Dissertation

Dissertation Glossary: G. Rincon (Updated - 07.01.13)

Title:

Acoustics: Sonic (Waves):

Acoustics:

The word "acoustic" is derived from the Greek word ακουστικός (akoustikos), meaning "of or for hearing, ready to hear"[2] and that from ἀκουστός (akoustos), "heard, audible",[3] which in turn derives from the verb ἀκούω (akouo), "I hear".[4]

The Latin synonym is "sonic", after which the term **sonics** used to be a synonym for acoustics[5] and later a branch of acoustics.[6] Frequencies above and below the audible range are called "ultrasonic" and "infrasonic", respectively.

Acoustics is the interdisciplinary science that deals with the study of all mechanical waves in gases, liquids, and solids including vibration, sound, ultrasound and infrasound. A scientist who works in the field of **acoustics** is an acoustician while someone working in the field of acoustics technology may be called an acoustical engineer.

Psychoacoustics:

Psychoacoustics is the scientific study of sound perception. More specifically, it is the branch of science studying the psychological and physiological responses associated with sound (including speech and music). It can be further categorized as a branch of psychophysics.

Background: Hearing is not a purely mechanical phenomenon of wave propagation, but is also a sensory and perceptual event; in other words, when a person hears something, that something arrives at the ear as a mechanical sound wave traveling through the air, but within the ear it is transformed into neural action potentials. These nerve pulses then travel to the brain where they are perceived. Hence, in many problems in acoustics, such as for audio processing, it is advantageous to take into account not just the mechanics of the environment, but also the fact that both the ear and the brain are involved in a person's listening experience. The inner ear, for example, does significant signal processing in converting sound waveforms into neural stimuli, so certain differences between waveforms may be imperceptible.[1] Data compression techniques, such as MP3, make use of this fact.[2] In addition, the ear has a nonlinear response to sounds of different intensity levels; this nonlinear response is called loudness. Telephone networks and audio noise reduction systems make use of this fact by nonlinearly compressing data samples before transmission, and then expanding them for playback.[3] Another effect of the ear's nonlinear response is that sounds that are close in frequency produce phantom beat notes, or intermodulation distortion products.[4]

Aesthetics

Aesthetics:

Aesthetics (also spelled **æsthetics**) is a branch of philosophy dealing with the nature of art, beauty, and taste, with the creation and appreciation of beauty.[1][2] It is more scientifically defined as the study of sensory or sensori-emotional values, sometimes called judgments of sentiment and taste.[3] More broadly, scholars in the field define aesthetics as "critical reflection on art, culture and nature."[4][5]

Etymology:

The word *aesthetic* is derived from the Greek *αἰσθητικός* (*aisthetikos*, meaning "esthetic, sensitive, sentient"), which in turn was derived from αἰσθάνομαι (*aisthanomai*, meaning "I perceive, feel, sense").[6] The term "aesthetics" was appropriated and coined with new meaning in the German form *Æsthetik* (modern spelling *Ästhetik*) by Alexander Baumgarten in 1734.

Affect:

Affect conveys influence over something that already exists

Algorithms:

Algorithms:

In mathematics and computer science, an **algorithm** (**i**/ˈælgərɪðəm/ ***al**-gə-ri-dhəm*) is a step-by-step procedure for calculations.

An algorithm is an effective method expressed as a finite list[1] of well-defined instructions[2] for calculating a function.[3] Starting from an initial state and initial input (perhaps empty),[4] the instructions describe a computation that, when executed, proceeds through a finite [5] number of well-defined successive states, eventually producing "output"[6] and terminating at a final ending state.

Expressing algorithms[edit]

Algorithms can be expressed in many kinds of notation, including natural languages, pseudocode, flowcharts, programming languages or control tables (processed by interpreters). Natural language expressions of algorithms tend to be verbose and ambiguous, and are rarely used for complex or technical algorithms. Pseudocode, flowcharts and control tables are structured ways to express algorithms that avoid many of the ambiguities common in natural language statements. Programming languages are primarily intended for expressing algorithms in a form that can be executed by a computer, but are often used as a way to define or document algorithms.

There is a wide variety of representations possible and one can express a given Turing machine program as a sequence of machine tables (see more at finite state machine, state transition table and control table), as flowcharts (see more at state diagram), or as a form of rudimentary machine code or assembly code called "sets of quadruples" (see more at Turing machine).

Representations of algorithms can be classed into three accepted levels of Turing machine description:[21]

•1 **High-level description**:

"...prose to describe an algorithm, ignoring the implementation details. At this level we do not need to mention how the machine manages its tape or head."

•2 **Implementation description**:

"...prose used to define the way the Turing machine uses its head and the way that it stores data on its tape. At this level we do not give details of states or transition function."

•3 **Formal description**:

Most detailed, "lowest level", gives the Turing machine's "state table".

For an example of the simple algorithm "Add m+n" described in all three levels see Algorithm examples.

Cellular Potts Model

Cellular Potts Model:

The **cellular Potts model** is a lattice-based computational modeling method to simulate the collective behavior of cellular structures. Other names for the CPM are **extended large-q Potts model** and **Glazier and Graner model**. First developed by James Glazier and Francois Graner in 1992 as an extension of large-q Potts model simulations of coarsening in metallic grains and soap froths, it has now been used to simulate foam, biological tissues, fluid flow and reaction-advection-diffusion-equations. In the CPM a generalized "cell" is a simply-connected domain of pixels with the same *cell id* (formerly spin). A generalized cell may be a single soap bubble, an entire biological cell, part of a biological cell, or even a region of fluid.

The CPM is evolved by updating the cell lattice one pixel at a time based on a set of probabilistic rules. In this sense, the CPM can be thought of as a generalized cellular automaton (*CA*). Although it also closely resembles certain Monte Carlo methods, such as the large-q Potts model, many subtle differences separate the CPM from Potts models and standard spin-based Monte Carlo schemes.

The primary rule base has three components:

1.rules for selecting putative lattice updates

2.a Hamiltonian or *effective energy* function that is used for calculating the probability of accepting lattice updates.

3.additional rules not included in 1. or 2..

The CPM can also be thought of as an agent based method in which cell agents evolve, interact via behaviors such as adhesion, signalling, volume and surface area control, chemotaxis and proliferation. Over time, the CPM has evolved from a specific model to a general framework with many extensions and even related methods that are entirely or partially off-lattice.[citation needed]

The central component of the CPM is the definition of the Hamiltonian. The Hamiltonian is determined by the configuration of the cell lattice and perhaps other sub-lattices containing information such as the concentrations of chemicals. The original CPM Hamiltonian included adhesion energies, and volume and surface area constraints. We present a simple example for illustration:

Where for cell σ, λ_{volume} is the volume constraint, V_{target} is the target volume, and for neighbouring lattice sites i and j, J is the boundary coefficient between two cells (σ,σ') of given types τ(σ),τ(σ'), and the boundary energy coefficients are symmetric: J[τ(σ),τ(σ')]=J[τ(σ'),τ(σ)], and the Kronecker delta is $\delta_{(x,y)}$={1,x=y; 0,x≠y}.
Many extensions to the original CPM Hamiltonian control cell behaviors including chemotaxis, elongation and haptotaxis.

Monte Carlo Method:

Monte Carlo Method:

Monte Carlo methods (or **Monte Carlo experiments**) are a broad class of computational algorithms that rely on repeated random sampling to obtain numerical results; i.e., by running simulations many times over in order to calculate those same probabilities heuristically just like actually playing and recording your results in a real casino situation: hence the name. They are often used in physical and mathematical problems and are most suited to be applied when it is impossible to obtain a closed-form expression or infeasible to apply a deterministic algorithm. Monte Carlo methods are mainly used in three distinct problems: optimization, numerical integration and generation of samples from a probability distribution.

Monte Carlo methods are especially useful for simulating systems with many coupled degrees of freedom, such as fluids, disordered materials, strongly coupled solids, and cellular structures (see cellular Potts model). They are used to model phenomena with significant uncertainty in inputs, such as the calculation of risk in business. They are widely used in mathematics, for example to evaluate multidimensional definite integrals with complicated boundary conditions. When Monte Carlo simulations have been applied in space exploration and oil exploration, their predictions of failures, cost overruns and schedule overruns are routinely better than human intuition or alternative "soft" methods.[1]

The modern version of the Monte Carlo method was invented in the late 1940s by Stanislaw Ulam, while he was working on nuclear weapon projects at the Los Alamos National Laboratory. It was named, by Nicholas Metropolis, after the Monte Carlo Casino, where Ulam's uncle often gambled.[2] Immediately after Ulam's breakthrough, John von Neumann understood its importance and programmed the ENIAC computer to carry out Monte Carlo calculations.

Analysis:

Analysis:

The word comes from the Ancient Greek ἀνάλυσις (*analusis*, "a breaking up", from *ana-* "up, throughout" and *lysis* "a loosening").[2]

Analysis is the process of breaking a complex topic or substance into smaller parts to gain a better understanding of it. The technique has been applied in the study of mathematics and logic since before Aristotle (384–322 B.C.), though *analysis* as a formal concept is a relatively recent development.[1]

As a formal concept, the method has variously been ascribed to Alhazen,[3] René Descartes (Discourse on the Method), and Galileo Galilei. It has also been ascribed to Isaac Newton, in the form of a practical method of physical discovery (which he did not name or formally describe).

Scientific Method:

The **scientific method** is a body of techniques for investigating phenomena, acquiring new knowledge, or correcting and integrating previous knowledge.[1] To be termed scientific, a method of inquiry must be based on empirical and measurable evidence subject to specific principles of reasoning.[2] The Oxford English Dictionary defines the scientific method as: "a method or procedure that has characterized natural science since the 17th century, consisting in systematic observation, measurement, and experiment, and the formulation, testing, and modification of hypotheses."[3]

The chief characteristic which distinguishes the scientific method from other methods of acquiring knowledge is that scientists seek to let reality speak for itself,[discuss] supporting a theory when a theory's predictions are confirmed and challenging a theory when its predictions prove false. Although procedures vary from one field of inquiry to another, identifiable features distinguish scientific inquiry from other methods of obtaining knowledge. Scientific researchers propose hypotheses as explanations of phenomena, and design experimental studies to test these hypotheses via predictions which can be derived from them. These steps must be repeatable, to guard against mistake or confusion in any particular experimenter. Theories that encompass wider domains of inquiry may bind many independently derived hypotheses together in a coherent, supportive structure. Theories, in turn, may help form new hypotheses or place groups of hypotheses into context.

Scientific inquiry is generally intended to be as objective as possible in order to reduce biased interpretations of results. Another basic expectation is to document, archive and share all data and methodology so they are available for careful scrutiny by other scientists, giving them the opportunity to verify results by attempting to reproduce them. This practice, called *full disclosure*, also allows statistical measures of the reliability of these data to be established (when data is sampled or compared to chance).

Overview:

Scientific method has been practiced in some form for at least one thousand years[4] and is the process by which science is carried out.[8] Because science builds on previous knowledge, it consistently improves our understanding of the world.[9] The scientific method also improves itself in the same way,[10] meaning that it gradually becomes more effective at generating new knowledge.[11][12] For example, the concept of falsification (first proposed in 1934) reduces confirmation bias by formalizing the attempt to *disprove* hypotheses rather than prove them.[13]

The overall process involves making conjectures (hypotheses), deriving predictions from them as logical consequences, and then carrying out experiments based on those predictions to determine whether the original conjecture was correct.[14] There are difficulties in a formulaic statement of method, however. Though the scientific method is often presented as a fixed sequence of steps, they are better considered as general principles.[15] Not all steps take place in every scientific inquiry (or to the same degree), and not always in the same order. As noted by William Whewell (1794–1866), "invention, sagacity, [and] genius"[16] are required at every step:

Formulation of a question: The question can refer to the explanation of a specific observation, as in "Why is the sky blue?", but can also be open-ended, as in "Does sound travel faster in air than in water?" or "How can I design a drug to cure this particular disease?" This stage also involves looking up and evaluating previous evidence from other scientists, including experience. If the answer is already known, a different question that builds on the previous evidence can be posed. When applying the scientific method to scientific research, determining a good question can be very difficult and affects the final outcome of the investigation.[17]

Hypothesis: An hypothesis is a conjecture, based on the knowledge obtained while formulating the question, that may explain the observed behavior of a part of our universe. The hypothesis might be very specific, e.g., Einstein's equivalence principle or Francis Crick's "DNA makes RNA makes protein",[18] or it might be broad, e.g., unknown species of life dwell in the unexplored depths of the oceans. A statistical hypothesis is a conjecture about some population. For example, the population might be people with a particular disease. The conjecture might be that a new drug will cure the disease in some of those people. Terms commonly associated with statistical hypotheses are null hypothesis and alternative hypothesis. A null hypothesis is the conjecture that the statistical hypothesis is false, e.g., that the new drug does nothing and that any cures are due to chance effects. Researchers normally want to show that the null hypothesis is false. The alternative hypothesis is the desired outcome, e.g., that the drug does better than chance. A final point: a scientific hypothesis must be falsifiable, meaning that one can identify a possible outcome of an experiment that conflicts with predictions deduced from the hypothesis; otherwise, it cannot be meaningfully tested.

Prediction: This step involves determining the logical consequences of the hypothesis. One or more predictions are then selected for further testing. The less likely that the prediction would be correct simply by coincidence, the stronger evidence it would be if the prediction were fulfilled; evidence is also stronger if the answer to the prediction is not already known, due to the effects of hindsight bias (see also postdiction). Ideally, the prediction must also distinguish the hypothesis from likely alternatives; if two hypotheses make the same prediction, observing the prediction to be correct is not evidence for either one over the other. (These statements about the relative strength of evidence can be mathematically derived using Bayes' Theorem.)

Testing: This is an investigation of whether the real world behaves as predicted by the hypothesis. Scientists (and other people) test hypotheses by conducting experiments. The purpose of an experiment is to determine whether observations of the real world agree with or conflict with the predictions derived from an hypothesis. If they agree, confidence in the hypothesis increases; otherwise, it decreases. Agreement does not assure that the hypothesis is true; future experiments may reveal problems. Karl Popper advised scientists to try to falsify hypotheses, i.e., to search for and test those experiments that seem most doubtful. Large numbers of successful confirmations are not convincing if they arise from experiments that avoid risk.[19] Experiments should be designed to minimize possible errors, especially through the use of appropriate scientific controls. For example, tests of medical treatments are commonly run as double-blind tests. Test personnel, who might unwittingly reveal to test subjects which samples are the desired test drugs and which are placebos, are kept ignorant of which are which. Such hints can bias the responses of the test subjects. Failure of an experiment does not necessarily mean the hypothesis is false. Experiments always depend on several hypotheses, e.g., that the test equipment is working properly, and a failure may be a failure of one of the auxiliary hypotheses. (See the Duhem-Quine thesis.) Experiments can be conducted in a college lab, on a kitchen table, at CERN's Large Hadron Collider, at the bottom of an ocean, on Mars (using one of the working rovers), and so on. Astronomers do experiments, searching for planets around distant stars. Finally, most individual experiments address highly specific topics for reasons of practicality. As a result, evidence about broader topics is usually accumulated gradually.

