<u>Astronomy</u>

1. The Planets Move (2000 B.C. – 500 B.C.)
A thousand years of observations reveal that there are stars that move in the sky and follow patterns, showing that the Earth is part of a solar system of planets separate from the fixed stars.

2. The Earth Moves (1543)
Nicolaus Copernicus places the sun, not the Earth, at the center of the solar system.

3. Planetary Orbits Are Elliptical (1605 – 1609)
Johannes Kepler devises mathematical laws that successfully and accurately predict the motions of the planets in elliptical orbits.

4. Jupiter Has Moons (1609 – 1612)
Galileo Galilei discovers that Jupiter has moons like the Earth, proving that Copernicus, not Ptolemy, is right. Copernicus believes that Earth is not unique, but instead resembles the other planets, all of which orbit the sun.

5. Halley's Comet Has a Predictable Orbit (1705 – 1758)
Edmund Halley proves that comets orbit the sun like the planets and successfully predicts the return of Halley's Comet. He determines that comets seen in 1531 and 1607 are the same object following a 76-year orbit. Halley's prediction is proven in 1758 when the comet returns. Unfortunately, Halley had died in 1742, missing the momentous event.

6. The Milky Way Is a Gigantic Disk of Stars (1780 – 1834)
Telescope-maker William Herschel and his sister Carolyn map the entire sky and prove that our solar system resides in a gigantic disk of stars that bulges in the center called the Milky Way. Herschel's technique involves taking a sample count of stars in the field of view of his telescope. His final count shows more than 90,000 stars in 2,400 sample areas. Later studies confirm that our galaxy is disk-shaped, but find that the sun is not near the center and that the system is considerably larger than Herschel's estimation.

7. General Relativity (1915 – 1919)
Albert Einstein unveils his theory of general relativity in which he proposes that mass warps both time and space, therefore large masses can bend light. The theory is proven in 1919 by astronomers using a solar eclipse as a test.

8. The Universe Is Expanding (1924 – 1929)
Edwin Hubble determines the distance to many nearby galaxies and discovers that the farther they are from us, the faster they are flying away from us. His calculations prove that the universe is expanding.

9. The Center of the Milky Way Emits Radio Waves (1932)
Karl Jansky invents radio astronomy and discovers a strange radio-emitting object at the center of the Milky Way. Jansky was conducting experiments on radio wavelength interference for his employer, Bell Telephone Laboratories, when he detected three groups of static; local thunderstorms, distant thunderstorms and a steady hiss-type static. Jansky determines that the static is coming from an unknown source at the center of the Milky Way by its position in the sky.

10. Cosmic Microwave Background Radiation (1964)
Arno Penzias and Robert Wilson discover cosmic microwave background radiation, which they suspect is the afterglow of the big bang. Their measurements, combined with Edwin Hubble's earlier finding that the galaxies are rushing away, make a strong case for the big bang theory of the birth of the universe.

11. Gamma-Ray Bursts (1969 – 1997)
The two-decade-long mystery of gamma-ray bursts is solved by a host of sophisticated ground-based and orbiting telescopes. Gamma-ray bursts are short-lived bursts of gamma-ray photons, which are the most energetic form of light and are associated with nuclear blasts. At least some of the bursts have now been linked with distant supernovae — explosions marking the deaths of especially massive stars.

12. Planets Around Other Stars (1995 – 2004)
Astronomers find a host of extrasolar planets as a result of improved telescope technology and prove that other solar systems exist, although none as yet resembles our own. Astronomers are able to detect extrasolar planets by measuring gravitational influences on stars.

13. The Universe Is Accelerating (1998 – 2000)
Unexpectedly, astronomers find that instead of slowing down due to the pull of gravity, the expansion of the universe at great distances is accelerating. If these observations are correct and the trend continues, it will result in the inability to see other galaxies. A new theory of the end of the universe based on this finding has been called the "big rip."

