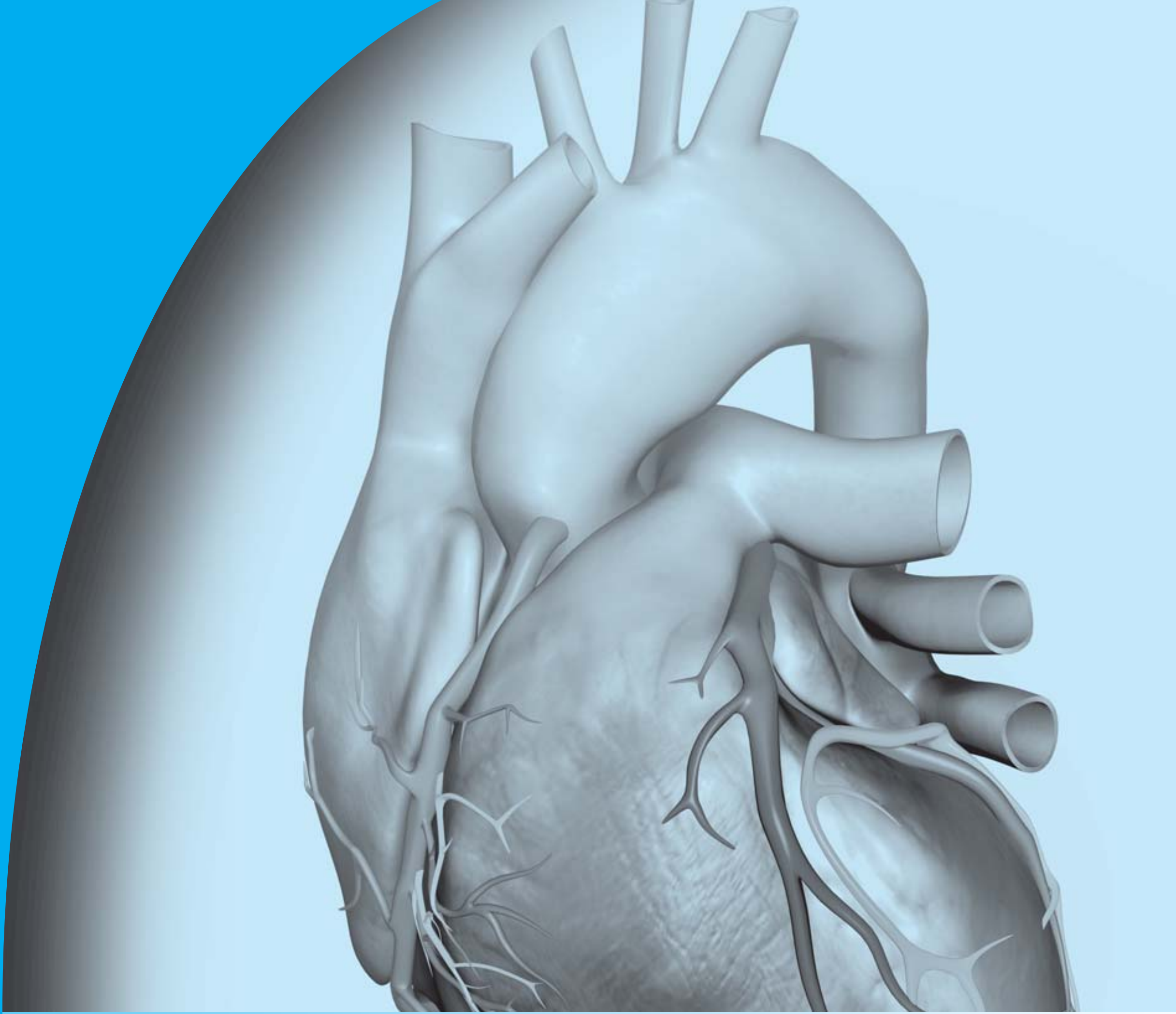

PART I

Concepts of Health and Disease in Public Health

INTRODUCTION

Constance Battle

"I seek a method by which teachers teach less and learners learn more."[1]

—Johann Amos Comenius (1592–1670)
Author of the first illustrated textbook and father of modern education

Part I attempts to make sure that education occurs by illustrating diverse ways for students to explore assorted themes around the science of human life on earth. By no means all-inclusive, these six chapters suggest additional or alternate ways to approach learning biology as a preparation for understanding health and disease.

