

## Chronology

### 1750–1799

- 1779:** Domenico Cotugno asserts that cerebrospinal fluid, and not “animal spirit,” as previously argued, fills the brain’s cavities and ventricles.
- 1780:** Antoine-Laurent Lavoisier and Pierre-Simon Laplace collaborate to demonstrate that respiration is a form of combustion. Breathing, like combustion, liberates heat, carbon dioxide and water.
- 1780:** George Adams devises the first microtome. This mechanical instrument cuts thin slices for examination under a microscope, thus replacing the imprecise procedure of cutting by a hand-held razor.
- 1780:** Lazzaro Spallanzani carries out experiments on fertilization in frogs and attempts to determine the role of semen in the development of amphibian eggs.
- 1796:** Edward Jenner uses cowpox virus to develop a smallpox vaccine. By modern standards, this was human experimentation as Jenner injected healthy eight-year-old James Phillips with cowpox and, after a period of months, with smallpox.
- 1796:** Erasmus Darwin, grandfather of Charles Darwin and Francis Galton, publishes his *Zoonomia*. In this work, Darwin argues that evolutionary changes are brought about by the direct influence of the environment on the organism—an idea primarily associated with Jean-Baptiste Lamarck.
- 1797:** Georges-Léopold-Christien-Frédéric Dagobert Cuvier establishes modern comparative zoology with the publication of his first book, *Basic Outline for a Natural History of Animals*. Cuvier studies the ways in which an animal’s function and habits determine its form. He argues that form always follows function and that the reverse relationship does not occur.
- 1798:** Government legislation is passed to establish hospitals in the United States devoted to the care of ill mariners. This initiative leads to the establishment of a Hygienic Laboratory that eventually grows to become the National Institutes of Health.
- 1799:** Humphrey Davy suggests nitrous oxide can be used to reduce pain during surgery.

### 1800–1849

- 1800:** Marie-François-Xavier Bichat publishes his first major work, *Treatise on Tissues*, that establishes histology as a new scientific discipline. Bichat distinguishes twenty-one kinds of tissue and relates particular diseases to particular tissues.
- 1802:** Jean-Baptiste Lamarck and Gottfried Reinhold Treviranus propose the term “biology” to denote a new general science of living beings that would supercede studies in natural history.
- 1802:** John Dalton introduces modern atomic theory into the science of chemistry.
- 1804:** F. W. Serturmer discovers how to isolate the chemical morphine from the poppy plant (*Papaver somniferum*).
- 1810:** Franz Joseph Gall lays the basis for modern neurology with his dissections of the brain and his correct suggestions about nerve organization.
- 1811:** Julien-Jean-César Legallois locates the first physiological center in the brain.

- 1812:** Charles Bell differentiates between sensory and motor roots of spinal nerves in his *New Idea of Anatomy of the Brain*. He asserts that each nerve carries either a motor or a sensory stimulus, and not both simultaneously.
- 1812:** Gustav Robert Kirchoff identifies catalysis and mechanisms of catalytic reactions.
- 1818:** William Charles Wells suggests the theory of natural selection in an essay dealing with human color variations. He notes that dark-skinned people are more resistant to tropical diseases than lighter-skinned people.
- 1820:** First United States *Pharmacopoeia* is published.
- 1821:** Jean-Louis Prévost and Jean-Baptiste-André Dumas jointly publish a paper that demonstrates that spermatozoa originate in tissues of the male sex glands. Three years later they publish the first detailed account of the segmentation of a frog's egg.
- 1822:** François Magendie publishes his paper "Functions of the Roots of the Spinal Nerves," that lays the foundation for the Bell-Magendie Law.
- 1824:** Performances at London's West End Adelphi Theatre entitled "M. Henry's Mechanical and Chemical Demonstrations" showed the effects of nitrous oxide on audience volunteers.
- 1824:** René-Joachim-Henri Dutrochet suggests that tissues are composed of living cells.
- 1825:** Jan Evangelista Purkinje describes the "germinal vesicle," or nucleus, in a hen's egg.
- 1826:** James Cowles Prichard presents his views on evolution in the second edition of his book *Researches into the Physical History of Man*. These ideas about evolution are suppressed in later editions.
- 1828:** Friedrich Wöhler synthesizes urea. This is generally regarded as the first organic chemical produced in the laboratory, and an important step in disproving the idea that only living organisms can produce organic compounds. Work by Wöhler and others establish the foundations of organic chemistry and biochemistry.
- 1828:** In his book *On the Developmental History of Animals*, Karl Ernst von Baer demonstrates that embryological development follows essentially the same pattern in a wide variety of mammals. von Baer's work establishes the modern field of comparative embryology.
- 1828:** Luigi Rolando achieves the first synthetic electrical stimulation of the brain.
- 1828:** Robert Brown observes a small body within the cells of plant tissue and calls it the "nucleus." He also discovers what becomes known as "Brownian movement."
- 1829:** Salicin, the precursor of aspirin, is purified from the bark of the willow tree.
- 1831:** Charles Robert Darwin begins his historic voyage on HMS *Beagle*. His observations during the voyage lead to his theory of evolution by means of natural selection.
- 1831:** Patrick Matthew includes a discussion of evolution and natural selection in his book *On Naval Timber and Arboriculture*. Matthew later claims priority in the discovery of evolution by means of natural selection in an article published in 1860 in the journal *Gardeners' Chronicle*.
- 1832:** Anselme Payen isolates diastase from barley. Diastase catalyzes the conversion of starch into sugar, and is an example of the organic catalysts within living tissue that eventually come to be called enzymes.
- 1833:** Johannes Peter Müller first proposes his law of specific nerve energies. According to this law, every sensory nerve gives rise to one form of sensation, even if it is excited by stimuli outside a normal range.
- 1836:** Félix Dujardin describes the "living jell" of the cytoplasm, which he calls "sarcode."
- 1836:** Theodor Schwann carries out experiments that refute the theory of the spontaneous generation of infusoria. He also demonstrates that alcoholic fermentation depends on the action of living yeast cells. The same conclusion is reached independently by Charles Caignard de la Tour.
- 1837:** René-Joachim Dutrochet publishes his research on plant physiology that includes pioneering work on osmosis. He is the first scientist to systematically investigate the process of osmosis, which he names, and that chlorophyll is necessary for photosynthesis.
- 1838:** Matthias Jakob Schleiden notes that the nucleus first described by Robert Brown is characteristic of all plant cells. Schleiden describes plants as a community of cells and cell products. He helps establish cell theory and stimulates Theodor Schwann's recognition that animals are also composed of cells and cell products.
- 1839:** Jan Evangelista Purkinje uses the term "protoplasm" to describe the substance within living cells.

- 1839:** Theodor Schwann extends the theory of cells to include animals and helps establish the basic unity of the two great kingdoms of life. He publishes *Microscopical Researches into the Accordance in the Structure and Growth of Animals and Plants*, where he asserts that all living things are made up of cells, and that each cell contains certain essential components. He also coins the term “metabolism” to describe the overall chemical changes that take place in living tissues.
- 1840:** Friedrich Gustav Jacob Henle publishes the first histology textbook, *General Anatomy*. This work includes the first modern discussion of the germ theory of communicable diseases.
- 1840:** Justus von Liebig shows that plants synthesize organic compounds from carbon dioxide in the air but take their nitrogenous compounds from the soil. He also states that ammonia (nitrogen) is needed for plant growth.
- 1840:** Karl Bogislaus Reichert introduces the cell theory into the discipline of embryology. He proves that the segments observed in fertilized eggs develop into individual cells, and that organs develop from cells.
- 1840:** Rudolf Albert von Kölliker establishes that spermatozoa and eggs are derived from tissue cells. He attempts to extend the cell theory to embryology and histology.
- 1841:** Anesthetic properties of ether were first used by Dr. Crawford W. Long as he surgically removed two tumors from the neck of an anesthetized patient.
- 1842:** Theodor Ludwig Wilhelm Bischoff publishes the first textbook of comparative embryology, *Developmental History of Mammals and Man*.
- 1843:** Martin Berry observes the union of the sperm and egg of a rabbit.
- 1844:** First recorded use of nitrous oxide in a United States dental practice by Gardner Quincy Colton, a former medical student, and dentist Horace Wells at Hartford, Connecticut.
- 1844:** Robert Chambers anonymously publishes *Vestiges of the Natural History of Creation*, which advocates the theory of evolution. This controversial book becomes a best seller and introduces the general reading public to the theory of evolution.
- 1845:** Karl Theodor Ernst von Siebold is the first scientist to determine protozoa are single-celled organisms.
- 1845:** J. Marion Sims conducts medical experiments on slaves in the United States. Sims becomes the first physician in the United States to have a statue in his honor.
- 1847:** A series of yellow fever epidemics sweeps the American Southern states. The epidemics recur every few years for more than thirty years.
- 1849:** Rudolf Wagner and Karl Georg Friedrich Rudolf Leuckart report that spermatozoa are a definite and essential part of semen, and that the liquid merely keeps them in suspension. They also reject the old hypothesis that spermatozoa are parasites, and argue that spermatozoa are essential for fertilization.

**1850–1899**

- 1851:** Hugo von Mohl publishes *Basic Outline of the Anatomy and Physiology of the Plant Cell*, in which he proposes that new cells are created by cell division.
- 1854:** George Newport performs the first experiments on animal embryos. He suggests that the point of sperm entry determines the planes of the segmentation of the egg.
- 1854:** Gregor Mendel begins to study thirty-four different strains of peas. He selects twenty-two kinds for further experiments. From 1856 to 1863, Mendel grows and tests over 28,000 plants and analyzes seven pairs of traits.
- 1854:** Rudolf Ludwig Carl Virchow first names the neuroglia, or supportive “glue cells” in the brain.
- 1855:** Alfred Russell Wallace writes an essay entitled “On the Law Which Has Regulated the Introduction of New Species” and sends it to Charles Darwin. Wallace’s essay and one by Darwin are published in the 1858 *Proceedings of the Linnaean Society*.
- 1855:** Barolomeo Panizza first proves that parts of the cerebral cortex are essential for vision.
- 1856:** Nathanael Pringsheim observes the sperm of a freshwater algae plant enter the egg.
- 1857:** Louis Pasteur demonstrates that lactic acid fermentation is caused by a living organism. Between 1857 and 1880, he performs a series of experiments that refute the doctrine of spontaneous generation. He also introduces vaccines for fowl cholera, anthrax, and rabies, based on attenuated strains of viruses and bacteria.
- 1858:** Charles Darwin and Alfred Russell Wallace agree to a joint presentation of their theory of evolution by natural selection.
- 1858:** Rudolf Ludwig Carl Virchow publishes his landmark paper “Cellular Pathology” and establishes

