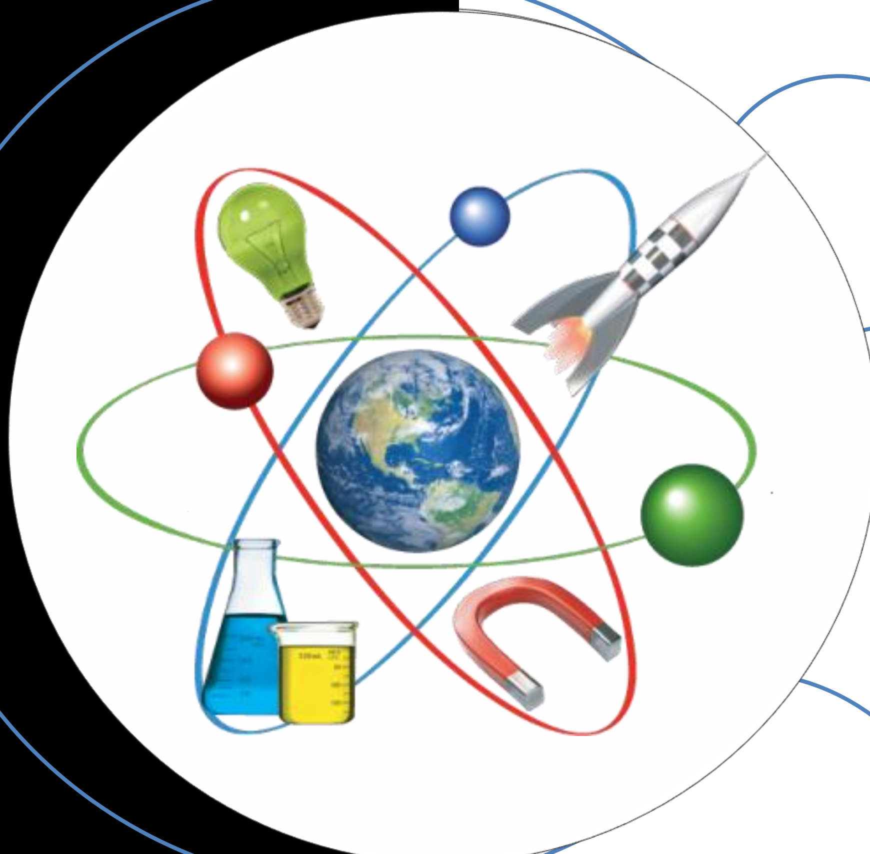
Young Scientist - Basic



About CASI Global

CASI New York
CASI Global is the apex body dedicated to promoting the knowledge & cause of CSR & Sustainability. We work on this agenda through certifications, regional chapters, corporate chapters, student chapters, research and alliances. CASI is basically from New York and now has a presence across 52 countries.

World Class Certifications
CASI is usually referred to as one of the BIG FOUR in education, CASI is also referred to as the global certification body
CASI offers world class certifications across multiple subjects and caters to a vast audience across primary school to management school to CXO level students. Many universities & colleges offer CASI programs as credit based programs.
CASI also offers joint / cobranded certifications in alliances with various institutes and universities.
www.casiglobal.us

CASI India
CASI India has alliances with hundreds of institutes in India where students of these institutes are eligible to enroll for world class certifications offered by CASI. The reach through such alliances is over 2 million citizens
CASI India also offers cobranded programs with Government Polytechnic and many other institutes of higher learning.

CASI India has multiple franchises across India to promote certifications especially for school students.
www.casi-india.com

Volunteering @ CASI NY
CASI India / CSR Diary also provide volunteering opportunities and organizes mega format events where in citizens at large can also volunteer for various causes. These are behavoural change events and further details on such events are available on www.csrdiary.com / www.mahawalkathon.com / www.copforaday.com

Value Proposition
Universities and institutes incorporate & adopt CASI programs within their core curriculum; this gives their students and edge in knowledge and placements.

Further with corporates keen to inculcate CSR & Sustainability across their value chain, most corporate prefer to recruit employees with a basic knowledge of CSR & Sustainability.
Finally, given the wide range of online / offline / MDP programs at CASI NY, Corporates, institutes of higher learning and senior management professionals globally rely on CASI programs to develop cutting edge knowledge.

Student Chapters
This is a grass root level representation and collaboration towards promoting the cause of sustainability. Institutes / Colleges / Universities / Schools are encouraged to form a chapter / council of students headed by a faculty to promote knowledge, networking and participate in behavioral change events. This is complimentary to every education institute across the world. For further details www.casi-india.com

About the Program

This reading material is suggested for students keen to pursue a career in science and related education / career streams. This is an open enrolment program

The Young Scientist Certification program aims at preparing the student to understand implications & applications in science other than their regular text books. This program primarily aims at enabling youngsters think in different directions.

Our pattern does not follow the regular physics, chemistry biology divisions but is created on natural themes which make it far more interesting for everyone, regardless of the chosen education / career path.

Dear Students,

It gives us great pleasure to welcome you to the CASI Global Community. Congratulations on successfully applying to this program.

CASI Global, New York has been educating responsible citizens and citizen-leaders for our society. When you join the CASI community, you are embarking on a journey that is meant to be transformative – academically, socially, and personally.

While at school we learn the basics of language, sciences and math, the educational system be it main stream or vocational is directed towards creating a better understanding of possibilities in life and career; & then as time progresses, the school children grow to college levels and then finally have a career…again main stream or vocational. Similarly learning the concepts of CSR and sustainable development alongside the basics helps them develop a holistic view of the world.

Just like it is important for children to prepare themselves for life by undergoing training and education in mainstream; it is even more important that children have an exposure to societal concepts of CSR and elementary sustainable development information.

Such an elementary knowledge or exposure to CSR & Sustainability concepts at a young age not only helps them be better citizens but lays a very strong foundation for higher education, be it sciences or engineering or management.

The foundation has to be laid at a young age, a very young age.

Each enrolled for the Global certification embarks on a journey to excel in life as a model citizen and is a brand ambassador for CASI Global New York.

If there is anything we at the CASI Secretariats office can do to help you better navigate through this program, we hope you will let us know. We want you to feel a part of the rich and varied community that is CASI. We wish you a happy, healthy, and a fruitful year. We welcome you once again, to CASI, The Global Certification body for CSR & Sustainability.

Warm Regards

Sd/ For the Secretariat
CASI Global, New York
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Table of Contents

Basics

1.Energy producers such as plants, algae, and cyanobacteria use the energy from sunlight to make organic matter from carbon dioxide and water. This establishes the beginning of energy flow through almost all food webs –

- **True**
- False

2.Generation of electricity with the use of water is called:

- **Hydro-power**
- Nuclear-power
- Horse-power

3.As on 2010, Hydro-power produced around 15% of world's electricity -

- **True**
- False

4.As of 2014, the wind provides for 2% of World electricity

- **True**
- False

5.As of 2014, Nuclear energy generates almost 15% of world electricity

- **True**
- False

6.As of 2014, Solar provides for less than 1% of world electricity

- **True**
- False

7.World data as on 2010, suggests that more than 1.3 billion people on earth with no access to electricity-

- **True**
- False

8.Toxic waste should be dumped into the sea-water for risk mitigation–

- True
- **False**

9. CSR for environment would entail the following: -
i. Sorting waste
ii. Utilisation of waste
iii. Double sided printing and copying

iv. Use of environmentally clean fuel
v. Gentle handling of electricity and water

- None of the above
- i, ii and iii only
- iii, iv and v only
- **All of the above options**

10. CSR and Sustainability simply means 'giving out donations'

- True
- **False**

11. CSR for local community would entail the following:
i. Corporate giving
ii. Volunteering hours for social cause
iii. Community education-

- i and iii only
- only ii
- **All of the above**

12. How can School students contribute towards Social Responsibility?
i. Volunteer their time for a cause
ii. save electricity
iii. Help create awareness amongst people (Home, school, building, etc.)
iv. Donate to NGO-

- Only iii
- **All of the above**
- Only i
- None of the above

13. Volunteering means to donate ones time for the good of other. An activity intended to promote goodness. There is no financial gain involved for the individual. –

- **True**
- False

14. Humans are modifying the energy balance of earth's ecosytem. –

- **True**
- False

15. The chemical elements that make-up the molecules of living things are passed through food chains and are combined and recombined in different ways–

- **True**
- False

16. Food is a biofuel used by organisms to acquire energy for internal living processes.
- **True**
- False

17. All primary source fuels except bio-mass are renewable
- True
- **False**

18. Fossil fuels and bio fuels are organic matters that contain energy captured from sunlight.
- **True**
- False

19. Electricity is not a primary source of energy, but a carrier of energy
- False
- **True**

20. When a magnet moves or magnetic field changes relative to coil of wire, electrons are induced to flow in the wire. Most human generation of electricity happens in this way. Electrons can also be induced to flow through direct interaction with light particles -- This is the basis upon which a solar cell operates.
- **True**
- False

21. Humans intentionally store energy for later use in a number of different ways.
- **True**
- False

22. Different sources of energy and different ways energy can be transported, transformed - each have same benefits and drawback and adverse impact to our climate
- True
- **False**

23. The Energy Conservation Act (EC Act) set with the goal of reducing energy intensity of Indian economy was enacted in the year
- **2001**
- 2010
- 2014

24. The primary energy demand in India has grown from about 450 million tons of oil equivalent (toe) in 2000 to about 770 million toe in 2012. This is expected to increase to about 1250 (estimated by International Energy Agency) to 1500 (estimated in the Integrated Energy Policy Report) million toe in 2030.
- **True**
- False

25. Power is measured in J/s (joules/second), which is known as watt (W). Thus, J/s = W and 1000 W = 1 kilowatt.

- **True**
- False

26. Electrical energy is measured in kWh (kilowatt hour). ! One kWh is the electrical energy used or supplied when one kW of power is used or supplied for one hour.

- **True**
- False

27. If dead plants are buried in swampy land, then oxidizing action of air cannot take place. The oxygen and hydrogen of the dead plant gradually escape into the air. The residue becomes rich in carbon and since it is under water, it becomes soggy. This is called peat, the first stage in the formation of coal.

- **True**
- False

28. Carbon footprint is the amount of carbon dioxide emitted by the activities undertaken by an organization, company or individual.

- **True**
- False

29. What is the most common and effective method to offset carbon emissions?

- **Plant trees**
- Drink more water
- Eat more fruits

30. Best and most common method to save fuel is:

- **Car-pool (travel together to School / Office)**
- Drive fast on the roads
- Do not halt on signals

31. Which of the following consumes less energy?

- **Electric choke**
- Traditional choke

32. Which of the following consumes more energy for the same output of light?

- Tube light
- **Incandescent Bulb**

33. What does CFL stand for?

- **Compact Fluorescent Light**
- Continuous Falling Light

34. Which of the following lightening appliances have longer life?

Tube Light

- Halogen lamp
- Incandescent Bulb

35. If a bulb of 60 W glows for 10 hours per day, what will be its energy consumption a day?

- 1 KW
- 6 KW
- **0.6 KW**

36. One unit of electricity is equal to

- **1 KW**
- 1 HP
- 1 WH

37. The energy consumption by 20 KW equipment in 60 minutes is

- **20 Units**
- 3 Units
- 2 Units

38. The supply voltage for domestic purpose is

- **220 volts**
- 440 volts
- 880 volts

39. Major fraction of power generated in India is by:

- **Thermal power plants**
- Hydro power plants
- Nuclear power plants

40. CSR for environment would entail the following:

i. Sorting waste
ii. Utilisation of waste
iii. Double sided printing and copying
iv. Use of environmentally clean fuel
v. Gentle handling of electricity and water

- None of the above
- i, ii and iii only
- iii, iv and v only
- **All of the above options**

41. CSR and Sustainability simply means 'giving out donations'

- True

- **False**

- CSR for local community would entail the following:

i. Corporate giving
ii. Volunteering hours for social cause
iii. Community educationi and iii only

- only ii
- **All of the above**

42. Energy producers such as plants, algae, and cyanobacteria use the energy from sunlight to make organic matter from carbon dioxide and water. This establishes the beginning of energy flow through almost all food webs

- **True**
- False

43. If you shade your home windows and walls and plant trees and shrubs, you may reduce air-conditioning energy use by how many percent?

- **40 percentage (approximately)**
- 30 percentage (approximately)
- 18 percentage (approximately)

44. Setting computers, monitors and copiers to sleep-mode when not in use helps cut energy costs by approximately __%

- 10%
- 60%
- **40%**

45. Best and most common method to save fuel is:

- **Car-pool (travel together to School / Office)**
- Drive fast on the roads
- Do not halt on signals

46. Which of the following consumes more energy for the same output of light?

- Tube light
- **Incandescent Bulb**

47. Major fraction of power generated in India is by:

- **Thermal power plants**
- Hydro power plants
- Nuclear power plants

48. It saves fuel to shut down the car and restart, if the car halts for more than __ seconds on a signal as it would consume fuel if kept idle on signal halt

- **10 seconds**
- 30 seconds
- 50 seconds

49. Where does India rank globally in terms of total electricity generation?

- Third place
- **Sixth place**

50. What is 'making good use of Garbage' called?

- **Vermicomposting**
- Waste management
- Waste Disposal

Chapter 1
Ancient Sciences & Advancement

PROTOSCIENCE

Its simplest meaning (most closely reflecting its roots of *proto-* + *science*) involves the earliest eras of the history of science, when the scientific method was still nascent. Thus, in the late 17th century and early 18th century, Isaac Newton contributed to the dawning sciences of chemistry and physics, even though he was also an alchemist who sought chrysopoeia in various ways including some that were unscientific.

The **history of science** is the study of the development of science and scientific knowledge, including both the natural and social sciences. (The history of the arts and humanities is termed history of scholarship.) Science is a body of empirical, theoretical, and practical knowledge about the natural world, produced by scientists who emphasize the observation, explanation, and prediction of real-world phenomena. Historiography of science, in contrast, studies the methods employed by historians of science.

The English word *scientist* is relatively recent—first coined by William Whewell in the 19th century. Previously, investigators of nature called themselves "natural philosophers"

The ancient Mesopotamians had no distinction between "rational science" and magic When a person became ill, doctors prescribed magical formulas to be recited as well as medicinal treatments. The earliest medical prescriptions appear in Sumerian during the Third Dynasty of Ur (c.2112 BC – c. 2004 BC). The most extensive Babylonian medical text, however, is the *Diagnostic Handbook* written by the *ummânū*, or chief scholar, Esagil-kin-apli of Borsippa,during the reign of the Babylonian king Adad-apla-iddina (1069–1046 BC).

In East Semitic cultures, the main medicinal authority was a kind of exorcist-healer known as an *āšipu*. The profession was generally passed down from father to son and was held in extremely high regard

Of less frequent recourse was another kind of healer known as an *asu*, who corresponds more closely to a modern physician and treated physical symptoms using primarily folk remedies composed of various herbs, animal products, and minerals, as well as potions, enemas, and ointments or poultices. These physicians, who could be either male or female, also dressed wounds, set limbs, and performed simple surgeries. The ancient Mesopotamians also practiced prophylaxis and took measures to prevent the spread of disease

The ancient Mesopotamians had extensive knowledge about the chemical properties of clay, sand, metal ore, bitumen, stone, and other natural materials, and applied this knowledge to practical use in manufacturing pottery, faience, glass, soap, metals, lime plaster, and waterproofing. Metallurgy required scientific knowledge about the properties of metals. Nonetheless, the Mesopotamians seem to have had little interest in gathering information about the natural world for the mere sake of gathering information and were far more interested in studying the manner in which the gods had ordered the universe. Biology of non-human organisms was generally only written about in the context of mainstream academic disciplines. Animal physiology was studied extensively for the purpose of divination; the anatomy of the liver, which was seen as an important organ in haruspicy, was studied in particularly intensive detail. Animal behaviour was also studied for divinatory purposes. Most information about the training and domestication of animals was probably transmitted orally without being written down, but one text dealing with the training of horses has survived. The Mesopotamian cuneiform tablet Plimpton 322, dating to the eighteenth-century BC, records a number of Pythagorean triplets (3,4,5) (5,12,13) ..., hinting that the ancient Mesopotamians might have been aware of the Pythagorean theorem over a millennium before Pythagoras

Mathematics:

The earliest traces of mathematical knowledge in the Indian subcontinent appear with the Indus Valley Civilization (c. 4th millennium BC ~ c. 3rd millennium BC). The people of this civilization made bricks whose dimensions were in the proportion 4:2:1, considered favourable for the stability of a brick structure. They also tried to standardize measurement of length to a high degree of accuracy. They designed a ruler—the *Mohenjo-Daro ruler*—whose unit of length (approximately 1.32 inches or 3.4 centimetres) was divided into ten equal parts. Bricks manufactured in ancient Mohenjo-Daro often had dimensions that were integral multiples of this unit of length.

Indian astronomer and mathematician Aryabhata (476–550), in his *Aryabhatiya* (499) introduced a number of trigonometric functions (including sine, versine, cosine and inverse sine) trigonometric tables, and techniques and algorithms of algebra. In 628 A.D Brahmagupta suggested that gravity was a force of attraction.He also lucidly explained the use of zero as both a placeholder and a decimal digit, along with the Hindu-Arabic numeral system now used universally throughout the world. Arabic translations of the two astronomers' texts were soon available in the Islamic world, introducing what would become Arabic numerals to the Islamic world by the 9th century. During the 14th–16th centuries, the Kerala school of astronomy and mathematics made significant advances in astronomy and especially mathematics, including fields such as trigonometry and analysis. In particular, Madhava of Sangamagrama is considered the "founder of mathematical analysis"

Astronomy:

The first textual mention of astronomical concepts comes from the Vedas, religious literature of India. According to Sarma (2008): "One finds in the Rigveda intelligent speculations about the genesis of the universe from nonexistence, the configuration of the universe, the spherical self-supporting earth, and the year of 360 days divided into 12 equal parts of 30 days each with a periodical intercalary month." The first 12 chapters of the *Siddhanta Shiromani*, written by Bhāskara in the 12th century, cover topics such as: mean longitudes of the planets; true longitudes of the planets; the three problems of diurnal rotation; syzygies; lunar eclipses; solar eclipses; latitudes of the planets; risings and settings; the moon's crescent; conjunctions of the planets with each other; conjunctions of the planets with the fixed stars; and the patas of the sun and moon. The 13 chapters of the second part cover the nature of the sphere, as well as significant astronomical and trigonometric calculations based on it.

NilakanthaSomayaji's astronomical treatise the Tantrasangraha similar in nature to the Tychonic system proposed by Tycho Brahe had been the most accurate astronomical model until the time of Johannes Kepler in the 17th century.

Linguistics:

Some of the earliest linguistic activities can be found in Iron Age India (1st millennium BC) with the analysis of Sanskrit for the purpose of the correct recitation and interpretation of Vedic texts. The most notable grammarian of Sanskrit was *Pāṇini* (c. 520–460 BC), whose grammar formulates close to 4,000 rules which together form a compact generative grammar of Sanskrit. Inherent in his analytic approach are the concepts of the phoneme, the morpheme and the root.

Medicine:

Findings from Neolithic graveyards in what is now Pakistan show evidence of proto-dentistry among an early farming culture.Ayurveda is a system of traditional medicine that originated in ancient India before 2500 BC, and is now practiced as a form of alternative medicine in other parts of the world. Its most famous text is the Suśrutasamhitā of Suśruta, which is notable for describing procedures on various forms of surgery, including rhinoplasty, the repair of torn ear lobes, perineal lithotomy, cataract surgery, and several other excisions and other surgical procedures.

Metallurgy:

The wootz, crucible and stainless steels were invented in India, and were widely exported in Classic Mediterranean world. It was known from Pliny the Elder as *ferrumindicum*. Indian Wootz steel was held in high regard in Roman Empire, was often considered to be the best. After in Middle Age it was imported in Syria to produce with special techniques the "Damascus steel" by the year 1000.

"The Hindus excel in the manufacture of iron, and in the preparations of those ingredients along with which it is fused to obtain that kind of soft iron which is usually styled Indian steel (Hindiah). They also have workshops wherein are forged the most famous sabres in the world."
—Henry Yule quoted the 12th-century Arab Edrizi.

Scientific Revolution

The Scientific Revolution was a series of events that marked the emergence of modern science during the early modern period, when developments in mathematics, physics, astronomy, biology (including human anatomy) and chemistry transformed the views of society about nature.

The Scientific Revolution took place in Europe towards the end of the Renaissance period and continued through the late 18th century, influencing the intellectual social movement known as the Enlightenment. While its dates are debated, the publication in 1543 of Nicolaus Copernicus's De revolutionibusorbiumcoelestium (On the Revolutions of the Heavenly Spheres) is often cited as marking the beginning of the Scientific Revolution.

The concept of a scientific revolution taking place over an extended period emerged in the eighteenth century in the work of Jean Sylvain Bailly, who saw a two-stage process of sweeping away the old and establishing the new.

The beginning of the Scientific Revolution, the Scientific Renaissance, was focused on the recovery of the knowledge of the ancients; this is generally considered to have ended in 1632 with publication of Galileo's Dialogue Concerning the Two Chief World Systems.

The completion of the Scientific Revolution is attributed to the "grand synthesis" of Isaac Newton's 1687 Principia. The work formulated the laws of motion and universal gravitation thereby completing the synthesis of a new cosmology.

By the end of the 18th century, the Age of Enlightenment that followed Scientific Revolution had given way to the "Age of Reflection.

Institutionalization

The Royal Society had its origins in Gresham College, and was the first scientific society in the world.

The first moves towards the institutionalization of scientific investigation and dissemination took the form of the establishment of societies, where new discoveries were aired, discussed and published. The first scientific society to be established was the Royal Society of London. This grew out of an earlier group, centred around Gresham College in the 1640s and 1650s. According to a history of the College:

The scientific network which centred on Gresham College played a crucial part in the meetings which led to the formation of the Royal Society.

Chapter 2
Weapons & Defence Technology

Military science

Military science is the study of military processes, institutions, and behavior, along with the study of warfare, and the theory and application of organized coercive force.

It is mainly focused on theory, method, and practice of producing military capability in a manner consistent with national defense policy. Military science serves to identify the strategic, political, economic, psychological, social, operational, technological, and tactical elements necessary to sustain relative advantage of military force; and to increase the likelihood and favorable outcomes of victory in peace or during a war.

Military scientists include theorists, researchers, experimental scientists, applied scientists, designers, engineers, test technicians, and other military personnel.

Military personnel obtain weapons, equipment, and training to achieve specific strategic goals. Military science is also used to establish enemy capability as part of technical intelligence.

In military history, military science had been used during the period of Industrial Revolution as a general term to refer to all matters of military theory and technology application as a single academic discipline, including that of the deployment and employment of troops in peacetime or in battle.

In military education, military science is often the name of the department in the education institution that administers officer candidate education. However, this education usually focuses on the officer leadership training and basic information about employment of military theories, concepts, methods and systems, and graduates are not military scientists on completion of studies, but rather junior military officers

Military technology

Military systems

How effectively and efficiently militaries accomplish their operations, missions and tasks is closely related not only to the methods they use, but the equipment and weapons they use.

Military intelligence

Military intelligence supports the combat commanders' decision making process by providing intelligence analysis of available data from a wide range of sources. To provide that informed analysis the commanders information requirements are identified and input to a process of gathering, analysis, protection, and dissemination of information about the operational environment, hostile, friendly and neutral forces and the civilian population in an area of combat operations, and broader area of interest. Intelligence activities are conducted at all levels from tactical to strategic, in peacetime, the period of transition to war, and during the war.

Most militaries maintain a military intelligence capability to provide analytical and information collection personnel in both specialist units and from other arms and services. Personnel selected for intelligence duties, whether specialist intelligence officers and enlisted soldiers or non-specialist assigned to intelligence may be selected for their analytical abilities and intelligence before receiving formal training.

Military intelligence serves to identify the threat, and provide information on understanding best methods and weapons to use in deterring or defeating it.

Military logistics

The art and science of planning and carrying out the movement and maintenance of military forces. In its most comprehensive sense, it is those aspects or military operations that deal with the design, development, acquisition, storage, distribution, maintenance, evacuation, and disposition of material; the movement, evacuation, and hospitalization of personnel; the acquisition or construction, maintenance, operation, and disposition of facilities; and the acquisition or furnishing of services.

Military technology and equipment

Military technology is not just the study of various technologies and applicable physical sciences used to increase military power. It may also extend to the study of production methods of military equipment, and ways to improve performance and reduce material and/or technological requirements for its production. An example is the effort expended by Nazi Germany to produce artificial rubbers and fuels to reduce or eliminate their dependence on imported POL (petroleum, oil, and lubricants) and rubber supplies.

Military technology is unique only in its application, not in its use of basic scientific and technological achievements. Because of the uniqueness of use, military technological studies strive to incorporate evolutionary, as well as the rare revolutionary technologies, into their proper place of military application.

Military inventions with civilian uses (Partial List)

Name	Date invented	Original purpose	Civilian uses
ASDIC	1910s	Submarine detection	Sonar
Aircraft tracking radar	mid-1930s	Early warning radar, air defence systems	Air traffic control systems, microwave oven
Walkie-talkie	1930s	Portable two-way radio communications system for military	Portable radio communications – business, public safety, marine, amateur radio, CB radio
Night vision	1939 - 1940s	Visibility for military personnel in low light situations	Low light photography, surveillance
Duct tape	1942	Sealing ion cases	Multiple uses

Name	Date invented	Original purpose	Civilian uses
Ballistic missiles	1940s	Long range attack	Space exploration, launch of communication, weather and global positioning satellites
Nuclear technology	1940s	Nuclear weapons, large scale destruction	Nuclear medicine, nuclear power
Jet engine	1940s	Jet fighters, jet bombers	Airliners
Digital photography	1960s	Spy satellites, eliminated the need to recover deorbited film canisters	Cameras
Internet	1960s - 1970s	Reliable computer networking	Led to invention of the World Wide Web by British scientist Tim Berners-Lee; subsequently widespread availability of information, telecommunication and electronic commerce
Satellite navigation	1970s	Nuclear weapons force multiplier, increased warhead accuracy through precise navigation	Navigation, personal tracking
Sanitary Napkins	1920s	Prevent bleeding using cellulose in bandages.	British & American nurses picked up the bandages and started using them as Sanitary Napkins.

Military technology

Military technology is the application of technology for use in warfare. It comprises the kinds of technology that are distinctly military in nature and not civilian in application, usually because they lack useful or legal civilian applications, or are dangerous to use without appropriate military training.

Military technology is often researched and developed by scientists and engineers specifically for use in battle by the armed forces. Many new technologies came as a result of the military funding of science. Weapons engineering is the design, development, testing and lifecycle management of military weapons and systems. It draws on the knowledge of several traditional engineering disciplines, including mechanical engineering, electrical engineering, mechatronics, electro-optics, aerospace engineering, materials engineering, and chemical engineering.

The line is porous; military inventions have been brought into civilian use throughout history, with sometimes minor modification if any, and civilian innovations have similarly been put to military use.

Chapter 3
Mysteries of Space

3.1 Oh-My-God particle

Not to be confused with the "God Particle", the Higgs boson.

The Oh-My-God particle was an ultra-high-energy cosmic ray detected on the evening of 15 October 1991 over Dugway Proving Ground, Utah, by the University of Utah's Fly's Eye Cosmic Ray Detector.

Its observation was a shock to astrophysicists (hence the name), who estimated its energy to be approximately 3×1020 eV or 3×108 TeV. This is 20000000 times more energetic than the highest energy measured in electromagnetic radiation emitted by an extragalactic object And 1020 (100 quintillion) times the photon energy of visible light. The particle had a kinetic energy of 48 joules, equivalent to a 142-gram (5 oz) baseball travelling at about 26 m/s (94 km/h; 58 mph).

This particle had so much kinetic energy for its size because it was travelling at 99.99999999999999999999951% of the speed of light. As a result, its Lorentz factor was 3.2×1011. This is so near the speed of light that if a photon were travelling with the particle, it would take over 215,000 years for the photon to gain a 1 cm lead as seen in Earth's reference frame.

The energy of this particle is some 40000000 times that of the highest energy protons that have been produced in any terrestrial particle accelerator. However, only a small fraction of this energy would be available for an interaction with a proton or neutron on Earth, with most of the energy remaining in the form of kinetic energy of the products of the interaction. The effective energy available for such a collision is √2Emc2,[citation needed] where E is the particle's energy and mc2 is the mass energy of the proton. For the Oh-My-God particle, this gives 7.5×1014 eV, roughly 60 times the collision energy of the Large Hadron Collider.

While the particle's energy was higher than anything achieved in terrestrial accelerators, it was still about 40000000 times lower than the Planck energy. Particles of such energy would be required in order to explore the Planck scale. A proton with that much energy would travel 1.665×1015 times closer to the speed of light than the Oh-My-God particle. As viewed from Earth it would take about 3.579×1020 years, or 2.59×1010 times the current age of the universe, for a photon to gain a 1 cm lead over a Planck energy proton as observed in Earth's reference frame.

Since the first observation, at least 72 similar (energy > 5.7×1019 eV) events have been recorded, confirming the phenomenon. These ultra-high-energy cosmic ray particles are very rare; the energy of most cosmic ray particles is between 10 MeV and 10 GeV. More recent studies using the Telescope Array have suggested a source for the particles within a 20-degree radius "warm spot" in the direction of the constellation Ursa Major.

3.2 Higgs boson

The Higgs boson is an elementary particle in the Standard Model of particle physics, produced by the quantum excitation of the Higgs field, one of the fields in particle physics theory. It is named after physicist Peter Higgs, who in 1964, along with five other scientists, proposed the mechanism, which suggested the existence of such a particle. Its existence was confirmed by the ATLAS and CMS collaborations based on collisions in the LHC at CERN.

On December 10, 2013, two of the physicists, Peter Higgs and François Englert, were awarded the Nobel Prize in Physics for their theoretical predictions. Although Higgs's name has come to be associated with this theory (the Higgs mechanism), several researchers between about 1960 and 1972 independently developed different parts of it.

In mainstream media the Higgs boson has often been called the "God particle", from a 1993 book on the topic.

3.2.1 The Standard Model

Physicists explain the properties of and forces between elementary particles in terms of the Standard Model – a widely accepted framework for understanding almost everything in the known universe, other than gravity. (A separate theory, general relativity, is used for gravity.) In this model, the fundamental forces in nature arise from properties of our universe called gauge invariance and symmetries. The forces are transmitted by particles known as gauge bosons.

In the Standard Model, the Higgs particle is a boson with spin zero, no electric charge and no colour charge. It is also very unstable, decaying into other particles almost immediately. The Higgs field is a scalar field, with two neutral and two electrically charged components that form a complex doublet of the weak isospin SU(2) symmetry. The Higgs field has a "Mexican hat-shaped" potential. In its ground state, this causes the field to have a nonzero value everywhere (including otherwise empty space), and as a result, below a very high energy it breaks the weak isospin symmetry of the electroweak interaction. (Technically the non-zero expectation value converts the Lagrangian's Yukawa coupling terms into mass terms.) When this happens, three components of the Higgs field are "absorbed" by the SU(2) and U(1) gauge bosons (the "Higgs mechanism") to become the longitudinal components of the now-massive W and Z bosons of the weak force. The remaining electrically neutral component either manifests as a Higgs particle, or may couple separately to other particles known as fermions (via Yukawa couplings), causing these to acquire mass as well.

3.2.2 Higgs mechanism

Following the 1962 and 1963 papers, three groups of researchers independently published the 1964 PRL symmetry breaking papers with similar conclusions: that the conditions for electroweak symmetry would be "broken" if an unusual type of field existed throughout the universe, and indeed, some fundamental particles would acquire mass. The field required for this to happen (which was purely hypothetical at the time) became known as the Higgs field (after Peter Higgs, one of the researchers) and the mechanism by which it led to symmetry breaking, known as the Higgs mechanism. A key feature of the necessary field is that it would take less energy for the field to have a non-zero value than a zero value, unlike all other known fields, therefore, the Higgs field has a non-zero value (or vacuum expectation) everywhere. It was the first proposal capable of showing how the weak force gauge bosons could have mass despite their governing symmetry, within a gauge invariant theory.

Although these ideas did not gain much initial support or attention, by 1972 they had been developed into a comprehensive theory and proved capable of giving "sensible" results that accurately described particles known at the time, and which, with exceptional accuracy, predicted several other particles discovered during the following years. During the 1970s these theories rapidly became the Standard Model of particle physics. There was not yet any direct evidence that the Higgs field existed, but even without proof of the field, the accuracy of its predictions led scientists to believe the theory might be true. By the 1980s the question of whether or not the Higgs field existed, and therefore whether or not the entire Standard Model was correct, had come to be regarded as one of the most important unanswered questions in particle physics.

3.2.3 Higgs field

According to the Standard Model, a field of the necessary kind (the Higgs field) exists throughout space and breaks certain symmetry laws of the electroweak interaction. Via the Higgs mechanism, this field causes the gauge bosons of the weak force to be massive at all temperatures below an extreme high value. When the weak force bosons acquire mass, this affects their range, which becomes very small. Furthermore, it was later realised that the same field would also explain, in a different way, why other fundamental constituents of matter (including electrons and quarks) have mass.

For many decades, scientists had no way to determine whether or not the Higgs field existed, because the technology needed for its detection did not exist at that time. If the Higgs field did exist, then it would be unlike any other known fundamental field, but it also was possible that these key ideas, or even the entire Standard Model, were somehow incorrect. Only discovering that the Higgs boson and therefore the Higgs field existed solved the problem.

Unlike other known fields such as the electromagnetic field, the Higgs field is scalar and has a non-zero constant value in vacuum. The existence of the Higgs field became the last unverified part of the Standard Model of particle physics, and for several decades, was considered "the central problem in particle physics".

The presence of the field, now confirmed by experimental investigation, explains why some fundamental particles have mass, despite the symmetries controlling their interactions implying that they should be massless. It also resolves several other long-standing puzzles, such as the reason for the extremely short range of the weak force.

Although the Higgs field is non-zero everywhere and its effects are ubiquitous, proving its existence was far from easy. In principle, it can be proved to exist by detecting its excitations, which manifest as Higgs particles (the Higgs boson), but these are extremely difficult to produce and detect. The importance of this fundamental question led to a 40-year search, and the construction of one of the world's most expensive and complex experimental facilities to date, CERN's Large Hadron Collider, in an attempt to create Higgs bosons and other particles for observation and study.

On 4 July 2012, the discovery of a new particle with a mass between 125 and 127 GeV/c2 was announced; physicists suspected that it was the Higgs boson. Since then, the particle has been shown to behave, interact, and decay in many of the ways predicted for Higgs particles by the Standard Model, as well as having even parity and zero spin, two fundamental attributes of a Higgs boson. This also means it is the first elementary scalar particle discovered in nature. As of 2018, in-depth research shows the particle continuing to behave in line with predictions for the Standard Model Higgs boson. More studies are needed to verify with higher precision that the discovered particle has all of the properties predicted, or whether, as described by some theories, multiple Higgs bosons exist.

3.3 Higgs boson

The hypothesised Higgs mechanism made several accurate predictions, however to confirm its existence there was an extensive search for a matching particle associated with it — the "Higgs boson". Detecting Higgs bosons was difficult due to the energy required to produce them and their very rare production even if the energy is sufficient. It was therefore several decades before the first evidence of the Higgs boson was found. Particle colliders, detectors, and computers capable of looking for Higgs bosons took more than 30 years (c. 1980–2010) to develop.

By March 2013, the existence of the Higgs boson was confirmed, and therefore, the concept of some type of Higgs field throughout space is strongly supported. The nature and properties of this field are now being investigated further, using more data collected at the LHC.

Interpretation

Various analogies have been used to describe the Higgs field and boson, including analogies with well-known symmetry-breaking effects such as the rainbow and prism, electric fields, ripples, and resistance of macro objects moving through media (such as people moving through crowds or some objects moving through syrup or molasses). However, analogies based on simple resistance to motion are inaccurate, as the Higgs field does not work by resisting motion

Particle physics

Validation of the Standard Model

The Higgs boson validates the Standard Model through the mechanism of mass generation. As more precise measurements of its properties are made, more advanced extensions may be suggested or excluded. As experimental means to measure the field's behaviours and interactions are developed, this fundamental field may be better understood. If the Higgs field had not been discovered, the Standard Model would have needed to be modified or superseded.

Related to this, a belief generally exists among physicists that there is likely to be "new" physics beyond the Standard Model, and the Standard Model will at some point be extended or superseded. The Higgs discovery, as well as the many measured collisions occurring at the LHC, provide physicists a sensitive tool to parse data for where the Standard Model fails, and could provide considerable evidence guiding researchers into future theoretical developments.

Symmetry breaking of the electroweak interaction

Below an extremely high temperature, electroweak symmetry breaking causes the electroweak interaction to manifest in part as the short-ranged weak force, which is carried by massive gauge bosons. This symmetry breaking is required for atoms and other structures to form, as well as for nuclear reactions in stars, such as our Sun. The Higgs field is responsible for this symmetry breaking.

Particle mass acquisition

It is worth noting that the Higgs field does not "create" mass out of nothing (which would violate the law of conservation of energy), nor is the Higgs field responsible for the mass of all particles. For example, approximately 99% of the mass of baryons (composite particles such as the proton and neutron), is due instead to quantum chromodynamics binding energy, which is the sum of the kinetic energies of quarks and the energies of the massless gluons mediating the strong interaction inside the baryons. In Higgs-based theories, the property of "mass" is a manifestation of potential energy transferred to fundamental particles when they interact ("couple") with the Higgs field, which had contained that mass in the form of energy.

Scalar fields and extension of the Standard Model

The Higgs field is the only scalar (spin 0) field to be detected; all the other fields in the Standard Model are spin ½ fermions or spin 1 bosons. According to Rolf-Dieter Heuer, director general of CERN when the Higgs boson was discovered, this existence proof of a scalar field is almost as important as the Higgs's role in determining the mass of other particles. It suggests that other hypothetical scalar fields suggested by other theories, from the inflaton to quintessence, could perhaps exist as well.

3.3. Cosmology

Inflation

The Higgs field is pivotal in generating the masses of quarks and charged leptons (through Yukawa coupling) and the W and Z gauge bosons (through the Higgs mechanism).

There has been considerable scientific research on possible links between the Higgs field and the inflaton – a hypothetical field suggested as the explanation for the expansion of space during the first fraction of a second of the universe (known as the "inflationary epoch"). Some theories suggest that a fundamental scalar field might be responsible for this phenomenon; the Higgs field is such a field, and its existence has led to papers analysing whether it could also be the inflaton responsible for this exponential expansion of the universe during the Big Bang. Such theories are highly tentative and face significant problems related to unitarity, but may be viable if combined with additional features such as large non-minimal coupling, a Brans–Dicke scalar, or other "new" physics, and they have received treatments suggesting that Higgs inflation models are still of interest theoretically.

3.4. Nature of the universe, and its possible fates

Diagram showing the Higgs boson and top quark masses, which could indicate whether our universe is stable, or a long-lived 'bubble'. As of 2012, the 2σ ellipse based on Tevatron and LHC data still allows for both possibilities.

In the Standard Model, there exists the possibility that the underlying state of our universe -known as the "vacuum" - is long-lived, but not completely stable. In this scenario, the universe as we know it could effectively be destroyed by collapsing into a more stable vacuum state. This was sometimes misreported as the Higgs boson "ending" the universe. If the masses of the Higgs boson and top quark are known more precisely, and the Standard Model provides an accurate description of particle physics up to extreme energies of the Planck scale, then it is possible to calculate whether the vacuum is stable or merely long-lived. A 125 – 127 GeV Higgs mass seems to be extremely close to the boundary for stability, but a definitive answer requires much more precise measurements of the pole mass of the top quark. New physics can change this picture.

If measurements of the Higgs boson suggest that our universe lies within a false vacuum of this kind, then it would imply – more than likely in many billions of years – that the universe's forces, particles, and structures could cease to exist as we know them (and be replaced by different ones), if a true vacuum happened to nucleate. It also suggests that the Higgs self-coupling λ and its βλ function could be very close to zero at the Planck scale, with "intriguing" implications, including theories of gravity and Higgs-based inflation. A future electron–positron collider would be able to provide the precise measurements of the top quark needed for such calculations.

Vacuum energy and the cosmological constant

More speculatively, the Higgs field has also been proposed as the energy of the vacuum, which at the extreme energies of the first moments of the Big Bang caused the universe to be a kind of featureless symmetry of undifferentiated, extremely high energy. In this kind of speculation, the single unified field of a Grand Unified Theory is identified as (or modelled upon) the Higgs field, and it is through successive symmetry breakings of the Higgs field, or some similar field, at phase transitions that the presently known forces and fields of the universe arise.

The relationship (if any) between the Higgs field and the presently observed vacuum energy density of the universe has also come under scientific study. As observed, the present vacuum energy density is extremely close to zero, but the energy density expected from the Higgs field, supersymmetry, and other current theories are typically many orders of magnitude larger. It is unclear how these should be reconciled. This cosmological constant problem remains a further major unanswered problem in physics.

Practical and technological impact

As yet, there are no known immediate technological benefits of finding the Higgs particle. However, a common pattern for fundamental discoveries is for practical applications to follow later, and once the discovery has been explored further, perhaps becoming the basis for new technologies of importance to society.

The challenges in particle physics have furthered major technological progress of widespread importance. For example, the World Wide Web began as a project to improve CERN's communication system. CERN's requirement to process massive amounts of data produced by the Large Hadron Collider also led to contributions to the fields of distributed and cloud computing

Nickname

The Higgs boson is often referred to as the "God particle" in popular media outside the scientific community. The nickname comes from the title of the 1993 book on the Higgs boson and particle physics, The God Particle: If the Universe Is the Answer, What Is the Question? by Physics Nobel Prize winner and Fermilab director Leon Lederman. Lederman wrote it in the context of failing US government support for the Superconducting Super Collider, a part-constructed titanic competitor to the Large Hadron Collider with planned collision energies of 2 × 20 TeV that was championed by Lederman since its 1983 inception and shut down in 1993. The book sought in part to promote awareness of the significance and need for such a project in the face of its possible loss of funding. Lederman, a leading researcher in the field, writes that he wanted to title his book The Goddamn Particle: If the Universe is the Answer, What is the Question? Lederman's editor decided that the title was too controversial and convinced him to change the title to The God Particle: If the Universe is the Answer, What is the Question?

While media use of this term may have contributed to wider awareness and interest, many scientists feel the name is inappropriate since it is sensational hyperbole and misleads readers; the particle also has nothing to do with God, leaves open numerous questions in fundamental physics, and does not explain the ultimate origin of the universe.
Higgs, an atheist, was reported to be displeased and stated in a 2008 interview that he found it "embarrassing" because it was "the kind of misuse... which I think might offend some people". The nickname has been satirised in mainstream media as well. Science writer Ian Sample stated in his 2010 book on the search that the nickname is "universally hate" by physicists and perhaps the "worst derided" in the history of physics, but that (according to Lederman) the publisher rejected all titles mentioning "Higgs" as unimaginative and too unknown.

Lederman begins with a review of the long human search for knowledge, and explains that his tongue-in-cheek title draws an analogy between the impact of the Higgs field on the fundamental symmetries at the Big Bang, and the apparent chaos of structures, particles, forces and interactions that resulted and shaped our present universe, with the biblical story of Babel in which the primordial single language of early Genesis was fragmented into many disparate languages and cultures.

Today ... we have the standard model, which reduces all of reality to a dozen or so particles and four forces. ... It's a hard-won simplicity [...and...] remarkably accurate. But it is also incomplete and, in fact, internally inconsistent... This boson is so central to the state of physics today, so crucial to our final understanding of the structure of matter, yet so elusive, that I have given it a nickname: the God Particle. Why God Particle? Two reasons. One, the publisher wouldn't let us call it the Goddamn Particle, though that might be a more appropriate title, given its villainous nature and the expense it is causing. And two, there is a connection, of sorts, to another book, a much older one...

— Leon M. Lederman and Dick Teresi, The God Particle: If the Universe is the Answer, What is the Question

Lederman asks whether the Higgs boson was added just to perplex and confound those seeking knowledge of the universe, and whether physicists will be confounded by it as recounted in that story, or ultimately surmount the challenge and understand "how beautiful is the universe [God has] made

Chapter 4
NASA Deep Space Network

The **NASA Deep Space Network** (**DSN**) is a worldwide network of U.S. spacecraft communication facilities, located in the United States (California), Spain (Madrid), and Australia (Canberra), that supports NASA's interplanetary spacecraft missions. It also performs radio and radar astronomy observations for the exploration of the Solar System and the universe, and supports selected Earth-orbiting missions. DSN is part of the NASA Jet Propulsion Laboratory (JPL). Similar networks are run by Russia, China, India, Japan and the European Space Agency.

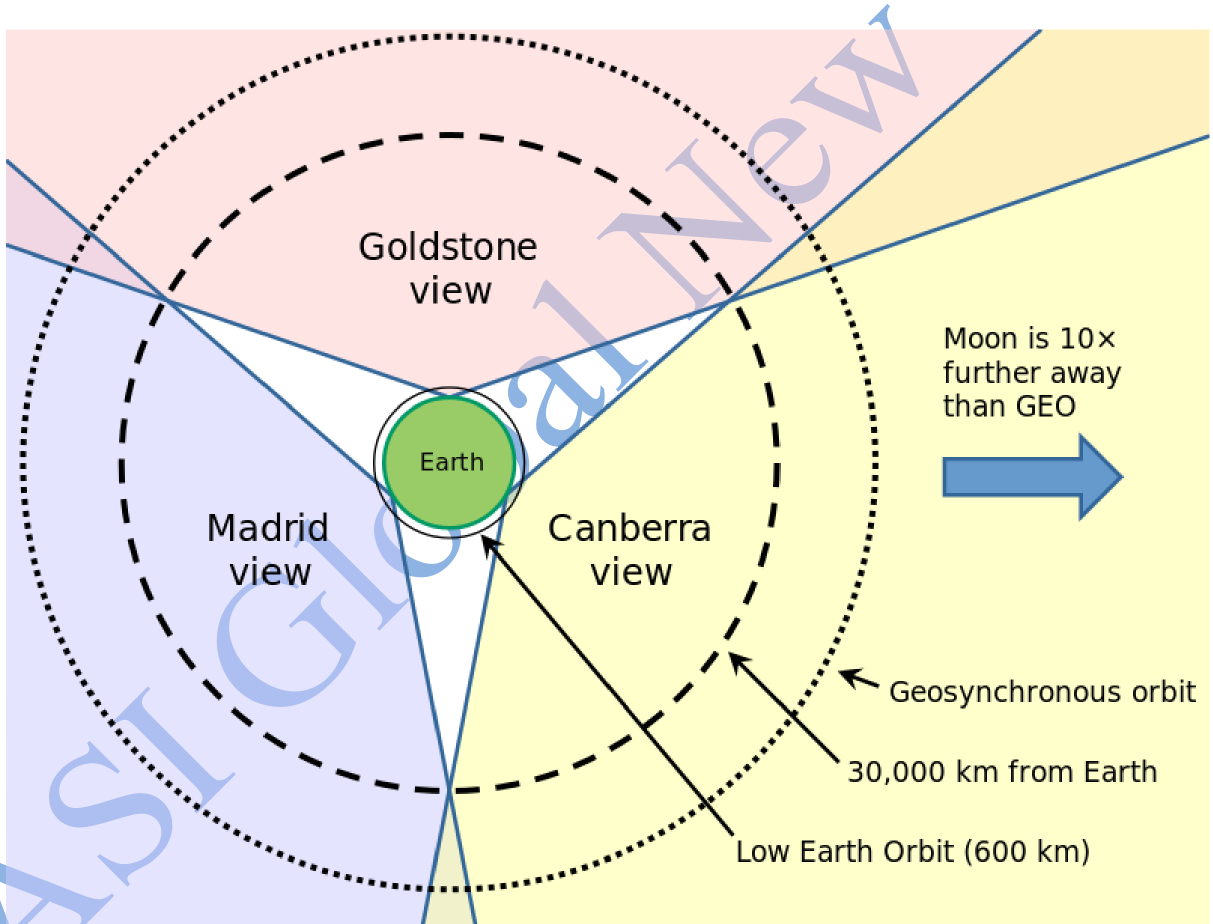
DSN currently consists of three deep-space communications facilities placed approximately 120 degrees apart around the Earth.[1][2] They are:

- The Goldstone Deep Space Communications Complex (35°25′36″N 116°53′24″W) outside Barstow, California. For details of Goldstone's contribution to the early days of space probe tracking, see Project Space Track;
- The Madrid Deep Space Communications Complex (40°25′53″N 4°14′53″W), 60 kilometres (37 mi) west of Madrid, Spain; and
- The Canberra Deep Space Communication Complex (CDSCC) in the Australian Capital Territory (35°24′05″S 148°58′54″E), 40 kilometres (25 mi) southwest of Canberra, Australia near the Tidbinbilla Nature Reserve.