The book begins as it should with history, with one philosopher-historian's insistence that science is **the** way of knowing. A second chapter maintains that students must go beyond biology to its fundamental level: to biochemistry. Three other chapters address the interactive and relative contributions of human genetics, individual behaviors, and the constantly changing environment—all major areas of inquiry for biologists. The interactions among germs, genes, geography, and human behavior have resulted in a marked increased in life expectancy over the last century, addressed in the chapter on aging. Finally, the remaining two chapters suggest new ways of thinking about disease causation: some diseases ameliorate others and some diseases are drug-induced.

In summary, these six chapters address several of the main disciplines that, when combined, reveal different interpretive, contributory approaches to understanding biological sciences, medical science, disease causation, science of ecology, science of epidemiology, the study of history, and the behavioral sciences.

I encourage you to read these chapters as Francis Bacon would have you do: "read not to contradict and confute; nor to believe and take for granted; nor to find talk and discourse; but to weigh and consider."[2]

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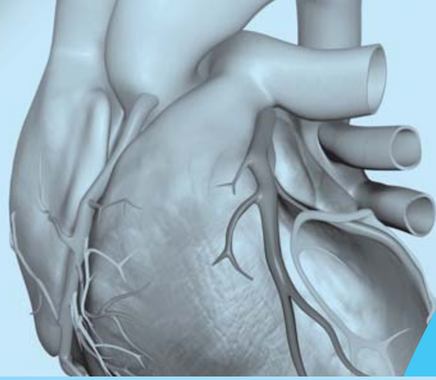

CHAPTER 1

Essay: The Origins and Achievements of Modern Science

Richard H. Schlagel

There is no human endeavor, whether it be artistic, musical, literary, political, or legal, more important than the acquisition of knowledge. Even morality depends upon understanding the principles, choices, and consequences of ethical behavior. The only reliable means so far for attaining knowledge is the scientific method. It has lifted humanity from a state of complete ignorance to some understanding of the universe and control of events.

For primitive humans, the causes of nearly everything were unknown: the origin and order of the universe; the nature of human conception and embryological development; the structure and function of our organs; the explanation of fire, lightning, and thunder; the nature of matter, energy, and chemical processes; the cause of diseases, plagues, and other natural disasters; the formation of the earth's topology; how inherited characteristics are acquired and transmitted, and so forth. Lacking more effective explanations, humans created mythical narratives to account for phenomena, such as Prometheus bringing fire or Zeus throwing thunderbolts, or they adopted as a model of explanation the most familiar form of causality, that human acts are intentional, willed, or commanded. Thus, phenomena were intentionally caused by "evil spirits," "demons," "guardian angels," or "deities," and supplications in the form of human or animal sacrifices were common.

THE GREEKS

The one ancient society capable of piercing the veil of myth and casting aside anthropomorphism was the ancient Greeks, who eventually sought natural, as opposed to supernatural, explanations. In the sixth century BC, Anaximander began the tradition with his theory that the present universe arose from a previous state of chaos by a process of "separation," not by an act of god. Subsequent Greek theories foreshadowed later developments of science: the Pythagorean claim that the numerical harmonies underlying the musical scale also generated the order of the cosmos; Empedocles' doctrine that fire, earth, air, and water constituted the four basic elements of the universe—factitiously referred to as the Greek Periodic Table—and that land creatures evolved from sea urchins; believing that the four elements were not sufficient to explain the great diversity of things, Anaxagoras declared that in its original state, "All things were together, infinite in respect of both number and smallness." To avoid the paradox of elements being both infinitely large and infinitely small, Leucippus and Democritus introduced the theory that matter consists of indivisible atoms, whose deterministic interactions cause the diversity in the universe which itself was eternal, infinite, and composed of endless solar systems.