- the field of cellular pathology. Virchow asserts that all cells arise from preexisting cells (*Omnis cellula e cellula*). He argues that the cell is the ultimate locus of all disease.
- 1859:** Charles Darwin publishes his landmark book *On the Origin of Species by Means of Natural Selection*.
- 1860:** Ernst Heinrich Haeckel describes the essential elements of modern zoological classification.
- 1860:** Louis Pasteur carries out experiments that disprove the doctrine of spontaneous generation.
- 1860:** Max Johann Sigismund Schultze describes the nature of protoplasm and shows that it is fundamentally the same for all life forms.
- 1861:** Carl Gegenbaur confirms Theodor Schwann's suggestion that all vertebrate eggs are single cells.
- 1861:** Pierre-Paul Broca first identifies a location in the brain's left hemisphere that, in most people, is associated with speech. It is later called "Broca's area."
- 1862:** Von Helmholtz describes the physiological mechanism of auditory senses (hearing and sound transmission).
- 1865:** An epidemic of rinderpest kills 500,000 cattle in Great Britain. Government inquiries into the outbreak pave the way for the development of contemporary theories of epidemiology and the germ theory of disease.
- 1865:** Franz Schweiger-Seidel proves that spermatozoa consist of a nucleus and cytoplasm.
- 1865:** Gregor Mendel presents his work on hybridization of peas to the Natural History Society of Brno, Czechoslovakia. The paper is published in the 1866 issue of the Society's *Proceedings*. Mendel presents statistical evidence that hereditary factors are inherited from both parents in a series of papers on "Experiments on Plant Hybridization" published between 1866 and 1869. His experiments provide evidence of dominance, the laws of segregation, and independent assortment, although the work is generally ignored until 1900.
- 1865:** Jules-Bernard Luys describes a nucleus in the hypothalamus, forming a part of the descending pathway from the corpus striatum. It becomes known as the "nucleus of Luys."
- 1865:** Claude Bernard publishes *Introduction to the Study of Human Experimentation* that advocates, "never perform an experiment which might be harmful to the patient even if advantageous to science."
- 1867:** Robert Koch establishes the role of bacteria in anthrax, providing the final piece of evidence in support of the germ theory of disease. Koch goes on to formulate postulates that, when fulfilled, confirm bacteria or viruses as the cause of infection.
- 1868:** Thomas Henry Huxley introduces the term "protoplasm" to the general public in a lecture entitled "The Physical Basis of Life."
- 1869:** Johann Friedrich Miescher discovers nuclein, a new chemical isolated from the nuclei of pus cells. Two years later, he isolates nuclein from salmon sperm. This material comes to be known as nucleic acid.
- 1869:** Paul Langerhans discovers irregular islands of cells in the pancreas which produce insulin. Ultimately, the cells become known as the "Isles of Langerhans."
- 1870:** Gustav Theodor Fritsch and Eduard Hitzig discover that electric shocks to one cerebral hemisphere of a dog's brain produce movement on the other side of the animal's body. This is the first clear demonstration of the existence of cerebral hemispheric lateralization.
- 1870:** Lambert Adolphe Jacques Quetelet shows the importance of statistical analysis for biologists and provides the foundations of biometry.
- 1870:** Thomas Huxley delivers a speech that introduces the terms biogenesis (life from life) and abiogenesis (life from non-life; spontaneous generation). The speech strongly supports Pasteur's claim to have refuted the concept of spontaneous generation.
- 1871:** Ferdinand Julius Cohn coins the term bacterium.
- 1873:** Camilo Golgi discovers that tissue samples can be stained with an inorganic dye (silver salts). Golgi uses this method to analyze the nervous system and characterizes the cells known as Golgi Type I and Golgi Type II cells and the "Golgi Apparatus." Golgi is subsequently awarded a Nobel Prize in 1906 for his studies of the nervous system.
- 1873:** Franz Anton Schneider describes cell division in detail. His drawings include both the nucleus and chromosomal strands.
- 1874:** Carl Wernicke discovers the area of the brain associated with word comprehension, eventually to be named "Wernicke's area."
- 1874:** Francis Galton demonstrates the usefulness of twin studies for elucidating the relative influence of nature (heredity) and nurture (environment).
- 1874:** Wilhelm August Oscar Hertwig concludes that fertilization in both animals and plants consists of the physical union of the two nuclei

- contributed by the male and female parents. Hertwig subsequently carries out pioneering studies of reproduction of the sea urchin.
- 1875:** Eduard Adolf Strasburger publishes *Cell-Formation and Cell-Division*, in which he describes nuclear division in plants. Strasburger accurately describes the process of mitosis and argues that new nuclei can only rise from the division of pre-existing nuclei. His treatise helps establish cytology as a distinct branch of histology.
- 1875:** Ferdinand Cohn publishes a classification of bacteria in which the genus name *Bacillus* is used for the first time.
- 1875:** Theodor Wilhelm Engelmann proves experimentally that the heartbeat is myogenic, which means that it originates in the heart muscle itself, and not from an external impulse.
- 1876:** Edouard G. Balbiani observes the formation of chromosomes.
- 1876:** Robert Koch publishes a paper on anthrax that implicates a bacterium as the cause of the disease, validating the germ theory of disease.
- 1877:** Paul Erlich recognizes the existence of the mast cells of the immune system.
- 1877:** Robert Koch describes new techniques for fixing, staining, and photographing bacteria.
- 1877:** Wilhelm Friedrich Kühne proposes the term enzyme (meaning “in yeast”). Kühne establishes the critical distinction between enzymes, or “ferments,” and the microorganisms that produce them.
- 1878:** Joseph Lister publishes a paper describing the role of a bacterium he names *Bacterium lactis* in the souring of milk.
- 1878:** Thomas Burrill demonstrates for the first time that a plant disease (pear blight) is caused by a bacterium (*Micrococcus amylophorous*).
- 1879:** Albert Nisser identifies *Neisseria gonorrhoeae* as the cause of gonorrhea.
- 1879:** Hermann Fol observes the penetration of the egg of a sea urchin by a sperm. He demonstrates that only one spermatozoon is needed for fertilization and suggests that the nucleus of the sperm is transferred into the egg.
- 1879:** Walther Flemming describes and names chromatin, mitosis, and the chromosome threads. Flemming’s drawings of the longitudinal splitting of chromosomes in eukaryotic cells provide the first accurate counts of chromosome numbers.
- 1880:** C. L. Alphonse Laveran isolates malarial parasites in erythrocytes of infected people and demonstrates that the organism can replicate in the cells. He is awarded the 1907 Nobel Prize in Medicine or Physiology for this work.
- 1880:** David Ferrier maps the region of the brain called the motor cortex and discovers the sensory strip.
- 1880:** First attempt at passage of a nationwide food and drug law. Although defeated in Congress, United States Department of Agriculture’s findings of widespread food adulteration spur continued interest in food and drug legislation.
- 1880:** The basic outlines of cell division and the distribution of chromosomes to the daughter cells are established by Walther Flemming, Eduard Strasburger, Edouard van Beneden, and others.
- 1880:** The first issue of the journal *Science* is published by the American Association for the Advancement of Science.
- 1881:** Eduard Strasburger coins the terms cytoplasm and nucleoplasm.
- 1881:** Wilhelm Roux, the founder of experimental embryology, publishes *The Struggle of the Parts in the Organism: A Contribution to the Completion of a Mechanical Theory of Teleology*. Roux argues that his experimental approach to embryonic development, based on mechanistic principles, provides evidence that development proceeds by means of self-differentiation.
- 1882:** Angelina Fannie and Walter Hesse in Koch’s laboratory develop agar as a solid grow medium for microorganisms. Agar replaces gelatin as the solid growth medium of choice in microbiology.
- 1882:** Edouard van Beneden outlines the principles of genetic continuity of chromosomes in eukaryotic cells and reports the occurrence of chromosome reduction during the formation of the germ cells.
- 1882:** Pierre Émile Duclaux suggest that enzymes should be named by adding the suffix “ase” to the name of their substrate.
- 1882:** Robert Koch discovers the tubercle bacillus and enunciates “Koch’s postulates,” which define the classic method of preserving, documenting, and studying bacteria.
- 1882:** Wilhelm Roux offers a possible explanation for the function of mitosis.
- 1883:** August F. Weismann begins work on his germ-plasm theory of inheritance. Weismann proposes a theory of chromosome behavior during cell division and fertilization and predicts the

- occurrence of a reduction division (meiosis) in all sexual organisms.
- 1883:** Edward Theodore Klebs and Frederick Loeffler independently discover *Corynebacterium diphtheriae*, the bacterium that causes diphtheria.
- 1883:** Walther Flemming, Eduard Strasburger and Edouard Van Beneden demonstrate that in eukaryotic cells, chromosome doubling occurs by a process of longitudinal splitting. Strasburger describes and names the prophase, metaphase, and anaphase stages of mitosis.
- 1883:** Wilhelm Roux suggests that chromosomes carry the hereditary factors.
- 1884:** Elie Metchnikoff discovers the antibacterial activity of white blood cells, which he calls “phagocytes,” and formulates the theory of phagocytosis. He also develops the cellular theory of vaccination.
- 1884:** Hans Christian J. Gram develops the Gram stain.
- 1884:** Karl Rabl suggests the concept of the individuality of the chromosomes. He argues that each chromosome originates from a preexisting chromosome in the mother cell that is like it in form and size.
- 1884:** Louis Pasteur and co-workers publish a paper entitled “A New Communication on Rabies.” Pasteur proves that the causal agent of rabies can be attenuated and the weakened virus can be used as a vaccine to prevent the disease. This work serves as the basis of future work on virus attenuation, vaccine development, and the concept that variation is an inherent characteristic of viruses.
- 1884:** Oscar Hertwig, Eduard Strasburger, Albrecht von Kölliker, and August Weismann independently report that the cell nucleus serves as the basis for inheritance.
- 1885:** Francis Galton devises a new statistical tool, the correlation table.
- 1885:** Louis Pasteur inoculates a boy, Joseph Meister, against rabies. Meister had been bitten by an infected dog. The treatment saves his life. This is the first time Pasteur uses an attenuated germ on a human being.
- 1885:** Theodor Escherich identifies a bacterium inhabiting the human intestinal tract that he names *Bacterium coli* and shows that the bacterium causes infant diarrhea and gastroenteritis. The bacterium is subsequently named *Escherichia coli*.
- 1886:** Adolf Mayer publishes the landmark article “Concerning the Mosaic Disease of Tobacco.” This paper is considered the beginning of modern experimental work on plant viruses. Mayer assumes that the causal agent was a bacterium, although he was unable to isolate it.
- 1887:** Julius Richard Petri develops a culture dish that has a lid to exclude airborne contaminants. The innovation is subsequently termed the petri plate.
- 1888:** Francis Galton publishes *Natural Inheritance*, considered a landmark in the establishment of biometry and statistical studies of variation. Galton also proposes the Law of Ancestral Inheritance, a statistical description of the relative contributions to heredity made by previous generations.
- 1888:** Heinrich Wilhelm Gottfried Waldeyer coins the term “chromosome.” Waldeyer also introduces the use of hematoxylin as a histological stain.
- 1888:** Martinus Beijerinck uses a growth medium enriched with certain nutrients to isolate the bacterium *Rhizobium*, demonstrating that nutritionally tailored growth media are useful in bacterial isolation.
- 1888:** The Institute Pasteur is formed in France.
- 1888:** Theodor Heinrich Boveri discovers and names the centrosome (the mitotic spindle that appears during cell division).
- 1888:** Woods Hole Marine Biological Station, which later became the headquarters of the Woods Hole Oceanographic Institution and the Marine Biological Laboratory, is established in Massachusetts.
- 1889:** Richard Altmann develops a method of preparing nuclein that was apparently free of protein. He calls his protein-free nucleins “nucleic acids.”
- 1889:** Theodor Boveri and Jean-Louis-Léon Guignard establish the numerical equality of the paternal and maternal chromosomes at fertilization.
- 1891:** Charles-Edouard Brown-Sequard suggests the concept of internal secretions (hormones).
- 1891:** Hermann Henking distinguishes between the sex chromosomes and the autosomes.
- 1891:** Paul Ehrlich proposes that antibodies are responsible for immunity.
- 1891:** Robert Koch proposes the concept of delayed type hypersensitivity.
- 1891:** The Prussian State dictates that even jailed prisoners must give consent prior to treatment (even for tuberculosis).
- 1892:** August Weismann publishes his landmark treatise *The Germ Plasm: A Theory of Heredity*, which emphasizes the role of meiosis in the distribution of chromosomes during the formation of gametes.

