 1988. The outcome for the U.S. was not a felicitous one, as Afghanistan came to serve as a bastion of the new enemies of the Western World, the Taliban and Al-Qaeda.

THE END OF THE COLD WAR. The Cold War was coming to end by the late 1980s, due partly to the economic exhaustion of the Soviet Union and partly to the unrest and uprisings against communist rule in the Eastern block countries. The arms race that the U.S. imposed on the Soviets led to severe economic hardships on the domestic front. By the early 1980s, the Soviets had an army and a military arsenal (including nuclear missiles) surpassing that of the U.S., with the military consuming as much as 25 percent of the gross national product. Investment in the civil sector declined, leading to shortages of food and essential goods. In contrast, with its economy booming, the U.S. kept escalating the space race by initiating "star wars." The Soviets began negotiations with the U.S. to reduce nuclear arms. The Intermediate-Range Nuclear Forces Treaty was signed in 1987, and an Arms Control Treaty in 1989.

COLLAPSE OF THE SOVIET UNION. The economic stagnation and harsh dictatorial rule led to widespread discontent in the Soviet Union and to uprisings in the Warsaw Pact countries. A revolution broke out in Hungary in 1956 and the new government that formed disbanded the secret police and promised free elections. After a few days the Soviet army invaded Hungary and ended the uprising. There was a growing liberation movement in Czechoslovakia in 1968, the Prague Spring, with growing freedom of speech and the press. That ended as Soviet tanks rolled into Prague and restored the communist regime. Rebellion in Poland began in 1980 with the Solidarity Movement and the Soviets were unable to quell that. 1989 was the momentous year, as Communist rule collapsed in Romania, Poland, and Hungary. Czechoslovakia held free elections; and the Berlin Wall fell in November. The termination of Soviet control of the occupied lands, and the introduction of social and political reforms at home also affected the relationship of the different Republics constituting the Soviet Union. The USSR ruled by the Moscow Politburo collapsed in 1991. Some Republics became completely independent, while others formed a loose Federation of Independent States with Russia.

12.5.5. The Contemporary World: Political, Economic and Social Advances, and Persisting Problems. The savagery of the Second World War and the trauma of the Cold War led to the widespread rational idea that cooperation might be a better way to resolve international conflicts than by fighting in the Western world. Concurrently, the phenomenal advances in science and technology led to a profound transformation of the economic order that resulted in increased prosperity, advances in medicine, better social services, and improved living conditions. However, many old problems as well as new ones remain unresolved.

Contemporary Political Advances. In the political domain the rational advances since the Cold War include the peacekeeping work of the United Nations, the formation of the European Union, and the ongoing democratization of several former dictatorships.

THE UNITED NATIONS. The United Nations (UN) is the foremost institution that has worked for world peace and for the promotion of human rights since the end of World War II (Meisler, 1995; Hanhimäki, 2008). The UN was founded in 1945 with 51 member nations, with headquarters in New York City; by 2008 it had 192 members. The drafters of the UN Charter conceived of this new world organization (which came to replace the defunct League of Nations) as an arbiter of conflicts that arise between its member nations and throughout the world. Although the UN failed to live up to the expectations of its founders by playing a minimal role during the Cold War, it is the only multi-national political organization that the world has ever known. The UN has an elaborate organization with a General Assembly, a Security Council, and numerous agencies and commission dealing with specific tasks and *ad hoc* issues. The Security Council has five permanent members—the U.S., Britain, France, Russia and China—each with veto powers, and ten rotating members that serve for two years. The UN does not have a standing army but relies on peacekeeping forces voluntarily supplied by member nations. Its soldiers do not engage in fighting except in self-defense. The UN operates under financial, logistical and political constraints, and it has a record of successes and failures. Among the past accomplishments of the UN have been the separation of combatants throughout the world, supervising cease-fire agreements, supporting peace initiatives, dealing with human rights violations, promoting economic development, and monitoring world health problems. With all its flaws, the UN has been a leader in the advocacy of human rights on a global scale since its inception. In 1948, the General Assembly adopted the "Universal Declaration of Human Rights," which proclaims that all human beings have the same economic, political and civil rights. The Declaration does not have legal enforcing power but the UN does investigate and report violations. In 1979, the General Assembly adopted the "Convention of the Elimination of all Forms of Discrimination Against Women," and in 1989, the "Convention of the Rights of the Child." In 1993 the "United Nations Commission on Human Rights" was formed; in 2006, the UN issued a "Declaration of the Rights of Indigenous People," and in 2011, the UN passed a resolution supporting the Rights of LGBT (lesbian, gay, bisexual and transgender) people.