Each facility is situated in semi-mountainous, bowl-shaped terrain to help shield against radio frequency interference. The strategic placement with nearly 120-degree separation permits constant observation of spacecraft as the Earth rotates, which helps to make the DSN the largest and most sensitive scientific telecommunications system in the world.

The DSN supports NASA's contribution to the scientific investigation of the Solar System: It provides a two-way communications link that guides and controls various NASA unmanned interplanetary space probes, and brings back the images and new scientific information these probes collect. All DSN antennas are steerable, high-gain, parabolic reflector antennas. The antennas and data delivery systems make it possible to:

- acquire telemetry data from spacecraft.
- transmit commands to spacecraft.
- upload software modifications to spacecraft.
- track spacecraft position and velocity.
- perform Very Long Baseline Interferometry observations.
- measure variations in radio waves for radio science experiments.
- gather science data.
- monitor and control the performance of the network



View from the Earth's north pole, showing the field of view of the main DSN antenna locations. Once a mission gets more than 30,000 km from earth, it is always in view of at least one of the stations.

Field of view of the Deep Space Network antennas, looking down from the North Pole. Illustrates that missions > 30,000 km from Earth are always in view of at least one station.

70 m antenna at Goldstone, California.

Tracking vehicles in deep space is quite different from tracking missions in low Earth orbit (LEO). Deep space missions are visible for long periods of time from a large portion of the Earth's surface, and so require few stations (the DSN has only three main sites). These few stations, however, require huge antennas, ultra-sensitive receivers, and powerful transmitters in order to transmit and receive over the vast distances involved.

Deep space is defined in several different ways. According to a 1975 NASA report, the DSN was designed to communicate with "spacecraft traveling approximately 16,000 km (10,000 miles) from Earth to the farthest planets of the solar system." JPL diagrams[8] state that at an altitude of 30,000 km, a spacecraft is always in the field of view of one of the tracking stations.

The International Telecommunications Union, which sets aside various frequency bands for deep space and near Earth use, defines "deep space" to start at a distance of 2 million km from the Earth's surface.

This definition means that missions to the Moon, and the Earth–Sun Lagrangian points L_1 and L_2, are considered near space and cannot use the ITU's deep space bands. Other Lagrangian points may or may not be subject to this rule due to distance.

Management

The network is a NASA facility and is managed and operated for NASA by JPL, which is part of the California Institute of Technology (Caltech). The Interplanetary Network Directorate (IND) manages the program within JPL and is charged with the development and operation of it. The IND is considered to be JPL's focal point for all matters relating to telecommunications, interplanetary navigation, information systems, information technology, computing, software engineering, and other relevant technologies. While the IND is best known for its duties relating to the Deep Space Network, the organization also maintains the JPL Advanced Multi-Mission Operations System (AMMOS) and JPL's Institutional Computing and Information Services (ICIS).

Harris Corporation is under a 5-year contract to JPL for the DSN's operations and maintenance. Harris has responsibility for managing the Goldstone complex, operating the DSOC, and for DSN operations, mission planning, operations engineering, and logistics.

Antennas

70 m antenna at Goldstone, California.

Each complex consists of at least four deep space terminals equipped with ultra-sensitive receiving systems and large parabolic-dish antennas. There are:

- One 34-meter (112 ft) diameter High Efficiency antenna (HEF).
- Two or more 34-meter (112 ft) Beam waveguide antennas (BWG) (three operational at the Goldstone Complex, two at the *Robledo de Chavela complex* (near Madrid), and two at the Canberra Complex).
- One 26-meter (85 ft) antenna.
- One 70-meter (230 ft) antenna.

Five of the 34-meter (112 ft) beam waveguide antennas were added to the system in the late 1990s. Three were located at Goldstone, and one each at Canberra and Madrid. A second 34-meter (112 ft) beam waveguide antenna (the network's sixth) was completed at the Madrid complex in 2004.

In order to meet the current and future needs of deep space communication services, a number of new Deep Space Station antennas need to be built at the existing Deep Space Network sites. At the Canberra Deep Space Communication Complex the first of these was completed October 2014 (DSS35), with a second becoming operational in October 2016 (DSS36).[21]Construction has also begun on an additional antenna at the Madrid Deep Space Communications Complex. By 2025, the 70 meter antennas at all three locations will be decommissioned and replaced with 34 meter BWG antennas that will be arrayed. All systems will be upgraded to have X-band uplink capabilities and both X and Ka-band downlink capabilities

Chapter 5
SPACE CRAFTS

SPACE CRAFTS

A spacecraft is a vehicle or machine designed to fly in outer space. Spacecraft are used for a variety of purposes, including communications, earth observation, meteorology, navigation, space colonization, planetary exploration, and transportation of humans and cargo. All spacecraft except single-stage-to-orbit vehicles cannot get into space on their own, and require a launch vehicle (carrier rocket)

On a sub-orbital spaceflight, a space vehicle enters space and then returns to the surface, without having gone into an orbit.
For orbital spaceflights, spacecraft enter closed orbits around the Earth or around other celestial bodies.

Spacecraft used for human spaceflight carry people on board as crew or passengers from start or on orbit (space stations) only, whereas those used for robotic space missions operate either autonomously or telerobotically. Robotic spacecraft used to support scientific research are space probes. Robotic spacecraft that remain in orbit around a planetary body are artificial satellites.

Only a handful of interstellar probes, such as Pioneer 10 and 11, Voyager 1 and 2, and New Horizons, are on trajectories that leave the Solar System.

Orbital spacecraft may be recoverable or not. By method of reentry to Earth they may be divided in non-winged space capsules and winged spaceplanes

Spacecraft types

i. Crewed spacecraft
ii. Space planes
iii. Unmanned spacecraft
iv. Designed as manned but flown as unmanned only spacecraft
v. Semi-manned – manned as space stations or part of space stations

vi. Earth-orbit satellites
vii. Lunar probes
viii. Planetary probes
ix. Other – deep space

Crewed spacecraft

As of 2016, only three nations have flown crewed spacecraft: USSR/Russia, USA, and China. The first crewed spacecraft was Vostok 1, which carried Soviet cosmonaut Yuri Gagarin into space in 1961, and completed a full Earth orbit. There were five other crewed missions which used a Vostok spacecraft. The second crewed spacecraft was named Freedom 7, and it performed a sub-orbital spaceflight in 1961 carrying American astronaut Alan Shepard to an altitude of just over 187 kilometers (116 mi). There were five other crewed missions using Mercury spacecraft.

Other Soviet crewed spacecraft include the Voskhod, Soyuz, flown un crewed as Zond/L1, L3, TKS, and the Salyut and Mir crewed space stations. Other American crewed spacecraft include the Gemini spacecraft, Apollo spacecraft, the Skylab space station, and the Space Shuttle with undetached European Spacelab and private US Spacehab space stations-modules. China developed, but did not fly Shuguang, and is currently using Shenzhou (its first crewed mission was in 2003

Except for the space shuttle, all of the recoverable crewed orbital spacecraft were space capsules.

The International Space Station, crewed since November 2000, is a joint venture between Russia, the United States, Canada and several other countries.

Space planes

Some reusable vehicles have been designed only for crewed spaceflight, and these are often called spaceplanes. The first example of such was the North American X-15 spaceplane, which conducted two crewed flights which reached an altitude of over 100 km in the 1960s. The first reusable spacecraft, the X-15, was air-launched on a suborbital trajectory on July 19, 1963.

The first partially reusable orbital spacecraft, a winged non-capsule, the Space Shuttle, was launched by the USA on the 20th anniversary of Yuri Gagarin's flight, on April 12, 1981. During the Shuttle era, six orbiters were built, all of which have flown in the atmosphere and five of which have flown in space. Enterprise was used only for approach and landing tests, launching from the back of a Boeing 747 SCA and gliding to deadstick landings at Edwards AFB, California. The first Space Shuttle to fly into space was Columbia, followed by Challenger, Discovery, Atlantis, and Endeavour. Endeavour was built to replace Challenger when it was lost in January 1986. Columbia broke up during reentry in February 2003.

The first automatic partially reusable spacecraft was the Buran-class shuttle, launched by the USSR on November 15, 1988, although it made only one flight and this was uncrewed. This spaceplane was designed for a crew and strongly resembled the U.S. Space Shuttle, although its drop-off boosters used liquid propellants and its main engines were located at the base of what would be the external tank in the American Shuttle. Lack of funding, complicated by the dissolution of the USSR, prevented any further flights of Buran. The Space Shuttle was subsequently modified to allow for autonomous re-entry in case of necessity.

Per the Vision for Space Exploration, the Space Shuttle was retired in 2011 due mainly to its old age and high cost of program reaching over a billion dollars per flight. The Shuttle's human transport role is to be replaced by SpaceX's Dragon V2 and Boeing's CST-100 Starliner no later than 2017. The Shuttle's heavy cargo transport role is to be replaced by expendable rockets such as the Space Launch System and SpaceX's Falcon Heavy.

Scaled Composites' SpaceShipOne was a reusable suborbital spaceplane that carried pilots Mike Melvill and Brian Binnie on consecutive flights in 2004 to win the Ansari X Prize. The Spaceship Company will build its successor SpaceShipTwo. A fleet of SpaceShipTwos operated by Virgin Galactic was planned to begin reusable private spaceflight carrying paying passengers in 2014, but was delayed after the crash of VSS Enterprise.

Subsystems

A spacecraft system comprises various subsystems, depending on the mission profile. Spacecraft subsystems comprise the spacecraft's "bus" and may include attitude determination and control (variously called ADAC, ADC, or ACS), guidance, navigation and control (GNC or GN&C), communications (comms), command and data handling (CDH or C&DH), power (EPS), thermal control (TCS), propulsion, and structures. Attached to the bus are typically payloads.

Life support

Spacecraft intended for human spaceflight must also include a life support system for the crew.

Attitude control

A Spacecraft needs an attitude control subsystem to be correctly oriented in space and respond to external torques and forces properly. The attitude control subsystem consists of sensors and actuators, together with controlling algorithms. The attitude-control subsystem permits proper pointing for the science objective, sun pointing for power to the solar arrays and earth pointing for communications.

GNC

Guidance refers to the calculation of the commands (usually done by the CDH subsystem) needed to steer the spacecraft where it is desired to be. Navigation means determining a spacecraft's orbital elements or position. Control means adjusting the path of the spacecraft to meet mission requirements.

Command and data handling

The CDH subsystem receives commands from the communications subsystem, performs validation and decoding of the commands, and distributes the commands to the appropriate spacecraft subsystems and components. The CDH also receives housekeeping data and science data from the other spacecraft subsystems and components, and packages the data for storage on a data recorder or transmission to the ground via the communications subsystem. Other functions of the CDH include maintaining the spacecraft clock and state-of-health monitoring.

Communications

Spacecraft, both robotic and crewed, utilize various communications systems for communication with terrestrial stations as well as for communication between spacecraft in space. Technologies utilized include RF and optical communication. In addition, some spacecraft payloads are explicitly for the purpose of ground–ground communication using receiver/retransmitter electronic technologies.

Power

Spacecraft need an electrical power generation and distribution subsystem for powering the various spacecraft subsystems. For spacecraft near the Sun, solar panels are frequently used to generate electrical power. Spacecraft designed to operate in more distant locations, for example Jupiter, might employ a radioisotope thermoelectric generator (RTG) to generate electrical power. Electrical power is sent through power conditioning equipment before it passes through a power distribution unit over an electrical bus to other spacecraft components. Batteries are typically connected to the bus via a battery charge regulator, and the batteries are used to provide electrical power during periods when primary power is not available, for example when a low Earth orbit spacecraft is eclipsed by Earth.

Thermal control

Spacecraft must be engineered to withstand transit through Earth's atmosphere and the space environment. They must operate in a vacuum with temperatures potentially ranging across hundreds of degrees Celsius as well as (if subject to reentry) in the presence of plasmas. Material requirements are such that either high melting temperature, low density materials such as beryllium and reinforced carbon–carbon or (possibly due to the lower thickness requirements despite its high density) tungsten or ablative carbon–carbon composites are used. Depending on mission profile, spacecraft may also need to operate on the surface of another planetary body. The thermal control subsystem can be passive, dependent on the selection of materials with specific radiative properties. Active thermal control makes use of electrical heaters and certain actuators such as louvers to control temperature ranges of equipments within specific ranges.

Spacecraft propulsion

Spacecraft may or may not have a propulsion subsystem, depending on whether or not the mission profile calls for propulsion. The Swift spacecraft is an example of a spacecraft that does not have a propulsion subsystem. Typically though, LEO spacecraft include a propulsion subsystem for altitude adjustments (drag make-up maneuvers) and inclination adjustment maneuvers. A propulsion system is also needed for spacecraft that perform momentum management maneuvers. Components of a conventional propulsion subsystem include fuel, tankage, valves, pipes, and thrusters. The thermal control system interfaces with the propulsion subsystem by monitoring the temperature of those components, and by preheating tanks and thrusters in preparation for a spacecraft maneuver.

Structures

Spacecraft must be engineered to withstand launch loads imparted by the launch vehicle, and must have a point of attachment for all the other subsystems. Depending on mission profile, the structural subsystem might need to withstand loads imparted by entry into the atmosphere of another planetary body, and landing on the surface of another planetary body.

Payload

The payload depends on the mission of the spacecraft, and is typically regarded as the part of the spacecraft "that pays the bills". Typical payloads could include scientific instruments (cameras, telescopes, or particle detectors, for example), cargo, or a human crew.

Ground segment

The ground segment, though not technically part of the spacecraft, is vital to the operation of the spacecraft. Typical components of a ground segment in use during normal operations include a mission operations facility where the flight operations team conducts the operations of the spacecraft, a data processing and storage facility, ground stations to radiate signals to and receive signals from the spacecraft, and a voice and data communications network to connect all mission elements

Launch vehicle

The launch vehicle propels the spacecraft from Earth's surface, through the atmosphere, and into an orbit, the exact orbit being dependent on the mission configuration. The launch vehicle may be expendable or reusable

More about Ground Segments

A ground segment consists of all the ground-based elements of a spacecraft system used by operators and support personnel, as opposed to the space segment and user segment.

The ground segment enables management of a spacecraft, and distribution of payload data and telemetry among interested parties on the ground. The primary elements of a ground segment include:

1. Ground (or Earth) stations, which provide radio interfaces with spacecraft
2. Mission (or flight) control (or operations) centers, from which spacecraft are managed
3. Ground networks, which connect the other ground elements to one another
4. Remote terminals, used by support personnel
5. Spacecraft integration and test facilities
6. Launch facilities

These elements are present in nearly all space missions, whether commercial, military, or scientific. They may be located together or separated geographically, and they may be operated by different parties. Some elements may support multiple spacecraft simultaneously

Ground stations

Ground stations provide radio interfaces between the space and ground segments for telemetry, tracking, and command (TT&C), as well as payload data transmission and reception. Tracking networks, such as NASA's Near Earth Network and Space Network, may handle communications with multiple spacecraft through time-sharing.

Ground station equipment may be monitored and controlled remotely, often via serial and/or IP interfaces. There are typically backup stations from which radio contact can be maintained if there is a problem at the primary ground station which renders it unable to operate, such as a natural disaster. Such contingencies are considered in a Continuity of Operations plan

Transmission and reception

Signals to be uplinked to a spacecraft must first be extracted from ground network packets, encoded to baseband, and modulated, typically onto an intermediate frequency (IF) carrier, before being up-converted to the assigned radio frequency (RF) band. The RF signal is then amplified to high power and carried via waveguide to an antenna for transmission. In colder climates, electric heaters or hot air blowers may be necessary to prevent ice or snow buildup on the parabolic dish.

Received ("downlinked") signals are passed through a low-noise amplifier (often located in the antenna hub to minimize the distance the signal must travel) before being down-converted to IF; these two functions may be combined in a low-noise block downconverter. The IF signal is then demodulated, and the data stream extracted via bit and frame synchronization and decoding. Data errors, such as those caused by signal degradation, are identified and corrected where possible. The decoded data stream is then packetized or saved to files for transmission on the ground network. Ground stations may temporarily store received telemetry for later playback to control centers.

A single spacecraft may make use of multiple RF bands for different telemetry, command, and payload data streams, depending on bandwidth and other requirements.

Passes

The timing of passes, when a line of sight exists to the spacecraft, is determined by the location of ground stations, and by the characteristics of the spacecraft orbit or trajectory. The Space Network uses geostationary relay satellites to extend pass opportunities over the horizon.

Tracking and ranging

Ground stations must track spacecraft in order to point their antennas properly, and must account for Doppler shifting of RF frequencies due to the motion of the spacecraft. Ground stations may also perform automated ranging; ranging tones may be multiplexed with command and telemetry signals. Ground station tracking and ranging data are passed to the control center along with spacecraft telemetry

Mission control centers

Mission control centers issue commands, data uploads, and software updates to spacecraft, and process, analyze, and distribute telemetry. For manned spacecraft, mission control manages voice and video communications with the crew. Control centers may also be responsible for configuration management and data archival. As with ground stations, there are typically backup control facilities available to support continuity of operations.

Telemetry processing

Control centers use telemetry to determine the status of a spacecraft and its systems. Housekeeping, diagnostic, science, and other types of telemetry may be carried on separate virtual channels. Flight control software performs the initial processing of received telemetry, including:

1. Separation and distribution of virtual channels
2. Time-ordering and gap-checking of received frames (gaps may be filled by commanding a re-transmission)
3. Decommutation of parameter values, and association of these values with mnemonics
4. Conversion of raw data to calibrated (engineering) values, and calculation of derived parameters
5. Limit and constraint checking (which may generate alert notifications)

A spacecraft database is called on to provide information on telemetry frame formatting, the positions and frequencies of parameters within frames, and their associated mnemonics, calibrations, and soft and hard limits. The contents of this database—especially calibrations and limits—

may be updated periodically to maintain consistency with flight software and operating procedures; these can change during the life of a mission in response to upgrades, hardware degradation in the space environment, and changes to mission parameters.

Commanding

Commands sent to spacecraft are formatted according to the spacecraft database, and are validated against the database before being transmitted via a ground station. Commands may be issued manually in real time, or they may be part of automated or semi-automated procedures. Typically, commands successfully received by the spacecraft are acknowledged in telemetry, and a command counter is maintained on the spacecraft and at the ground to ensure synchronization. In certain cases, closed-loop control may be performed. Commanded activities may pertain directly to mission objectives, or they may be part of housekeeping. Commands (and telemetry) may be encrypted to prevent unauthorized access to the spacecraft or its data.

Spacecraft procedures are often developed and tested against a spacecraft simulator prior to use with the actual spacecraft.

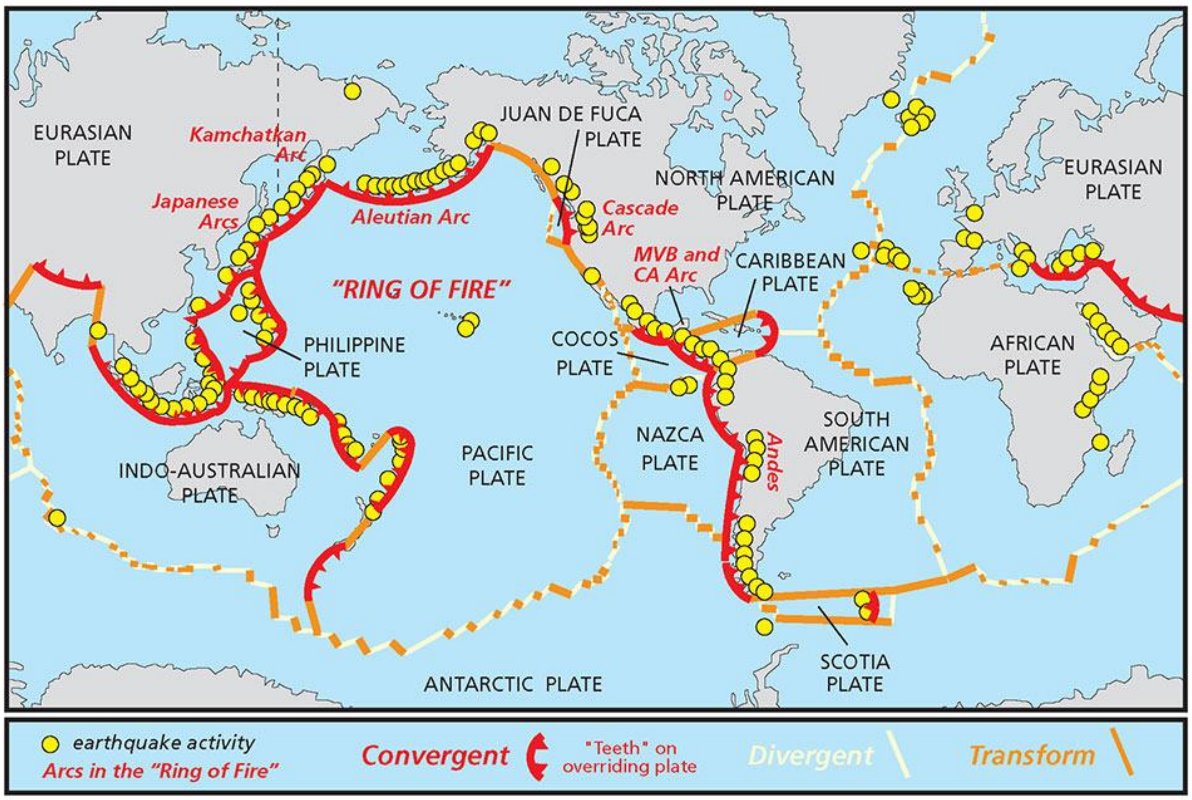
Staffing

Control centers may be continuously or regularly staffed by flight controllers. Staffing is typically greatest during the early phases of a mission, and during critical procedures and periods. Increasingly commonly, control centers for unmanned spacecraft may be set up for "lights-out" (or automated) operation, as a means of controlling costs. Flight control software will typically generate alerts regarding significant events – both planned and unplanned – in the ground or space segment that may require operator action.

Chapter 6
Under Sea

What is Tectonic Shift?

Tectonic shift is the movement of the plates that make up Earth's crust.
Map of tectonic plates from National Park Service; source:



http://www.nature.nps.gov/geology/education/education_graphics.cfm
(Modified by NPS from: R. J. Lillie. 2005. Parks and Plates.)
The Earth is made up of roughly a dozen major plates and several minor plates.

The Earth is in a constant state of change. Earth's crust, called the lithosphere, consists of 15 to 20 moving tectonic plates. The plates can be thought of like pieces of a cracked shell that rest on the hot, molten rock of Earth's mantle and fit snugly against one another. The heat from radioactive processes within the planet's interior causes the plates to move, sometimes toward and sometimes away from each other. This movement is called plate motion, or tectonic shift.

Our planet looks very different from the way it did 250 million years ago, when there was only one continent, called Pangaea, and one ocean, called Panthalassa. As Earth's mantle heated and cooled over many millennia, the outer crust broke up and commenced the plate motion that continues today.

The huge continent eventually broke apart, creating new and ever-changing land masses and oceans. Have you ever noticed how the east coast of South America looks like it would fit neatly into the west coast of Africa? That's because it did, millions of years before tectonic shift separated the two great continents.

Earth's land masses move toward and away from each other at an average rate of about 0.6 inch a year. That's about the rate that human toenails grow! Some regions, such as coastal California, move quite fast in geological terms — almost two inches a year — relative to the more stable interior of the continental United States. At the "seams" where tectonic plates come in contact, the crustal rocks may grind violently against each other, causing earthquakes and volcano eruptions. The relatively fast movement of the tectonic plates under California explains the frequent earthquakes that occur there.

What is geodesy?

Geodesy is the science of accurately measuring and understanding the Earth's geometric shape, orientation in space, and gravity field.
Geodesy is the science of accurately measuring and understanding three fundamental properties of the Earth: its geometric shape, its orientation in space, and its gravity field— as well as the changes of these properties with time. By using GPS, geodesists can monitor the movement of a site 24 hours a day, seven days a week.

Many organizations use geodesy to map the U.S. shoreline, determine land boundaries, and improve transportation and navigation safety. To measure points on the Earth's surface, geodesists assign coordinates (similar to a unique address) to points all over the Earth. In the past, geodesists determined the coordinates of points by using Earth-based surveying tools to measure the distances between points. Today, geodesists use space-based tools like the Global Positioning System (GPS) to measure points on the Earth's surface.

Geodesists must accurately define the coordinates of points on the surface of the Earth in a consistent manner. A set of accurately measured points is the basis for the National Spatial Reference System, which allows different kinds of maps to be consistent with one another.

To measure the Earth, geodesists build simple mathematical models of the Earth which capture the largest, most obvious features. Geodesists have adopted the ellipsoid as the most basic model of the Earth. Because the ellipsoid is based on a very simple mathematical model, it can be completely smooth and does not include any mountains or valleys. When additional detail of the Earth is needed, geodesists use the geoid. A geoid has a shape very similar to global mean sea level, but this exists over the whole globe, not just over the oceans.

What is the most common form of ocean litter?

Broken bottles, plastic toys, food wrappers ... during a walk along the coast one finds any of these items, and more. In all that litter, there is one item more common than any other: cigarette butts.

Cigarette butts are a pervasive, long-lasting, and a toxic form of marine debris. They primarily reach our waterways through improper disposal on beaches, rivers, and anywhere on land, transported to our coasts by runoff and stormwater. Once butts reach the beach, they may impact marine organisms and habitats.

Most cigarette filters are made out of cellulose acetate, a plastic-like material that's easy to manufacture, but not easy to degrade. The fibers in cigarette filters behave just like plastics in our oceans, the UV rays from our sun may break the fibers down into smaller pieces, but they don't disappear. One solid filter ends up being thousands of tiny microplastics

Did you know?

Cigarette butts continue to rank among the most common types of marine debris found. The Ocean Conservancy's 2018 International Coastal

Cleanup Report stated that 2,412,151 cigarette butts were collected worldwide in 2017. This is an increase from the 1,863,838 butts collected around the world in 2016.

What is the intertidal zone?

The intertidal zone is the area where the ocean meets the land between high and low tides.

Intertidal zones exist anywhere the ocean meets the land, from steep, rocky ledges to long, sloping sandy beaches and mudflats that can extend for hundreds of meters. Four physical divisions, each with distinct characteristics and ecological differences, divide the intertidal zone. They are the:

- **Spray zone:** dampened by ocean spray and high waves and is submerged only during very high tides or severe storms.
- **High intertidal zone:** floods during the peaks of daily high tides but remains dry for long stretches between high tides. It is inhabited by hardy sea life that can withstand pounding waves, such as barnacles, marine snails, mussels, limpets, shore crabs, and hermit crabs.
- **Middle intertidal zone:** over which the tides ebb and flow twice a day, and which is inhabited by a greater variety of both plants and animals, including sea stars and anemones.
- **Low intertidal zone:** virtually always underwater except during the lowest of spring tides. Life is more abundant there because of the protection provided by the water.

Sea creatures arrange themselves vertically in the intertidal zone depending on their abilities to compete for space, avoid predators from above and below, and resist drying out. Residents of the higher intertidal zones can either close themselves up in their shells to remain moist and ward off predators, or are mobile enough to retreat to a submerged zone when the tide goes out. In the lower parts of the intertidal zone, many plants and animals attach themselves in place and are very sturdy, very flexible, or otherwise well suited to stand up to wave energy.

Larger marine life, such as seals, sea lions, and fish, find foraging for food ideal at high tide in the intertidal zone, while a large variety of shorebirds, looking for their meals, stroll hungrily over the intertidal zone at low tide.

What is a lagoon?

A lagoon is a body of water separated from larger bodies of water by a natural barrier.

This NASA satellite image shows the lagoons and reefs of New Caledonia. This French-governed archipelago contains the world's third-largest coral reef structure.

Lagoons are separated from larger bodies of water by sandbars, barrier reefs, coral reefs, or other natural barriers. The word "lagoon" derives from the Italian word laguna, which means "pond" or "lake."

Although lagoons are well defined geographically, the word "lagoon" is sometimes used as a name for a larger region that contains one or more lagoons. For example, Laguna Madre on the Texas Gulf Coast is actually made up of smaller bays and lagoons, while Laguna Beach in Southern California is actually a beach and not a lagoon at all.

There are two types of lagoons: atoll and coastal. Atoll lagoons form when an island completely subsides beneath the water, leaving a ring of coral that continues to grow upwards. At the center of the ring is a body of water that is often deep. The combination of coral growth and water creates a lagoon. It may take as long as 300,000 years for an atoll formation to occur.

Coastal lagoons form along gently sloping coasts. They are generally shallower than atoll lagoons and tend to be separated from the ocean by an island, reef, or sand bank. Most of the time, coastal lagoons are connected to the ocean by an inlet.

Sea level rise, the amount of existing sediment, and tidal range all contribute to the formation of coastal lagoons. Younger and more dynamic than atoll lagoons, coastal lagoons may have shorter "lifespans" due to their exposed locations on the shore.

How do hurricanes affect sea life?

Hurricanes generate high waves, rough undercurrents, and shifting sands, all of which may harm sea life

When a storm churns across the ocean, the warm surface waters provide additional moisture and can fuel the storm into a hurricane. As the hurricane grows larger and more potent, it can generate waves as high as 18.3 meters, tossing and mixing warmer surface waters with the colder, saltier water below. The resulting currents can extend as far as 91.5 meters below the surface, wreaking deadly havoc on marine life.

If the wild currents fail to break up coral reefs in their path, the rain-infused water they bring reduces salt levels and otherwise stresses corals. As the hurricane moves toward shore, the underwater tumult can cause shifting sands and muddy shallow waters, blocking the essential sunlight on which corals and other sea creatures rely.

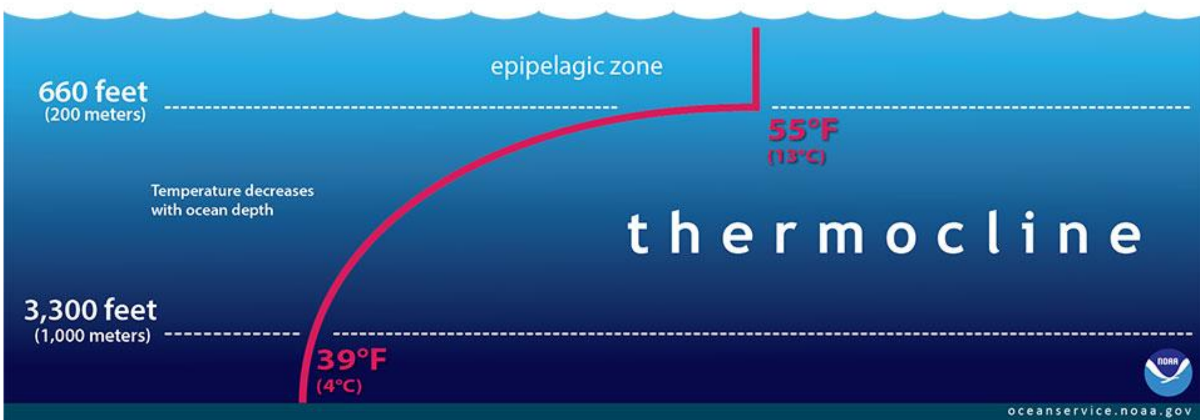
Slow-moving fish and turtles and shellfish beds are often decimated by the rough undercurrents and rapid changes in water temperature and salinity wrought by a hurricane. Sharks, whales, and other large animals swiftly move to calmer waters, however, and, generally speaking, are not overly affected by hurricanes.

Did you know?

Delicate branching corals, like staghorn and elkhorn species, are among the most vulnerable to breakage and can be reduced to rubble during hurricanes or even less severe storms. Sometimes, though, the breaking of coral into pieces may actually help a coral colony reproduce through a process called fragmentation. If conditions are favorable and the coral fragments come to rest where they can reattach to the seafloor, fragmentation can result in colonies flourishing in new locations. In other instances, corals that reproduce through broadcast spawning may get a little extra help from late summer storms, which help the coral larvae disburse to uncolonized areas.

What is a thermocline?

A thermocline is the transition layer between warmer mixed water at the ocean's surface and cooler deep water below.



The red line in this illustration shows a typical seawater temperature profile. In the thermocline, temperature decreases rapidly from the mixed upper layer of the ocean (called the epipelagic zone) to much colder deep water in the thermocline (mesopelagic zone). Below 3,300 feet to a depth of about 13,100 feet, water temperature remains constant. At depths below 13,100 feet, the temperature ranges from near freezing to just above the freezing point of water as depth increases.

Bodies of water are made up of layers, determined by temperature. The top surface layer is called the *epipelagic zone*, and is sometimes referred to as the "ocean skin" or "sunlight zone." This layer interacts with the wind and waves, which mixes the water and distributes the warmth. At the base of this layer is the thermocline. A thermocline is the transition layer between the warmer mixed water at the surface and the cooler deep water below. It is relatively easy to tell when you have reached the thermocline in a body of water because there is a sudden change in temperature. In the thermocline, the temperature decreases rapidly from the mixed layer temperature to the much colder deep water temperature.

In the ocean, the depth and strength of the thermocline vary from season to season and year to year. It is semi-permanent in the tropics, variable in temperate regions (often deepest during the summer), and shallow to nonexistent in the polar regions, where the water column is cold from the surface to the bottom.

Thermoclines also play a role in meteorological forecasting. For example, hurricane forecasters must consider not just the temperature of the ocean's skin (the sea surface temperature), but also the depth of warm water above the thermocline. Water vapor evaporated from the ocean is a hurricane's primary fuel. The depth of the thermocline is the measure of the size of the "fuel tank" and helps to predict the risk of hurricane formation.

What is a glass sponge?

The glass sponge is a deep-dwelling animal named for its intricate glass-like skeletal structure.

The most famous glass sponge is a species of *Euplectella,* shown here in the northwestern Gulf of Mexico. Commonly called the "Venus flower basket," this sponge builds its skeleton in a way that entraps a certain species of crustacean inside for life.

Glass sponges in the class *Hexactinellida* are animals commonly found in the deep ocean. Their tissues contain glass-like structural particles, called spicules, that are made of silica (hence their name). Some species of glass sponges produce extremely large spicules that fuse together in beautiful patterns to form a "glass house"—a complex skeleton that often remains intact even after the sponge itself dies. The skeleton of the glass sponge, together with various chemicals, provides defense against many predators.

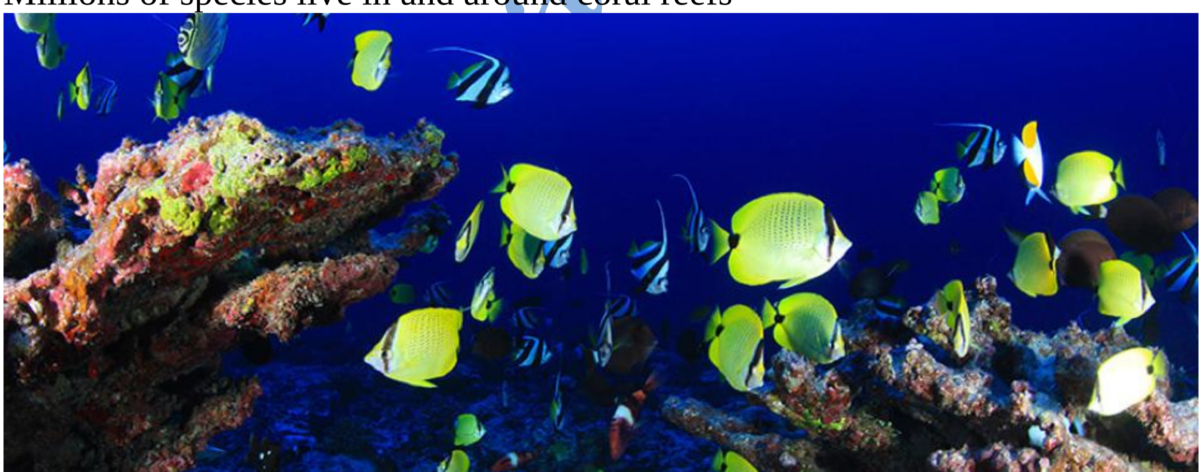
Nonetheless, some starfish are known to feed on these rare creatures of the deep.

Most glass sponges live attached to hard surfaces and consume small bacteria and plankton that they filter from the surrounding water. Their intricate skeletons provide many other animals with a home.

The most famous glass sponge is a species of *Euplectella*, known as the "Venus flower basket," which builds its skeleton in a way that entraps a certain species of crustacean inside for life. This sponge often houses two small, shrimp-like Stenopodidea, a male and a female, who live out their lives inside the sponge. The crustaceans breed, and when their offspring are tiny, they escape to find a new Venus flower basket of their own. The pair inside the basket clean it and, in return, the basket provides food for the crustaceans through its waste. The animals eventually grow too large to escape the sponge, so they are forced to "stay put" for the rest of their lives.

What species live in and around coral reefs?

Millions of species live in and around coral reefs



Coral reefs are home to millions of species.

Hidden beneath the ocean waters, coral reefs teem with life. Fish, corals, lobsters, clams, seahorses, sponges, and sea turtles are only a few of the thousands of creatures that rely on reefs for their survival.

Coral reefs are also living museums and reflect thousands of years of history. Many U.S. coral reefs were alive and thriving centuries before the European colonization of the nearby shores. Some reefs are even older than our old-growth redwood forests. They are an integral part of many cultures and our natural heritage.

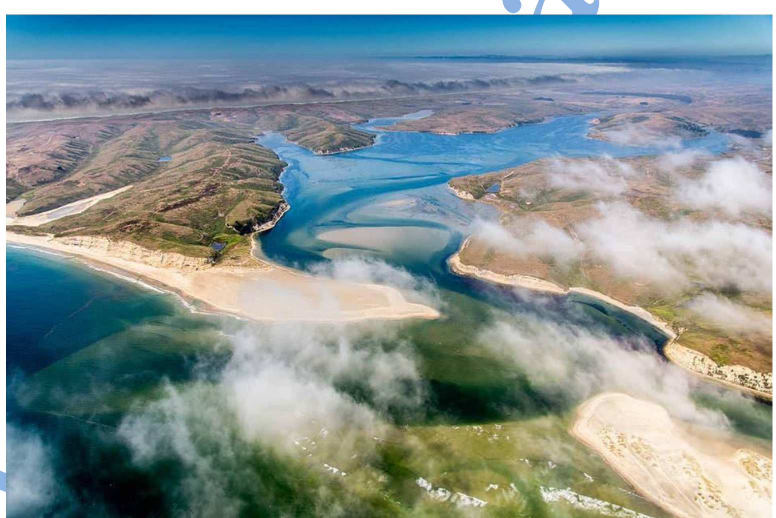
Today, these important habitats are threatened by a range of human activities. Many of the world's reefs have already been destroyed or severely damaged by water pollution, overfishing and destructive fishing practices, disease, global climate change, and ship groundings. However, we can still protect and preserve our remaining reefs by acting now

Did you know?

Glass sponge reefs were thought to have gone extinct about 40 million years ago, leaving behind giant fossil cliffs that stretch across parts of Spain, France, Germany, and Romania. In 1987, however, a team of Canadian scientists discovered 9,000-year-old living glass sponge reefs on British Columbia's northern coast. To date, these are the only such reefs known to exist.

What is a watershed?

It's a land area that channels rainfall and snowmelt to creeks, streams, and rivers, and eventually to outflow points such as reservoirs, bays, and the ocean.



While some watersheds are relatively small, others encompass thousands of square miles and may contain streams, rivers, lakes, reservoirs, and underlying groundwater that are hundreds of miles inland. Shown here: an aerial view of Drakes Bay, part of California's Tomales-Drake watershed. The size of a watershed (also called a drainage basin or catchment) is defined on several scales—referred to as its Hydrologic Unit Codes (HUC)—based on the geography that is most relevant to its specific area. A watershed can be small, such as a modest inland lake or a single county.

Conversely, some watersheds encompass thousands of square miles and may contain streams, rivers, lakes, reservoirs, and underlying groundwater that are hundreds of miles inland. The largest watershed in the United States is the Mississippi River Watershed, which drains 1.15 million square miles from all or parts of 31 U.S. states and two Canadian provinces stretching from the Rockies to the Appalachians!

Water from hundreds, and often thousands, of creeks and streams flow from higher ground to rivers that eventually wind up in a larger waterbody. As the water flows, it often picks up pollutants, which may have sinister effects on the ecology of the watershed and, ultimately, on the reservoir, bay, or ocean where it ends up.

Not all water flows directly to the sea, however. When rain falls on dry ground, it can soak into, or infiltrate, the ground. This groundwater remains in the soil, where it will eventually seep into the nearest stream. Some water infiltrates much deeper, into underground reservoirs called aquifers. In other areas, where the soil contains a lot of hard clay, very little water may infiltrate. Instead, it quickly runs off to lower ground.

Rain and snowmelt from watersheds travel via many routes to the sea. During periods of heavy rain and snowfall, water may run onto and off of impervious surfaces such as parking lots, roads, buildings, and other structures because it has nowhere else to go. These surfaces act as "fast lanes" that transport the water directly into storm drains. The excess water volume can quickly overwhelm streams and rivers, causing them to overflow and possibly result in floods.

What is eutrophication?

Harmful algal blooms, dead zones, and fish kills are the results of a process called eutrophication—which begins with the increased load of nutrients to estuaries and coastal waters.

Eutrophication is a big word that describes a big problem in the nation's estuaries. Harmful algal blooms, dead zones, and fish kills are the results of a process called eutrophication—which begins with the increased load of nutrients to estuaries and coastal waters.

Sixty-five percent of U.S. estuaries and coastal water bodies are moderately to severely degraded by excessive nutrient inputs, which lead to algal blooms and low-oxygen (hypoxic) waters that can kill fish and seagrass and reduce essential fish habitats. Many of these estuaries also support bivalve mollusk populations (e.g., oysters, clams, scallops), which naturally reduce nutrients through their filter-feeding activities.

The primary culprits in eutrophication appear to be excess nitrogen and phosphorus—from sources including fertilizer runoff and septic system effluent to atmospheric fallout from burning fossil fuels—which enter waterbodies and fuel the overgrowth of algae, which, in turn, reduces water quality and degrades estuarine and coastal ecosystems.

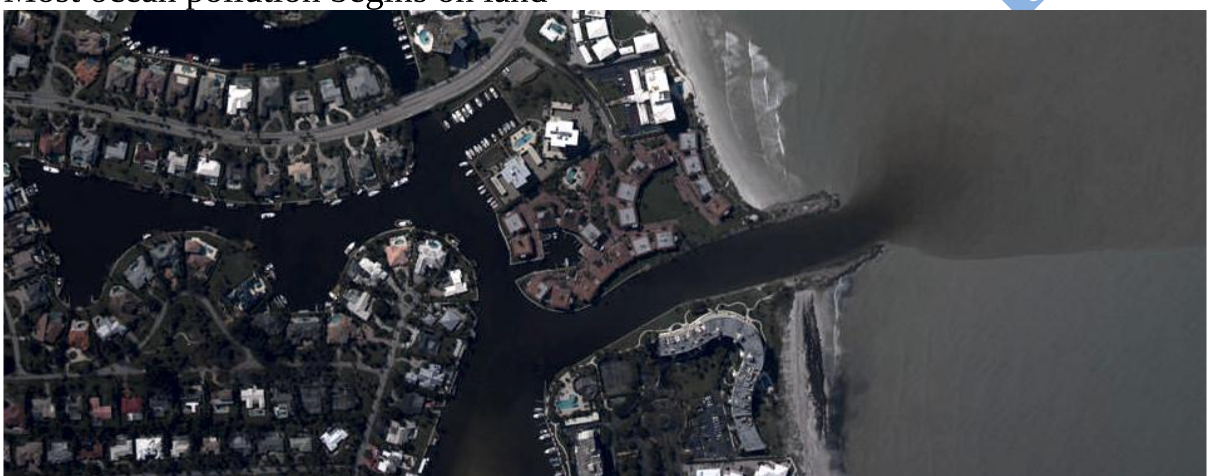
Eutrophication can also produce carbon dioxide, which lowers the PH of seawater (ocean acidification). This slows the growth of fish and shellfish, may prevent shell formation in bivalve mollusks, and reduces the catch of commercial and recreational fisheries, leading to smaller harvests and more expensive seafood.
In recent years, NOAA's National Centers for Coastal Ocean Science (NCCOS), in collaboration with NOAA's Northeast Fisheries Science Center, has enlisted estuaries' indigenous residents, namely, bivalve mollusks, to help slow and, in some cases, reverse the process of eutrophication, since they efficiently remove nutrients from the water as they feed on phytoplankton and detritus.

A groundbreakingmodeling project in Long Island Sound showed that the oyster aquaculture industry in Connecticut provides $8.5 – $23 million annually in nutrient reduction benefits. The project also showed that reasonable expansion of oyster aquaculture could provide as much nutrient reduction as the comparable investment of $470 million in traditional nutrient-reduction measures, such as wastewater treatment improvements and agricultural best management practices.

