The purpose of this chart is to promote the study of biology, to trace its development as a science over time, and to illustrate a variety of its career applications.
The mission of the Serenus Press is to promote the study and use of history and the liberal arts, demonstrating their application in nonacademic settings. We also encourage employers in all sectors of the economy to provide insight on how to strengthen education that connects good scholarship with professional success. To this end we publish Road Map Publications, freely downloadable material for educational distribution.

Serenus publications have many applications. They help students choose a college major, reinforce reasons for diligent study, and provide concrete career options. They also aid college administrators in recruiting high school students, and show parents as well as teachers the value of their children's liberal arts education. To date, our material has been used in nearly half the colleges throughout the United States, as well as numerous schools, historical associations, and libraries.

While many of our publications deal with history, we believe that history – rigorous history – cannot be written, studied, or applied without due regard to other core subjects: English, science, mathematics, and geography. Nor can mastery be achieved of English, science, mathematics, or geography without an attentive focus on history.

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The study of biology offers many career opportunities. Whether your search is long term (a career) or short term (a job), take inventory of what you have to offer, then consider your goals and search this chart for prospects. Talk to potential employers to confirm that their requirements for academic preparation and experience fit your profile. Note that there is a near-universal call for the knowledge, skills, and attitudes shown under “Education & General Requirements.”

### Biology: Fields of Study

- General Biology (study of living things)
- Anatomy (study of organisms’ structures)
- Bacteriology (study of bacteria and their relations to medicine)
- Biochemistry (study of chemical compounds and processes)
- Biometrics (study of statistical analysis of biological observations)
- Biophysics (study of physical principles applied to biology)
- Botany (study of plants)
- Cell Biology (study of cellular structures)
- Ecology (study of interrelations of organisms and their environment)
- Entomology (study of insects)
- Genetics - plant & animal (study of heredity)
- Marine/Aquatic Biology (study of sea life)
- Microbiology (study of microscopic forms of life)
- Molecular Biology (study of physiochemical structure of living organisms)
- Neurosciences (study of nerves)
- Nutritional Sciences (study of nourishment)
- Pathology - human & animal (study of disease)
- Pharmacology - human & animal (study of drugs)
- Physiology - human & animal (study of life functions and activities)
- Plant Pathology (study of plant disease)
- Toxicology (study of poisons)
- Zoology (study of animal life)

Other fields of study of biology, e.g. Astrobiology, Bioengineering, Bioinformatics, Mathematical Biology, Forensic Biology, Immunology, Oceanography, Parasitology, Virology.
**General Requirements**

**Knowledge & Skills**

Learning is a lifelong occupation: Improve your store of knowledge and understand how to apply what you have learned to your work. Problem solving methods are valuable, there is no time to research solutions during the press of business; normally an immediate response is expected.

Be numerate, able to accurately, and without electronic aids, add, subtract, multiply, divide. Be familiar with basic statistical techniques, their strength and weaknesses.

Know history, be aware of the way the world works, how we got where we are. Be aware of the context that surrounds the growth of the field you wish to enter, be able to identify cause and effect. Direction requires knowing where you have been.

Know your chosen field and its boundaries, the current scientific literature and the laws, restrictions, requirements, and accepted practices that regulate and control it. Attend and participate in scientific conferences.

Master information technology. Be familiar with applications packages, especially communications, word processing, spreadsheet, and database. Be able to extract and produce material for the web. Know how to mine for data, judge its value, and draw valid conclusions.

Be skilled at applying your English: know how to craft technical reports, summaries, memos, critiques, all under stringent deadlines. Be able to express yourself orally, extemporaneously and in formal settings.

Be expert in your laboratory skills. Know how to collect, measure, weigh, observe, record, and analyze. Be competent in the use and care of laboratory instruments, in following aseptic techniques and in working with hazardous materials.

Prove your competence: show how you are able to pursue your chosen career by offering evidence of accomplishment, writing, web expertise, work, or other related experience.

**Attitudes & Related**

A good work ethic is imperative. Be enthusiastic about your tasks and positive about those you work for. Be prompt, preferably early. Work hard until your tasks are complete; don’t measure your day by the clock. Know how to lead and how to take orders.