Analysis: This involves determining what the results of the experiment show and deciding on the next actions to take. The predictions of the hypothesis are compared to those of the null hypothesis, to determine which is better able to explain the data. In cases where an experiment is repeated many times, a statistical analysis such as a chi-squared test may be required. If the evidence has falsified the hypothesis, a new hypothesis is required; if the experiment supports the hypothesis but the evidence is not strong enough for high confidence, other predictions from the hypothesis must be tested. Once a hypothesis is strongly supported by evidence, a new question can be asked to provide further insight on the same topic. Evidence from other scientists and experience are frequently incorporated at any stage in the process. Many iterations may be required to gather sufficient evidence to answer a question with confidence, or to build up many answers to highly specific questions in order to answer a single broader question.**Replication:** If an experiment cannot be repeated to produce the same results, this implies that the original results were in error. As a result, it is common for a single experiment to be performed multiple times, especially when there are uncontrolled variables or other indications of experimental error. For significant or surprising results, other scientists may also attempt to replicate the results for themselves, especially if those results would be important to their own work.

External review: The process of peer review involves evaluation of the experiment by experts, who give their opinions anonymously to allow them to give unbiased criticism. It does not certify correctness of the results, only that the experiments themselves were sound (based on the description supplied by the experimenter). If the work passes peer review, which may require new experiments requested by the reviewers, it will be published in a peer-reviewed scientific journal. The specific journal that publishes the results indicates the perceived quality of the work.

Data recording and sharing: Scientists must record all data very precisely in order to reduce their own bias and aid in replication by others, a requirement first promoted by Ludwik Fleck (1896–1961) and others.[31] They must supply this data to other scientists who wish to replicate any results, extending to the sharing of any experimental samples that may be difficult to obtain.[32]

Elements of the scientific method

There are different ways of outlining the basic method used for scientific inquiry. The scientific community and philosophers of science generally agree on the following classification of method components. These methodological elements and organization of procedures tend to be more characteristic of natural sciences than social sciences. Nonetheless, the cycle of formulating hypotheses, testing and analyzing the results, and formulating new hypotheses, will resemble the cycle described below.

Four essential elements[42][43][44] of the scientific method[45] are iterations,[46][47] recursions,[48] interleavings, or orderings of the following:

•Characterizations (observations,[49] definitions, and measurements of the subject of inquiry)

•Hypotheses[50][51] (theoretical, hypothetical explanations of observations and measurements of the subject)[52]

•Predictions (reasoning including logical deduction[53] from the hypothesis or theory)

•Experiments[54] (tests of all of the above)

Each element of the scientific method is subject to peer review for possible mistakes. These activities do not describe all that scientists do (see below) but apply mostly to experimental sciences (e.g., physics, chemistry, and biology). The elements above are often taught in the educational system as "the scientific method".[55]

The scientific method is not a single recipe: it requires intelligence, imagination, and creativity.[56] In this sense, it is not a mindless set of standards and procedures to follow, but is rather an ongoing cycle, constantly developing more useful, accurate and comprehensive models and methods. For example, when Einstein developed the Special and General Theories of Relativity, he did not in any way refute or discount Newton's *Principia*. On the contrary, if the astronomically large, the vanishingly small, and the extremely fast are removed from Einstein's theories — all phenomena Newton could not have observed — Newton's equations are what remain. Einstein's theories are expansions and refinements of Newton's theories and, thus, increase our confidence in Newton's work.

A linearized, pragmatic scheme of the four points above is sometimes offered as a guideline for proceeding:[57]

1.Define a question

2.Gather information and resources (observe)

3.Form an explanatory hypothesis

4.Test the hypothesis by performing an experiment and collecting data in a reproducible manner

5.Analyze the data

6.Interpret the data and draw conclusions that serve as a starting point for new hypothesis

7.Publish results

8.Retest (frequently done by other scientists)

The iterative cycle inherent in this step-by-step method goes from point 3 to 6 back to 3 again.

While this schema outlines a typical hypothesis/testing method,[58] it should also be noted that a number of philosophers, historians and sociologists of science (perhaps most notably Paul Feyerabend) claim that such descriptions of scientific method have little relation to the ways science is actually practiced.

The "operational" paradigm combines the concepts of operational definition, instrumentalism, and utility:

The essential elements of scientific method are operations, observations, models, and a utility function for evaluating models.[59][not in citation given]

•Operation - Some action done to the system being investigated

•Observation - What happens when the operation is done to the system

•Model - A fact, hypothesis, theory, or the phenomenon itself at a certain moment

•Utility Function - A measure of the usefulness of the model to explain, predict, and control, and of the cost of use of it. One of the elements of any scientific utility function is the refutability of the model. Another is its simplicity, on the Principle of Parsimony more commonly known as Occam's Razor.

Models of Scientific Inquiry:

In the philosophy of science, **models of scientific inquiry** have two functions: first, to provide a descriptive account of *how* scientific inquiry is carried out in practice, and second, to provide an explanatory account of *why* scientific inquiry succeeds as well as it appears to do in arriving at genuine knowledge of its objects. Such accounts tend to reflect different philosophical positions in epistemology, the branch of philosophy concerned with the nature and scope of knowledge.

The search for scientific knowledge extends far back into antiquity. At some point in the past, at least by the time of Aristotle, philosophers recognized that a fundamental distinction should be drawn between two kinds of scientific knowledge — roughly, knowledge *that* and knowledge *why*. It is one thing to know *that* each planet periodically reverses the direction of its motion with respect to the background of fixed stars; it is quite a different matter to know *why*. Knowledge of the former type is descriptive; knowledge of the latter type is explanatory. It is explanatory knowledge that provides scientific understanding of the world. (Salmon, 1990)

Additional Reference:

Architecture:

Summary:

Architecture: **Architecture** (Latin architectura, from the Greek ἀρχιτέκτων – arkhitekton, from ἀρχι- "chief" and τέκτων "builder, carpenter, mason") is both the process and product of planning, designing, and construction, usually of buildings and other physical structures. Architectural works, in the material form of buildings, are often perceived as cultural symbols and as works of art. Historical civilizations are often identified with their surviving architectural achievements.

"Architecture" can mean:

•A general term to describe buildings and other physical structures.

•The art and science of designing and erecting buildings and other physical structures.

•The style and method of design and construction of buildings and other physical structures.

•The practice of the architect, where architecture means the offering or rendering of professional services in connection with the design and construction of buildings, or built environments.[1]

•The design activity of the architect, from the macro-level (urban design, landscape architecture) to the micro-level (construction details and furniture).

•The term "architecture" has been adopted to describe the activity of designing any kind of system, and is commonly used in describing information technology.

In relation to buildings, architecture has to do with the planning, designing and constructing form, space and ambience that reflect functional, technical, social, environmental, and aesthetic considerations. It requires the creative manipulation and coordination of material, technology, light and shadow. Architecture also encompasses the pragmatic aspects of realizing buildings and structures, including scheduling, cost estimating and construction administration. As documentation produced by architects, typically drawings, plans and technical specifications, architecture defines the structure and/or behavior of a building or any other kind of system that is to be or has been constructed.

Art:

Art:

Art is a diverse range of human activities and the products of those activities; this article focuses primarily on the visual arts, which includes the creation of images or objects in fields including painting, sculpture, printmaking, photography, and other visual media. Architecture is often included as one of the visual arts; however, like the decorative arts, it involves the creation of objects where the practical considerations of use are essential—in a way that they are usually not for a painting, for example. Music, theatre, film, dance, and other performing arts, as well as literature, and other media such as interactive media are included in a broader definition of art or the arts.[1] Until the 17th century, *art* referred to any skill or mastery and was not differentiated from crafts or sciences, but in modern usage the fine arts, where aesthetic considerations are paramount, are distinguished from acquired skills in general, and the decorative or applied arts.

Art has been characterized in terms of mimesis, expression, communication of emotion, or other values. During the Romantic period, art came to be seen as "a special faculty of the human mind to be classified with religion and science".[2] Though the definition of what constitutes art is disputed[3][4][5] and has changed over time, general descriptions mention an idea of human agency[6] and creation through imaginative or technical skill.[7]

The nature of art, and related concepts such as creativity and interpretation, are explored in a branch of philosophy known as aesthetics.[8]

Artificial :

Artificial:

Etymology:

Via Old French (French: artificiel), from Latin artificialis from artificium ("skill"), from artifex, from ars ("skill"), and -fex, from facere ("to make").

Definition:

Artificial Chemistry

Artificial Chemistry

An **artificial chemistry** is a computer model used to simulate various types of systems. Artificial chemistry is in some ways similar to a chemical reaction, hence the name. The field of artificial chemistry originated in artificial life but has shown to be a versatile method with applications in many fields such as chemistry, economics, sociology and linguistics.

Artificial Ecologies: (see artificial & ecology)

Artificial Intelligence:

Artificial Intelligence: AI

Artificial intelligence (**AI**) is technology and a branch of computer science that studies and develops intelligent machines and software. Major AI researchers and textbooks define the field as "the study and design of intelligent agents",[1] where an intelligent agent is a system that perceives its environment and takes actions that maximize its chances of success.[2] John McCarthy, who coined the term in 1955,[3] defines it as "the science and engineering of making intelligent machines".[4]

AI research is highly technical and specialised, deeply divided into subfields that often fail to communicate with each other.[5] Some of the division is due to social and cultural factors: subfields have grown up around particular institutions and the work of individual researchers. AI research is also divided by several technical issues. There are subfields which are focused on the solution of specific problems, on one of several possible approaches, on the use of widely differing tools and towards the accomplishment of particular applications.

The central problems (or goals) of AI research include reasoning, knowledge, planning, learning, communication, perception and the ability to move and manipulate objects.[6] General intelligence (or "strong AI") is still among the field's long term goals.[7] Currently popular approaches include statistical methods, computational intelligence and traditional symbolic AI. There are an enormous number of tools used in AI, including versions of search and mathematical optimization, logic, methods based on probability and economics, and many others.

The field was founded on the claim that a central property of humans, intelligence—the sapience of Homo sapiens—can be so precisely described that it can be simulated by a machine.[8] This raises philosophical issues about the nature of the mind and the ethics of creating artificial beings, issues which have been addressed by myth, fiction and philosophy since antiquity.[9] Artificial intelligence has been the subject of tremendous optimism[10] but has also suffered stunning setbacks.[11] Today it has become an essential part of the technology industry and many of the most difficult problems in computer science.[12]

Goals:

2.1 Deduction, reasoning, problem solving

2.2 Knowledge representation

2.3 Planning

2.4 Learning

2.5 Natural language processing

2.6 Motion and manipulation

2.7 Perception

2.8 Social intelligence

2.9 Creativity

2.10 General intelligence

Approaches:

3.1 Cybernetics and brain simulation

3.2 Symbolic

3.3 Sub-symbolic

3.4 Statistical

3.5 Integrating the approaches

Tools:

4.1 Search and optimization

4.2 Logic

4.3 Probabilistic methods for uncertain reasoning

4.4 Classifiers and statistical learning methods

4.5 Neural networks

4.6 Control theory

4.7 Languages

Augmented Reality:

Augmented Reality:

Augmented reality (AR) is a live, direct or indirect, view of a physical, real-world environment whose elements are *augmented* (or supplemented) by computer-generated sensory input such as sound, video, graphics or GPS data. It is related to a more general concept called mediated reality, in which a view of reality is modified (possibly even diminished rather than augmented) by a computer. As a result, the technology functions by enhancing one's current perception of reality.[1] By contrast, virtual reality replaces the real world with a simulated one.[2][3] Augmentation is conventionally in real-time and in semantic context with environmental elements, such as sports scores on TV during a match. With the help of advanced AR technology (e.g. adding computer vision and object recognition) the information about the surrounding real world of the user becomes interactive and digitally manipulable. Artificial information about the environment and its objects can be overlaid on the real world.[4][5][6][7]

Behavior:

Behavior:

Behavior or **behaviour** is the range of actions and mannerisms made by organisms, systems, or artificial entities in conjunction with their environment, which includes the other systems or organisms around as well as the physical environment. It is the response of the system or organism to various stimuli or inputs, whether internal or external, conscious or subconscious, overt or covert, and voluntary or involuntary.

Biology:

Although there is some disagreement as to how to precisely define behavior in a biological context, one common interpretation based on a meta-analysis of scientific literature states that "behavior is the internally coordinated responses (actions or inactions) of whole living organisms (individuals or groups) to internal and/or external stimuli"[1]

In humans, behavior is believed to be controlled primarily by the endocrine system and the nervous system. It is most commonly believed that complexity in the behavior of an organism is correlated to the complexity of its nervous system. Generally, organisms with more complex nervous systems have a greater capacity to learn new responses and thus adjust their behavior.

Behaviors can be either innate or learned.

Behavior can be regarded as any action of an organism that changes its relationship to its environment. Behavior provides outputs from the organism to the environment.[2]

Computer Science:

Behavior as used in computer science is an anthropomorphic construct that assigns "life" to the activities carried out by a computer, computer application, or computer code in response to stimuli, such as user input. Also, "a behavior" is a reusable block of computer code or script that, when applied to an object, especially a graphical one, causes it to respond to user input in meaningful patterns or to operate independently. Also, behavior is a value that changes over time[3] (one of the key concepts in functional reactive programming). The term can also be applied to some degree to functions in mathematics, referring to the anatomy of curves.

Earth Sciences:

In environmental modeling and especially in hydrology, a "behavioral model" means a model that is acceptably consistent with observed natural processes, i.e., that simulates well, for example, observed river discharge. It is a key concept of the so-called Generalized Likelihood Uncertainty Estimation (GLUE) methodology to quantify how uncertain environmental predictions are.

Behavioral Models:

Behavioral Modeling:

In behavioral science, system theory and dynamic system modeling, a **behavioral model** reproduces the required behavior of the original analyzed system, such as there is a one-to-one correspondence between the behavior of the original system and the simulated system. The behavioral approach is motivated by the aim of obtaining a framework for system analysis that respects the underlying physics. The behavior may be achieved in simulation with a mixture of ideal or otherwise physically unrealistic components if it successfully recapitulates the behavior of the system under analysis.

A key question of the behavioral approach is whether a quantity w1 can be deduced given an observed quantity w2 and a model. If w1 can be deduced given w2 and the model, w2 is said to be observable. In terms of mathematical modeling, the to-be-deduced quantity or variable is often referred to as the latent variable and the observed variable is the manifest variable. Such a system is then called an observable (latent variable) system.

The above system theoretic definition, underlies to some degree most current usages of the term **behavioral model**. More specifically, the term behavioral modeling is also encountered in the following fields:

•In computer-aided design, it designates a circuit modeling technique.

Biology:

Biology:

Etymology:

The term biology is derived from the Greek word βίος, *bios*, "life" and the suffix -λογία, *-logia*, "study of."[4][5] The Latin form of the term first appeared in 1736 when Linnaeus (Carl von Linné) used *biologi* in his *Bibliotheca botanica*.