Although Plato did not believe an exact knowledge of the Receptacle or imperfect world of becoming was possible, his pupil Aristotle created one of the most enduring and comprehensive cosmologies and theories of explanation in history. His organismic cosmology culminating in the Prime Mover and explanatory framework of substance and form, the four causes, and syllogistic reasoning dominated Western thought from the 13th through the 17th centuries. The influence of Greek astronomers is evident in Copernicus' justification of his defense of heliocentrism by citing Greek forerunners: Proclus, who held that the earth revolved around a central fire analogous to heliocentrism; Heraclides, who argued that it was simpler to attribute the apparent diurnal rotation of the whole universe from east to west to the rotation of the smaller earth from west to east; and Aristarchus, who first proposed the heliocentric system in the second century BC.

Because these proposals contradicted ordinary observations, it was Claudius Ptolemy, a Greco-Roman who lived in Alexandria in the second century AD and whose geocentrism comprised a complex system of epicycles and equants "to save the phenomena," who was the leading astronomer until Copernicus. Other innovations were Euclid's geometry so essential to astronomical calculations and Archimedes' "method of exhaustion" that anticipated modern differential calculus in computing the rate of change of a function with respect to an independent variable.

Another area where the Greeks made outstanding contributions was medical science. While the practice of medicine in other societies at that time generally relied on magical potions, mysterious remedies, or superstitious rituals in the hope of curing wounds, illnesses, or diseases, the Greeks advanced the science of medicine by empirical research. As Morris Cohen and I. E. Drabkin assert in their excellent book, *A Source Book in Greek Science*, "Although reason and observation were not absent from pre-Hellenic medicine, it was among the Greeks that rational systems of medicine developed largely free from magical and religious elements and based on natural causes."

Hippocrates of Cos, the founder of the tradition, is called the Father of Medicine. Among its contributors was Aristotle, whose treatises on the history, parts (describing vivisection of animals), and generation of animals were extremely influential, and Herophilus, who lived in the latter part of the fourth century BC and advocated the humoral theory. Herophilus was famous for his investigations of the eye, brain, and nervous and vascular systems. His younger contemporary, Erasistratus of Ceos, is known particularly for his anatomical and physiological research, and his theories of digestion, blood flow, and the causes of disease. Asclepiades of Bithynia worked mainly in the first century BC and, like Erasistratus, rejected the humoral theory for a mechanistic-atomic theory, which maintained that health depended upon the harmonious status of the corpuscles throughout the body. Finally, the Greco-Roman Galen in the second century AD is considered the greatest physician of antiquity. His influence extended to that of Vesalius and Fabricius in the 16th century.

THE POST HELLENIC WORLD: THE MIDDLE AGES

This great legacy of Greek scientific research ended about the second century AD and was not carried on by the Romans, who did not produce a single outstanding mathematician or scientist. With the transfer of the seat of the Roman Empire to Constantinople by the Emperor Constantine in the fourth century AD, subsequently making Christianity with its otherworldly orientation the dominant religion of Byzantium, there was no interest in scientific inquiry throughout the Medieval Period. As St. Augustine (Bishop of Hippo and early Church Father of the fourth and fifth centuries) declared: "Nothing is to be accepted except on the authority of Scripture, since greater is that authority than all powers of the human mind."

It was the Muslim Empire that was largely responsible for the preservation of Greek manuscripts and the continuation of scientific research from the 9th to the 12th centuries in places like Aleppo, Damascus, Babylon, and Cordoba. This preservation was due to the prophet of Islam, Muhammad's declaration that one can learn of Allah by studying his manifestations in nature as well as by revelation. Creation of the Baghdad Academy of Science by the Caliph Al-Mamun, with its collection of Greek philosophical, mathematical, and scientific manuscripts, centered scientific research in the Middle East, attracting scholars from India, Persia, and Syria. Yet it was the Arabs at this time who were the main contributors.