- 1892:** Dmitri Ivanowski demonstrates that filterable material causes tobacco mosaic disease. The infectious agent is subsequently shown to be the tobacco mosaic virus. Ivanowski's discovery creates the field of virology.
- 1892:** George M. Sternberg publishes his *Practical Results of Bacteriological Researches*. Sternberg's realization that a specific antibody was produced after infection with vaccinia virus and that immune serum could neutralize the virus becomes the basis of virus serology. The neutralization test provides a technique for diagnosing viral infections, measuring the immune response, distinguishing antigenic similarities and differences among viruses, and conducting retrospective epidemiological surveys.
- 1892:** In an experiment with syphilis, Albert Neisser injects and infects human subjects.
- 1893:** Hans Adolf Eduard Driesch discovers that he could separate sea urchin embryos into individual cells and that the separated cells continued to develop. Driesch concludes that all the cells of the early embryo are capable of developing into whole organisms. Therefore, embryonic cells are equipotent, but differentiated and developed in response to their position within the embryo.
- 1894:** Alexandre Yersin isolates *Yersinia (Pasteurella) pestis*, the bacterium responsible for bubonic plague.
- 1894:** Wilhelm Konrad Roentgen discovers x rays.
- 1895:** Heinrich Dreser, working for the Bayer Company in Germany, produces a drug he thought to be as effective an analgesic as morphine, but without the harmful side effects. Bayer began mass production of diacetylmorphine, and in 1898 began marketing the new drug under the brand name "heroin" as a cough sedative.
- 1896:** Edmund Beecher Wilson publishes the first edition of his highly influential treatise *The Cell in Development and Heredity*. Wilson calls attention to the relationship between chromosomes and sex determination.
- 1897:** John Jacob Abel isolates epinephrine (adrenalin). This is the first hormone to be isolated.
- 1898:** Carl Benda discovers and names mitochondria, the subcellular entities previously seen by Richard Altmann.
- 1898:** Friedrich Loeffler and Paul Frosch publish their *Report on Foot-and-Mouth Disease*. They prove that this animal disease is caused by a filterable virus and suggest that similar agents might cause other diseases.
- 1898:** The First International Congress of Genetics is held in London.
- 1899:** A meeting to organize the Society of American Bacteriologists is held at Yale University. The society will later become the American Society for Microbiology.
- 1899:** Jacques Loeb proves that it is possible to induce parthenogenesis in unfertilized sea urchin eggs by means of specific environmental changes.

### 1900–1949

- 1900:** Carl Correns, Hugo de Vries, and Erich von Tschermak independently rediscover Mendel's laws of inheritance. Their publications mark the beginning of modern genetics. William Bateson describes the importance of Mendel's contribution in an address to the Royal Society of London.
- 1900:** Hugo Marie de Vries describes the concept of genetic mutations in his book *Mutation Theory*. He uses the term mutation to describe sudden, spontaneous, and drastic alterations in hereditary material.
- 1900:** Karl Landsteiner discovers the blood-agglutination phenomenon and the four major blood types in humans.
- 1900:** Karl Pearson develops the chi-square test.
- 1900:** Paul Erlich proposes the theory concerning the formation of antibodies by the immune system.
- 1900:** Thomas H. Montgomery studies spermatogenesis in various species of Hemiptera. He concludes that maternal chromosomes only pair with corresponding paternal chromosomes during meiosis.
- 1900:** Walter Reed demonstrates that yellow fever is caused by a virus transmitted by mosquitoes. This is the first demonstration of a viral cause of a human disease. Reed injects paid Spanish immigrant workers in Cuba with the agent, paying them if they survive and paying them still more should they contract the disease.
- 1901:** Clarence E. McClung argues that particular chromosomes determine the sex of the individual carrying them. Although his work is done with insects, he suggests that this might be true for human beings and other animals.
- 1901:** Jokichi Takamine and T. B. Aldrich first isolate epinephrine from the adrenal gland. Later known by the trade name Adrenalin, it is eventually

- identified as a neurotransmitter. This is also the first time a pure hormone has been isolated.
- 1901:** Jules Bordet and Octave Gengou develop the complement fixation test.
- 1901:** William Bateson coins the terms genetics, F1 and F2 generations, allelomorph (later shortened to allele), homozygote, heterozygote, and epistasis.
- 1902:** Carl Neuberg introduces the term biochemistry.
- 1902:** Ernest H. Starling and William H. Bayliss discover and isolate the first hormone (“secretin,” found in the duodenum).
- 1902:** Santiago Ramon y Cajal first discovers the nature of the connection between nerves, showing that the nervous system consists of a maze of individual cells. He demonstrates that neurons do not touch but that the signal somehow crosses a gap (now called a synapse).
- 1903:** Archibald Edward Garrod provides evidence that errors in genes caused several hereditary disorders in human beings. His 1909 book *The Inborn Errors of Metabolism* is the first treatise in biochemical genetics.
- 1903:** Willem Einthoven invents the electrocardiograph (EKG).
- 1903:** Ernst Ruska develops a primitive electron microscope.
- 1903:** Arne Tiselius offers electrophoresis techniques that become the basis for the separation of biological molecules by charge, mass, and size.
- 1903:** Walter S. Sutton publishes a paper in which he presents the chromosome theory of inheritance. The theory, which states that the hereditary factors are located in the chromosomes, is independently proposed by Theodor Boveri and is generally referred to as the Sutton-Boveri hypothesis.
- 1905:** Nettie Maria Stevens discovers the connection between chromosomes and sex determination. She determines that there are two basic types of sex chromosomes, which are now called X and Y. Stevens proves that females are XX and males are XY. Stevens and Edmund B. Wilson independently describe the relationship between the so-called accessory or X chromosome and sex determination in insects.
- 1905:** William Bateson and Reginald C. Punnett report the discovery of two new genetic principles: linkage and gene interaction.
- 1906:** The United States Congress passes the Pure Food and Drug Act.
- 1906:** Viennese physician and immunological researcher Clemens von Pirquet coins the term “allergy” to describe the immune reaction to certain compounds.
- 1906:** Dr. Richard Strong, a professor of tropical medicine at Harvard, experiments with cholera on prisoners, some of whom die.
- 1907:** Ivan Petrovich Pavlov, investigates the conditioned reflex. A great stimulus for behaviorist psychology, his work establishes physiologically oriented psychology.
- 1907:** William Bateson urges biologists to adopt the term “genetics” to indicate the importance of the new science of heredity.
- 1908:** Godfrey Harold Hardy and Wilhelm Weinberg independently publish similar papers describing a mathematical system that accounts for the stability of gene frequencies in succeeding generations of population. Their resulting Hardy-Weinberg law links the Mendelian hypothesis with population studies.
- 1908:** Margaret A. Lewis successfully cultures mammalian cells *in vitro*.
- 1908:** Thomas H. Morgan publishes a paper expressing doubts about Mendelian explanations for inherited traits.
- 1909:** Jean de Mayer first suggests the name “insulin” for the hormone of the islet cells.
- 1909:** Korbinian Bordmann publishes a “map” of the cerebral cortex, assigning numbers to particular regions.
- 1909:** Phoebus Aaron Theodore Levene discovers the chemical difference between DNA (deoxyribonucleic acid) and RNA (ribonucleic acid).
- 1909:** Sigurd Orla-Jensen proposes that the physiological reactions of bacteria are primarily important in their classification.
- 1909:** Thomas Hunt Morgan selects the fruit fly *Drosophila* as a model system for the study of genetics. Morgan and his co-workers confirm the chromosome theory of heredity and realize the significance of the fact that certain genes tend to be transmitted together. Morgan postulates the mechanism of “crossing over.” His associate, Alfred Henry Sturtevant demonstrates the relationship between crossing over and the rearrangement of genes in 1913.
- 1909:** Wilhelm Ludwig Johannsen argues the necessity of distinguishing between the appearance of an organism and its genetic constitution. He invents the terms “gene” (carrier of heredity), “genotype”

- (an organism's genetic constitution), and "phenotype" (the appearance of the actual organism).
- 1910:** Harvey Cushing and his team present the first experimental evidence of the link between the anterior pituitary and the reproductive organs.
- 1911:** Francis Peyton Rous publishes the landmark paper "Transmission of a Malignant New Growth by Means of a Cell-Free Filtrate." His work provides the first rigorous proof of the experimental transmission of a solid tumor and suggests that a filterable virus is the causal agent.
- 1912:** Casimir Funk coins the term "vitamine." Since the dietary substances he discovers are in the amine group he calls all of them "life-amines" (using the Latin word *vita* for "life").
- 1912:** Paul Ehrlich discovers a chemical cure for syphilis. This is the first chemotherapeutic agent for a bacterial disease.
- 1912:** The United States Public Health Service is established.
- 1913:** Calvin Blackman Bridges discovers evidence of nondisjunction of the sex chromosomes in *Drosophila*. This evidence helps support Thomas H. Morgan's new chromosome theory of heredity.
- 1914:** Edward Calvin Kendall extracts thyroxin from the thyroid gland (in crystalline form).
- 1914:** Frederick William Twort and Felix H. D'Herelle independently discover bacteriophages, viruses which destroy bacteria.
- 1914:** Thomas Hunt Morgan, Alfred Henry Sturtevant, Calvin Blackman Bridges, and Hermann Joseph Muller publish the classic treatise of modern genetics, *The Mechanism of Mendelian Heredity*.
- 1915:** Katherine K. Sanford isolates a single mammalian cell *in vitro* and allows it to propagate to form identical descendants. Her clone of mouse fibroblasts is called L929, because it took 929 attempts before a successful propagation was achieved. Sanford's work is important step in establishing pure cell lines for biomedical research.
- 1915:** United States Public Health Office allows induction of pellagra in Mississippi housed prisoners.
- 1916:** Felix Hubert D'Herelle carries out further studies of the agent that destroys bacterial colonies and gives it the name "bacteriophage" (bacteria eating agent). D'Herelle and others unsuccessfully attempt to use bacteriophages as bactericidal therapeutic agents.
- 1917:** D'Arcy Wentworth Thompson publishes *On Growth and Form*, which suggests that the evolution of one species into another occurs as a series of transformations involving the entire organism, rather than a succession of minor changes in parts of the body.
- 1918:** Calvin B. Bridges discovers chromosomal duplications in *Drosophila*.
- 1918:** Global influenza pandemic kills more people than the number of soldiers who died fighting during World War I. By the end of 1918, approximately 25 million people die from virulent strain of Spanish influenza.
- 1918:** Thomas Hunt Morgan and co-workers publish *The Physical Basis of Heredity*, a survey of the remarkable development of the new science of genetics.
- 1919:** James Brown uses blood agar to study the destruction of blood cells by the bacterium *Streptococcus*. He observes three reactions that he designates alpha, beta, and gamma.
- 1919:** The Health Organization of the League of Nations was established for the prevention and control of disease around the world.
- 1919:** San Quentin doctors perform testicular transplant experiments on hundreds of prisoners.
- 1920:** Frederick Grant Banting, Charles Best, and James B. Collip discover insulin. They develop a method of extracting insulin from the human pancreas. The insulin is then injected into the blood of diabetics to lower their blood sugar.
- 1921:** Otto Loewi discovers that acetylcholine functions as a neurotransmitter. It is the first such brain chemical to be so identified.
- 1922:** Elmer Verner McCollum discovers Vitamin D.
- 1922:** Frederick Banting and Charles Best make the first clinical adaptation of insulin for the treatment of diabetes.
- 1922:** Herbert McLean Evans and colleagues discover Vitamin E.
- 1923:** A. E. Boycott and C. Diver describe a classic example of "delayed Mendelian inheritance." The direction of the coiling of the shell in the snail *Limnaea peregra* is under genetic control, but the gene acts on the egg prior to fertilization. Thus, the direction of coiling is determined by the egg cytoplasm, which is controlled by the mother's genotype.
- 1924:** Albert Jan Kluyver publishes *Unity and Diversity in the Metabolism of Micro-organisms*. He demonstrates that different microorganisms have common metabolic pathways of oxidation, fermentation, and synthesis of certain compounds.