Be prepared to work under pressure, to work independently, with minimal supervision, and to work as an effective team member. Learn to deal with people of all sorts, older and younger, capable and inept.

Take suggestions and give them, negotiate, politely but firmly. In all your dealings, honesty and decency aren’t options, they are essentials.

**If You Don’t Have “Experience”**

Part-time and summer jobs, volunteering for community projects, docentships, internships, even well-executed hobbies can provide a measure of experience sought by employers. Your task will be to demonstrate how your knowledge and skills have been applied in a positive way to make such activities worthwhile.
A high school diploma may be sufficient for some clerical and administrative entry-level positions, but for others a college degree, or degrees, are all but mandatory. See job specifications to determine what degree(s) may be required: AA, BA, BS, MS, MA, PhD, or other professional degree.

If you are offering your expertise to the public in specialized roles (environmental consultant, consulting biologist, etc.) be prepared with a postgraduate degree. Otherwise, you will have to use your own judgment in determining the need for formal education beyond high school or associate level.

Requirements for clerical and administrative careers can begin with a high school degree or a BA/BS. Teaching jobs require, with increasing frequency, postgraduate work in the field.

Clerical and administrative careers excepted, most professional jobs require postgraduate work in specialized fields.

Requirements for clerical and administrative careers can begin with a high school degree or a BA/BS. Most professional jobs require postgraduate work in your field.

Key

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<th>High School Diploma</th>
<th>Associate of Arts</th>
<th>Associate of Science</th>
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Entry-level career opportunities for graduates in biology are available in biotech, bioresearch, microbiological, pharmaceutical, and other corporations. Here are a few position descriptions:

**Assay Analyst** - Perform assays, cell cultures, and tests on tissues. Prepare glassware, reagents, and media for cell culture use. Help modify procedures. Maintain records. High school diploma or equivalent.

**Biochemical Development Engineer** - Develop cost-effective processes, formulas, equipment specifications, and technologies to assure product quality. BS, biological engineering.

**Buyer** - Obtain reliable, cost-effective materials, scientific equipment, and services. Develop new supply sources and price quotations. Examine bids. Maintain inventory at planned levels, ensuring quality and contract value. BS.

**Clinical Data Specialist** - Develop systems for organizing data, defining logical aspects of data sets, and identifying data interrelationships. Analyze, document, and report on trends and other findings. BS, with statistical coursework.

**Clinical Research Assistant** - Enter and validate clinical data, ensuring legibility, completeness, and consistency. Prepare logs, reports, and forms. Collect, review, and track financial and regulatory documents. AS or BS, biology or health field.

**Customer Service Representative** - Respond to product inquiries, take orders, and input data. Investigate and resolve problems related to product shipments and customer credit assuring prompt product delivery. BA, preferably BS.

**Drug Experience Associate** - Coordinate the receipt, classification, investigation, and processing of adverse experience reports. Provide tabulations and summaries of all events. BS with pharmaceutical degree preferred.

**Environmental Health Technician** - Assess job hazards and perform laboratory safety audits, controlling hazardous materials. Maintain inventories of chemical and personal protective equipment. BS.

**Environmental Specialist** - Implement and monitor environmental compliance programs. Participate in inspections, keep records, write reports, and prevent accidents. Requires familiarity with environmental regulations. BS.

**Instrument/Calibration Technician** - Maintain, test, troubleshoot, calibrate, and repair laboratory equipment. Perform and analyze validation studies. Maintain logs and electrical schematics. Prepare technical reports. AA.

**Laboratory Assistant** - Perform assays on raw materials and finished products. Make detailed observations, analyze data, interpret and report on results. Calibrate instruments. Maintain logbook, equipment, and inventories. AA or BS.

**Manufacturing Associate** - Troubleshoot and resolve technical production issues. Draft operating procedures. Purify laboratory substances for tests. Package and distribute products. Maintain equipment and records. BS.

**Market Research Analyst** - Research and analyze markets, market trends, competition, and product mix. Perform literature research, write and document reports. Make presentations to management. BA or BS.