THE EUROPEAN UNION. The horror of World War II made some Western politicians dedicate themselves to the idea of uniting Europe economically and politically (Rumford, 2009). Robert Schuman, the French foreign minister, proposed the integration of the coal and steel industries, which led to the Treaty of Paris in 1951, and the formation of the European Coal and Steel Community by France, Germany, Belgium, Italy, the Netherlands and Luxembourg. The Treaty of Rome in 1957 led to the formation of the European Economic Community (known as the Common Market), which was joined by Denmark, Ireland and Britain in 1973, and Greece, Portugal and Spain in 1980. The Maastricht Treaty created the European Union in 1993—which established the free movement of goods, services, people and money across borders (McCormick, 2011). All countries that wish to join the EU are required to have a democratically elected government that guarantees human rights and the rule of law, and protects the rights of minorities. The candidate country must also be economically solvent and prepared to follow the objectives of the EU. Austria, Finland and Sweden joined the EU in 1995; and 12 more countries had joined by 2007. Croatia joined the EU in 2013. The European Central Bank launched the Euro in 1999 as the shared currency of many nations, which is now in circulation in 18 of the 28 member states. As an attempt at political unification, the European Parliament had its first election by universal suffrage in 1993. By 2005, 25 member states participated in the election of representatives to the European Parliament, and its Constitutional Treaty was signed in 2007. While not without serious problems, the EU has survived the severe economic depression of 2008.

ONGOING DEMOCRATIZATION. A constitutional system of government was beginning to form in England in the 17th century and in association with the Industrial Revolution the English political system assumed a democratic character by the end of the 19th century with freely elected representatives of political parties forming governments. Democracy was much slower developing in the rest of Europe as autocratic monarchs and privileged nobles continued to govern most nations. However, by the latter half of the 19th century, most industrializing European nations also began to experiment with democratic systems of government. But, then, while democratization continued in Britain, France and the Scandinavian nations during the Interwar Period, Germany, Italy, Spain, Portugal, and most of the eastern European countries turned into fascist dictatorships. That course of events suggests that economic development and political democratization are not necessarily linked.

While some statistical evidence suggests a relationship between prosperity (GDP/capita) and democratization in some select countries (Boix and Stokes, 2003), another important factor appears to be the civic character of nations (Almond and Verba, 1963). The latter view is supported by a comparison between political developments in countries with stronger or weaker democratic traditions. While the more conservative Catholic-dominated southern European countries (with the exception of anticlerical France) became quasi-fascist or fascist dictatorships during the interwar Period, the more progressive Protestant-dominated northern countries remained democracies. That is, although economic modernization became the shared endeavor of all nations of Europe after World War II, that development was not associated with democratization. Indeed, nations that had little or no democratic tradition and came under Soviet domination—Romania, Yugoslavia, Bulgaria, Hungary and East Germany—endured for decades as dictatorships. And while it can be argued that the Soviet Union and the Eastern European countries were dictatorship under duress, their ultimate liberation was motivated more by nationalistic sentiments and economic hardship than a yearning for democracy. To this day democracy remains a weak institution in Russia and in most of the Eastern European nations.

Contemporary Economic Advances. The extreme economic systems prevailing through much of the 20th century—the ultra-capitalist and individualistic free market economy favored by the U.S., and the ultra-socialist and centralized command economy favored by the defunct USSR—are slowly moving, in line with Keynesian theory, towards a more rational form of government-supervised and mixed economies (Keynes, 1936; Mokyr, 2003; Samuelson and Nordhaus, 2004).

MARKET ECONOMIES AND PLANNED ECONOMIES. In market economies goods are produced and prices are set by supply and demand, with minimal government regulation. In planned economies the government regulates what goods are produced and how they are priced. In market economies industries are owned and financed by rich individuals or by shareholding investors with the principal aim to generate profit. In planned economies industries are publicly owned and regulated by politicians and bureaucrats whose principal motive is to use the profits generated to finance their political objectives. During the Interwar Period, market economies were favored by the Western democracies on the assumption that a free enterprise system managed by entrepreneurs is more productive than a centrally regulated system based on involuntary participation. Radical socialists and communists, on the other hand, advocated the nationalization of industries on the assumption that capitalists will never abandon their practice of exploiting the working class in order to generate more profit for themselves. The historic evidence suggests that in liberal democracies—as in Britain, France and the Scandinavian countries—the enfranchised working class was able to gain concessions and gradually came to receive a larger share of the national wealth. This happened for two reasons. First, joining trade unions and engaging in collective bargaining, the working class was able to compel industrialists to pay them a living wage. Second, through their elected representatives, the working class could compel the government to reign in capitalist abuses. In contrast, notwithstanding the rhetoric that the USSR was a socialist country, the working class lacked the power to demand and receive a greater share of the national wealth, and their economic conditions failed to improve. The public ownership of the means of production turned into a fiction as the communists, preoccupied with the maintenance of their dictatorial rule and the defense of the country, put most of their resources into the maintenance of a vast police apparatus and a powerful military force.