The NOAA scientists used aquaculture modeling tools to demonstrate that shellfish aquaculture compares favorably to existing nutrient management strategies in terms of efficiency of nutrient removal and implementation cost. Documenting the water quality benefits provided by shellfish aquaculture has increased both communities' and regulators' acceptance of shellfish farming, not only in Connecticut but across the nation. In Chesapeake Bay, for example, nutrient removal policies include the harvesting of oyster tissue as an approved method, and in Mashpee Bay, Massachusetts, cultivation and harvest of oysters and clams are part of the official nutrient management plan.

What is the biggest source of pollution in the ocean?

Most ocean pollution begins on land



When large tracts of land are plowed, the exposed soil can erode during rainstorms. Much of this runoff flows to the sea, carrying with it agricultural fertilizers and pesticides.

Eighty percent of pollution to the marine environment comes from the land. One of the biggest sources is called nonpoint source pollution, which occurs as a result of runoff. Nonpoint source pollution includes many small sources, like septic tanks, cars, trucks, and boats, plus larger sources, such as farms, ranches, and forest areas. Millions of motor vehicle engines drop small amounts of oil each day onto roads and parking lots. Much of this, too, makes its way to the sea.

Some water pollution actually starts as air pollution, which settles into waterways and oceans. Dirt can be a pollutant. Top soil or silt from fields or construction sites can run off into waterways, harming fish and wildlife habitats.

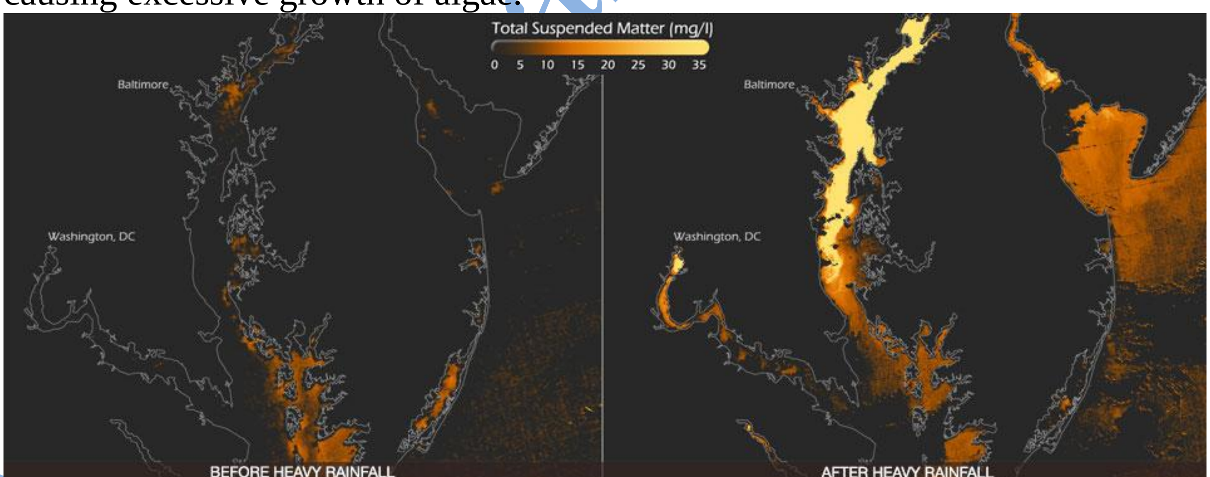
Nonpoint source pollution can make river and ocean water unsafe for humans and wildlife. In some areas, this pollution is so bad that it causes beaches to be closed after rainstorms.

More than one-third of the shellfish-growing waters of the United States are adversely affected by coastal pollution.

Correcting the harmful effects of nonpoint source pollution is costly. Each year, millions of dollars are spent to restore and protect areas damaged or endangered by nonpoint source pollutants. NOAA works with the U.S. Environmental Protection Agency, Department of Agriculture, and other federal and state agencies to develop ways to control nonpoint source pollution. These agencies work together to monitor, assess, and limit nonpoint source pollution that may result naturally and by human actions.

What is nutrient pollution?

Nutrient pollution is the process where too many nutrients, mainly nitrogen and phosphorus, are added to bodies of water and can act like fertilizer, causing excessive growth of algae.



Nutrients can run off of land in urban areas where lawn fertilizers are used. Pet and wildlife wastes are also sources of nutrients. To see how this happens, consider this visualization of the Chesapeake Bay, part of the largest watershed in the Northeast. This illustration shows the amount of suspended matter (e.g., silt, mud, debris) in waterways **before** (left) and **after** (right) areas in this region received exceptionally heavy rainfall in 2011. All of this rain and runoff eventually made its way into the Chesapeake Bay.

This process is also known as eutrophication. Excessive amounts of nutrients can lead to more serious problems such as low levels of oxygen dissolved in the water. Severe algal growth blocks light that is needed for plants, such as seagrasses, to grow. When the algae and seagrass die, they decay. In the process of decay, the oxygen in the water is used up and this leads to low levels of dissolved oxygen in the water. This, in turn, can kill fish, crabs, oysters, and other aquatic animals.

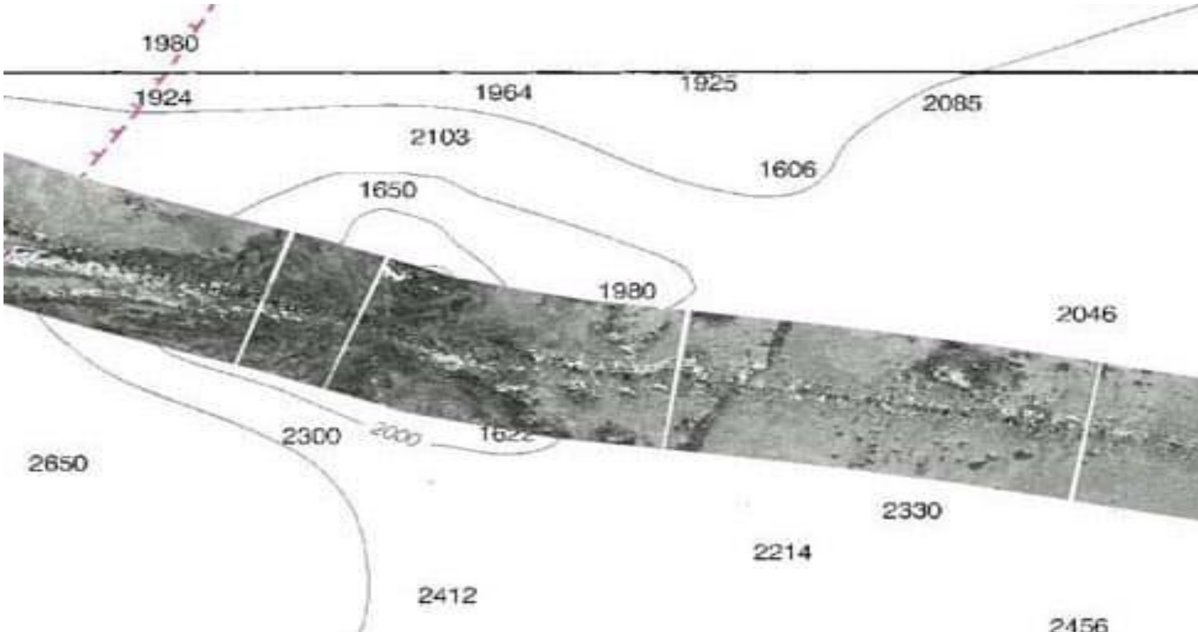
Nutrients come from a variety of different sources. They can occur naturally as a result of weathering of rocks and soil in the watershed and they can also come from the ocean due to mixing of water currents. Scientists are most interested in the nutrients that are related to people living in the coastal zone because human-related inputs are much greater than natural inputs. Because there are increasingly more people living in coastal areas, there are more nutrients entering our coastal waters from wastewater treatment facilities, runoff from land in urban areas during rains, and from farming.

All of these factors can lead to increased nutrient pollution.

How does backscatter help us understand the sea floor?

Intensity of sound reflected off the sea floor indicates the bottom type.

Backscatter is the reflection of a signal (such as sound waves or light) back in the direction from where it originated. Backscatter is commonly used in medical ultrasounds to understand characteristics of the human body, but in the world of hydrography and marine science, backscatter from soundwaves helps us understand characteristics of the sea floor.



<u>A backscatter mosaic, which records the strength of the sonar return from the ocean floor, is overlaid on a nautical chart.</u>

NOAA ships equipped with multibeam echo sounders use beams of sound to map the ocean floor. These sonar systems collect two types of 3D data: sea floor depth and backscatter. The sea floor depth, or bathymetry, is computed by measuring the time it takes for the sound to leave the sonar, hit the sea floor, and return to the sonar. Backscatter is computed by measuring the amount of sound that is reflected by the sea floor and received by the sonar.

Different bottom types “scatter” sound energy differently, telling scientists about their relative hardness and roughness. Harder bottom types (like rock) reflect more sound than softer bottom types (like mud), and smoother bottom types (like pavement) reflect more sound than bumpier bottom types (like coral reef).

Combining bathymetry and backscatter data collected by multibeam echo sounders allows scientists to create very detailed 3D maps of the sea floor and the habitats present there. The information is used for multiple purposes, including marine ecosystem protection, coastal hazard preparedness, and navigation safety.

Backscatter—measure of sound that is reflected by the sea floor and received by the sonar. A stronger return signal indicates a hard bottom such as coral or rocks. A weaker return signal indicates a soft bottom such as mud. Scientists use this information to create detailed 3D maps of the sea floor and the habitats present on the bottom of the ocean with the goal of improving navigation safety and marine ecosystem protection.

Did you know?

A 3D map of the ocean floor can tell scientists and resource managers important details, such as the distribution and health of a coral reef ecosystem or which areas certain species of fish prefer for spawning. This helps us better conserve and protect our ocean and all the creatures that live there.

What is a ghost forest?

A ghost forest is the watery remains of a once verdant woodland.

A ghost forest on Capers Island, South Carolina.

As sea level rises, more and more saltwater encroaches on the land. Along the world's coasts and estuaries, invading seawater advances and overtakes the fresh water that deciduous trees rely upon for sustenance. The salty water slowly poisons living trees, leaving a haunted ghost forest of dead and dying timber. Still standing in or near brackish water, the decaying trees of a ghost forest resemble giant graying pillars that protrude into the air.

Researchers report that the rapid increase in ghost forests represents a dramatic visual picture of environmental changes along coastal plains located at or near sea level. In many areas, rising sea levels combine with land sinking from the last ice age, as is currently happening in the Chesapeake Bay watershed.

The Mississippi Delta region of Louisiana is undergoing changes due to rising waters, the sinking of Earth's crust, and sediments compacting along the Mississippi River. With land and water constantly shifting, woodlands die and are buried in open water. This is apparent along North Carolina's maritime forests, where only a glimpse of once peaceful and verdant groves, now ghost forests, remain.

What is a maritime forest?

Maritime forests protect our shorelines from ongoing movement of the coast.

These stumps are evidence that trees once grew here, but due to a constantly changing shoreline, they are now mostly submerged in the ocean.

Maritime forests are shoreline estuaries that grow along coastal barrier islands that support a great diversity of plants and animals. Many maritime forests in the United States remain largely untouched by commercial development and closely resemble the woodlands where Native Americans lived and early colonists settled hundreds of years ago. Trees, bushes, and other plants in maritime forests and estuaries withstand strong winds, periodic flooding, and salt spray. Many species of mammals and reptiles make the forests their home, and thousands of birds migrate to maritime forests each year.

Currituck Banks Reserve, on North Carolina's Outer Banks, is a maritime forest.

A good example of a maritime forest is the Currituck Banks Reserve, located on the Outer Banks of North Carolina. The western, ocean side of Currituck consists of sand dunes of beach grass and sea oats, which front a tightly woven canopy of shrub-like thickets of wax myrtle, holly, and stunted oaks. The canopy acts as a windscreen to protect the forest's less tolerant interior trees, often consisting of American holly, beach olive, ironwood, loblolly pine, red maple, and live oak. On the other side of the barrier island's maritime forest lies the estuary of Currituck Sound, where fresh water meets the ocean's salt water. This shallow intertidal area is home to the estuary's abundant flora and fauna.

Like all barrier islands, maritime forests are constantly changing and on the move. On Currituck, for example, one can see stumps of deciduous trees along the sandy beach. These trees were once in the center of the island, but due to the constantly changing shoreline, they are now mostly submerged in the ocean. Maritime forests, like all estuaries, are essential for storm protection. They also conserve important nutrients and groundwater.

How does sand form?

Sand is the end product of many things, including decomposed rocks, organic by-products, and even parrotfish poop**.**

The giant bumphead parrotfish is an amazing fish that can live to be 40 years old, growing up to four feet long and 100 pounds. They use their large head bumps to literally bump heads during competitive displays, when large numbers of fish aggregate to spawn on a lunar cycle. The bumphead parrotfish excretes white sand, which it may produce at the rate of several hundred pounds a year!

The environmentalist Rachel Carson wrote, "In every curving beach, in every grain of sand, there is a story of the Earth."

Sand comes from many locations, sources, and environments. Sand forms when rocks break down from weathering and eroding over thousands and even millions of years. Rocks take time to decompose, especially quartz (silica) and feldspar.

Often starting thousands of miles from the ocean, rocks slowly travel down rivers and streams, constantly breaking down along the way. Once they make it to the ocean, they further erode from the constant action of waves and tides.

The tan color of most sand beaches is the result of iron oxide, which tints quartz a light brown, and feldspar, which is brown to tan in its original form. Black sand comes from eroded volcanic material such as lava, basalt rocks, and other dark-colored rocks and minerals, and is typically found on beaches near volcanic activity. Black-sand beaches are common in Hawaii, the Canary Islands, and the Aleutians.

The by-products of living things also play an important part in creating sandy beaches. Bermuda's preponderance of pleasantly pink beaches results from the perpetual decay of single-celled, shelled organisms called foraminifera.

Less common but no less inviting beaches, devoid of quartz as a source of sand, rely on an entirely different ecologic process. The famous white-sand beaches of Hawaii, for example, actually come from the poop of parrotfish. The fish bite and scrape algae off of rocks and dead corals with their parrot-like beaks, grind up the inedible calcium-carbonate reef material (made mostly of coral skeletons) in their guts, and then excrete it as sand. At the same time that it helps to maintain a diverse coral-reef ecosystem, parrotfish can produce hundreds of pounds of white sand each year!

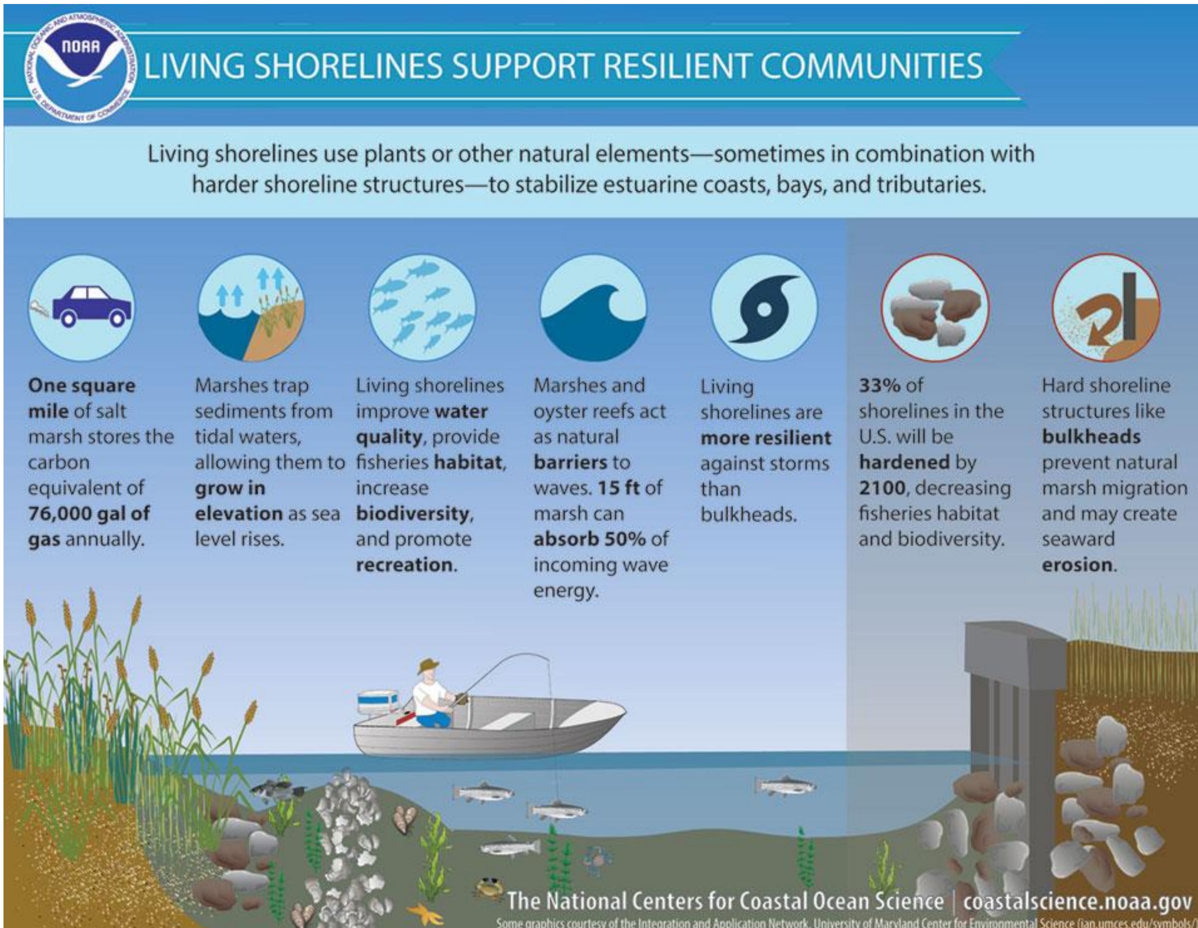
So the next time you unfurl your beach towel down by the shore, ponder the sand beneath you, which, as Rachel Carson said, is telling you a story about the Earth. You may be about to comfortably nestle down in the remains of million-year-old rocks. Then again, you may soon come to rest upon an endless heap of parrotfish poop.

Did you know?

Sand is measured according to specific parameters. If more than 50 percent of the material is larger in diameter than 75 microns (.03 inches) but smaller than .18 inches, it is said to be sand. If the average particle size is smaller, it is considered to be silt or clay, and if the average particle size is larger, it is garden-variety gravel.

What is a living shoreline?

A protected and stabilized shoreline that is made of natural materials **such as plants, sand, or rock.**



Living shorelines use plants or other natural elements to stabilize estuarine coasts, bays, or tributaries.

Living shorelines are a green infrastructure technique using native vegetation alone or in combination with offshore sills to stabilize the shoreline. Living shorelines provide a natural alternative to 'hard' shoreline stabilization methods like stone sills or bulkheads, and provide numerous benefits including nutrient pollution remediation, essential fish habitat provision, and buffering of shoreline from waves and storms.

Living shorelines are known to store carbon (known as carbon sequestration), which keeps carbon out of the atmosphere. Continued use of this approach to coastal resilience will result in increased carbon sequestration and storage, potentially mitigating the effects of climate change.

Living Shorelines Support Resilient Communities

Living shorelines use plants or other natural elements—sometimes in combination with harder shoreline structures—to stabilize estuarine coasts, bays, and tributaries.

- One square mile of salt marsh stores the carbon equivalent of 76,000 gal of gas annually.
- Marshes trap sediments from tidal waters, allowing them to grow in elevation as sea level rises.
- Living shorelines improve water quality, provide fisheries habitat, increase biodiversity, and promote recreation.
- Marshes and oyster reefs act as natural barriers to waves. 15 ft of marsh can absorb 50% of incoming wave energy.
- Living shorelines are more resilient against storms than bulkheads.
- 33% of shorelines in the U.S. will be hardened by 2100, decreasing fisheries habitat and biodiversity.
- Hard shoreline structures like bulkheads prevent natural marsh migration and may create seaward erosion.

Chapter 7
Evolution

Evolution is change in the heritable characteristics of biological populations over successive generations. These characteristics are the expressions of genes that are passed on from parent to offspring during reproduction. Different characteristics tend to exist within any given population as a result of mutation, genetic recombination and other sources of genetic variation. Evolution occurs when evolutionary processes such as natural selection (including sexual selection) and genetic drift act on this variation, resulting in certain characteristics becoming more common or rare within a population. It is this process of evolution that has given rise to biodiversity at every level of biological organisation, including the levels of species, individual organisms and molecules.

The scientific theory of evolution by natural selection was proposed by Charles Darwin and Alfred Russel Wallace in the mid-19th century and was set out in detail in Darwin's book *On the Origin of Species* (1859). Evolution by natural selection was first demonstrated by the observation that more offspring are often produced than can possibly survive. This is followed by three observable facts about living organisms: 1) traits vary among individuals with respect to their morphology, physiology and behaviour (phenotypic variation), 2) different traits confer different rates of survival and reproduction (differential fitness) and 3) traits can be passed from generation to generation (heritability of fitness). Thus, in successive generations members of a population are more likely to be replaced by the progenies of parents with favourable characteristics that have enabled them to survive and reproduce in their respective environments. In the early 20th century, other competing ideas of evolution such as mutationism and orthogenesis were refuted as the modern synthesis reconciled Darwinian evolution with classical genetics, which established adaptive evolution as being caused by natural selection acting on Mendelian genetic variation.

All life on Earth shares a last universal common ancestor (LUCA) that lived approximately 3.5–3.8 billion years ago. The fossil record includes a progression from early biogenic graphite, to microbial mat fossils, to fossilised multicellular organisms. Existing patterns of biodiversity have been shaped by repeated formations of new species (speciation), changes within species (anagenesis) and loss of species (extinction) throughout the evolutionary history of life on Earth. Morphological and biochemical traits are more similar among species that share a more recent common ancestor, and can be used to reconstruct phylogenetic trees.

Evolutionary biologists have continued to study various aspects of evolution by forming and testing hypotheses as well as constructing theories based on evidence from the field or laboratory and on data generated by the methods of mathematical and theoretical biology. Their discoveries have influenced not just the development of biology but numerous other scientific and industrial fields, including agriculture, medicine and computer science.

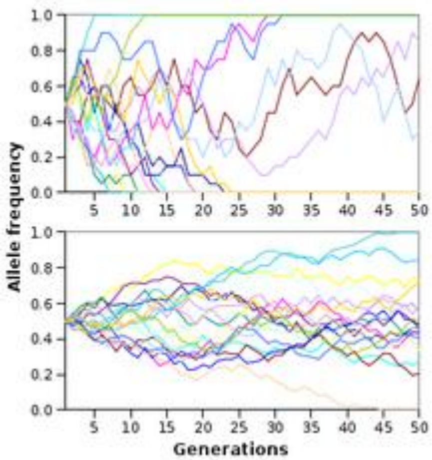
Biased mutation

In addition to being a major source of variation, mutation may also function as a mechanism of evolution when there are different probabilities at the molecular level for different mutations to occur, a process known as mutation bias. If two genotypes, for example one with the nucleotide G and another with the nucleotide A in the same position, have the same fitness, but mutation from G to

A happens more often than mutation from A to G, then genotypes with A will tend to evolve. Different insertion vs. deletion mutation biases in different taxa can lead to the evolution of different genome sizes. Developmental or mutational biases have also been observed in morphological evolution. For example, according to the phenotype-first theory of evolution, mutations can eventually cause the genetic assimilation of traits that were previously induced by the environment.

Mutation bias effects are superimposed on other processes. If selection would favour either one out of two mutations, but there is no extra advantage to having both, then the mutation that occurs the most frequently is the one that is most likely to become fixed in a population. Mutations leading to the loss of function of a gene are much more common than mutations that produce a new, fully functional gene. Most loss of function mutations are selected against. But when selection is weak, mutation bias towards loss of function can affect evolution. For example, pigments are no longer useful when animals live in the darkness of caves, and tend to be lost. This kind of loss of function can occur because of mutation bias, and/or because the function had a cost, and once the benefit of the function disappeared, natural selection leads to the loss. Loss of sporulation ability in *Bacillus subtilis* during laboratory evolution appears to have been caused by mutation bias, rather than natural selection against the cost of maintaining sporulation ability. When there is no selection for loss of function, the speed at which loss evolves depends more on the mutation rate than it does on the effective population size, indicating that it is driven more by mutation bias than by genetic drift. In parasitic organisms, mutation bias leads to selection pressures as seen in *Ehrlichia*. Mutations are biased towards antigenic variants in outer-membrane proteins.

Genetic drift



Simulation of genetic drift of 20 unlinked alleles in populations of 10 (top) and 100 (bottom). Drift to fixationis more rapid in the smaller population.

Genetic drift is the random fluctuations of allele frequencies within a population from one generation to the next. When selective forces are absent or relatively weak, allele frequencies are equally likely to *drift* upward or downward at each successive generation because the alleles are subject to sampling error. This drift halts when an allele eventually becomes fixed, either by disappearing from the population or replacing the other alleles entirely. Genetic drift may therefore eliminate some alleles from a population due to chance alone. Even in the absence of selective forces, genetic drift can cause two separate populations that began with the same genetic structure to drift apart into two divergent populations with different sets of alleles

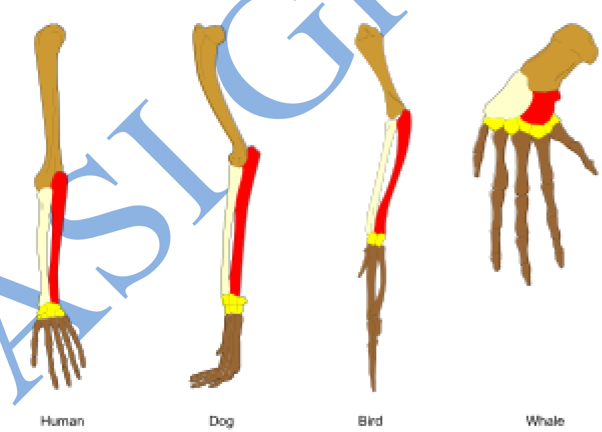
The neutral theory of molecular evolution proposed that most evolutionary changes are the result of the fixation of neutral mutations by genetic drift. Hence, in this model, most genetic changes in a population are the result of constant mutation pressure and genetic drift. This form of the neutral theory is now largely abandoned, since it does not seem to fit the genetic variation seen in nature. However, a more recent and better-supported version of this model is the nearly neutral theory, where a mutation that would be effectively neutral in a small population is not necessarily neutral in a large population. Other alternative theories propose that genetic drift is dwarfed by other stochastic forces in evolution, such as genetic hitchhiking, also known as genetic draft.

The time for a neutral allele to become fixed by genetic drift depends on population size, with fixation occurring more rapidly in smaller populations. The number of individuals in a population is not critical, but instead a measure known as the effective population size. The effective population is usually smaller than the total population since it takes into account factors such as the level of inbreeding and the stage of the lifecycle in which the population is the smallest. The effective population size may not be the same for every gene in the same population.

It is usually difficult to measure the relative importance of selection and neutral processes, including drift. The comparative importance of adaptive and non-adaptive forces in driving evolutionary change is an area of current research.

Adaptation

Homologous bones in the limbs of tetrapods. The bones of these animals have the same basic structure, but have been adapted for specific uses.

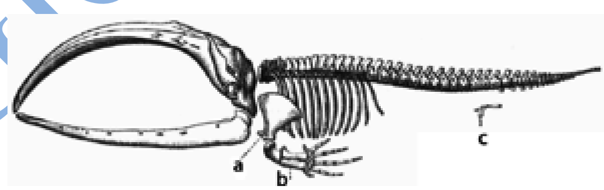


Adaptation is the process that makes organisms better suited to their habitat. Also, the term adaptation may refer to a trait that is important for an organism's survival. For example, the adaptation of horses' teeth to the grinding of grass. By using the term *adaptation* for the evolutionary process and *adaptive trait* for the product (the bodily part or function), the two senses of the word may be distinguished. Adaptations are produced by natural selection.

The following definitions are due to Theodosius Dobzhansky:

1. *Adaptation* is the evolutionary process whereby an organism becomes better able to live in its habitat or habitats.
2. *Adaptedness* is the state of being adapted: the degree to which an organism is able to live and reproduce in a given set of habitats.
3. An *adaptive trait* is an aspect of the developmental pattern of the organism which enables or enhances the probability of that organism surviving and reproducing.

Adaptation may cause either the gain of a new feature, or the loss of an ancestral feature. An example that shows both types of change is bacterial adaptation to antibiotic selection, with genetic changes causing antibiotic resistance by both modifying the target of the drug, or increasing the activity of transporters that pump the drug out of the cell. Other striking examples are the bacteria *Escherichia coli* evolving the ability to use citric acid as a nutrient in a long-term laboratory experiment, *Flavobacterium* evolving a novel enzyme that allows these bacteria to grow on the by-products of nylon manufacturing, and the soil bacterium *Sphingobium* evolving an entirely new metabolic pathway that degrades the synthetic pesticide pentachlorophenol. An interesting but still controversial idea is that some adaptations might increase the ability of organisms to generate genetic diversity and adapt by natural selection (increasing organisms' evolvability).



A baleen whale skeleton, *a* and *b* label flipper bones, which were adapted from front leg bones: while *c* indicates vestigial leg bones, suggesting an adaptation from land to sea.

Adaptation occurs through the gradual modification of existing structures. Consequently, structures with similar internal organisation may have different functions in related organisms. This is the result of a single ancestral structure being adapted to function in different ways. The bones within bat wings, for example, are very similar to those in mice feet and primate hands, due to the descent of all these structures from a common mammalian ancestor. However, since all living organisms are related to some extent, even organs that appear to have little or no structural similarity, such as arthropod, squid and vertebrate eyes, or the limbs and wings of arthropods and vertebrates, can depend on a common set of homologous genes that control their assembly and function; this is called deep homology.

During evolution, some structures may lose their original function and become vestigial structures. Such structures may have little or no function in a current species, yet have a clear function in ancestral species, or other closely related species. Examples include pseudogenes, the non-functional remains of eyes in blind cave-dwelling fish, wings in flightless birds, the presence of hip bones in whales and snakes, and sexual traits in organisms that reproduce via asexual reproduction. Examples of vestigial structures in humans include wisdom teeth, the coccyx, the vermiform appendix, and other behavioural vestiges such as goose bumps and primitive reflexe

However, many traits that appear to be simple adaptations are in fact exaptations: structures originally adapted for one function, but which coincidentally became somewhat useful for some other function in the process. One example is the African lizard *Holaspisguentheri*, which developed an extremely flat head for hiding in crevices, as can be seen by looking at its near relatives. However, in this species, the head has become so flattened that it assists in gliding from tree to tree—an exaptation.Within cells, molecular machines such as the bacterial flagella and protein sorting machinery evolved by the recruitment of several pre-existing proteins that previously had different functions. Another example is the recruitment of enzymes from glycolysis and xenobiotic metabolism to serve as structural proteins called crystallins within the lenses of organisms' eyes.

An area of current investigation in evolutionary developmental biology is the developmental basis of adaptations and exaptations. This research addresses the origin and evolution of embryonic development and how modifications of development and developmental processes produce novel features. These studies have shown that evolution can alter development to produce new structures, such as embryonic bone structures that develop into the jaw in other animals instead forming part of the middle ear in mammals.It is also possible for structures that have been lost in evolution to reappear due to changes in developmental genes, such as a mutation in chickens causing embryos to grow teeth similar to those of crocodiles. It is now becoming clear that most alterations in the form of organisms are due to changes in a small set of conserved genes.

Role of extinction

Extinction is the disappearance of an entire species. Extinction is not an unusual event, as species regularly appear through speciation and disappear through extinction. Nearly all animal and plant species that have lived on Earth are now extinct,and extinction appears to be the ultimate fate of all species. These extinctions have happened continuously throughout the history of life, although the rate of extinction spikes in occasional mass extinction events.

The Cretaceous–Paleogene extinction event, during which the non-avian dinosaurs became extinct, is the most well-known, but the earlier Permian–Triassic extinction event was even more severe, with approximately 96% of all marine species driven to extinction. The Holocene extinction event is an ongoing mass extinction associated with humanity's expansion across the globe over the past few thousand years.

Present-day extinction rates are 100–1000 times greater than the background rate and up to 30% of current species may be extinct by the mid 21st century. Human activities are now the Despite the estimated extinction of more than 99 percent of all species that ever lived on Earth, about 1 trillion species are estimated to be on Earth currently with only one-thousandth of one percent described.

The role of extinction in evolution is not very well understood and may depend on which type of extinction is considered. The causes of the continuous "low-level" extinction events, which form the majority of extinctions, may be the result of competition between species for limited resources (the competitive exclusion principle). If one species can out-compete another, this could produce species selection, with the fitter species surviving and the other species being driven to extinction. The intermittent mass extinctions are also important, but instead of acting as a selective force, they drastically reduce diversity in a nonspecific manner and promote bursts of rapid evolution and speciation in survivors.

Origin of life

The Earth is about 4.54 billion years old. The earliest undisputed evidence of life on Earth dates from at least 3.5 billion years ago, during the Eoarchean Era after a geological crust started to solidify following the earlier molten Hadean Eon. Microbial mat fossils have been found in 3.48 billion-year-old sandstone in Western Australia. Other early physical evidence of a biogenic substance is graphite in 3.7 billion-year-old metasedimentary rocks discovered in Western Greenland as well as "remains of biotic life" found in 4.1 billion-year-old rocks in Western Australia.Commenting on the Australian findings, Stephen Blair Hedges wrote, "If life arose relatively quickly on Earth, then it could be common in the universe." In July 2016, scientists reported identifying a set of 355 genes from the last universal common ancestor (LUCA) of all organisms living on Earth.

More than 99 percent of all species, amounting to over five billion species, that ever lived on Earth are estimated to be extinct. Estimates on the number of Earth's current species range from 10 million to 14 million, of which about 1.9 million are estimated to have been named and 1.6 million documented in a central database to date, leaving at least 80 percent not yet described.

Highly energetic chemistry is thought to have produced a self-replicating molecule around 4 billion years ago, and half a billion years later the last common ancestor of all life existed. The current scientific consensus is that the complex biochemistry that makes up life came from simpler chemical reactions. The beginning of life may have included self-replicating molecules such as RNA and the assembly of simple cells.

Chapter 8
Pyramids

What is a pyramid?

A pyramid is a geometrical solid with a square base and four equilateral triangular sides, the most structurally stable shape for projects involving large amounts of stone or masonry. Pyramids of various types, sizes and complexities were built in many parts of the ancient world (like Central America, Greece, China and Egypt). In the history of Egypt and China, they were primarily tombs and monuments to kings and leaders. The pyramids of the Mayans and Aztecs of Central America were mainly religious temples, though some of them housed burial chambers.

The Central American pyramids were smaller and sometimes wider than their Egyptian counterparts. These pyramids also took longer to finish -- they were often built and modified over hundreds of years, while Egyptian pyramids took a couple of decades to construct. Pyramids in Central America were integrated into Aztec and Mayan cities, whereas Egyptian pyramids were located away from the major cities.

The ancestors of these great structures are the burial tombs found throughout North America and Europe -- simple mounds of earth that covered burial chambers. The first tombs of the Egyptian pharaohs were flat, box-shaped buildings called **mastabas** (Arabic for "bench"). Pharaohs later built grander tombs by adding levels on top of the box to form **stepped pyramids**. Stepped pyramids are prevalent in Central America. In Mesopotamia, they were called **ziggurats**.

The Egyptians took pyramid design to new heights, culminating in the construction of the pyramids of Giza in the 26th century B.C. Laborers used 2.3 million blocks of limestone and granite to build the **Great Pyramid of Khufu**, which stands 146 meters high, has a 230-meter-square base and weighs about 6.5 million tons. A number of pyramids, including the Great Pyramid of Khufu, have survived thousands of years of exposure to the elements, a tribute to the ancient architects, engineers and workers who built them.

The Giza pyramid complex, on the west bank of the Nile, is the most famous group of pyramids in the world. This was the grandest pyramid and was built for Sneferu's son, Khufu, in 2540 B.C. The two smaller pyramids nearby were for Khufu's son, Khafre, and his grandson, Menkaure.

The **Great Pyramid of Khufu** on the Giza plateau in Egypt is the largest and most elaborately constructed pyramid in existence, representing the most advanced aspects of pyramid construction.

Some astonishing facts are

- The **primary burial chamber**, or king's chamber, contains the **sarcophagus** (tomb) that held Khufu's body, and the walls are adorned with **hieroglyphs** (writing) depicting various aspects of ancient Egyptian history and religion.
- The smaller **queen's chamber** lies within the pyramid, while another unfinished **secondary burial chamber** lies underneath the pyramid.
- **Weight-relieving chambers** above the king's chamber distribute the weight of the overlying rock and prevent the king's chamber from collapsing.
- The **gallery** is a large passageway with a vaulted, corbelled ceiling (the walls are layered upward, and each vertical layer sticks out further than the one below to form a primitive arch).
- Descending and ascending **passageways** connect various chambers to each other and to the outside.
- **Air shafts** connect the king's chamber to the outside.
- The **entrance** was sealed after the pharaoh's body was placed inside.
- **White limestone rocks** line the pyramid's exterior, giving it a smooth face.

Chapter 9
Dinosaurs

Dinosaur

Dinosaurs are a diverse group of reptiles of the clade Dinosauria. They first appeared during the Triassic period, between 243 and 233.23 million years ago, although the exact origin and timing of the evolution of dinosaurs is the subject of active research. They became the dominant terrestrial vertebrates after the Triassic–Jurassic extinction event 201 million years ago; their dominance continued through the Jurassic and Cretaceous periods. Reverse genetic engineering and the fossil record both demonstrate that birds are modern feathered dinosaurs, having evolved from earlier theropods during the late Jurassic Period. As such, birds were the only dinosaur lineage to survive the Cretaceous–Paleogene extinction event 66 million years ago. Dinosaurs can therefore be divided into avian dinosaurs, or birds; and non-avian dinosaurs, which are all dinosaurs other than birds

Distinguishing anatomical features

While recent discoveries have made it more difficult to present a universally agreed-upon list of dinosaurs' distinguishing features, nearly all dinosaurs discovered so far share certain modifications to the ancestral archosaurian skeleton, or are clear descendants of older dinosaurs showing these modifications.

Although some later groups of dinosaurs featured further modified versions of these traits, they are considered typical for Dinosauria; the earliest dinosaurs had them and passed them on to their descendants. Such modifications, originating in the most recent common ancestor of a certain taxonomic group, are called the synapomorphies of such a group.

A detailed assessment of archosaur interrelations by Sterling Nesbitt confirmed or found the following twelve unambiguous synapomorphies, some previously known:

i. In the skull, a supratemporal fossa (excavation) is present in front of the supratemporal fenestra, the main opening in the rear skull roof

ii. Epipophyses, obliquely backward pointing processes on the rear top corners, present in the anterior (front) neck vertebrae behind the atlas and axis, the first two neck vertebrae
iii. Apex of deltopectoral crest (a projection on which the deltopectoral muscles attach) located at or more than 30% down the length of the humerus (upper arm bone)
iv. Radius, a lower arm bone, shorter than 80% of humerus length
v. Fourth trochanter (projection where the caudofemoralis muscle attaches on the inner rear shaft) on the femur (thighbone) is a sharp flange
vi. Fourth trochanter asymmetrical, with distal, lower, margin forming a steeper angle to the shaft
vii. On the astragalus and calcaneum, upper ankle bones, the proximal articular facet, the top connecting surface, for the fibula occupies less than 30% of the transverse width of the element
viii. Exoccipitals (bones at the back of the skull) do not meet along the midline on the floor of the endocranial cavity, the inner space of the braincase
ix. In the pelvis, the proximal articular surfaces of the ischium with the ilium and the pubis are separated by a large concave surface (on the upper side of the ischium a part of the open hip joint is located between the contacts with the pubic bone and the ilium)
x. Cnemial crest on the tibia (protruding part of the top surface of the shinbone) arcs anterolaterally (curves to the front and the outer side)
xi. Distinct proximodistally oriented (vertical) ridge present on the posterior face of the distal end of the tibia (the rear surface of the lower end of the shinbone)
xii. Concave articular surface for the fibula of the calcaneum (the top surface of the calcaneum, where it touches the fibula, has a hollow profile)

Nesbitt found a number of further potential synapomorphies, and discounted a number of synapomorphies previously suggested. Some of these are also present in silesaurids, which Nesbitt recovered as a sister group to Dinosauria, including a large anterior trochanter, metatarsals II and IV of subequal length, reduced contact between ischium and pubis, the presence of a cnemial crest on the tibia and of an ascending process on the astragalus, and many others

Chapter 10
Snippets

Digital Revolution

The Digital Revolution, also known as the Third Industrial Revolution, is the shift from mechanical and analogue electronic technology to digital electronics which began anywhere from the late 1950s to the late 1970s with the adoption and proliferation of digital computers and digital record keeping that continues to the present day.

Implicitly, the term also refers to the sweeping changes brought about by digital computing and communication technology during (and after) the latter half of the 20th century. Analogous to the Agricultural Revolution and Industrial Revolution, the Digital Revolution marked the beginning of the Information Age.

Central to this revolution is the mass production and widespread use of digital logic circuits, and its derived technologies, including the computer, digital cellular phone, and the Internet. These technological innovations have transformed traditional production and business techniques

Post-Fordism

Post-Fordism is the dominant system of economic production, consumption, and associated socio-economic phenomena in most industrialized countries since the late 20th century. It is contrasted with Fordism, the system formulated in Henry Ford's automotive factories, in which workers work on a production line, performing specialized tasks repetitively, and in which his workers could afford the products they built. Definitions of the nature and scope of post-Fordism vary considerably and are a matter of debate among scholars. Changes in the nature of the workforce include the shift of emphasis to new information technologies and the rise of the service and the white-collar worker.

Chapter 11
Timelines of Computing

Timeline of computing presents events in the history of computing organized by year and grouped into six topic areas: predictions and concepts, first use and inventions, hardware systems and processors, operating systems, programming languages, and new application areas.

1980

Date	Place	Event
January	UK	Sinclair ZX80 was released for under £100.
May	Japan	On 22 May the game Pac-Man was released.
June	United States	Commodore released the VIC-20, which had 3.5 KB of usable memory and was based on the MOS Technology 6502 processor. Magazines became available which contained the code for various utilities and games. A 5¼" disk drive was available, along with a cassette storage system which used standard audio cassette tapes. Also available were a number of games, a color plotter which printed on 6 in (152 mm) wide paper tape, a graphics tablet (the KoalaPad). A TV screen served as monitor. The VIC-20 became the first computer to sell 1 million units.
July	United States	Tandy released the TRS-80 Color Computer, based on the Motorola 6809E processor and using Microsoft Basic as its programming language. It was the first Tandy computer to support color graphics, and also supported cartridge programs and games, attempting to bridge both the home computing and video gaming markets.
October	United States	Development of MS-DOS/PC DOS began. Microsoft (known mainly for their programming languages) were commissioned to write the Operating System for the PC; Digital Research failed to get the contract (there is much legend as to the real reason for this). DR's Operating

Date	Place	Event
		System, CP/M-86, was later shipped, but it was actually easier to adapt programs to DOS rather than to CP/M-86, and CP/M-86 cost $495. As Microsoft didn't have an operating system to sell, they bought Seattle Computer Product's 86-DOS which had been written by Tim Paterson earlier that year (86-DOS was also known as QDOS, Quick & Dirty Operating System, it was a more-or-less 16 bit version of CP/M). The rights were actually bought in July 1981. It is reputed that IBM found over 300 bugs in the code when they subjected the operating system to scrutiny and re-wrote much of the code. Tim Paterson's DOS 1.0 was 4000 lines of assembler.
?	Netherlands Japan	Red Book on Audio CDs was introduced by Sony and Philips. This was the beginning of the Compact disc, it was released in Japan and then in Europe and America a year later.

1981

Date	Place	Event
March	UK	Sinclair ZX81 was released, for a similar price to the ZX80 (see 1980).
April	United States	On April 8 Osborne 1 portable computer introduced; the company sold many units before filing for bankruptcy only two years later.
August	United States	On August 12 IBM announced their open architecture IBM Personal Computer. 100,000 orders were taken by Christmas. The design becomes far more successful than IBM had anticipated, and becomes the basis for most of the modern personal computer industry. MDA (Monochrome Display Adapter), text only, introduced with IBM PC. MS-DOS 1.0, PC DOS 1.0. Microsoft (known mainly for their programming languages)

Date	Place	Event
		were commissioned by IBM to write the operating system, they bought a program called 86-DOS from Tim Paterson which was loosely based on CP/M-80. The final program from Microsoft was marketed by IBM as PC DOS and by Microsoft as MS-DOS, collaboration on subsequent versions continued until version 5.0 in 1991. Compared to modern versions of DOS, version 1 was very basic. The most notable difference was the presence of just 1 directory, the root directory, on each disk. Subdirectories were not supported until version 2.0 (March 1983). MS-DOS was the main operating system for all IBM-PC compatible computers until Microsoft released Windows 95. According to Microsoft, in 1994, MS-DOS was running on some 100 million computers worldwide.
September	United States	The TCP/IP protocol is established. This is the protocol that carries most of the information across the Internet. RFC 793
	United States	Richard Feynman proposed quantum computers. The main application he had in mind was the simulation of quantum systems, but he also mentioned the possibility of solving other problems.
	United States	The Xerox 8010 ('Star') System, the first commercial system to use a WIMP (Windows, Icons, Menus and Pointing Devices) graphic user interface. Apple incorporated many of the ideas therein in the development of the interface for the Apple Lisa (see January 1983)
	United States	Symbolics introduced the LM-2 workstation, a Lisp-based workstation based on the MIT CADR architecture.

1982

Date	Place	Event
January	UK	Introduction of the BBC Micro, announced in December last year. Based on the MOS Technology 6502 processor, it was a very popular computer for British schools up to the development of the Acorn Archimedes (in 1987). In 1984 the government offered to pay half the cost of such

Date	Place	Event
		computers in an attempt to promote their use in secondary education.
January	United States	Commodore unveils the Commodore 64 at the Consumer Electronics Show in Las Vegas. Built in just two months around the VIC-II Video Integrated Circuit and the SID Sound Interface Device chips, the C64 used the 6510 processor to access 64K of RAM plus 16K of switchable ROM. This "epitome of the 8-bit computer" sold up to 22 million units in the next decade.
February	United States	On February 1 the 80286 processor was released. It implements a new mode of operation, protected mode – allowing access to more memory (up to 16 MBcompared to 1 MB for the 8086). At introduction the fastest version ran at 12.5 MHz, achieved 2.7 MIPS and contained 134,000 transistors.
March	United States	Compaq released their IBM PC compatible Compaq Portable.
March	United States	MS-DOS 1.25, PC DOS 1.1
April	UK	The Sinclair ZX Spectrum was announced, released later in the year. It is based on the Z80 microprocessor from Zilog, running at 3.5 MHz with an 8 color graphics display. The Spectrum sold with two memory options, a 16 KB version for £125 or a 48 KB version for £175.
May	United States	IBM launch the double-sided 320 KB floppy disk drive.
July	UK United States	Timex/Sinclair introduced the first computer touted to cost under $100 marketed in the U.S., the Timex Sinclair 1000. In spite of the flaws in the early versions, half a million units were sold in the first 6 months alone, surpassing the sales of Apple, Tandy, and Commodore combined.
August	United States	The Commodore 64 is released, retailing at US$595. The price rapidly dropped, creating a price war and causing the departure of numerous companies from the home computing market. Total C64 sales during its lifetime (from 1982 to

Date	Place	Event
		1994) are estimated at more than 17 million units, making it the best-selling computer model of all time.
October	United States	MIDI, Musical Instrument Digital Interface, (pronounced "middy") published by International MIDI Association (IMA). The MIDI standard allows computers to be connected to instruments like keyboards through a low-bandwidth (31,250 bit/s) protocol.
December	United States	IBM bought 12% of Intel.
?	United States	Introduction of 80186/80188. These are rarely used in personal computers as they incorporate a built in DMA and timer chip – and thus have register addresses incompatible with IBM PCs.