**Media Prep Technician** - Prepare media and perform supervised experiments. Maintain equipment. Record results of experiments. AS or AA with science coursework.

**Process Development Associate** - Research and implement new methods and technologies to improve product yield, reduce manufacturing costs, and satisfy regulatory requirements. Maintain production equipment. BS.
Production Plan Scheduler - Plan, schedule, and coordinate the final approval of products. Review back order status, prioritize production orders, and assure materials arrive according to schedule. BS or BA.

Quality Control Analyst - Analyze raw material, initiate and document test procedures. Assure compliance with product specifications and report on abnormalities. BS.

Research Assistant/Associate - Assist research experiments, analyze data, and interpret results. Prepare technical reports, summaries, and protocols. Maintain control of laboratory supplies. BS.

Safety Officer - Develop, implement, and monitor industrial safety programs. Inspect plant to ensure compliance with OSHA regulations. Monitor employee exposure to chemicals and other toxic substances. BS.

Sales Representative - Sell company product and services. Meet or exceed sales expectations. Assess market trends, demonstrate products, and cement customer relationships. Train sales representatives. BS or BA.

Technical Information Coordinator - Develop, analyze, and produce information for the sales force and for customers. Draft executive summaries. Knowledge of regulatory and stewardship issues required. BS or BA.

Technician - Test and validate raw materials, packaging materials, and finished products. Train administrative assistants on procedures and use of equipment. Write reports. AS degree in biology or chemistry.

Training Specialist - Identify staff training needs. Develop and implement training plan consistent with staff objectives. Create procedures, documentation, and certification programs. BS or BA.

Validation Technician - Develop, revise, and analyze validation procedures, ensuring that production conforms to regulatory agency requirements, internal company standards, and current industry practices. AS or AA.

With advanced degrees and experience, career paths open further to students of biology. Typical positions include: Anatomist, Bacteriologist, Biochemist, Bioengineer, Biologist, Biometrician, Biophysicist, Botanist, Cell Biologist, Ecologist, Embryologist, Entomologist, Forensic Biologist, Geneticist, Historiologist, Immunologist, Marine/Aquatic Biologist, Mathematical Biologist, Microbiologist, Molecular Biologist, Neuroscientist, Nutritional Scientist, Parasitologist, Pathologist, Pharmacologist, Physiologist, Plant Pathologist, Protozoologist, Toxicologist, Virologist, Zoologist.

Advanced Degrees & Corporate Structure

Professional: e.g., Senior Molecular Biologist, Senior Scientist, generally require PhD or MS and 3-5 years' experience. They typically plan, execute, and report on laboratory research with little technical supervision.

Management: e.g., Research Manager, Operations Manager, may well require an MS or PhD and 5-10 years' experience. Typically they are responsible for managing other scientists and technicians, as well as controlling operations, planning, and budgeting.

Executive: e.g., Vice President, Chief Executive Officer, find academic requirements highly useful but generally less important than long, successful track records managing businesses or large public agencies.
Practitioners in the field of agriculture include: agricultural engineers, agronomists, animal nutritionists, animal physiologists, aquiculturist, botanists, ecologists, entomologists, environmental scientists, fisheries scientists, florists, food scientists, foresters, geneticists, horticulturists, logging engineers, marine scientists, naturalists, plant pathologists and physiologists, soil scientists, toxicologists, turf and weed scientists, viticulturists, and wildlife biologists. Advanced degrees frequently required.

Outreach Horticulturist - Develop and maintain exhibits, bookstore, and visitor services. Select and purchase material for sale to public. Train and manage professional and volunteer staff. Present educational programs to public. BS, MA.

Plant Breeder - Design, develop, execute, and implement plant breeding research projects. Participate in the development of patents or proposals. Agronomical experience or training in plant breeding or plant science. BS.

Greenhouse Assistant - Perform greenhouse research and experiments, make detailed observations, detect horticultural or pest problems, and institute corrective action. Maintain equipment. High school diploma or AA.