Biology is a natural science concerned with the study of life and living organisms, including their structure, function, growth, evolution, distribution, and taxonomy.[1] Biology has many subdisciplines unified by five so-called axioms of modern biology:[2]

1.Cells are the basic unit of life

2.Genes are the basic unit of heredity

3.New species and inherited traits are the product of evolution

4.An organism regulates its internal environment to maintain a stable and constant condition

5.Living organisms consume and transform energy

Subdisciplines of biology are defined by the scale at which organisms are studied and the methods used to study them: biochemistry examines the rudimentary chemistry of life; molecular biology studies the complex interactions among biological molecules; cellular biology examines the basic building block of all life, the cell;

physiology examines the physical and chemical functions of tissues, organs, and organ systems of an organism; evolutionary biology examines the processes that produced the diversity of life; and ecology examines how organisms interact in their environment.[3]

Foundations of Modern Biology:

Evolution:

Evolution

Natural selection of a population for dark coloration.

Main article: Evolution

A central organizing concept in biology is that life changes and develops through evolution, and that all life-forms known have a common origin. Introduced into the scientific lexicon by Jean-Baptiste de Lamarck in 1809,[18] evolution was established by Charles Darwin fifty years later as a viable scientific model when he articulated its driving force: natural selection.[19][20] (Alfred Russel Wallace is recognized as the co-discoverer of this concept as he helped research and experiment with the concept of evolution.)[21] Evolution is now used to explain the great variations of life found on Earth.

Darwin theorized that species and breeds developed through the processes of natural selection and artificial selection or selective breeding.[22] Genetic drift was embraced as an additional mechanism of evolutionary development in the modern synthesis of the theory.[23]

The evolutionary history of the species—which describes the characteristics of the various species from which it descended—together with its genealogical relationship to every other species is known as its phylogeny. Widely varied approaches to biology generate information about phylogeny. These include the comparisons of DNA sequences conducted within molecular biology or genomics, and comparisons of fossils or other records of ancient organisms in paleontology.[24] Biologists organize and analyze evolutionary relationships through various methods, including phylogenetics, phenetics, and cladistics. (For a summary of major events in the evolution of life as currently understood by biologists, see evolutionary timeline.)

The theory of evolution postulates that all organisms on the Earth, both living and extinct, have descended from a common ancestor or an ancestral gene pool. This last universal common ancestor of all organisms is believed to have appeared about 3.5 billion years ago.[25] Biologists generally regard the universality and ubiquity of the genetic code as definitive evidence in favor of the theory of universal common descent for all bacteria, archaea, and eukaryotes (see: origin of life).[26]

Research:

Structural:

Structural

Main articles: Molecular biology, Cell biology, Genetics, and Developmental biology Schematic of typical animal cell depicting the various organelles and structures.Molecular biology is the study of biology at a molecular level.[37] This field overlaps with other areas of biology, particularly with genetics and biochemistry. Molecular biology chiefly concerns itself with understanding the interactions between the various systems of a cell, including the interrelationship of DNA, RNA, and protein synthesis and learning how these interactions are regulated.Cell biology studies the structural and physiological properties of cells, including their behaviors, interactions, and environment. This is done on both the microscopic and molecular levels, for single-celled organisms such as bacteria as well as the specialized cells in multicellular organisms such as humans. Understanding the structure and function of cells is fundamental to all of the biological sciences. The similarities and differences between cell types are particularly relevant to molecular biology.Anatomy considers the forms of macroscopic structures such as organs and organ systems.[38]Genetics is the science of genes, heredity, and the variation of organisms.[39][40] Genes encode the information necessary for synthesizing proteins, which in turn play a large role in influencing (though, in many instances, not completely determining) the final phenotype of the organism. In modern research, genetics provides important tools in the investigation of the function of a particular gene, or the analysis of genetic interactions. Within organisms, genetic information generally is carried in chromosomes, where it is represented in the chemical structure of particular DNA molecules.Developmental biology studies the process by which organisms grow and develop. Originating in embryology, modern developmental biology studies the genetic control of cell growth, differentiation, and "morphogenesis," which is the process that progressively gives rise to tissues, organs, and anatomy. Model organisms for developmental biology include the round worm *Caenorhabditis elegans*,[41] the fruit fly *Drosophila melanogaster*,[42] the zebrafish *Danio rerio*,[43] the mouse *Mus musculus*,,[44] and the weed *Arabidopsis thaliana*.[45][46] (A model organism is a species that is extensively studied to understand particular biological phenomena, with the expectation that discoveries made in that organism provide insight into the workings of other organisms.)[47]

Chemistry:

Chemistry:

Chemistry, a branch of physical science, is the study of the composition, properties and behavior of matter.[1][2] As it is a fundamental component of matter, the atom is the basic unit of chemistry. Chemistry is concerned with atoms and their interactions with other atoms, with particular focus on the properties of the chemical bonds formed between species. Chemistry is also concerned with the interactions between atoms or molecules and various forms of energy (e.g. photochemical reactions, oxidation-reduction reactions, changes in phases of matter, separation of mixtures, properties of polymers, etc.).

Chemistry is sometimes called "the central science" because it bridges other natural sciences like physics, geology and biology with each other.[3][4] Chemistry is a branch of physical science but distinct from physics.[5]

The etymology of the word chemistry has been much disputed.[6] The genesis of chemistry can be traced to certain practices, known as alchemy, which had been practiced for several millennia in various parts of the world, particularly the Middle East.[7]

Etymology:

Main article: Chemistry (etymology)

The word *chemistry* comes from the word *alchemy*, an earlier set of practices that encompassed elements of chemistry, metallurgy, philosophy, astrology, astronomy, mysticism and medicine; it is commonly thought of as the quest to turn lead or another common starting material into gold.[8] Alchemy, which was practiced around 330, is the study of the composition of waters, movement, growth, embodying, disembodying, drawing the spirits from bodies and bonding the spirits within bodies (Zosimos).[9] An alchemist was called a 'chemist' in popular speech, and later the suffix "-ry" was added to this to describe the art of the chemist as "chemistry".

The word *alchemy* in turn is derived from the Arabic word al-kīmīā (الكيمياء). The Arabic term is borrowed from the Greek χημία or χημεία.[10][11] This may have Egyptian origins. Many believe that al-kīmīā is derived from χημία, which is in turn derived from the word **Chemi** or **Kimi**, which is the ancient name of Egypt in Egyptian.[10] Alternately, al-kīmīā may be derived from χημεία, meaning "cast together".[12]

Definition:

In retrospect, the definition of chemistry has changed over time, as new discoveries and theories add to the functionality of the science. The term "chymistry", in the view of noted scientist Robert Boyle in 1661, meant the subject of the material principles of mixed bodies.[13] In 1663, "chymistry" meant a scientific art, by which one learns to dissolve bodies, and draw from them the different substances on their composition, and how to unite them again, and exalt them to a higher perfection - this definition was used by chemist Christopher Glaser.[14]

The 1730 definition of the word "chemistry", as used by Georg Ernst Stahl, meant the art of resolving mixed, compound, or aggregate bodies into their principles; and of composing such bodies from those principles.[15] In 1837, Jean-Baptiste Dumas considered the word "chemistry" to refer to the science concerned with the laws and effects of molecular forces.[16] This definition further evolved until, in 1947, it came to mean the science of substances: their structure, their properties, and the reactions that change them into other substances - a characterization accepted by Linus Pauling.[17] More recently, in 1998, the definition of "chemistry" was broadened to mean the study of matter and the changes it undergoes, as phrased by Professor Raymond Chang.[18]

Principles of Modern Chemistry:

Principles of modern chemistry

3.1 Matter

3.1.1 Atom

3.1.2 Element

3.1.3 Compound

3.1.4 Substance

3.1.5 Molecule

3.1.6 Mole and amount of substance

3.2 Properties

3.2.1 Ions and salts

3.2.2 Acidity and basicity

3.2.3 Phase

3.2.4 Bonding

3.3 Reaction

3.3.1 Redox

3.3.2 Equilibrium

3.3.3 Energy

3.4 Chemical laws

Cognitive Psychology:

Cognitive Psychology:

Cognitive psychology is the study of mental processesincluding how people perceive, think, remeber and learn. The American Psychological Association defines cognitive psychology as "The study of higher mental processes such as attention, language use, memory, perception, problem solving, and thinking."[1] Much of the work derived from cognitive psychology has been integrated into various other modern disciplines of psychological study including social psychology, personality psychology, abnormal psychology, developmental psychology, and educational psychology.

Experimental Psychology:

Experimental Psychology:

Experimental psychology refers to work done by those who apply experimental methods to the study of behavior 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.[1]

Scales of Measurement:

Measurement can be defined as "the assignment of numerals to objects or events according to rules." [23][24] Almost all psychological experiments involve some sort of measurement, if only to determine the reliability and validity of results, and of course measurement is essential if results are to be relevant to quantitative theories.

The rule for assigning numbers to a property of an object or event is called a "scale". Following are the basic scales used in psychological measurement.[24]

Nominal measurement[edit]

In a nominal scale, numbers are used simply as labels – a letter or name would do as well. Examples are the numbers on the shirts of football or baseball players. The labels are more useful if the same label can be given to more than one thing, meaning that the things are equal in some way, and can be classified together.

Ordinal measurement[edit]

An ordinal scale arises from the ordering or ranking objects, so that A is greater than B, B is greater than C, and so on. Many psychological experiments yield numbers of this sort; for example, a participant might be able to rank odors such that A is more pleasant than B, and B is more pleasant than C, but these rankings ("1, 2, 3 ...") would not tell by how much each odor differed from another. Some statistics can be computed from ordinal measures - for example, median, percentile, and order correlation - but others, such as standard deviation, cannot properly be used.

Interval measurement[edit]

An interval scale is constructed by determining the equality of differences between the things measured. That is, numbers form an interval scale when the differences between the numbers correspond to differences between the properties measured. For instance, one can say that the difference between 5 and 10 degrees on a Fahrenheit thermometer equals the difference between 25 and 30, but it is meaningless to say that something with a temperature of 20 degrees Fahrenheit is "twice as hot" as something with a temperature of 10 degrees. (Such ratios are meaningful on an absolute temperature scale such as the Kelvin scale. See next section.) "Standard scores" on an achievement test are said to be measurements on an interval scale, but this is difficult to prove.[24]

Ratio measurement[edit]

A ratio scale is constructed by determining the equality of ratios. For example, if, on a balance instrument, object A balances two identical objects B, then one can say that A is twice as heavy as B and can give them appropriate numbers, for example "A weighs 2 grams" and "B weighs 1 gram". A key idea is that such ratios remain the same regardless of the scale units used; for example, the ratio of A to B remains the same whether grams or ounces are used. Length, resistance, and Kelvin temperature are other things that can be measured on ratio scales. Some psychological properties such as the loudness of a sound can be measured on a ratio scale.[24]

Research Design:

One-Way designs

The simplest experimental design is a one-way design. In this type of design, there is one and only one independent variable. Furthermore, the simplest kind of one-way design is called two-group design. In a two-group design, there is only one independent variable and this variable has two levels. A two-group design mainly consists of an experimental group (a group that receives treatment) and a control group (a group that doesn't receive treatment).[25] In addition to two group designs, experimenters often make use of another kind of one-way design called the one-way, multiple groups design. This is another design in which there is only a single independent variable, but the independent variable takes on three or more levels.[26] This type of design is useful in studies such as those that measure perception. Although these types of designs may be simple, they do have limitations.

Factorial Designs

One major limitation of one-way designs is the fact that they allow researchers to look at only one independent variable at a time. The problem is that a great deal of human behavior is a result of multiple variables acting together. Because of this, R.A Fisher popularized the use of factorial designs. Factorial designs are designs that contain two or more independent variables that are completely crossed. This means that every level of the independent variable appears in combination with every level of every other independent variable. There are a broad variety of factorial designs, so researchers have specific descriptions for the different designs. The label given to a factorial design specifies how many independent variables exist in the design and how many levels of each independent variable exist in the design. Therefore a 2x3 factorial design has two independent variables (because there are two numbers in the description), the first of which has two levels and the second having three levels.

Main Effects and Interactions

The simple straightforward effects of independent variables in factorial studies are referred to as main effects. Main effects are the factorial equivalent of the only kind of effect that you can detect in a one-way design. This refers to the overall effect of an independent variable, averaging across all levels of the other independent variables.[27] Main effects are simple. They only have to do with one variable. In addition to providing information about main effects, studies can also produce a second, very important kind of information called interactions. Interactions exist when the effect of one independent variable on a dependent variable depends on the level of a second independent variable.

Within-Subjects Designs

The two basic approaches to research design include between-subjects design and within-subjects design. Between-subjects designs are designs in which each participant serves in one and only one condition of an experiment. In contrast, within-subjects or repeated measures designs are those in which each participant serves in more than one or perhaps all of the conditions of a study.[28] Within-subjects have some huge advantages over between-subjects designs especially when it comes to complex factorial designs that have many conditions. Within-subjects designs eliminate person confounds. When researchers use this type of design, they eliminate person confounds in a much more direct approach. They ask the same people to serve in the different experimental conditions in which they happen to be interested. In a sense, these designs take advantage of the only perfect form of matching and in doing so, they totally eliminate person confounds. While there are advantages to this type of design, there are disadvantages as well. There are three closely related biases that are applicable to within-subjects designs. The first bias has to do with the fact that people's psychological states change as they spend time working on one or more tasks. More specifically, sequence effects can pose serious problems. Sequence effects occur when the simple passage of time begins to take its toll on people's responses. A second closely related problem has to do with carry-over effects. Carry-over effects occur when people's responses to one stimulus in a study directly influence their responses to a second stimulus.[29] Another kind of carry-over effect can occur when participants knowingly or unknowingly learn something by performing an experimental task. When a participants' experience with one task makes it easier for them to perform a different task that comes along later, they have benefited from practice effects. This is a problem because researchers cannot tell if people's superior performance on the second task happened because of an experimental manipulation or because of simple practice.

Alternative Resources

Complexity:

Definition:

In general usage, **complexity** tends to be used to characterize something with many parts in intricate arrangement. The study of these complex linkages is the main goal of complex systems theory.

In science,[1] there are at this time a number of approaches to characterizing complexity, many of which are reflected in this article. Neil Johnson admits that "even among scientists, there is no unique definition of complexity - and the scientific notion has traditionally been conveyed using particular examples..." Ultimately he adopts the definition of 'complexity science' as "the study of the phenomena which emerge from a collection of interacting objects."[2]

Complex Systems:

Complex Systems:

Complex systems present problems both in mathematical modelling and philosophical foundations. The study of complex systems represents a new approach to science that investigates how relationships between parts give rise to the collective behaviors of a system and how the system interacts and forms relationships with its environment.

The equations from which models of complex systems are developed generally derive from statistical physics, information theory and non-linear dynamics, and represent organized but unpredictable behaviors of natural systems that are considered fundamentally complex. The physical manifestations of such systems are difficult to define, so a common choice is to identify "the system" with the mathematical information model rather than referring to the undefined physical subject the model represents. One of a variety of journals using this approach to complexity is Complex Systems.

Such systems are used to model processes in computer science, biology,[1] economics, physics, chemistry,[2] and many other fields. It is also called *complex systems theory*, *complexity science*, *study of complex systems*, *sciences of complexity*, *non-equilibrium physics*, and *historical physics*. A variety of abstract theoretical complex systems is studied as a field of mathematics.