THE DEVELOPMENT OF MIXED ECONOMIES. Mixed economies combine free economic enterprise and state control but vary in different countries as to how large the public sector is relative to the private sector and how much control the government exercises. In some countries, such as the U.S., all industries are privately owned, while in others, such as China, virtually all of them are fully or partially state owned. In still others, some industries and facilities—such as railroads, airlines, public transportation, electric power, mines, oil wells, and medical facilities—are either state monopolies or private enterprises. But there appears to be an ongoing trend for market economies to become more and more regulated by the government, and of planned economies to become more and more market dominated. The Great Depression in the U.S. proved that unregulated capitalism cannot prevent the collapse of a market economy, and legislation is needed to provide a safety net for those who become unemployed. Moreover, it has also become evident that without government regulation, the greed of those bent on making a profit at any cost threatens the wellbeing of people and the protection of the environment. Conversely, the collapse of state economies proves that without a profit motive, people will not exert themselves to make industries flourish.

Increasing Globalization. Worldwide trading is not a new phenomenon. There was long distance commercial trading in the ancient world (Chapter 10, Fig. 10-39) and in medieval times (Chapter 11, Fig. 11-19). However the commercial transactions were small-scale affairs transporting luxury items, such as wine and oil, or fur and textiles in small boats or wagons. Silk and spices were carried on camels' backs. Global trade greatly increased as large sailboats began to carry more goods back and forth between the colonies and the industrializing nations. International trade became more brisk in the 19th century as steamships and trains began to carry raw materials and finished products in still larger quantities and much faster over increasing distances. By the mid-20th century economic globalization has became the backbone of the economy in industrialized nations. Large tankers were built to transport oil from wells on one continent to distant refineries on another. Enormous container cargo ships carry manufactured products across the oceans, and jet aircraft transport quality goods swiftly around the globe. This accelerated international movement of goods has led to the current integration of the world economy, with the result that nations that have previously been relatively isolated and