Conservation Biology Research Assistant - Search for and observe bird nests, monitor and record wildlife activities on film and video. Sample insect populations and analyze vegetation. Write, edit, and present reports. BS.

Environmental Planner - Conduct regional land use inventories and assessments. Develop planning documents and Environmental Impact Statements. Host public meetings. BA plus MA in environmental planning or related field.

Environmental Specialist - Identify sources of pollution or other activities with adverse ecological impacts. Gather, store, analyze, and report on data. Identify funding opportunities and prepare grant proposals. Physically active. BS.

Naturalist - Design and provide tours of site. Maintain educational exhibits and facilities. Answer public requests for information, keep records, and coordinate activities of volunteer naturalists. Public speaking experience. BA or BS.

Wildlife Biologist - Gather, collect, report, and share wildlife data in the field. Manage threatened and endangered species surveys and monitor activities. Extensive knowledge of federal, state, and local wildlife acts. BS, MA preferred.
**Opportunities Combining Biology with Other Liberal Arts Studies**

**Art**

**Graphics Specialist** - Design print and electronic material. Prepare text, tables, and illustrations for publications and presentations. Transform written material in graphic terms. Provide guidance on graphic technology. BS, BA.

**Economics**

**Ecological Economist** - Research, document, analyze, and present studies linking ecological and economic systems. Collaborate with botanists to develop computer-based cost and benefit analyses. BS and MA in economics and biology.

**English**

**Communications Specialist** - Develop print and electronic material to promote the organization’s mission. Write, edit, and proof material for technical staff, guiding their presentation methods. BA in journalism, English, or related field.

**Science/Technical Writer** - Develop research, write, compile, summarize, edit, and proof science/technical material. Produce graphics and statistical tables as well as material for web site. BS or BA in field related to communications.

**Technical Information Coordinator** - Develop and analyze input, quality, and production systems, produce information for the sales force and for customers. Draft summaries of regulatory and stewardship issues. BS.

**Technical Librarian** - Perform data searches on technical, legal, political, and competitive matters. Analyze, sort, compile, catalog, and maintain results. Train staff in web-based retrieval methods. BA or BS, with MA in library science.

**History**

**Archivist** - Develop, process, and manage historical botanical records programs. Prepare and maintain electronic finding aids. Plan document retention. Report information to state and national databases. MA or PhD in archival sciences.

**Historian of Science and/or Biology** - Research history of science and biology. Compose narratives and summaries for historical reports. Present findings to public, responding to requests for historical information. MA or PhD in history of science.

**Law**

**Patent Administrator** - Coordinate patent filing applications and documentation. Recommend necessity and timing of patent filings. Assist attorneys draft and edit applications. Maintain tracking systems. BS.

**Regulatory Affairs Specialist** - Coordinate and prepare documents for submission to regulatory agencies, auditors, and inspectors. Assist timely approvals of clinical trial applications. Manage information and control systems. BS or BA.

**Public Relations** – Identifies public trends; interprets corporate activities over time. Develops national communications activities. Promotes public policy initiatives. Draws on biological material for promotion and advertising of firm.

**Public Affairs** – Provides support for seminars, programs, public events and training. Develops and coordinates community events. Draws on biological resources of institution to support public image. Manages corporate philanthropy program.
**Biological Sciences – Information Technology Positions**

**Bioinformatics Scientist** - Develop methods and software to manage biological data. Search databases and analyze data for trends and underlying relationships. Advise staff. MS in biochemistry, bioinformatics, or computer sciences.

**Biostatistician** - Propose and initiate statistical analyses. Develop quantitative methods for data mining and modeling. Create, proofread, and evaluate data and report on findings. BS and MS in statistics, computer science.

**Clinical Programmer** - Coordinate, input, and monitor the flow of clinical data into the computer database. Analyze and evaluate data, spot inconsistencies, and resolve problems. BS and MS in computer science.

**Scientific Programmer** - Design, develop, evaluate, and modify computer programs. Assure compatibility with existing hardware and software. Prepare flow charts, perform coding, test, debug and document programs. BS.

**Systems Analyst** - Plan, configure, validate, and operate all system software, perform upgrades, and maintain user documentation. Troubleshoot system-related problems and interact with vendors. BS in computer science.