The key problems of complex systems are difficulties with their formal modelling and simulation. From such a perspective, in different research contexts complex systems are defined on the basis of their different attributes. Since all complex systems have many interconnected components, the science of networks and network theory are important aspects of the study of complex systems. A consensus regarding a single universal definition of complex system does not yet exist.

For systems that are less usefully represented with equations various other kinds of narratives and methods for identifying, exploring, designing and interacting with complex systems are used.

Topics:

TopicsEmergence

[show]Self-Organization

[show]Collective Behaviour

[show]Networks

[show]Evolution **&** Adaption

[show]Pattern formation

[show]Systems Theory

[show]Nonlinear Dynamics

[show]Game Theory

[show]

Emergence:

Emergence:

See also: Emergent (disambiguation)*,* Spontaneous order*, and* Self-organization Snowflakes forming complex symmetrical patterns is an example of emergence in a physical system. A termite "cathedral" mound produced by a termite colony is a classic example of emergence in nature.

In philosophy, systems theory, science, and art, **emergence** is the way complex systems and patterns arise out of a multiplicity of relatively simple interactions. Emergence is central to the theories of integrative levels and of complex systems.

Definition:

The idea of emergence has been around since at least the time of Aristotle.[1] John Stuart Mill[2] and Julian Huxley[3] are just some of the historical scientists who have written on the concept.

The term "emergent" was coined by philosopher G. H. Lewes, who wrote:

"Every resultant is either a sum or a difference of the co-operant forces; their sum, when their directions are the same -- their difference, when their directions are contrary. Further, every resultant is clearly traceable in its components, because these are homogeneous and commensurable. It is otherwise with emergents, when, instead of adding measurable motion to measurable motion, or things of one kind to other individuals of their kind, there is a co-operation of things of unlike kinds. The emergent is unlike its components insofar as these are incommensurable, and it cannot be reduced to their sum or their difference."[4][5]

Economist Jeffrey Goldstein provided a current definition of emergence in the journal *Emergence*.[6] Goldstein initially defined emergence as: "the arising of novel and coherent structures, patterns and properties during the process of self-organization in complex systems".

Goldstein's definition can be further elaborated to describe the qualities of this definition in more detail: "The common characteristics are: (1) radical novelty (features not previously observed in systems); (2) coherence or correlation (meaning integrated wholes that maintain themselves over some period of time); (3) A global or macro "level" (i.e. there is some property of "wholeness"); (4) it is the product of a dynamical process (it evolves); and (5) it is "ostensive" (it can be perceived). For good measure, Goldstein throws in supervenience -- downward causation."[7]

Corning's description of emergence:

Rules, or laws, have no causal efficacy; they do not in fact “generate” anything. They serve merely to describe regularities and consistent relationships in nature. These patterns may be very illuminating and important, but the underlying causal agencies must be separately specified (though often they are not). But that aside, the game of chess illustrates precisely why any laws or rules of emergence and evolution are insufficient. Even in a chess game, you cannot use the rules to predict “history” — i.e., the course of any given game. Indeed, you cannot even reliably predict the next move in a chess game. Why? Because the “system” involves more than the rules of the game. It also includes the players and their unfolding, moment-by-moment decisions among a very large number of available options at each choice point. The game of chess is inescapably historical, even though it is also constrained and shaped by a set of rules, not to mention the laws of physics. Moreover, and this is a key point, the game of chess is also shaped by teleonomic, cybernetic, feedback-driven influences. It is not simply a self-ordered process; it involves an organized, “purposeful” activity.[7]

Emergent properties and processes:

An **emergent behavior** or **emergent property** can appear when a number of simple entities (agents) operate in an environment, forming more complex behaviors as a collective. If emergence happens over disparate size scales, then the reason is usually a causal relation across different scales. In other words there is often a form of top-down feedback in systems with emergent properties.[12] The processes from which emergent properties result may occur in either the observed or observing system, and can commonly be identified by their patterns of accumulating change, most generally called 'growth'. Why emergent behaviours occur include: intricate causal relations across different scales and feedback, known as interconnectivity. The emergent property itself may be either very predictable or unpredictable and unprecedented, and represent a new level of the system's evolution. The complex behaviour or properties are not a property of any single such entity, nor can they easily be predicted or deduced from behaviour in the lower-level entities, and might in fact be irreducible to such behavior. The shape and behaviour of a flock of birds [2] or school of fish are also good examples.

One reason why emergent behaviour is hard to predict is that the number of interactions between components of a system increases exponentially with the number of components, thus potentially allowing for many new and subtle types of behaviour to emerge.

On the other hand, merely having a large number of interactions is not enough by itself to guarantee emergent behaviour; many of the interactions may be negligible or irrelevant, or may cancel each other out. In some cases, a large number of interactions can in fact work against the emergence of interesting behaviour, by creating a lot of "noise" to drown out any emerging "signal"; the emergent behaviour may need to be temporarily isolated from other interactions before it reaches enough critical mass to be self-supporting. Thus it is not just the sheer number of connections between components which encourages emergence; it is also how these connections are organised. A hierarchical organisation is one example that can generate emergent behaviour (a bureaucracy may behave in a way quite different from that of the individual humans in that bureaucracy); but perhaps more interestingly, emergent behaviour can also arise from more decentralized organisational structures, such as a marketplace. In some cases, the system has to reach a combined threshold of diversity, organisation, and connectivity before emergent behaviour appears.Unintended consequences and side effects are closely related to emergent properties. Luc Steels writes: "*A component has a particular functionality but this is not recognizable as a subfunction of the global functionality. Instead a component implements a behaviour whose side effect contributes to the global functionality [...] Each behaviour has a side effect and the sum of the side effects gives the desired functionality*" (Steels 1990). In other words, the global or macroscopic functionality of a system with "emergent functionality" is the sum of all "side effects", of all emergent properties and functionalities.

Systems with emergent properties or emergent structures may appear to defy entropic principles and the second law of thermodynamics, because they form and increase order despite the lack of command and central control. This is possible because open systems can extract information and order out of the environment.

Emergence helps to explain why the fallacy of division is a fallacy.

Emergent structures in nature:

Emergent structures are patterns that emerge via collective actions of many individual entities. To explain such patterns, one might conclude, per Aristotle,[1] that emergent structures are more than the sum of their parts on the assumption that the emergent order will not arise if the various parts simply interact independently of one another. However, there are those who disagree.[13] According to this argument, the interaction of each part with its immediate surroundings causes a complex chain of processes that can lead to order in some form. In fact, some systems in nature are observed to exhibit emergence based upon the interactions of autonomous parts, and some others exhibit emergence that at least at present cannot be reduced in this way. See the discussion in this article of strong and weak emergence.

Emergent structures can be found in many natural phenomena, from the physical to the biological domain. For example, the shape of weather phenomena such as hurricanes are emergent structures. The development and growth of complex, orderly crystals, as driven by the random motion of water molecules within a conducive natural environment, is another example of an emergent process, where randomness can give rise to complex and deeply attractive, orderly structures. Water crystals forming on glass demonstrate an emergent natural process occurring under appropriate conditions of temperature and humidity.

However, crystalline structure and hurricanes are said to have a self-organizing phase. Symphony of the Stones carved by Goght River at Garni Gorge in Armenia is an example of an emergent natural structure.

It is useful to distinguish three forms of emergent structures. A **first-order** emergent structure occurs as a result of shape interactions (for example, hydrogen bonds in water molecules lead to surface tension). A **second-order** emergent structure involves shape interactions played out sequentially over time (for example, changing atmospheric conditions as a snowflake falls to the ground build upon and alter its form). Finally, a **third-order** emergent structure is a consequence of shape, time, and heritable instructions. For example, an organism's genetic code sets boundary conditions on the interaction of biological systems in space and time.

Non-living, physical systems[edit]

In physics, emergence is used to describe a property, law, or phenomenon which occurs at macroscopic scales (in space or time) but not at microscopic scales, despite the fact that a macroscopic system can be viewed as a very large ensemble of microscopic systems.

An emergent property need not be more complicated than the underlying non-emergent properties which generate it. For instance, the laws of thermodynamics are remarkably simple, even if the laws which govern the interactions between component particles are complex. The term emergence in physics is thus used not to signify complexity, but rather to distinguish which laws and concepts apply to macroscopic scales, and which ones apply to microscopic scales.

Some examples include

•Classical mechanics: The laws of classical mechanics can be said to emerge as a limiting case from the rules of quantum mechanics applied to large enough masses. This may be puzzling, because quantum mechanics is generally thought of as *more* complicated than classical mechanics.

•Friction: Forces between elementary particles are conservative. However, friction emerges when considering more complex structures of matter, whose surfaces can convert mechanical energy into heat energy when rubbed against each other. Similar considerations apply to other emergent concepts in continuum mechanics such as viscosity, elasticity, tensile strength, etc.

•Patterned ground: the distinct, and often symmetrical geometric shapes formed by ground material in periglacial regions.

•Statistical mechanics was initially derived using the concept of a large enough ensemble that fluctuations about the most likely distribution can be all but ignored. However, small clusters do not exhibit sharp first order phase transitions such as melting, and at the boundary it is not possible to completely categorize the cluster as a liquid or solid, since these concepts are (without extra definitions) only applicable to macroscopic systems. Describing a system using statistical mechanics methods is much simpler than using a low-level atomistic approach.

•Weather.Temperature is sometimes used as an example of an emergent macroscopic behaviour. In classical dynamics, a *snapshot* of the instantaneous momenta of a large number of particles at equilibrium is sufficient to find the average kinetic energy per degree of freedom which is proportional to the temperature. For a small number of particles the instantaneous momenta at a given time are not statistically sufficient to determine the temperature of the system. However, using the ergodic hypothesis, the temperature can still be obtained to arbitrary precision by further averaging the momenta over a long enough time.Convection in a liquid or gas is another example of emergent macroscopic behaviour that makes sense only when considering differentials of temperature. Convection cells, particularly Bénard cells, are an example of a self-organizing system (more specifically, a dissipative system) whose structure is determined both by the constraints of the system and by random perturbations: the possible realizations of the shape and size of the cells depends on the temperature gradient as well as the nature of the fluid and shape of the container, but which configurations are actually realized is due to random perturbations (thus these systems exhibit a form of symmetry breaking).

In some theories of particle physics, even such basic structures as mass, space, and time are viewed as emergent phenomena, arising from more fundamental concepts such as the Higgs boson or strings. In some interpretations of quantum mechanics, the perception of a deterministic reality, in which all objects have a definite position, momentum, and so forth, is actually an emergent phenomenon, with the true state of matter being described instead by a wavefunction which need not have a single position or momentum. Most of the laws of physics themselves as we experience them today appear to have emerged during the course of time making emergence the most fundamental principle in the universe and raising the question of what might be the most fundamental law of physics from which all others emerged. Chemistry can in turn be viewed as an emergent property of the laws of physics. Biology (including biological evolution) can be viewed as an emergent property of the laws of chemistry. Finally, psychology could at least theoretically be understood as an emergent property of neurobiological laws.

Living, biological systems[edit]

Emergence and evolution[edit]Life is a major source of complexity, and evolution is the major process behind the varying forms of life. In this view, evolution is the process describing the growth of complexity in the natural world and in speaking of the emergence of complex living beings and life-forms, this view refers therefore to processes of sudden changes in evolution.

Regarding causality in evolution Peter Corning observes:

"Synergistic effects of various kinds have played a major causal role in the evolutionary process generally and in the evolution of cooperation and complexity in particular... Natural selection is often portrayed as a “mechanism”, or is personified as a causal agency... In reality, the differential “selection” of a trait, or an adaptation, is a consequence of the functional effects it produces in relation to the survival and reproductive success of a given organism in a given environment. It is these functional effects that are ultimately responsible for the trans-generational continuities and changes in nature." (Corning 2002)

Per his definition of emergence, Corning also addresses emergence and evolution:

"[In] evolutionary processes, causation is iterative; effects are also causes. And this is equally true of the synergistic effects produced by emergent systems. In other words, emergence itself... has been the underlying cause of the evolution of emergent phenomena in biological evolution; it is the synergies produced by organized systems that are the key." (Corning 2002)Swarming is a well-known behaviour in many animal species from marching locusts to schooling fish to flocking birds. Emergent structures are a common strategy found in many animal groups: colonies of ants, mounds built by termites, swarms of bees, shoals/schools of fish, flocks of birds, and herds/packs of mammals.

An example to consider in detail is an ant colony. The queen does not give direct orders and does not tell the ants what to do. Instead, each ant reacts to stimuli in the form of chemical scent from larvae, other ants, intruders, food and build up of waste, and leaves behind a chemical trail, which, in turn, provides a stimulus to other ants. Here each ant is an autonomous unit that reacts depending only on its local environment and the genetically encoded rules for its variety of ant. Despite the lack of centralized decision making, ant colonies exhibit complex behavior and have even been able to demonstrate the ability to solve geometric problems. For example, colonies routinely find the maximum distance from all colony entrances to dispose of dead bodies.[14]

Organization of life[edit]

A broader example of emergent properties in biology is viewed in the biological organisation of life, ranging from the subatomic level to the entire biosphere. For example, individual atoms can be combined to form molecules such as polypeptide chains, which in turn fold and refold to form proteins, which in turn create even more complex structures. These proteins, assuming their functional status from their spatial conformation, interact together and with other molecules to achieve higher biological functions and eventually create an organism. Another example is how cascade phenotype reactions, as detailed in chaos theory, arise from individual genes mutating respective positioning.[15] At the highest level, all the biological communities in the world form the biosphere, where its human participants form societies, and the complex interactions of meta-social systems such as the stock market.

Self Organization:

Self-organization is a process where some form of global order or coordination arises out of the local interactions between the components of an initially disordered system. This process is spontaneous: it is not directed or controlled by any agent or subsystem inside or outside of the system; however, the laws followed by the process and its initial conditions may have been chosen or caused by an agent. It is often triggered by random fluctuations that are amplified by positive feedback. The resulting organization is wholly decentralized or distributed over all the components of the system. As such it is typically very robust and able to survive and self-repair substantial damage or perturbations.

Self-organization occurs in a variety of physical, chemical, biological, social and cognitive systems. Common examples are crystallization, the emergence of convection patterns in a liquid heated from below, chemical oscillators, the invisible hand of the market, swarming in groups of animals, and the way neural networks learn to recognize complex patterns.

Evolution:

Evolution:

For a generally accessible and less technical introduction to the topic, see Introduction to evolution.

Part of a series on

Evolutionary biology

Diagrammatic representation of thedivergence of modern taxonomic groups from their common ancestor.