- Kluyver also states that life on Earth depends on microbial activity.
- 1925:** Johannes Hans Berger records the first human electroencephalogram (EEG).
- 1926:** Bernard O. Dodge begins genetic studies on *Neurospora*.
- 1926:** James B. Sumner publishes a report on the isolation of the enzyme urease and his proof that the enzyme is a protein. This idea is controversial until 1930 when John Howard Northrop confirms Sumner's ideas by crystallizing pepsin. Sumner, Northrop, and Wendell Meredith Stanley ultimately share the Nobel Prize for Chemistry in 1946.
- 1926:** Thomas C. Vanterpool publishes a paper that clarifies the problem of "mixed infections" of plant viruses. His study of the condition known as "streak" or "winter blight" of tomatoes shows that it was the result of simultaneous infection of tomato plants by tomato mosaic virus and a potato mosaic virus.
- 1927:** Hermann Joseph Muller induces artificial mutations in fruit flies by exposing them to x rays. His work proves that mutations result from some type of physical-chemical change. Muller goes on to write extensively about the danger of excessive x rays and the burden of deleterious mutations in human populations.
- 1927:** Thomas Rivers publishes a paper that differentiates bacteria from viruses, establishing virology as a field of study that is distinct from bacteriology.
- 1928:** Alexander Fleming discovers penicillin. He observes that the mold *Penicillium notatum* inhibits the growth of some bacteria. This is the first anti-bacterial, and it opens a new era of "wonder drugs" to combat infection and disease.
- 1928:** Fred Griffith discovers that certain strains of pneumococci could undergo some kind of transmutation of type. After injecting mice with living R type pneumococci and heat-killed S type, Griffith is able to isolate living virulent bacteria from the infected mice. Griffith suggests that some unknown "principle" had transformed the harmless R strain of the pneumococcus to the virulent S strain.
- 1928:** Wilder Graves Penfield first uses microelectrodes to map areas in the human cerebral cortex.
- 1929:** Francis O. Holmes introduces the technique of "local lesion" as a means of measuring the concentration of tobacco mosaic virus. The method becomes extremely important in virus purification.
- 1929:** Frank M. Burnet and Margot McKie report critical insights into the phenomenon known as lysogeny (the inherited ability of bacteria to produce bacteriophage in the absence of infection). Burnet and McKie postulate that the presence of a "lytic unit" as a normal hereditary component of lysogenic bacteria. The "lytic unit" is proposed to be capable of liberating bacteriophage when it is activated by certain conditions. This concept is confirmed in the 1950s.
- 1929:** Willard Myron Allen and George Washington Corner discover progesterone. They demonstrate that it is necessary for the maintenance of pregnancy.
- 1930:** Curt Stern, and, independently, Harriet B. Creighton and Barbara McClintock, demonstrate cytological evidence of genetic crossing over between eukaryotic chromosomal strands.
- 1930:** Max Theiler demonstrates the advantages of using mice as experimental animals for research on animal viruses. Theiler uses mice in his studies of the yellow fever virus.
- 1930:** Ronald A. Fisher publishes *Genetical Theory of Natural Selection*, a formal analysis of the mathematics of selection.
- 1930:** United States Food, Drug, and Insecticide Administration is renamed the Food and Drug Administration.
- 1931:** Alice Miles Woodruff and Ernest W. Goodpasture demonstrate the advantages of using the membranes of the chick embryo to study the mechanism of viral infections.
- 1931:** Joseph Needham publishes his landmark work *Chemical Embryology*, which emphasizes the relationship between biochemistry and embryology.
- 1931:** Phoebus A. Levene publishes a book that summarizes his work on the chemical nature of the nucleic acids. His analysis of nucleic acids seemed to support the hypothesis known as the tetranucleotide interpretation, which suggests that the four bases are present in equal amounts in DNA from all sources. Perplexingly, this indicated that DNA is a highly repetitious polymer that is incapable of generating the diversity that would be an essential characteristic of the genetic material.
- 1932:** Hans Adolf Krebs describes and names the citric acid cycle.
- 1932:** William J. Elford and Christopher H. Andrewes develop methods of estimating the sizes of viruses

- by using a series of membranes as filters. Later studies prove that the viral sizes obtained by this method were comparable to those obtained by electron microscopy.
- 1932:** At Tuskegee, Alabama, African American sharecroppers become unknowing and unwilling subjects of experimentation on the untreated natural course of syphilis. Even after penicillin comes into use in the 1940s, men remain untreated.
- 1933:** “Regulation on New Therapy and Experimentation” decreed in Germany.
- 1933:** Twenty-first Amendment to the Constitution repeals Eighteenth Amendment and prohibition laws banning the sale and consumption of alcohol in United States.
- 1934:** J. B. S. Haldane presents the first calculations of the spontaneous mutation frequency of a human gene.
- 1934:** John Marrack begins a series of studies that leads to the formation of the hypothesis governing the association between an antigen and the corresponding antibody.
- 1935:** Wendall Meredith Stanley discovers that viruses are partly protein-based. By purifying and crystallizing viruses, he enables scientists to identify the precise molecular structure and propagation modes of several viruses.
- 1936:** George P. Berry and Helen M. Dedrick report that the Shope virus could be “transformed” into myxomatosis/Sanarelli virus. This virological curiosity was variously referred to as “transformation,” “recombination,” and “multiplicity of reactivation.” Subsequent research suggests that it is the first example of genetic interaction between animal viruses, but some scientists warn that the phenomenon might indicate the danger of reactivation of virus particles in vaccines and in cancer research.
- 1936:** Theodosius Dobzhansky publishes *Genetics and the Origin of Species*, a text eventually considered a classic in evolutionary genetics.
- 1937:** James W. Papez, suggests the name “limbic system” for the old mammalian part of the human brain that produces human emotions.
- 1937:** Marijuana Tax Act effectively criminalizes its use and possession, even for medical reasons.
- 1937:** Richard Benedict Goldschmidt postulates that the gene is a chemical entity rather than a discrete physical structure.
- 1938:** Emory L. Ellis and Max Delbrück perform studies on phage replication that mark the beginning of modern phage work. They introduce the “one-step growth” experiment, which demonstrates that after bacteriophages attack bacteria, replication of the virus occurs within the bacterial host during a “latent period,” after which viral progeny are released in a “burst.”
- 1938:** Federal Food, Drug, and Cosmetics Act gives regulatory powers to the Food and Drug Administration.
- 1938:** Hans Adolf Krebs identifies and defines the tricarboxylic acid (TCA) cycle.
- 1938:** Japanese scientists conduct experiments on Chinese prisoners.
- 1939:** Ernest Chain and H. W. Florey refine the purification of penicillin, allowing the mass production of the antibiotic.
- 1939:** Moses Kunitz reports the purification and crystallization of ribonuclease from beef pancreas.
- 1939:** Richard E. Shope reports that the swine influenza virus survived between epidemics in an intermediate host. This discovery is an important step in revealing the role of intermediate hosts in perpetuating specific diseases.
- 1939:** Studies on twins are conducted in Nazi Germany as part of genetic research.
- 1939:** Ishii experiments conducted on Unit 731 inmates at Ping Fan Prison in Manchuria.
- 1940:** Helmuth Ruska obtains the first electron microscopic image of a virus.
- 1940:** Kenneth Mather coins the term “polygenes” and describes polygenic traits in various organisms.
- 1941:** George W. Beadle and Edward L. Tatum publish their classic study on the biochemical genetics entitled *Genetic Control of Biochemical Reactions in Neurospora*. Beadle and Tatum irradiate red bread mold *Neurospora* and prove that genes produce their effects by regulating particular enzymes. This work leads to the one gene–one enzyme theory.
- 1941:** Lipmann describes and identifies the biochemical and physiological role of high energy phosphates (such as ATP).
- 1941:** Involuntary sterilization experiments and procedures carried out by Nazis at Auschwitz.
- 1941:** Nazi scientists perform experiments exposing Buchenwald and Natzweiler concentration camp prisoners to typhus and, in separate experiments, phosphorus burns.