1983

Date	Place	Event
January	United States	Apple introduced its Lisa. The first mass market personal computer with a graphical user interface, its development was central in the move to such systems for personal computers. The Lisa's sloth and high price ($10,000) led to its ultimate failure. The Lisa ran on a Motorola 68000 microprocessor and came equipped with 1 MB of RAM, a 12-inch black-and-white monitor, dual 5¼" floppy disk drives and a 5 MB Profile hard drive. The Xerox Star – which included a system called Smalltalk that involved a mouse, windows, and pop-up menus – inspired the Lisa's designers.
January	United States Europe	IBM PC gets European launch at Which Computer Show.
March	United States	IBM XT released, similar to the original IBM PC but with a hard drive. It had a 10 MB hard disk, 128 KB of RAM, one floppy drive, mono monitor and a printer, all for $5000.

Date	Place	Event
March	United States	MS-DOS 2.0, PC DOS 2.0 Introduced with the IBM XT this version included a Unix style hierarchical sub-directory structure, and altered the way in which programs could load and access files on the disk.
May	United States	Thinking Machines Corporation formed.
May	United States	MS-DOS 2.01
September	United States	Richard Stallman announces the GNU Project, to create a free software alternative to proprietary Unixes, on Usenet. He works towards this goal over the next years, but GNU's own kernel, the GNU Hurd, is delayed indefinitely and GNU only becomes a complete usable alternative to Unix with the creation of the Linux kernel in 1991.
October	United States	IBM released the IBM PCjr in an attempt to get further into the home market; it cost just $699. Cheaper alternatives from other companies were more preferable to the home buyer, but businesses continued to buy IBM. PC DOS 2.1 (for PCjr). Like the PCjr this was not a great success and quickly disappeared from the market. MS-DOS 2.11, MS-DOS 2.25 Version 2.25 included support for foreign character sets, and was marketed in the Far East.
October	United States	Microsoft Word software released.
November	United States	Domain Name System (DNS) introduced to the Internet, which then consisted of about 1000 hosts. RFC 881 (now obsoleted by subsequent revisions) Microsoft Windows is announced.
December	Serbia	Detailed schematic diagrams for build-it-yourself computer Galaksija released in Belgrade. Thousands were soon assembled by computer enthusiasts.

Date	Place	Event
	United States	Borland formed.
	Japan	Epson QX-10 released; first Japanese computer sold in the US
	United States	Lotus 1-2-3 spreadsheet software launched.
	Italy	Olivetti M24 was put on sale. This personal computer had good success and was later rebranded by AT&T.

1984

Date	Place	Event
January	UK	Sinclair Research Ltd announced its first (and only) personal computer aimed to the business market, the Sinclair QL, at an attractive introductory price of £399. The machine was based on the 68008 CPU of Motorola, the low-cost version of Motorola 68000 with 8-bit external bus. The QL (abbreviation of Quantum Leap) did not become a market success, because of quality issues of the first series and due to the Microdrive used as storage medium instead of the much more reliable floppy discs, and its development and production later caused serious financial difficulties to the company.
January	United States	Apple Macintosh released, based on the 8 MHz version of the Motorola 68000 processor. The 68000 can address 16 MB of RAM, a noticeable improvement over Intel's 8088/8086 family. However the Apple achieved 0.7 MIPS and originally came with just 128 KB of RAM. It came fitted with a monochrome monitor and was the first successful mouse-driven computer with a Graphical user interface. The Macintosh included many of the Lisa's features at a much more affordable price: $2,500. Applications that came as part of the package included MacPaint, which made use of the mouse, and MacWrite, which demonstrated WYSIWYG (What You See Is What You Get) word processing.

Date	Place	Event
May	United States	Hewlett-Packard release the immensely popular LaserJet printer, by 1993 they had sold over 10 million LaserJet printers and over 20 million printers overall. HP were also pioneering inkjet technology.
June	UK	Amstrad CPC was introduced first in Britain, later in other European markets as well. The machine was based on the popular 8 bit Z80 CPU. The mainboard (i.e. the computer itself) and a cassette recorder (Datacorder) were both integrated in the keyboard. The CPC could be bought in a bundle with a monochrome (GT64) monitor for £249 or a colour (CTM640) monitor for £359. The monitor also served as the power supply in order to have only one plug to be connected to the wall outlet. CPC became very popular in France and Spain, and in Germany where it was marketed by Schneider Rundfunkwerke AG under its own label. In 1985 two further models (CPC 664 and 6128) with built-in 3-inch floppy disc drive were released.
August	United States	MS-DOS 3.0, PC DOS 3.0 Released for the IBM AT, it supported larger hard disks as well as High Density (1.2 MB) 5¼" floppy disks.
September	United States	Apple released a 512KB version of the Macintosh, known as the "Fat Mac".
	United States	Compaq started the development of the IDE interface (see also 1989). IDE = Intelligent Drive Electronics. This standard was designed specially for the IBM PC and can achieve high data transfer rates through a 1:1 interleave factor and caching by the actual disk controller – the bottleneck is often the old AT bus and the drive may read data far quicker than the bus can accept it, so the cache is used as a buffer. Theoretically 1 MB/s is possible but 700 kB/s is perhaps more typical of such drives. This standard has been adopted by many other models of computer, such the Acorn Archimedes A4000 and above. A later improvement was EIDE, laid down in 1989, which also removed the maximum drive size of 528 MB and increased

Date	Place	Event
		data transfer rates.
	United States	Turbo Pascal introduced by Borland.
	United States	Motorola released the 68020 processor.

1985

Date	Place	Event
January	United States	PostScript introduced by Adobe Systems. It is a powerful page description language used in the Apple Laserwriter printer. Adopted by IBM for their use in March 1987.
March	United States	MS-DOS 3.1, PC DOS 3.1 This was the first version of DOS to provide network support, and provides some new functions to handle networking.
March	United States	Symbolics registered the symbolics.com domain, the first .com domain in the world.
April	United States	Expanded memory specification, a memory paging scheme for PCs, was introduced by Lotus and Intel.
June	United States	Commodore 128 was released. Based on a complex multi-mode architecture, this was Commodore's last 8-bit computer. Cost: $299.95 for each of the CPU unit and accompanying 1571 disk drive.
June	United States	The Atari ST, an inexpensive 8 MHz Motorola 68000-based computer, appeared. Nicknamed the "Jackintosh", after Atari owner Jack Tramiel, it featured 512 KB of memory and used GEM graphical interface from Digital Research. It was priced under US$1,000.
June	USSR	Tetris was written by Russian Alexey Pazhitnov. It was later released for various western games machines, the crown jewel being its inclusion with Nintendo's Game Boy in 1989. Alexey made nothing from the game, since under the Communist Regime it was owned by the people.

Date	Place	Event
		However, after the collapse of Communism he was able to move to the USA where he now works for Microsoft.
July	United States	Commodore released the Amiga, based on a 7.16 MHz Motorola 68000 and a custom chipset. It was the first home computer to feature pre-emptive multitasking operating system. It used a Macintosh-like GUI. Cost: US$1,295 for a system with a single 880 KB 3.5 in disk drive and 256 KB of RAM.
September	UK	Amstrad introduced Amstrad PCW 8256/8512, an 8 bit, Z80 based computer system with 256 or 512 KB of RAM, dedicated to word processing and promoted as the alternative of electronic typewriters. PCW was the abbreviation of personal computer for word processing (or personal computer word processor). 8 million PCWs were sold until 1998 when Amstrad discontinued this range of computers.
October	United States	On October 17 80386 DX was released. It supports clock frequencies of up to 33 MHz and can address up to 4 GB of memory (and in theory virtual memory of up to 64 TB, which was important for marketing purposes). It also includes a bigger instruction set than the 80286. At the date of release the fastest version ran at 20 MHz and achieved 6.0 MIPS. It contained 275,000 transistors.
November	United States	Microsoft Windows launched. Not really widely used until version 3, released in 1990, Windows required DOS to run and so was not a complete operating system (until Windows 95, released on August 21, 1995). It merely provided a G.U.I. similar to that of the Macintosh. It was so similar that Apple tried to sue Microsoft for copying the 'look and feel' of their operating system. This court case was not dropped until August 1997.
December	United States	MS-DOS 3.2, PC DOS 3.2 This version was the first to support 3½" disks, although only the 720 KB ones. Version 3.2 remained the standard version until 1987 when version 3.3 was released with the IBM PS/2.

Date	Place	Event
	Netherlands Japan	CD-ROM, invented by Philips, produced in collaboration with Sony.
	United States	Enhanced Graphics Adapter released.
	UK	Meiko Scientific formed.

1986

Date	Place	Event
January	United States	Apple released another enhanced version of the Macintosh (the Macintosh Plus personal computer) – this one could cope with 4 MB of RAM (for the first time, upgradable via SIMMs) and it had a built-in SCSI adapter based on the NCR 5380.
February	UK	Sinclair ZX Spectrum 128 released. It had 128 KB of RAM, but little other improvement over the original ZX (except improved sound capabilities). Later models were produced by Amstrad – but they showed no major advances in technology.
April	United States	Apple released another version of the Macintosh (the Macintosh 512Ke) equipped with a double sided 3.5 inch Floppy Disk drive.
April	UK	On April 7 it was officially announced that Amstrad Plc acquired the computer division of Sinclair Research Ltd including the marketing and development rights of all ZX Spectrum models and the exclusive right to use the well-known *Sinclair* brand itself. As ZX Spectrum still had 40% market share and CPC also had some 20%, by the merger a very strong player was established in the British home computer market.
June	France	LISTSERV, the first automated mailing list management application, was invented by Eric Thomas.

Date	Place	Event
September	UK	Amstrad announced Amstrad PC 1512, a cheap and powerful PC. Which included a slightly enhanced CGA graphics adapter, 512 KB RAM (upgradable to 640KB), 8086 processor (upgradable to NEC V30) and a 20 MB hard disk (optional). To ensure the computer was accessible they made sure the manuals could be read by everyone, and also included DR's GEM desktop (a WIMP system) and a mouse to try to make to machine more user friendly. It was sold in many high street shops and was a complete success, being bought by Business and Home users alike.
September	Nederlands	At EUSPICO '86 conference it was presented RIPAC, a microprocessor specialized for speech-recognition designed by CSELT, Elsag and manufactured by SGS. It was used for telephone dialogue-based services in Italy.
November	United States	At Comdex Las Vegas Atari invited Gene Mosher to introduce his touchscreen point of sale graphic user interface with direct manipulation widget toolkit editing, including the Atari ST's 12" CRT with a Microtouch capacitance touchscreen overlay, 320x200 resolution graphics and a 16-color bitmapped display.

1987

Date	Place	Event
March	United States	Macintosh II and Macintosh SE released on March 2. The SE was based on the 68000, but could cope with 4 MB of RAM and had an internal and external SCSI adapter. It offered a high performance PDS interrupt slot which provided some of the first expandability on a Mac. The SE also offered the capability of displaying color with a third-party video card with its new ROM. The Macintosh II was based on the newer Motorola 68020, that ran at 16 MHz and achieved a much more respectable 2.6 MIPS (comparable to an 80286). It too had a SCSI adapter but was also fitted with a colour video adapter.

Date	Place	Event
April	United States	On April 2 PS/2 Systems were introduced by IBM. The first 4 models were released on this date. The PS/2 Model 30 based on an 8086 processor and an old XT bus, Models 50 and 60 based on the 80286 processor and the Model 80 based on the 80386 processor. These used the 3½" floppy disks, storing 1.44 MB on each (although the Model 30 could only use the low 720KB density). These systems (except the Model 30, released in September 1988) included a completely new bus, the MCA (Micro Channel Architecture) bus, which did not catch on as it did not provide support for old-style 16 bit AT bus expansion cards. The MCA bus did show many improvements in design and speed over the ISA bus most PCs used, and IBM (if no-one else) still use it in some of their machines. The PS/2 models were very successful – selling well over 2 million machines in less than 2 years.
April	United States	MS-DOS 3.3, PC DOS 3.3 Released with the IBM PS/2 this version included support for the High Density (1.44 MB) 3½" disks. It also supported hard disk partitions, splitting a hard disk into 2 or more logical drives.
April	United States	OS/2 Launched by Microsoft and IBM. A later enhancement, OS/2 Warp provided many of the 32 bit enhancements boasted by Windows 95 – but several years earlier, yet the product failed to dominate the market in the way Windows 95 did 8 years later.
June	UK	Introduction of Acorn Archimedes.
August	Canada	AD-LIB soundcard released. Not widely supported until a software company, Taito, released several games fully supporting AD-LIB – the word then spread how much the special sound effects and music enhanced the games. Ad Lib, Inc., a Canadian Company, had a virtual monopoly until 1989 when the SoundBlaster card was released.

Date	Place	Event
August	United States	LIM EMS v4.0
October–November	United States	Compaq DOS (CPQ-DOS) v3.31 released to cope with disk partitions >32Mb. Used by some other OEMs, but not Microsoft.
December	United States	Microsoft Windows 2 released on December 9.
	United States	Connection Machine, an interesting supercomputer which instead of integration of circuits operates up to 64,000 fairly ordinary microprocessors – using parallel architecture – at the same time, in its most powerful form it can do somewhere in the region of 2 billion operations per second.
	UK	Fractal Image Compression Algorithm invented by English mathematician Michael F. Barnsley, allowing digital images to be compressed and stored using fractal codes rather than normal image data.
	United States	Motorola released the 68030 processor.
	United States	HyperCard software released.
	United States	Commodore released the Amiga 500 and the Amiga 2000. The Amiga 500 was similar to the original Amiga 1000, but in an all-in-one case with 512 KB of RAM and at a lower price. The Amiga 2000 was built in a large PC-style case and included 1 MB of RAM and Zorro II expansion slots.
	United States	VGA released (designed for the PS/2) by IBM.
	United States	MCGA released (only for low end PS/2s, i.e. the Model 30) by IBM.
	United States	The 8514/A introduced by IBM. This was a graphics card that included its own processor to speed up the drawing of common objects. The advantages included a reduction in CPU workload.

1988

Date	Place	Event
January	Italy	Foundation of the MPEG group by Leonardo Chiariglione and Hiroshi Yasuda.
June	United States	80386SX was released on June 16 as a cheaper alternative to the 80386DX. It had a narrower (16 bit) time multiplexed bus. This reduction in pins, and the easier integration with 16 bit devices made the cost savings.
July–August	United States	PC DOS 4.0, MS-DOS 4.0 Version 3.4 – 4.x are confusing due to lack of correlation between IBM and Microsoft and also the US and Europe. Several 'Internal Use only' versions were also produced. This version reflected increases in hardware capabilities; it supported hard drives greater than 32 MB (up to 2 GB) and also EMS memory. This version was not properly tested and was bug ridden, causing system crashes and loss of data. The original release was IBM's, but Microsoft's version 4.0 (in October) was no better and version 4.01 was released (in November) to correct this, then version 4.01a (in April 1989) as a further improvement. However many people could not trust this and reverted to version 3.3 while they waited for the complete re-write (version 5 – 3 years later). Betas of Microsoft's version 4.0 were apparently shipped as early as 1986–1987.
September	United States	IBM PS/2 Model 30 286 released, based on an 80286 processor and the old AT bus – IBM abandoned the MCA bus, released less than 18 months earlier. Other IBM machines continued to use the MCA bus.
October		Common Access Method committee (CAM) formed. They invented the ATA standard in March 1989.
October	United States	Macintosh IIx released. It was based on a new processor, the Motorola 68030. It still ran at 16 MHz but now achieved 3.9 MIPS. It could be expanded to 128 MB of RAM and had 6 NuBus expansions slots.

Date	Place	Event
November	United States	MS-DOS 4.01, PC DOS 4.01 This corrected many of the bugs seen in version 4.0, but many users simply switched back to version 3.3 and waited for a properly re-written and fully tested version – which did not come until version 5 in June 1991. Support for disk partitions >32 MB.
		First optical chip developed, it uses light instead of electricity to increase processing speed.
		XMS Standard introduced.
		EISA Bus standard introduced.
	United States	WORM (Write Once Read Many times) – disks marketed for first time by IBM.
	United States	Adobe Photoshop software created.

1989

Date	Place	Event
January	United States	Apple Computer Macintosh SE/30 released. Like the SE of March 1987 it only had a monochrome display adapter but was fitted with the newer 68030 processor.
March		Command set for E-IDE disk drives was defined by CAM (formed Oct. 1988). This supports drives over 528 MB in size. Early controllers often imposed a limit of 2.1 GB, then later ones 8.4GB. Newer controllers support much higher capacities. Drives greater in size than 2.1GB must be partitioned under DOS since the drive structure (laid down in MS-DOS 4) used by DOS and even Windows 95 prevents partitions bigger than 2.1 GB. EIDE controllers also support the ATAPI interface that is used by most CD-ROM drives produced after its introduction. Newer implementations to EIDE, designed for the PCI bus, can achieve data transfer at up to 16.67 MB/s. A later enhancement, called UDMA, allows transfer rates of

Date	Place	Event
		up to 33.3 MB/s.
March	United States	The Macintosh IIcx released, with the same basic capabilities of the Macintosh IIx but in a more compact half-width case.
April	United States	80486DX released by Intel on April 10. It contains the equivalent of about 1.2 million transistors. At the time of release the fastest version ran at 25 MHz and achieved up to 20 MIPS. Later versions, such as the DX/2 and DX/4 versions achieved internal clock rates of up to 120 MHz.
September	United States	Apple Computer Macintosh IIci released based on a faster version of the 68030 – now running at 25 MHz, and achieved 6.3 MIPS. Apple also released the Macintosh Portable – the first notebook computer Mac, which went back to the original 68000 processor (but now ran it at 16 MHz to achieve 1.3 MIPS). It had a monochrome display.
November	Singapore	Release of Sound Blaster Card, by Creative Labs, its success was ensured by maintaining compatibility with the widely supported AdLib soundcard of 1987.
	Switzerland	World Wide Web, invented by Tim Berners-Lee who wanted to use hypertext to make documents and information seamlessly accessible over different kinds of computers and systems, and wherever they might be in the world. He was working in computing at CERN, the European Particle Physics Laboratory in Switzerland, at the time. The Web was a result of the integration of hypertext and networking, the best known vehicle being the Internet. The hyperlinked pages not only provided static information but also transparent access to databases and to existing Internet facilities such as File Transfer Protocol, telnet, Gopher, WAIS and Usenet. He was awarded the Institute of Physics' 1997 Duddell Medal for this contribution to the advancement of knowledge. The first Web browser was actually an integrated

Date	Place	Event
		browser/editor with a GUI interface, written for the sophisticated but fairly rare NeXT Computer. Berners-Lee and his colleagues offered a stripped down text-only browser as a downloadable demo, and asked the emerging Web community to write full GUI versions for other platforms. By early 1993 there were GUI browsers for UNIX and PC, including Erwise, ViolaWWW, Midas, and Cello, Samba, and Mosaic; Lynx was an important text-only browser. None of these included the editing features of the first NeXT browser, which were more labor-intensive to implement on non-NeXT platforms. Mosaic, written at the National Center for Supercomputing Applications (NCSA) was the first browser with full-time programmers and institutional support behind it. It was reliable and easy to install, and soon offered images embedded in the text rather than in separate windows. The Web's popularity exploded with Mosaic, which made it accessible to the novice user. This explosion started in earnest during 1993, a year in which Web traffic over the Internet increased by 300,000%. The bulk of the Mosaic programmers went on to found Netscape.
	United States	Lotus Notes software launched.

1990

Date	Event
	A consortium of major SVGA card manufacturers (called Video Electronic Standard Association, VESA) was formed and then introduced VESA SVGA Standard.
	Motorola releases the 68040 capable of 35 MIPS and integrated a far superior FPU. The 68040 was included in some of the Apple Macintosh and Commodore Amiga lineup.

Date	Event
March 19	Macintosh IIfx released. Based on a 40 MHz version of the 68030 it achieved 10 MIPS. It also featured a faster SCSIadapter, which could transfer 3.0 Mbit/s.
May 22	Introduction of Windows 3.0 by Microsoft. It is a multitasking system that maintains compatibility with MS-DOS, allowing several MS-DOS tasks to be run at once on an 80386 or above. This created a real threat to the Macintosh and despite a similar product, IBM's OS/2, it was very successful.
June	Commodore releases the Amiga 3000, the first 32-bit Amiga. It featured the Motorola 68030 processor and the upgraded ECS chipset. Amiga OS 2.0 was released with the launch of the A3000, which took advantage of its 32-bit architecture. Later variants included the Amiga 3000UX, launched as a low end UNIX workstation, running UNIX System V. The A3000T was the first Amiga to use a tower form factor, which increased expansion potential.
October	Macintosh Classic released, an identical replacement to the Macintosh Plus of January 1986. Also came the Macintosh IIsi which ran a 68030 processor at 20 MHz to achieve 5.0 MIPS, and also a 256 colour video adapter.
November 19	Microsoft Office released
November	Macintosh LC released. This ran a 68020 processor at 16 MHz to achieve 2.6 MIPS, it had a slightly improved SCSI adapter and a 256 colour video adapter.
	Multimedia PC (MPC) Level 1 specification published by a council of companies including Microsoft and Creative Labs. This specified the minimum standards for a Multimedia IBM PC. The MPC level 1 specification originally required a 12 MHz 80286 microprocessor, but this was later revised to require a 16 MHz 80386SX microprocessor as the 80286 was realised to be inadequate. It also required a CD-ROM drive capable of 150 kB/s (single speed) and also of Audio CD output. Companies can, after paying a fee, use the MPC logo on their product.

1991

Date	Event
	Borland acquires Ashton-Tate Corporation and the Dbase program.
	Phil Zimmermann releases the public key encryption program PGP along with its source code, which quickly appears on the Internet.
March	Commodore release the CDTV, an Amiga multimedia appliance with CD-ROM drive but no floppy drive.
April 22	The Intel 80486 SX is released as a cheaper alternative to 80486 DX, with the key difference being the lack of an integrated FPU.
May	Creative Labs introduces the Sound Blaster Pro sound card.
June	To promote OS/2, Bill Gates took every opportunity after its release to say 'DOS is dead'; however, the development of DOS 5.0 led to the permanent dropping of OS/2 development. This version, after the mess of version 4, was properly tested through the distribution of Beta versions to over 7,500 users. This version included the ability to load device drivers and TSR programs above the 640 KiB boundary (into UMBs and the HMA), freeing more RAM for programs. This version marked the end of collaboration between Microsoft and IBM on DOS.
August	The Linux kernel is born with the following post to the Usenet Newsgroup comp.os.minix by Linus Torvalds, a Finnish college student: *"Hello everybody out there using minix- I'm doing a (free) operating system (just a hobby, won't be big and professional like gnu) for 386(486) AT clones."* Linux has become one of the most widely used Unix-like operating system kernels in the world today. It originally only ran on Intel 386 processors but years later added many different types of computers (now includes complete range from small to supercomputers and IBM mainframes), including the Sun SPARC and the DEC/Compaq Alpha, as well as many ARM, MIPS, PowerPC and Motorola 68000 based computers. In 1992, the GNU project adopted the Linux kernel for use with GNU systems while they waited for the development of their own kernel, GNU Hurd, to be completed. The GNU project's aim is to provide a complete and free Unix-like operating system, combining the Hurd or Linux kernel with a complete suite of free software to run on it. Torvalds changed the licence of the Linux kernel from one prohibiting commercial use to the GNU General Public License on February 1, 1992.

1992

Date	Event
	First 64-bit microprocessors; the first 64-bit variant of MIPS, the MIPS R4000 was introduced in 1992 (announced October 1, 1991) and another major RISC microprocessor, DEC Alpha (no longer produced), was also introduced in 1992. Intel had introduced the Intel i860 RISC microprocessor in 1989, marketed as a "64-Bit Microprocessor", while it had essentially a 32-bit architecture (non-pure "32/64-bit"), enhanced with a 3D Graphics Unit capable of 64-bit. Computers with 64-bit registers (but not addressing, and not microprocessors) had appeared decades earlier, as far back as IBM 7030 Stretch (considered a failure) in 1962, and in the Cray-1 supercomputer installed at Los Alamos National Laboratory in 1976.
	Windows NT addresses 2 Gigabytes of RAM which is more than any application will ever need — *Microsoft on the development of Windows NT.*
	Introduction of CD-i launched by Philips.
	The PowerPC 601, developed by IBM, Motorola and Apple Computer, was released. This was the first generation of PowerPC processors.
	IBM ThinkPad 700C laptop created. It was lightweight compared to its predecessors.
April	Introduction of Windows 3.1
May	*Wolfenstein 3D* released by id Software
June	Sound Blaster 16 ASP Introduced by Creative Labs.
October	Commodore International releases the Amiga 1200 and Amiga 4000. Both machines included the improved Advanced Graphics Architecture chipset. The Amiga 1200 featured a 14 MHz 68020 processor, whilst the Amiga 4000 featured a 25 MHz 68040.

Date	Event
November 10	Digital Equipment Corporation introduces the Alpha AXP architecture and the Alpha-based DEC 3000 AXP workstations, DEC 4000 AXP departmental servers and the DEC 7000 AXP enterprise servers.

1993

Date	Event
	Mosaic graphical web browser launched.
	Commercial providers were allowed to sell internet connections to individuals. Its use exploded, especially with the new interface provided by the World-Wide Web (see 1989) and NCSA Mosaic.
	Release of the first version of ELOQUENS, a Text-To-Speech commercial software, from CSELT.
	The first web magazine, *The Virtual Journal*, is published but fails commercially.
	Novell purchased Digital Research, DR DOS became Novell DOS.
	The MP3 file format was published. This sound format later became the most common standard for music on PCs and later digital audio players.
March	Microsoft introduces MS-DOS 6.0, including DoubleSpace disk compression.
March 22	Intel releases the P5-based Pentium processor, with 60 and 66 MHz versions. The Pentium has over 3.1 million transistors and can achieve up to 100 MIPS. John H. Crawford co-managed the design of the P5; Donald Alpert managed the architectural team; and Vinod K. Dham headed the P5 group.
May	MPC Level 2 specification introduced (see November 1990). This was designed to allow playback of a 15 frames per second video in a 320x240 pixel window. The key difference from MPC level 1 is the requirement of a CD-ROM drive capable of 300 kB/s (double speed). Products are also required to be tested by the MPC council, making MPC Level 2 compatibility a stamp of certification.

Date	Event
June	Severe Tire Damage made the first live music performance on the Internet, using MBone technology.
July 27	Microsoft released the Windows NT 3.1 operating system that supported 32-bit programs.
December 10	*Doom* was released by id Software. The PC began to be considered as a serious games playing machine, reinforced by the earlier release in November of *Sam & Max Hit the Road*.

Chapter 12
Career Possibilities in Science and Related Fields

Generally speaking, we use the term scientist very vaguely. Let's have a look at various career possibilities as a scientist.

Physical science

• Astronomer
  ◦ Astrobiologist
  ◦ Planetary scientist
• Chemist
  ◦ Agrochemist
  ◦ Analytical chemist
  ◦ Astrochemist
  ◦ Atmospheric chemist
  ◦ Biophysic
	• Earth scientist
	  ◦ Astrogeologist
	  ◦ Biogeochemist
	  ◦ Climatologist
	  ◦ Dendroarchaeologist
	  ◦ Dendrologist
	  ◦ Edaphologist
	  ◦ Gemologist
	  ◦ Geoarchaeologist
	  ◦ Geobiologist
	  ◦ Geochemist
	  ◦ Geographer
	  ◦ Geologist
		• Physicist
		  ◦ Agrophysicist
		  ◦ Astrophysicist
		  ◦ Atmospheric physicist
		  ◦ Atomic physicist
		  ◦ Chemical physicist
		  ◦ Computational physicist
		  ◦ Cosmologist
		  ◦ Condensed-matter

al chemist • Clinical chemist • Computational chemist • Electrochemist • Femtochemist • Green chemist • Inorganic chemist • Medicinal chemist • Neurochemist • Nuclear chemist • Organic chemist • Organometallic chemist • Pharmacologist • Physical chemist • Quantum chemist • Solid-state chemist • Stereochemist • Structural chemist • Supramolecular	• Geomicrobiologist • Geomorphologist • Geophysicist • Glaciologist • Hydrogeologist • Hydrologist • Hydrometeorologist • Limnologist • Meteorologist • Mineralogist • Oceanographer • Paleoclimatologist • Paleoecologist • Paleogeologist • Paleoseismologist • Palynologist • Petrologist • Sedimentologist • Seismologist • Speleologist • Volcanologist	physicist • Engineering physicist • Material physicist • Molecular physicist • Nuclear physicist • Particle physicist • Plasma physicist • Polymer physicist • Psychophysicist • Quantum physicist • Theoretical physicist

chemist • Theoretical chemist • Thermochemist		

Life science

• Biologist • Acarologist • Aerobiologist • Anatomist • Arachnologist • Bacteriologist • Biochemist • Bioclimatologist • Biogeographer • Biotechnologist • Bioarcheologist • Biolinguist • Botanist • Cell biologist • Chronobiologist • Cognitive biologist • Cognitive neuroscienist • Computational biologist	• Conservation biologist • Dendrochronologist • Developmental biologist • Ecologist • Electrophysiologist • Embryologist • Endocrinologist • Entomologist • Epidemiologist • Ethologist • Evolutionary biologist • Geneticist • Hematologist • Herbchronologist • Herpetologist • Histologist • Human behavioral ecologist	• Ichnologist • Ichthyologist • Immunologist • Integrative biologist • Lepidopterist • Mammalogist • Marine biologist • Microbiologist • Molecular biologist • Mycologist • Neuroendocrinologist • Neuroscientist • Ornithologist • Osteologist • Paleoanthropologist • Paleobotanist • Paleobiologist • Paleontologist • Paleopathologist	• Parasitologist • Pathologist • Physiologist • Phytopathologist • Population biologist • Primatologist • Quantum biologist • Radiobiologist • Sclerochronologist • Sociobiologist • Structural biologist • Theoretical biologist • Toxicologist • Virologist • Wildlife biologist • Zoologist

	• Human biologist		

Social science

• Anthropologist
    • Archaeologist
    • Biological anthropologist
    • Cultural anthropologist
• Communication scientist
• Criminologist
• Demographer
• Economist
• Linguist
• Management scientist
• Political economist
Political scientist
	• Psychologist
	    • Abnormal psychologist
	    • Behavioral psychologist
	    • Biopsychologist
	    • Clinical psychologist
	    • Cognitive psychologist
	    • Comparative psychologist
	    • Developmental psychologist
	    • Educational psychologist
	    • Evolutionary psychologist
	    • Experimental psychologist
	    • Forensic psychologist
	    • Health psychologist
	    • Industrial and organizational psychologist
	    • Medical psychologist
	    • Neuropsychologist
	    • Psychopharmacologist
	    • Psychophysicist
	    • Social psychologist
	    • Sport psychologist

	• Sociologist

Scientist by specialization

I. Physical science

1.a. Astronomer

An astronomer is a scientist in the field of astronomy who focuses their studies on a specific question or field outside the scope of Earth. They observe astronomical objects such as stars, planets, moons, comets, and galaxies – in either observational (by analyzing the data) or theoretical astronomy. Examples of topics or fields astronomers study include planetary science, solar astronomy, the origin or evolution of stars, or the formation of galaxies. Related but distinct subjects like physical cosmology, which studies the Universe as a whole.

Astronomers usually fall under either of two main types: observational and theoretical. Observational astronomers make direct observations of celestial objects and analyze the data. In contrast, theoretical astronomers create and investigate models of things that cannot be observed. Because it takes millions to billions of years for a system of stars or a galaxy to complete a life cycle, astronomers must observe snapshots of different systems at unique points in their evolution to determine how they form, evolve, and die. They use these data to create models or simulations to theorize how different celestial objects work.

Further subcategories under these two main branches of astronomy include planetary astronomy, galactic astronomy, or physical cosmology.

- Astrobiologist

Astrobiology is an interdisciplinary scientific field concerned with the origins, early evolution, distribution, and future of life in the universe. Astrobiology considers the question of whether extraterrestrial life exists, and how humans can detect it if it does. The term exobiology is similar.

Astrobiology makes use of molecular biology, biophysics, biochemistry, chemistry, astronomy, physical cosmology, exoplanetology and geology to investigate the possibility of life on other worlds and help recognize biospheres that might be different from that on Earth. The origin and early evolution of life is an inseparable part of the discipline of astrobiology.

Astrobiology concerns itself with interpretation of existing scientific data, and although speculation is entertained to give context, astrobiology concerns itself primarily with hypotheses that fit firmly into existing scientific theories.

This interdisciplinary field encompasses research on the origin of planetary systems, origins of organic compounds in space, rock-water-carbon interactions, abiogenesis on Earth, planetary habitability, research on biosignatures for life detection, and studies on the potential for life to adapt to challenges on Earth and in outer space

➢ Planetary scientist

Planetary science or, more rarely, planetology, is the scientific study of planets (including Earth), moons, and planetary systems (in particular those of the Solar System) and the processes that form them. It studies objects ranging in size from micrometeoroids to gas giants, aiming to determine their composition, dynamics, formation, interrelations and history. It is a strongly interdisciplinary field, originally growing from astronomy and earth science, but which now incorporates many disciplines, including planetary geology (together with geochemistry and geophysics), cosmochemistry, atmospheric science, oceanography, hydrology, theoretical planetary science, glaciology, and exoplanetology. Allied disciplines include space physics, when concerned with the effects of the Sun on the bodies of the Solar System, and astrobiology.

There are interrelated observational and theoretical branches of planetary science. Observational research can involve a combination of space exploration, predominantly with robotic spacecraft missions using remote sensing, and comparative, experimental work in Earth-based laboratories. The theoretical component involves considerable computer simulation and mathematical modelling.

Planetary scientists are generally located in the astronomy and physics or Earth sciences departments of universities or research centres, though there are several purely planetary science institutes worldwide. There are several major conferences each year, and a wide range of peer-reviewed journals. In the case of some exclusive planetary scientists, many of whom are in relation to the study of dark matter, they will seek a private research centre and often initiate partnership research tasks

1.b. Chemist

➢ Agrochemist

Agricultural chemistry is the study of both chemistry and biochemistry which are important in agricultural production, the processing of raw products into foods and beverages, and in environmental monitoring and remediation. These studies emphasize the relationships between plants, animals and bacteria and their environment. The science of chemical compositions and changes involved in the production, protection, and use of crops and livestock. As a basic science, it embraces, in addition to test-tube chemistry, all the life processes through which humans obtain food and fiber for themselves and feed for their animals. As an applied science or technology, it is directed toward control of those processes to increase yields, improve quality, and reduce costs. One important branch of it, chemurgy, is concerned chiefly with utilization of agricultural products as chemical raw materials. Etc.

- Analytical chemist

Analytical chemistry studies and uses instruments and methods used to separate, identify, and quantify matter. In practice, separation, identification or quantification may constitute the entire analysis or be combined with another method. Separation isolates analytes. Qualitative analysis identifies analytes, while quantitative analysis determines the numerical amount or concentration.

Analytical chemistry consists of classical, wet chemical methods and modern, instrumental methods. Classical qualitative methods use separations such as precipitation, extraction, and distillation. Identification may be based on differences in color, odor, melting point, boiling point, radioactivity or reactivity. Classical quantitative analysis uses mass or volume changes to quantify amount. Instrumental methods may be used to separate samples using chromatography, electrophoresis or field flow fractionation. Then qualitative and quantitative analysis can be performed, often with the same instrument and may use light interaction, heat interaction, electric fields or magnetic fields. Often the same instrument can separate, identify and quantify an analyte.

Analytical chemistry is also focused on improvements in experimental design, chemometrics, and the creation of new measurement tools. Analytical chemistry has broad applications to forensics, medicine, science and engineering.

➢ Astrochemist

Astrochemistry is the study of the abundance and reactions of molecules in the Universe, and their interaction with radiation. The discipline is an overlap of astronomy and chemistry. The word "astrochemistry" may be applied to both the Solar System and the interstellar medium. The study of the abundance of elements and isotope ratios in Solar System objects, such as meteorites, is also called cosmochemistry, while the study of interstellar atoms and molecules and their interaction with radiation is sometimes called molecular astrophysics. The formation, atomic and chemical composition, evolution and fate of molecular gas clouds is of special interest, because it is from these clouds that solar systems form

➢ Atmospheric chemist

Atmospheric chemistry is a branch of atmospheric science in which the chemistry of the Earth's atmosphere and that of other planets is studied. It is a multidisciplinary approach of research and draws on environmental chemistry, physics, meteorology, computer modeling, oceanography, geology and volcanology and other disciplines. Research is increasingly connected with other areas of study such as climatology.

The composition and chemistry of the Earth's atmosphere is of importance for several reasons, but primarily because of the interactions between the atmosphere and living organisms. The composition of the Earth's atmosphere changes as result of natural processes such as volcano emissions, lightning and bombardment by solar particles from corona. It has also been changed by human activity and some of these changes are harmful to human health, crops and ecosystems. Examples of problems which have been addressed by atmospheric chemistry include acid rain, ozone depletion, photochemical smog, greenhouse gases and global warming. Atmospheric chemists seek to understand the causes of these problems, and by obtaining a theoretical understanding of them, allow possible solutions to be tested and the effects of changes in government policy evaluated.

➢ Biophysical chemist

Biophysical chemistry is a physical science that uses the concepts of physics and physical chemistry for the study of biological systems. The most common feature of the research in this subject is to seek explanation of the various phenomena in biological systems in terms of either the molecules that make up the system or the supra-molecular structure of these systems.

Biophysical chemists employ various techniques used in physical chemistry to probe the structure of biological systems. These techniques include spectroscopic methods such as nuclear magnetic resonance (NMR) and X-ray diffraction. For example, the work for which Nobel Prize was awarded in 2009 to three chemists was based on X-ray diffraction studies of ribosomes. Some of the areas in which biophysical chemists engage themselves are protein structure and the functional structure of cell membranes. For example, enzyme action can be explained in terms of the shape of a pocket in the protein molecule that matches the shape of the substrate molecule or its modification due to binding of a metal ion. Similarly the structure and function of the biomembranes may be understood through the study of model supramolecular structures as liposomes or phospholipid vesicles of different compositions and sizes.

- Clinical chemist

Clinical chemistry (also known as chemical pathology, clinical biochemistry or medical biochemistry) is the area of chemistry that is generally concerned with analysis of bodily fluids for diagnostic and therapeutic purposes. It is an applied form of biochemistry (not to be confused with medicinal chemistry, which involves basic research for drug development).

The discipline originated in the late 19th century with the use of simple chemical reaction tests for various components of blood and urine. In the many decades since, other techniques have been applied as science and technology have advanced, including the use and measurement of enzyme activities, spectrophotometry, electrophoresis, and immunoassay. There are now many blood tests and clinical urine tests with extensive diagnostic capabilities.

Most current laboratories are now highly automated to accommodate the high workload typical of a hospital laboratory. Tests performed are closely monitored and quality controlled.

All biochemical tests come under chemical pathology. These are performed on any kind of body fluid, but mostly on serum or plasma. Serum is the yellow watery part of blood that is left after blood has been allowed to clot and all blood cells have been removed. This is most easily done by centrifugation, which packs the denser blood cells and platelets to the bottom of the centrifuge tube, leaving the liquid serum fraction resting above the packed cells. This initial step before analysis has recently been included in instruments that operate on the "integrated system" principle.

Plasma is in essence the same as serum, but is obtained by centrifuging the blood without clotting. Plasma is obtained by centrifugation before clotting occurs. The type of test required dictates what type of sample is used.

- Computational chemist

Computational chemistry is a branch of chemistry that uses computer simulation to assist in solving chemical problems. It uses methods of theoretical chemistry, incorporated into efficient computer programs, to calculate the structures and properties of molecules and solids. It is necessary because, apart from relatively recent results concerning the hydrogen molecular ion (dihydrogen cation, see references therein for more details), the quantum many-body problem cannot be solved analytically, much less in closed form. While computational results normally complement the information obtained by chemical experiments, it can in some cases predict hitherto unobserved chemical phenomena. It is widely used in the design of new drugs and materials.

Examples of such properties are structure (i.e., the expected positions of the constituent atoms), absolute and relative (interaction) energies, electronic charge density distributions, dipoles and higher multipole moments, vibrational frequencies, reactivity, or other spectroscopic quantities, and cross sections for collision with other particles.

The methods used cover both static and dynamic situations. In all cases, the computer time and other resources (such as memory and disk space) increase rapidly with the size of the system being studied. That system can be one molecule, a group of molecules, or a solid. Computational chemistry methods range from very approximate to highly accurate; the latter are usually feasible for small systems only. Ab initio methods are based entirely on quantum mechanics and basic physical constants. Other methods are called empirical or semi-empirical because they use additional empirical parameters

- Electrochemist

Electrochemistry is the branch of physical chemistry that studies the relationship between electricity, as a measurable and quantitative phenomenon, and identifiable chemical change, with either electricity considered an outcome of a particular chemical change or vice versa. These reactions involve electric charges moving between electrodes and an electrolyte (or ionic species in a solution). Thus electrochemistry deals with the interaction between electrical energy and chemical change.

When a chemical reaction is caused by an externally supplied current, as in electrolysis, or if an electric current is produced by a spontaneous chemical reaction as in a battery, it is called an electrochemical reaction. Chemical reactions where electrons are transferred directly between molecules and/or atoms are called oxidation-reduction or (redox) reactions. In general, electrochemistry describes the overall reactions when individual redox reactions are separate but connected by an external electric circuit and an intervening electrolyte.

➢ Femtochemist

Femtochemistry is the area of physical chemistry that studies chemical reactions on extremely short timescales (approximately 10 raised to −15 seconds or one femtosecond, hence the name) in order to study the very act of atoms within molecules (reactants) rearranging themselves to form new molecules (products). In 1999, Ahmed Hassan Zewail received the Nobel Prize in Chemistry for his pioneering work in this field showing that it is possible to see how atoms in a molecule move during a chemical reaction with flashes of laser light.

Application of femtochemistry in biological studies has also helped to elucidate the conformational dynamics of stem-loop RNA structures.

Many publications have discussed the possibility of controlling chemical reactions by this method, but this remains controversial. The steps in some reactions occur in the femtosecond timescale and sometimes in attosecond timescales, and will sometimes form intermediate products. These intermediate products cannot always be deduced from observing the start and end products.

➢ Green chemist

Green chemistry, also called sustainable chemistry, is an area of chemistry and chemical engineering focused on the designing of products and processes that minimize the use and generation of hazardous substances. Whereas environmental chemistry focuses on the effects of polluting chemicals on nature, green chemistry focuses on the environmental impact of chemistry, including technological approaches to preventing pollution and reducing consumption of nonrenewable resources.

The overarching goals of green chemistry—namely, more resource-efficient and inherently safer design of molecules, materials, products, and processes—can be pursued in a wide range of contexts.

IUPAC definition

Green chemistry (sustainable chemistry): Design of chemical products and processes that reduce or eliminate the use or generation of substances hazardous to humans, animals, plants, and the environment.
Green chemistry discusses the engineering concept of pollution prevention and zero waste both at laboratory and industrial scales. It encourages the use of economical and ecocompatible techniques that not only improve the yield but also bring down the cost of disposal of wastes at the end of a chemical process

- Inorganic chemist

Inorganic chemistry deals with the synthesis and behavior of inorganic and organometallic compounds. This field covers all chemical compounds except the myriad organic compounds (carbon-based compounds, usually containing C-H bonds), which are the subjects of organic chemistry. The distinction between the two disciplines is far from absolute, as there is much overlap in the subdiscipline of organometallic chemistry. It has applications in every aspect of the chemical industry, including catalysis, materials science, pigments, surfactants, coatings, medications, fuels, and agriculture

- Medicinal chemist

Medicinal chemistry and pharmaceutical chemistry are disciplines at the intersection of chemistry, especially synthetic organic chemistry, and pharmacology and various other biological specialties, where they are involved with design, chemical synthesis and development for market of pharmaceutical agents, or bio-active molecules (drugs).
Compounds used as medicines are most often organic compounds, which are often divided into the broad classes of small organic molecules (e.g., atorvastatin, fluticasone, clopidogrel) and "biologics" (infliximab, erythropoietin, insulin glargine), the latter of which are most often medicinal preparations of proteins (natural and recombinant antibodies, hormones, etc.). Inorganic and organometallic compounds are also useful as drugs (e.g., lithium and platinum-based agents such as lithium carbonate and cisplatin as well as gallium).

In particular, medicinal chemistry in its most common practice—focusing on small organic molecules—encompasses synthetic organic chemistry and aspects of natural products and computational chemistry in close combination with chemical biology, enzymology and structural biology, together aiming at the discovery and development of new therapeutic agents. Practically speaking, it involves chemical aspects of identification, and then systematic, thorough synthetic alteration of new chemical entities to make them suitable for therapeutic use. It includes synthetic and computational aspects of the study of existing drugs and agents in development in relation to their bioactivities (biological activities and properties), i.e., understanding their structure-activity relationships (SAR). Pharmaceutical chemistry is focused on quality aspects of medicines and aims to assure fitness for purpose of medicinal products.

At the biological interface, medicinal chemistry combines to form a set of highly interdisciplinary sciences, setting its organic, physical, and computational emphases alongside biological areas such as biochemistry, molecular biology, pharmacognosy and pharmacology, toxicology and veterinary and human medicine; these, with project management, statistics, and pharmaceutical business practices, systematically oversee altering identified chemical agents such that after pharmaceutical formulation, they are safe and efficacious, and therefore suitable for use in treatment of disease.

- Neurochemist

Neurochemistry is the study of neurochemicals, including neurotransmitters and other molecules such as psychopharmaceuticals and neuropeptides, that influence the function of neurons. This field within neuroscience examines how neurochemicals influence the operation of neurons, synapses, and neural networks. Neurochemistsanalyze the biochemistry and molecular biology of organic compounds in the nervous system, and their roles in such neural processes as cortical plasticity, neurogenesis, and neural differentiation.