Chemistry

1. Oxygen (1770s)
Joseph Priestley discovers oxygen; later, Antoine Lavoisier clarifies the nature of elements. Priestley produces oxygen in experiments and describes its role in combustion and respiration. Then, by dissolving fixed air in water, he invents carbonated water. Priestley, oblivious to the importance of his discovery, calls the new gas "dephlogisticated air." Lavoisier gives oxygen its name and correctly describes its role in combustion. Lavoisier then works with others to devise a chemical nomenclature, which serves as the basis of the modern system.

2. Atomic Theory (1808)
John Dalton provides a way of linking invisible atoms to measurable quantities like the volume of a gas or mass of a mineral. His atomic theory states that elements consist of tiny particles called atoms. Thus, a pure element consists of identical atoms, all with the same mass, and compounds consist of atoms of different elements combined together.

3. Atoms Combine Into Molecules (1811 onward)
Italian chemist Amedeo Avogadro finds that the atoms in elements combine to form molecules. Avogadro proposes that equal volumes of gases under equal conditions of temperature and pressure contain equal numbers of molecules.

4. Synthesis of Urea (1828)
Friedrich Woehler accidentally synthesizes urea from inorganic materials, proving that substances made by living things can be reproduced with nonliving substances. Until 1828, it was believed that organic substances could only form with the help of the "vital force" present in animals and plants.

5. Chemical Structure (1850s)
Friedrich Kekule figures out the chemical structure of benzene, bringing the study of molecular structure to the forefront of chemistry. He writes that after years of studying the nature of carbon-carbon bonds, he came up with the ring shape of the benzene molecule after dreaming of a snake seizing its own tail. The unusual structure solves the problem of how carbon atoms can bond with up to four other atoms at the same time.

6. Periodic Table of the Elements (1860s – 1870s)
Dmitry Mendeleyev realizes that if all of the 63 known elements are arranged in order of increasing atomic weight, their properties are repeated according to certain periodic cycles. He formulates the periodic table of the elements and predicts the existence of elements that have not yet been discovered. Three of those elements are found during his lifetime: gallium, scandium and germanium.

7. Electricity Transforms Chemicals (1807 – 1810)
Humphry Davy finds that electricity transforms chemicals. He uses an electric pile (an early battery) to separate salts by a process now known as electrolysis. With many batteries he is able to separate elemental potassium and sodium in calcium, strontium, barium and magnesium.

8. The Electron (1897)
J.J. Thomson discovers that the negatively charged particles emitted by cathode ray tubes are smaller than atoms and part of all atoms. He calls these particles, now known as electrons, "corpuscles."

9. Electrons for Chemical Bonds (1913 onward)
Niels Bohr publishes his model of atomic structure in which electrons travel in specific orbits around the nucleus, and the chemical properties of an element are largely determined by the number of electrons in its atoms' outer orbits. This paves the way to an understanding of how electrons are involved in chemical bonding.

10. Atoms Have Signatures of Light (1850s)
Gustav Kirchhoff and Robert Bunsen find that each element absorbs or emits light at specific wavelengths, producing specific spectra.

11. Radioactivity (1890s – 1900s)
Marie and Pierre Curie discover and isolate radioactive materials. After chemically extracting uranium from uranium ore, Marie notes the residual material is more "active" than the pure uranium. She concludes that the ore contains, in addition to uranium, new elements that are also radioactive. This leads to the discovery of the elements polonium and radium.

12. Plastics (1869 and 1900s)
John Wesley Hyatt formulates celluloid plastic for use as a substitute for ivory in the manufacture of billiard balls. Celluloid is the first important synthetic plastic and is used as a substitute for expensive substances such as ivory, amber, horn and tortoiseshell. Later, Leo Baekeland invents hardened plastics, specifically Bakelite, a synthetic substitute for the shellac used in electronic insulation.

13. Fullerenes (1985)
Robert Curl, Harold Kroto and Rick Smalley discover an entirely new class of carbon compound with a cage-like structure. This leads to the discovery of similar tube-like carbon structures. Collectively, the compounds come to be called buckminsterfullerenes, or fullerenes. The molecules are composed

entirely of carbon and take the form of a hollow sphere, ellipsoid, tube or ring. Named for Richard Buckminster Fuller, the architect who created the geodesic dome, they are sometimes called "buckyballs" or "buckytubes."