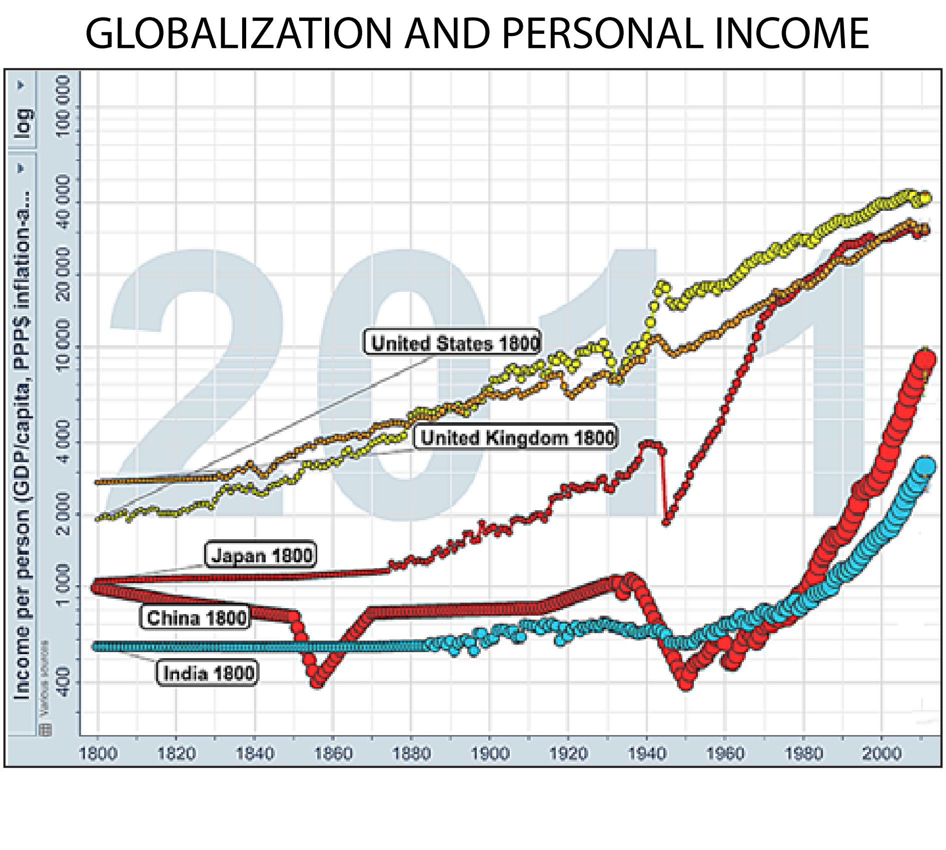

Fig. 12-91. Globalization and income growth a measured by GDP/capita. (Globalization-5.png)

self-sufficient are more and more interdependent with other parts of the world. The consequent growth in prosperity as measured by GDP/capita has been phenomenal (Fig. 12-91).

Globalization of the economy has been facilitated by a variety of rational methods. Paramount among them has been capital investment anywhere in the world where there are untapped resources: raw materials are procured from the cheapest sources; goods are manufactured wherever workers have to be paid the least; goods are rapidly transported using the most economical methods; business transactions are accounted for virtually instantaneously by electronic communication (Osterhammel, 2005; Pfister, 2012). Some giant multinational corporations have capital surpassing many sovereign nations. These corporations have invested in the exploration and exploitation of fossil fuel reserves and mineral resources in underdeveloped nations lacking both money and technology. No less important have been investments made by the World Bank and the International Monetary Fund to foster economic development in backward countries. Other agencies—such as the International Trade Organization—have been instrumental in reducing trade barriers—tariffs and taxes—that impede the international movement of goods. Free Trade Zones around seaports and international airports have been established where goods may be landed, handled and redistributed with little or no intervention by custom officials. Thus many commodities now move rapidly across borders. The outcome has been that goods sold by a company in one country are often manufactured or assembled in another country (or countries) where production costs are cheaper. All the complex financial transactions that go along with this global making, buying, and selling of goods are conducted instantaneously between computers that link branches of these multinational companies with their suppliers for goods and services.

The industrial development of China is an illustration of the rise of the global economy. The social disaster of the "Great Leap Forward" and the "Cultural Revolution" instituted by Mao Zedong in Communist China led in the late 1970s to an economic reform modeled on Western capitalist principles, referred to as a "socialist market economy." Under the leadership of Deng Xiaoping, collective farms were changed into village cooperatives or privatized. Special economic zones were set up with free enterprise businesses, and many industrial plants were changed into joint-stock companies in which the government holds the majority of shares but managers make most of the decisions how to make their operations profitable. Over a period of about 35 years, undeveloped China has become the fastest growing economy, the largest exporter of goods, and the largest creditor nation in the world. Changing from a traditionally isolationist stance, China is gradually becoming a global economic entity with a high proportion of its enterprises financed by foreign investors. In turn, the Chinese themselves are making investments in both the developed and underdeveloped regions of the world. Shanghai has become the world's busiest trading port.

Contemporary Social Advances. A major consequence of industrialization—indeed, what sustains it—has been fundamental changes in the life style of a vast number of people. Paramount among these changes are an increase in the average person's standard of living and greater individual freedom in choosing what career a person might follow.

THE GROWTH OF PROSPERITY AND THE CHANGED LIFE STYLE. The transformation of state economies into market economies throughout much of the world, and the consequent globalization, has had many beneficial consequences. The immense rise in productivity, brought about by the international flow of capital investment has led to the availability of a variety of goods that the average working person can afford to buy and enjoy. More and more people in the economically developed nations have come to own their home furnished with such conveniences as electric refrigerators, washers, driers, air conditioning, telephones, television sets, private cars and many other conveniences. More and more people are taking advantage of the immense variety of food items displayed on the shelves of supermarkets and dine out in fast-food restaurants where they are served tasty meals relatively cheaply. Worldwide travel, something that has been the privilege of the rich in the past, has become available to people with average means. Large jet planes take masses of people to visit distant lands or to vacation sites, or they can get on board of large ships, basically floating hotels, to tour the world.