In the 1950s, neurochemistry became a recognized scientific research discipline. The founding of neurochemistry as a discipline traces it origins to a series of "International Neurochemical Symposia", of which the first symposium volume published in 1954 was titled Biochemistry of the Developing Nervous System. These meetings led to the formation of the International Society for Neurochemistry and the American Society for Neurochemistry. These early gatherings discussed the tentative nature of possible neurotransmitter substances such as acetylcholine, histamine, substance P, and serotonin. By 1972, ideas were more concrete. Neurochemicals such as norepinephrine, dopamine, and serotonin were classified as "putative neurotransmitters in certain neuronal tracts in the brain.

- Nuclear chemist

Nuclear chemistry is the subfield of chemistry dealing with radioactivity, nuclear processes, such as nuclear transmutation, and nuclear properties.
It is the chemistry of radioactive elements such as the actinides, radium and radon together with the chemistry associated with equipment (such as nuclear reactors) which are designed to perform nuclear processes. This includes the corrosion of surfaces and the behavior under conditions of both normal and abnormal operation (such as during an accident). An important area is the behavior of objects and materials after being placed into a nuclear waste storage or disposal site.
It includes the study of the chemical effects resulting from the absorption of radiation within living animals, plants, and other materials. The radiation chemistry controls much of radiation biology as radiation has an effect on living things at the molecular scale, to explain it another way the radiation alters the biochemicals within an organism, the alteration of the biomolecules then changes the chemistry which occurs within the organism, this change in chemistry then can lead to a biological outcome. As a result, nuclear chemistry greatly assists the understanding of medical treatments (such as cancer radiotherapy) and has enabled these treatments to improve.
It includes the study of the production and use of radioactive sources for a range of processes. These include radiotherapy in medical applications; the use of radioactive tracers within industry, science and the environment; and the use of radiation to modify materials such as polymers.
It also includes the study and use of nuclear processes in non-radioactive areas of human activity. For instance, nuclear magnetic resonance (NMR) spectroscopy is commonly used in synthetic organic chemistry and physical chemistry and for structural analysis in macromolecular chemistry.

- Organic chemist

Organic chemistry is the chemistry subdiscipline for the scientific study of structure, properties, and reactions of organic compounds and organic materials (materials that contain carbon atoms). Study of structure determines their chemical composition and formula. Study of properties includes physical and chemical properties, and evaluation of chemical reactivity to understand their behavior. The study of organic reactions includes the chemical synthesis of natural products, drugs, and polymers, and study of individual organic molecules in the laboratory and via theoretical (in silico) study.

The range of chemicals studied in organic chemistry includes hydrocarbons (compounds containing only carbon and hydrogen) as well as compounds based on carbon, but also containing other elements, especially oxygen, nitrogen, sulfur, phosphorus (included in many biochemicals) and the halogens.
In the modern era, the range extends further into the periodic table, with main group elements, including:
Group 1 and 2 organometallic compounds involving alkali (lithium, sodium, and potassium) or alkaline earth metals (magnesium)
Metalloids (boron and silicon) or other metals (aluminium and tin)
In addition, contemporary research focuses on organic chemistry involving other organometallics including the lanthanides, but especially the transition metals zinc, copper, palladium, nickel, cobalt, titanium and chromium
Organic compounds form the basis of all earthly life and constitute the majority of known chemicals. The bonding patterns of carbon, with its valence of four—formal single, double, and triple bonds, plus structures with delocalized electrons—make the array of organic compounds structurally diverse, and their range of applications enormous. They form the basis of, or are constituents of, many commercial products including pharmaceuticals; petrochemicals and agrichemicals, and products made from them including lubricants, solvents; plastics; fuels and explosives. The study of organic chemistry overlaps organometallic chemistry and biochemistry, but also with medicinal chemistry, polymer chemistry, and materials science.

- Organometallic chemist

Organometallic chemistry is the study of organometallic compounds, chemical compounds containing at least one chemical bond between a carbon atom of an organic molecule and a metal, including alkaline, alkaline earth, and transition metals, and sometimes broadened to include metalloids like boron, silicon, and tin, as well. Aside from bonds to organyl fragments or molecules, bonds to 'inorganic' carbon, like carbon monoxide (metal carbonyls), cyanide, or carbide, are generally considered to be organometallic as well. Some related compounds such as transition metal hydrides and metal phosphine complexes are often included in discussions of organometallic compounds, though strictly speaking, they are not necessarily organometallic. The related but distinct term "metalorganic compound" refers to metal-containing compounds lacking direct metal-carbon bonds but which contain organic ligands. Metal βdiketonates, alkoxides, dialkylamides, and metal phosphine complexes are representative members of this class. The field of organometallic chemistry combines aspects of traditional inorganic and organic chemistry.

Organometallic compounds are widely used both stoichiometrically in research and industrial chemical reactions, as well as in the role of catalysts to increase the rates of such reactions (e.g., as in uses of homogeneous catalysis), where target molecules include polymers, pharmaceuticals, and many other types of practical products.

Industrial applications

Organometallic compounds find wide use in commercial reactions, both as homogeneous catalysis and as stoichiometric reagents For instance, organolithium, organomagnesium, and organoaluminium compounds, examples of which are highly basic and highly reducing, are useful stoichiometrically, but also catalyze many polymerization reactions.

Almost all processes involving carbon monoxide rely on catalysts, notable examples being described as carbonylations. The production of acetic acid from methanol and carbon monoxide is catalyzed via metal carbonyl complexes in the Monsanto process and Cativa process. Most synthetic aldehydes are produced via hydroformylation. The bulk of the synthetic alcohols, at least those larger than ethanol, are produced by hydrogenation of hydroformylation-derived aldehydes. Similarly, the Wacker process is used in the oxidation of ethylene to acetaldehyde.

Almost all industrial processes involving alkene-derived polymers rely on organometallic catalysts. The world's polyethylene and polypropylene are produced via both heterogeneously via Ziegler-Natta catalysis and homogeneously, e.g., via constrained geometry catalysts.

Most processes involving hydrogen rely on metal-based catalysts. Whereas bulk hydrogenations, e.g. margarine production, rely on heterogeneous catalysts, For the production of fine chemicals, such hydrogenations rely on soluble organometallic complexes or involve organometallic intermediates.

Organometallic complexes allow these hydrogenations to be effected asymmetrically.

A constrained geometry organotitanium complex is a precatalyst for olefin polymerization.

Many semiconductors are produced from trimethylgallium, trimethylindium, trimethylaluminium, and trimethylantimony. These volatile compounds are decomposed along with ammonia, arsine, phosphine and related hydrides on a heated substrate via metalorganic vapor phase epitaxy (MOVPE) process in the production of light-emitting diodes (LEDs)

- Pharmacologist

Pharmacology is the branch of biology concerned with the study of drug action, where a drug can be broadly defined as any man-made, natural, or endogenous (from within the body) molecule which exerts a biochemical or physiological effect on the cell, tissue, organ, or organism (sometimes the word pharmacon is used as a term to encompass these endogenous and exogenous bioactive species). More specifically, it is the study of the interactions that occur between a living organism and chemicals that affect normal or abnormal biochemical function. If substances have medicinal properties, they are considered pharmaceuticals.
The field encompasses drug composition and properties, synthesis and drug design, molecular and cellular mechanisms, organ/systems mechanisms, signal transduction/cellular communication, molecular diagnostics, interactions, toxicology, chemical biology, therapy, and medical applications and antipathogenic capabilities. The two main areas of pharmacology are pharmacodynamics and pharmacokinetics. Pharmacodynamics studies the effects of a drug on biological systems, and Pharmacokinetics studies the effects of biological systems on a drug. In broad terms, pharmacodynamics discusses the chemicals with biological receptors, and pharmacokinetics discusses the absorption, distribution, metabolism, and excretion (ADME) of chemicals from the biological systems. Pharmacology is not synonymous with pharmacy and the two terms are frequently confused. Pharmacology, a biomedical science, deals with the research, discovery, and characterization of chemicals which show biological effects and the elucidation of cellular and organismal function in relation to these chemicals. In contrast, pharmacy, a health services profession, is concerned with application of the principles learned from pharmacology in its clinical settings; whether it be in a dispensing or clinical care role. In either field, the primary contrast between the two are their distinctions between direct-patient care, for pharmacy practice, and the science-oriented research field, driven by pharmacology

- Physical chemist

Physical chemistry is the study of macroscopic, atomic, subatomic, and particulate phenomena in chemical systems in terms of the principles,

practices, and concepts of physics such as motion, energy, force, time, thermodynamics, quantum chemistry, statistical mechanics, analytical dynamics and chemical equilibrium.
Physical chemistry, in contrast to chemical physics, is predominantly (but not always) a macroscopic or supra-molecular science, as the majority of the principles on which it was founded relate to the bulk rather than the molecular/atomic structure alone (for example, chemical equilibrium and colloids).
Some of the relationships that physical chemistry strives to resolve include the effects of:
1) Intermolecular forces that act upon the physical properties of materials (plasticity, tensile strength, surface tension in liquids).
2) Reaction kinetics on the rate of a reaction.
3) The identity of ions and the electrical conductivity of materials.
4) Surface science and electrochemistry of cell membranes.
5) Interaction of one body with another in terms of quantities of heat and work called thermodynamics.
6) Transfer of heat between a chemical system and its surroundings during change of phase or chemical reaction taking place called thermochemistry
7) Study of colligative properties of number of species present in solution.
8) Number of phases, number of components and degree of freedom (or variance) can be correlated with one another with help of phase rule.
9) Reactions of electrochemical cells.

➢ Quantum chemist
Quantum chemistry studies the ground state of individual atoms and molecules, and the excited states, and transition states that occur during chemical reactions.

Experimental quantum chemists rely heavily on spectroscopy, through which information regarding the quantization of energy on a molecular scale can be obtained. Common methods are infra-red (IR) spectroscopy, nuclear magnetic resonance (NMR) spectroscopy, and scanning probe microscopy.
Theoretical quantum chemistry, the workings of which also tend to fall under the category of computational chemistry, seeks to calculate the predictions of quantum theory as atoms and molecules can only have discrete energies; as this task, when applied to polyatomic species, invokes

the many-body problem, these calculations are performed using computers rather than by analytical "back of the envelope" methods.
It involves heavy interplay of experimental and theoretical methods. In these ways, quantum chemists investigate chemical phenomena.
On the calculations, quantum chemical studies use also semi-empirical and other methods based on quantum mechanical principles, and deal with time dependent problems. Many quantum chemical studies assume the nuclei are at rest (Born–Oppenheimer approximation). Many calculations involve iterative methods that include self-consistent field methods. Major goals of quantum chemistry include increasing the accuracy of the results for small molecular systems, and increasing the size of large molecules that can be processed, which is limited by scaling considerations—the computation time increases as a power of the number of atoms.

- Solid-state chemist

Solid-state chemistry, also sometimes referred as materials chemistry, is the study of the synthesis, structure, and properties of solid phase materials, particularly, but not necessarily exclusively of, non-molecular solids. It therefore has a strong overlap with solid-state physics, mineralogy, crystallography, ceramics, metallurgy, thermodynamics, materials science and electronics with a focus on the synthesis of novel materials and their characterisation. Solids can be classified as crystalline or amorphous on basis of the nature of order present in the arrangement of their constituent particles.

- Stereochemist

Stereochemistry, a subdiscipline of chemistry, involves the study of the relative spatial arrangement of atoms that form the structure of molecules and their manipulation. The study of stereochemistry focuses on stereoisomers, which by definition have the same molecular formula and sequence of bonded atoms (constitution), but differ in the three-dimensional orientations of their atoms in space. For this reason, it is also known as 3D chemistry—the prefix "stereo-" means "three-dimensionality".
An important branch of stereochemistry is the study of chiral molecules. Stereochemistry spans the entire spectrum of organic, inorganic, biological, physical and especially supramolecular chemistry. Stereochemistry includes methods for determining and describing these relationships; the effect on the physical or biological properties these relationships impart upon the molecules in question, and the manner in

which these relationships influence the reactivity of the molecules in question (dynamic stereochemistry).
Example; Louis Pasteur could rightly be described as the first stereochemist, having observed in 1842 that salts of tartaric acid collected from wine production vessels could rotate plane polarized light, but that salts from other sources did not. This property, the only physical property in which the two types of tartrate salts differed, is due to optical isomerism. In 1874, Jacobus Henricusvant Hoff and Joseph Le Bel explained optical activity in terms of the tetrahedral arrangement of the atoms bound to carbon.

- Structural chemist

A chemical structure determination includes a chemist's specifying the molecular geometry and, when feasible and necessary, the electronic structure of the target molecule or other solid. Molecular geometry refers to the spatial arrangement of atoms in a molecule and the chemical bonds that hold the atoms together, and can be represented using structural formulae and by molecular models; complete electronic structure descriptions include specifying the occupation of a molecule's molecular orbitals. Structure determination can be applied to a range of targets from very simple molecules (e.g., diatomic oxygen or nitrogen), to very complex ones (e.g., such as of protein or DNA).
Theories of chemical structure were first developed by August Kekule, Archibald Scott Couper, and Aleksandr Butlerov, among others, from about 1858. These theories were first to state that chemical compounds are not a random cluster of atoms and functional groups, but rather had a definite order defined by the valency of the atoms composing the molecule, giving the molecules a three dimensional structure that could be determined or solved.
In determining structures of chemical compounds, one generally aims to obtain, minimally, the pattern and multiplicity of bonding between all atoms in the molecule; when possible, one seeks the three dimensional spatial coordinates of the atoms in the molecule (or other solid). The methods by which one can elucidate the structure of a molecule include spectroscopies such as nuclear magnetic resonance (proton and carbon-13 NMR), various methods of mass spectrometry (to give overall molecular mass, as well as fragment masses), and x-ray crystallography when applicable. The last technique can produce three-dimensional models at atomic-scale resolution, as long as crystals are available. When a molecule has an unpaired electron spin in a functional group of its structure,

ENDOR and electron-spin resonance spectroscopes may also be performed. Techniques such as absorption spectroscopy and the vibrational spectroscopies, infrared and Raman, provide, respectively, important supporting information about the numbers and adjacencies of multiple bonds, and about the types of functional groups (whose internal bonding gives vibrational signatures); further inferential studies that give insight into the contributing electronic structure of molecules include cyclic voltammetry and X-ray photoelectron spectroscopy.
These latter techniques become all the more important when the molecules contain metal atoms, and when the crystals required by crystallography or the specific atom types that are required by NMR are unavailable to exploit in the structure determination. Finally, more specialized methods such as electron microscopy are also applicable in some cases.

➢ Supramolecular chemist

Supramolecular chemistry is the domain of chemistry beyond that of molecules that focuses on the chemical systems made up of a discrete number of assembled molecular subunits or components. The forces responsible for the spatial organization may vary from weak (intermolecular forces, electrostatic or hydrogen bonding) to strong (covalent bonding), provided that the degree of electronic coupling between the molecular component remains small with respect to relevant energy parameters of the component. While traditional chemistry focuses on the covalent bond, supramolecular chemistry examines the weaker and reversible non-covalent interactions between molecules. These forces include hydrogen bonding, metal coordination, hydrophobic forces, van der Waals forces, pi–pi interactions and electrostatic effects. Important concepts that have been demonstrated by supramolecular chemistry include molecular self-assembly, folding, molecular recognition, host–guest chemistry, mechanically-interlocked molecular architectures, and dynamic covalent chemistry. The study of non-covalent interactions is crucial to understanding many biological processes from cell structure to vision that rely on these forces for structure and function. Biological systems are often the inspiration for supramolecular research.
Supermolecules are to molecules and the intermolecular bond what molecules are to atoms and the covalent bond.

➢ Theoretical chemist

Theoretical chemistry is a branch of chemistry, which develops theoretical generalizations that are part of the theoretical arsenal of modern chemistry, for example, the concept of chemical bonding, chemical reaction, valence, the surface of potential energy, molecular orbitals, orbital interactions, molecule activation etc

Branches of theoretical chemistry

i. Quantum chemistry
   a. The application of quantum mechanics or fundamental interactions to chemical and physico-chemical problems. Spectroscopic and magnetic properties are between the most frequently modelled.

ii. Computational chemistry
   a. The application of computer codes to chemistry, involving approximation schemes such as Hartree–Fock, post-Hartree–Fock, density functional theory, semiempirical methods (such as PM3) or force field methods. Molecular shape is the most frequently predicted property. Computers can also predict vibrational spectra and vibronic coupling, but also acquire and Fourier transform Infra-red Data into frequency information. The comparison with predicted vibrations supports the predicted shape.

iii. Molecular modelling
   a. Methods for modelling molecular structures without necessarily referring to quantum mechanics. Examples are molecular docking, protein-protein docking, drug design, combinatorial chemistry. The fitting of shape and electric potential are the driving factor in this graphical approach.

iv. Molecular dynamics
   a. Application of classical mechanics for simulating the movement of the nuclei of an assembly of atoms and molecules. The rearrangement of molecules within an ensemble is controlled by Van der Waals forces and promoted by temperature.

v. Molecular mechanics
   a. Modeling of the intra- and inter-molecular interaction potential energy surfaces via potentials. The latter are usually parameterized from ab initio calculations.

vi. Mathematical chemistry
   a. Discussion and prediction of the molecular structure using mathematical methods without necessarily referring to quantum mechanics. Topology is a branch of mathematics that allows researchers to predict properties of flexible finite size bodies like clusters.

vii. Theoretical chemical kinetics
   a. Theoretical study of the dynamical systems associated to reactive chemicals, the activated complex and their corresponding differential equations.

viii. Cheminformatics (also known as chemoinformatics)

a. The use of computer and informational techniques, applied to crop information to solve problems in the field of chemistry.

➢ Thermochemist

Thermochemistry is the study of the heat energy associated with chemical reactions and/or physical transformations. A reaction may release or absorb energy, and a phase change may do the same, such as in melting and boiling. Thermochemistry focuses on these energy changes, particularly on the system's energy exchange with its surroundings. Thermochemistry is useful in predicting reactant and product quantities throughout the course of a given reaction. In combination with entropy determinations, it is also used to predict whether a reaction is spontaneous or non-spontaneous, favorable or unfavorable.

Endothermic reactions absorb heat, while exothermic reactions release heat. Thermochemistry coalesces the concepts of thermodynamics with the concept of energy in the form of chemical bonds. The subject commonly includes calculations of such quantities as heat capacity, heat of combustion, heat of formation, enthalpy, entropy, free energy, and calories.

Earth scientist

Astrogeologist

Planetary geology, alternatively known as astrogeology or exogeology, is a planetary science discipline concerned with the geology of the celestial bodies such as the planets and their moons, asteroids, comets, and meteorites. Although the geo- prefix typically indicates topics of or relating to the Earth, planetary geology is named as such for historical and convenience reasons; applying geological science to other planetary bodies. Due to the types of investigations involved, it is also closely linked with Earth-based geology.

Planetary geology includes such topics as determining the internal structure of the terrestrial planets, and also looks at planetary volcanism and surface processes such as impact craters, fluvial and aeolian processes. The structures of the giant planets and their moons are also examined, as is the make-up of the minor bodies of the Solar System, such as asteroids, the Kuiper Belt, and comets.

Planetary geology uses a wide variety of standardised descriptor names for features. All planetary feature names recognised by the International

Astronomical Union combine one of these names with a possibly unique identifying name. The conventions which decide the more precise name are dependent on which planetary body the feature is on, but the standard descriptors are in general common to all astronomical planetary bodies. Some names have a long history of historical usage, but new must be recognised by the IAU Working Group for Planetary System Nomenclature as features are mapped and described by new planetary missions. This means that in some cases names may change as new imagery becomes available or in other cases widely adopted informal names changed in line with the rules. The standard names are chosen to consciously avoid interpreting the underlying cause of the feature, but rather to describe only its appearance.

Biogeochemist

Biogeochemistry is the scientific discipline that involves the study of the chemical, physical, geological, and biological processes and reactions that govern the composition of the natural environment (including the biosphere, the cryosphere, the hydrosphere, the pedosphere, the atmosphere, and the lithosphere). In particular, biogeochemistry is the study of the cycles of chemical elements, such as carbon and nitrogen, and their interactions with and incorporation into living things transported through earth scale biological systems in space through time.

The field focuses on chemical cycles which are either driven by or influence biological activity. Particular emphasis is placed on the study of carbon, nitrogen, sulfur, and phosphorus cycles. Biogeochemistry is a systems science closely related to systems ecology.

Climatologist

Climatology (from Greek κλίμα, klima, "place, zone"; and -λογία, -logia) or climate science is the scientific study of climate, scientifically defined as weather conditions averaged over a period of time. This modern field of study is regarded as a branch of the atmospheric sciences and a subfield of physical geography, which is one of the Earth sciences. Climatology now includes aspects of oceanography and biogeochemistry. Basic knowledge of climate can be used within shorter term weather forecasting using analog techniques such as the El Niño–Southern Oscillation (ENSO), the Madden–Julian oscillation (MJO), the North Atlantic oscillation (NAO), the Northern Annular Mode (NAM) which is also known as the Arctic oscillation (AO), the Northern Pacific (NP) Index, the Pacific decadal oscillation (PDO), and the Interdecadal Pacific Oscillation (IPO). Climate models are used for a variety of purposes from study of the dynamics of the weather and climate system to projections of future climate. Weather is known as the condition of the atmosphere over a period of time, while climate has to do with the atmospheric condition over an extended to indefinite period of time.

Dendroarchaeologist

Dendroarchaeology is a term used for the study of vegetation remains, old buildings, artifacts, furniture, art and musical instruments using the techniques of dendrochronology (tree-ring dating). It refers to dendrochronological research of wood from the past regardless of its current physical context (in or above the soil). This form of dating is the most accurate and precise absolute dating method available to archaeologists, as the last ring that grew is the first year the tree could have been incorporated into an archaeological structure.
Tree-ring dating is useful in that it can contribute to "chronometric", "environmental", and "behavioral" archaeological research.

The utility of tree-ring dating in an environmental sense is the most applicable of the three in today's world. Tree rings can be used to "reconstruct numerous environmental variables" such as "temperature", "precipitation", "stream flow", "drought society", "fire frequency and intensity", "insect infestation", "atmospheric circulation patterns", among others.

Dendrologist

Dendrology (Ancient Greek: δένδρον, dendron, "tree"; and Ancient Greek: -λογία, -logia, science of or study of) or xylology (Ancient Greek: ξύλον, ksulon, "wood") is the science and study of wooded plants (trees, shrubs, and lianas), specifically, their taxonomic classifications. There is no sharp boundary between plant taxonomy and dendrology; however, woody plants not only belong to many different plant families, but these families may be made up of both woody and non-woody members. Some families include only a few woody species. Dendrology, as a discipline of industrial forestry, tends to focus on identification of economically useful woody plants and their taxonomic interrelationships. As an academic course of study, dendrology will include all woody plants, native and non-native, that occur in a region. A related discipline is the study of sylvics, which focuses on the autecology of genera and species.

Edaphologist

Edaphology (from Greek ἔδαφος, edaphos, "ground", and -λογία, -logia) is one of two main divisions of soil science, the other being pedology. Edaphology is concerned with the influence of soils on living things, particularly plants. Edaphology includes the study of how soil influences humankind's use of land for plant growth as well as man's overall use of the land. General subfields within edaphology are agricultural soil science (known by the term agrology in some regions) and environmental soil science. (Pedology deals with pedogenesis, soil morphology, and soil classification.)

In Russia, edaphology is considered equivalent to pedology, but is recognized to have an applied sense consistent with agrophysics and agrochemistry outside Russia.

Gemologist

Gemology or gemmology is the science dealing with natural and artificial gemstone materials. It is considered a geoscience and a branch of mineralogy. Some jewelers are academically trained gemologists and are qualified to identify and evaluate gems.

Geoarchaeologist

Geoarchaeology is a multi-disciplinary approach which uses the techniques and subject matter of geography, geology and other Earth sciences to examine topics which inform archaeological knowledge and thought. Geoarchaeologists study the natural physical processes that affect archaeological sites such as geomorphology, the formation of sites through geological processes and the effects on buried sites and artifacts post-deposition. Geoarchaeologists' work frequently involves studying soil and sediments as well as other geographical concepts to contribute an archaeological study. Geoarchaeologists may also use computer cartography, geographic information systems (GIS) and digital elevation models (DEM) in combination with disciplines from human and social sciences and earth sciences. Geoarchaeology is important to society because it informs archaeologists about the geomorphology of the soil, sediments and the rocks on the buried sites and artifacts they're researching on. By doing this we are able locate ancient cities and artifacts and estimate by the quality of soil how "prehistoric" they really are.

Geobiologist

Geobiology is a field of scientific research that explores the interactions between the physical Earth and the biosphere. It is a relatively young field, and its borders are fluid. There is considerable overlap with the fields of ecology, evolutionary biology, microbiology, paleontology, and particularly biogeochemistry. Geobiology applies the principles and methods of biology and geology to the study of the ancient history of the co-evolution of life and Earth as well as the role of life in the modern world. Geobiologic studies tend to be focused on microorganisms, and on the role that life plays in altering the chemical and physical environment of the lithosphere, atmosphere, hydrosphere and/or cryosphere. It differs from biogeochemistry in that the focus is on processes and organisms over space and time rather than on global chemical cycles.

Geobiological research synthesizes the geologic record with modern biologic studies. It deals with process - how organisms affect the Earth and vice versa - as well as history - how the Earth and life have changed together. Much research is grounded in the search for fundamental understanding, but geobiology can also be applied, as in the case of microbes that clean up oil spills.

Geobiology employs molecular biology, environmental microbiology, chemical analyses, and the geologic record to investigate the evolutionary interconnectedness of life and Earth. It attempts to understand how the Earth has changed since the origin of life and what it might have been like along the way. Some definitions of geobiology even push the boundaries of this time frame - to understanding the origin of life and to the role that man has played and will continue to play in shaping the Earth in the Anthropocene.

Geochemist

Geochemistry is the science that uses the tools and principles of chemistry to explain the mechanisms behind major geological systems such as the Earth's crust and its oceans. The realm of geochemistry extends beyond the Earth, encompassing the entire Solar System, and has made important contributions to the understanding of a number of processes including mantle convection, the formation of planets and the origins of granite and basalt.

Geographer

Geography (from Greek: γεωγραφία, geographia, literally "earth description") is a field of science devoted to the study of the lands, features, inhabitants, and phenomena of the Earth and planets. The first person to use the word γεωγραφία was Eratosthenes (276–194 BC). Geography is an all-encompassing discipline that seeks an understanding of Earth and its human and natural complexities—not merely where objects are, but also how they have changed and come to be.

Geography is often defined in terms of two branches: human geography and physical geography. Human geography deals with the study of people and their communities, cultures, economies, and interactions with the environment by studying their relations with and across space and place. Physical geography deals with the study of processes and patterns in the natural environment like the atmosphere, hydrosphere, biosphere, and geosphere.

The four historical traditions in geographical research are: spatial analyses of natural and the human phenomena, area studies of places and regions, studies of human-land relationships, and the Earth sciences. Geography has been called "the world discipline" and "the bridge between the human and the physical sciences".

Geologist

A geologist is a scientist who studies the solid, liquid, and gaseous matter that constitutes the Earth and other terrestrial planets, as well as the processes that shape them. Geologists usually study geology, although backgrounds in physics, chemistry, biology, and other sciences are also useful. Field work is an important component of geology, although many subdisciplines incorporate laboratory work.

Geologists work in the energy and mining sectors searching for natural resources such as petroleum, natural gas, and precious metals. They are also in the forefront of preventing and mitigating damage from natural hazards and disasters such as earthquakes, volcanoes, tsunamis and landslides. Their studies are used to warn the general public of the occurrence of these events. Geologists are also important contributors to climate change discussions.

Geomicrobiologist

Geomicrobiology is the scientific field at the intersection of geology and microbiology. It concerns the effect of microbes on geological and geochemical processes and vice versa. Such interactions occur in the geosphere (rocks, minerals, soils, and sediments), the atmosphere and the hydrosphere. Applications include aquifers and public drinking water supplies.

Geomorphologist

Geomorphology (from Ancient Greek: γῆ, gê, "earth"; μορφή, morphḗ, "form"; and λόγος, lógos, "study") is the scientific study of the origin and evolution of topographic and bathymetric features created by physical, chemical or biological processes operating at or near the Earth's surface. Geomorphologists seek to understand why landscapes look the way they do, to understand landform history and dynamics and to predict changes through a combination of field observations, physical experiments and numerical modeling. Geomorphologists work within disciplines such as physical geography, geology, geodesy, engineering geology, archaeology, climatology and geotechnical engineering. This broad base of interests contributes to many research styles and interests within the field.

Geophysicist

Geophysics /dʒiːoʊfɪzɪks/ is a subject of natural science concerned with the physical processes and physical properties of the Earth and its surrounding space environment, and the use of quantitative methods for their analysis. The term geophysics sometimes refers only to the geological applications: Earth's shape; its gravitational and magnetic fields; its internal structure and composition; its dynamics and their surface expression in plate tectonics, the generation of magmas, volcanism and rock formation. However, modern geophysics organizations use a broader definition that includes the water cycle including snow and ice; fluid dynamics of the oceans and the atmosphere; electricity and magnetism in the ionosphere and magnetosphere and solar-terrestrial relations; and analogous problems associated with the Moon and other planets.

Although geophysics was only recognized as a separate discipline in the 19th century, its origins date back to ancient times. The first magnetic compasses were made from lodestones, while more modern magnetic compasses played an important role in the history of navigation. The first seismic instrument was built in 132 AD. Isaac Newton applied his theory of mechanics to the tides and the precession of the equinox; and instruments were developed to measure the Earth's shape, density and gravity field, as well as the components of the water cycle. In the 20th century, geophysical methods were developed for remote exploration of the solid Earth and the ocean, and geophysics played an essential role in the development of the theory of plate tectonics.

Geophysics is applied to societal needs, such as mineral resources, mitigation of natural hazards and environmental protection. In Exploration Geophysics, Geophysical survey data are used to analyze potential petroleum reservoirs and mineral deposits, locate groundwater, find archaeological relics, determine the thickness of glaciers and soils, and assess sites for environmental remediation.

Glaciologist

Glaciology (from Latin: glacies, "frost, ice", and Ancient Greek: λόγος, logos, "subject matter"; literally "study of ice") is the scientific study of glaciers, or more generally ice and natural phenomena that involve ice.

Glaciology is an interdisciplinary Earth science that integrates geophysics, geology, physical geography, geomorphology, climatology, meteorology, hydrology, biology, and ecology. The impact of glaciers on people includes the fields of human geography and anthropology. The discoveries of water ice on the Moon, Mars, Europa and Pluto add an extraterrestrial component to the field, as in "astroglaciology".

Hydrogeologist

Hydrogeology (hydro- meaning water, and -geology meaning the study of the Earth) is the area of geology that deals with the distribution and movement of groundwater in the soil and rocks of the Earth's crust (commonly in aquifers). The terms groundwater hydrology, geohydrology, and hydrogeology are often used interchangeably.

Groundwater engineering, another name for hydrogeology, is a branch of engineering which is concerned with groundwater movement and design of wells, pumps, and drains. The main concerns in groundwater engineering include groundwater contamination, conservation of supplies, and water quality.

Wells are constructed for use in developing nations, as well as for use in developed nations in places which are not connected to a city water system. Wells must be designed and maintained to uphold the integrity of the aquifer, and to prevent contaminants from reaching the groundwater. Controversy arises in the use of groundwater when its usage impacts surface water systems, or when human activity threatens the integrity of the local aquifer system.

Hydrologist

Hydrology (from Greek: ὕδωρ, "hýdōr" meaning "water"; and λόγος, "lógos" meaning "study") is the scientific study of the movement, distribution, and quality of water on Earth and other planets, including the water cycle, water resources and environmental watershed sustainability. A practitioner of hydrology is a hydrologist, working within the fields of earth or environmental science, physical geography, geology or civil and environmental engineering. Using various analytical methods and scientific techniques, they collect and analyze data to help solve water related problems such as environmental preservation, natural disasters, and water management.

Hydrology subdivides into surface water hydrology, groundwater hydrology (hydrogeology), and marine hydrology. Domains of hydrology include hydrometeorology, surface hydrology, hydrogeology, drainage-basin management and water quality, where water plays the central role.

Oceanography and meteorology are not included because water is only one of many important aspects within those fields.
Hydrological research can inform environmental engineering, policy and planning.

Hydrometeorologist

Hydrometeorology is a branch of meteorology and hydrology that studies the transfer of water and energy between the land surface and the lower atmosphere. Hydrologists often utilize meteorologists and products produced by meteorologists As an example, a meteorologist would forecast 2-3 inches of rain is a specific area, and a hydrologist would then forecast what the specific impact of that rain would be on the terrain. UNESCO has several programmes and activities in place that deal with the study of natural hazards of hydrometeorological origin and the mitigation of their effects. Among these hazards are the results of natural processes or atmospheric, hydrological, or oceanographic phenomena such as floods, tropical cyclones, drought and desertification. Many countries have established an operational hydrometeorological capability to assist with forecasting, warning, and informing the public of these developing hazards.

Limnologist

Limnology (/lɪmˈnɒlədʒi/ lim-NOL-ə-jee; from Greek λίμνη, limne, "lake" and λόγος, logos, "knowledge"), is the study of inland aquatic ecosystems. The study of limnology includes aspects of the biological, chemical, physical, and geological characteristics and functions of inland waters (running and standing waters, fresh and saline, natural or man-made). This includes the study of lakes, reservoirs, ponds, rivers, springs, streams, wetlands, and groundwater. A more recent sub-discipline of limnology, termed landscape limnology, studies, manages, and seeks to conserve these ecosystems using a landscape perspective, by explicitly examining connections between an aquatic ecosystem and its watershed. Recently, the need to understand global inland waters as part of the Earth System created a sub-discipline called global limnology. This approach considers the role of inland aquatic ecosystems in carbon cycling.

Limnology is closely related to aquatic ecology and hydrobiology, which study aquatic organisms and their interactions with the abiotic (non-living) environment. While limnology has substantial overlap with freshwater-focused disciplines (e.g., freshwater biology), it also includes the study of inland salt lakes.

Meteorologist

Meteorology is a branch of the atmospheric sciences which includes atmospheric chemistry and atmospheric physics, with a major focus on weather forecasting. The study of meteorology dates back millennia, though significant progress in meteorology did not occur until the 18th century. The 19th century saw modest progress in the field after weather observation networks were formed across broad regions. Prior attempts at prediction of weather depended on historical data. It was not until after the elucidation of the laws of physics and more particularly, the development of the computer, allowing for the automated solution of a great many equations that model the weather, in the latter half of the 20th century that significant breakthroughs in weather forecasting were achieved.

Meteorological phenomena are observable weather events that are explained by the science of meteorology. Meteorological phenomena are described and quantified by the variables of Earth's atmosphere: temperature, air pressure, water vapour, mass flow, and the variations and interactions of those variables, and how they change over time. Different spatial scales are used to describe and predict weather on local, regional, and global levels.

Meteorology, climatology, atmospheric physics, and atmospheric chemistry are sub-disciplines of the atmospheric sciences. Meteorology and hydrology compose the interdisciplinary field of hydrometeorology. The interactions between Earth's atmosphere and its oceans are part of a coupled ocean-atmosphere system. Meteorology has application in many diverse fields such as the military, energy production, transport, agriculture, and construction.
The word meteorology is from the Ancient Greek μετέωροςmetéōros (meteor) and -λογία -logia (-(o)logy), meaning "the study of things high in the air".

Mineralogist
Mineralogy is a subject of geology specializing in the scientific study of the chemistry, crystal structure, and physical (including optical) properties of minerals and mineralized artifacts. Specific studies within mineralogy include the processes of mineral origin and formation, classification of minerals, their geographical distribution, as well as their utilization.

Oceanographer
Oceanography (compound of the Greek words ὠκεανός meaning "ocean" and γράφω meaning "write"), also known as oceanology, is the study of the physical and biological aspects of the ocean. It is an Earth science, which covers a wide range of topics, including ecosystem dynamics; ocean currents, waves, and geophysical fluid dynamics; plate tectonics and the geology of the sea floor; and fluxes of various chemical substances and physical properties within the ocean and across its boundaries. These diverse topics reflect multiple disciplines that oceanographers blend to further knowledge of the world ocean and understanding of processes within: astronomy, biology, chemistry, climatology, geography, geology, hydrology, meteorology and physics. Paleoceanography studies the history of the oceans in the geologic past.

Paleoclimatologist

Paleoclimatology (in British spelling, palaeoclimatology) is the study of changes in climate taken on the scale of the entire history of Earth. It uses a variety of proxy methods from the Earth and life sciences to obtain data previously preserved within things such as rocks, sediments, ice sheets, tree rings, corals, shells, and microfossils. It then uses the records to determine the past states of the Earth's various climate regions and its atmospheric system. Studies of past changes in the environment and biodiversity often reflect on the current situation, specifically the impact of climate on mass extinctions and biotic recovery.

Paleoecologist

Paleoecology (also spelled palaeoecology) is the study of interactions between organisms and/or interactions between organisms and their environments across geologic timescales. As a discipline, paleoecology interacts with, depends on and informs a variety of fields including paleontology, ecology, climatology and biology.

Paleoecology emerged out of the field of paleontology in the 1950s, though paleontologists have conducted paleoecological studies since the creation of paleontology in the 1700s and 1800s. Combining the investigative approach of searching for fossils with the theoretical approach of Charles Darwin and Alexander von Humboldt, paleoecology began as paleontologists began examining both the ancient organisms they discovered and the reconstructed environments in which they lived. Visual depictions of past marine and terrestrial communities has been considered an early form of paleoecology.

Paleogeologist

Historical geology or paleogeology is a discipline that uses the principles and techniques of geology to reconstruct and understand the geological history of Earth. It focuses on geologic processes that change the Earth's surface and subsurface; and the use of stratigraphy, structural geology and paleontology to tell the sequence of these events. It also focuses on the evolution of plants and animals during different time periods in the geological timescale. The discovery of radioactivity and the development of several radiometric dating techniques in the first half of the 20th century provided a means of deriving absolute versus relative ages of geologic history.

Economic geology, the search for and extraction of fuel and raw materials, is heavily dependent on an understanding of the geological history of an area. Environmental geology, including most importantly the geologic hazards of earthquakes and volcanism, must also include a detailed knowledge of geologic history.

Paleoseismologist

Paleoseismology looks at geologic sediments and rocks, for signs of ancient earthquakes. It is used to supplement seismic monitoring, for the calculation of seismic hazard. Paleoseismology is usually restricted to geologic regimes that have undergone continuous sediment creation for the last few thousand years, such as swamps, lakes, river beds and shorelines.

In this typical example, a trench is dug in an active sedimentation regime. Evidence of thrust faulting can be seen in the walls of the trench. It becomes a matter of deducting the relative age of each fault, by cross-cutting patterns. The faults can be dated in absolute terms, if there is dateable carbon, or human artifacts.

Many notable discoveries have been made using the techniques of paleoseismology. For example, there is a common misconception that having many smaller earthquakes can somehow 'relieve' a major fault such as the San Andreas Fault, and reduce the chance of a major earthquake. It is now known (using paleoseismology) that nearly all the movement of the fault takes place with extremely large earthquakes. All of these seismic events (with a moment magnitude of over 8), leave some sort of trace in the sedimentation record.
Another famous example involves the megathrust earthquakes of the Pacific Northwest. It was thought for some time that there was low seismic hazard in the region because relatively few modern earthquakes have been recorded. It was thought that the Cascadia subduction zone was merely sliding in a benign manner.

All of these comforting notions were shattered by paleoseismology studies showing evidence of extremely large earthquakes (the most recent being in 1700), along with historical tsunami records. In effect, the subduction zone under British Columbia, Washington, Oregon, and far northern California, is perfectly normal, being extremely hazardous in the long term, with the capability of generating coastal tsunamis of several hundred feet in height at the coast. These are caused by the interface between the subducted sea floor stressing the overlaying coastal soils in compression. Periodically a slip will occur which causes the coastal portion to reduce in elevation and thrust toward the west, leading to tsunamis in the central and eastern north Pacific Ocean (with several hours of warning) and a reflux of water toward the coastal shore, with little time for residents to escape.

Palynologist

Palynology is the "study of dust" (from Greek: παλύνω, translit. palunō, "strew, sprinkle" and -logy) or "particles that are strewn". A classic palynologist analyses particulate samples collected from the air, from water, or from deposits including sediments of any age. The condition and identification of those particles, organic and inorganic, give the palynologist clues to the life, environment, and energetic conditions that produced them.

The term is sometimes narrowly used to refer to a subset of the discipline, which is defined as "the study of microscopic objects of macromolecular organic composition (i.e., compounds of carbon, hydrogen, nitrogen and oxygen), not capable of dissolution in hydrochloric or hydrofluoric acids". It is the science that studies contemporary and fossil palynomorphs, including pollen, spores, orbicules, dinocysts, acritarchs, chitinozoans and scolecodonts, together with particulate organic matter (POM) and kerogen found in sedimentary rocks and sediments. Palynology does not include diatoms, foraminiferans or other organisms with siliceous or calcareous exoskeletons.

Palynology is an interdisciplinary science and is a branch of earth science (geology or geological science) and biological science (biology), particularly plant science (botany). Stratigraphical palynology is a branch of micropalaeontology and paleobotany, which studies fossil palynomorphs from the Precambrian to the Holocene.

Petrologist

Petrology (from the Greek πέτρος, pétros, "rock" and λόγος, lógos, "subject matter", see -logy) is the branch of geology that studies rocks and the conditions under which they form. Petrology has three subdivisions: igneous, metamorphic, and sedimentary petrology. Igneous and metamorphic petrology are commonly taught together because they both contain heavy use of chemistry, chemical methods, and phase diagrams. Sedimentary petrology is, on the other hand, commonly taught together with stratigraphy because it deals with the processes that form sedimentary rock.

Lithology was once approximately synonymous with petrography, but in current usage, lithology focuses on macroscopic hand-sample or outcrop-scale description of rocks while petrography is the speciality that deals with microscopic details.
In the petroleum industry, lithology, or more specifically mud logging, is the graphic representation of geological formations being drilled through, and drawn on a log called a mud log. As the cuttings are circulated out of the borehole they are sampled, examined (typically under a 10× microscope) and tested chemically when needed.

Sedimentologist
Sedimentology encompasses the study of modern sediments such as sand, silt, and clay, and the processes that result in their formation (erosion and weathering), transport, deposition and diagenesis. Sedimentologists apply their understanding of modern processes to interpret geologic history through observations of sedimentary rocks and sedimentary structures.

Sedimentary rocks cover up to 75% of the Earth's surface, record much of the Earth's history, and harbor the fossil record. Sedimentology is closely linked to stratigraphy, the study of the physical and temporal relationships between rock layers or strata.

The premise that the processes affecting the earth today are the same as in the past is the basis for determining how sedimentary features in the rock record were formed. By comparing similar features today to features in the rock record—for example, by comparing modern sand dunes to dunes preserved in ancient aeolian sandstones—geologists reconstruct past environments.

Seismologist
Seismology (/saɪzˈmɒlədʒi/; from Ancient Greek σεισμός (seismós) meaning "earthquake" and -λογία (-logía) meaning "study of") is the scientific study of earthquakes and the propagation of elastic waves through the Earth or through other planet-like bodies. The field also includes studies of earthquake environmental effects such as tsunamis as well as diverse seismic sources such as volcanic, tectonic, oceanic, atmospheric, and artificial processes such as explosions. A related field that uses geology to infer information regarding past earthquakes is paleoseismology. A recording of earth motion as a function of time is

called a seismogram. A seismologist is a scientist who does research in seismology.

Speleologist

Speleology is the scientific study of caves and other karst features, as well as their make-up, structure, physical properties, history, life forms, and the processes by which they form (speleogenesis) and change over time (speleomorphology). The term speleology is also sometimes applied to the recreational activity of exploring caves, but this is more properly known as caving or potholing, or (not usually by participants) by the uncommon American term spelunking. Speleology and caving are often connected, as the physical skills required for in situ study are the same.

Speleology is a cross-disciplinary field that combines the knowledge of chemistry, biology, geology, physics, meteorology, and cartography to develop portraits of caves as complex, evolving systems.

Volcanologist

Volcanology (also spelled vulcanology) is the study of volcanoes, lava, magma, and related geological, geophysical and geochemical phenomena. The term volcanology is derived from the Latin word vulcan. Vulcan was the ancient Roman god of fire.

A volcanologist is a geologist who studies the eruptive activity and formation of volcanoes, and their current and historic eruptions. Volcanologists frequently visit volcanoes, especially active ones, to observe volcanic eruptions, collect eruptive products including tephra (such as ash or pumice), rock and lava samples. One major focus of enquiry is the prediction of eruptions; there is currently no accurate way to do this, but predicting eruptions, like predicting earthquakes, could save many lives.

Physicist

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Agrophysicist

Agrophysics is a branch of science bordering on agronomy and physics, whose objects of study are the agroecosystem - the biological objects, biotope and biocoenosis affected by human activity, studied and described using the methods of physical sciences. Using the achievements of the exact sciences to solve major problems in agriculture, agrophysics involves the study of materials and processes occurring in the production and processing of agricultural crops, with particular emphasis on the condition of the environment and the quality of farming materials and food production.

Agrophysics is closely related to biophysics, but is restricted to the biology of the plants, animals, soil and an atmosphere involved in agricultural activities and biodiversity. It is different from biophysics in having the necessity of taking into account the specific features of biotope and biocoenosis, which involves the knowledge of nutritional science and agroecology, agricultural technology, biotechnology, genetics etc.

The needs of agriculture, concerning the past experience study of the local complex soil and next plant-atmosphere systems, lay at the root of the emergence of a new branch – agrophysics – dealing this with experimental physics. The scope of the branch starting from soil science (physics) and originally limited to the study of relations within the soil environment, expanded over time onto influencing the properties of agricultural crops and produce as foods and raw postharvest materials, and onto the issues of quality, safety and labeling concerns, considered distinct from the field of nutrition for application in food science.

Research centres focused on the development of the agrophysical sciences include the Institute of Agrophysics, Polish Academy of Sciences in Lublin, and the Agrophysical Research Institute, Russian Academy of Sciences in St. Petersburg.

Astrophysicist

Astrophysics is the branch of astronomy that employs the principles of physics and chemistry "to ascertain the nature of the astronomical objects, rather than their positions or motions in space". Among the objects studied are the Sun, other stars, galaxies, extrasolar planets, the interstellar medium and the cosmic microwave background. Their emissions are examined across all parts of the electromagnetic spectrum, and the properties examined include luminosity, density, temperature, and chemical composition. Because astrophysics is a very broad subject, astrophysicists typically apply many disciplines of physics, including mechanics, electromagnetism, statistical mechanics, thermodynamics, quantum mechanics, relativity, nuclear and particle physics, and atomic and molecular physics.