Earth Science

1. Earth's Core (1906)
Seismologist Richard Oldham determines that earthquake waves move through the central part of the Earth much slower than through the mantle around it. He surmises that the Earth has a core composed of liquid.

2. Earth's Inner Core (1930s) In 1936, Inge Lehmann documents that some seismic waves from deep inside the Earth's core do not pass through, but are reflected back. It becomes clear that the Earth has an inner core consisting of a small, solid iron sphere that is surrounded by a thick outer core composed of liquid iron.

3. Continental Drift (1911)
Alfred Wegener proposes that all the continents in the world once formed a single, giant landmass that was eventually split apart in a process called "continental drift." Wegener's evidence consists of the "fit" of South America with Africa, fossil distribution and geological similarities.

4. Seafloor Spreading (1950s – 1960s)
Adding his own data on changes in seafloor depth and geology to discoveries of his peers, Harry Hess proposes that Wegener's theory of continental drift is a result of seafloor spreading. He hypothesizes that molten magma from beneath the Earth's crust is oozing up between the plates in the Great Global Rift (now referred to as the Mid-Ocean Ridge). As the hot magma cools, it expands and pushes the plates out from the rift, causing the Atlantic Ocean to get wider over time.

5. Plate Tectonics (1960s)
The work of many scientists reveals that the Earth's surface is broken into several interconnected plates of rock. Earth's outermost layer, the lithosphere, is broken into at least seven large, rigid pieces. These plates are moving in different directions and at different speeds (about 1 to 4 inches per year) and are crashing together, pulling apart and sideswiping each other. All the action at plate boundaries produces phenomena such as mountains, volcanoes and earthquakes.

6. Troposphere and Stratosphere (1890s)
With the aid of scientific instruments placed on unmanned balloons, Leon Teisserenc de Bort discovers that the atmosphere consists of layers. Bort notices that air temperature decreases steadily up to about seven miles, but remains constant at higher altitudes. After more than 200 balloon experiments, he suggests that the atmosphere is divided into two layers called the "troposphere" and the "stratosphere."

7. Global Warming (late 20th century)
A number of scientists see evidence of a warming trend on the Earth's surface and attribute it to a rise in the concentration of "greenhouse gases." Global warming theory states that an increase of the average temperature of Earth's atmosphere and oceans since the late 19th century can be attributed to humans and increased emissions of carbon dioxide. According to the theory, temperatures will increase further if emissions of these greenhouse gases continue.

8. Cosmic Radiation (1911 onward)
In 1912, Victor Hess travels to 17,500 feet in a hot air balloon (without oxygen) and observes that radiation increases with altitude. Further experiments convince him the radiation is coming from space. We now know that the vast majority of cosmic rays are protons, and therefore have a positive electrical charge.

9. Magnetic Field Reversal (1906)
Bernard Brunhes discovers that the Earth's magnetic field has changed direction and reversed itself. His paleomagnetic study of clay baked by a Miocene lava flow 13 million years ago provides the evidence. It is nearly 50 years before his discovery is accepted by the scientific community.

10. Geological Change (1830s)
Charles Lyell offers proof that the Earth evolved slowly in his multivolume *Principles of Geology: An Attempt to Explain the Former Changes of the Earth's Surface by Reference to Causes Now in Operation*, published between 1830 and 1833. In his work, he advocates the then-controversial idea of uniformitarianism — the idea that the Earth was shaped entirely by slow-moving forces acting over a very long period of time. Catastrophism, a geologic idea that uses biblical chronology to date the Earth, was more accepted at the time.

11. Radiometric Dating (1907)
Bertram Boltwood discovers how to calculate the age of a rock by measuring the rate of its radioactive decay. His observations and calculations put Earth's age at 2.2 billion years. Although we now think the Earth is nearly twice that age, this number was a dramatic increase over the accepted age at the time. Boltwood's formulas are compatible with several radioactive elements, including carbon-14, which has been used to date historical artifacts.