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Evolution is the change in the inherited characteristics of biological populations over successive generations. Evolutionary processes give rise to diversity at every level of biological organisation, including species, individual organisms and molecules such as DNA and proteins.[1]

All life on earth is descended from a last universal ancestor that lived approximately 3.8 billion years ago. Repeated speciation and the divergence of life can be inferred from shared sets of biochemical and morphological traits, or by shared DNA sequences.[2] These homologous traits and sequences are more similar among species that share a more recent common ancestor, and can be used to reconstruct evolutionary histories, using both existing species and the fossil record. Existing patterns of biodiversity have been shaped both by speciation and by extinction.[3]Charles Darwin was the first to formulate a scientific argument for the theory of evolution by means of natural selection. Evolution by natural selection is a process that is inferred from three facts about populations: 1) more offspring are produced than can possibly survive, 2) traits vary among individuals, leading to different rates of survival and reproduction, and 3) trait differences are heritable.[4] Thus, when members of a population die they are replaced by the progeny of parents that were better adapted to survive and reproduce in the environment in which natural selection took place. This process creates and preserves traits that are seemingly fitted for the functional roles they perform.[5] Natural selection is the only known cause of adaptation, but not the only known cause of evolution. Other, nonadaptive causes of evolution include mutation and genetic drift.[6]

In the early 20th century, genetics was integrated with Darwin's theory of evolution by natural selection through the discipline of population genetics. The importance of natural selection as a cause of evolution was accepted into other branches of biology. Moreover, previously held notions about evolution, such as orthogenesis and "progress" became obsolete.[7] Scientists continue to study various aspects of evolution by forming and testing hypotheses, constructing scientific theories, using observational data, and performing experiments in both the field and the laboratory. Biologists agree that descent with modification is one of the most reliably established facts in science.[8] Discoveries in evolutionary biology have made a significant impact not just within the traditional branches of biology, but also in other academic disciplines (e.g., anthropology and psychology) and on society at large.[9][10]

History:

The proposal that one type of animal could descend from an animal of another type goes back to some of the first pre-Socratic Greek philosophers, such as Anaximander and Empedocles.[11][12] In contrast to these materialistic views, Aristotle understood all natural things, not only living things, as being imperfect actualisations of different fixed natural possibilities, known as "forms", "ideas", or (in Latin translations) "species".[13][14] This was part of his teleological understanding of nature in which all things have an intended role to play in a divine cosmic order. The Roman poet and philosopher Titus Lucretius Carus proposed the possibility of evolutionary changes of organisms.[15] Variations of this idea became the standard understanding of the Middle Ages, and were integrated into Christian learning, but Aristotle did not demand that real types of animals corresponded one-for-one with exact metaphysical forms, and specifically gave examples of how new types of living things could come to be.[16] Leonardo da Vinci simply wrote, *"Motion is the cause of all life"*.[17]

In the 17th century the new method of modern science rejected Aristotle's approach, and sought explanations of natural phenomena in terms of laws of nature which were the same for all visible things, and did not need to assume any fixed natural categories, nor any divine cosmic order. But this new approach was slow to take root in the biological sciences, which became the last bastion of the concept of fixed natural types. John Ray used one of the previously more general terms for fixed natural types, "species", to apply to animal and plant types, but unlike Aristotle he strictly identified each type of living thing as a species, and proposed that each species can be defined by the features that perpetuate themselves each generation.[18] These species were designed by God, but showing differences caused by local conditions. The biological classification introduced by Carolus Linnaeus in 1735 also viewed species as fixed according to a divine plan.[19] In 1842 Charles Darwin penned his first sketch of what became On the Origin of Species.[20] Other naturalists of this time speculated on evolutionary change of species over time according to natural laws. Maupertuis wrote in 1751 of natural modifications occurring during reproduction and accumulating over many generations to produce new species.[21] Buffon suggested that species could degenerate into different organisms, and Erasmus Darwin proposed that all warm-blooded animals could have descended from a single micro-organism (or "filament").[22] The first full-fledged evolutionary scheme was Lamarck's "transmutation" theory of 1809[23] which envisaged spontaneous generation continually producing simple forms of life developed greater complexity in parallel lineages with an inherent progressive tendency, and that on a local level these lineages adapted to the environment by inheriting changes caused by use or disuse in parents.[24][25] (The latter process was later called Lamarckism.)[24][26][27][28] These ideas were condemned by established naturalists as speculation lacking empirical support. In particular Georges Cuvier insisted that species were unrelated and fixed, their similarities reflecting divine design for functional needs. In the meantime, Ray's ideas of benevolent design had been developed by William Paley into a natural theology which proposed complex adaptations as evidence of divine design, and was admired by Charles Darwin.[29][30][31]

The critical break from the concept of fixed species in biology began with the theory of evolution by natural selection, which was formulated by Charles Darwin. Partly influenced by An Essay on the Principle of

Population by Thomas Robert Malthus, Darwin noted that population growth would lead to a "struggle for existence" where favorable variations could prevail as others perished. Each generation, many offspring fail to survive to an age of reproduction because of limited resources. This could explain the diversity of animals and plants from a common ancestry through the working of natural laws working the same for all types of thing.[32][33][34][35] Darwin was developing his theory of "natural selection" from 1838 onwards until Alfred Russel Wallace sent him a similar theory in 1858. Both men presented their separate papers to the Linnean Society of London.[36] At the end of 1859, Darwin's publication of On the Origin of Species explained natural selection in detail and in a way that led to an increasingly wide acceptance of Darwinian evolution. Thomas Henry Huxley applied Darwin's ideas to humans, using paleontology and comparative anatomy to provide strong evidence that humans and apes shared a common ancestry. Some were disturbed by this since it implied that humans did not have a special place in the universe.[37]

Precise mechanisms of reproductive heritability and the origin of new traits remained a mystery. Towards this end, Darwin developed his provisional theory of pangenesis.[38] In 1865 Gregor Mendel reported that traits were inherited in a predictable manner through the independent assortment and segregation of elements (later known as genes). Mendel's laws of inheritance eventually supplanted most of Darwin's pangenesis theory.[39] August Weismann made the important distinction between germ cells (sperm and eggs) and somatic cells of the body, demonstrating that heredity passes through the germ line only. Hugo de Vries connected Darwin's pangenesis theory to Weismann's germ/soma cell distinction and proposed that Darwin's pangenes were concentrated in the cell nucleus and when expressed they could move into the cytoplasm to change the cells structure. De Vries was also one of the researchers who made Mendel's work well-known, believing that Mendelian traits corresponded to the transfer of heritable variations along the germline.[40] To explain how new variants originate, De Vries developed a mutation theory that led to a temporary rift between those who accepted Darwinian evolution and biometricians who allied with de Vries.[25][41][42] At the turn of the 20th century, pioneers in the field of population genetics, such as J.B.S. Haldane, Sewall Wright, and Ronald Fisher, set the foundations of evolution onto a robust statistical philosophy. The false contradiction between Darwin's theory, genetic mutations, and Mendelian inheritance was thus reconciled.[43]

In the 1920s and 1930s a modern evolutionary synthesis connected natural selection, mutation theory, and Mendelian inheritance into a unified theory that applied generally to any branch of biology. The modern synthesis was able to explain patterns observed across species in populations, through fossil transitions in palaeontology, and even complex cellular mechanisms in developmental biology.[25][44] The publication of the structure of DNA by James Watson and Francis Crick in 1953 demonstrated a physical basis for inheritance.[45] Molecular biology improved our understanding of the relationship between genotype and phenotype. Advancements were also made in phylogenetic systematics, mapping the transition of traits into a comparative and testable framework through the publication and use of evolutionary trees.[46][47] In 1973, evolutionary biologist Theodosius Dobzhansky penned that "nothing in biology makes sense except in the light of evolution", because it has brought to light the relations of what first seemed disjointed facts in natural history into a coherent explanatory body of knowledge that describes and predicts many observable facts about life on this planet.[48]

Since then, the modern synthesis has been further extended to explain biological phenomena across the full and integrative scale of the biological hierarchy, from genes to species. This extension has been dubbed "eco-evo-devo".[49][49][50][51]

Heredity:

Further information: Introduction to genetics*,* Genetics*,* Heredity*, and* Norms of reaction DNA structure. Bases are in the centre, surrounded by phosphate–sugar chains in a double helix.

Evolution in organisms occurs through changes in heritable traits – particular characteristics of an organism. In humans, for example, eye colour is an inherited characteristic and an individual might inherit the "brown-eye trait" from one of their parents.[52] Inherited traits are controlled by genes and the complete set of genes within an organism's genome is called its genotype.[53]

The complete set of observable traits that make up the structure and behaviour of an organism is called its phenotype. These traits come from the interaction of its genotype with the environment.[54] As a result, many aspects of an organism's phenotype are not inherited. For example, suntanned skin comes from the interaction between a person's genotype and sunlight; thus, suntans are not passed on to people's children. However, some people tan more easily than others, due to differences in their genotype; a striking example are people with the inherited trait of albinism, who do not tan at all and are very sensitive to sunburn.[55]

Heritable traits are passed from one generation to the next via DNA, a molecule that encodes genetic information.[53] DNA is a long polymer composed of four types of bases. The sequence of bases along a particular DNA molecule specify the genetic information, in a manner similar to a sequence of letters spelling out a sentence. Before a cell divides, the DNA is copied, so that each of the resulting two cells will inherit the DNA sequence. Portions of a DNA molecule that specify a single functional unit are called genes; different genes have different sequences of bases. Within cells, the long strands of DNA form condensed structures called chromosomes. The specific location of a DNA sequence within a chromosome is known as a locus. If the DNA sequence at a locus varies between individuals, the different forms of this sequence are called alleles. DNA sequences can change through mutations, producing new alleles. If a mutation occurs within a gene, the new allele may affect the trait that the gene controls, altering the phenotype of the organism.[56] However, while this simple correspondence between an allele and a trait works in some cases, most traits are more complex and are controlled by multiple interacting genes.[57][58]

Recent findings have confirmed important examples of heritable changes that cannot be explained by changes to the sequence of nucleotides in the DNA. These phenomena are classed as epigenetic inheritance systems.[59] DNA methylation marking chromatin, self-sustaining metabolic loops, gene silencing by RNA interference and the three dimensional conformation of proteins (such as prions) are areas where epigenetic inheritance systems have been discovered at the organismic level.[60][61] Developmental biologists suggest that complex interactions in genetic networks and communication among cells can lead to heritable variations that may underlay some of the mechanics in developmental plasticity and canalization.[62] Heritability may also occur at even larger scales. For example, ecological inheritance through the process of niche construction is defined by the regular and repeated activities of organisms in their environment. This generates a legacy of effects that modify and feed back into the selection regime of subsequent generations. Descendants inherit genes plus environmental characteristics generated by the ecological actions of ancestors.[63] Other examples of heritability in evolution that are not under the direct control of genes include the inheritance of cultural traits and symbiogenesis.[64][65]

Variation:

Further information: Genetic diversity *and* Population genetics

An individual organism's phenotype results from both its genotype and the influence from the environment it has lived in. A substantial part of the variation in phenotypes in a population is caused by the differences between their genotypes.[58] The modern evolutionary synthesis defines evolution as the change over time in this genetic variation. The frequency of one particular allele will become more or less prevalent relative to other forms of that gene. Variation disappears when a new allele reaches the point of fixation — when it either disappears from the population or replaces the ancestral allele entirely.[66]

Natural selection will only cause evolution if there is enough genetic variation in a population. Before the discovery of Mendelian genetics, one common hypothesis was blending inheritance. But with blending inheritance, genetic variance would be rapidly lost, making evolution by natural selection implausible. The Hardy-Weinberg principle provides the solution to how variation is maintained in a population with Mendelian inheritance. The frequencies of alleles (variations in a gene) will remain constant in the absence of selection, mutation, migration and genetic drift.[67]

Variation comes from mutations in genetic material, reshuffling of genes through sexual reproduction and migration between populations (gene flow). Despite the constant introduction of new variation through mutation and gene flow, most of the genome of a species is identical in all individuals of that species.[68] However, even relatively small differences in genotype can lead to dramatic differences in phenotype: for example, chimpanzees and humans differ in only about 5% of their genomes.[69]

Mutation:

Further information: Mutation Duplication of part of a chromosome.

Mutations are changes in the DNA sequence of a cell's genome. When mutations occur, they can either have no effect, alter the product of a gene, or prevent the gene from functioning. Based on studies in the fly Drosophila melanogaster, it has been suggested that if a mutation changes a protein produced by a gene, this will probably be harmful, with about 70% of these mutations having damaging effects, and the remainder being either neutral or weakly beneficial.[70]

Mutations can involve large sections of a chromosome becoming duplicated (usually by genetic recombination), which can introduce extra copies of a gene into a genome.[71] Extra copies of genes are a major source of the raw material needed for new genes to evolve.[72] This is important because most new genes evolve within gene families from pre-existing genes that share common ancestors.[73] For example, the human eye uses four genes to make structures that sense light: three for colour vision and one for night vision; all four are descended from a single ancestral gene.[74]

New genes can be generated from an ancestral gene when a duplicate copy mutates and acquires a new function. This process is easier once a gene has been duplicated because it increases the redundancy of the system; one gene in the pair can acquire a new function while the other copy continues to perform its original function.[75][76] Other types of mutations can even generate entirely new genes from previously noncoding DNA.[77][78]

The generation of new genes can also involve small parts of several genes being duplicated, with these fragments then recombining to form new combinations with new functions.[79][80] When new genes are assembled from shuffling pre-existing parts, domains act as modules with simple independent functions, which can be mixed together to produce new combinations with new and complex functions.[81] For example, polyketide synthases are large enzymes that make antibiotics; they contain up to one hundred independent domains that each catalyze one step in the overall process, like a step in an assembly line.[82]

Sex and recombination:

Further information: Sexual reproduction*,* Genetic recombination*, and* Evolution of sexual reproduction

In asexual organisms, genes are inherited together, or *linked*, as they cannot mix with genes of other organisms during reproduction. In contrast, the offspring of sexual organisms contain random mixtures of their parents' chromosomes that are produced through independent assortment. In a related process called homologous recombination, sexual organisms exchange DNA between two matching chromosomes.[83] Recombination and reassortment do not alter allele frequencies, but instead change which alleles are associated with each other, producing offspring with new combinations of alleles.[84] Sex usually increases genetic variation and may increase the rate of evolution.[85][86]

Gene flow:

Further information: Gene flowGene flow is the exchange of genes between populations and between species.[87] It can therefore be a source of variation that is new to a population or to a species. Gene flow can be caused by the movement of individuals between separate populations of organisms, as might be caused by the movement of mice between inland and coastal populations, or the movement of pollen between heavy metal tolerant and heavy metal sensitive populations of grasses.

Gene transfer between species includes the formation of hybrid organisms and horizontal gene transfer. Horizontal gene transfer is the transfer of genetic material from one organism to another organism that is not its offspring; this is most common among bacteria.[88] In medicine, this contributes to the spread of antibiotic resistance, as when one bacteria acquires resistance genes it can rapidly transfer them to other species.[89] Horizontal transfer of genes from bacteria to eukaryotes such as the yeast Saccharomyces cerevisiae and the adzuki bean beetle *Callosobruchus chinensis* has occurred.[90][91] An example of larger-scale transfers are the eukaryotic bdelloid rotifers, which have received a range of genes from bacteria, fungi and plants.[92] Viruses can also carry DNA between organisms, allowing transfer of genes even across biological domains.[93]

Large-scale gene transfer has also occurred between the ancestors of eukaryotic cells and bacteria, during the acquisition of chloroplasts and mitochondria. It is possible that eukaryotes themselves originated from horizontal gene transfers between bacteria and archaea.[94]

Mechanisms:

Mutation Diagram Mutation followed by natural selection, results in a population with darker colouration.