In practice, modern astronomical research often involves a substantial amount of work in the realms of theoretical and observational physics. Some areas of study for astrophysicists include their attempts to determine the properties of dark matter, dark energy, and black holes; whether or not time travel is possible, wormholes can form, or the multiverse exists; and the origin and ultimate fate of the universe. Topics also studied by theoretical astrophysicists include Solar System formation and evolution; stellar dynamics and evolution; galaxy formation and evolution; magnetohydrodynamics; large-scale structure of matter in the universe; origin of cosmic rays; general relativity and physical cosmology, including string cosmology and astroparticle physics.

Atmospheric physicist

Atmospheric physics is the application of physics to the study of the atmosphere. Atmospheric physicists attempt to model Earth's atmosphere and the atmospheres of the other planets using fluid flow equations, chemical models, radiation budget, and energy transfer processes in the atmosphere (as well as how these tie into other systems such as the oceans). In order to model weather systems, atmospheric physicists employ elements of scattering theory, wave propagation models, cloud physics, statistical mechanics and spatial statistics which are highly mathematical and related to physics. It has close links to meteorology and climatology and also covers the design and construction of instruments for studying the atmosphere and the interpretation of the data they provide, including remote sensing instruments. At the dawn of the space age and the introduction of sounding rockets, aeronomy became a subdiscipline concerning the upper layers of the atmosphere, where dissociation and ionization are important.

Atomic physicist

Atomic physics is the field of physics that studies atoms as an isolated system of electrons and an atomic nucleus. It is primarily concerned with the arrangement of electrons around the nucleus and the processes by which these arrangements change. This comprises ions, neutral atoms and, unless otherwise stated, it can be assumed that the term atom includes ions.

The term atomic physics can be associated with nuclear power and nuclear weapons, due to the synonymous use of atomic and nuclear in standard English. Physicists distinguish between atomic physics — which deals with the atom as a system consisting of a nucleus and electrons — and nuclear physics, which considers atomic nuclei alone.

As with many scientific fields, strict delineation can be highly contrived and atomic physics is often considered in the wider context of atomic, molecular, and optical physics. Physics research groups are usually so classified.

Chemical physicist

Chemical physics is a subdiscipline of chemistry and physics that investigates physicochemical phenomena using techniques from atomic and molecular physics and condensed matter physics; it is the branch of physics that studies chemical processes from the point of view of physics. While at the interface of physics and chemistry, chemical physics is distinct from physical chemistry in that it focuses more on the characteristic elements and theories of physics. Meanwhile, physical chemistry studies the physical nature of chemistry. Nonetheless, the distinction between the two fields is vague, and workers often practice in both fields during the course of their research.

The United States Department of Education defines chemical physics as "A program that focuses on the scientific study of structural phenomena combining the disciplines of physical chemistry and atomic/molecular physics. Includes instruction in heterogeneous structures, alignment and surface phenomena, quantum theory, mathematical physics, statistical and classical mechanics, chemical kinetics, and laser physics.

Computational physicist

Computational physics is the study and implementation of numerical analysis to solve problems in physics for which a quantitative theory already exists. Historically, computational physics was the first application of modern computers in science, and is now a subset of computational science.

It is sometimes regarded as a subdiscipline (or offshoot) of theoretical physics, but others consider it an intermediate branch between theoretical and experimental physics, a third way that supplements theory and experiment.

Cosmologist

Cosmology (from the Greek κόσμος, kosmos "world" and -λογία, -logia "study of") is a branch of astronomy concerned with the studies of the origin and evolution of the universe, from the Big Bang to today and on into the future. It is the scientific study of the origin, evolution, and eventual fate of the universe. Physical cosmology is the scientific study of the universe's origin, its large-scale structures and dynamics, and its ultimate fate, as well as the laws of science that govern these areas.

The term cosmology was first used in English in 1656 in Thomas Blount's Glossographia, and in 1731 taken up in Latin by German philosopher Christian Wolff, in CosmologiaGeneralis.

Religious or mythological cosmology is a body of beliefs based on mythological, religious, and esoteric literature and traditions of creation myths and eschatology.

Physical cosmology is studied by scientists, such as astronomers and physicists, as well as philosophers, such as metaphysicians, philosophers of physics, and philosophers of space and time. Because of this shared scope with philosophy, theories in physical cosmology may include both scientific and non-scientific propositions, and may depend upon assumptions that cannot be tested. Cosmology differs from astronomy in that the former is concerned with the Universe as a whole while the latter deals with individual celestial objects. Modern physical cosmology is dominated by the Big Bang theory, which attempts to bring together observational astronomy and particle physics; more specifically, a standard parameterization of the Big Bang with dark matter and dark energy, known as the Lambda-CDM model.

Theoretical astrophysicist David N. Spergel has described cosmology as a "historical science" because "when we look out in space, we look back in time" due to the finite nature of the speed of light.

Condensed-matter physicist

Condensed matter physics is the field of physics that deals with the macroscopic and microscopic physical properties of matter. In particular it is concerned with the "condensed" phases that appear whenever the number of constituents in a system is extremely large and the interactions between the constituents are strong. The most familiar examples of condensed phases are solids and liquids, which arise from the electromagnetic forces between atoms. Condensed matter physicists seek to understand the behavior of these phases by using physical laws. In particular, they include the laws of quantum mechanics, electromagnetism and statistical mechanics.

The most familiar condensed phases are solids and liquids while more exotic condensed phases include the superconducting phase exhibited by certain materials at low temperature, the ferromagnetic and antiferromagnetic phases of spins on crystal lattices of atoms, and the Bose–Einstein condensate found in ultracold atomic systems. The study of condensed matter physics involves measuring various material properties via experimental probes along with using methods of theoretical physics to develop mathematical models that help in understanding physical behavior.

The diversity of systems and phenomena available for study makes condensed matter physics the most active field of contemporary physics: one third of all American physicists self-identify as condensed matter physicists, and the Division of Condensed Matter Physics is the largest division at the American Physical Society. The field overlaps with chemistry, materials science, and nanotechnology, and relates closely to atomic physics and biophysics. The theoretical physics of condensed matter shares important concepts and methods with that of particle physics and nuclear physics.

A variety of topics in physics such as crystallography, metallurgy, elasticity, magnetism, etc., were treated as distinct areas until the 1940s, when they were grouped together as solid state physics. Around the 1960s, the study of physical properties of liquids was added to this list, forming the basis for the new, related specialty of condensed matter physics. According to physicist Philip Warren Anderson, the term was coined by him and Volker Heine, when they changed the name of their group at the Cavendish Laboratories, Cambridge from Solid state theory to Theory of Condensed Matter in 1967, as they felt it did not exclude their interests in the study of liquids, nuclear matter, and so on. Although Anderson and Heine helped popularize the name "condensed matter", it had been present in Europe for some years, most prominently in the form of a journal published in English, French, and German by Springer-Verlag titled Physics of Condensed Matter, which was launched in 1963. The funding environment and Cold War politics of the 1960s and 1970s were also factors that lead some physicists to prefer the name "condensed matter physics", which emphasized the commonality of scientific problems encountered by physicists working on solids, liquids, plasmas, and other complex matter, over "solid state physics", which was often associated with the industrial applications of metals and semiconductors. The Bell Telephone Laboratories was one of the first institutes to conduct a research program in condensed matter physics.

References to "condensed" state can be traced to earlier sources. For example, in the introduction to his 1947 book Kinetic Theory of Liquids, Yakov Frenkel proposed that "The kinetic theory of liquids must accordingly be developed as a generalization and extension of the kinetic theory of solid bodies. As a matter of fact, it would be more correct to unify them under the title of 'condensed bodies'".

Engineering physicist

Engineering physics or engineering science refers to the study of the combined disciplines of physics, mathematics and engineering, particularly computer, nuclear, electrical, electronic, materials or mechanical engineering. By focusing on the scientific method as a rigorous basis, it seeks ways to apply, design, and develop new solutions in engineering.

Material physicist

Material physics is the use of physics to describe the physical properties of materials. It is a synthesis of physical sciences such as chemistry, solid mechanics, solid state physics, and materials science. Materials physics is considered a subset of condensed matter physics and applies fundamental condensed matter concepts to complex multiphase media, including materials of technological interest.

Current fields that materials physicists work in include electronic, optical, and magnetic materials, novel materials and structures, quantum phenomena in materials, nonequilibrium physics, and soft condensed matter physics. New experimental and computational tools are constantly improving how materials systems are modeled and studied and are also fields when materials physicists work in.

Molecular physicist

Molecular physics is the study of the physical properties of molecules, the chemical bonds between atoms as well as the molecular dynamics. Its most important experimental techniques are the various types of spectroscopy; scattering is also used. The field is closely related to atomic physics and overlaps greatly with theoretical chemistry, physical chemistry and chemical physics.

In addition to the electronic excitation states which are known from atoms, molecules exhibit rotational and vibrational modes whose energy levels are quantized. The smallest energy differences exist between different rotational states: pure rotational spectra are in the far infrared region (about 30 - 150 µm wavelength) of the electromagnetic spectrum. Vibrational spectra are in the near infrared (about 1 - 5 µm) and spectra resulting from electronic transitions are mostly in the visible and ultraviolet regions. From measuring rotational and vibrational spectra properties of molecules like the distance between the nuclei can be specifically calculated.

One important aspect of molecular physics is that the essential atomic orbital theory in the field of atomic physics expands to the molecular orbital theory.

Nuclear physicist

Nuclear physics is the field of physics that studies atomic nuclei and their constituents and interactions. Other forms of nuclear matter are also studied. Nuclear physics should not be confused with atomic physics, which studies the atom as a whole, including its electrons.

Discoveries in nuclear physics have led to applications in many fields. This includes nuclear power, nuclear weapons, nuclear medicine and magnetic resonance imaging, industrial and agricultural isotopes, ion implantation in

materials engineering, and radiocarbon dating in geology and archaeology. Such applications are studied in the field of nuclear engineering.
Particle physics evolved out of nuclear physics and the two fields are typically taught in close association. Nuclear astrophysics, the application of nuclear physics to astrophysics, is crucial in explaining the inner workings of stars and the origin of the chemical elements.

Particle physicist

Particle physics (also known as high energy physics) is a branch of physics that studies the nature of the particles that constitute matter and radiation. Although the word particle can refer to various types of very small objects (e.g. protons, gas particles, or even household dust), particle physics usually investigates the irreducibly smallest detectable particles and the fundamental interactions necessary to explain their behaviour. By our current understanding, these elementary particles are excitations of the quantum fields that also govern their interactions. The currently dominant theory explaining these fundamental particles and fields, along with their dynamics, is called the Standard Model. Thus, modern particle physics generally investigates the Standard Model and its various possible extensions, e.g. to the newest "known" particle, the Higgs boson, or even to the oldest known force field, gravity.

Plasma physicist

Plasma (from Ancient Greek πλάσμα, meaning 'moldable substance') is one of the four fundamental states of matter, and was first described by chemist Irving Langmuir in the 1920s. Plasma can be artificially generated by heating or subjecting a neutral gas to a strong electromagnetic field to the point where an ionized gaseous substance becomes increasingly electrically conductive, and long-range electromagnetic fields dominate the behaviour of the matter.

Plasma and ionized gases have properties and display behaviours unlike those of the other states, and the transition between them is mostly a matter of nomenclature and subject to interpretation. Based on the surrounding environmental temperature and density, partially ionized or fully ionized forms of plasma may be produced. Neon signs and lightning are examples of partially ionized plasma. The Earth's ionosphere is a plasma and the magnetosphere contains plasma in the Earth's surrounding space environment. The interior of the Sun is an example of fully ionized plasma, along with the solar corona and stars.

Positive charges in ions are achieved by stripping away electrons orbiting the atomic nuclei, where the total number of electrons removed is related to either increasing temperature or the local density of other ionized matter. This also can be accompanied by the dissociation of molecular bonds, though this process is distinctly different from chemical processes of ion interactions in liquids or the behaviour of shared ions in metals. The response of plasma to electromagnetic fields is used in many modern technological devices, such as plasma televisions or plasma etching.
Plasma may be the most abundant form of ordinary matter in the universe, although this hypothesis is currently tentative based on the existence and unknown properties of dark matter. Plasma is mostly associated with stars, extending to the rarefied intracluster medium and possibly the intergalactic regions.

Polymer physicist
Polymer physics is the field of physics that studies polymers, their fluctuations, mechanical properties, as well as the kinetics of reactions involving degradation and polymerisation of polymers and monomers respectively.
While it focuses on the perspective of condensed matter physics, polymer physics is originally a branch of statistical physics. Polymer physics and polymer chemistry are also related with the field of polymer science, where this is considered the applicative part of polymers.

Polymers are large molecules and thus are very complicated for solving using a deterministic method. Yet, statistical approaches can yield results and are often pertinent, since large polymers (i.e., polymers with a large number of monomers) are describable efficiently in the thermodynamic limit of infinitely many monomers (although the actual size is clearly finite).

Thermal fluctuations continuously affect the shape of polymers in liquid solutions, and modeling their effect requires using principles from statistical mechanics and dynamics. As a corollary, temperature strongly affects the physical behavior of polymers in solution, causing phase transitions, melts, and so on.

The statistical approach for polymer physics is based on an analogy between a polymer and either a Brownian motion, or other type of a random walk, the self-avoiding walk. The simplest possible polymer model is presented by the ideal chain, corresponding to a simple random walk. Experimental approaches for characterizing polymers are also common, using polymer characterization methods, such as size exclusion chromatography, viscometry, dynamic light scattering, and Automatic Continuous Online Monitoring of Polymerization Reactions (ACOMP) for determining the chemical, physical, and material properties of polymers. These experimental methods also helped the mathematical modeling of polymers and even for a better understanding of the properties of polymers.

Psychophysicist

Psychophysics quantitatively investigates the relationship between physical stimuli and the sensations and perceptions they produce. Psychophysics has been described as "the scientific study of the relation between stimulus and sensation" or, more completely, as "the analysis of perceptual processes by studying the effect on a subject's experience or behaviour of systematically varying the properties of a stimulus along one or more physical dimensions".

Psychophysics also refers to a general class of methods that can be applied to study a perceptual system. Modern applications rely heavily on threshold measurement, ideal observer analysis, and signal detection theory.

Psychophysics has widespread and important practical applications. For example, in the study of digital signal processing, psychophysics has informed the development of models and methods of lossy compression. These models explain why humans perceive very little loss of signal quality when audio and video signals are formatted using lossy compression.

Quantum physicist

Quantum mechanics (QM; also known as quantum physics, quantum theory, the wave mechanical model, or matrix mechanics), including quantum field theory, is a fundamental theory in physics which describes nature at the smallest scales of energy levels of atoms and subatomic particles.

Classical physics, the physics existing before quantum mechanics, describes nature at ordinary (macroscopic) scale. Most theories in classical physics can be derived from quantum mechanics as an approximation valid at large (macroscopic) scale. Quantum mechanics differs from classical physics in that energy, momentum, angular momentum and other quantities of a bound system are restricted to discrete values (quantization); objects have characteristics of both particles and waves (wave-particle duality); and there are limits to the precision with which quantities can be measured (uncertainty principle).

Quantum mechanics gradually arose from theories to explain observations which could not be reconciled with classical physics, such as Max Planck's solution in 1900 to the black-body radiation problem, and from the correspondence between energy and frequency in Albert Einstein's 1905 paper which explained the photoelectric effect. Early quantum theory was profoundly re-conceived in the mid-1920s by Erwin Schrödinger, Werner Heisenberg, Max Born and others. The modern theory is formulated in various specially developed mathematical formalisms. In one of them, a mathematical function, the wave function, provides information about the probability amplitude of position, momentum, and other physical properties of a particle.

Important applications of quantum theory include quantum chemistry, quantum optics, quantum computing, superconducting magnets, light-emitting diodes, and the laser, the transistor and semiconductors such as the microprocessor, medical and research imaging such as magnetic resonance imaging and electron microscopy. Explanations for many biological and physical phenomena are rooted in the nature of the chemical bond, most notably the macro-molecule DNA.

Theoretical physicist

Theoretical physics is a branch of physics that employs mathematical models and abstractions of physical objects and systems to rationalize, explain and predict natural phenomena. This is in contrast to experimental physics, which uses experimental tools to probe these phenomena.

The advancement of science generally depends on the interplay between experimental studies and theory. In some cases, theoretical physics adheres to standards of mathematical rigor while giving little weight to experiments and observations. For example, while developing special relativity, Albert Einstein was concerned with the Lorentz transformation which left Maxwell's equations invariant, but was apparently uninterested in the Michelson–Morley experiment on Earth's drift through a luminiferous ether. Conversely, Einstein was awarded the Nobel Prize for explaining the photoelectric effect, previously an experimental result lacking a theoretical formulation.

ii Life Science

Biologist

A biologist is a scientist who has specialized knowledge in the field of biology, the scientific study of life. Biologists involved in fundamental research attempt to explore and further explain the underlying mechanisms that govern the functioning of living matter. Biologists involved in applied research attempt to develop or improve more specific processes and understanding, in fields such as medicine and industry.

Biologists are interested in understanding the underlying mechanisms that govern the functioning of living matter as well as the complex properties that emerge from the biophysical, biochemical, cellular and systemic interactions of living systems. Biologists conduct research using the scientific method to test the validity of a theory in a rational, unbiased and reproducible manner. This consists of hypothesis formation, experimentation and data analysis to establish the validity or invalidity of a scientific theory.

There are different types of biologists. Theoretical biologists use mathematical methods and develop models to understand phenomena and ideally predict future experimental results, while experimental biologists conceive experiments to test those predictions. Some biologists work on microorganisms, while others study multicellular organisms (including humans). Some investigate the nano or micro-scale, others emergent properties such as ecological interactions or cognition. There is much overlap between different fields of biology (e.g. zoology, microbiology, genetics and evolutionary biology) and due to the interdisciplinary nature of the field it is often difficult to classify a life scientist as only one of them. Many biological scientists work in research and development. Some conduct fundamental research to advance human knowledge of life. Furthermore, applied biological research often aids the development of solutions to problems in areas such as human health and the natural environment. Biological scientists mostly work in government, university, and private industry laboratories.

Acarologist

Acarology (from Greek ἀκαρί/ἄκαρι, akari, a type of mite; and -λογία, -logia) is the study of mites and ticks, the animals in the order Acarina. It is a subfield of arachnology, a sub-discipline of the field of zoology. A zoologist specializing in acarology is called an acarologist. There are many acarologists studying around the world both professionally and amateur. It is a developing science and long awaited research has been provided for it in more recent history.

Aerobiologist

Aerobiology (from Greek ἀήρ, aēr, "air"; βίος, bios, "life"; and -λογία, -logia) is a branch of biology that studies organic particles, such as bacteria, fungal spores, very small insects, pollen grains and viruses, which are passively transported by the air. Aerobiologists have traditionally been involved in the measurement and reporting of airborne pollen and fungal spores as a service to allergy sufferers.

The first finding of airborne algae took place in Germany in 1910.

The minimum requirements published after a big consensus are an international standard to ensure the quality in Aerobiological method.

Anatomist

Anatomy (Greek anatomē, "dissection") is the branch of biology concerned with the study of the structure of organisms and their parts. Anatomy is a branch of natural science which deals with the structural organization of living things. It is an old science, having its beginnings in prehistoric times. Anatomy is inherently tied to developmental biology, embryology, comparative anatomy, evolutionary biology, and phylogeny, as these are the processes by which anatomy is generated over immediate (embryology) and long (evolution) timescales. Anatomy and physiology, which study (respectively) the structure and function of organisms and their parts, make a natural pair of related disciplines, and they are often studied together. Human anatomy is one of the essential basic sciences that are applied in medicine.

The discipline of anatomy is divided into macroscopic and microscopic anatomy. Macroscopic anatomy, or gross anatomy, is the examination of an animal's body parts using unaided eyesight. Gross anatomy also includes the branch of superficial anatomy. Microscopic anatomy involves the use of optical instruments in the study of the tissues of various structures, known as histology, and also in the study of cells.

The history of anatomy is characterized by a progressive understanding of the functions of the organs and structures of the human body. Methods have also improved dramatically, advancing from the examination of animals by dissection of carcasses and cadavers (corpses) to 20th century medical imaging techniques including X-ray, ultrasound, and magnetic resonance imaging.

Arachnologist

Arachnology is the scientific study of spiders and related animals such as scorpions, pseudoscorpions, and harvestmen, collectively called arachnids. Those who study spiders and other arachnids are arachnologists.
The word arachnology derives from Greek ἀράχνη, arachnē, "spider"; and -λογία, -logia.

Bacteriologist

Bacteriology is the branch and specialty of biology that studies the morphology, ecology, genetics and biochemistry of bacteria as well as many other aspects related to them. This subdivision of microbiology involves the identification, classification, and characterization of bacterial species. Because of the similarity of thinking and working with microorganisms other than bacteria, such as protozoa, fungi, and viruses, there has been a tendency for the field of bacteriology to extend as microbiology. The terms were formerly often used interchangeably. However, bacteriology can be classified as a distinct science.

Biochemist

Bioclimatologist

Bioclimatology is the interdisciplinary field of science that studies the interactions between the biosphere and the Earth's atmosphere on time scales of the order of seasons or longer (by opposition to biometeorology).

Biogeographer

Biogeography is the study of the distribution of species and ecosystems in geographic space and through geological time. Organisms and biological communities often vary in a regular fashion along geographic gradients of latitude, elevation, isolation and habitat area. Phytogeography is the branch of biogeography that studies the distribution of plants. Zoogeography is the branch that studies distribution of animals.

Knowledge of spatial variation in the numbers and types of organisms is as vital to us today as it was to our early human ancestors, as we adapt to heterogeneous but geographically predictable environments. Biogeography is an integrative field of inquiry that unites concepts and information from ecology, evolutionary biology, geology, and physical geography.

Modern biogeographic research combines information and ideas from many fields, from the physiological and ecological constraints on organismal dispersal to geological and climatological phenomena operating at global spatial scales and evolutionary time frames.

The short-term interactions within a habitat and species of organisms describe the ecological application of biogeography. Historical biogeography describes the long-term, evolutionary periods of time for broader classifications of organisms. Early scientists, beginning with Carl Linnaeus, contributed to the development of biogeography as a science. Beginning in the mid-18th century, Europeans explored the world and discovered the biodiversity of life.

Biotechnologist

Biotechnology is the broad area of biology involving living systems and organisms to develop or make products, or "any technological application that uses biological systems, living organisms, or derivatives thereof, to make or modify products or processes for specific use" (UN Convention on Biological Diversity, Art. 2). Depending on the tools and applications, it often overlaps with the (related) fields of molecular biology, bio-engineering, biomedical engineering, biomanufacturing, molecular engineering, etc.

For thousands of years, humankind has used biotechnology in agriculture, food production, and medicine. The term is largely believed to have been coined in 1919 by Hungarian engineer KárolyEreky. In the late 20th and early 21st centuries, biotechnology has expanded to include new and diverse sciences such as genomics, recombinant gene techniques, applied immunology, and development of pharmaceutical therapies and diagnostic tests.

Bioarcheologist

The term bioarchaeology was first coined by British archaeologist Grahame Clark in 1972 as a reference to zooarchaeology, or the study of animal bones from archaeological sites. Redefined in 1977 by Jane

Buikstra, bioarchaeology in the US now refers to the scientific study of human remains from archaeological sites, a discipline known in other countries as osteoarchaeology or palaeo-osteology. In England and other European countries, the term 'bioarchaeology' is borrowed to cover all biological remains from sites.

Bioarchaeology was largely born from the practices of New Archaeology, which developed in the US in the 1970s as a reaction to a mainly cultural-historical approach to understanding the past. Proponents of New Archaeology advocated using processual methods to test hypotheses about the interaction between culture and biology, or a biocultural approach. Some archaeologists advocate a more holistic approach to bioarchaeology that incorporates critical theory and is more relevant to modern descent populations.

Biolinguist

Biolinguistics is the study of the biology and evolution of language. It is a highly interdisciplinary field, including linguists, biologists, neuroscientists, psychologists, mathematicians, and others. By shifting the focus of investigation in linguistics to a comprehensive scheme that embraces natural sciences, it seeks to yield a framework by which we can understand the fundamentals of the faculty of language.

Botanist

Botany, also called plant science(s), plant biology or phytology, is the science of plant life and a branch of biology. A botanist, plant scientist or phytologist is a scientist who specialises in this field. The term "botany" comes from the Ancient Greek word βοτάνη (botanē) meaning "pasture", "grass", or "fodder"; βοτάνη is in turn derived from βόσκειν (boskein), "to feed" or "to graze". Traditionally, botany has also included the study of fungi and algae by mycologists and phycologists respectively, with the study of these three groups of organisms remaining within the sphere of interest of the International Botanical Congress. Nowadays, botanists (in the strict sense) study approximately 410,000 species of land plants of which some 391,000 species are vascular plants (including approximately 369,000 species of flowering plants), and approximately 20,000 are bryophytes.

Botany originated in prehistory as herbalism with the efforts of early humans to identify – and later cultivate – edible, medicinal and poisonous plants, making it one of the oldest branches of science. Medieval physic gardens, often attached to monasteries, contained plants of medical importance. They were forerunners of the first botanical gardens attached to universities, founded from the 1540s onwards. One of the earliest was the Padua botanical garden. These gardens facilitated the academic study of plants. Efforts to catalogue and describe their collections were the beginnings of plant taxonomy, and led in 1753 to the binomial system of Carl Linnaeus that remains in use to this day.

In the 19th and 20th centuries, new techniques were developed for the study of plants, including methods of optical microscopy and live cell imaging, electron microscopy, analysis of chromosome number, plant chemistry and the structure and function of enzymes and other proteins. In the last two decades of the 20th century, botanists exploited the techniques of molecular genetic analysis, including genomics and proteomics and DNA sequences to classify plants more accurately.

Modern botany is a broad, multidisciplinary subject with inputs from most other areas of science and technology. Research topics include the study of plant structure, growth and differentiation, reproduction, biochemistry and primary metabolism, chemical products, development, diseases, evolutionary relationships, systematics, and plant taxonomy. Dominant themes in 21st century plant science are molecular genetics and epigenetics, which are the mechanisms and control of gene expression during differentiation of plant cells and tissues. Botanical research has diverse applications in providing staple foods, materials such as timber, oil, rubber, fibre and drugs, in modern horticulture, agriculture and forestry, plant propagation, breeding and genetic modification, in the synthesis of chemicals and raw materials for construction and energy production, in environmental management, and the maintenance of biodiversity.

Cell biologist

Cell biology (also called cytology, from the Greek κύτος, kytos, "vessel") is a branch of biology that studies the structure and function of the cell, which is the basic unit of life. Cell biology is concerned with the physiological properties, metabolic processes, signaling pathways, life cycle, chemical composition and interactions of the cell with their environment. This is done both on a microscopic and molecular level as it encompasses prokaryotic cells and eukaryotic cells. Knowing the components of cells and how cells work is fundamental to all biological sciences; it is also essential for research in bio-medical fields such as cancer, and other diseases. Research in cell biology is closely related to genetics, biochemistry, molecular biology, immunology and cytochemistry .

Chronobiologist

Chronobiology is a field of biology that examines periodic (cyclic) phenomena in living organisms and their adaptation to solar- and lunar-related rhythms. These cycles are known as biological rhythms. Chronobiology comes from the ancient Greek χρόνος (chrónos, meaning "time"), and biology, which pertains to the study, or science, of life. The related terms chronomics and chronome have been used in some cases to describe either the molecular mechanisms involved in chronobiological phenomena or the more quantitative aspects of chronobiology, particularly where comparison of cycles between organisms is required.

Chronobiological studies include but are not limited to comparative anatomy, physiology, genetics, molecular biology and behavior of organisms within biological rhythms mechanics. Other aspects include epigenetics, development, reproduction, ecology and evolution.

Cognitive biologist

Cognitive biology is an emerging science that regards natural cognition as a biological function. It is based on the theoretical assumption that every organism—whether a single cell or multicellular—is continually engaged in systematic acts of cognition coupled with intentional behaviors, i.e., a sensory-motor coupling. That is to say, if an organism can sense stimuli in its environment and respond accordingly, it is cognitive. Any explanation of how natural cognition may manifest in an organism is constrained by the biological conditions in which its genes survives from one generation to the next. And since by Darwinian theory the species of every organism is evolving from a common root, three further elements of cognitive biology are required: (i) the study of cognition in one species of organism is useful, through contrast and comparison, to the study of another species' cognitive abilities; (ii) it is useful to proceed from organisms with simpler to those with more complex cognitive systems, and (iii) the greater the number and variety of species studied in this regard, the more we understand the nature of cognition.

Cognitive neuroscientist

The term cognitive neuroscience was coined by George Armitage Miller and Michael Gazzaniga in year 1976. Cognitive neuroscience is the scientific field that is concerned with the study of the biological processes and aspects that underlie cognition, with a specific focus on the neural connections in the brain which are involved in mental processes. It addresses the questions of how cognitive activities are affected or controlled by neural circuits in the brain. Cognitive neuroscience is a branch of both neuroscience and psychology, overlapping with disciplines such as behavioral neuroscience, cognitive psychology, physiological psychology and affective neuroscience. Cognitive neuroscience relies upon theories in cognitive science coupled with evidence from neurobiology, and computational modeling.

Parts of the brain play an important role in this field. Neurons play the most vital role, since the main point is to establish an understanding of cognition from a neural perspective, along with the different lobes of the cerebral cortex.

Methods employed in cognitive neuroscience include experimental procedures from psychophysics and cognitive psychology, functional neuroimaging, electrophysiology, cognitive genomics, and behavioral genetics.

Studies of patients with cognitive deficits due to brain lesions constitute an important aspect of cognitive neuroscience. The damages in lesioned brains provide a comparable basis with regards to healthy and fully functioning brains. These damages change the neural circuits in the brain and cause it to malfunction during basic cognitive processes, such as memory or learning. With the damage, we can compare how the healthy neural circuits are functioning, and possibly draw conclusions about the basis of the affected cognitive processes.

Also, cognitive abilities based on brain development are studied and examined under the subfield of developmental cognitive neuroscience. This shows brain development over time, analyzing differences and concocting possible reasons for those differences.

Computational biologist

Computational biology involves the development and application of data-analytical and theoretical methods, mathematical modeling and computational simulation techniques to the study of biological, ecological, behavioral, and social systems. The field is broadly defined and includes foundations in biology, applied mathematics, statistics, biochemistry, chemistry, biophysics, molecular biology, genetics, genomics, computer science and evolution.

Computational biology is different from biological computing, which is a subfield of computer science and computer engineering using bioengineering and biology to build computers, but is similar to bioinformatics, which is an interdisciplinary science using computers to store and process biological data.

Conservation biologist

Conservation biology is the management of nature and of Earth's biodiversity with the aim of protecting species, their habitats, and ecosystems from excessive rates of extinction and the erosion of biotic interactions. It is an interdisciplinary subject drawing on natural and social sciences, and the practice of natural resource management.

Dendrochronologist

Dendrochronology (or tree-ring dating) is the scientific method of dating tree rings (also called growth rings) to the exact year they were formed. As well as dating them this can give data for dendroclimatology, the study of climate and atmospheric conditions during different periods in history from wood.

Dendrochronology is useful for determining the precise age of samples, especially those that are too recent for radiocarbon dating, which always produces a range rather than an exact date, to be very accurate. However, for a precise date of the death of the tree a full sample to the edge is needed, which most trimmed timber will not provide. It also gives data on the timing of events and rates of change in the environment (most prominently climate) and also in wood found in archaeology or works of art and architecture, such as old panel paintings. It is also used as a check in radiocarbon dating to calibrate radiocarbon ages.

New growth in trees occurs in a layer of cells near the bark. A tree's growth rate changes in a predictable pattern throughout the year in response to seasonal climate changes, resulting in visible growth rings. Each ring marks a complete cycle of seasons, or one year, in the tree's life.

As of 2013, the oldest tree-ring measurements in the Northern Hemisphere are a floating sequence extending from about 12,580 to 13,900 years. Dendrochronology derives from Ancient Greek: δένδρον (dendron), meaning "tree", χρόνος (khronos), meaning "time", and -λογία (-logia), "the study of".

Developmental biologist

Developmental biology is the study of the process by which animals and plants grow and develop. Developmental biology also encompasses the biology of regeneration, asexual reproduction, metamorphosis, and the growth and differentiation of stem cells in the adult organism.

Ecologist

Ecology (from Greek: οἶκος, "house", or "environment"; -λογία, "study of")[A] is the branch of biology which studies the interactions among organisms and their environment. Objects of study include interactions of organisms with each other and with abiotic components of their environment. Topics of interest include the biodiversity, distribution, biomass, and populations of organisms, as well as cooperation and competition within and between species. Ecosystems are dynamically interacting systems of organisms, the communities they make up, and the non-living components of their environment. Ecosystem processes, such as primary production, pedogenesis, nutrient cycling, and niche construction, regulate the flux of energy and matter through an environment. These processes are sustained by organisms with specific life history traits. Biodiversity means the varieties of species, genes, and ecosystems, enhances certain ecosystem services.

Ecology is not synonymous with environmentalism, natural history, or environmental science. It overlaps with the closely related sciences of evolutionary biology, genetics, and ethology. An important focus for ecologists is to improve the understanding of how biodiversity affects ecological function. Ecologists seek to explain:

<u>Life processes, interactions, and adaptations</u>
The movement of materials and energy through living communities
The successional development of ecosystems
The abundance and distribution of organisms and biodiversity in the context of the environment.

Ecology has practical applications in conservation biology, wetland management, natural resource management (agroecology, agriculture, forestry, agroforestry, fisheries), city planning (urban ecology), community health, economics, basic and applied science, and human social interaction (human ecology). For example, the

Circles of Sustainability approach treats ecology as more than the environment 'out there'. It is not treated as separate from humans. Organisms (including humans) and resources compose ecosystems which, in turn, maintain biophysical feedback mechanisms that moderate processes acting on living (biotic) and non-living (abiotic) components of the planet. Ecosystems sustain life-supporting functions and produce natural capital like biomass production (food, fuel, fiber, and medicine), the regulation of climate, global biogeochemical cycles, water filtration, soil formation, erosion control, flood protection, and many other natural features of scientific, historical, economic, or intrinsic value.

The word "ecology" ("Ökologie") was coined in 1866 by the German scientist Ernst Haeckel. Ecological thought is derivative of established currents in philosophy, particularly from ethics and politics. Ancient Greek philosophers such as Hippocrates and Aristotle laid the foundations of ecology in their studies on natural history. Modern ecology became a much more rigorous science in the late 19th century. Evolutionary concepts relating to adaptation and natural selection became the cornerstones of modern ecological theory.

Electrophysiologist

Electrophysiology (from Greek ἤλεκτρον, ēlektron, "amber" [see the etymology of "electron"]; φύσις, physis, "nature, origin"; and -λογία, -logia) is the study of the electrical properties of biological cells and tissues. It involves measurements of voltage changes or electric current or manipulations on a wide variety of scales from single ion channel proteins to whole organs like the heart. In neuroscience, it includes measurements of the electrical activity of neurons, and, in particular, action potential activity. Recordings of large-scale electric signals from the nervous system, such as electroencephalography, may also be referred to as electrophysiological recordings. They are useful for electrodiagnosis and monitoring.

Embryologist

Embryology (from Greek ἔμβρυον, embryon, "the unborn, embryo"; and -λογία, -logia) is the branch of biology that studies the prenatal development of gametes (sex cells), fertilization, and development of embryos and fetuses. Additionally, embryology encompasses the study of congenital disorders that occur before birth, known as teratology.

Embryology has a long history. Aristotle proposed the currently accepted theory of epigenesis, that organisms develop from seed or egg in a sequence of steps. The alternative theory, preformationism, that organisms develop from pre-existing miniature versions of themselves, however held sway until the 18th century. Modern embryology developed from the work of von Baer, though accurate observations had been made in Italy by anatomists such as Aldrovandi and Leonardo da Vinci in the Renaissance.

Endocrinologist

Endocrinology (from endocrine + -ology) is a branch of biology and medicine dealing with the endocrine system, its diseases, and its specific secretions known as hormones. It is also concerned with the integration of developmental events proliferation, growth, and differentiation, and the psychological or behavioral activities of metabolism, growth and development, tissue function, sleep, digestion, respiration, excretion, mood, stress, lactation, movement, reproduction, and sensory perception caused by hormones. Specializations include behavioral endocrinology and comparative endocrinology.

The endocrine system consists of several glands, all in different parts of the body, that secrete hormones directly into the blood rather than into a duct system. Hormones have many different functions and modes of action; one hormone may have several effects on different target organs, and, conversely, one target organ may be affected by more than one hormone.

Entomologist

Entomology (from Ancient Greek ἔντομον (entomon), meaning 'insect', and -λογία (-logia), meaning 'study of') is the scientific study of insects, a branch of zoology. In the past the term "insect" was more vague, and historically the definition of entomology included the study of terrestrial animals in other arthropod groups or other phyla, such as arachnids, myriapods, earthworms, land snails, and slugs. This wider meaning may still be encountered in informal use.

Like several of the other fields that are categorized within zoology, entomology is a taxon-based category; any form of scientific study in which there is a focus on insect-related inquiries is, by definition, entomology. Entomology therefore overlaps with a cross-section of topics as diverse as molecular genetics, behavior, biomechanics, biochemistry, systematics, physiology, developmental biology, ecology, morphology, and paleontology.

At some 1.3 million described species, insects account for more than two-thirds of all known organisms, date back some 400 million years, and have many kinds of interactions with humans and other forms of life on earth.

Epidemiologist

Epidemiology is the study and analysis of the distribution (who, when, and where) and determinants of health and disease conditions in defined populations.

It is the cornerstone of public health, and shapes policy decisions and evidence-based practice by identifying risk factors for disease and targets for preventive healthcare. Epidemiologists help with study design, collection, and statistical analysis of data, amend interpretation and dissemination of results (including peer review and occasional systematic review). Epidemiology has helped develop methodology used in clinical research, public health studies, and, to a lesser extent, basic research in the biological sciences.

Major areas of epidemiological study include disease causation, transmission, outbreak investigation, disease surveillance, environmental epidemiology, forensic epidemiology, occupational epidemiology, screening, biomonitoring, and comparisons of treatment effects such as in clinical trials. Epidemiologists rely on other scientific disciplines like biology to better understand disease processes, statistics to make efficient use of the data and draw appropriate conclusions, social sciences to better understand proximate and distal causes, and engineering for exposure assessment.

Ethologist

Ethology is the scientific and objective study of animal behaviour, usually with a focus on behaviour under natural conditions, and viewing behaviour as an evolutionarily adaptive trait. Behaviourism is a term that also describes the scientific and objective study of animal behaviour, usually referring to measured responses to stimuli or trained behavioural responses in a laboratory context, without a particular emphasis on evolutionary adaptivity. Many naturalists have studied aspects of animal behaviour throughout history. Ethology has its scientific roots in the work of Charles Darwin and of American and German ornithologists of the late 19th and early 20th century, including Charles O. Whitman, Oskar Heinroth, and Wallace Craig. The modern discipline of ethology is generally considered to have begun during the 1930s with the work of Dutch biologist Nikolaas Tinbergen and by Austrian biologists Konrad Lorenz and Karl von Frisch, joint awardees of the 1973 Nobel Prize in Physiology or Medicine. Ethology is a combination of laboratory and field science, with a strong relation to some other disciplines such as neuroanatomy, ecology, and evolutionary biology. Ethologists are typically interested in a behavioural process rather than in a particular animal group, and often study one type of behaviour, such as aggression, in a number of unrelated animals.

Ethology is a rapidly growing field. Since the dawn of the 21st century, many aspects of animal communication, emotions, culture, learning and sexuality that the scientific community long thought it understood have been re-examined, and new conclusions reached. New fields, such as neuroethology, have developed.

Understanding ethology or animal behaviour can be important in animal training. Considering the natural behaviours of different species or breeds enables the trainer to select the individuals best suited to perform the required task. It also enables the trainer to encourage the performance of naturally occurring behaviours and also the discontinuance of undesirable behaviours.

Evolutionary biologist

Evolutionary biology is the subfield of biology that studies the evolutionary processes that produced the diversity of life on Earth, starting from a single common ancestor. These processes include natural selection, common descent, and speciation.

The discipline emerged through what Julian Huxley called the modern synthesis (of the 1930s) of understanding from several previously unrelated fields of biological research, including genetics, ecology, systematics, and paleontology.

Current research has widened to cover the genetic architecture of adaptation, molecular evolution, and the different forces that contribute to evolution including sexual selection, genetic drift and biogeography. The newer field of evolutionary developmental biology ("evo-devo") investigates how embryonic development is controlled, thus creating a wider synthesis that integrates developmental biology with the fields covered by the earlier evolutionary synthesis.

Geneticist

A geneticist is a biologist who studies genetics, the science of genes, heredity, and variation of organisms.

Hematologist

Hematology, also spelled haematology, is the branch of medicine concerned with the study of the cause, prognosis, treatment, and prevention of diseases related to blood. It involves treating diseases that affect the production of blood and its components, such as blood cells, hemoglobin, blood proteins, bone marrow, platelets, blood vessels, spleen, and the mechanism of coagulation. Such diseases might include hemophilia, blood clots, other bleeding disorders and blood cancers such as leukemia, multiple myeloma, and lymphoma. The laboratory work that goes into the study of blood is frequently performed by a medical technologist or medical laboratory scientist. Many hematologists work as hematologist-oncologists, also providing medical treatment for all types of cancer. The term is from the Greek αἷμα, haima meaning "blood," and -λογία meaning study.

Herbchronologist

Herbchronology is the analysis of annual growth rings (or simply annual rings) in the secondary root xylem of perennial herbaceous plants. While leaves and stems of perennial herbs die down at the end of the growing season the root often persists for many years or even the entire life. Perennial herb species belonging to the dicotyledon group (also known as perennial forbs) are characterized by secondary growth, which shows as a new growth ring added each year to persistent roots. About two thirds of all perennial dicotyledonous herb species with a persistent root that grow in the strongly seasonal zone of the northern hemisphere show at least fairly clear annual growth rings.

Counting of annual growth rings can be used to determine the age of a perennial herb similarly as it is done in trees using dendrochronology. This way it was found that some perennial herbs live up to 50 years and more.

Herpetologist

Herpetology (from Greek ἑρπετόν herpetón, meaning "reptile" or "creeping animal") is the branch of zoology concerned with the study of amphibians (including frogs, toads, salamanders, newts, and caecilians (gymnophiona)) and reptiles (including snakes, lizards, amphisbaenids, turtles, terrapins, tortoises, crocodilians, and the tuataras). Birds, which are cladistically included within Reptilia, are traditionally excluded here; the scientific study of birds is the subject of ornithology.

Thus, the definition of herpetology can be more precisely stated as the study of ectothermic (cold-blooded) tetrapods. Under this definition "herps" (or sometimes "herptiles" or "herpetofauna") exclude fish, but it is not uncommon for herpetological and ichthyological scientific societies to "team up", publishing joint journals and holding conferences in order to foster the exchange of ideas between the fields, as the American Society of Ichthyologists and Herpetologists does. Many herpetological societies have been formed to promote interest in reptiles and amphibians, both captive and wild.

Herpetology offers benefits to humanity in the study of the role of amphibians and reptiles in global ecology, especially because amphibians are often very sensitive to environmental changes, offering a visible warning to humans that significant changes are taking place. Some toxins and venoms produced by reptiles and amphibians are useful in human medicine. Currently, some snake venom has been used to create anti-coagulants that work to treat strokes and heart attacks.

Histologist

Histology, also microanatomy, is the branch of biology which studies the tissues of animals and plants using microscopy. It is commonly studied using a light microscope or electron microscope, the specimen having been sectioned, stained, and mounted on a microscope slide. Histological studies may be conducted using tissue culture, where live animal cells are isolated and maintained in an artificial environment for various research projects. The ability to visualize or differentially identify microscopic structures is frequently enhanced through the use of staining. Histology is one of the major preclinical subjects in medical school, often stretching over several semesters.

Histopathology, the microscopic study of diseased tissue, is an important tool in anatomical pathology, since accurate diagnosis of cancer and other diseases usually requires histopathological examination of samples. Trained physicians, frequently licensed pathologists, are the personnel who perform histopathological examination and provide diagnostic information based on their observations. The trained personnel who prepare histological specimens for examination are histotechnicians, histotechnologists, histology technicians (HT), histology technologists (HTL), medical scientists, medical laboratory technicians, or biomedical scientists, and their support workers. Their field of study is called histotechnology.

Human behavioral ecologist

Human behavioral ecology (HBE) or human evolutionary ecology applies the principles of evolutionary theory and optimization to the study of human behavioral and cultural diversity. HBE examines the adaptive design of traits, behaviors, and life histories of humans in an ecological context. One aim of modern human behavioral ecology is to determine how ecological and social factors influence and shape behavioral flexibility within and between human populations. Among other things, HBE attempts to explain variation in human behavior as adaptive solutions to the competing life-history demands of growth, development, reproduction, parental care, and mate acquisition.

HBE overlaps with evolutionary psychology, human or cultural ecology, and decision theory. It is most prominent in disciplines such as anthropology and psychology where human evolution is considered relevant for a holistic understanding of human behavior or in economics where self-interest, methodological individualism, and maximization are key elements in modelingbehavioral responses to various ecological factors.

Human biologist

Human biology is an interdisciplinary area of study that examines humans through the influences and interplay of many diverse fields such as genetics, evolution, physiology, anatomy, epidemiology, anthropology, ecology, nutrition, population genetics and sociocultural influences. It is closely related to biological anthropology and other biological fields tying in various aspects of human functionality.

Ichnologist

A trace fossil, also ichnofossil(/ˈɪknoʊfɒsɪl/; from Greek: ἴχνοςikhnos "trace, track"), is a geological record of biological activity. Ichnology is the study of such traces, and is the work of ichnologists. Trace fossils may consist of impressions made on or in the substrate by an organism: for example, burrows, borings (bioerosion), urolites (erosion caused by evacuation of liquid wastes), footprints and feeding marks, and root cavities. The term in its broadest sense also includes the remains of other organic material produced by an organism — for example coprolites (fossilized droppings) or chemical markers — or sedimentological structures produced by biological means - for example, stromatolites. Trace fossils contrast with body fossils, which are the fossilized remains of parts of organisms' bodies, usually altered by later chemical activity or mineralization.

Sedimentary structures, for example those produced by empty shells rolling along the sea floor, are not produced through the behaviour of an organism and not considered trace fossils.

The study of traces - ichnology - divides into paleoichnology, or the study of trace fossils, and neoichnology, the study of modern traces. Ichnological science offers many challenges, as most traces reflect the behaviour — not the biological affinity — of their makers. Accordingly, researchers classify trace fossils into form genera, based on their appearance and on the implied behaviour, or ethology, of their makers.