To mention a few, the first half of the ninth century included al-Kindi, known as the Arabic "philosopher King," and the famous Arabic mathematician, al-Khwarizmi. Al-Kindi, who taught in Bagdad, is known for his treatises on meteorology, geometrical optics, and physiology, while al-Khwarizmi gave to the West a treatise on *Algebra* (*al-jabr*), so crucial for formulating mathematical equations, the word 'algorithm,' and the so-called "Arabic numerals" that he had derived from the Hindus. Al-Battani, the greatest of the Arabian astronomers, lived in the second half of the ninth century and is known for his precise measurements of the obliquity of the ecliptic, the precession of the equinoxes, and the orbital motions of the sun and the moon. Ptolemy's book, the *Almagest*, derived its name from al-Battani's Arabic version.

Al-Farabi, who worked in Aleppo and Damascus in the early tenth century, is known as the "second Aristotle" for having translated his *Organon* into Arabic, introducing syllogistic reasoning into Arabic scientific inquiry, and for his refinement of Aristotle's distinction between the material and formal causes in medical research. A scholar of the early eleventh century especially renowned in the West is the Persian scholar Ibn Sina (or Avicenna), whose *Cannon of Medicine* integrating the medical investigations of Aristotle, Galen, and the Arabs was one of the most influential medical works of the late Middle Ages and early Renaissance. His famous book on philosophy, *Healing*, interpreted Aristotle as a Neoplatonist. The last Arabic scientist to be mentioned was not from the Arabic Near East but was born in Cordoba in the twelfth century. Though his Arabic name is Ibn Rushd, he is commonly known as Averroës and, like Avicenna, wrote a series of commentaries on Aristotle from a Neoplatonic perspective.

THE RENAISSANCE

Beginning in the 13th century after their translation into Latin, it was the dissemination throughout Europe of Greek texts from the Arabic schools of Cordoba in Spain and Salerno in Italy that contributed to the renewal of scientific research in the West; this lasted during the 14th and 15th centuries. While important contributions to experimental science were made by Robert Grosseteste, Roger Bacon, Erazmus Witelo, and others during these two centuries, it is convenient to date the beginning of modern science with the publication of Copernicus' *De Revolutionibus orbium coelestium* in 1543 because it marks a dramatic transition to the modern worldview.

Influenced by his Greek predecessors, Copernicus believed that a sun-centered planetary system offered a simpler, more exact, and more harmonious system of the universe than geocentrism. Having the same vision, Johannes Kepler used Tycho Brahe's astronomical data to drive his three astronomical laws replacing Aristotle's uniform circular motions of the planets with *elliptical orbits* whose nonuniform revolutions was swifter at the perihelion than the aphelion. Undergoing a remarkable intellectual development, his final conception was that the heavens resembled "a kind of clockwork" that runs on purely physical laws. It was Kepler's third law, that "*the ratio which exists between the periodic times of any two planets is precisely the ratio of the 3/2th power of the mean distances of the spheres themselves*," which suggested to Newton that the strength of the gravitational force decreases with the 3/2 power of the distance from the sun.

Although the works of both Copernicus and Kepler challenged Aristotle's cosmological system, they were not influential enough to pose a serious threat to his authority. Thomas Aquinas' 13th century synthesis of Aristotle with Christianity revised the worldview and provided the theoretical foundation of Christianity. Thus, it was the authority of the Catholic Church plus the fact that Aristotle's cosmological system seemed at the time to be in agreement with ordinary experiences and common sense beliefs that made it such a lasting system. For example, it does appear that the earth is stationary in the center of the universe; that all the heavenly bodies revolve around the earth; that the natural motion of the celestial bodies is uniform, circular, and eternal while natural terrestrial motion is vertical, accelerating downward proportional to the weight of objects to the earth's center, or the "unnatural or violent" motion of projectiles. Thus, revolving is inherent to the celestial realm while a state of rest is normal for the terrestrial world. Conceiving the celestial heaven as composed of a weightless, incorruptible aither, while the terrestrial world consists of the four elements, fire, earth, air, and water, with contrasting motions and properties, reinforced the distinction between the two realms.