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**Biological Sciences – Selected Support Positions**

**Biological sciences require financial and administrative support. Consider combining business expertise with the study of biology to strengthen career opportunities.**

**Finance and Control**
Finance and control functions deal with planning, directing, monitoring, organizing, and measuring monetary resources. Positions include accountants, auditors, business analysts, bookkeepers, brokers, credit analysts, financial analysts, financial planners, internal auditors, investment advisors, and loan officers.

**Information Technology**
See Information Technology above.

**Marketing**
Marketing aims to assure the successful movement of goods and services from the producer to the market. Marketing functions include marketing research, sales, and advertising.

**Public Affairs**
See Political Sciences, page 7.

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**Human Resource Management**
Human resource management activities deal with assuring that an organization is adequately staffed with personnel who are appropriately skilled, motivated and rewarded. Positions include benefit and remuneration specialists, human resource generalists, manpower planning and development officers, organizational diagnosis experts, personnel managers, recruiters, and staff training officers.

**Sales** positions include account representatives, development specialists, market development representative, sales analysts, sales assistants, sales engineers, sales managers, sales recruiters, sales trainers, salespersons.

**Advertising** positions include advertising analysts, advertising account managers, artists, copywriters, graphic designers, film and audio producers, researchers, media buyers/planners, and survey designers,

**Marketing** positions include market/marketing analysts, marketing communications specialists, marketing specialists, market researchers, and product marketing engineers.

**Public Relations**
See Political Sciences, page 7.
### Agriculture
Examples: animal breeder and trainer, arborist, farmer, fish farmer, fisherman, florist, forester, herbalist, kennel keeper, landscape gardener, livestock rancher, market gardener, poultry farmer.

### Education
The study of biology provides a foundation for careers in education. Examples: elementary and secondary school teachers of science and biology, college and university professors of biology and other life sciences, science curriculum advisors, adult education instructors of biology.

### Consulting
Examples: botanical systematist, ecologist, forensic biologist, nutritionist, plant pathologist. Clients: corporations, public, law enforcement, and environmental agencies, museums, zoos, aquariums, and botanical gardens. Advanced degree and experience required.

### Government
The study of biology provides a foundation for careers in government. Practitioners include: agriculture researchers, ecologists, editors, fishery biologists, gardeners, medical biological technicians, parasitologists, park rangers, plant pathologists, soil scientists, wildlife managers, zoologists.

### Health Care
The study of biology provides a foundation for careers in health care, such as: chiropractors, dentists, dietitians and nutritionists, optometrists, pharmacists, physicians and surgeons, physician assistants, podiatrists, registered nurses, therapists, and veterinarians.

### Writing and the Arts
Examples: writers for biology-related media, including newspapers, magazines, web sites, and naturalist filmmakers, illustrators for text and electronic media, photographers for still shots, video, and film.

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*The study of biology provides a foundation for careers in private, public and nonprofit sectors.*

*Self-employment and entrepreneurial options are open to students of biology. Here are a few; let your imagination and enterprise guide you further.*
In what may be the first book on natural science, Anaximander (c. 610-c. 545 BC, Greece) develops an allegory for early development of life that some claim suggests development over time.

Internal disease examined insightfully by Alcmaeon of Crotone (c. 535 BC, Greece).

The heart is identified as center of blood vessel system by Empedocles (c. 490-c. 430 BC, Greece).

Theophrastus (c. 372-287 BC, Greece) refines Aristotle’s concepts of botany and natural history. His writings on plants, rediscovered and reprinted in 1483, helped stimulate new scientific views on botany.

Relatively accurate theory of embryological development introduced by Democritus (c. 460-370 BC, Greece), who influences Aristotle by distinguishing between blooded and bloodless invertebrates.

Hippocrates (c. 460-c. 375 BC, Greece) founds one of many healing sects. Though probably not the author of the Hippocratic Oath, he encouraged the separation of science from philosophy and religion.