12. Periodic Ice Ages (1930s)
Serbian astrophysicist Miultin Milankovitch develops a theory relating Earth's motion to long-term climate change and ice ages. His mathematical theory of climate uses variations in solar radiation based on season and latitude. His theory posits that cyclical variations in Earth-sun geometry, such as orbit shape and axis angle, result in different levels of solar energy reaching the Earth.

Evolution

1. K-T Asteroid Theory of Dinosaur Extinction (1980)
Walter Alvarez postulates that high levels of iridium found in rock core samples around the world provide evidence that an asteroid impact caused the extinction of dinosaurs. Iridium, a common mineral found in asteroids, was discovered in the clay layer at what is known as the K-T boundary. This layer, at 65 million years, lies between the rocks of the Cretaceous and the Tertiary periods and coincides with the mass extinction of dinosaurs.

2. First Dinosaur Fossils Identified (1820s – 1840s)
In 1822, geologist William Buckland uncovers some really big teeth in England. At the time, there is no word to describe his finds. Twenty years later, in 1842, Sir Richard Owen comes up with the word "dinosaur" to describe several spectacular creatures whose fossils are discovered across England. *Megalosaurus* is the first dinosaur ever named.

3. Potential for Life Created (1953)
Graduate student Stanley Miller, combining the ideas of other scientists, reproduces the early atmosphere of Earth by creating a chamber containing only hydrogen, water, methane and ammonia. He boils the water and exposes the elements to an electric discharge like lightning, simulating Earth's early processes. After a week, Miller finds organic compounds have formed, including some amino acids, the "building blocks of life."

4. New Life-forms Discovered Around Hydrothermal Vents (1977)
Bob Ballard and the crew of the submersible *Alvin* find amazing new life-forms living completely independent of the sun's energy around deep-sea, hydrothermal vents. These undersea geysers form along volcanic mid-ocean ridges, where cold seawater penetrates deep into cracks in the Earth's crust. Heated water rises back out and the scalding vent water mixes with cold ocean-bottom seawater, creating a rising plume of warm, black fluid filled with mineral particles. The chemicals support a thriving ecosystem on the ocean floor.

5. The Burgess Shale (1909)
Charles Walcott exposes a mother lode of Cambrian fossils high in the Canadian Rocky Mountains, providing a glimpse of what life was like on Earth more than 500 million years ago. He collects more than 65,000 specimens and classifies each, discovering that the fossils are ancestors of living animals.

6. Classification of Species (1735)
Carl Linnaeus, considered the "father of taxonomy," develops a system for naming, ranking and classifying all forms of life that is still in use today (although many changes have been made). The Linnaean system, based on shared physical characteristics, uses a hierarchy starting with kingdoms divided into classes, then into orders, families, genera and species.

7. Theory of Natural Selection (1858)
Charles Darwin publishes *On the Origin of Species by Means of Natural Selection*, in which he challenges contemporary beliefs about the creation of life on Earth. Darwin had served as an unpaid naturalist on the *HMS Beagle*, which set out on a five-year scientific expedition to the Pacific coast of South America in early 1832. The data he collected on the expedition, especially specimens from the Galapagos Islands, was the inspiration for his theories on evolution by the mechanism of natural selection. His work has been at the center of controversy ever since it was published.

8. *Australopithecus* Afarensis or "Lucy" (1974)
Donald Johanson discovers the partial skeleton of a 3.2 million-year-old female hominid in Ethiopia. Johnson dubs his find "Lucy" after the Beatles' song *Lucy in the Sky With Diamonds*, which was playing on the radio as the team celebrated the find.

9. Laetoli Footprints (1978)
A team led by Mary Leaky discovers fossilized *Australopithecus* footprints in Laetoli, Tanzania. The footprints, dated to 3.5 million years ago, were formed when two individuals walked over wet volcanic ash that had hardened like cement. These human ancestors had perfect, two-footed strides, indicating that the hominids walked upright.