Instead of doing virtually everything manually, as was the old way, almost everything people do in the contemporary developed world is done with the aid of laborsaving devices and machines. The farmer who produces wheat no longer holds on to the handle of the plow or wields a scythe to harvest, and his wife does not spend hours grinding the wheat to make flour. The farmer drives a tractor and his wife, instead of collecting wood and making fire in the morning to bake bread, goes to the supermarket and buys readymade bread of her choice. And she does not walk or rides on an uncomfortable wagon to get to the market but gets into a car that takes her to the shopping center swiftly and comfortably. To have company after breakfast she can call family or friends by dialing their number on the phone, and to be entertained she can turn on the television set and watch a program of her choice. That change in life style has accelerated in the last few decades as people carry miniaturized devices in their pockets to watch the news, play games, or communicate with others irrespective of the distance between them. Not everybody currently enjoys this life style but few reasonable people on earth would reject adopting this life style given the opportunity.

THE GROWTH OF DEMOCRATIZATION. The basis of growing prosperity has been advanced industrialization combined with a free market economy. Virtually all nations of the world have adopted it or are in the process of adopting it because industries with superior tools and technologies, and businesses with superior management and accounting practices displace those that use less rational means and methods. However, people also desire political and social freedom guaranteed by a democratic system of government, and that has been slower in developing. That is so because growing prosperity can also be masterminded by dictatorships, as demonstrated by communist China's adoption of a state-controlled capitalistic system. But even though political democracy is not a prerequisite of economic prosperity, there are reasons to believe that economic modernization will ultimately lead to increased democratization. First, on the national level, economic development has led to an increasing complexity of the social order, with consequent decentralization of political power (Charlton and Andras, 2003). Nations with a multiplicity of institutions, such as central and regional civil services and a large military force on the one hand, and a banking system, a stock market, professional associations, medical establishments, schools and universities, etc. on the other hand, will develop different powerful interest groups that have to engage in dialogues and make compromises. Second, advanced industrialization needs a growing educated class and, unless amply rewarded by the political system, educated people are less likely to accept the propaganda of dictatorships than the uneducated. Third, and most important, modern communication technology—the Internet with its search engines, cell phones and global social networks—are inevitably changing closed societies into open societies. People with computers, cameras and i-phones come to know what transpires in the world instantly and can access information with a few clicks on any subject or issue. Better-informed and better-educated people tend to think for themselves and demand freedom of expression more than do ignorant people. Millions of people throughout the world with computers and smart phones use the search engines of the Internet to find information on any subject that interests them and keep abreast of what goes on in the world. This is a democratic trend that is bound to end the ability of dictatorships to retain their monopoly on the dissemination of information available to the public.

Persisting and New Social and Political Problems. But in spite of increased affluence and growing democratization, the modern world has many unsolved old problems as well as some new ones. Among the social problems are: unchecked population explosion; persisting poverty throughout much of the world; rising unemployment; and a growing income gap between the rich and the poor. Among the persisting political problems are: hostilities between minorities within nations; wars between nations; the inability of the industrial nations to agree how to curb the degradation of the environment; and the conflict between the secular Western world and the religious fundamentalists in the Muslim world.

POPULATION EXPLOSION, POVERTY AND CRIME. A dangerous development directly attributable to the great advances in science and technology has been the human population explosion. Populations remain constant if there is a balance between birth rate and death rate; there will be an incremental population growth if the birth rate exceeds mortality. The great gain in agricultural productivity since the Industrial Revolution combined with the reduction in infant mortality and the increase in life expectancy have led to an immense acceleration of today's world population. From about 1 billion people in the world in 1800, population increased to 2 billion in 1927—a little more than 200 years. Another billion was added in little more than three decades. But then it increased from about 3 billion in 1960 to 7 billion in 2011 (U.S. Government Census, 2011)—only 5 decades for an increase of 133%. Importantly, much of the recent population increase (an estimated 74 million persons/year) is taking place in the underdeveloped world. Poor people lacking adequate education and steady jobs, and without government-guaranteed social services tend to have many more children as a traditional way of economic survival and an attempt to assure life support in old age. The problems of overpopulation are multiple. If it continues, overpopulation may exceed the resource capacity of the planet for food and shelter. Overpopulation leads to the degradation of the environment as the production of more and more goods and food lead to the burning of growing amounts of fossil fuels, pollution of the atmosphere, and pollution of the hydrosphere by overuse of herbicides and fertilizers.