From a Neo-Darwinian perspective, evolution occurs when there are changes in the frequencies of alleles within a population of interbreeding organisms.[67] For example, the allele for black colour in a population of moths becoming more common. Mechanisms that can lead to changes in allele frequencies include natural selection, genetic drift, genetic hitchhiking, mutation and gene flow.

Natural Selection:

Further information: Natural selection *and* Fitness (biology)

Evolution by means of natural selection is the process by which genetic mutations that enhance reproduction become and remain more common in successive generations of a population. It has often been called a "self-evident" mechanism because it necessarily follows from three simple facts:

•Heritable variation exists within populations of organisms.

•Organisms produce more progeny than can survive.

•These offspring vary in their ability to survive and reproduce.

These conditions produce competition between organisms for survival and reproduction. Consequently, organisms with traits that give them an advantage over their competitors pass these advantageous traits on, while traits that do not confer an advantage are not passed on to the next generation.[95]

The central concept of natural selection is the evolutionary fitness of an organism.[96] Fitness is measured by an organism's ability to survive and reproduce, which determines the size of its genetic contribution to the next generation.[96] However, fitness is not the same as the total number of offspring: instead fitness is indicated by the proportion of subsequent generations that carry an organism's genes.[97] For example, if an organism could survive well and reproduce rapidly, but its offspring were all too small and weak to survive, this organism would make little genetic contribution to future generations and would thus have low fitness.[96]

If an allele increases fitness more than the other alleles of that gene, then with each generation this allele will become more common within the population. These traits are said to be "selected *for*". Examples of traits that can increase fitness are enhanced survival and increased fecundity. Conversely, the lower fitness caused by having a less beneficial or deleterious allele results in this allele becoming rarer — they are "selected *against*".[98] Importantly, the fitness of an allele is not a fixed characteristic; if the environment changes, previously neutral or harmful traits may become beneficial and previously beneficial traits become harmful.[56] However, even if the direction of selection does reverse in this way, traits that were lost in the past may not re-evolve in an identical form (see Dollo's law).[99][100] A chart showing three types of selection. 1. Disruptive selection 2. Stabilizing selection 3. Directional selection

Natural selection within a population for a trait that can vary across a range of values, such as height, can be categorised into three different types. The first is directional selection, which is a shift in the average value of a trait over time — for example, organisms slowly getting taller.[101] Secondly, disruptive selection is selection for extreme trait values and often results in two different values becoming most common, with selection against the average value. This would be when either short or tall organisms had an advantage, but not those of medium height. Finally, in stabilizing selection there is selection against extreme trait values on both ends, which causes a decrease in variance around the average value and less diversity.[95][102] This would, for example, cause organisms to slowly become all the same height.

A special case of natural selection is sexual selection, which is selection for any trait that increases mating success by increasing the attractiveness of an organism to potential mates.[103] Traits that evolved through sexual selection are particularly prominent in males of some animal species, despite traits such as cumbersome antlers, mating calls or bright colours that attract predators, decreasing the survival of individual males.[104] This survival disadvantage is balanced by higher reproductive success in males that show these hard to fake, sexually selected traits.[105]

Natural selection most generally makes nature the measure against which individuals and individual traits, are more or less likely to survive. "Nature" in this sense refers to an ecosystem, that is, a system in which organisms interact with every other element, physical as well as biological, in their local environment. Eugene Odum, a founder of ecology, defined an ecosystem as: "Any unit that includes all of the organisms...in a given area interacting with the physical environment so that a flow of energy leads to clearly defined trophic structure, biotic diversity and material cycles (ie: exchange of materials between living and nonliving parts) within the system."[106] Each population within an ecosystem occupies a distinct niche, or position, with distinct relationships to other parts of the system. These relationships involve the life history of the organism, its position in the food chain and its geographic range. This broad understanding of nature enables scientists to delineate specific forces which, together, comprise natural selection.

Natural selection can act at different levels of organisation, such as genes, cells, individual organisms, groups of organisms and species.[107][108][109] Selection can act at multiple levels simultaneously.[110] An example of selection occurring below the level of the individual organism are genes called transposons, which can replicate and spread throughout a genome.[111] Selection at a level above the individual, such as group selection, may allow the evolution of co-operation, as discussed below.[112]

Biased Selection:

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.[113] 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.[114] Different insertion vs. deletion mutation biases in different taxa can lead to the evolution of different genome sizes.[115][116] Developmental or mutational biases have also been observed in morphological evolution.[117][118] 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.[119][120]

Mutation bias effects are superimposed on other processes. If selection would favor 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.[121][122] 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.[123] For example, pigments are no longer useful when animals live in the darkness of caves, and tend to be lost.[124] 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 a bacterium during laboratory evolution appears to have been caused by mutation bias, rather than natural selection against the cost of maintaining sporulation ability.[125] 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,[126] indicating that it is driven more by mutation bias than by genetic drift.

Genetic drift

Further information: Genetic drift *and* Effective population size Simulation of genetic drift of 20 unlinked alleles in populations of 10 (top) and 100 (bottom). Drift to fixation is more rapid in the smaller population.

Genetic drift is the change in allele frequency from one generation to the next that occurs because alleles are subject to sampling error.[127] As a result, when selective forces are absent or relatively weak, allele frequencies tend to "drift" upward or downward randomly (in a random walk). 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.[128]

It is usually difficult to measure the relative importance of selection and neutral processes, including drift.[129] The comparative importance of adaptive and non-adaptive forces in driving evolutionary change is an area of current research.[130]

The neutral theory of molecular evolution proposed that most evolutionary changes are the result of the fixation of neutral mutations by genetic drift.[6] Hence, in this model, most genetic changes in a population are the result of constant mutation pressure and genetic drift.[131] This form of the neutral theory is now largely abandoned, since it does not seem to fit the genetic variation seen in nature.[132][133] However, a more recent and better-supported version of this model is the nearly neutral theory, where a mutation that would be neutral in a small population is not necessarily neutral in a large population.[95] Other alternative theories propose that genetic drift is dwarfed by other stochastic forces in evolution, such as genetic hitchhiking, also known as genetic draft.[127][134][135]

The time for a neutral allele to become fixed by genetic drift depends on population size, with fixation occurring more rapidly in smaller populations.[136] The number of individuals in a population is not critical, but instead a measure known as the effective population size.[137] 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.[137] The effective population size may not be the same for every gene in the same population.[138]

Genetic hitchhiking:

Further information: Genetic hitchhiking*,* Hill-Robertson effect*,* Selective sweep*, and* Genetic drift

Recombination allows alleles on the same strand of DNA to become separated. However, the rate of recombination is low (approximately two events per chromosome per generation). As a result, genes close together on a chromosome may not always be shuffled away from each other and genes that are close together tend to be inherited together, a phenomenon known as linkage.[139] This tendency is measured by finding how often two alleles occur together on a single chromosome compared to expectations, which is called their linkage disequilibrium. A set of alleles that is usually inherited in a group is called a haplotype. This can be important when one allele in a particular haplotype is strongly beneficial: natural selection can drive a selective sweep that will also cause the other alleles in the haplotype to become more common in the population; this effect is called genetic hitchhiking or genetic draft.[140] Genetic draft caused by the fact that some neutral genes are genetically linked to others that are under selection can be partially captured by an appropriate effective population size.[134]

Gene flow

Further information: Gene flow*,* Hybrid (biology)*, and* Horizontal gene transferGene flow is the exchange of genes between populations and between species.[87] The presence or absence of gene flow fundamentally changes the course of evolution. Due to the complexity of organisms, any two completely isolated populations will eventually evolve genetic incompatibilities through neutral processes, as in the

Bateson-Dobzhansky-Muller model, even if both populations remain essentially identical in terms of their adaptation to the environment.

If genetic differentiation between populations develops, gene flow between populations can introduce traits or alleles which are disadvantageous in the local population and this may lead to organism within these populations to evolve mechanisms that prevent mating with genetically distant populations, eventually resulting in the appearance of new species. Thus, exchange of genetic information between individuals is fundamentally important for the development of the biological species concept (BSC).

During the development of the modern synthesis, Sewall Wright's developed his shifting balance theory that gene flow between partially isolated populations was an important aspect of adaptive evolution.[141] However, recently there has been substantial criticism of the importance of the shifting balance theory.[142]

Outcomes:

Summary:

Evolution influences every aspect of the form and behaviour of organisms. Most prominent are the specific behavioural and physical adaptations that are the outcome of natural selection. These adaptations increase fitness by aiding activities such as finding food, avoiding predators or attracting mates. Organisms can also respond to selection by co-operating with each other, usually by aiding their relatives or engaging in mutually beneficial symbiosis. In the longer term, evolution produces new species through splitting ancestral populations of organisms into new groups that cannot or will not interbreed.

These outcomes of evolution are sometimes divided into macroevolution, which is evolution that occurs at or above the level of species, such as extinction and speciation and microevolution, which is smaller evolutionary changes, such as adaptations, within a species or population.[143] In general, macroevolution is regarded as the outcome of long periods of microevolution.[144] Thus, the distinction between micro- and macroevolution is not a fundamental one – the difference is simply the time involved.[145] However, in macroevolution, the traits of the entire species may be important. For instance, a large amount of variation among individuals allows a species to rapidly adapt to new habitats, lessening the chance of it going extinct, while a wide geographic range increases the chance of speciation, by making it more likely that part of the population will become isolated. In this sense, microevolution and macroevolution might involve selection at different levels – with microevolution acting on genes and organisms, versus macroevolutionary processes such as species selection acting on entire species and affecting their rates of speciation and extinction.[146][147][148]

A common misconception is that evolution has goals or long-term plans; realistically however, evolution has no long-term goal and does not necessarily produce greater complexity.[149][150] Although complex species have evolved, they occur as a side effect of the overall number of organisms increasing and simple forms of life still remain more common in the biosphere.[151] For example, the overwhelming majority of species are microscopic prokaryotes, which form about half the world's biomass despite their small size,[152] and constitute the vast majority of Earth's biodiversity.[153] Simple organisms have therefore been the dominant form of life on Earth throughout its history and continue to be the main form of life up to the present day, with complex life only appearing more diverse because it is more noticeable.[154] Indeed, the evolution of microorganisms is particularly important to modern evolutionary research, since their rapid reproduction allows the study of experimental evolution and the observation of evolution and adaptation in real time.[155][156]

Adaptation:

For more details on this topic, see 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.[157][158] 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.[159] 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.[160]

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.[161]

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.[162]

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.[163] Other striking examples are the bacteria Escherichia coli evolving the ability to use citric acid as a nutrient in a long-term laboratory experiment,[164] Flavobacterium evolving a novel enzyme that allows these bacteria to grow on the by-products of nylon manufacturing,[165][166] and the soil bacterium Sphingobium evolving an entirely new metabolic pathway that degrades the synthetic pesticide pentachlorophenol.[167][168] 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).[169][170][171][172] 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.[173]

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.[174] However, since all living organisms are related to some extent,[175] 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.[176][177]

During evolution, some structures may lose their original function and become vestigial structures.[178] 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,[179] the non-functional remains of eyes in blind cave-dwelling fish,[180] wings in flightless birds,[181] and the presence of hip bones in whales and snakes.[173] Examples of vestigial structures in humans include wisdom teeth,[182] the coccyx,[178] the vermiform appendix,[178] and other behavioural vestiges such as goose bumps[183][184] and primitive reflexes.[185][186][187]

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.[188] One example is the African lizard *Holaspis guentheri*, 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.[188] Within cells, molecular machines such as the bacterial flagella[189] and protein sorting machinery[190] evolved by the recruitment of several pre-existing proteins that previously had different functions.[143] 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.[191][192]

A critical principle of ecology is that of competitive exclusion: no two species can occupy the same niche in the same environment for a long time.[193] Consequently, natural selection will tend to force species to adapt to different ecological niches. This may mean that, for example, two species of cichlid fish adapt to live in different habitats, which will minimise the competition between them for food.[194]

An area of current investigation in evolutionary developmental biology is the developmental basis of adaptations and exaptations.[195] This research addresses the origin and evolution of embryonic development and how modifications of development and developmental processes produce novel features.[196] 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.[197] 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.[198] It is now becoming clear that most alterations in the form of organisms are due to changes in a small set of conserved genes.[199]

Co-evolution:

Further information: Co-evolution

Interactions between organisms can produce both conflict and co-operation. When the interaction is between pairs of species, such as a pathogen and a host, or a predator and its prey, these species can develop matched sets of adaptations. Here, the evolution of one species causes adaptations in a second species. These changes in the second species then, in turn, cause new adaptations in the first species. This cycle of selection and response is called co-evolution.[200] An example is the production of tetrodotoxin in the rough-skinned newt and the evolution of tetrodotoxin resistance in its predator, the common garter snake. In this predator-prey pair, an evolutionary arms race has produced high levels of toxin in the newt and correspondingly high levels of toxin resistance in the snake.[201]

Co-operation:

Further information: Co-operation (evolution)

Not all co-evolved interactions between species involve conflict.[202] Many cases of mutually beneficial interactions have evolved. For instance, an extreme cooperation exists between plants and the mycorrhizal fungi that grow on their roots and aid the plant in absorbing nutrients from the soil.[203] This is a reciprocal relationship as the plants provide the fungi with sugars from photosynthesis. Here, the fungi actually grow inside plant cells, allowing them to exchange nutrients with their hosts, while sending signals that suppress the plant immune system.[204]

Coalitions between organisms of the same species have also evolved. An extreme case is the eusociality found in social insects, such as bees, termites and ants, where sterile insects feed and guard the small number of organisms in a colony that are able to reproduce. On an even smaller scale, the somatic cells that make up the body of an animal limit their reproduction so they can maintain a stable organism, which then supports a small number of the animal's germ cells to produce offspring. Here, somatic cells respond to specific signals that instruct them whether to grow, remain as they are, or die. If cells ignore these signals and multiply inappropriately, their uncontrolled growth causes cancer.[205]

Such cooperation within species may have evolved through the process of kin selection, which is where one organism acts to help raise a relative's offspring.[206] This activity is selected for because if the *helping* individual contains alleles which promote the helping activity, it is likely that its kin will *also* contain these alleles and thus those alleles will be passed on.[207] Other processes that may promote cooperation include group selection, where cooperation provides benefits to a group of organisms.[208]

Speciation:

Further information: Speciation

The four mechanisms of speciation.