- 1942:** Jules Freund and Katherine McDermott identify adjuvants (such as paraffin oil) that act to boost antibody production.
- 1942:** Luria and Max Delbruck demonstrate statistically that inheritance of genetic characteristics in bacteria follows the principles of genetic inheritance proposed by Charles Darwin. For their work, the two (along with Alfred Day Hershey) are awarded the 1969 Nobel Prize in Medicine or Physiology.
- 1942:** Selman Waksman suggests that the word “antibiotics” be used to identify antimicrobial compounds that are made by bacteria.
- 1942:** Nazi scientists perform experiments subjecting Dachau concentration camp prisoners to high altitude conditions (freezing and low pressure) and, in other experiments, diseases such as malaria.
- 1942:** Nazi scientists perform experiments on bone regeneration on prisoners at Ravensbrueck concentration camp.
- 1942:** United States military conducts mustard gas experiments on U.S. soldiers.
- 1943:** At University of Cincinnati Hospital experiments are performed using mentally disabled patients.
- 1944:** New techniques and instruments, such as partition chromatography on paper strips and the photoelectric ultraviolet spectrophotometer, stimulate the development of biochemistry after World War II. New methodologies make it possible to isolate, purify, and identify many important biochemical substances, including the purines, pyrimidines, nucleosides, and nucleotides derived from nucleic acids.
- 1944:** At Dachau concentration camp, prisoners are forced to drink only seawater as part of medical experiments.
- 1944:** Oswald T. Avery, Maclyn McCarty, and Colin MacLeod discover the “blueprint” function of DNA (that DNA carries genetic information).
- 1944:** Salvador E. Luria and Alfred Day Hershey prove that mutations occur in bacterial viruses, and develop methods to distinguish the mutations from other alterations.
- 1944:** To combat battle fatigue during World War II, nearly 200 million amphetamine tablets are issued to American soldiers stationed in Great Britain during the war.
- 1944:** Manhattan Project sub program experiments with effects of radioactive implants on U.S. soldiers at Oak Ridge.
- 1944:** United States Public Health Service Act passed.
- 1944:** University of Chicago Medical School professor Dr. Alf Alving conducts malaria experiments on more than 400 Illinois prisoners.
- 1945:** Joshua Lederberg and Edward L. Tatum demonstrate genetic recombination in bacteria.
- 1945:** Max Delbruck organizes the first session of the phage course at Cold Spring Harbor Laboratory. The widely influential phage course, which is subsequently taught for twenty-six consecutive years, serves as the training center for the first two generations of molecular biologists.
- 1946:** Nazi physicians and scientists tried by international court at Nuremberg.
- 1946:** Felix Bloch and Edward Mills Purcell develop nuclear magnetic resonance (NMR) as a viable tool for observation and analysis.
- 1946:** Hermann J. Muller is awarded the Nobel Prize in Medicine or Physiology for his contributions to radiation genetics.
- 1946:** James B. Sumner, John H. Northrop, and Wendell M. Stanley are awarded the Nobel Prize in Chemistry for their independent work on the purification and crystallization of enzymes and viral proteins.
- 1946:** Max Delbruck and W. T. Bailey, Jr. publish a paper entitled “Induced Mutations in Bacterial Viruses.” Despite some confusion about the nature of the phenomenon in question, this paper establishes the fact that genetic recombinations occur during mixed infections with bacterial viruses. Alfred Hershey and R. Rotman make the discovery of genetic recombination in bacteriophage simultaneously and independently. Hershey and his colleagues prove that this phenomenon can be used for genetic analyses. They construct a genetic map of phage particles and show that phage genes can be arranged in a linear fashion.
- 1947:** Nuremberg Code issued regarding voluntary consent of human subjects.
- 1948:** Barbara McClintock publishes her research on transposable regulatory elements (“jumping genes”) in maize. Her work was not appreciated until similar phenomena were discovered in bacteria and fruit flies in the 1960s and 1970s. McClintock was awarded the Nobel Prize in Medicine or Physiology in 1983.
- 1948:** James V. Neel reports evidence that the sickle-cell disease caused by a Mendelian autosomal recessive trait.
- 1948:** Alfred Kinsey publishes *Sexual Behavior in the Human Male*.

- 1949:** Atomic Energy Commission “Green Run” study using intentional release of radiiodine and xenon 133 over Hanford, Washington.
- 1949:** John F. Ender, Thomas H. Weller, and Frederick C. Robbins publish “Cultivation of Polio Viruses in Cultures of Human Embryonic Tissues.” The report by Enders and co-workers is a landmark in establishing techniques for the cultivation of poliovirus in cultures on non-neural tissue and for further virus research. The technique leads to the polio vaccine and other advances in virology.
- 1949:** Macfarlane Burnet and his colleagues begin studies that lead to the immunological tolerance hypothesis and the clonal selection theory. Burnet receives the 1960 Nobel Prize in Physiology or Medicine for this research.
- 1949:** The role of mitochondria is finally revealed. These slender filaments within the cell, that participate in protein synthesis and lipid metabolism, are the cell’s source of energy.
- 1949:** Walter R. Hess receives the Nobel Prize for his experiments involving probes of deep-brain functions. Using microelectrodes to stimulate or destroy specific areas of the brain in experimental animals, he discovers the role played by particular brain areas in determining and coordinating the functions of internal organs.
- 1949:** Atomic Energy Commission studies radioactive isotopes using mentally challenged school children.
- 1950–1999**
- 1950:** Douglas Bevis demonstrates that amniocentesis could be used to test fetuses for Rh-factor incompatibility.
- 1950:** Erwin Chargaff demonstrates that the Tetranucleotide Theory is incorrect and that DNA is more complex than the model that developed by Phoebus A. Levene. Chargaff proves that the nucleic acids are not monotonous polymers. Chargaff also discovers interesting regularities in the base composition of DNA; these findings are later known as “Chargaff’s rules.” Chargaff discovers a one-to-one ratio of adenine to thymine and guanine to cytosine in DNA samples from a variety of organisms.
- 1950:** Robert Hungate develops the roll-tube culture technique, which is the first technique that allows anaerobic bacteria to be grown in culture.
- 1950:** Ruth Sager’s work on the algae *Chlamydomonas* proves that cytoplasmic genes exist and that they can undergo mutation. She shows that such genes can be mapped on a “cytoplasmic chromosome.” Confirmation is provided when other researchers report similar findings in yeast and *Neurospora*. Subsequently the DNA is shown to be associated with cytoplasmic organelles.
- 1950:** Dr. Joseph Stokes of the University of Pennsylvania infects 200 women prisoners with viral hepatitis.
- 1951:** Esther M. Lederberg discovers a lysogenic strain of *Escherichia coli* K12 and isolates a new bacteriophage, called lambda.
- 1951:** Alan Hodgkin, Andrew Huxley, and Bernard Katz offer modern analysis of the mechanisms of nerve impulse transmission.
- 1951:** Rosalind Franklin obtains sharp x-ray diffraction photographs of deoxyribonucleic acid.
- 1951:** University of Pennsylvania under contract with U.S. Army conducts psychopharmacological experiments on hundreds of Pennsylvania prisoners.
- 1952:** Alfred Hershey and Martha Chase publish their landmark paper “Independent Functions of Viral Protein and Nucleic Acid in Growth of Bacteriophage.” The famous “blender experiment” suggests that DNA is the genetic material.
- 1952:** James T. Park and Jack L. Strominger demonstrate that penicillin blocks the synthesis of the peptidoglycan of bacteria. This represents the first demonstration of the action of a natural antibiotic.
- 1952:** Karl Maramorosch demonstrates that some viruses could multiply in both plants and insects. This work leads to new questions about the origins of viruses.
- 1952:** Joshua and Ester Lederberg develop the replica plating method that allows for the rapid screening of large numbers of genetic markers. They use the technique to demonstrate that resistance to antibacterial agents such as antibiotics and viruses is not induced by the presence of the antibacterial agent.
- 1952:** Renato Dulbecco develops a practical method for studying animal viruses in cell cultures. His so-called plaque method is comparable to that used in studies of bacterial viruses, and the method proves to be important in genetic studies of viruses. These methods are described in his paper “Production of Plaques in Monolayer Tissue Cultures by Single Particles of an Animal Virus.”
- 1952:** Rosalind Franklin completes a series of x-ray crystallography studies of two forms of DNA. Her colleague, Maurice Wilkins, gives information about her work to James Watson.

- 1952:** William Hayes isolates a strain of *E. coli* that produces recombinants thousands of times more frequently than previously observed. The new strain of K12 is named Hfr (high-frequency recombination) Hayes.
- 1953:** James D. Watson and Francis H. C. Crick publish two landmark papers in the journal *Nature*. The papers are entitled “Molecular Structure of Nucleic Acids: A Structure for Deoxyribose Nucleic Acid” and “Genetic Implications of the Structure of Deoxyribonucleic Acid.” Watson and Crick propose a double helical model for DNA and call attention to the genetic implications of their model.
- 1953:** Jonas Salk begins testing a polio vaccine comprised of a mixture of killed viruses.
- 1953:** CIA conducts brainwashing experiments with LSD at eighty institutions on hundreds of subjects in a project code named “MKULTRA.”
- 1954:** Frederick Sanger determines the entire sequence of the amino acids in insulin.
- 1954:** Seymour Benzer deduces the fine structure of the rII region of the bacteriophage T4 of *Escherichia coli*, and coins the terms cistron, recon, and muton.
- 1955:** Fred L. Schaffer and Carlton E. Schwerdt report on their successful crystallization of the polio virus. Their achievement is the first successful crystallization of an animal virus.
- 1955:** Heinz Fraenkel-Conrat and Robley C. Williams prove that tobacco mosaic virus can be reconstituted from its nucleic acid and protein subunits. The reconstituted particles exhibit normal morphology and infectivity.
- 1956:** Alfred Gierer and Gerhard Schramm demonstrate that naked RNA from tobacco mosaic virus is infectious. Subsequently, infectious RNA preparations are obtained for certain animal viruses.
- 1956:** American Medical Association defines alcoholism as a disease.
- 1956:** Joe Hin Tijo and Albert Levan prove that the number of chromosomes in a human cell is forty-six, and not forty-eight, as argued since the early 1920s.
- 1956:** Mary F. Lyon proposes that one of the X chromosomes of normal females is inactivated. This concept became known as the Lyon hypothesis and helped explain some confusing aspects of sex-linked diseases. Females are usually “carriers” of genetic diseases on the X chromosome because the normal gene on the other chromosome protects them, but some X-linked disorders are partially expressed in female carriers. Based on studies of mouse coat color genes, Lyon proposes that one X chromosome is randomly inactivated in the cells of female embryos.
- 1956:** Vernon M. Ingram reports that normal and sickle cell hemoglobin differ by a single amino acid substitution.
- 1956–1980:** Researchers conduct hepatitis experiments on mentally disabled children at The Willowbrook State School.
- 1957:** Alick Isaacs and Jean Lindemann discover interferon.
- 1957:** François Jacob and Elie L. Wollman demonstrate that the single linkage group of *Escherichia coli* is circular and suggest that the different linkage groups found in different Hfr strains result from the insertion at different points of a factor in the circular linkage group that determines the rupture of the circle.
- 1957:** Francis Crick proposes that during protein formation each amino acid is carried to the template by an adapter molecule containing nucleotides and that the adapter is the part that actually fits on the RNA template. Later research demonstrates the existence of transfer RNA.
- 1957:** The World Health Organization advances the oral polio vaccine developed by Albert Sabin as a safer alternative to the Salk vaccine.
- 1958:** Frederick Sanger is awarded the Nobel Prize in Chemistry for his work on the structure of proteins, especially for determining the primary sequence of insulin.
- 1958:** Matthew Meselson and Frank W. Stahl publish their landmark paper “The replication of DNA in *Escherichia coli*,” which demonstrated that the replication of DNA follow the semiconservative model.
- 1959:** Arthur Kornberg and Severo Ochoa are awarded the Nobel Prize in Medicine or Physiology for their discovery of enzymes that produce artificial DNA and RNA.
- 1959:** Rodney Porter begins studies that lead to the discovery of the structure of antibodies. Porter receives the 1972 Nobel Prize in Physiology or Medicine for this research.
- 1959:** Jerome Lejeune, Marthe Gautier, and Raymond A. Turpin report that Down syndrome is a chromosomal aberration involving trisomy of a small telocentric chromosome.