Billions of people have not fared well in the contemporary world. Increased availability of industrial jobs have made poor people move in masses from the countryside to the cities, and from poor countries to rich countries, where they earn little and live under miserable conditions. And even where conditions have improved in terms of wages earned, daily life has become very difficult in terms of the hours that people have to spend at work and the tempo they have to maintain. People seeking employment cannot choose where to live but are forced to move wherever jobs are available, often by leaving behind or abandoning their families. And even in developed nations, as a consequence of rapid industrial development, jobs are no longer enduring. Companies that were profitable one year, fold up in the next, and due to increasing automation, machines or robots increasingly carry out work that people earlier performed manually. High unemployment has become a ubiquitous feature of the prevailing social order.

The growing gap between the rich and the poor. After the end of the Second World War, the U.S. promoted the adoption of market economies in its sphere of influence, whereas the Soviets insisted on the adoption of planned economies by the Eastern bloc nations that they dominated. While free trade was not exactly established in the West after 1945, it was considerably liberalized, in particular in areas that served U.S. commercial interests. Large business corporations and financial firms were created with multinational branches that became ubiquitous throughout the world. The fall of the Soviet Union, which was due largely to economic failure, appeared to prove the superiority of free market economies relative to planned economies. However, since the end of communist threat, there has been a resurgence in the power of large financial and commercial corporations and a diminution in the power of the trade unions in many countries, a development that has contributed to the increasing gap between the rich and the poor in the share of national wealth (Gregory and Stuart, 2003; Rosanvallon, 2003; Piketty, 2014).

Culture wars between the West and radical Islam. The hostility between the Muslim and Western civilizations has a long history. Arab Muslim conquerors routed Christianity in the Near East and Egypt in rapid order in the 7th century, and later Arabs and Berbers occupied most of Spain, and still later, Ottoman Turks occupied much of southeastern Europe (Lewis, 1993; Saikal, 2003). When the backward West began its military and economic recovery, a holy war developed between Christianity and Islam (the Crusade and Jihad, respectively). As both Muslims and Christians were proselytizers, firmly believing that their religion was the absolutely true one that all people had to adopt to remain in God's good graces, that clash was unavoidable. That culture war ended eventually in Western victory, with the Catholic re-conquest of Spain and the slow disintegration and subsequent dissolution of the Turkish Empire. The hostility was re-ignited as Muslim lands formerly under Turkish rule (Syria, Iraq, Iran, Arabia) came under Western imperialistic domination, and the discovery of their immense oil reserves made that domination of great economic and strategic importance. Muslim opposition to Western imperialism developed partly under the banner of nationalism but more importantly it took the form of religious resistance. The Islamic world has had no Reformation or Enlightenment and the majority of Muslims still live in a medieval style Age of Faith run by clerics, fighting religious wars among themselves as the Christians did a few centuries ago. Although the more advanced Muslim nations have lately adopted Western industrialization—Pakistan has a nuclear arsenal and Iran seeks to acquire one—they still reject Western science and secularization. The population explosion is rampant in several Muslim countries and poverty is widespread. Muslim nationalists and religious fundamentalists currently fight the West with whatever means are available to them, which has taken mostly the form of terrorism led by partisan-style groups.

DEGRADATION OF THE ENVIRONMENT. We have already referred to the degradation of the environment by such practices as mountain top removal for mining coal. Far more devastating than that has been the large-scale burning of coal and other fossil fuels that, releasing carbon dioxide into the atmosphere has led to global warming, due to the greenhouse effect. Climate change is a natural phenomenon and a perennial feature of the earth's history with a profound effect on the survival of different species of plants and animals. Alternating glacial and interglacial periods of the past have been attributed to variations in solar radiation and changes in the earth's orbit, volcanic eruptions, mountain building tectonic plate movements, and other physical forces (Dryzek et al., 2011; Black et al., 2013). An altogether new phenomenon has been global warming attributable to human activity, the unremitting burning of fossil fuels in immense quantities, which has led to the accumulation of carbon dioxide in the atmosphere (Fig. 12-92). The energy distribution of global warming is a complex phenomenon since it is affected by changes in the movement of air masses, levels of precipitation, different forms of water sequestration, changing ocean currents, and other factors. But it is an established fact