10. Toumai skull (2002)
Michel Brunet unearths the oldest hominid fossil to date in the desert of the central African nation of Chad. The fragments of this 6 to 7 million-year-old skull, with characteristics resembling humans,

were found outside eastern and southern Africa, suggesting human evolution may have been taking place all across the continent.

Genetics

1. Rules of Heredity (1850s)
Austrian monk and botanist Gregor Mendel discovers how genetic information is passed down through generations. In experiments performed on pea plants, he notices that characteristics of a plant's offspring, such as height, exhibit recessive and dominant behavior. Mendel's findings are ridiculed during his lifetime and he dies never knowing that he would come to be known as the "father of genetics."

2. Genes Are Located on Chromosomes (1910 – 1920s)
Thomas Hunt Morgan discovers that genes are located on chromosomes. Working on fruit flies, he concludes that certain traits are linked to gender and that those traits are probably carried on one of the sex chromosomes (X or Y). He hypothesizes that other genes are also carried on specific chromosomes. Using chromosome recombination, he and his students map the locations of genes on chromosomes. Morgan and his students write the seminal book *The Mechanism of Mendelian Heredity*.

3. Genes Control Biochemical Events (1930)
George Beadle and Edward Tatum discover through experiments on neurospora, a bread mold, that genes are responsible for the production of enzymes. Their report is the genesis of the "one gene-one enzyme" concept.

4. Some Genes Can Jump (1940)
Barbara McClintock discovers transposons — genes that can jump on a chromosome — while seeking to explain color variations in corn. Transposons are segments of DNA that can move to different positions in the genome of a single cell. In the process, they may cause mutations and increase (or decrease) the amount of DNA in the genome. These mobile segments of DNA are sometimes called "jumping genes."

5. DNA Is the Genetic Material (1928, 1944, 1952)
Several scientists prove that DNA is the chemical basis of genetic information. Oswald Avery proves that DNA carries genetic information. Linus Pauling discovers that many proteins take the shape of a spiral, like a spring coil. Finally, biochemist Erwin Chargaff finds the arrangement of certain nitrogen bases in DNA always occurs in a 1-to-1 ratio, forming base pairs.

6. DNA Is a Double Helix (1953)
James Watson and Francis Crick describe the DNA molecule. The scientists suggest that the DNA molecule is made of two chains of nucleotides, each in a helix, one going up and the other going down. Crick adds the idea that matching base pairs interlock in the middle of the double helix to keep the distance between the chains constant. They show that each strand of the DNA molecule is a template for the other, and that DNA can reproduce itself without changing its structure, except for occasional errors or mutations.

7. Cracking the Genetic Code (1960s)
Marshall Nirenberg leads the team that discovers the genetic code, showing that a sequence of three nucleotide bases (a codon) determines each of the 20 amino acids.

8. RNA Conveys Genetic Information (1960s)
A number of scientists discover ribonucleic acid, or RNA, a chemical found in the nucleus and cytoplasm of cells with a structure similar to DNA. They find that RNA plays an important role in protein synthesis and other chemical activities in the cell.

9. Restriction Enzymes (1950s – 1960s)
Several scientists discover restriction enzymes — biological scissors that recognize and cut specific DNA sequences.

10. RNA Splicing (1976)
Several groups of scientists discover RNA splicing. They learn that for cells to produce protein, DNA is first transcribed into pre-messenger RNA. For reasons that remain unclear, pre-messenger RNA molecules are then spliced to create mature messenger RNA. In many genetic diseases, gene mutations cause errors in the RNA splicing process. Improperly spliced messenger RNA molecules create altered proteins and result in disease.

11. DNA Polymorphism (1985)
Alec Jeffreys discovers that some DNA sequences are unique to each individual, leading to the birth of DNA forensics. His DNA technique is first used to hunt down a child molester who killed two girls. The suspect, Colin Pitchfork, is convicted of murder after DNA samples taken from him match semen samples taken from the two dead girls.

12. Humans Have 20,000 to 25,000 Genes (2003)
Upon sequencing the human genome, it's discovered that humans have approximately 20,000 to 25,000 genes, far fewer than most scientists had predicted. It is hoped that understanding the genome will boost the fields of medicine and biotechnology, eventually leading to cures for diseases such as cancer and Alzheimer's disease.