Ichthyologist

Ichthyology (from Greek: ἰχθύς, ikhthys, "fish"; and λόγος, logos, "study"), also known as fish science, is the branch of zoology devoted to the study of fish. This includes bony fish (Osteichthyes), cartilaginous fish (Chondrichthyes), and jawless fish (Agnatha). While a large number of species have been discovered, approximately 250 new species are officially described by science each year. According to FishBase, 33,400 species of fish had been described by October 2016.

Immunologist

Immunology is a branch of biology that covers the study of immune systems in all organisms. Immunology charts, measures, and contextualizes the physiological functioning of the immune system in states of both health and diseases; malfunctions of the immune system in immunological disorders (such as autoimmune diseases, hypersensitivities, immune deficiency, and transplant rejection); and the physical, chemical, and physiological characteristics of the components of the immune system in vitro, in situ, and in vivo. Immunology has applications in numerous disciplines of medicine, particularly in the fields of organ transplantation, oncology, rheumatology, virology, bacteriology, parasitology, psychiatry, and dermatology.

The term was coined by Russian biologist Ilya Ilyich Mechnikov, who advanced studies on immunology and received the Nobel Prize for his work in 1908. He pinned small thorns into starfish larvae and noticed unusual cells surrounding the thorns. This was the active response of the body trying to maintain its integrity. It was Mechnikov who first observed the phenomenon of phagocytosis, in which the body defends itself against a foreign body.

Prior to the designation of immunity, from the etymological root immunis, which is Latin for "exempt", early physicians characterized organs that would later be proven as essential components of the immune system. The important lymphoid organs of the immune system are the thymus, bone marrow, and chief lymphatic tissues such as spleen, tonsils, lymph vessels, lymph nodes, adenoids, and liver. When health conditions worsen to emergency status, portions of immune system organs, including the thymus, spleen, bone marrow, lymph nodes, and other lymphatic tissues, can be surgically excised for examination while patients are still alive.

Many components of the immune system are typically cellular in nature and not associated with any specific organ, but rather are embedded or circulating in various tissues located throughout the body.

Integrative biologist

Integrative Biology is a monthly peer-reviewed scientific journal covering the interface between biology and the fields of physics, chemistry, engineering, imaging, and informatics. It is published by the Royal Society of Chemistry.

Lepidopterist

Lepidopterology (from Ancient Greek λεπίδος (scale) and πτερόν (wing); and -λογία -logia.), is a branch of entomology concerning the scientific study of moths and the three superfamilies of butterflies. Someone that studies in this field is a lepidopterist or, archaically, an aurelian.

Mammalogist

In zoology, mammalogy is the study of mammals – a class of vertebrates with characteristics such as homeothermic metabolism, fur, four-chambered hearts, and complex nervous systems. Mammalogy has also been known as "mastology," "theriology," and "therology." There are about 4,200 different species of mammals. The major branches of mammalogy include natural history, taxonomy and systematics, anatomy and physiology, ethology, ecology, and management and control. The approximate salary of a mammalogist varies from $20,000 to $60,000 a year, depending on their experience. Mammalogists are typically involved in activities such as conducting research, managing personnel, and writing proposals.

Mammalogy branches off into other taxonomically-oriented disciplines such as primatology (study of primates), and cetology (study of cetaceans). Like other studies, mammalogy is also a part of zoology which is also a part of biology.

Marine biologist

Marine biology is the scientific study of marine life, organisms in the sea. Given that in biology many phyla, families and genera have some species that live in the sea and others that live on land, marine biology classifies species based on the environment rather than on taxonomy.

A large proportion of all life on Earth lives in the ocean. The exact size of this large proportion is unknown, since many ocean species are still to be discovered. The ocean is a complex three-dimensional world[3] covering approximately 71% of the Earth's surface. The habitats studied in marine biology include everything from the tiny layers of surface water in which organisms and abiotic items may be trapped in surface tension between the ocean and atmosphere, to the depths of the oceanic trenches, sometimes 10,000 meters or more beneath the surface of the ocean. Specific habitats include coral reefs, kelp forests, seagrass meadows, the surrounds of seamounts and thermal vents, tidepools, muddy, sandy and rocky bottoms, and the open ocean (pelagic) zone, where solid objects are rare and the surface of the water is the only visible boundary. The organisms studied range from microscopic phytoplankton and zooplankton to huge cetaceans (whales) 25–32 meters (82–105 feet) in length. Marine ecology is the study of how marine organisms interact with each other and the environment.

Marine life is a vast resource, providing food, medicine, and raw materials, in addition to helping to support recreation and tourism all over the world. At a fundamental level, marine life helps determine the very nature of our planet. Marine organisms contribute significantly to the oxygen cycle, and are involved in the regulation of the Earth's climate. Shorelines are in part shaped and protected by marine life, and some marine organisms even help create new land.

Many species are economically important to humans, including both finfish and shellfish. It is also becoming understood that the well-being of marine organisms and other organisms are linked in fundamental ways. The human body of knowledge regarding the relationship between life in the sea and important cycles is rapidly growing, with new discoveries being made nearly every day. These cycles include those of matter (such as the carbon cycle) and of air (such as Earth's respiration, and movement of energy through ecosystems including the ocean). Large areas beneath the ocean surface still remain effectively unexplored.

Microbiologist

A microbiologist (from Greek μῑκρος) is a scientist who studies microscopic life forms and processes. This includes study of the growth, interactions and characteristics of microscopic organisms such as bacteria, algae, fungi, and some types of parasites and their vectors. Most microbiologists work in offices and/or research facilities, both in private biotechnology companies as well as in academia. Most microbiologists specialize in a given topic within microbiology such as bacteriology, parasitology, virology, or immunology.

Molecular biologist

Molecular biology /məˈlɛkjʊlər/ is a branch of biology that concerns the molecular basis of biological activity between biomolecules in the various systems of a cell, including the interactions between DNA, RNA, proteins and their biosynthesis, as well as the regulation of these interactions.

Writing in Nature in 1961, William Astbury described molecular biology as:

...not so much a technique as an approach, an approach from the viewpoint of the so-called basic sciences with the leading idea of searching below the large-scale manifestations of classical biology for the corresponding molecular plan. It is concerned particularly with the forms of biological molecules and [...] is predominantly three-dimensional and structural – which does not mean, however, that it is merely a refinement of morphology. It must at the same time inquire into genesis and function.

Mycologist

Mycology is the branch of biology concerned with the study of fungi, including their genetic and biochemical properties, their taxonomy and their use to humans as a source for tinder, medicine, food, and entheogens, as well as their dangers, such as toxicity or infection.

A biologist specializing in mycology is called a mycologist.

Mycology branches into the field of phytopathology, the study of plant diseases, and the two disciplines remain closely related because the vast majority of plant pathogens are fungi.

Neuroendocrinologist

Neuroendocrinology is the branch of biology (specifically of physiology) which studies the interaction between the nervous system and the endocrine system, that is how the brain regulates the hormonal activity in the body. The nervous and endocrine systems often act together in a process called neuroendocrine integration, to regulate the physiological processes of the human body. Neuroendocrinology arose from the recognition that the brain, especially the hypothalamus, controls secretion of pituitary gland hormones, and has subsequently expanded to investigate numerous interconnections of the endocrine and nervous systems.

The neuroendocrine system is the mechanism by which the hypothalamus maintains homeostasis, regulating reproduction, metabolism, eating and drinking behaviour, energy utilization, osmolarity and blood pressure.

Neuroscientist

A neuroscientist (or neurobiologist) is a scientist who has specialised knowledge in the field of neuroscience, the branch of biology that deals with the physiology, biochemistry, anatomy and molecular biology of neurons and neural circuits and especially their association with behaviour and learning.

Camillo Golgi (1843–1926), Italian physician, neuroscientist, and namesake of the Golgi apparatus

Neuroscientists generally work as researchers within a college, university, government agency, or private industry setting. In research-oriented careers, neuroscientists typically spend their time designing and carrying out scientific experiments that contribute to the understanding of the nervous system and its function. They can engage in basic or applied research. Basic research seeks to add information to our current understanding of the nervous system, whereas applied research seeks to address a specific problem, such as developing a treatment for a neurological disorder. Biomedically-oriented neuroscientists typically engage in applied research. Neuroscientists also have a number of career opportunities outside the realm of research, including careers in industry, science writing, government program management, science advocacy, and education. These individuals most commonly hold doctorate degrees in the sciences, but may also hold a master's degree. The Neuroscientists day is celebrated on August 13th.

Ornithologist

Ornithology is a branch of zoology that concerns the study of birds. Several aspects of ornithology differ from related disciplines, due partly to the high visibility and the aesthetic appeal of birds.

The science of ornithology has a long history and studies on birds have helped develop several key concepts in evolution, behaviour and ecology such as the definition of species, the process of speciation, instinct, learning, ecological niches, guilds, island biogeography, phylogeography, and conservation. While early ornithology was principally concerned with descriptions and distributions of species, ornithologists today seek answers to very specific questions, often using birds as models to test hypotheses or predictions based on theories. Most modern biological theories apply across taxonomic groups, and the number of professional scientists who identify themselves as "ornithologists" has therefore declined. A wide range of tools and techniques is used in ornithology, both inside the laboratory and out in the field, and innovations are constantly made.

Osteologist

Osteology is the scientific study of bones, practiced by osteologists. A subdiscipline of anatomy, anthropology, and archaeology, osteology is a detailed study of the structure of bones, skeletal elements, teeth, microbone morphology, function, disease, pathology, the process of ossification (from cartilaginous molds), the resistance and hardness of bones (biophysics), etc. often used by scientists with identification of vertebrate remains with regard to age, death, sex, growth, and development and can be used in a biocultural context. Osteologists frequently work in the public and private sector as consultants for museums, scientists for research laboratories, scientists for medical investigations and/or for companies producing osteological reproductions in an academic context.

Osteology and osteologists should not be confused with the holistic practice of medicine known as osteopathy and its practitioners, osteopaths.

Paleoanthropologist

Paleoanthropology or paleo-anthropology is a branch of archaeology with a human focus, which seeks to understand the early development of anatomically modern humans, a process known as hominization, through the reconstruction of evolutionary kinship lines within the family Hominidae, working from biological evidence (such as petrified skeletal remains, bone fragments, footprints) and cultural evidence (such as stone tools, artifacts, and settlement localities).

The field draws from and combines paleontology, biological anthropology, and cultural anthropology. As technologies and methods advance, genetics plays an ever-increasing role, in particular to examine and compare DNA structure as a vital tool of research of the evolutionary kinship lines of related species and genera.

Paleobotanist

Paleobotany, also spelled as palaeobotany (from the Greek words paleon = old and "botany", study of plants), is the branch of paleontology or paleobiology dealing with the recovery and identification of plant remains from geological contexts, and their use for the biological reconstruction of past environments (paleogeography), and both the evolutionary history of plants, with a bearing upon the evolution of life in general. A synonym is paleophytology. Paleobotany includes the study of terrestrial plant fossils, as well as the study of prehistoric marine photoautotrophs, such as photosynthetic algae, seaweeds or kelp. A closely related field is palynology, which is the study of fossilized and extant spores and pollen.

Paleobotany is important in the reconstruction of ancient ecological systems and climate, known as paleoecology and paleoclimatology respectively; and is fundamental to the study of green plant development and evolution. Paleobotany has also become important to the field of archaeology, primarily for the use of phytoliths in relative dating and in paleoethnobotany.

The emergence of paleobotany as a scientific discipline can be seen in the early 19th century, especially in the works of the German palaeontologist Ernst Friedrich von Schlotheim, the Czech (Bohemian) nobleman and scholar Kaspar Maria von Sternberg, and the French botanist Adolphe-Théodore Brongniart.

Paleobiologist

Paleobiology (UK & Canadian English: palaeobiology) is a growing and comparatively new discipline which combines the methods and findings of the natural science biology with the methods and findings of the earth science paleontology. It is occasionally referred to as "geobiology".

Paleobiological research uses biological field research of current biota and of fossils millions of years old to answer questions about the molecular evolution and the evolutionary history of life. In this scientific quest, macrofossils, microfossils and trace fossils are typically analyzed. However, the 21st-century biochemical analysis of DNA and RNA samples offers much promise, as does the biometric construction of phylogenetic trees.

Paleontologist

Paleontology or palaeontology (/ˌpeɪliɒnˈtɒlədʒi, ˌpæli-, -ən-/) is the scientific study of life that existed prior to, and sometimes including, the start of the Holocene Epoch (roughly 11,700 years before present). It includes the study of fossils to determine organisms' evolution and interactions with each other and their environments (their paleoecology). Paleontological observations have been documented as far back as the 5th century BC. The science became established in the 18th century as a result of Georges Cuvier's work on comparative anatomy, and developed rapidly in the 19th century. The term itself originates from Greek παλαιός, palaios, "old, ancient", ὄν, on (gen. ontos), "being, creature" and λόγος, logos, "speech, thought, study".

Paleontology lies on the border between biology and geology, but differs from archaeology in that it excludes the study of anatomically modern humans. It now uses techniques drawn from a wide range of sciences, including biochemistry, mathematics, and engineering. Use of all these techniques has enabled paleontologists to discover much of the evolutionary history of life, almost all the way back to when Earth became capable of supporting life, about 3.8 billion years ago. As knowledge has increased, paleontology has developed specialised sub-divisions, some of which focus on different types of fossil organisms while others study ecology and environmental history, such as ancient climates.

Body fossils and trace fossils are the principal types of evidence about ancient life, and geochemical evidence has helped to decipher the evolution of life before there were organisms large enough to leave body fossils. Estimating the dates of these remains is essential but difficult: sometimes adjacent rock layers allow radiometric dating, which provides absolute dates that are accurate to within 0.5%, but more often paleontologists have to rely on relative dating by solving the "jigsaw puzzles" of biostratigraphy. Classifying ancient organisms is also difficult, as many do not fit well into the Linnaean taxonomy that is commonly used for classifying living organisms, and paleontologists more often use cladistics to draw up evolutionary "family trees". The final quarter of the 20th century saw the development of molecular phylogenetics, which investigates how closely organisms are related by measuring how similar the DNA is in their genomes. Molecular phylogenetics has also been used to estimate the dates when species diverged, but there is controversy about the reliability of the molecular clock on which such estimates depend.

Paleopathologist

Paleopathology, also spelled palaeopathology, is the study of ancient diseases. Studying pathologies, these abnormalities in biologic individuals and systems, may be intrinsic to the system itself (examples: autoimmune disorders or traumatic arthritis) or caused by an extrinsic factor (examples: viruses or lead poisoning from pipes). Any living organism can have pathology. Studies have historically focused on humans, but there is no evidence that humans are more prone to pathologies than any other animal.

Paleopathology is an interdisciplinary science. The majority of the work has historically been done by anthropologists studying diseases in ancient cultures. Medically trained professionals have also made substantial contributions, especially in modern comparative studies. Paleontologists have sporadically contributed to the field, focusing on non-avian dinosaurs and Cenozoic mammals.

Parasitologist

Parasitology is the study of parasites, their hosts, and the relationship between them. As a biological discipline, the scope of parasitology is not determined by the organism or environment in question but by their way of life. This means it forms a synthesis of other disciplines, and draws on techniques from fields such as cell biology, bioinformatics, biochemistry, molecular biology, immunology, genetics, evolution and ecology.

Pathologist

Pathology (from the Ancient Greek roots of pathos (πάθος), meaning "experience" or "suffering" and -logia (-λογία), "study of") is concerned mainly with the causal study of disease.

The word pathology itself may be used broadly to refer to the study of disease in general, incorporating a wide range of bioscience research fields and medical practices. However, when used in the context of modern medical treatment, the term is often used in a more narrow fashion to refer to processes and tests which fall within the contemporary medical field of "general pathology," an area which includes a number of distinct but inter-related medical specialties that diagnose disease, mostly through analysis of tissue, cell, and body fluid samples. Idiomatically, "a pathology" may also refer to the predicted or actual progression of particular diseases (as in the statement "the many different forms of cancer have diverse pathologies"), and the affix path is sometimes used to indicate a state of disease in cases of both physical ailment (as in cardiomyopathy) and psychological conditions (such as psychopathy). A physician practicing pathology is called a pathologist.

As a field of general inquiry and research, pathology addresses four components of disease: cause, mechanisms of development (pathogenesis), structural alterations of cells (morphologic changes), and the consequences of changes (clinical manifestations). In common medical practice, general pathology is mostly concerned with analyzing known clinical abnormalities that are markers or precursors for both infectious and non-infectious disease and is conducted by experts in one of two major specialties, anatomical pathology and clinical pathology. Further divisions in specialty exist on the basis of the involved sample types (comparing, for example, cytopathology, hematopathology, and histopathology), organs (as in renal pathology), and physiological systems (oral pathology), as well as on the basis of the focus of the examination (as with forensic pathology).

Physiologist

Physiology (/ˌfɪziˈɒlədʒi/; from Ancient Greek φύσις (physis), meaning 'nature, origin', and -λογία (-logia), meaning 'study of') is the scientific study of the functions and mechanisms which work within a living system.

As a sub-discipline of biology, the focus of physiology is on how organisms, organ systems, organs, cells, and biomolecules carry out the chemical and physical functions that exist in a living system.

Central to an understanding of physiological functioning is the investigation of the fundamental biophysical and biochemical phenomena, the coordinated homeostatic control mechanisms, and the continuous communication between cells.

The physiologic state is the condition occurring from normal body function, while the pathological state is centered on the abnormalities that occur in animal diseases, including humans.

According to the type of investigated organisms, the field can be divided into, animal physiology (including that of humans), plant physiology, cellular physiology and microbial physiology.

Phytopathologist

Plant pathology (also phytopathology) is the scientific study of diseases in plants caused by pathogens (infectious organisms) and environmental conditions (physiological factors). Organisms that cause infectious disease include fungi, oomycetes, bacteria, viruses, viroids, virus-like organisms, phytoplasmas, protozoa, nematodes and parasitic plants. Not included are ectoparasites like insects, mites, vertebrate, or other pests that affect plant health by eating of plant tissues. Plant pathology also involves the study of pathogen identification, disease etiology, disease cycles, economic impact, plant disease epidemiology, plant disease resistance, how plant diseases affect humans and animals, pathosystem genetics, and management of plant diseases.

Population biologist

Population biology is an interdisciplinary field combining the areas of ecology and evolutionary biology. Population biology draws on tools from mathematics, statistics, genomics, genetics, and systematics. Population biologists study allele frequency changes (evolution) within populations of the same species (population genetics), and interactions between populations of different species (ecology).

Primatologist

Primatology is the scientific study of primates. It is a diverse discipline at the boundary between mammalogy and anthropology, and researchers can be found in academic departments of anatomy, anthropology, biology, medicine, psychology, veterinary sciences and zoology, as well as in animal sanctuaries, biomedical research facilities, museums and zoos. Primatologists study both living and extinct primates in their natural habitats and in laboratories by conducting field studies and experiments in order to understand aspects of their evolution and behaviour.

Quantum biologist

Quantum biology refers to applications of quantum mechanics and theoretical chemistry to biological objects and problems. Many biological processes involve the conversion of energy into forms that are usable for chemical transformations, and are quantum mechanical in nature. Such processes involve chemical reactions, light absorption, formation of excited electronic states, transfer of excitation energy, and the transfer of electrons and protons (hydrogen ions) in chemical processes, such as photosynthesis, olfaction and cellular respiration. Quantum biology may use computations to model biological interactions in light of quantum mechanical effects. Quantum biology is concerned with the influence of non-trivial quantum phenomena, which can be explained by reducing the biological process to fundamental physics, although these effects are difficult to study and can be speculative. The field of study does not imply any new physical principles are needed, since the quantum mechanical study of reaction rates and energy transfer is well established. To date, there are no observations of quantum biology that imply quantum effects are observable in macroscopic organisms (aside from thought experiments such as Schrodinger's cat), or that are crucial for the existence of life.

Radiobiologist

Radiobiology (also known as radiation biology) is a field of clinical and basic medical sciences that involves the study of the action of ionizing radiation on living things, especially health effects of radiation. Ionizing radiation is generally harmful and potentially lethal to living things but can have health benefits in radiation therapy for the treatment of cancer and thyrotoxicosis. Its most common impact is the induction of cancer with a latent period of years or decades after exposure. High doses can cause visually dramatic radiation burns, and/or rapid fatality through acute radiation syndrome. Controlled doses are used for medical imaging and radiotherapy.

Sclerochronologist

Sclerochronology is the study of physical and chemical variations in the accretionary hard tissues of invertebrates and coralline red algae, and the temporal context in which they formed. It is particularly useful in the study of marine paleoclimatology. The term was coined in 1974 following pioneering work on nuclear test atolls by Knutson and Buddemeier and comes from the three Greek words scleros (hard), chronos (time) and logos (science), which together refer to the use of the hard parts of living organisms to order events in time. It is, therefore, a form of stratigraphy. Sclerochronology focuses primarily upon growth patterns reflecting annual, monthly, fortnightly, tidal, daily, and sub-daily (ultradian) increments of time.

The regular time increments are controlled by biological clocks, which, in turn, are caused by environmental and astronomical pacemakers.

Familiar examples include annual bandings in reef coral skeletons or annual, fortnightly, daily and ultradian growth increments in mollusk shells as well as annual bandings in the ear bones of fish, called otoliths. Sclerochronology is analogous to dendrochronology, the study of annual rings in trees, and equally seeks to deduce organismal life history traits as well as to reconstruct records of environmental and climatic change through space and time.

The science of sclerochronology as applied to hard parts of various organism groups is now routinely used for paleoceanographic and paleoclimate reconstructions. The study includes isotopic and elemental proxies, sometimes termed sclerochemistry.

Improvements in imaging techniques have now realised the potential to decipher coral banding at daily resolution, although biological 'vital' effects may blur the climate signal at such a high resolution.

Sociobiologist

Sociobiology is a field of biology that aims to examine and explain social behavior in terms of evolution. It draws from disciplines including ethology, anthropology, evolution, zoology, archaeology, and population genetics. Within the study of human societies, sociobiology is closely allied to Darwinian anthropology, human behavioral ecology and evolutionary psychology.

Sociobiology investigates social behaviors such as mating patterns, territorial fights, pack hunting, and the hive society of social insects. It argues that just as selection pressure led to animals evolving useful ways of interacting with the natural environment, so also it led to the genetic evolution of advantageous social behavior.

While the term "sociobiology" originated at least as early as the 1940s, the concept did not gain major recognition until the publication of E. O. Wilson's book Sociobiology: The New Synthesis in 1975. The new field quickly became the subject of controversy. Critics, led by Richard Lewontin and Stephen Jay Gould, argued that genes played a role in human behavior, but that traits such as aggressiveness could be explained by social environment rather than by biology. Sociobiologists responded by pointing to the complex relationship between nature and nurture.

Structural biologist

Structural biology is a branch of molecular biology, biochemistry, and biophysics concerned with the molecular structure of biological macromolecules (especially proteins, made up of amino acids, and RNA or DNA, made up of nucleotides), how they acquire the structures they have, and how alterations in their structures affect their function. This subject is of great interest to biologists because macromolecules carry out most of the functions of cells, and it is only by coiling into specific three-dimensional shapes that they are able to perform these functions. This architecture, the "tertiary structure" of molecules, depends in a complicated way on each molecule's basic composition, or "primary structure."

Hemoglobin, the oxygen transporting protein found in red blood cells
Biomolecules are too small to see in detail even with the most advanced light microscopes. The methods that structural biologists use to determine their structures generally involve measurements on vast numbers of identical molecules at the same time. These methods include:

1. Mass spectrometry
2. Macromolecular crystallography
3. Proteolysis
4. Nuclear magnetic resonance spectroscopy of proteins (NMR)
5. Electron paramagnetic resonance (EPR)
6. Cryo-electron microscopy (cryo-EM)
7. Multiangle light scattering
8. Small angle scattering
9. Ultrafast laser spectroscopy
10. Dual-polarization interferometry and circular dichroism

Most often researchers use them to study the "native states" of macromolecules. But variations on these methods are also used to watch nascent or denatured molecules assume or reassume their native states. See protein folding.

A third approach that structural biologists take to understanding structure is bioinformatics to look for patterns among the diverse sequences that give rise to particular shapes. Researchers often can deduce aspects of the structure of integral membrane proteins based on the membrane topology predicted by hydrophobicity analysis. See protein structure prediction.

Examples of protein structures from the Protein Data Bank

In the past few years it has become possible for highly accurate physical molecular models to complement the in silico study of biological structures. Examples of these models can be found in the Protein Data Bank.

Theoretical biologist

Mathematical and theoretical biology is a branch of biology which employs theoretical analysis, mathematical models and abstractions of the living organisms to investigate the principles that govern the structure, development and behavior of the systems, as opposed to experimental biology which deals with the conduction of experiments to prove and validate the scientific theories. The field is sometimes called mathematical biology or biomathematics to stress the mathematical side, or theoretical biology to stress the biological side. Theoretical biology focuses more on the development of theoretical principles for biology while mathematical biology focuses on the use of mathematical tools to study biological systems, even though the two terms are sometimes interchanged.

Mathematical biology aims at the mathematical representation and modeling of biological processes, using techniques and tools of applied mathematics. It has both theoretical and practical applications in biological, biomedical and biotechnology research. Describing systems in a quantitative manner means their behavior can be better simulated, and hence properties can be predicted that might not be evident to the experimenter. This requires precise mathematical models.

Mathematical biology employs many components of mathematics, and has contributed to the development of new techniques.

Toxicologist

Toxicology is a discipline, overlapping with biology, chemistry, pharmacology, and medicine, that involves the study of the adverse effects of chemical substances on living organisms and the practice of diagnosing and treating exposures to toxins and toxicants. The relationship between dose and its effects on the exposed organism is of high significance in toxicology. Factors that influence chemical toxicity include the dosage (and whether it is acute or chronic), route of exposure, species, age, sex, and environment. Toxicologists are experts on poisons and poisoning.

Virologist

Virology is the study of viruses – submicroscopic, parasitic particles of genetic material contained in a protein coat – and virus-like agents. It focuses on the following aspects of viruses: their structure, classification and evolution, their ways to infect and exploit host cells for reproduction, their interaction with host organism physiology and immunity, the diseases they cause, the techniques to isolate and culture them, and their use in research and therapy. Virology is considered to be a subfield of microbiology or of medicine.

Wildlife biologist

Zoologist

Zoology (/zuˈɒlədʒi, zoʊ-/) is the branch of biology that studies the animal kingdom, including the structure, embryology, evolution, classification, habits, and distribution of all animals, both living and extinct, and how they interact with their ecosystems. The term is derived from Ancient Greek ζῷον, zōion, i.e. "animal" and λόγος, logos, i.e. "knowledge, study".

III. Social science

Anthropologist

An anthropologist is a person engaged in the practice of anthropology. Anthropology is the study of various aspects of humans within past and present societies. Social anthropology, cultural anthropology, and philosophical anthropology study the norms and values of societies. Linguistic anthropology studies how language affects social life, while economic anthropology studies human economic behavior. Biological (physical), forensic, and medical anthropology study the biological development of humans, the application of biological anthropology in a legal setting, and the study of diseases and their impacts on humans over time, respectively.

Archaeologist

Archaeology, or archeology, is the study of human activity through the recovery and analysis of material culture. The archaeological record consists of artifacts, architecture, biofacts or ecofacts and cultural landscapes. Archaeology can be considered both a social science and a branch of the humanities. In North America archaeology is a sub-field of anthropology, while in Europe it is often viewed as either a discipline in its own right or a sub-field of other disciplines.

Archaeologists study human prehistory and history, from the development of the first stone tools at Lomekwi in East Africa 3.3 million years ago up until recent decades. Archaeology is distinct from palaeontology, the study of fossil remains. It is particularly important for learning about prehistoric societies, for whom there may be no written records to study. Prehistory includes over 99% of the human past, from the Paleolithic until the advent of literacy in societies across the world. Archaeology has various goals, which range from understanding culture history to reconstructing past lifeways to documenting and explaining changes in human societies through time.

The discipline involves surveying, excavation and eventually analysis of data collected to learn more about the past. In broad scope, archaeology relies on cross-disciplinary research. It draws upon anthropology, history, art history, classics, ethnology, geography, geology, literary history, linguistics, semiology, textual criticism, physics, information sciences, chemistry, statistics, paleoecology, paleography, paleontology, paleozoology, and paleobotany.

Archaeology developed out of antiquarianism in Europe during the 19th century, and has since become a discipline practiced across the world. Archaeology has been used by nation-states to create particular visions of the past. Since its early development, various specific sub-disciplines of archaeology have developed, including maritime archaeology, feminist archaeology and archaeoastronomy, and numerous different scientific techniques have been developed to aid archaeological investigation. Nonetheless, today, archaeologists face many problems, such as dealing with pseudoarchaeology, the looting of artifacts, a lack of public interest, and opposition to the excavation of human remains.

Biological anthropologist

Biological anthropology, also known as physical anthropology, is a scientific discipline concerned with the biological and behavioral aspects of human beings, their extinct hominin ancestors, and related non-human primates, particularly from an evolutionary perspective. It is a subfield of anthropology that provides a biological perspective to the systematic study of human beings.

Cultural anthropologist

Cultural anthropology is a branch of anthropology focused on the study of cultural variation among humans. It is in contrast to social anthropology, which perceives cultural variation as a subset of the anthropological constant.

Cultural anthropology has a rich methodology, including participant observation (often called fieldwork because it requires the anthropologist spending an extended period of time at the research location), interviews, and surveys. One of the earliest articulations of the anthropological meaning of the term "culture" came from Sir Edward Tylor who writes on the first page of his 1871 book: "Culture, or civilization, taken in its broad, ethnographic sense, is that complex whole which includes knowledge, belief, art, morals, law, custom, and any other capabilities and habits acquired by man as a member of society." The term "civilization" later gave way to definitions given by V. Gordon Childe, with culture forming an umbrella term and civilization becoming a particular kind of culture.

The anthropological concept of "culture" reflects in part a reaction against earlier Western discourses based on an opposition between "culture" and "nature", according to which some human beings lived in a "state of nature". Anthropologists have argued that culture is "human nature", and that all people have a capacity to classify experiences, encode classifications symbolically (i.e. in language), and teach such abstractions to others.

Since humans acquire culture through the learning processes of enculturation and socialization, people living in different places or different circumstances develop different cultures. Anthropologists have also pointed out that through culture people can adapt to their environment in non-genetic ways, so people living in different environments will often have different cultures. Much of anthropological theory has originated in an appreciation of and interest in the tension between the local (particular cultures) and the global (a universal human nature, or the web of connections between people in distinct places/circumstances).

The rise of cultural anthropology took place within the context of the late 19th century, when questions regarding which cultures were "primitive" and which were "civilized" occupied the minds of not only Marx and Freud, but many others. Colonialism and its processes increasingly brought European thinkers into direct or indirect contact with "primitive others." The relative status of various humans, some of whom had modern advanced technologies that included engines and telegraphs, while others lacked anything but face-to-face communication techniques and still lived a Paleolithic lifestyle, was of interest to the first generation of cultural anthropologists.

Communication scientist

Communication studies or communication sciences is an academic discipline that deals with processes of human communication and behavior. There are three types of communication: verbal, involving listening to a person to understand the meaning of a message; written, in which a message is read; and nonverbal communication involving observing a person and inferring meaning. The discipline encompasses a range of topics, from face-to-face conversation to mass media outlets, such as television broadcasting.

Communication studies shares with cultural studies an interest in how messages are interpreted through the political, cultural, economic, semiotic, hermeneutic, and social dimensions of their contexts. In political economics, communication studies examines how the politics of ownership affects content. Quantitative communication studies examines statistics in order to help substantiate claims.

Criminologist

Criminology (from Latin crīmen, "accusation" originally derived from the Ancient Greek verb "krino" "κρίνω", and Ancient Greek -λογία, -logy|-logia, from "logos" meaning: "word," "reason," or "plan") is the scientific study of the nature, extent, management, causes, control, consequences, and prevention of criminal behavior, both on individual and social levels. Criminology is an interdisciplinary field in both the behavioral and social sciences, drawing primarily upon the research of sociologists, psychologists, philosophers, psychiatrists, biologists, social anthropologists, as well as scholars of law.

The term criminology was coined in 1885 by Italian law professor Raffaele Garofalo as criminologia. Later, French anthropologist Paul Topinard used the analogous French term criminologie.

From 1900 through to 2000 the study underwent three significant phases in the United States: (1) Golden Age of Research (1900-1930)-which has been described as multiple-factor approach, (2) Golden Age of Theory (1930-1960)-which shows that there was no systematic way of connecting criminological research to theory, and (3) a 1960-2000 period-which was seen as a significant turning point for criminology.

Demographer

Demography (from prefix demo- from Ancient Greek δῆμοςdēmos meaning "the people", and -graphy from γράφωgraphō, implies "writing, description or measurement") is the statistical study of populations, especially human beings. As a very general science, it can analyze any kind of dynamic living population, i.e., one that changes over time or space (see population dynamics). Demography encompasses the study of the size, structure, and distribution of these populations, and spatial or temporal changes in them in response to birth, migration, aging, and death. Based on the demographic research of the earth, earth's population up to the year 2050 and 2100 can be estimated by demographers. Demographics are quantifiable characteristics of a given population.

Demographic analysis can cover whole societies or groups defined by criteria such as education, nationality, religion, and ethnicity. Educational institutions usually treat demography as a field of sociology, though there are a number of independent demography departments.

Formal demography limits its object of study to the measurement of population processes, while the broader field of social demography or population studies also analyses the relationships between economic, social, cultural, and biological processes influencing a population.

Economist

An economist is a practitioner in the social science discipline of economics.

The individual may also study, develop, and apply theories and concepts from economics and write about economic policy. Within this field there are many sub-fields, ranging from the broad philosophical theories to the focused study of minutiae within specific markets, macroeconomic analysis, microeconomic analysis or financial statement analysis, involving analytical methods and tools such as econometrics, statistics, economics computational models, financial economics, mathematical finance and mathematical economics.

Linguist

Linguistics is the scientific study of language. It involves analysing language form, language meaning, and language in context. The earliest activities in the documentation and description of language have been attributed to the 6th-century-BC Indian grammarian Pāṇini who wrote a formal description of the Sanskrit language in his Aṣṭādhyāyī.

Linguists traditionally analyse human language by observing an interplay between sound and meaning. Phonetics is the study of speech and non-speech sounds, and delves into their acoustic and articulatory properties. The study of language meaning, on the other hand, deals with how languages encode relations between entities, properties, and other aspects of the world to convey, process, and assign meaning, as well as manage and resolve ambiguity. While the study of semantics typically concerns itself with truth conditions, pragmatics deals with how situational context influences the production of meaning.

Grammar is a system of rules which governs the production and use of utterances in a given language. These rules apply to sound as well as meaning, and include componential subsets of rules, such as those pertaining to phonology (the organisation of phonetic sound systems), morphology (the formation and composition of words), and syntax (the formation and composition of phrases and sentences). Modern theories that deal with the principles of grammar are largely based within Noam Chomsky's framework of generative linguistics.

In the early 20th century, Ferdinand de Saussure distinguished between the notions of langue and parole in his formulation of structural linguistics. According to him, parole is the specific utterance of speech, whereas langue refers to an abstract phenomenon that theoretically defines the principles and system of rules that govern a language. This distinction resembles the one made by Noam Chomsky between competence and performance in his theory of transformative or generative grammar. According to Chomsky, competence is an individual's innate capacity and potential for language (like in Saussure's langue), while performance is the specific way in which it is used by individuals, groups, and communities (i.e., parole, in Saussurean terms).

Management scientist

Management science (MS) is the broad interdisciplinary study of problem solving and decision making in human organizations, with strong links to management, economics, business, engineering, management consulting, and other sciences. It uses various scientific research-based principles, strategies, and analytical methods including mathematical modeling, statistics and numerical algorithms to improve an organization's ability to enact rational and accurate management decisions by arriving at optimal or near optimal solutions to complex decision problems. Management sciences help businesses to achieve goals using various scientific methods.

The field was initially an outgrowth of applied mathematics, where early challenges were problems relating to the optimization of systems which could be modeled linearly, i.e., determining the optima (maximum value of profit, assembly line performance, crop yield, bandwidth, etc. or minimum of loss, risk, costs, etc.) of some objective function. Today, management science encompasses any organizational activity for which the problem can be structured as a functional system so as to obtain a solution set with identifiable characteristics.

Political economist

Political economy is the study of production and trade and their relations with law, custom and government; and with the distribution of national income and wealth. As a discipline, political economy originated in moral philosophy, in the 18th century, to explore the administration of states' wealth, with "political" signifying the Greek word polity and "economy" signifying the Greek word "okonomie" (household management). The earliest works of political economy are usually attributed to the British scholars Adam Smith, Thomas Malthus, and David Ricardo, although they were preceded by the work of the French physiocrats, such as François Quesnay (1694–1774) and Anne-Robert-Jacques Turgot (1727–1781).[1]

In the late 19th century, the term "economics" gradually began to replace the term "political economy" with the rise of mathematical modelling coinciding with the publication of an influential textbook by Alfred Marshall in 1890. Earlier, William Stanley Jevons, a proponent of mathematical methods applied to the subject, advocated economics for brevity and with the hope of the term becoming "the recognised name of a science". Citation measurement metrics from Google Ngram Viewer indicate that use of the term "economics" began to overshadow "political economy" around roughly 1910, becoming the preferred term for the discipline by 1920. Today, the term "economics" usually refers to the narrow study of the economy absent other political and social considerations while the term "political economy" represents a distinct and competing approach.

Political economy, where it is not used as a synonym for economics, may refer to very different things. From an academic standpoint, the term may reference Marxian economics, applied public choice approaches emanating from the Chicago school and the Virginia school. In common parlance, "political economy" may simply refer to the advice given by economists to the government or public on general economic policy or on specific economic proposals developed by political scientists. A rapidly growing mainstream literature from the 1970s has expanded beyond the model of economic policy in which planners maximize utility of a representative individual toward examining how political forces affect the choice of economic policies, especially as to distributional conflicts and political institutions. It is available as a stand-alone area of study in certain colleges and universities.

Political scientist

Political science is a social science which deals with systems of governance, and the analysis of political activities, political thoughts, and political behavior. It deals extensively with the theory and practice of politics which is commonly thought of as determining of the distribution of power and resources. Political scientists "see themselves engaged in revealing the relationships underlying political events and conditions, and from these revelations they attempt to construct general principles about the way the world of politics works."

Political science—occasionally called politicology—comprises numerous subfields, including comparative politics, political economy, international relations, political theory, public administration, public policy, and political methodology. Furthermore, political science is related to, and draws upon, the fields of economics, law, sociology, history, philosophy, geography, psychology/psychiatry, and anthropology.

Comparative politics is the science of comparison and teaching of different types of constitutions, political actors, legislature and associated fields, all of them from an intrastate perspective. International relations deals with the interaction between nation-states as well as intergovernmental and transnational organizations. Political theory is more concerned with contributions of various classical and contemporary thinkers and philosophers.

Political science is methodologically diverse and appropriates many methods originating in social research. Approaches include positivism, interpretivism, rational choice theory, behaviouralism, structuralism, post-structuralism, realism, institutionalism, and pluralism. Political science, as one of the social sciences, uses methods and techniques that relate to the kinds of inquiries sought: primary sources such as historical documents and official records, secondary sources such as scholarly journal articles, survey research, statistical analysis, case studies, experimental research, and model building.

Psychologist

A psychologist studies normal and abnormal mental states, cognitive, emotional, and social processes and behavior by observing, interpreting, and recording how individuals relate to one another and to their environments. To become a psychologist, a person often completes a graduate university degree in psychology, but in most jurisdictions, members of other behavioral professions (such as counselors and psychiatrists) can also evaluate, diagnose, treat, and study mental processes.

Abnormal psychologist

Abnormal psychology is the branch of psychology that studies unusual patterns of behavior, emotion and thought, which may or may not be understood as precipitating a mental disorder. Although many behaviors could be considered as abnormal, this branch of psychology generally deals with behavior in a clinical context. There is a long history of attempts to understand and control behavior deemed to be aberrant or deviant (statistically, functionally, morally or in some other sense), and there is often cultural variation in the approach taken. The field of abnormal psychology identifies multiple causes for different conditions, employing diverse theories from the general field of psychology and elsewhere, and much still hinges on what exactly is meant by "abnormal". There has traditionally been a divide between psychological and biological explanations, reflecting a philosophical dualism in regard to the mind-body problem. There have also been different approaches in trying to classify mental disorders. Abnormal includes three different categories; they are subnormal, supernormal and paranormal.

The science of abnormal psychology studies two types of behaviors: adaptive and maladaptive behaviors. Behaviors that are maladaptive suggest that some problem(s) exist, and can also imply that the individual is vulnerable and cannot cope with environmental stress, which is leading them to have problems functioning in daily life in their emotions, mental thinking, physical actions and talks. Behaviors that are adaptive are ones that are well-suited to the nature of people, their lifestyles and surroundings, and to the people that they communicate with, allowing them to understand each other. Clinical psychology is the applied field of psychology that seeks to assess, understand and treat psychological conditions in clinical practice. The theoretical field known as 'abnormal psychology' may form a backdrop to such work, but clinical psychologists in the current field are unlikely to use the term 'abnormal' in reference to their practice. Psychopathology is a similar term to abnormal psychology but has more of an implication of an underlying pathology (disease process), and as such is a term more commonly used in the medical specialty known as psychiatry.

Behavioral psychologist

Behaviorism (or behaviourism) is a systematic approach to understanding the behavior of humans and other animals. It assumes that all behaviors are either reflexes produced by a response to certain stimuli in the environment, or a consequence of that individual's history, including especially reinforcement and punishment, together with the individual's current motivational state and controlling stimuli. Although behaviorists generally accept the important role of inheritance in determining behavior, they focus primarily on environmental factors.

Behaviorism combines elements of philosophy, methodology, and psychological theory. It emerged in the late nineteenth century as a reaction to depth psychology and other traditional forms of psychology, which often had difficulty making predictions that could be tested experimentally. The earliest derivatives of Behaviorism can be traced back to the late 19th century where Edward Thorndike pioneered the law of effect, a process that involved strengthening behavior through the use of reinforcement.

During the first half of the twentieth century, John B. Watson devised methodological behaviorism, which rejected introspective methods and sought to understand behavior by only measuring observable behaviors and events. It was not until the 1930s that B. F. Skinner suggested that private events—including thoughts and feelings—should be subjected to the same controlling variables as observable behavior, which became the basis for his philosophy called "radical behaviorism." While Watson and Ivan Pavlov investigated the stimulus-response procedures of classical conditioning, Skinner assessed the controlling nature of consequences and also its potential effect on the antecedents (or discriminative stimuli) that strengthens behavior; the technique became known as operant conditioning.

Skinner's radical behaviorism has been highly successful experimentally, revealing new phenomena with new methods, but Skinner's dismissal of theory limited its development. Theoretical behaviorism recognized that a historical system, an organism, has a state as well as sensitivity to stimuli and the ability to emit responses. Indeed, Skinner himself acknowledged the possibility of what he called "latent" responses in humans, even though he neglected to extend this idea to rats and pigeons. Latent responses constitute a repertoire, from which operant reinforcement can select.

The application of radical behaviorism—known as applied behavior analysis—is used in a variety of settings, including, for example, organizational behavior management, to the treatment of mental disorders, such as autism and substance abuse. In addition, while behaviorism and cognitive schools of psychological thought may not agree theoretically, they have complemented each other in cognitive-behavior therapies, which have demonstrated utility in treating certain pathologies, including simple phobias, PTSD, and mood disorders.

Biopsychologist

Behavioral neuroscience, also known as biological psychology, biopsychology, or psychobiology, is the application of the principles of biology to the study of physiological, genetic, and developmental mechanisms of behavior in humans and other animals.

Clinical psychologist

Clinical psychology is an integration of science, theory, and clinical knowledge for the purpose of understanding, preventing, and relieving psychologically-based distress or dysfunction and to promote subjective well-being and personal development. Central to its practice are psychological assessment, clinical formulation, and psychotherapy, although clinical psychologists also engage in research, teaching, consultation, forensic testimony, and program development and administration. In many countries, clinical psychology is a regulated mental health profession.

The field is generally considered to have begun in 1896 with the opening of the first psychological clinic at the University of Pennsylvania by Lightner Witmer. In the first half of the 20th century, clinical psychology was focused on psychological assessment, with little attention given to treatment. This changed after the 1940s when World War II resulted in the need for a large increase in the number of trained clinicians. Since that time, three main educational models have developed in the USA—the Ph.D. Clinical Science model (heavily focused on research), the Ph.D. science-practitioner model (integrating research and practice), and the Psy.D. practitioner-scholar model (focusing on clinical practice). In the UK and the Republic of Ireland the Clinical Psychology Doctorate falls between the latter two of these models, whilst in much of mainland Europe the training is at masters level and predominantly psychotherapeutic. Clinical psychologists are expert in providing psychotherapy, and generally train within four primary theoretical orientations—psychodynamic, humanistic, cognitive behavioral therapy (CBT), and systems or family therapy.

Cognitive psychologist

Cognitive psychology is the study of mental processes such as "attention, language use, memory, perception, problem solving, creativity, and thinking". Much of the work derived from cognitive psychology has been integrated into various other modern disciplines such as Cognitive Science and of psychological study, including educational psychology, social psychology, personality psychology, abnormal psychology, developmental psychology, linguistics, and economics.

Comparative psychologist

Comparative psychology refers to the scientific study of the behavior and mental processes of non-human animals, especially as these relate to the phylogenetic history, adaptive significance, and development of behavior. Research in this area addresses many different issues, uses many different methods and explores the behavior of many different species from insects to primates.

Comparative psychology is sometimes assumed to emphasize cross-species comparisons, including those between humans and animals. However, some researchers feel that direct comparisons should not be the sole focus of comparative psychology and that intense focus on a single organism to understand its behavior is just as desirable; if not more so. Donald Dewsbury reviewed the works of several psychologists and their definitions and concluded that the object of comparative psychology is to establish principles of generality focusing on both proximate and ultimate causation.

Using a comparative approach to behavior allows one to evaluate the target behavior from four different, complementary perspectives, developed by Niko Tinbergen. First, one may ask how pervasive the behavior is across species (i.e. how common is the behavior between animal species?). Second, one may ask how the behavior contributes to the lifetime reproductive success of the individuals demonstrating the behavior (i.e. does the behavior result in animals producing more offspring than animals not displaying the behavior)? Theories addressing the ultimate causes of behavior are based on the answers to these two questions.

Third, what mechanisms are involved in the behavior (i.e. what physiological, behavioral, and environmental components are necessary and sufficient for the generation of the behavior)? Fourth, a researcher may ask about the development of the behavior within an individual (i.e. what maturational, learning, social experiences must an individual undergo in order to demonstrate a behavior)? Theories addressing the proximate causes of behavior are based on answers to these two questions.