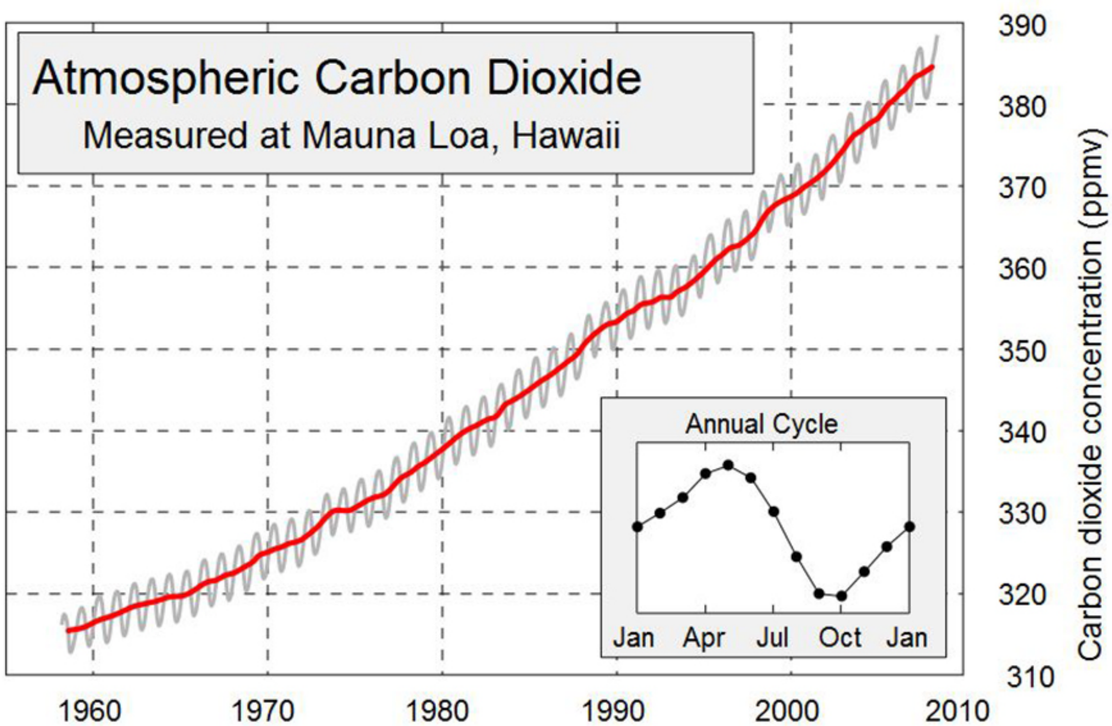

Fig. 12-92. Seasonal variation (inset) and cumulative increase in CO_2 accumulation in the atmosphere since 1960. (MaunaLoaCarbondioxide-en.svg)