Speciation is the process where a species diverges into two or more descendant species.[209] There are multiple ways to define the concept of "species". The choice of definition is dependent on the particularities of the species concerned.[210] For example, some species concepts apply more readily toward sexually reproducing organisms while others lend themselves better toward asexual organisms. Despite the diversity of various species concepts, these various concepts can be placed into one of three broad philosophical approaches: interbreeding, ecological and phylogenetic.[211] The biological species concept (BSC) is a classic example of the interbreeding approach. Defined by Ernst Mayr in 1942, the BSC states that "species are groups of actually or potentially interbreeding natural populations, which are reproductively isolated from other such groups".[212] Despite its wide and long-term use, the BSC like others is not without controversy, for example because these concepts cannot be applied to prokaryotes,[213] and this is called the species problem.[210] Some researchers have attempted a unifying monistic definition of species, while others adopt a pluralistic approach and suggest that there may be different ways to logically interpret the definition of a species.[210][211] "

Barriers to reproduction between two diverging sexual populations are required for the populations to become new species. Gene flow may slow this process by spreading the new genetic variants also to the other populations. Depending on how far two species have diverged since their most recent common ancestor, it may still be possible for them to produce offspring, as with horses and donkeys mating to produce mules.[214] Such hybrids are generally infertile. In this case, closely related species may regularly interbreed, but hybrids will be selected against and the species will remain distinct. However, viable hybrids are occasionally formed and these new species can either have properties intermediate between their parent species, or possess a totally new phenotype.[215] The importance of hybridisation in producing new species of animals is unclear, although cases have been seen in many types of animals,[216] with the gray tree frog being a particularly well-studied example.[217]

Speciation has been observed multiple times under both controlled laboratory conditions and in nature.[218] In sexually reproducing organisms, speciation results from reproductive isolation followed by genealogical divergence. There are four mechanisms for speciation. The most common in animals is allopatric speciation, which occurs in populations initially isolated geographically, such as by habitat fragmentation or migration. Selection under these conditions can produce very rapid changes in the appearance and behaviour of organisms.[219][220] As selection and drift act independently on populations isolated from the rest of their species, separation may eventually produce organisms that cannot interbreed.[221]

The second mechanism of speciation is peripatric speciation, which occurs when small populations of organisms become isolated in a new environment. This differs from allopatric speciation in that the isolated populations are numerically much smaller than the parental population. Here, the founder effect causes rapid speciation after an increase in inbreeding increases selection on homozygotes, leading to rapid genetic change.[222]

The third mechanism of speciation is parapatric speciation. This is similar to peripatric speciation in that a small population enters a new habitat, but differs in that there is no physical separation between these two populations. Instead, speciation results from the evolution of mechanisms that reduce gene flow between the two populations.[209] Generally this occurs when there has been a drastic change in the environment within the parental species' habitat. One example is the grass *Anthoxanthum odoratum*, which can undergo parapatric speciation in response to localised metal pollution from mines.[223] Here, plants evolve that have resistance to high levels of metals in the soil. Selection against interbreeding with the metal-sensitive parental population produced a gradual change in the flowering time of the metal-resistant plants, which eventually produced complete reproductive isolation. Selection against hybrids between the two populations may cause *reinforcement*, which is the evolution of traits that promote mating within a species, as well as character displacement, which is when two species become more distinct in appearance.[224]

Geographical isolation of finches on the Galápagos Islands produced over a dozen new species.

Finally, in sympatric speciation species diverge without geographic isolation or changes in habitat. This form is rare since even a small amount of gene flow may remove genetic differences between parts of a population.[225] Generally, sympatric speciation in animals requires the evolution of both genetic differences and non-random mating, to allow reproductive isolation to evolve.[226]

One type of sympatric speciation involves cross-breeding of two related species to produce a new hybrid species. This is not common in animals as animal hybrids are usually sterile. This is because during meiosis the homologous chromosomes from each parent are from different species and cannot successfully pair. However, it is more common in plants because plants often double their number of chromosomes, to form polyploids.[227] This allows the chromosomes from each parental species to form matching pairs during meiosis, since each parent's chromosomes are represented by a pair already.[228] An example of such a speciation event is when the plant species *Arabidopsis thaliana* and *Arabidopsis arenosa* cross-bred to give the new species *Arabidopsis suecica*.[229] This happened about 20,000 years ago,[230] and the speciation process has been repeated in the laboratory, which allows the study of the genetic mechanisms involved in this process.[231] Indeed, chromosome doubling within a species may be a common cause of reproductive isolation, as half the doubled chromosomes will be unmatched when breeding with undoubled organisms.[232]

Speciation events are important in the theory of punctuated equilibrium, which accounts for the pattern in the fossil record of short "bursts" of evolution interspersed with relatively long periods of stasis, where species remain relatively unchanged.[233] In this theory, speciation and rapid evolution are linked, with natural selection and genetic drift acting most strongly on organisms undergoing speciation in novel habitats or small populations. As a result, the periods of stasis in the fossil record correspond to the parental population and the organisms undergoing speciation and rapid evolution are found in small populations or geographically restricted habitats and therefore rarely being preserved as fossils.[234]

Extinction:

Further information: Extinction

Tyrannosaurus rex. Non-avian dinosaurs died out in the Cretaceous–Paleogene extinction event at the end of the Cretaceous period.

Extinction is the disappearance of an entire species. Extinction is not an unusual event, as species regularly appear through speciation and disappear through extinction.[235] Nearly all animal and plant species that have lived on Earth are now extinct,[236] and extinction appears to be the ultimate fate of all species.[237] These extinctions have happened continuously throughout the history of life, although the rate of extinction spikes in occasional mass extinction events.[238] The Cretaceous–Paleogene extinction event, during which the non-avian dinosaurs went extinct, is the most well-known, but the earlier Permian–Triassic extinction event was even more severe, with approximately 96% of species driven to extinction.[238] 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.[239] Human activities are now the primary cause of the ongoing extinction event;[240] global warming may further accelerate it in the future.[241]

The role of extinction in evolution is not very well understood and may depend on which type of extinction is considered.[238] 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 (competitive exclusion).[49] 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.[108] 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.[242]

Failure to adapt:

Main article: Red Queen hypothesis

The environment an organism exploits and confronts is constantly changing, and may, sometimes, change rapidly and drastically, or deteriorate. Constant adaption to small, and large, changes is required if the organism is to continue to thrive, or even survive. This is the "Red Queen hypothesis," so named after the assertion by the Red Queen in *Through the Looking-Glass* that her land was a place where, “it takes all the running you can do, to keep in the same place.”[243][244]

Evolutionary history of life:

Main article: Evolutionary history of life

See also: Timeline of evolution and *Timeline of human evolution*

Origin of life

Further information: Abiogenesis and RNA world hypothesis

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.[245] The current scientific consensus is that the complex biochemistry that makes up life came from simpler chemical reactions.[246] The beginning of life may have included self-replicating molecules such as RNA[247] and the assembly of simple cells.[248]

Common descent

Further information: Common descent and Evidence of common descent

The hominoids are descendants of a common ancestor.

All organisms on Earth are descended from a common ancestor or ancestral gene pool.[175][249] Current species are a stage in the process of evolution, with their diversity the product of a long series of speciation and extinction events.[250] The common descent of organisms was first deduced from four simple facts about organisms: First, they have geographic distributions that cannot be explained by local adaptation. Second, the diversity of life is not a set of completely unique organisms, but organisms that share morphological similarities. Third, vestigial traits with no clear purpose resemble functional ancestral traits and finally, that organisms can be classified using these similarities into a hierarchy of nested groups – similar to a family tree.[251] However, modern research has suggested that, due to horizontal gene transfer, this "tree of life" may be more complicated than a simple branching tree since some genes have spread independently between distantly related species.[252][253]

Past species have also left records of their evolutionary history. Fossils, along with the comparative anatomy of present-day organisms, constitute the morphological, or anatomical, record.[254] By comparing the anatomies of both modern and extinct species, paleontologists can infer the lineages of those species. However, this approach is most successful for organisms that had hard body parts, such as shells, bones or teeth. Further, as prokaryotes such as bacteria and archaea share a limited set of common morphologies, their fossils do not provide information on their ancestry.

More recently, evidence for common descent has come from the study of biochemical similarities between organisms. For example, all living cells use the same basic set of nucleotides and amino acids.[255] The development of molecular genetics has revealed the record of evolution left in organisms' genomes: dating when species diverged through the molecular clock produced by mutations.[256] For example, these DNA sequence comparisons have revealed that humans and chimpanzees share 98% of their genomes and analyzing the few areas where they differ helps shed light on when the common ancestor of these species existed.[257]

Evolution of life

Main articles: Evolutionary history of life and Timeline of evolution

Evolutionary tree showing the divergence of modern species from their common ancestor in the centre.[258] The three domains are coloured, with bacteria blue, archaea green and eukaryotes red.

Prokaryotes inhabited the Earth from approximately 3–4 billion years ago.[259][260] No obvious changes in morphology or cellular organisation occurred in these organisms over the next few billion years.[261] The eukaryotic cells emerged between 1.6 – 2.7 billion years ago. The next major change in cell structure came when bacteria were engulfed by eukaryotic cells, in a cooperative association called endosymbiosis.[262][263] The engulfed bacteria and the host cell then underwent co-evolution, with the bacteria evolving into either mitochondria or hydrogenosomes.[264] Another engulfment of cyanobacterial-like organisms led to the formation of chloroplasts in algae and plants.[265]

The history of life was that of the unicellular eukaryotes, prokaryotes and archaea until about 610 million years ago when multicellular organisms began to appear in the oceans in the Ediacaran period.[259][266] The evolution of multicellularity occurred in multiple independent events, in organisms as diverse as sponges, brown algae, cyanobacteria, slime moulds and myxobacteria.[267]

Soon after the emergence of these first multicellular organisms, a remarkable amount of biological diversity appeared over approximately 10 million years, in an event called the Cambrian explosion. Here, the majority of types of modern animals appeared in the fossil record, as well as unique lineages that subsequently became extinct.[268] Various triggers for the Cambrian explosion have been proposed, including the accumulation of oxygen in the atmosphere from photosynthesis.[269]

About 500 million years ago, plants and fungi colonised the land and were soon followed by arthropods and other animals.[270] Insects were particularly successful and even today make up the majority of animal species.[271] Amphibians first appeared around 364 million years ago, followed by early amniotes and birds around 155 million years ago (both from "reptile"-like lineages), mammals around 129 million years ago, homininae around 10 million years ago and modern humans around 250,000 years ago.[272][273][274] However, despite the evolution of these large animals, smaller organisms similar to the types that evolved early in this process continue to be highly successful and dominate the Earth, with the majority of both biomass and species being prokaryotes.[153]

Applications:

Main articles: Applications of evolution, Artificial selection, and Evolutionary computation

Concepts and models used in evolutionary biology, such as natural selection, have many applications.[275] Artificial selection is the intentional selection of traits in a population of organisms. This has been used for thousands of years in the domestication of plants and animals.[276] More recently, such selection has become a vital part of genetic engineering, with selectable markers such as antibiotic resistance genes being used to manipulate DNA. In repeated rounds of mutation and selection proteins with valuable properties have evolved, for example modified enzymes and new antibodies, in a process called directed evolution.[277]

Understanding the changes that have occurred during organism's evolution can reveal the genes needed to construct parts of the body, genes which may be involved in human genetic disorders.[278] For example, the mexican tetra is an albino cavefish that lost its eyesight during evolution. Breeding together different populations of this blind fish produced some offspring with functional eyes, since different mutations had occurred in the isolated populations that had evolved in different caves.[279] This helped identify genes required for vision and pigmentation.[280]

In computer science, simulations of evolution using evolutionary algorithms and artificial life started in the 1960s and was extended with simulation of artificial selection.[281] Artificial evolution became a widely recognised optimisation method as a result of the work of Ingo Rechenberg in the 1960s. He used evolution strategies to solve complex engineering problems.[282] Genetic algorithms in particular became popular through the writing of John Holland.[283] Practical applications also include automatic evolution of computer programs.[284] Evolutionary algorithms are now used to solve multi-dimensional problems more efficiently than software produced by human designers and also to optimise the design of systems.[285]

Composition: (Language)

Summary:

The term **composition** (from Latin *com-* "with" and *ponere* "to place"), in written language, refers to the collective body of important features established by the author in their creation of literature. Most often, composition relates to narrative works of literature, but may also relate to essays, biographies, and other works.

In narratives (primarily fiction), composition includes, but is not limited to,

•Outline, the organisation of thoughts and/or ideas which is used to determine organisational technique

•Plot, the course or arrangement of events

•Theme, the unifying subject or idea

•Dialogue, a reciprocal conversation between two or more persons

•Characterisation, the process of creating characters

•Setting, the time and location in which the composition takes place

•Description, definitions of things in the composition

•Style, specifically, the linguistic style of the composition

•Setting tone or mood, conveying one or more emotions or feelings through words

•Voice, the individual writing style of the author

•Tone, which encompasses the attitudes toward the subject and toward the audience

Composition: (Visual Arts)

Summary:

In the visual arts – in particular painting, graphic design, photography and sculpture – **composition** is the placement or arrangement of visual elements or ingredients in a work of art, as distinct from the subject of a work. It can also be thought of as the organization of the elements of art according to the principles of art. The term composition means 'putting together,' and can apply to any work of art, from music to writing to photography, that is arranged or put together using conscious thought. In the visual arts, composition is often used interchangeably with various terms such as *design, form, visual ordering,* or *formal structure,* depending on the context. In graphic design for press and desktop publishing composition is commonly referred to as page layout.

These paintings all show the same *subject*, the *Raising of Lazarus*, and essentially the same figures, but have very different compositions:

Elements of design:

Main article: Elements of art

The various visual elements, known as *elements of design*, *formal elements*, or *elements of art,* are the vocabulary with which the visual artist composes. These elements in the overall design usually relate to each other and to the whole art work.

"Elements of design" are:

•Line - the visual path that enables the eye to move within the piece

•Shape - areas defined by edges within the piece, whether geometric or organic

•Color - hues with their various values and intensities

•Texture - surface qualities which translate into tactile illusions

•Tone - Shading used to emphasize form

•Form - 3-D length, width, or depth

•Space - the space taken up by (positive) or in between (negative) objects

•Depth - perceived distance from the observer, separated in foreground, background, and optionally middle ground

Line and shape[edit]

Literal lines do not exist in nature, but are the optical phenomena created when objects curve away from the viewer. Nonetheless, line-like shapes are for all intents considered line elements by the artist; for example, telephone and power cables or rigging on boats. Any such elements can be of dramatic use in the composition of the image. Additionally, less obvious lines can be created, intentionally or not, which influence the direction of the viewer's gaze. These could be the borders of areas of differing color or contrast, or sequences of discrete elements, or the artist may exaggerate or create lines perhaps as part of his style, for this purpose. Many lines without a clear subject point suggest chaos in the image and may conflict with the mood the artist is trying to evoke.

Movement is also a source of line, and blur can also create a reaction. Subject lines by means of illusion contribute to both mood and linear perspective, giving the illusion of depth. Oblique lines convey a sense of movement and angular lines generally convey a sense of dynamism and possibly tension. Lines can also direct attention towards the main subject of picture, or contribute to organization by dividing it into compartments.

The brain often unconsciously reads near continuous lines between different elements and subjects at varying distances.

Straight lines[edit]

Straight lines are called linear when used in a piece of art work. Straight lines add affection and can make it look more detailed and challenging. Horizontal, vertical, and angled lines often contribute to creating different moods of a picture. The angle and the relationship to the size of the frame both work to determine the influence the line has on the image. They are also strongly influenced by tone, color, and repetition in relation to the rest of the photograph. Horizontal lines, commonly found in landscape photography, can give the impression of calm, tranquility, and space. An image filled with strong vertical lines tends to have the impression of height, and grandeur. Tightly angled convergent lines give a dynamic, lively, and active effect to the image whereas strongly angled, almost diagonal lines generally produce tension in the image. Viewpoint is very important when dealing with lines particularly in photography, because every different perspective elicits a different response to the photograph. By changing the perspective only by some degrees or some centimetres lines in images can change tremendously and a totally different feeling can be transported.