13. RNA Interference (1998)
Andrew Fire and Craig Mello discover RNA interference (RNAi), in which the presence of small fragments of double-stranded RNA (dsRNA) whose sequence matches a given gene interferes with the expression of that gene. Scientists believe that dsRNAs that trigger RNAi may be usable as drugs.

Medicine

1. Human Anatomy (1538)
Andreas Vesalius dissects human corpses, revealing detailed information about human anatomy and correcting earlier views. Vesalius believes that understanding anatomy is crucial to performing surgery, so he dissects human corpses himself (unusual for the time). His anatomical charts detailing the blood and nervous systems, produced as a reference aid for his students, are copied so often that he is forced to publish them to protect their accuracy. In 1543 he publishes *De Humani Corporis Fabrica*, transforming the subject of anatomy.

2. Blood Circulation (1628)
William Harvey discovers that blood circulates through the body and names the heart as the organ responsible for pumping the blood. His groundbreaking work, *Anatomical Essay on the Motion of the Heart and Blood in Animals*, published in 1628, lays the groundwork for modern physiology.

3. Blood Groups (1902)
Austrian biologist Karl Landsteiner and his group discover four blood groups and develop a system of classification. Knowledge of the different blood types is crucial to performing safe blood transfusions, now a common practice.

4. Anesthesia (1842–1846)
Several scientists discover that certain chemicals can be used as anesthetics, making it possible to perform surgery without pain. The earliest experiments with anesthetic agents — nitrous oxide (laughing gas) and sulfuric ether — are performed mainly by 19th-century dentists.

5. X-rays (1895)
Wilhelm Roentgen accidentally discovers X-rays as he conducts experiments with the radiation from cathode rays (electrons). He notices that the rays are able to penetrate opaque black paper wrapped around a cathode ray tube, causing a nearby table to glow with florescence. His discovery revolutionizes physics and medicine, earning him the first-ever Nobel Prize for physics in 1901.

6. Germ Theory (1800s)
French chemist Louis Pasteur finds that certain microbes are disease-causing agents. At the time, the origin of diseases such as cholera, anthrax and rabies is a mystery. Pasteur formulates a germ theory, postulating that these diseases and many others are caused by bacteria. Pasteur is called the "father of bacteriology" because his work leads to a new branch of scientific study.

7. Vitamins (early 1900s)
Frederick Hopkins and others discover that some diseases are caused by deficiencies of certain nutrients, later called vitamins. Through feeding experiments with laboratory animals, Hopkins concludes that these "accessory food factors" are essential to health.

8. Penicillin (1920s–1930s)
Alexander Fleming discovers penicillin, then Howard Florey and Boris Chain isolate and purify the compound, producing the first antibiotic. Fleming's discovery comes completely by accident when he notices that mold has killed a bacteria sample in a petri dish that is languishing under a pile in his lab's sink. Fleming isolates a sample of the mold and identifies it as *Penicillium* notatum. With controlled experimentation, Florey and Chain later find the compound cures mice with bacterial infections.

9. Sulfa Drugs (1930s)
Gerhard Domagk discovers that Prontosil, an orange-red dye, cures infections caused by the common bacteria streptococci. The finding opens the door to the synthesis of chemotherapeutic drugs (or "wonder drugs") and sulfa drugs in particular.

10. Vaccination (1796)
Edward Jenner, an English country doctor, performs the first vaccination against smallpox after discovering that inoculation with cowpox provides immunity. Jenner formulated his theory after

noticing that patients who work with cattle and had come into contact with cowpox never came down with smallpox when an epidemic ravaged the countryside in 1788.

11. Insulin (1920s)
Frederick Banting and his colleagues discover the hormone insulin, which helps balance blood sugar levels in diabetes patients and allows them to live normal lives. Before insulin, diabetes meant a slow and certain death.