Basic concepts and principles of sciences commonly accepted per se for centuries introduced by Aristotle (c. 384-322 BC, Greece). Stating that knowledge must come from experience, he classified animals and wrote the oldest existing monograph on general zoology, as well as works on general biology and marine biology.

Early physiology practiced by Erasistratus (c. 304-250 BC, Greece). While dissecting humans, he developed a theory of blood flow, which, though erroneously reversing its motion, was only resolved by William Harvey in 1628. He also distinguished between sensory and motor nerves.

Library of Alexandria, repository of significant bio-medical knowledge, founded.

Crop rotation and other sound agricultural practices described by Marcus Terentius Varro (116 BC-27 BC, Rome).

Medical Botany practiced by Pedanius Dioscorides (c. AD 40-90, Greece), who writes a pharmacology text describing the use of some 600 plants, widely regarded until the 1500s.

Multi-volume work, “Historia naturalis” compiling existing facts and myths, written by Pliny the Elder (c. AD 23-79, Rome); veracity first challenged in 1492.

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1658 – Red blood cells first identified and described by Jan Swammerdam (1637-1680, Holland). Known for his research in microscopic studies, he later laid the foundation for modern entomology.

c. 1660 – Plant physiology advanced by John Ray (1627-1705, England), who introduces a classification scheme based on the number of seed leaves.

1660 – By observing blood flowing over lungs through capillaries, Marcello Malpighi (1628-1694, Italy), a founder of microscopic anatomy, clarifies and extends William Harvey's observations.

c. 1665 – Though considered of limited function, cells, the basic unit of human life, identified and named by Robert Hooke (1635-1703, England).

1667 – Transfusion of animal blood to a human performed by Jean-Baptiste Denis (c. 1640-1704, France); the patient remarkably survived although later experiments failed tragically. Transfusions were prohibited in the early 1670s.

1668 – Spontaneous generation of maggots disproved by Francesco Redi (1626-1697, Italy). Nevertheless, the theory of spontaneous generation re-emerged over the next two centuries.

1674 – Using a self-made compound microscope, Anton van Leeuwenhoek (1632-1723, Holland) observes and identifies protozoa. His research was also used to counter theories of spontaneous generation.

1683 – Bacteria identified by Anton van Leeuwenhoek.

c. 1701 – Mechanical seed drill invented by Jethro Tull (1674-1741, England), offering an economical replacement to sowing rows of seeds by hand.

c. 1721 – Variolation, a long-standing method of immunization developed before vaccination, carried out against smallpox in England by Lady Mary Wortley Montagu (1689-1762, England).

1724 – The possibility of corn cross-fertilization validated by Paul Dudley (1675-1751, U.S.), increasing the variability of species.

1727 – First significant work on plant physiology published by Stephen Hales (1677-1761, England).

1731 – Jethro Tull completes “Horseshoeing husbandry” on plant nutrition and farming, a basis for modern agriculture.

1735 – Plant and animal classification system introduced by Carolus Linnaeus (1707-1778, Sweden), in his “Systema Naturae.” In 1753 he introduces binomial nomenclature in taxonomy.

1742 – First permanent graft of animal tissue made by Abraham Trembley (1710-1784, Switzerland).


1754 – Preventive for scurvy, citrus fruit (though known for over two centuries) scientifically confirmed by James Lind (1716-1794, Scotland).

1761 – Cause of diseases related to lesions in organs rather than an imbalance of the humours by Giovanni Battista Morgagni (1682-1771, Italy), countering long-held humoral theories of disease.

1767 – Experiments of Lazzaro Spallanzani (1729-1799, Italy) help disprove the theory of spontaneous generation in microorganisms.

1769-1771 – Over 800 previously unknown plant species collected by Joseph Banks (1743-1820, England) in expedition on Endeavour to South Seas. Later, as honorary director of Kew Gardens he launched numerous scientific expeditions benefiting the science of botany.

1771 – Plant conversion of carbon dioxide into oxygen identified by Joseph Priestley (1733-1804, England).

1785 – Lazzaro Spallanzani demonstrates critical role of seminal material from males for reproduction.