- 1959:** Severo Ochoa and Arthur Kornberg are awarded the Nobel Prize in Medicine or Physiology for their discovery of the mechanisms in the biological synthesis of ribonucleic acid and deoxyribonucleic acid.
- 1959:** Sydney Brenner and Robert W. Horne publish a paper entitled “A Negative Staining Method for High Resolution Electron Microscopy of Viruses.” The two researchers develop a method for studying the architecture of viruses at the molecular level using the electron microscope.
- 1961:** Francis Crick, Sydney Brenner and others propose that a molecule called transfer RNA uses a three base code in the manufacture of proteins.
- 1961:** Jacques Miller discovers the role of the thymus in cellular immunity.
- 1961:** Marshall Warren Nirenberg synthesizes a polypeptide using an artificial messenger RNA (a synthetic RNA containing only the base uracil) in a cell-free protein-synthesizing system. The resulting polypeptide only contains the amino acid phenylalanine, indicating that UUU was the codon for phenylalanine. This important step in deciphering the genetic code is described in the landmark paper by Nirenberg and J. Heinrich Matthaei, “The Dependence of Cell-Free Synthesis in *E. coli* upon Naturally Occurring or Synthetic Polyribonucleotides.”
- 1961:** Noel Warner establishes the physiological distinction between the cellular and humoral immune responses.
- 1961:** Rachel Carson publishes *Silent Spring* exposing harmful effects of pollutants, including DDT.
- 1962:** James D. Watson, Francis Crick, and Maurice Wilkins are awarded the Nobel Prize in Medicine or Physiology for their work in elucidating the structure of DNA.
- 1962:** After thousands of birth deformities are blamed on the drug, Thalidomide is withdrawn from the market.
- 1962:** FDA requires multiphase human clinical trials before drugs can be released to market.
- 1963:** John Carew Eccles shares a Nobel Prize for his work on the mechanisms of nerve-impulse transmission. He also suggests that the mind is separate from the brain. The mind, he affirms, acts upon the brain by effecting subtle changes in the chemical signals that flow among brain cells.
- 1963:** Ruth Sager discovers DNA in chloroplasts. Boris Ephrussi discovers DNA in mitochondria.
- 1964:** Barbara Bain publishes a classic account of her work on the mixed leukocyte culture (MLC) system that is critical in determining donor-recipient matches for organ or bone marrow transplantation. Bain shows that the MLC phenomenon is caused by complex genetic differences between individuals.
- 1964:** The first Surgeon General’s Report on Smoking and Health is released, and the United States government first acknowledges and publicizes that cigarette smoking is a leading cause of cancer, bronchitis, and emphysema.
- 1964:** World Medical Association adopts Helsinki Declaration.
- 1965:** At the height of tobacco use in America, surveys show 52 percent of adult men and 32 percent of adult women use tobacco products.
- 1965:** François Jacob, André Lwoff, and Jacques Monod are awarded the Nobel Prize in Medicine or Physiology for their discoveries concerning genetic control of enzymes and virus synthesis.
- 1966:** Bruce Ames develops a test to screen for compounds that cause mutations, including those that are cancer causing. The so-called Ames test utilizes the bacterium *Salmonella typhimurium*.
- 1966:** FDA and National Academy of Sciences begin investigation of effectiveness of drugs previously approved because they were thought safe.
- 1966:** Marshall Nirenberg and Har Gobind Khorana lead teams that decipher the genetic code. All of the sixty-four possible triplet combinations of the four bases (the codons) and their associated amino acids are determined and described.
- 1966:** United States passes Fair Packaging and Labeling Act.
- 1966:** National Institutes of Health Office for Protection of Research Subjects created.
- 1966:** *New England Journal of Medicine* article exposes unethical Tuskegee syphilis study.
- 1967:** Charles T. Caskey, Richard E. Marshall, and Marshall Nirenberg suggest that there is a universal genetic code shared by all life forms.
- 1967:** Charles Yanofsky demonstrates that the sequence of codons in a gene determines the sequence of amino acids in a protein.
- 1967:** Thomas Brock discovers the heat-loving bacterium *Thermus aquaticus* from a hot spring in Yellowstone National Park. The bacterium yields the enzyme that becomes the basis of the DNA polymerase reaction.

- 1967:** British physician M. H. Pappworth publishes “Human Guinea Pigs,” advising “No doctor has the right to choose martyrs for science or for the general good.”
- 1968:** FDA administratively moves to Public Health Service.
- 1968:** Lynne Margulis proposes that mitochondria and chloroplasts in eukaryotic cells originated from bacterial symbiosis.
- 1968:** Mark Steven Ptashne and Walter Gilbert independently identify the bacteriophage genes that are the repressors of the lac operon.
- 1968:** Robert W. Holley, Har Gobind Khorana, and Marshall W. Nirenberg are awarded the Nobel Prize in Medicine or Physiology for their interpretation of the genetic code and its function in protein synthesis.
- 1968:** Werner Arber discover that bacteria defend themselves against viruses by producing DNA-cutting enzymes. These enzymes quickly become important tools for molecular biologists.
- 1969:** Jonathan R. Beckwith and colleagues isolate a single gene.
- 1969:** Julius Adler discovers protein receptors in bacteria that function in the detection of chemical attractants and repellents. The so-called chemoreceptors are critical for the directed movement of bacteria that comes to be known as chemotaxis.
- 1969:** Max Delbruck, Alfred D. Hershey, and Salvador E. Luria are awarded the Nobel Prize in Medicine or Physiology for their discoveries concerning the replication mechanism and the genetic structure of viruses.
- 1969:** Stanford Moore and William H. Stein determine the sequence of the 124-amino acid chain of the enzyme ribonuclease.
- 1970:** Controlled Substance Act puts strict controls on the production, import, and prescription of amphetamines. Many amphetamine forms, particularly diet pills, are removed from the over-the-counter market.
- 1970:** FDA requires a patient information package insert in oral contraceptives. The insert must contain information regarding specific risks and benefits.
- 1970:** Hamilton Smith and Kent Wilcox isolate the first restriction enzyme, HindII, an enzyme that cuts DNA molecules at specific recognition sites.
- 1970:** Har Gobind Khorana announces the synthesis of the first wholly artificial gene. Khorana and his co-workers synthesize the gene that codes for alanine transfer RNA in yeast.
- 1970:** Howard Martin Temin and David Baltimore independently discover reverse transcriptase in viruses. Reverse transcriptase is an enzyme that catalyzes the transcription of RNA into DNA.
- 1970:** United States Congress passes Controlled Substance Act.
- 1971:** Christian B. Anfinsen, Stanford Moore, and William H. Stein are awarded the Nobel Prize in Chemistry. Anfinsen is cited for his work on ribonuclease, especially concerning the connection between the amino acid sequence and the biologically active conformation, and Moore and Stein are cited for their contribution to the understanding of the connection between chemical structure and catalytic activity of the active center of the ribonuclease molecule.
- 1972:** Paul Berg and Herbert Boyer produce the first recombinant DNA molecules.
- 1972:** Recombinant technology emerges as one of the most powerful techniques of molecular biology. Scientists are able to splice together pieces of DNA to form recombinant genes. As the potential uses, therapeutic and industrial, became increasingly clear, scientists and venture capitalists establish biotechnology companies.
- 1973:** Annie Chang and Stanley Cohen show that a recombinant DNA molecule can be maintained and replicated in *Escherichia coli*.
- 1973:** Concerns about the possible hazards posed by recombinant DNA technologies, especially work with tumor viruses, leads to the establishment of a meeting at Asilomar, California. The proceedings of this meeting are subsequently published by the Cold Spring Harbor Laboratory as a book entitled *Biohazards in Biological Research*.
- 1973:** First report is made claiming a circadian variation in blood melatonin levels (pineal hormone) in humans. These variations affect mood and may cause the type of depression association with seasonal affective disorder (SAD).
- 1973:** Herbert Wayne Boyer and Stanley H. Cohen create recombinant genes by cutting DNA molecules with restriction enzymes. These experiments mark the beginning of genetic engineering.
- 1973:** Joseph Sambrook and co-workers refine DNA electrophoresis by using agarose gel and staining with ethidium bromide.
- 1974:** Peter Doherty and Rolf Zinkernagel discover the basis of immune determination of self and non-self.

- 1974:** National Research Act establishes “The Common Rule” for protection of human subjects.
- 1975:** César Milstein and George Kohler create monoclonal antibodies.
- 1975:** David Baltimore, Renato Dulbecco, and Howard Temin share the Nobel Prize in Medicine or Physiology for their discoveries concerning the interaction between tumor viruses and the genetic material of the cell and the discovery of reverse transcriptase.
- 1975:** John R. Hughes and others discover enkephalin. This first known opioid peptide, popularly called “brain morphine,” occurs naturally in the brain, indicating that the brain’s chemicals block the transmission of pain signals.
- 1975:** Scientists at an international meeting in Asilomar, California, called for the adoption of guidelines regulating recombinant DNA experimentation.
- 1975:** Department of Health and Human Services promulgates Title 45 of Federal Regulations titled “Protection of Human Subjects,” requiring appointment and utilization of IRBs.
- 1975:** Edward O. Wilson publishes *Sociobiology* proposing interrelation of biology, human behavior, and culture.
- 1976:** FBI warns “crack” cocaine use and cocaine addiction on the rise in the United States.
- 1976:** First outbreak of Ebola virus observed in Zaire. More than 300 cases with a 90 percent death rate.
- 1976:** Michael J. Bishop, Harold Elliot Varmus, and co-workers establish definitive evidence of the oncogene hypothesis. They discover that normal genes could malfunction and cause cells to become cancerous.
- 1976:** New Jersey Supreme Court rules that coma patient Karen Ann Quinlan can be disconnected from her respirator. Quinlan lives in a persistent vegetative state until her death in 1985.
- 1976:** Swine flu identified in soldiers stationed in New Jersey. Virus identified as H1N1 virus causes concern due to its similarities to H1N1 responsible for Spanish flu pandemic. President Gerald Ford calls for emergency vaccination program. More than twenty deaths result from Guillain-Barre syndrome related to the vaccine.
- 1977:** Carl R. Woese and George E. Fox publish an account of the discovery of a third major branch of living beings, the Archaea. Woese suggests that an rRNA database could be used to generate phylogenetic trees.
- 1977:** Frederick Sanger develops the chain termination (dideoxy) method for sequencing DNA, and uses the method to sequence the genome of a microorganism.
- 1977:** Holger Jannasch demonstrates that heat-loving bacteria found at hydrothermal vents are the basis of an ecosystem that exists in the absence of light.
- 1977:** Philip Allen Sharp and Richard John Roberts independently discover that the DNA making up a particular gene could be present in the genome as several separate segments. Although both Roberts and Sharp use a common cold-causing virus, called adenovirus, as their model system, researchers later find “split genes” in higher organisms, including humans. Sharp and Roberts are subsequently awarded the Nobel Prize in Medicine or Physiology in 1993 for the discovery of split genes.
- 1977:** The first known human fatality from H5N1 avian flu occurs in Hong Kong.
- 1977:** The last reported smallpox case is recorded. Ultimately, the World Health Organization declares the disease eradicated.
- 1978:** Scientists clone the gene for human insulin.
- 1978:** Louise Brown, the world’s first “test-tube baby,” is born.
- 1979:** National Commission issues Belmont Report.
- 1980:** Paul Berg, Walter Gilbert, and Frederick Sanger share a Nobel Prize in Chemistry. Berg is honored for his fundamental studies of the biochemistry of nucleic acids, with particular regard to recombinant-DNA. Gilbert and Sanger are honored for their contributions to the sequencing of nucleic acids.
- 1980:** Researchers successfully introduce a human gene, which codes for the protein interferon, into a bacterium.
- 1980:** Congress passes the Bayh-Dole Act to encourage the utilization of inventions produced under federal funding. The act is amended by the Technology Transfer Act in 1986.
- 1980:** The FDA promulgates 21 CFR 50.44 prohibiting use of prisoners as subjects in clinical trials.
- 1980:** In *Diamond v. Chakrabarty* the United States Supreme Court rules that a genetically modified bacterium can be patented.
- 1981:** Karl Illmensee clones baby mice.
- 1982:** The United States Food and Drug Administration approves the first genetically engineered drug, a form of human insulin produced by bacteria.