12. Oncogenes (1975)
Harold Varmus and Michael Bishop discover oncogenes — normal genes that control growth in every living cell, but can contribute to converting normal cells into cancer cells if mutated or present in abnormally high amounts. Cancer cells are cells that multiply uncontrollably. Varmus and Bishop worked from the theory that the growth of cancerous cells does not occur as the result of an invasion from outside the cell, but as a result of mutations possibly aggravated by environmental toxins such as radiation or smoke.

13. The Human Retrovirus HIV (1980s)
Competing scientists Robert Gallo and Luc Montagnier separately discover a new retrovirus later dubbed HIV (human immunodeficiency virus), and identify it as the causative agent of AIDS (acquired immunodeficiency syndrome).

Physics

1. The Law of Falling Bodies (1604)
Galileo Galilei overturns nearly 2,000 years of Aristotelian belief that heavier bodies fall faster than lighter ones by proving that all bodies fall at the same rate.

2. Universal Gravitation (1666)
Isaac Newton comes to the conclusion that all objects in the universe, from apples to planets, exert gravitational attraction on each other.

3. Laws of Motion (1687)
Isaac Newton changes our understanding of the universe by formulating three laws to describe the movement of objects. 1) An object in motion remains in motion unless an external force is applied to it. 2) The relationship between an object's mass (m), its acceleration (a) and the applied force (F) is $F = ma$. 3) For every action there is an equal and opposite reaction.

4. The Second Law of Thermodynamics (1824 – 1850)
Scientists working to improve the efficiency of steam engines develop an understanding of the conversion of heat into work. They learn that the flow of heat from higher to lower temperatures is what drives a steam engine, likening the process to the flow of water that turns a mill wheel. Their work leads to three principles: heat flows spontaneously from a hot to a cold body; heat cannot be completely converted into other forms of energy; and systems become more disorganized over time.

5. Electromagnetism (1807 – 1873)
Pioneering experiments uncover the relationship between electricity and magnetism and lead to a set of equations that express the basic laws governing them. One of those experiments unexpectedly yields results in a classroom. In 1820, Danish physicist Hans Christian Oersted is speaking to students about

the possibility that electricity and magnetism are related. During the lecture, an experiment demonstrates the veracity of his theory in front of the whole class.

6. Special Relativity (1905)
Albert Einstein overthrows basic assumptions about time and space by describing how clocks tick slower and distances appear to stretch as objects approach the speed of light.

7. $E = mc^2$ (1905)
Or energy is equal to mass times the speed of light squared. Albert Einstein's famous formula proves that mass and energy are different manifestations of the same thing, and that a very small amount of mass can be converted into a very large amount of energy. One profound implication of his discovery is that no object with mass can ever go faster than the speed of light.

8. The Quantum Leap (1900 – 1935)
To describe the behavior of subatomic particles, a new set of natural laws is developed by Max Planck, Albert Einstein, Werner Heisenberg and Erwin Schrodinger. A quantum leap is defined as the change of an electron within an atom from one energy state to another. This change happens all at once, not gradually.

9. The Nature of Light (1704 – 1905)
Thought and experimentation by Isaac Newton, Thomas Young and Albert Einstein lead to an understanding of what light is, how it behaves, and how it is transmitted. Newton uses a prism to split white light into its constituent colors and another prism to mix the colors into white light, proving that colored light mixed together makes white light. Young establishes that light is a wave and that wavelength determines color. Finally, Einstein recognizes that light always travels at a constant speed, no matter the speed of the measurer.

10. The Neutron (1935)
James Chadwick discovers neutrons, which, together with protons and electrons comprise the atom. This finding dramatically changes the atomic model and accelerates discoveries in atomic physics.

11. Superconductors (1911 – 1986)
The unexpected discovery that some materials have no resistance to the flow of electricity promises to revolutionize industry and technology. Superconductivity occurs in a wide variety of materials, including simple elements like tin and aluminum, various metallic alloys and certain ceramic compounds.

12. Quarks (1962)
Murray Gell-Mann proposes the existence of fundamental particles that combine to form composite objects such as protons and neutrons. A quark has both an electric and a "strong" charge. Protons and neutrons each contain three quarks.