1800-1805 – The science of modern comparative anatomy initiated by Georges Cuvier (1769-1832, France), who relates the function of each organ to all others in an animal’s body and recognizes the existence of four, rather than one, phyla in the animal kingdom.

1802 – The term “biology,” derived from the Greek word “bios” (life) and “logos” (study), used in modern sense by Gottfried Reinhold Treviranus (1776-1837, Germany) and simultaneously adapted in French by Jean-Baptiste Lamarck (1744-1829, France).

1809 – Theory of transmutation by inheritance of acquired characteristics used and disused and environmental pressure introduced by Jean-Baptiste Lamarck.

1823 – Fingerprints recognized as a means of identification by Jan Evangelista Purkinje (1787-1869, Czechoslovakia).

1830s – Physiology established as a distinct science by Johannes Peter Müller (1801-1858, Germany).

1831 – H.M.S. Beagle sets sail on exploration of South America with Charles Darwin (1809-1882, England) as unpaid naturalist.

1833-1843 – Extensive study of fossilized fish by Louis Agassiz (1807-1873, Switzerland/U.S.) emphasizes first-hand investigation and encourages the investigation of extinct life.

1836-1839 – A theory of cell biology, that cells are the fundamental particles of plants and animals, developed by Theodor Schwann (1810-1882, Germany) and Matthias Schleiden (1804-1881, Germany). Schwann, who coined the term “metabolism,” is credited as an early leader in modern histology.


1855 – Principle of cell division, “that every cell is descended from a cell,” made by Rudolf Carl Virchow (1821-1902, Germany).

1855 – Ductless glands found to produce hormones by Claude Bernard (1813-1878, France), one of the founders of experimental medicine.

1856 – Discovery that microorganisms, not chemicals, cause fermentation, the process of pasteurization, made by Louis Pasteur (1822-1895, France).


1860-1866 – The basis for modern genetics established by Gregor Johann Mendel (1822-1884, Austria). Though largely ignored for decades, his discovery that traits were transmitted from parents to progeny by discrete, independent units, later called genes, was independently verified in 1900.

1866 – The term “ecology” is used for first time, though undefined, by Ernst Heinrich Haeckel (1834-1919, Germany) and Eugenius Warming (1841-1924, Denmark). Haeckel later established plant ecology as a new discipline within botany and defined ecology in the modern sense.

1869 – Nucleic acids, substances that comprise the genetic material of living cells, recognized by Friedrich Miescher (1844-1895, Switzerland), though he does not assign to them a physiological function.

1870 – The germ theory of disease established by Louis Pasteur and Robert Koch (1843-1910, Germany), founders of modern bacteriology.

1875 – The transmission of hereditary material through two sex cells confirmed by Oscar Hertwig (1849-1922, Germany).

1876 – Anthrax bacteria cultivated in blood serum by Robert Koch, leading to techniques for identifying bacteria.

1878 – The first method for isolation of bacteria cultures, based on the most probable number technique, introduced by Joseph Lister.

1879-1882 – Threadlike structures in cell nucleus later termed “chromosomes” observed by Walther Flemming (1843-1905, Germany), who described and named the process of cell division “mitosis.”

1881 – The theory of protective vaccines established by Louis Pasteur.

1882-1883 – Robert Koch discovers bacillus responsible for tuberculosis and cholera.

1883 – The ability to measure biological activity by the rate a tissue consumes oxygen made by Paul Ehrlich (1854-1915, Germany).

1886 – The germ-plasm theory of heredity developed by August Weismann (1834-1914, Germany), an early leader in the science of genetics.

1892 – Dmitri I. Ivanovsky (1864-1920, Russia) identifies a seemingly invisible viral microorganism but supposes it a bacteria.

1897 – Concept of conditioned reflex developed by Ivan Petrovich Pavlov (1849-1936, Russia).

1898 – Certain infective agents determined to be viral by Martinus Willem Beijerinck (1851-1931, Holland), who introduces the term “filterable virus.”

1900-1903 – Rediscovering the work of Mendel. Hugo DeVries (1848-1935, Holland) and other scientists working independently introduce the term “genetics.”