- 1983:** *Escherichia coli* O157:H7 is identified as a human pathogen.
- 1983:** Andrew W. Murray and Jack William Szostak create the first artificial chromosome.
- 1983:** Luc Montaner and Robert Gallo discover the human immunodeficiency virus that is believed to cause acquired immunodeficiency syndrome.
- 1984:** Steen A. Willadsen successfully clones a sheep.
- 1985:** Alec Jeffreys develops “genetic fingerprinting,” a method of using DNA polymorphisms (unique sequences of DNA) to identify individuals. The method, which has been used in paternity, immigration, and murder cases, is generally referred to as “DNA fingerprinting.”
- 1985:** Leroy Hood leads a team that discovers the genes that code for the T cell receptor.
- 1985:** Elizabeth Blackburn and Carol Greider discover the enzyme telomerase, an unusual RNA-containing DNA polymerase that can add to the telomeres (specialized structures found at the ends of chromosomal DNA). Telomeres appear to protect the integrity of the chromosome. Most normal somatic cells lack telomerase, but cancer cells have telomerase activity, which might explain their ability to multiply indefinitely.
- 1985:** Susuma Tonegawa discovers the genes that code for immunoglobulins. He receives the 1986 Nobel Prize in Physiology or Medicine for this discovery.
- 1985:** Kary Mullis, who was working at Cetus Corporation, develops the polymerase chain reaction (PCR), a new method of amplifying DNA. This technique quickly becomes one of the most powerful tools of molecular biology. Cetus patents PCR and sells the patent to Hoffman-LaRoche, Inc. in 1991.
- 1986:** Congress passes the National Childhood Vaccine Injury Act, requiring patient information on vaccines and reporting of adverse events after vaccination.
- 1986:** First gene known to inhibit growth is produced by an American team led by molecular biologist Robert A. Weinberg. The gene is able to suppress the cancer retinoblastoma.
- 1986:** Robert A. Weinberg and co-workers isolate a gene that inhibits growth and appears to suppress retinoblastoma (a cancer of the retina).
- 1986:** The United States Food and Drug Administration approves the first genetically engineered human vaccine for hepatitis B.
- 1986:** United States Surgeon General’s report focuses on the hazards of environmental tobacco smoke to nonsmokers.
- 1987:** David C. Page and colleagues discover the gene responsible for maleness in mammals. It is a single gene on the Y chromosome that causes the development of testes instead of ovaries.
- 1987:** Maynard Olson creates and names yeast artificial chromosomes (YACs), which provide a technique to clone long segments of DNA.
- 1987:** The United States Congress charts a Department of Energy advisory committee, the Health and Environmental Research Advisory Committee, that recommends a 15-year, multi-disciplinary, scientific, and technological undertaking to map and sequence the human genome. National Institute of General Medical Sciences at the National Institutes of Health begins funding genome projects.
- 1987:** National Institutes of Mental Health concludes that a researcher fabricated and falsified data in a study. The researcher, Steven Breuning, is convicted a year later of defrauding the federal government.
- 1988:** Canadian sprinter Ben Johnson tests positive for anabolic-androgenic steroids at the Seoul Olympic games and must forfeit his gold medal to the second-place finisher, American Carl Lewis.
- 1988:** Harvard University and Dow Chemical patent a genetically engineered mouse with plans to use it in cancer studies.
- 1988:** The Human Genome Organization is established by scientists in order to coordinate international efforts to sequence the human genome.
- 1989:** Cells from one embryo are used to produce seven cloned calves.
- 1989:** Sidney Altman and Thomas R. Cech are awarded the Nobel Prize in Chemistry for their discovery of ribozymes (RNA molecules with catalytic activity).
- 1989:** Office of Scientific Integrity and the Office of Scientific Integrity Review form to investigate scientific misconduct.
- 1990:** Michael R. Blaese and French W. Anderson conduct the first gene replacement therapy experiment on a four-year-old girl with adenosine deaminase (ADA) deficiency, an immune-system disorder. T cells from the patient are isolated and exposed to retroviruses containing an RNA copy of a normal ADA gene. The treated cells are

- returned to her body where they help restore some degree of function to her immune system.
- 1990:** National Council on Alcoholism and Drug Dependence along with the American Society of Addictive Medicine define alcoholism as a chronic disease that has genetic, psychological, and environmental factors that influence it. Alcoholism is described as a loss of control over drinking; a preoccupation with drinking despite negative consequences to one's physical, mental, and emotional makeup as well as one's work and family life.
- 1990:** Research and development begins for the efficient production of more stable, large-insert bacterial artificial chromosomes.
- 1990:** Supreme Court decision in *Employment Division v. Smith* determines that the religious use of peyote by Native Americans is not protected by the First Amendment.
- 1990:** United States Congress passes Nutrition Labeling and Education Act permitted manufacturers to make some health claims for foods, including dietary supplements.
- 1991:** Mary-Claire King concludes, based on her studies of the chromosomes of women in cancer-prone families, that a gene on chromosome 17 causes the inherited form of breast cancer and also increases the risk of ovarian cancer.
- 1991:** The gender of a mouse is changed at the embryo stage.
- 1991:** The Genome Database, a human chromosome mapping data repository, is established.
- 1991:** World Health Organization announces Council for International Organizations of Medical Sciences guidelines.
- 1992:** American and British scientists develop a technique for testing embryos *in vitro* for genetic abnormalities such as cystic fibrosis and hemophilia.
- 1992:** Congress passes the Prescription Drug User Fee Act requiring the FDA to use product application fees collected from drug manufacturers to hire more reviewers to assess applications.
- 1992:** National Academy of Science publishes *Responsible Science: Ensuring the Integrity of the Research Process*.
- 1992:** Craig Venter establishes the Institute for Genomic Research in Rockville, Maryland. The institute later sequences the genome of *Haemophilus influenzae* and many other bacterial genomes.
- 1992:** Guidelines for data release and resource sharing related to the Human Genome Project are announced by the United States Department of Energy and National Institutes of Health.
- 1992:** The United States Army begins collecting blood and tissue samples from all new recruits as part of a "genetic dog tag" program aimed at better identification of soldiers killed in combat.
- 1993:** An international research team, led by Daniel Cohen of the Center for the Study of Human Polymorphisms in Paris, produces a rough map of all twenty-three pairs of human chromosomes.
- 1993:** French Gépnéthon makes mega-YACs available to the genome community.
- 1993:** George Washington University researchers clone human embryos and nurture them in a petri dish for several days. The project provokes protests from ethicists, politicians, and critics of genetic engineering.
- 1993:** Hanta virus emerges in the western United States in a 1993 outbreak on a Native American reservation. The resulting Hanta pulmonary syndrome (HPS) has a 43 percent mortality rate.
- 1993:** Scientists identify p53, a tumor suppressor gene, as the crucial factor preventing uncontrolled cell growth. In addition, scientists find that p53 performs a variety of functions ensuring cell health.
- 1994:** Biologists discover that both vertebrates and invertebrates share certain developmental genes.
- 1994:** U.S. Department of Energy announce the establishment of the Microbial Genome Project as a spin-off of the Human Genome Project.
- 1994:** Geneticists determine that DNA repair enzymes perform several vital functions, including preserving genetic information and protecting the cell from cancer.
- 1994:** The five-year goal for genetic-mapping is achieved one year ahead of schedule.
- 1994:** The Human Genome Project Information Web site is made available to researchers and the public.
- 1994:** United States Congress passes Dietary Supplement Health and Education Act expressly defining a dietary supplement as a vitamin, a mineral, an herb or other botanical, an amino acid, or any other "dietary substance."
- 1994:** Harvard psychologist Richard Herrnstein and Charles Murray publish *The Bell Curve* that stirs controversy about biology, race, and intelligence.
- 1995:** Peter Funch and Reinhardt Moberg Kristensen create a new phylum, Cycliophora, for a novel

- invertebrate called *Symbion pandora*, which is found living in the mouths of Norwegian lobsters.
- 1995:** Public awareness of potential use of chemical or biological weapons by terrorist groups increases following the release of sarin gas in a Tokyo subway by Aum Shinrikyo, a Japanese cult, killing a dozen people and sending thousands to the hospital.
- 1995:** Researchers at Duke University Medical Center report that they have transplanted hearts from genetically altered pigs into baboons. All three transgenic pig hearts survive at least a few hours, suggesting that xenotransplants (cross-species organ transplantation) might be possible.
- 1995:** Religious leaders and biotechnology critics protest the patenting of plants, animals, and human body parts.
- 1995:** The sequence of *Mycoplasma genitalium* is completed. *Mycoplasma genitalium*, regarded as the smallest known bacterium, is considered a model of the minimum number of genes needed for independent existence.
- 1996:** Chris Paszty and co-workers successfully employ genetic engineering techniques to create mice with sickle-cell anemia, a serious human blood disorder.
- 1996:** H5N1 avian flu virus is identified in Guangdong, China.
- 1996:** International participants in the genome project meet in Bermuda and agree to formalize the conditions of data access. The agreement, known as the “Bermuda Principles,” calls for the release of sequence data into public databases within twenty-four hours.
- 1996:** Researchers Henrich Cheng, Yihai Cao, and Lars Olson demonstrate that the spinal cord can be regenerated in adult rats.
- 1996:** Researchers find that abuse and violence can alter a child’s brain chemistry, placing him or her at risk for various problems, including drug abuse, cognitive disabilities, and mental illness, later in life.
- 1996:** Scientists discover a link between autophagy (cellular suicide, a natural process whereby the body eliminates useless cells) gone awry and several neurodegenerative conditions, including Alzheimer’s disease.
- 1996:** Dolly, the world’s first cloned sheep, is born. Several European Union nations ban human cloning. United States Congress debates a bill to ban human cloning.
- 1996:** Scientists report further evidence that individuals with two mutant copies of the CC-CLR-5 gene are generally resistant to HIV infection.
- 1996:** South Carolina Supreme Court decides in favor of the Medical University of South Carolina policy to secretly test pregnant patients for cocaine use. The court upheld MUSC’s drug testing in an effort to protect the unborn. Cocaine greatly increases the chances of a miscarriage. Low-birth-weight “crack babies” have twenty times as great a risk of dying in their first month of life than normal-weight babies. Those who survive are at increased risk for birth defects.
- 1996:** William R. Bishai and co-workers reports that SigF, a gene in the tuberculosis bacterium, enables the bacterium to enter a dormant stage.
- 1997:** Donald Wolf and co-workers announce that they cloned rhesus monkeys from early stage embryos, using nuclear transfer methods.
- 1997:** Mickey Selzer, neurologist at the University of Pennsylvania, and co-workers, finds that in lampreys, which have a remarkable ability to regenerate a severed spinal cord, neurofilament messenger RNA effects the regeneration process by literally pushing the growing axons and moving them forward.
- 1997:** Oregon voters approve the Death with Dignity Act allowing terminally ill people to receive prescriptions for lethal dosages of drugs to end their lives.
- 1997:** Researchers identify a gene that plays a crucial role in establishing normal left-right configuration during organ development.
- 1997:** Researchers report progress in using the study of genetic mutations in humans and mice to decipher the molecular signals that lead undeveloped neurons from inside the brain to their final position in the cerebral cortex.
- 1997:** The DNA sequence of *Escherichia coli* is completed.
- 1997:** The National Center for Human Genome Research at the National Institutes of Health becomes the National Human Genome Research Institute.
- 1997:** United States passes Food and Drug Administration Modernization Act and reauthorizes the Prescription Drug User Fee Act of 1992. The changes in policy allow for a more rapid review of drugs and delivery devices. The Act also expands FDA regulatory powers over advertising, especially with regard to health claims.