It was this distinction that Galileo refuted with his new telescopic observations: that the surface of the moon with its observable craters and canyons resembles the earth, not celestial bodies; that Mars' orbital distances from the earth vary and therefore could not be circular; that the satellites of Jupiter, the rings of Saturn, the phases of Venus, and the sun spots were discoveries not mentioned by Aristotle; that Venus and Mercury were seen to revolve around the sun, not the earth; and that new comets were observed in the celestial world, contradicting Aristotle's belief that the heavens were immutable.

While these unique telescopic observations tended to refute Aristotle's cosmological system, Galileo still had to rebut the arguments supporting geocentrism, which he did brilliantly in his *Dialogues Concerning the Two Chief World Systems* published in 1632. For instance, how could the earth, a stationary material body, exist and revolve in the celestial realm? Why do we not feel the motion of the earth if it has a diurnal rotation and annual revolution around the sun? Why does the sun appear to rise in the east and set in the west if the earth rotates in the opposite direction? If the earth rotates on its axis, why does an object thrown vertically upward fall straight down, rather than at a removed distance, because during its trajectory the earth would have rotated beneath it? These objections were rebutted by Galileo by showing that they were relative to the perspective of someone on the earth, and not absolute. If one views the planetary system from the perspective of an orbiting earth, as required by heliocentrism, the objections fade away. As Einstein noted, his theories of relativity began with Galileo.

Despite the new telescopic evidence and credibility of his arguments, the Commission of the Inquisition under Pope Urban VIII forced Galileo to recant on his knees his belief in the heliocentric system. It challenged the authority of the Church that endorsed geocentrism. Yet after recovering from the trial he wrote his last book, *Dialogues Concerning Two New Sciences*, describing his earlier experiments with falling objects, incline planes, and projectiles. This work also proved his laws of motion, that in a vacuum similar objects would fall with the same velocity regardless of their weights, in contrast to Aristotle's theory that free falling objects accelerate with the squares of the times. He also explained that the trajectory of projectiles is parabolic and described his conception of the true method of scientific inquiry. Thus, Galileo achieved his objectives of demolishing Aristotle's system, freeing science from the authority of the Catholic Church, and demonstrating the use of experimentation and mathematics in scientific inquiry, illustrating how science has had to rectify erroneous beliefs due to the naturally limited and distorted perspective of human beings.

Galileo's eradication of Aristotle's organismic cosmology led to Newton replacing it with an entirely new framework: mechanistic materialism. This consisted of the concepts of mass, motion, and forces of attraction, repulsion, and gravity operating within the absolute frameworks of space and time. While the latter were disproved by Einstein's general theory of relativity, they still apply to velocities insignificant compared to that of light. Newton's *Principia Mathematica*, considered the greatest scientific treatise ever written, describes all the various kinds of motions in Volume I, while Volume II, *The System of the World*, presents his celestial mechanics and terrestrial motions based on his laws of motion, especially the universal law of gravitation and equation $F = ma$. His *Opticks* presents his prism experiments showing that ordinary light is composed of a spectrum of color-rays that he interpreted mainly as corpuscular. Newton created differential calculus and even constructed a reflecting telescope entirely by himself. Because of his genius as a theoretical physicist, experimentalist, and mathematician, he could be considered the greatest scientist who ever lived.

THE 18TH AND 19TH CENTURIES

The last sections of this chapter describe the main scientific advances that were a legacy of prior scientific developments. In the late 18th century, two major investigations pertained to electricity and the explanation of combustion. The name "electric" comes from the Greeks who first identified it, but its properties were not fully discovered until the 18th century when Franklin introduced the distinction between positive and negative charges. In the late 19th century Faraday demonstrated that a moving electric current generates a magnetic field, while a change in the magnetic field generates an electric current, thus discovering electromagnetism. Then Maxwell devised the equations describing the spatial structure of the magnetic field and how it changes with time. Experimenting with light in the early 19th century, Fresnel and Young discovered the diffraction patterns of light that led them to reintroduce the wave theory. After Foucault and Fizeau had measured the finite velocity of light and Hertz found it to be the same as the propagation of electromagnetic waves, it too was identified as electromagnetic in one of the grand unifications of science.