1901 – Yellow fever transmitted by mosquitoes established by Walter Reed (1851-1902, U.S.) in collaboration with James Carroll (1854-1907, Great Britain). For the first time a human disease is proven to be caused by a virus.

1901 – Karl Landsteiner (1868-1943, Austria/U.S.) defines the present classification system of four human blood groups based on inherited properties of red blood cells, making successful blood transfusions possible.
1902 – Demonstration that chromosomes may hold the cell’s unit of inheritance given by Walter Sutton (1877-1916, U.S.).

1906-1907 – “Accessory factors” contained in foods identified as vitamins by Frederick Hopkins (1861-1947, Great Britain).

1909 – Wilhelm Johannsen (1857-1927, Denmark) uses the term “genotype” as distinguished from “phenotype” to describe Mendel’s factors of inheritance. He emphasizes quantitative variations of characteristics in populations.

1910 – Thomas Hunt Morgan (1866-1945, U.S.) demonstrates chromosome theory of inheritance through work on Drosophila.


1912 – The term “vitamine” (for “vital compound”) introduced by Casimir Funk (1884-1967, Poland/U.S.). He and Frederick Hopkins advance the hypothesis that vitamin deficiency can cause disease.


1919 – Methods of insect communication identified by Karl von Frisch (1886-1982, Austria), a founder of modern ethology.

1921 – Insulin isolated by Frederick Grant Banting (1891-1941, Canada), Charles Herbert Best (1899-1978, Canada), and J.J.R. Macleod (1876-1935, Scotland). Banting and Macleod received the Nobel Prize (1923) for isolating insulin.


1926 – The power of X-rays to produce mutations demonstrated by Hermann Joseph Muller (1890-1967, U.S.).

1928 – Development of penicillin begun by discoveries made by Alexander Fleming (1881-1955, Great Britain), though practicality realized a dozen years later.

1930 – An offshoot of the Marine Hospital Service founded in 1798, the Hygienic Laboratory is transformed by the Ransdell Act into the National Institute of Health (NIH).

1931 – Method of culturing viruses in fertile eggs introduced by Ernest William Goodpasture (1886-1960, U.S.); leads to vaccines against smallpox, yellow fever, typhus, and later influenza.

1931 – Thesis that chromosomes form the basis of genetics confirmed by Barbara McClintock (1902-1992, U.S.) and her graduate student Harriet Creighton.

1932 – First realistic estimate of mutation rates in humans made by J. B. S. Haldane (1892-1964, Great Britain).


1934 – Sea habitats studied at a depth not before possible in a bathysphere invented by William Beebe (1877-1962, U.S) and his U.S. colleague Otis Barton.

1935 – Imprinting, communicating behavior patterns on the part of parents, identified by Konrad Lorenz (1903-1989, Austria), a founder of modern ethology.

1967 – Biologically active virus successfully synthesized for first time in a laboratory by Arthur Kornberg.

1970 – First synthesis of an artificial gene announced by Har Gobind Khorana.


1977 – First genetic engineering company, Genentech, founded; uses recombinant DNA to produce drugs; produces the first human protein manufactured in a bacteria.


1980 – U.S. Supreme Court rules genetically altered life forms can be patented.

1981 – U.S. Centers for Disease Control recognizes acquired immune deficiency (AIDS) caused by the human immunodeficiency virus (HIV).

1983 – Technique of rapidly synthesizing the DNA sequence called polymerase chain reaction (PCR) developed by Kary B. Mullis (1944-, U.S.).


1993 – Human embryos cloned and nurtured in petri dishes by George Washington University researchers.

1994 – First genetically engineered food product, a tomato, approved by U.S. Food and Drug Administration.

1996 – Identical lambs cloned from the sheep Dolly by Ian Wilmut (1944-, Scotland).

1998 – Human embryonic stem cells grown in U.S. by scientists from the University of Wisconsin and the Johns Hopkins University School of Medicine.

1999 – “Labs on a chip,” silicon wafers, enable biologists to monitor nearly 10,000 genes in a single experiment.

2002 – First virus produced “from scratch,” an artificial polio virus tested on mice.

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