13. Nuclear Forces (1666 – 1957)
Discoveries of the basic forces at work on the subatomic level lead to the realization that all interactions in the universe are the result of four fundamental forces of nature — the strong and weak nuclear forces, the electromagnetic force and gravitation.

Biology

1. Microorganisms (1674)
Microscope lens grinder Anton Van Leeuwenhoek accidentally discovers microorganisms in a drop of water. Using his own microscopes, he observes sperm, bacteria and red blood cells. His observations lay the foundation for the sciences of bacteriology and microbiology.

2. The Cell Nucleus (1831)
While studying an orchid, botanist Robert Brown identifies a structure within the cells that he terms the "nucleus."

3. *Archaea* (1977)
Carl Woese discovers bacteria are not the only simple-celled prokaryotes (unicellular organisms without a nucleus) on Earth. Many of the organisms classified in the new kingdom of *Archaea* are extremophiles. Some live at very high or low temperatures, others in highly saline, acidic or alkaline water. Some have been found in environments like marshland, sewage and soil. *Archaea* are usually harmless to other organisms and none are known to cause disease.

4. Cell Division (1879)
Walther Flemming carefully observes that animal cells divide in stages and calls the process mitosis. Eduard Strasburger independently identifies a similar process of cellular division in plant cells.

5. Sex Cells (1884)
August Weismann identifies that sex cells must have divided differently to end up with only half of a chromosomal set. This very special division of sex cells is called meiosis. Weismann's experiments with reproduction in jellyfish lead him to the conclusion that variations in offspring result from the union of a substance from the parents. He refers to this substance as "germ plasm."

6. Cell Differentiation (late 19th century)
Several scientists participate in the discovery of cell differentiation, eventually leading to the isolation of human embryonic stem cells. During differentiation, a cell turns into one of the many cell types that make up the body, such as a lung, skin or muscle cell. Certain genes are activated and others are inactivated, so the cell develops structures to perform a specific function. Cells that are not yet differentiated and have the potential to become any type of cell are called stem cells.

7. Mitochondria (late 19th century to the present)
Scientists discover mitochondria, the powerhouses of the cell. These small structures within animal cells are responsible for metabolism and convert food into chemicals that cells can use. Originally thought to be part of the cell, scientists now believe they are specialized bacteria with their own DNA.

8. The Krebs Cycle (1937)
Hans Krebs identifies the many steps the cell takes to convert sugars, fats and proteins into energy. Also known as the citric acid cycle, it is a series of chemical reactions using oxygen as part of cellular respiration. The cycle contributes to the breakdown of carbohydrates, fats and proteins into carbon dioxide and water.

9. Neurotransmission (late 19th to early 20th century)
Scientists discover neurotransmitters and how they tell the body what to do by passing signals from one nerve cell to another via chemical substances or electrical signals.

10. Hormones (1903)
William H. Bayliss and Ernest H. Starling give hormones their name and reveal their role as chemical messengers. The team specifically describes secretin, a substance released into the blood from the duodenum (between the stomach and small intestine) that stimulates secretion of pancreatic digestive juice into the intestine.

11. Photosynthesis (1770s)
Jan Ingenhousz discovers that plants react to sunlight differently than shade. The underpinnings of the understanding of photosynthesis are born. Photosynthesis is a process in which plants, algae and certain bacteria convert the energy of light into chemical energy. In plants, leaves take in carbon dioxide and roots absorb water. Sunlight runs a reaction that yields glucose (food for the plant) and oxygen (a waste product released into the environment). Nearly all living things on Earth are ultimately dependent on this process.

12. Ecosystem (1935)
Arthur George Tansley coins the term ecosystem and single-handedly bridges the biology in ecology with the physics, chemistry and other fields of science that describe the environment. An ecosystem is defined as a dynamic and complex whole that functions as an ecological unit.

13. Tropical Biodiversity (15th century to the present)
On sailing expeditions around the world, early European explorers notice that the tropics host a much greater variety of species. Answering why this is the case allows today's scientists to help protect life on Earth.