Other developments in the late 18th century were the explanation of combustion and the discovery of oxygen. Priestly had detected a gas that was extremely inflammable but had misinterpreted it as "dephlogisticated air." It was Lavoisier who correctly identified it and named it "oxygène" after experiments meticulously weighing the ingredients. He proposed a definition of "element," and showed that it was possible to identify particular gases and determine their proportion by weight in the compounds. He found that ordinary air is composed mainly of nitrogen and oxygen with some carbon dioxide and water vapor, and that water consists of two parts hydrogen and one part oxygen. Thus, Lavoisier's experiments foreshadowed the development of modern chemistry and atomism.

The 19th century is noted for three critical scientific developments. It is difficult to accept today that the adherents of the three Abrahamic religions believed that the universe was created by God in six days about six thousand years ago; that all the myriad genera and species were created in their present forms; that Adam and Eve were the progenitors of the human race tainted by Eve's disobedience, which so angered God that He destroyed all living creatures in the great Deluge except Noah, his family, and pairs of each genera and species, which were preserved in the Ark; and that it was this Deluge that formed the earth's topology.

Scientific disclosures in the 19th century, however, refuted each of these claims.

Geologists' discovery of strata in the earth's surface indicated a much longer history. Paleontologists' uncovering of fossilized remains of earlier creatures showed that genera and species were not immutable but had evolved in prehistory. During his trip to the Archipelago Islands, Charles Darwin observed the great diversity of species despite their being too distant from the mainland for any interbreeding. He suggested that, rather than being specially created, living creatures had evolved, a finding supported by his familiarity with animal breeding and awareness that the earliest stages of mammalian embryological development were similar despite their later diverse characteristics, thus implying they had a common ancestry.

Refuting current beliefs about the Deluge, a young Swiss naturalist, Louis Agassiz, stunned a meeting of Natural Sciences in Switzerland in 1837 by endorsing glaciation as the cause of the earth's geological formations. Although most in the audience had seen glaciers in the Alps, they could not imagine they were the cause. Only after an American sea captain and polar explorer brought back from Greenland exact sketches of its enormous size were they largely persuaded. Then a convincing explanation of the origin of the story of the Deluge emerged when two geologists, William Ryan and Walter Pitman, proposed in their book, *Noah's Flood*, that the Black Sea was formed about 7,800 years ago, at about the time when the Old Testament was formulated. According to their account, melting glaciers caused the Mediterranean Sea to rise and overflow the Bosporus Strait, flooding the Black Sea and "covering thousands of square miles of dry land . . . killing thousands of people and billions of land and sea creatures." Recently, additional confirmation was provided by a team of deep-sea explorers led by Robert D. Ballard. Based on radioactive dating of mollusk shells, they found evidence of a huge flooding about 7,500 years ago (the same time alluded to by Ryan and Pitman) along with locating the submerged pre-flood shoreline that also had been predicted. These discoveries are too convergent to be coincidental, indicating that these ancient legends often have some factual basis.

The third remarkable advance in the 19th century was an affirmation of the Ancient Greek doctrine of atomism with the development of the atomic-molecular theory and chemistry. As indicated previously, Lavoisier had identified individual gases as well as a number of compound gases, such as nitric oxide, carbon dioxide, and mercury oxide, but questions remained concerning the *number and weights* of the atoms comprising the various gases and molecular compounds. These questions were first answered by John Dalton, who is credited with laying the foundations for modern physical meteorology as well as modern atomism.

Dalton envisioned an entirely new conceptual framework in which the components of every sample of a substance such as water or salt contain "*ultimate particles*" (like hydrogen and oxygen) that "*are perfectly alike in weight, figure, etc.*," ensuring their uniformity. Consequently, all chemical investigations have as their objective to determine "*the relative weights of the ultimate particles, both of simple and compound bodies,*" along with "*the number of simple elementary particles which constitute one compound particle*" (i.e., molecule), such as H_2O, NaCl, or HCl. He also introduced "the rules of greatest simplicity" for arranging them and the first Atomic Table of twenty known elements was established, with individual symbols and weights relative to hydrogen taken as 1; this eventuated in the Periodic Tables of Mendeleev and Meyer. The Periodic Table was refined later in the century, owing to the theory of valences, of complex chemical structures and their chemical bonds, and the creation of organic chemistry.