- 1997:** While performing a cloning experiment, Christof Niehrs, a researcher at the German Center for Cancer Research, identifies a protein responsible for the creation of the head in a frog embryo.
- 1997:** William Jacobs and Barry Bloom creates a biological entity that combines the characteristics of a bacterial virus and a plasmid (a DNA structure that functions and replicates independently of the chromosomes). This entity is capable of triggering mutations in *Mycobacterium tuberculosis*.
- 1998:** Dolly, the first cloned sheep, gives birth to a lamb that had been conceived by a natural mating with a Welsh Mountain ram. Researches said the birth of Bonnie proved that Dolly was a fully normal and healthy animal.
- 1998:** Immunologist Ellen Heber-Katz, a researcher at the Wistar Institute in Philadelphia, reports than a strain of laboratory mice can regenerate tissue in their ears, closing holes which scientists had created for identification purposes. This discovery reopens the discussion on possible regeneration in humans.
- 1998:** Scientists find that an adult human's brain can replace cells. This discovery heralds potential breakthroughs in neurology
- 1998:** Scientists in Korea claim to have cloned human cells.
- 1998:** Two research teams succeed in growing embryonic stem cells.
- 1999:** Scientists announce the complete sequencing of the DNA making up human chromosome 22. The first complete human chromosome sequence is published in December 1999.
- 1999:** The public genome project plans to produce a draft genome sequence by 2000.
- 1999:** The National Institutes of Health and the Office for Human Research Protections require researchers conducting or overseeing human subjects to ethics training.
- 2000–**
- 2000:** On June 26, 2000, leaders of the public genome project and Celera announce the completion of a working draft of the entire human genome sequence.
- 2000:** The first volume of *Annual Review of Genomics and Human Genetics* is published. Genomics is defined as the new science dealing with the identification and characterization of genes and their arrangement in chromosomes and human genetics as the science devoted to understanding the origin and expression of human individual uniqueness.
- 2000:** The National Cancer Institute estimates that 3,000 lung cancer deaths, and as many as 40,000 cardiac deaths per year among adult nonsmokers in the United States can be attributed to passive smoke or environmental tobacco smoke.
- 2000:** United States Congress considers but does not pass the Pain Relief Promotion Act, which would have amended the Controlled Substances Act to say that relieving pain or discomfort—within the context of professional medicine—is a legitimate use of controlled substances. The bill died in the Senate.
- 2000:** United States Congress passes a transportation spending bill including establishment of a national standard for drunk driving for adults at a 0.08 percent blood alcohol level (BAL). States are required to adopt this stricter standard by 2004 or face penalties. By 2001, more than half the states adopt this stricter standard.
- 2000:** United States Drug Addiction Treatment Act allows opioids to be distributed to physicians for the treatment of opioid dependence.
- 2000:** President Bill Clinton signs the Hillary J. Farias and Samantha Reid Date Rape Drug Prohibition Act into law.
- 2001:** In February 2001, the complete draft sequence of the human genome is published.
- 2001:** Scientists from the Whitehead Institute announce test results that show patterns of errors in cloned animals that might explain why such animals die early and exhibit a number of developmental problems. The report stimulates new debate on ethical issues related to cloning.
- 2001:** The company Advanced Cell Technology announces that its researchers have created cloned human embryos that grew to the six-cell stage.
- 2001:** In the aftermath of the September 11 terrorist attacks on the United States, a number of deaths result from the deliberate release of the bacterial agent of anthrax.
- 2001:** The United States announces that the National Institutes of Health will fund research on only sixty-four embryonic stem cell lines created from human embryos.
- 2001:** International Olympic Committee announces that 15–20 percent of the approximately 600 nutritional supplements the agency tested were

- adulterated with substances that could lead to positive doping tests.
- 2001:** The National Football League joins the National College Athletic Association and the International Olympic Committee in issuing a ban on ephedrine use.
- 2001:** National Institute of Drug Abuse research asserts that children exposed to cocaine prior to birth sustain long-lasting brain changes.
- 2001:** Office of National Drug Control Policy annual report asserts that that approximately 80 percent of Americans abusing illegal drugs use marijuana.
- 2001:** Study entitled *Global Illicit Drug Trends* conducted by the United Nations Office for Drug Control and Crime Prevention, estimates that 14 million people use cocaine worldwide. Although cocaine use leveled off, the United States still maintains the highest levels of cocaine abuse.
- 2001:** The annual Monitoring the Future study, conducted by the University of Michigan and funded by the National Institute on Drug Abuse, found that 17.1 percent of eighth graders had abused inhalants at some point in their lives.
- 2001:** The U.S. military endorses the situational temporary usefulness of caffeine, recommending it as a safe and effective stimulant for its soldiers in good health.
- 2001:** United State Supreme Court ruled 8 to 0 in *United States vs. Oakland Cannabis Buyers' Cooperative* that the cooperatives permitted under California law to sell marijuana to medical patients who had a physician's approval to use the drug were unconstitutional under federal law.
- 2001:** In August, President George W. Bush announces the United States will allow and support limited forms of stem cell growth and research.
- 2001:** Terrorists attack United States on September 11 and kill thousands by crashing airplanes into buildings. Several weeks later, an unknown terrorist sends four letters, including letters to government leaders, that contain anthrax. The anthrax ultimately kills five people.
- 2002:** A company called DrinkSafe Technology announces the invention of a coaster that can be used to test whether a drink has been drugged. If Rohypnol, GHB, or ketamine has been added, the coaster will change color when a drop of the tampered drink is placed on it.
- 2002:** A Florida physician is convicted of manslaughter for prescribing OxyContin to four patients who died after overdosing on the powerful drug. News reports assert that he is the first doctor ever convicted in the death of patients whose deaths were related to OxyContin use.
- 2002:** Following September 11, 2001, terrorist attacks on the United States, the Public Health Security and Bioterrorism Preparedness and Response Act of 2002 is passed in an effort to improve the ability to prevent and respond to public health emergencies.
- 2002:** Health Canada, the Canadian health regulatory agency, requests a voluntary recall of products containing both natural and chemical ephedra.
- 2002:** In June traces of biological and chemical weapon agents are found in Uzbekistan on a military base used by U.S. troops fighting in Afghanistan. Early analysis dates and attributes the source of the contamination to former Soviet Union biological and chemical weapons programs that utilized the base.
- 2002:** Several states, including Connecticut and Minnesota, pass laws that ban teachers from recommending psychotropic drugs, especially Ritalin, to parents.
- 2002:** The Best Pharmaceuticals for Children Act passed in an effort to improve safety and efficacy of patented and off-patent medicines for children.
- 2002:** The planned destruction of stocks of smallpox-causing Variola virus at the two remaining depositories in the United States and Russia is delayed over fears that large scale production of vaccine might be needed in the event of a bioterrorist action.
- 2002:** United States Federal district court judge rejects a Justice Department attempt to overturn Oregon's physician-assisted suicide law. The Justice Department claims that the state law violates the federal Controlled Substances Act.
- 2003:** An unusual pneumonia is reported in Hanoi, Vietnam (later identified as SARS).
- 2003:** World Health Organization officer Carlo Urbani, MD, identifies sudden acute respiratory syndrome or SARS. Urbani later dies of the disease.
- 2003:** Commissioner of Food and Drugs establishes an obesity working group to deal with U.S. obesity epidemic. In March 2004 the group releases "Calories Count: Report of the Obesity Working Group."
- 2003:** Differences in outbreaks in Hong Kong between 1997 and 2003 cause investigators to conclude that the H5N1 virus has mutated.

- 2003:** Food and Drug Administration requires food labels to include trans fat content. This is the first major change to the nutrition facts panel on foods since 1993.
- 2003:** SARS is added to the list of quarantinable diseases in the United States.
- 2003:** The Medicare Prescription Drug Improvement and Modernization Act addresses issues related to making medical information available to the blind and visually impaired.
- 2003:** World Health Organization Global Influenza Surveillance Network intensifies work on development of a H5N1 vaccine for humans.
- 2004:** Anabolic Steroid Control Act of 2004 bans over-the-counter steroid precursors.
- 2004:** Based on recent results from controlled clinical studies indicating that Cox-2 selective agents may be connected to an elevated risk of serious cardiovascular events, including heart attack and stroke, the Food and Drug Administration issues a public health advisory urging health professionals to limit the use of these drugs.
- 2004:** Food and Drug Administration bans dietary supplements containing ephedrine.
- 2004:** Food Allergy Labeling and Consumer Protection Act requires the labeling of food containing a protein derived from peanuts, soybeans, cow's milk, eggs, fish, crustacean shellfish, tree nuts, and wheat that accounts for a majority of food allergies.
- 2004:** Project BioShield Act of 2004 authorizes U.S. government agencies to expedite procedures related to rapid distribution of treatments as countermeasures to chemical, biological, and nuclear attack.
- 2004:** On December 26, the most powerful earthquake in more than forty years occurred underwater off the Indonesian island of Sumatra. The tsunami produced a disaster of unprecedented proportion in the modern era. Less than two weeks after the tsunami impact, the International Red Cross put the death toll at over 150,000 lives and most experts expected that number to continue to climb. Many experts claim this will be the costliest, longest, and most difficult recovery period ever endured as a result of a natural disaster.
- 2005:** H5N1 virus, responsible for avian flu, moves from Asia to Europe. The World Health Organization attempts to coordinate multinational disaster and containment plans. Some nations begin to stockpile antiviral drugs.
- 2005:** Major League Baseball players are subpoenaed to testify before Congress concerning the use of steroids in the sport.
- 2005:** Hurricane Katrina slams into the U.S. Gulf Coast, causing levee breaks and massive flooding to New Orleans. Damage is extensive across the coasts of Louisiana, Mississippi, and Alabama. Federal Emergency Management Agency is widely criticized for a lack of coordination in relief efforts. Three other major hurricanes make landfall in the United States within a two-year period stressing relief and medical supply efforts. Long term health studies begin of populations in devastated areas.
- 2005:** Food and Drug Administration Drug Safety Board is founded.
- 2005:** Death of Theresa (Terri) Schiavo ignites national debate in United States over right to die and ethical treatment practices.
- 2005:** A massive 7.6-magnitude earthquake leaves more than 3 million homeless and without food and basic medical supplies in the Kashmir mountains between India and Pakistan. 80,000 people die.
- 2006:** European Union bans the importation of avian feathers (non-treated feathers) from countries neighboring or close to Turkey.
- 2006:** More than a dozen people are diagnosed with avian flu in Turkey, but United Nations health experts assure public that human-to-human transmission is still rare and only suspected in a few cases in Asia.
- 2006:** Mad cow disease confirmed in Alabama cow as third reported case in the United States.