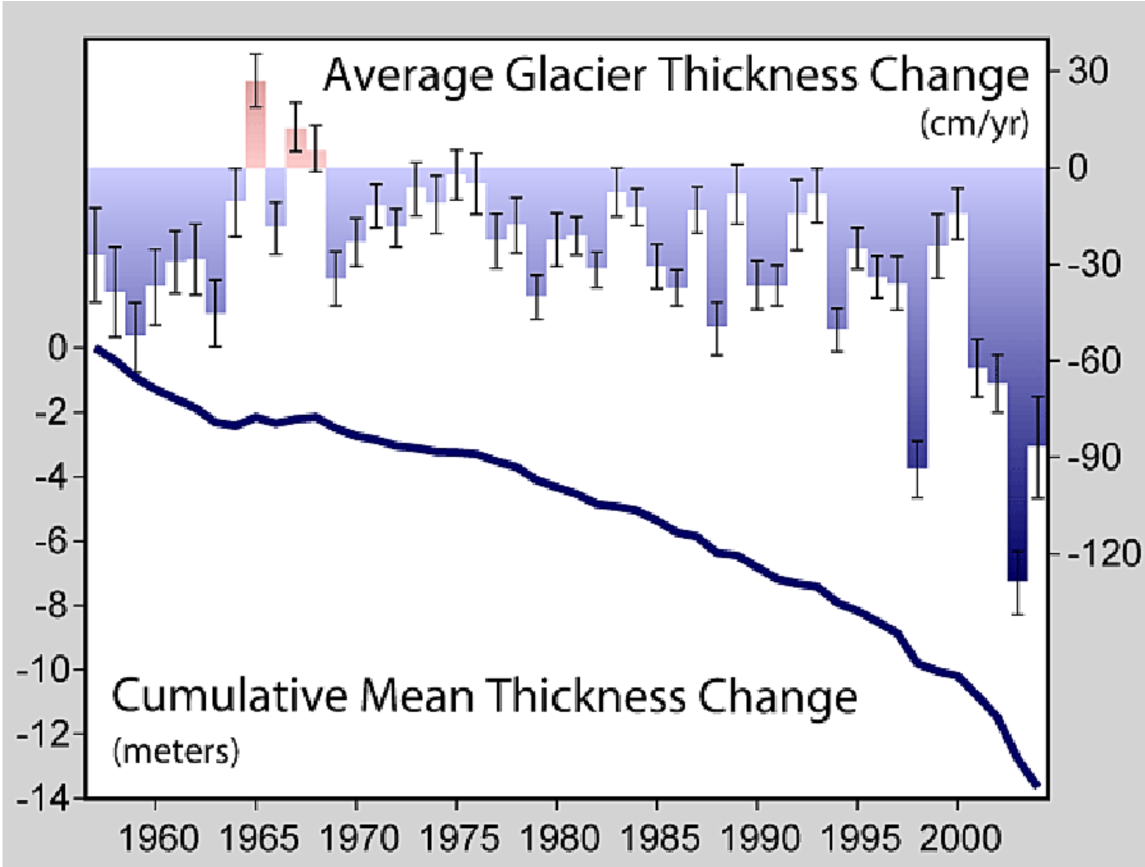

Fig. 12-93. Changes in the thickness of mountain glaciers throughout the world since 1960, and considerable reduction since about 1995. (GlacierMassBalance.png)

that, due to its greenhouse effect, carbon dioxide accumulation has led to the melting of ice sheets and rising sea levels. An illustration of this is the World Glacier Inventory, compiled since 1970 and based mostly on satellite photographic tracking of more than 100,000 glaciers. The glaciers have been retreating and become thinner in recent decades (Fig. 12-93). This reduction of the ice fields and snow accumulation threatens agriculture in many lands where water for irrigation comes from the great rivers fed by the thawing of snow in the spring, and rising sea levels threaten to swamp low lying lands and cities. It is unknown whether or not it is still possible to halt or reverse global warming but it certainly something that cannot be accomplished without the united actions of rationalist governments that respect scientific evidence.

In summary, a powerful force in the history of Western civilization since the 17th century to the present has been an uninterrupted advance in science and technology. The commitment of scientists and scholars to use observation, experimentation, record keeping and logical reasoning to advance our knowledge of the world we live in, and the effort of engineers and inventors to exploit its resources has been a continuous rationalist effort and has profoundly changed the pattern of our culture. However, what we have called universal rationalism—the application of reason to solve political problems, ordering social relations, and guide individual behavior—has only been partially achieved and has suffered many reversals. Irrationalism still prevails by resorting to brute force in solving personal, social and international problems, and in the failure of equitably distributing the planet's natural resources and the fruit of the labor of its inhabitants. Science and technology are still being used to design ever more powerful and destructive weapons, and industrialization has led to the impoverishment and displacement of large populations, and the degradation of the environment. Billions of people live in abject poverty, not because they do not wish to become members of the modern world, but because the goods produced are not distributed fairly and equitably. Ruled by the privileged few with immense power and wealth, the world economy remains exploitative and the political system dysfunctional.

Our argument has been that this state of affairs prevails because we are not universally but only selectively rational creatures. As part of our evolutionary heritage and neurobiological constitution, our thinking and behavior are motivated, guided and biased by inborn emotions and/or products of our early learning, education and the assimilation of our cultural heritage. In dealing with personal and social problems—existential matters rather than theoretical issues—we regularly use rational means in pursuit of irrational ends. Feelings and emotions, such as love and hate, hope and fear, generosity and greed, compassion and envy, admiration and resentment, gratification and frustration, and so forth, influence how we think of others and interact with them. Our thinking and behavior are also influenced by our life experiences and the conventions, tradition, mores and morals of our culture, which we acquire through social facilitation, education and indoctrination. These include emulation of role models, assimilation of religious convictions and political ideologies, acceptance of prevalent prejudices and superstitions, and obsessions and compulsions traceable to personal life experiences and traumas. Our thinking and behavior are also influenced by the political and social system we are born into and our social status within it. We think and act differently whether we are raised in a democracy or in a dictatorship, as members of a privileged or an underprivileged social class, wealthy or poor, with a talent that is highly prized or one that is not valued. We discuss this complex interaction of feelings and emotions, learning and traditions, and empirical and critical reasoning in the formation of the mindset of modern man and the ethos of modern culture in the next chapter.