Developmental psychologist

Developmental psychology is the scientific study of how and why human beings change over the course of their life. Originally concerned with infants and children, the field has expanded to include adolescence, adult development, aging, and the entire lifespan. Developmental psychologists aim to explain how thinking, feeling, and behaviors change throughout life. This field examines change across three major dimensions: physical development, cognitive development, and socioemotional development. Within these three dimensions are a broad range of topics including motor skills, executive functions, moral understanding, language acquisition, social change, personality, emotional development, self-concept, and identity formation.

Developmental psychology examines the influences of nature and nurture on the process of human development, and processes of change in context and across time. Many researchers are interested in the interactions among personal characteristics, the individual's behavior, and environmental factors, including the social context and the built environment. Ongoing debates include biological essentialism vs. neuroplasticity and stages of development vs. dynamic systems of development.

Developmental psychology involves a range of fields, such as educational psychology, child psychopathology, forensic developmental psychology, child development, cognitive psychology, ecological psychology, and cultural psychology. Influential developmental psychologists from the 20th century include Urie Bronfenbrenner, Erik Erikson, Sigmund Freud, Jean Piaget, Barbara Rogoff, Esther Thelen, and Lev Vygotsky.

Educational psychologist

An educational psychologist is a psychologist whose differentiating functions may include diagnostic and psycho-educational assessment, psychological counseling in educational communities (students, teachers, parents and academic authorities), community-type psycho-educational intervention, and mediation, coordination, and referral to other professionals, at all levels of the educational system. Many countries use this term to signify those who provide services to students, their teachers, and families while other countries use this term to signify academic expertise in teaching Educational Psychology.

Evolutionary psychologist

Evolutionary psychology is a theoretical approach in the social and natural sciences that examines psychological structure from a modern evolutionary perspective. It seeks to identify which human psychological traits are evolved adaptations – that is, the functional products of natural selection or sexual selection in human evolution. Adaptationist thinking about physiological mechanisms, such as the heart, lungs, and immune system, is common in evolutionary biology. Some evolutionary psychologists apply the same thinking to psychology, arguing that the modularity of mind is similar to that of the body and with different modular adaptations serving different functions. Evolutionary psychologists argue that much of human behavior is the output of psychological adaptations that evolved to solve recurrent problems in human ancestral environments.

Evolutionary psychology is not simply a subdiscipline of psychology but its evolutionary theory can provide a foundational, metatheoretical framework that integrates the entire field of psychology in the same way evolutionary biology has for biology.

Evolutionary psychologists hold that behaviors or traits that occur universally in all cultures are good candidates for evolutionary adaptations including the abilities to infer others' emotions, discern kin from non-kin, identify and prefer healthier mates, and cooperate with others. They report successful tests of theoretical predictions related to such topics as infanticide, intelligence, marriage patterns, promiscuity, perception of beauty, bride price, and parental investment.

The theories and findings of evolutionary psychology have applications in many fields, including economics, environment, health, law, management, psychiatry, politics, and literature.

Criticism of evolutionary psychology involves questions of testability, cognitive and evolutionary assumptions (such as modular functioning of the brain, and large uncertainty about the ancestral environment), importance of non-genetic and non-adaptive explanations, as well as political and ethical issues due to interpretations of research results.

Experimental psychologist

Experimental psychology refers to work done by those who apply experimental methods to psychological study and the processes that underlie it. Experimental psychologists employ human participants and animal subjects to study a great many topics, including (among others) sensation & perception, memory, cognition, learning, motivation, emotion; developmental processes, social psychology, and the neural substrates of all of these.

Forensic psychologist

Forensic psychology is the intersection between psychology and the justice system. It involves understanding fundamental legal principles, particularly with regard to expert witness testimony and the specific content area of concern (e.g., competence to stand trial, child custody and visitation, or workplace discrimination), as well as relevant jurisdictional considerations (e.g., in the United States, the definition of insanity in criminal trials differs from state to state) in order to be able to interact appropriately with judges, attorneys, and other legal professionals. An important aspect of forensic psychology is the ability to testify in court as an expert witness, reformulating psychological findings into the legal language of the courtroom, providing information to legal personnel in a way that can be understood. Further, in order to be a credible witness, the forensic psychologist must understand the philosophy, rules, and standards of the judicial system. Primarily, they must understand the adversarial system. There are also rules about hearsay evidence and most importantly, the exclusionary rule. Lack of a firm grasp of these procedures will result in the forensic psychologist losing credibility in the courtroom. A forensic psychologist can be trained in clinical, social, organizational, or any other branch of psychology.

Generally, a forensic psychologist is designated as an expert in a specific field of study. The number of areas of expertise in which a forensic psychologist qualifies as an expert increases with experience and reputation. Forensic neuropsychologists are generally asked to appear as expert witnesses in court to discuss cases that involve issues with the brain or brain damage. They may also deal with issues of whether a person is legally competent to stand trial.

Questions asked by the court of a forensic psychologist are generally not questions regarding psychology but are legal questions and the response must be in language the court understands. For example, a forensic psychologist is frequently appointed by the court to assess a defendant's competence to stand trial. The court also frequently appoints a forensic psychologist to assess the state of mind of the defendant at the time of the offense. This is referred to as an evaluation of the defendant's sanity or insanity (which relates to criminal responsibility) at the time of the offense. These are not primarily psychological questions but rather legal ones. Thus, a forensic psychologist must be able to translate psychological information into a legal framework.

Health psychologist

Health psychology is the study of psychological and behavioral processes in health, illness, and healthcare. It is concerned with understanding how psychological, behavioral, and cultural factors contribute to physical health and illness. Psychological factors can affect health directly. For example, chronically occurring environmental stressors affecting the hypothalamic–pituitary–adrenal axis, cumulatively, can harm health. Behavioral factors can also affect a person's health. For example, certain behaviors can, over time, harm (smoking or consuming excessive amounts of alcohol) or enhance health (engaging in exercise). Health psychologists take a biopsychosocial approach. In other words, health psychologists understand health to be the product not only of biological processes (e.g., a virus, tumor, etc.) but also of psychological (e.g., thoughts and beliefs), behavioral (e.g., habits), and social processes (e.g., socioeconomic status and ethnicity).

By understanding psychological factors that influence health, and constructively applying that knowledge, health psychologists can improve health by working directly with individual patients or indirectly in large-scale public health programs. In addition, health psychologists can help train other healthcare professionals (e.g., physicians and nurses) to take advantage of the knowledge the discipline has generated, when treating patients. Health psychologists work in a variety of settings: alongside other medical professionals in hospitals and clinics, in public health departments working on large-scale behavior change and health promotion programs, and in universities and medical schools where they teach and conduct research.

Although its early beginnings can be traced to the field of clinical psychology, four different divisions within health psychology and one related field, occupational health psychology (OHP), have developed over time. The four divisions include clinical health psychology, public health psychology, community health psychology, and critical health psychology. Professional organizations for the field of health psychology include Division 38 of the American Psychological Association (APA), the Division of Health Psychology of the British Psychological Society (BPS), and the European Health Psychology Society. Advanced credentialing in the US as a clinical health psychologist is provided through the American Board of Professional Psychology.

Industrial and organizational psychologist

Industrial and organizational psychology (I/O psychology), which is also known as occupational psychology, organizational psychology, and work and organizational psychology, is an applied discipline within psychology. I/O psychology is the science of human behaviour relating to work and applies psychological theories and principles to organizations and individuals in their places of work as well as the individual's work-life more generally. I/O psychologists are trained in the scientist–practitioner model. They contribute to an organization's success by improving the performance, motivation, job satisfaction, and occupational safety and health as well as the overall health and well-being of its employees. An I/O psychologist conducts research on employee behaviours and attitudes, and how these can be improved through hiring practices, training programs, feedback, and management systems.

As of 2018, I/O psychology is one of the 16 recognized specialties by the American Psychological Association (APA) in the United States. It is represented by Division 14 of the APA, and was formally known as the Society for Industrial and Organizational Psychology (SIOP). In the United Kingdom, industrial and organizational psychologists are referred to as occupational psychologists. Occupational psychology in the UK is one of nine 'protected titles' within the profession "practitioner psychologist" regulated by the Health and Care Professions Council. In the UK, graduate programs in psychology, including occupational psychology, are accredited by the British Psychological Society.

In Australia, the title organizational psychologist is protected by law, and regulated by the Australian Health Practitioner Regulation Agency (AHPRA). Organizational psychology is one of nine areas of specialist endorsement for psychology practice in Australia.

In Europe someone with a specialist EuroPsy Certificate in Work and Organisational Psychology is a fully qualified psychologist and an expert in the work psychology field. Industrial and organizational psychologists reaching the EuroPsy standard are recorded in the Register of European Psychologists and industrial and organizational psychology is one of the three main psychology specializations in Europe.

Medical psychologist

Medical psychology is the application of psychological principles to the practice of medicine, and is clearly comprehensive rather than primarily drug-oriented, for both physical and mental disorders. The specialty of Medical Psychology and the National Alliance of Professional Psychology Providers (www.nappp.org) has been instrumental in advocacy and professional publications in increasing the awareness of Governmental Agencies, Scientific Societies, and the World Health Associations about the limited effect of "medication only approaches" to mental disorders and many related chronic physical disorders. A Medical Psychologist is a specialist who holds board certification in Medical Psychology from the American Board of Medical Psychology (www.amphome.org) and approved by the national psychology practitioner association in psychology(www.nappp.org). A specialist in Medical Psychology holds a doctoral degree in one of the clinical specialties in psychology, has done post doctoral graduate or approved didactic training in biomedical and pharmaceutical sciences and physical disease with behavioral and lifestyle components, and has completed a supervised residency providing advanced clinical diagnoses, prescribing or collaborating on medication and psychological treatment interventions in a comprehensive treatment plan, and they have passed one of the acceptable national written examinations, and supplied reviewed work product, and passed an Oral Examination. Medical psychologists are prepared to provide leadership and active roles in primary care and specialty healthcare facilities or consultation services essential for these facilities. A psychopharmacologist is very different than a Medical Psychologist, though one state uses confusing language in its laws.

The American Society for the Advancement of Pharmacotherapy defines medical psychology (an affiliate of the American Psychological Association) as "that branch of psychology integrating somatic and psychotherapeutic modalities into the management of mental illness and emotional, cognitive, behavioral and substance use disorders".

A medical psychologist who holds prescriptive authority for specific psychiatric medications and other pharmaceutical drugs must first obtain specific qualifications in Psychopharmacology. A trained medical psychologist, or psychopharmacologist who has prescriptive authority is equated with a mid-level provider who has the authority to prescribe psychotropic medication such as antidepressants for neurotic disorders. However, a medical psychologist does not automatically equate with a psychologist who has the authority to prescribe medication. In fact, most medical psychologists do not prescribe medication and do not have the authority to do so.

Neuropsychologist

Neuropsychology is the study of the structure and function of the brain as they relate to specific psychological processes and behaviours. It is both an experimental and clinical field of psychology that aims to understand how behavior and cognition are influenced by brain functioning and is concerned with the diagnosis and treatment of behavioral and cognitive effects of neurological disorders. Whereas classical neurology focuses on the physiology of the nervous system and classical psychology is largely divorced from it, neuropsychology seeks to discover how the brain correlates with the mind. It thus shares concepts and concerns with neuropsychiatry and with behavioral neurology in general. The term neuropsychology has been applied to lesion studies in humans and animals. It has also been applied in efforts to record electrical activity from individual cells (or groups of cells) in higher primates (including some studies of human patients). It makes use of neuroscience, and shares an information processing view of the mind with cognitive psychology and cognitive science.

In practice, neuropsychologists tend to work in research settings (universities, laboratories or research institutions), clinical settings (medical hospitals or rehabilitation settings, often involved in assessing or treating patients with neuropsychological problems), or forensic settings or industry (often as clinical-trial consultants where CNS function is a concern).

Psychopharmacologist

Psychopharmacology (from Greek ψῡχή, psȳkhē, 'breath, life, soul'; φάρμακον, pharmakon, 'drug'; and -λογία, -logia) is the scientific study of the effects drugs have on mood, sensation, thinking, and behavior. It is distinguished from neuropsychopharmacology, which emphasizes the correlation between drug-induced changes in the functioning of cells in the nervous system and changes in consciousness and behavior.

The field of psychopharmacology studies a wide range of substances with various types of psychoactive properties, focusing primarily on the chemical interactions with the brain. The term "psychopharmacology" was probably first coined by David Macht in 1920.

Psychoactive drugs interact with particular target sites or receptors found in the nervous system to induce widespread changes in physiological or psychological functions. The specific interaction between drugs and their receptors is referred to as "drug action", and the widespread changes in physiological or psychological function is referred to as "drug effect". These drugs may originate from natural sources such as plants and animals, or from artificial sources such as chemical synthesis in the laboratory.

Psychophysicist

Psychophysics quantitatively investigates the relationship between physical stimuli and the sensations and perceptions they produce. Psychophysics has been described as "the scientific study of the relation between stimulus and sensation" or, more completely, as "the analysis of perceptual processes by studying the effect on a subject's experience or behaviour of systematically varying the properties of a stimulus along one or more physical dimensions".

Psychophysics also refers to a general class of methods that can be applied to study a perceptual system. Modern applications rely heavily on threshold measurement, ideal observer analysis, and signal detection theory.

Psychophysics has widespread and important practical applications. For example, in the study of digital signal processing, psychophysics has informed the development of models and methods of lossy compression. These models explain why humans perceive very little loss of signal quality when audio and video signals are formatted using lossy compression.

Social psychologist

Social psychology is the scientific study of how people's thoughts, feelings and behaviors are influenced by the actual, imagined or implied presence of others. In this definition, scientific refers to the empirical investigation using the scientific method. The terms thoughts, feelings and behavior refer to psychological variables that can be measured in humans. The statement that others' presence may be imagined or implied suggests that humans are malleable to social influences even when alone, such as when watching television or following internalized cultural norms. Social psychologists typically explain human behavior as a result of the interaction of mental states and social situations.

Social psychologists examine factors that cause behaviors to unfold in a given way in the presence of others. They study conditions under which certain behavior, actions, and feelings occur. Social psychology is concerned with the way these feelings, thoughts, beliefs, intentions, and goals are cognitively constructed and how these mental representations, in turn, influence our interactions with others.

Social psychology traditionally bridged the gap between psychology and sociology. During the years immediately following World War II there was frequent collaboration between psychologists and sociologists. The two disciplines, however, have become increasingly specialized and isolated from each other in recent years, with sociologists focusing on "macro variables" (e.g., social structure) to a much greater extent than psychologists. Nevertheless, sociological approaches to psychology remain an important counterpart to psychological research in this area.

In addition to the split between psychology and sociology, there has been a somewhat less pronounced difference in emphasis between American social psychologists and European social psychologists. As a generalization, American researchers traditionally have focused more on the individual, whereas Europeans have paid more attention to group level phenomena (see group dynamics).

Sport psychologist

Sport psychology is an interdisciplinary science that draws on knowledge from many related fields including biomechanics, physiology, kinesiology and psychology. It involves the study of how psychological factors affect performance and how participation in sport and exercise affect psychological and physical factors. In addition to instruction and training of psychological skills for performance improvement, applied sport psychology may include work with athletes, coaches, and parents regarding injury, rehabilitation, communication, team building, and career transitions.

Sociologist

Sociology is the scientific study of society, patterns of social relationships, social interaction, and culture of everyday life. It is a social science that uses various methods of empirical investigation and critical analysis to develop a body of knowledge about social order, acceptance, and change or social evolution. While some sociologists conduct research that may be applied directly to social policy and welfare, others focus primarily on refining the theoretical understanding of social processes. Subject matter ranges from the micro-sociology level of individual agency and interaction to the macro level of systems and the social structure.

The different traditional focuses of sociology include social stratification, social class, social mobility, religion, secularization, law, sexuality, gender, and deviance. As all spheres of human activity are affected by the interplay between social structure and individual agency, sociology has gradually expanded its focus to other subjects, such as health, medical, economy, military and penal institutions, the Internet, education, social capital, and the role of social activity in the development of scientific knowledge.

The range of social scientific methods has also expanded. Social researchers draw upon a variety of qualitative and quantitative techniques. The linguistic and cultural turns of the mid-20th century led to increasingly interpretative, hermeneutic, and philosophic approaches towards the analysis of society. Conversely, the end of the 1990s and the beginning of the 2000s have seen the rise of new analytically, mathematically, and computationally rigorous techniques, such as agent-based modelling and social network analysis.

Social research informs politicians and policy makers, educators, planners, legislators, administrators, developers, business magnates, managers, social workers, non-governmental organizations, non-profit organizations, and people interested in resolving social issues in general. There is often a great deal of crossover between social research, market research, and other statistical fields.

Interdisciplinary

Applied physicists

Applied physics is intended for a particular technological or practical use. It is usually considered as a bridge or connection between physics and engineering.

"Applied" is distinguished from "pure" by a subtle combination of factors, such as the motivation and attitude of researchers and the nature of the relationship to the technology or science that may be affected by the work. Applied physics is rooted in the fundamental truths and basic concepts of the physical sciences, but is concerned with the utilization of scientific principles in practical devices and systems, and in the application of physics in other areas of science.

It usually differs from engineering in that an applied physicist may not be designing something in particular, but rather is using physics or conducting physics research with the aim of developing new technologies or solving an engineering problem. This approach is similar to that of applied mathematics.

In other words, applied physics is rooted in the fundamental truths and basic concepts of the physical sciences but is concerned with the utilization of these scientific principles in practical devices and systems.

Applied physicists can also be interested in the use of physics for scientific research. For instance, the field of accelerator physics can contribute to research in theoretical physics by working with engineers enabling design and construction of high-energy colliders.

Bioinformatician

Bioinformatics /ˌbaɪ.oʊˌɪnfərˈmætɪks/ (About this soundlisten) is an interdisciplinary field that develops methods and software tools for understanding biological data. As an interdisciplinary field of science, bioinformatics combines biology, computer science, information engineering, mathematics and statistics to analyze and interpret biological data. Bioinformatics has been used for in silico analyses of biological queries using mathematical and statistical techniques.

Bioinformatics is both an umbrella term for the body of biological studies that use computer programming as part of their methodology, as well as a reference to specific analysis "pipelines" that are repeatedly used, particularly in the field of genomics. Common uses of bioinformatics include the identification of candidates genes and single nucleotide polymorphisms (SNPs). Often, such identification is made with the aim of better understanding the genetic basis of disease, unique adaptations, desirable properties (esp. in agricultural species), or differences between populations. In a less formal way, bioinformatics also tries to understand the organisational principles within nucleic acid and protein sequences, called proteomics.

Biophysicist

Biophysics is an interdisciplinary science that applies approaches and methods traditionally used in physics to study biological phenomena. Biophysics covers all scales of biological organization, from molecular to organismic and populations. Biophysical research shares significant overlap with biochemistry, molecular biology, physical chemistry, physiology, nanotechnology, bioengineering, computational biology, biomechanics, developmental biology and systems biology.

The term biophysics was originally introduced by Karl Pearson in 1892. Ambiguously, the term biophysics is also regularly used in academia to indicate the study of the physical quantities (e.g. electric current, temperature, stress, entropy) in biological systems, which is, by definition, performed by physiology. Nevertheless, other biological sciences also perform research on the biophysical properties of living organisms including molecular biology, cell biology, biophysics, and biochemistry.

Neurophysicist

Neurophysics (or neurobiophysics) is the branch of biophysics dealing with the development and use of physical techniques to gain information about the nervous system on a molecular level.

The term is a portmanteau of neuron and physics, to represent an interdisciplinary science which applies the approaches and methods of experimental biophysics to study the nervous system.

Examples of techniques developed and used in neurophysics are magnetic resonance imaging (MRI), patch clamp, tomography, and two-photon excitation microscopy.

Biostatistician

Biostatistics are the application of statistics to a wide range of topics in biology. It encompasses the design of biological experiments, especially in medicine, pharmacy, agriculture and fishery; the collection, summarization, and analysis of data from those experiments; and the interpretation of, and inference from, the results. A major branch is medical biostatistics, which is exclusively concerned with medicine and health.

Health physicist

Health physics is the applied physics of radiation protection for health and health care purposes. It is the science concerned with the recognition, evaluation, and control of health hazards to permit the safe use and application of ionizing radiation. Health physics professionals promote excellence in the science and practice of radiation protection and safety. Health physicists principally work at facilities where radionuclides or other sources of ionizing radiation (such as X-ray generators) are used or produced; these include hospitals, government laboratories, academic and research institutions, nuclear power plants, regulatory agencies, and manufacturing plants.

Library scientist

Library science (often termed library studies, bibliothecography, library economy) is an interdisciplinary or multidisciplinary field that applies the practices, perspectives, and tools of management, information technology, education, and other areas to libraries; the collection, organization, preservation, and dissemination of information resources; and the political economy of information. Martin Schrettinger, a Bavarian librarian, coined the discipline within his work (1808–1828) VersucheinesvollständigenLehrbuchs der Bibliothek-WissenschaftoderAnleitungzurvollkommenenGeschäftsführungeinesBibliothekars. Rather than classifying information based on nature-oriented elements, as was previously done in his Bavarian library, Schrettinger organized books in alphabetical order. The first American school for library science was founded by Melvil Dewey at Columbia University in 1887.

Historically, library science has also included archival science. This includes how information resources are organized to serve the needs of select user groups, how people interact with classification systems and technology, how information is acquired, evaluated and applied by people in and outside libraries as well as cross-culturally, how people are trained and educated for careers in libraries, the ethics that guide library service and organization, the legal status of libraries and information resources, and the applied science of computer technology used in documentation and records management.

There is no generally agreed-upon distinction between the terms library science, and librarianship, and to a certain extent they are interchangeable, perhaps differing most significantly in connotation. The term library science or library studies (LIS) is most often used; most librarians consider it as only a terminological variation, intended to emphasize the scientific and technical foundations of the subject and its relationship with information science. LIS should not be confused with information theory, the mathematical study of the concept of information. Library philosophy has been contrasted with library science as the study of the aims and justifications of librarianship as opposed to the development and refinement of techniques.

Materials chemist

The interdisciplinary field of materials science, also commonly termed materials science and engineering is the design and discovery of new materials, particularly solids. The intellectual origins of materials science stem from the Enlightenment, when researchers began to use analytical thinking from chemistry, physics, and engineering to understand ancient, phenomenological observations in metallurgy and mineralogy. Materials science still incorporates elements of physics, chemistry, and engineering. As such, the field was long considered by academic institutions as a sub-field of these related fields. Beginning in the 1940s, materials science began to be more widely recognized as a specific and distinct field of science and engineering, and major technical universities around the world created dedicated schools of the study, within either the Science or Engineering schools, hence the naming.

Materials science is a syncretic discipline hybridizing metallurgy, ceramics, solid-state physics, and chemistry. It is the first example of a new academic discipline emerging by fusion rather than fission.

Many of the most pressing scientific problems humans currently face are due to the limits of the materials that are available and how they are used. Thus, breakthroughs in materials science are likely to affect the future of technology significantly.

Materials scientists emphasize understanding how the history of a material (its processing) influences its structure, and thus the material's properties and performance. The understanding of processing-structure-properties relationships is called the § materials paradigm. This paradigm is used to advance understanding in a variety of research areas, including nanotechnology, biomaterials, and metallurgy. Materials science is also an important part of forensic engineering and failure analysis – investigating materials, products, structures or components which fail or do not function as intended, causing personal injury or damage to property. Such investigations are key to understanding, for example, the causes of various aviation accidents and incidents.

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Mathematical biologist

Mathematical and theoretical biology is a branch of biology which employs theoretical analysis, mathematical models and abstractions of the living organisms to investigate the principles that govern the structure, development and behavior of the systems, as opposed to experimental biology which deals with the conduction of experiments to prove and validate the scientific theories. The field is sometimes called mathematical biology or biomathematics to stress the mathematical side, or theoretical biology to stress the biological side. Theoretical biology focuses more on the development of theoretical principles for biology while mathematical biology focuses on the use of mathematical tools to study biological systems, even though the two terms are sometimes interchanged.

Mathematical biology aims at the mathematical representation and modeling of biological processes, using techniques and tools of applied mathematics. It has both theoretical and practical applications in biological, biomedical and biotechnology research. Describing systems in a quantitative manner means their behavior can be better simulated, and hence properties can be predicted that might not be evident to the experimenter. This requires precise mathematical models.
Mathematical biology employs many components of mathematics, and has contributed to the development of new techniques.

Mathematical chemist
Mathematical chemistry is the area of research engaged in novel applications of mathematics to chemistry; it concerns itself principally with the mathematical modeling of chemical phenomena.Mathematical chemistry has also sometimes been called computer chemistry, but should not be confused with computational chemistry.

Major areas of research in mathematical chemistry include chemical graph theory, which deals with topology such as the mathematical study of isomerism and the development of topological descriptors or indices which find application in quantitative structure-property relationships; and chemical aspects of group theory, which finds applications in stereochemistry and quantum chemistry.

The history of the approach may be traced back to the 19th century. Georg Helm published a treatise titled "The Principles of Mathematical Chemistry: The Energetics of Chemical Phenomena" in 1894. Some of the more contemporary periodical publications specializing in the field are MATCH Communications in Mathematical and in Computer Chemistry, first published in 1975, and the Journal of Mathematical Chemistry, first published in 1987. In 1986 a series of annual conferences

MATH/CHEM/COMP taking place in Dubrovnik was initiated by the late Ante Graovac.

The basic models for mathematical chemistry are molecular graph and topological index.

In 2005 the International Academy of Mathematical Chemistry (IAMC) was founded in Dubrovnik (Croatia) by Milan Randić. The Academy has 82 members (2009) from all over the world, including six scientists awarded with a Nobel Prize.

Mathematical physicist

Mathematical physics refers to the development of mathematical methods for application to problems in physics. The Journal of Mathematical Physics defines the field as "the application of mathematics to problems in physics and the development of mathematical methods suitable for such applications and for the formulation of physical theories". It is a branch of applied mathematics, but deals with physical problems.

Test your Knowledge of Science Q&A format

1.LIGHT

Objective Questions:

1.Light is composed of ________ type of particles.

1. Particle 2. ATP 3. Electron 4. **Photon**

2.Light has ________ nature.

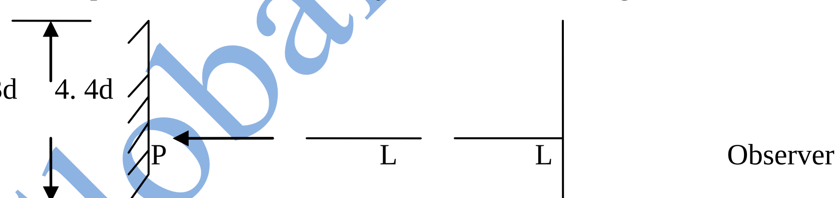
1. Particle 2. Wave 3. **Both 1,2** 4. None of these

3. Light is ________ type of wave.

1. Longitudinal 2. Transverse 3. **Electromagnetic** 4. Oscillation

4. d is the height of plane mirror fitted on the wall. S is point source kept, at a distance of L meter from mirror. Observer starts moving towards mirror. Initial distance between observer and mirror is 2 L meter, so up to how much distance you can observe image of source in the mirror

1. d 2. 2d 3. 3d 4. 4d



5. Focal length of plain mirror is ________

1. Zero 2. **Infinite** 3. Depends on size of the mirror 4. None of these

6. Light shows ________ Properties

1. Rectilinear 2. Reflection 3. Refraction 4. **All**

7. Which is a correct statement

1. Lunar Eclipse – No moon day 2. Sun - Earth – Moon – Full moon

3. Sun – Earth – Moon – Lnar eclipse 4. None of these

8. Why do we observe shadow effect of the light ?

1. Light cannot pass through opaque objecys 2. Light cannot pass through transparnt objects

3. Rectilinear ropagation 4. **A and C correct**

9. If the ray incidence is perpendicular to mirror, reflected rey will be _______

1. **It will get reflected along same path in opposite direction**

2. It will get reflected along same path in same direction

3. No reflection 4. None of these

10. Angle between Incident rey is 90^o . find out the angle of incidence

1. **45^o** 2. 90^o 3. 180^o 4. 60^o

11. Angle between Ray of Incidence and a mirror is 30^o, FinedAngle of Reflection

1. 100^o 2. 30^o 3.**60^o** 4. 90^o

12. If we increase Angle of Incidence by 30^o, Angle of Reflection wil increase by ________

1. **60^o** 2. 90^o 3. 120^o 4. 30

13. Keep rey of incidence fixed and rotate the mirror through 10^o reflected rey turns through_________

1. **120^o** 2. 10^o 3. 80^o 4. 5^o

14. What are the characteristics of image in plane mirror?

1. Distance between object and mirror = Distance between image and mirror

2. Image is virtual

3. Image is laterally opposite [lateral inversion]

4. Hight of the plane mirror should be atleast half of the object to get complete mage of the object

5. **All are correct**

15. How many images will we get?

1. 6

2. 4

3. **8**

4. None of these

16. In case of concave mirror or convex lens, eays get ___________

1. Diversified 2. **Donverge** 3. Parallel 4. None of these

17. In periscope angle between the two mirror is __________

1. 40 2. **46** 3. 90 4. Parallel 5.45

18. In searchlight _________mirror is used.

1. Plane 2. **Concave** 3. Convex 4. Angular

19. Candela is a unit of ________

1. **Intersity of light** 2. Light 3.Fluroescence 4. None of these

20. Intensity of light at a particular point depends on ________

1. **(Source – point), distance** 2. Type of source

3. Independent of anything 4. None of these

21. To get virtual image by concave mirror we should keep candle at _________

1. F 2. P 3. **Between P and F** 4. Between C and

22. In a Solar cooker, we use ________

1. Concave lens 2. Convexlens **3. Concave mirror** **4. Plane mirror**

23. Mirror on the driver side is of ________ type.

1. Plane 2. Cancave 3. **Canvex** 4. None of these

24. Example of Refraction in day-to-day life are_________

1. Mirage 2. Bottom of the water tank seems to be lifted up

3. A stick partially dipped in water seems to be bent 4. **2 and 3 correct**

25. A Ray of incidence (RI) falls on prism (P) and get dispersed. What will happen if these seven wavelengths are passed through convex lens?

1. **White ray forms** 2. They will divert

3. No offect 4. Can't say

2. EVOLUTION

Objective Questions:

1. The greatest weakness of Darwin's theory was his failure to give satisfactory explanation for___

1. Over production 2. Struggle for existence 3. Survival of fittest 4. **Variations**

2.Which concept attributed to Charles Darwin?

1. Acquired characters are inherited 2. Evert cell must come from pre-existing cell.

3. Struggle for existence. 4. **Survival of the fittest**

3. In formulating the theory of evolution by natural selection Darwin was greatly impressed by Writings of ____

1. Mendel 2. Lamarck 3. De veries 4. **Malthus**

4. Use & disuse principal proposed by ____

1. Hugo & De vries 2. Weismann 3. Darwin 4. **None of these**

5. Bird having tech in break is ____

1. Kiwi 2. **Archaeopteryx** 3. Ostrich 4. None of these

6. Homologous organs are ____

1. **Similar in origin but similar or dissimilar in function**

2. dissimilar in origin but similar in function

7. Analogous structures are _____

1. Structurally similar 2. **Functionally similar**

3. Normally non-functional 4. None of these

8. Devonian period is called age of:

1. Giant Molluses 2. **Fishes** 3.Amphibians 4.Reptils

9. Wings of insects and bat are_____

1. Homologous 2. Analogous 3. Vestigal 4. None of these

10. Which one of the following is not a vestigial organ in human body?

1. Hairs on body 2. Pinna muscles 3. Coccyx 4. **None of these**

11. Animal which has become extinct very recently-

1. Mammoth 2. Dinosaur 3. Pterodactyl 4.**Dodo**

12. Which of these birds cannot fly____

1. Peacock 2. **Duck** 3. Emu 4. Stork

13. Which structures provide strong evidence of organic evolution____

1. Gill clefts in vertebrate embryos 3. Jointed legs in arthropods and mammals

2. **Wings in insects, birds and bat** 4. Excretory organs in earth worms and frogs.

14. Most modern breeds of domestic dogs have evolved by _____

1. **Natural selection** 2. Artificial selection 3. Sexual selection 4. Reproductive isolation

15. Important evidences of organic evolution_____

1. Occurrence of homologous and vestigial organs in different animals.

2. Occurrence of analogous and vestigial organs in different animals.

3. Occurrence of homologous and analogous organs in different animals.

4. **All of these**

16. Most primitive living mammals which provide an evidence of organic evolution from geographical distribution are found in____

1. China 2. India 3. **Australia** 4. Africa

17. Which one represents a connecting link as an evidence from anatomy in favour of organic evolution____

1. Whale between fishes and mammals

2. Archaeopteryx between birds and mammals

3. Duckbill platypus between reptiles and mammals.

4. Java apemen between modern man and Peking man.

18. Which group includes homologous organs _____

1. Bird's wings, but's wings and moth's wings 2. Hindlegs of dog, duck and kangaroo

3. for limbs of bat and horse 4. **All**

19. Which group includes analogous organs ______

1. Wings of bat, birds, butterfly 2. Wings of bat, cockroach and sparrow

3. **both** 4. None of these

20. Galapagos islands are associated with the name of ____

1. Wallace 2. Malthus 3. Darwin 4. Lamarck

3. SOURCE OF ENERGY

Objective Questions:

1.Solar cells convert: -

1.Electrical energy to mechanical energy 2. Mechanical energy to electrical energy
3.**Solar energy to electrical energy** 4. Potential energy to chemical energy

2.The wind power potential of India is

1. **20,000MW** 2. 2000MW 3. 12000MW 4. 14000N1W

3. A solar panel is made by combining a large number of:-

1. Solar cookers 2. **Solar cells** 3. Solar water heaters 4. Solar concentrators

4. To produce biogas in a biogas plant, we need.

1. air but not water 2. **Water but not air** 3. Air and water 4. Neither air nor water

5. When we use biomass to generate electricity the conversion of energy is from

1. **Chemical to electrical energy** 2. Kinetic to electrical energy

3. Nuclear energy to electrical 4. Muscular energy to electrical energy

6. The nuclear fuel in the sun is.

1. **Hydrogen** 2. Nitrogen 3. Carbon 4. Helium

7. The part of sunlight used in heating solar cooker is

1. Ultraviolet rays
2. **Infrared radiations**
3. Visible radiations
4. All of these

8. A wind mill can function with a minimum wind velocity of about.

1. 10 km/hr 2. 7km/hr 3. **15 km/hr** 4. 20km/hr

9. The energy of the stars is produced by

1. Chemical reaction
2. **Thermonuclear reactions**
3. Nuclear fission
4. Gravitation condensation

10. The purpose of the glass cover on the top of a box type solar cooker is to

1. Allow more sunlight inti the box

2. Allow people to see the food being cooked

3. Prevent dust from entering the box

4. **Reduce heat loss by radiation**

4. CHEMICAL BONDING

Objective Question:

1.Electronic theory of valency was developed by ________and________ . It was extended by Irving Langmuir.

1.**W. Kossel, G. N Lewis** 2. Heitlor, London 3. Raighlay, soddy 4. None of these

2.Every element has tendency to acquire inert gas configuration i.e.____.

1. ns^2np 2.ns^2np^2 3. n^s2np^5 4. $\mathbf{ns^2np^6}$

3.Octet rule was given by _____

1. W. Kossel, G. N Lewis 2. **Heitlor, London** 3.Raighlay, soddy 4. None of these

4.Which one of the following is a drawback of octet rule?

1.It could not explain the geometry of molecule

2.Expanded octet

3.Incomplete Octet 4. **All**

5.Anion formation is favored by _______

1.Low electro positivity 2. High electron affinity 3. Lattice energy 4. All

6.Cation formation is favored by_______

1. Low I. P 2. Low electron affinity 3. Lattice energy 4. All

5.NERVOUS SYSTEM

Objective Question

1. Voluntary movement in vertebrates are co-ordinated by
1. **Cerebellum** 2. Cerebrum 3. Thyroid 4. Pituitary

2.Cerebral hemispheres are centre of

1. Thinking 2. Will power 3. Reasoning 4. **All of these**

3. Lateral ventricles are found in

1. Brain and heart 2. Thyroid 3. Cerebellum 4. **Cerebrum**

4. Outermost covering of brain of man is

1. **Duramater** 2. Piamater 3. Arachnoid 4. Choroid

5. The ventricles of CNS are filled with

1. Spinal fluid 2.**Cerebrospinal fluid** 3.Cranial fluid 4. Pericardial fluid

6.NEWTON'S LAWS OF MOTION

Objection Questions:

1. Newton's law is applicable if _____ force is acting on a body in inertial frame of reference of reference
1. **Pseudo** 2. True 3. Real 4. Virtul

2.A cricket ball of mass 150 gm is moving with a velocity of 12m/s and is hit by a bat so that the ball is turned back with velocity of 20m/s. The force of blow acts for 0.01 second on the ball. Find average force exerted by the ball?

1. **480 N** 2. 40 dy 3. 49 N 4. 9.8 N

3.Newton's first Law is also called as _______

1. **Laws of inertia** 2. Law of conservation of mass

3. Law of mass action 4. None of these

4. The second Law provides_________

1. Quantitive measure of torque 2. **Quantitive measure of force**

3. Quantitive measure of inertia 4. None of these

5. When a scooter and huge truck collide(both having high speed) the scooter

is thrown away because of_______

1.**Law of conservation of momentum** 2. High momentum

3.High of impulse 4. None of these.

6. Inertial frame of reference is a frame which is / her ______

1. Net external force is zero 2. Zero acceleration

3. Moving with constant uniform velocity 4. **All are correct**

7. Impulse is _______

1. Large force acting for small 2. Rate of change of momentum

3. Vector 4. **1, 3 both**

8. Frame of reference in which Newton's laws of motion hold true is called as

1. **Inertial** 2. Static 3. Non-inertial 4. None of these

9. A constant force acting on a body of mass 5kg changes its speed form 2m/s to 7m/s in 10 sec the direction of motion is unchanged. Find magnitude of force.

1. 2.5 dy 2. **2.5 N** 3. 25 N 4. None of these

10. A retarding of 100 N is applicable on body of mass 50kg moving with speed 20m/s.

How long does the body take to stop?

1. **10 sec** 2. 5 sec 3. 20 sec 4. 15 sec

7.GRAVITATION

Objective Question:

1. The weight of a body at the center of earth is _____
1. Infinite 2. **Zero** 3. Slightly less than at equator 4. None of the above

2.A pendulum clock is set to give correct time at sea level. This clock moved to a hill station at an altitude of 200m above sea level. In order to get correct time on the hill station the length of the pendulum_____

1. **Has to be reduced** 2. No change 3. Has to be increase 4. None of these

3. Two satellites are moving around the earth in same circular orbit. They must have same______

1. KE 2. Angular momentum 3. **Speed** 4. None of these

4. A body released from height h takes time t to reach earth's surface. The time taken by same body released from same height to reach moon's surface is _____

1. t 2. t/6 3. 6t 4. **None of these**

5. How much deep inside the earth should a man go so that his weighed becomes $1/4^{th}$ of the weight on earth's surface

1. R/2 2. 2R 3. $4R^{1/2}$ 4. **None of these**

8. HEAT

Objective Questions:

1. Heat transferred by radiator of a refrigerator is _______

1. **More than that of a freezer** 2. Less than that of a freezer

3. Same as that of a freezer 4. None of these

2. Melting point of ice ______

1. Increases with increase in pressure 2. **Decreases with increasing pressure**

3. Independent of pressure 4. None of these

3. Boiling point of water _______

1. **Increases with increase in pressure** 2. Decreases with increase in pressure

3. Independent of pressure 4. None of these

4. The pressure cooker is fastest method to cook, because

1. **Boiling point is raised by increasing the pressure**

2. Boiling point is lowered by increasing the pressure

3. More steam is available to cook the food at 100^oC

4. None of these

5. It is difficult to cook at high altitudes because ________

1. Of less oxygen.

2. Of fall in temperature, more heat has to ne supplied

3. **Of decrease in atmospheric pressure Boiling Point of water increases**

4. Of high moisture content

6. Cooking takes longer time at ______

1. Sea level 2. At Simla

3. **At Mount Everest** 4. Submarine, 100 meter below surface of water.

7. Water is boiling in a flask over a burner. What is to be done to reduce the Boiling Point ?

1. Reduce the surrounding temperature 2. Connect evacuating system

3. **Close the container with a tight cork** 4. Supply more heat

8. A closed bottle containing water at room temperature is taken to moon and then the lid is opened. Then water will.

1. Freeze 2. **Boil** 3. Decompose 4. No Change

^{o}9. The relative humidity of air can decrease, in spite of an increase in absolute humidity when ______

1. Pressure rises 2. Pressure is lowered

3. Temperature rises 4. **Temperature is lowered**

10. Water evaporates at the atmospheric pressure at certain rate. If water is placed in vaccum rate of decreases

1. Will decrease 2. **Will increase** 3. Unchanged 4. None of these

11. If atmospheric pressure and dew point are equal then humidity will be______

1. **100%** 2. Zero 3. 50% 4. None of these

12. At a particular day room temperature is 400C relative humidity is 100%. Then dew point will be

1. 10^{o}C 2. 20^{o}C 3. 0^{o}C 4. **40^o**

13. The air in the room has 12 hgm/cc water water vapour. For saturation of 16 gm/cc vapour is required, the relative humidity will be ______

1. **75%** 2. ¾% 3. 60% 4. 30%

14. Formation of water current is due to _____

1. **Convection** 2. Conduction 3. Radiation 4. All

15. Absorptive power of perfectly black-body is _____

1. **Maximum** 2. Minimum 3. Medium 4. None of these

16. The temperature will be same on both Celsius and Fahrenheit Scales at ______

1.- **40^{o}C** 2. 40^{o}C 3. 50^{o}C 4. -50^{o}C

17. Degree of hotness or coldness of a body is known as ______

1. Kinetic energy 2. Hotness 3. **Temperature** 4. None of these

18. In radiation, Process of heating transfer occurs by ______ waves.

1. Longitudinal 2. Transverse 3. **Electromagnetic** 4. No Waves ai all

19. We heat water at 1000C, what will happen?

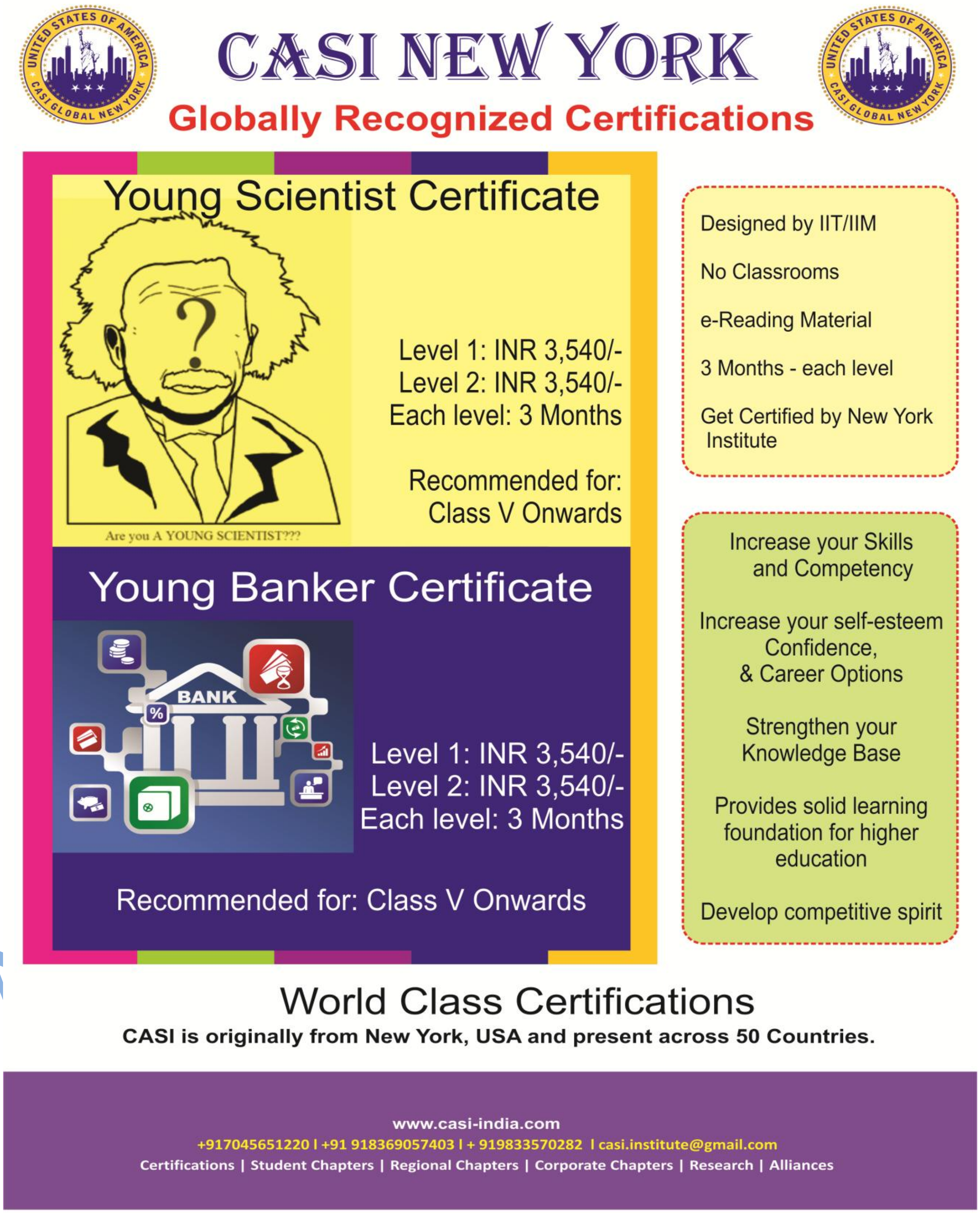
1. Its temperature increases 2. It will expand

3. **Heat will be utilized in the formation of vapours** 4. All correct

20. In spherical hot body heat transfer to surrounding's occurs by ______

1. Rotation 2. Convection 3. **Radiation** 4. @ & $ are correct

Young Scientist Brochure



College Program Brochure

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Mahawalkathon

Felicitating Community Leaders Community Leaders from across Maharashtra were felicitated at an award function held at YB Chavhan auditorium, opposite Mantralaya, Mumbai on the 22nd March 2019. Deans, Vice Chancellors, Principals and nominated professors from universities institutes which participated at the PWD, MMVD, Government of Maharashtra, CASI and CSR Diary events were felicitated, Nominees / representatives of Mumbai Fire brigade department, Maharashtra RTO, leading corporates, GPO, Banks, Foundations and NGO's and CASI Global Fellows were also felicitated at this event.

MahaWalkathon 2018 Stamp Postal Stamp Release

The Mahawalkathon 2018 was held at 503 locations on the same day at the same time,
The event witnessed over 5 lac participants creating a record.
To commensurate the success of the event a postal stamp was released at the award function.

"MAHAWALKATHON 2018" STAMP