THE MODERN WORLD

It was in 20th century that more advances were made in scientific inquiry than in all past history, of which only a brief summary can be given here. At the turn of the century, discoveries of subatomic particles such as electrons, protons, and neutrons, along with radiation, indicated that atoms, rather than being indivisible, had a composite structure that explains their physical properties and interactions. Then in 1900, Max Planck's investigation of blackbody radiation creating quantum mechanics opened up a whole new field of scientific inquiry. This resulted in Einstein's 1905 paper on the photoelectric effect introducing light quanta and Werner Heisenberg's injecting an element of uncertainty or indeterminacy in the measurement of the properties of light and other subatomic phenomena in 1925. The discovery of subatomic particles (to which he contributed) enabled Ernest Rutherford to depict the structure of the atomic nucleus and Niels Bohr to construct the Saturnian model of the atom, contributing to the explanation of radiation and chemical properties.

In 1905, in "*l'anno mirabile*," Einstein published five revolutionary papers including one on Brownian motion, one on the photoelectric effect just mentioned, and one on the special theory of relativity containing his famous equation, $E = mc^2$. Then in 1915 he published his general theory of relativity, describing the four-dimensional manifold of space-time that is fundamental to modern cosmology. Predicting that light would be curved in a strong gravitational field like the sun, this was confirmed four years later. In the 1920s, Edwin Hubble's telescopic observations revealed millions of galaxies beyond our Milky Way, along with the "red shift" in the light waves from outer space that implied an inflationary expansion of the universe. In 1927, the Belgian priest, Georges Lemaître, posited that if the universe were expanding it must have had a beginning. This phenomenon was coined the "Big Bang" by Fred Hoyle; it allowed astrophysicists finally to resolve the controversy over the age of the universe, computing it to have occurred about 14.7 billion years ago. The expansionary theory was firmly substantiated in 1965 when Arno Penzias and Robert Wilson of the Bell Laboratories discovered the background radiation left over from the Big Bang.

Then in 1938–1939 Otto Hahn announced his experiments injecting slow-moving neutrons into the nucleus of uranium, which created two units of barium and released a tremendous energy. Lisa Meitner and her nephew Otto Frisch interpreted these experiments and named the action *atomic fission*. This led to the building of the atomic bomb and nuclear reactors, confirming the structure of the atomic nucleus.

There were major advances in pharmacology, health care, and medicine beginning with the discovery of penicillin in 1929, followed by the polio vaccine created in 1954 by Dr. Jonas Salk, along with organ transplants and computed axial tomography (CAT) scans. But the major achievement was Watson and Crick's discovery in 1953 of DNA and the deciphering of the genetic code announced in 1993. This was revolutionary because, instead of treating the adverse consequences of genetic defects, one now would be able to eliminate their genetic causes by locating and removing or altering the defective gene that produced them. In addition, the recent breakthrough technology of creating stem cells (without destroying human embryos) by injecting retroviruses into skin cells in the future will allow for the replacement of any damaged tissue in the human organism.

Finally, tremendous advances in technology are exemplified in the development of nuclear reactors, computer science, and space explorations with the stunning lunar landing in 1969 along with the future expectations of landing on Mars. It is fair to say that whatever advances have been made in health care, standards of living, and enlightenment can be attributed to the achievements of science. And thus ends our odyssey through the history of science.

RESOURCES

The background research, along with bibliographical references to the original sources, and cited quotations can be found in my two volume work: *From Myth to Modern Mind: A Study of the Origins and Growth of Scientific Thought,* Vol. I, *Theogony through Ptolemy*, and Vol. II, *Copernicus through Quantum Mechanics* (New York: Peter Lang Publishers, Inc.; 1995, 1996). Also, they can be found in my upcoming book entitled, *Seeking the Truth: How Science Contested Revelation and Faith as the Basis of Belief.*