Curved lines[edit]

Curved lines are generally used to create a sense of flow within an image. They are also generally more aesthetically pleasing, as we associate them with soft things. Compared to straight lines, curves provide a greater dynamic influence in a picture.

In photography, curved lines can give gradated shadows when paired with soft-directional lighting, which usually results in a very harmonious line structure within the image.

Color[edit]

Color is characterized by attributes such as hue, brightness, and saturation. Color symbolism assigns additional associations, dependent on culture. For example, white has long suggested purity, but it can also take slightly different meanings such as peace, or innocence. However, in some places (for instance, Japan) it signifies death.

Principle of organization:

Main article: Principles of art

The artist determines what the center of interest (focus in photography) of the art work will be, and composes the elements accordingly. The gaze of the viewer will then tend to linger over these points of interest, elements are arranged with consideration of several factors (known variously as the *principles of organization, principles of art,* or *principles of design*) into a harmonious whole which works together to produce the desired statement – a phenomenon commonly referred to as **unity.** Such factors in composition should not be confused with the elements of art (or elements of design) themselves. For example, shape is an *element*; the usage of shape is characterized by various *principles.*

Some principles of organization affecting the composition of a picture are:

•Shape and proportion

•Positioning/Orientation/Balance/Harmony among the elements

•The area within the field of view used for the picture ("cropping")

•The path or direction followed by the viewer's eye when they observe the image.

•Negative space

•Color

•Contrast: the value, or degree of lightness and darkness, used within the picture.

•Geometry: for example, use of the golden mean

•Lines

•Rhythm

•Illumination or lighting

•Repetition (Sometimes building into pattern; rhythm also comes into play, as does geometry)

•Perspective

•Breaking the rules can create tension or unease, yet it can add interest to the picture if used carefully

Viewpoint[edit]

The position of the viewer can strongly influence the aesthetics of an image, even if the subject is entirely imaginary and viewed "within the mind's eye". Not only does it influence the elements within the picture, but it also influences the viewer's interpretation of the subject.

For example, if a boy is photographed from above, perhaps from the eye level of an adult, he is diminished in stature. A photograph taken at the child's level would treat him as an equal, and one taken from below could result in an impression of dominance. Therefore, the photographer is choosing the viewer's positioning.

A subject can be rendered more dramatic when it fills the frame. There exists a tendency to perceive things as larger than they actually are, and filling the frame fulfills this psychological mechanism. This can be used to eliminate distractions from the background.

In photography, altering the position of the camera can change the image so that the subject has fewer or more distractions with which to compete. This may be achieved by getting closer, moving laterally, tilting, panning, or moving the camera vertically.

Compositional Techniques

There are numerous approaches or "compositional techniques" to achieving a sense of unity within an artwork, depending on the goals of the artist. For example, a work of art is said to be aesthetically pleasing to the eye if the elements within the work are arranged in a balanced compositional way.[1] However, there are artists such as Salvador Dalí whose sole aim is to disrupt traditional composition and challenge the viewer to rethink balance and design elements within art works.

Conventional composition can be achieved by utilizing a number of techniques:

Rule of thirds[edit]

Main article: Rule of thirds

The rule of thirds is a guideline followed by some visual artists. The objective is to stop the subject(s) and areas of interest (such as the horizon) from bisecting the image, by placing them near one of the lines that would divide the image into three equal columns and rows, ideally near the intersection of those lines.

Rule of thirds: Note how the horizon falls close to the bottom grid line, and how the dark areas are in the left third, the overexposed in the right third.

The rule of thirds is thought to be a simplification of the golden mean. The golden mean is a ratio that has been used by visual artists for centuries as an aid to composition. When two things are in the proportion of 1:1.618 (approximately 3/8 to 5/8), they are said to be in the golden mean.

Dividing the parts of an image according to this proportion helps to create a pleasing, balanced composition. The intersection points on a golden mean grid appear at 3/8 in and 3/8 down/up, rather than at 1/3 in and 1/3 down/up on the grid of thirds.

Rule of odds[edit]

The "rule of odds" states that by framing the object of interest with an even number of surrounding objects, it becomes more comforting to the eye, thus creates a feeling of ease and pleasure. It is based on the assumption that humans tend to find visual images that reflect their own preferences/wishes in life more pleasing and attractive.

The "rule of odds" suggests that an odd number of subjects in an image is more interesting than an even number. Thus if you have more than one subject in your picture, the suggestion is to choose an arrangement with at least three subjects. An even number of subjects produces symmetries in the image, which can appear less natural for a naturalistic, informal composition.

An image of a person surrounded/framed by two other persons, for instance, where the person in the center is the object of interest in that image/artwork, is more likely to be perceived as friendly and comforting by the viewer, than an image of a single person with no significant surroundings.

Rule of space[edit]

Main article: lead room

The rule of space applies to artwork (photography, advertising, illustration) picturing object(s) to which the artist wants to apply the illusion of movement, or which is supposed to create a contextual bubble in the viewer's mind.

This can be achieved, for instance, by leaving white space in the direction the eyes of a portrayed person are looking, or, when picturing a runner, adding white space in front of him rather than behind him to indicate movement.

Simplification[edit]

Images with clutter can distract from the main elements within the picture and make it difficult to identify the subject. By decreasing the extraneous content, the viewer is more likely to focus on the primary objects. Clutter can also be reduced through the use of lighting, as the brighter areas of the image tend to draw the eye, as do lines, squares and colour. In painting, the artist may use less detailed and defined brushwork towards the edges of the picture.

Limiting focus[edit]

In photography, and also (via software simulation of real lens limitations) in 3D graphics, one approach to achieving simplification is to use a wide aperture when shooting to limit the depth of field. When used properly in the right setting, this technique can place everything that is not the subject of the photograph out of focus.

The blurred background focuses the eye on the flowers.

At a smaller aperture, the background competes for the viewer's attention.

A similar approach, given the right equipment, is to take advantage of the Scheimpflug principle to change the plane of focus.

Geometry and symmetry[edit]

A simple composition with cloud and rooftop that creates asymmetry.

Related to the rule of odds is the observation that triangles are an aesthetically pleasing implied shape within an image. In a canonically attractive face, the mouth and eyes fall within the corners of the area of an equilateral triangle. Paul Cézanne successfully used triangles in his compositions of still lifes.

Other techniques[edit]

•There should be a center of interest or focus in the work, to prevent it becoming a pattern in itself;

•The direction followed by the viewer's eye should lead the viewer's gaze around all elements in the work before leading out of the picture;

•The subject should not be facing out of the image;

•A moving subject should have space in front;

•Exact bisections of the picture space should be avoided;

•Small, high contrast, elements have as much impact as larger, duller elements;

•The prominent subject should be off-centre, unless a symmetrical or formal composition is desired, and can be balanced by smaller satellite elements

•the horizon line should not divide the art work in two equal parts but be positioned to emphasize either the sky or ground; showing more sky if painting is of clouds, sun rise/set, and more ground if a landscape

These principles *can* be means of a good composition yet they *cannot* be applied separately but should act together to form a good composition.

Computation:

Summary:

Computation is any type of calculation[1] or use of computing technology in information processing.[2][3]

Computation is a process following a well-defined model understood and expressed as, for example, an algorithm, or a protocol.

The study of computation is paramount to the discipline of computer science.

Look up ***computation*** in Wiktionary, the free dictionary.

Classification[edit]

Computation can be classified by mainly three unique criteria: digital versus analog, sequential versus parallel versus concurrent, batch versus interactive.

In practice, digital computation aids simulation of natural processes (for example, evolutionary computation), including those that are naturally described by analog models of computation (for example, artificial neural network).

Physical phenomenon[edit]

A computation can be seen as a purely physical phenomenon occurring inside a closed physical system called a computer. Examples of such physical systems include digital computers, mechanical computers, quantum computers, DNA computers, molecular computers, analog computers or wetware computers. This point of view is the one adopted by the branch of theoretical physics called the physics of computation.

An even more radical point of view is the postulate of digital physics that the evolution of the universe itself is a computation - pancomputationalism.

Mathematical models[edit]

In the theory of computation, a diversity of mathematical models of computers have been developed. Typical mathematical models of computers are the following:

•State models including Turing machine, push-down automaton, finite state automaton, and PRAM

•Functional models including lambda calculus

•Logical models including logic programming

•Concurrent models including actor model and process calculi

History[edit]

The word computation has an archaic meaning (from its Latin etymological roots), but the word has come back in use with the arising of a new scientific discipline: computer science.

Comparison to calculation[edit]

•See Calculation#Comparison to computation

Computer Science portal

•Computing

•Physical information

•Real computation

•Reversible computation

•Hypercomputation

Computing:

Summary:

Computing is any goal-oriented activity requiring, benefiting from, or creating computers. For example, computing includes designing, developing and building hardware and software systems; processing, structuring, and managing various kinds of information; doing scientific research on and with computers; making computer systems behave intelligently; creating and using communications and entertainment media etc. Sub-disciplines of computing include computer engineering, software engineering, computer science, information systems, and information technology.

Definitions:

The ACM *Computing Curricula 2005*[1] defined "computing" as:

"In a general way, we can define computing to mean any goal-oriented activity requiring, benefiting from, or creating computers. Thus, computing includes designing and building hardware and software systems for a wide range of purposes; processing, structuring, and managing various kinds of information; doing scientific studies using computers; making computer systems behave intelligently; creating and using communications and entertainment media; finding and gathering information relevant to any particular purpose, and so on. The list is virtually endless, and the possibilities are vast."

and it defines five sub-disciplines of the *computing* field: Computer Science, Computer Engineering, Information Systems, Information Technology, and Software Engineering.[2]

However, *Computing Curricula 2005*[1] also recognizes that the meaning of "computing" depends on the context:

Computing also has other meanings that are more specific, based on the context in which the term is used. For example, an information systems specialist will view computing somewhat differently from a software engineer. Regardless of the context, doing computing well can be complicated and difficult. Because society needs people to do computing well, we must think of computing not only as a profession but also as a discipline.

The term "computing" has sometimes been narrowly defined, as in a 1989 ACM report on *Computing as a Discipline*:[3]

The discipline of computing is the systematic study of algorithmic processes that describe and transform information: their theory, analysis, design, efficiency, implementation, and application. The fundamental question underlying all computing is "What can be (efficiently) automated?"

The term "computing" is also synonymous with counting and calculating. In earlier times, it was used in reference to mechanical computing machines.

History:

Main articles: History of computing and Timeline of computing

The history of computing is longer than the history of computing hardware and modern computing technology and includes the history of methods intended for pen and paper or for chalk and slate, with or without the aid of tables.

Computing is intimately tied to the representation of numbers. But long before abstractions like *the number* arose, there were mathematical concepts to serve the purposes of civilization. These concepts include one-to-one correspondence (the basis of counting), comparison to a standard (used for measurement), and the *3-4-5* right triangle (a device for assuring a *right angle*).

The earliest known tool for use in computation was the abacus, and it was thought to have been invented in Babylon circa 2400 BC. Its original style of usage was by lines drawn in sand with pebbles. Abaci, of a more modern design, are still used as calculation tools today. This was the first known computer and most advanced system of calculation known to date - preceding Greek methods by 2,000 years.

Computer:

Main articles: Computer, Outline of computers, and Glossary of computer terms

A computer is a machine that manipulates data according to a set of instructions called a computer program. The program has an executable form that the computer can use directly to execute the instructions. The same program in its human-readable source code form, enables a programmer to study and develop the algorithm. Because the instructions can be carried out in different types of computers, a single set of source instructions converts to machine instructions according to the central processing unit type.

The execution process carries out the instructions in a computer program. Instructions express the computations performed by the computer. They trigger sequences of simple actions on the executing machine. Those actions produce effects according to the semantics of the instructions.

Computer software and hardware[edit]

Main articles: Software and Computer hardware

Computer software or just "software", is a collection of computer programs and related data that provides the instructions for telling a computer what to do and how to do it. Software refers to one or more computer programs and data held in the storage of the computer for some purposes. In other words, software is a set of *programs, procedures, algorithms* and its *documentation* concerned with the operation of a data processing system. Program software performs the function of the program it implements, either by directly providing instructions to the computer hardware or by serving as input to another piece of software. The term was coined to contrast with the old term hardware (meaning physical devices). In contrast to hardware, software "cannot be touched".[4] Software is also sometimes used in a more narrow sense, meaning application software only. Sometimes the term includes data that has not traditionally been associated with computers, such as film, tapes, and records.[5]

Application software[edit]

Main article: Application software

Application software, also known as an "application" or an "app", is computer software designed to help the user to perform specific tasks. Examples include enterprise software, accounting software, office suites, graphics software and media players. Many application programs deal principally with documents. Apps may be bundled with the computer and its system software, or may be published separately. Some users are satisfied with the bundled apps and need never install one.

Application software is contrasted with system software and middleware, which manage and integrate a computer's capabilities, but typically do not directly apply them in the performance of tasks that benefit the user. The system software serves the application, which in turn serves the user.[6]

Application software applies the power of a particular computing platform or system software to a particular purpose. Some apps such as Microsoft Office are available in versions for several different platforms; others have narrower requirements and are thus called, for example, a Geography application for Windows or an Android application for education or Linux gaming. Sometimes a new and popular application arises that only runs on one platform, increasing the desirability of that platform. This is called a killer application.

Computer network[edit]

Main article: Computer network

A computer network, often simply referred to as a network, is a collection of hardware components and computers interconnected by communication channels that allow sharing of resources and information.[7] Where at least one process in one device is able to send/receive data to/from at least one process residing in a remote device, then the two devices are said to be in a network.

Networks may be classified according to a wide variety of characteristics such as the medium used to transport the data, communications protocol used, scale, topology, and organizational scope.

Communications protocols define the rules and data formats for exchanging information in a computer network, and provide the basis for network programming. Well-known communications protocols are Ethernet, a hardware and Link Layer standard that is ubiquitous in local area networks, and the Internet Protocol Suite, which defines a set of protocols for internetworking, i.e. for data communication between multiple networks, as well as host-to-host data transfer, and application-specific data transmission formats.

Computer networking is sometimes considered a sub-discipline of electrical engineering, telecommunications, computer science, information technology or computer engineering, since it relies upon the theoretical and practical application of these disciplines.

Internet[edit]

Main articles: Internet, Outline of the Internet, and Glossary of Internet-related terms

The Internet is a global system of interconnected computer networks that use the standard Internet protocol suite (TCP/IP) to serve billions of users worldwide. It is a *network of networks* that consists of millions of private, public, academic, business, and government networks, of local to global scope, that are linked by a broad array of electronic, wireless and optical networking technologies. The Internet carries an extensive range of information resources and services, such as the inter-linked hypertext documents of the World Wide Web (WWW) and the infrastructure to support email.

Computer user[edit]

Main articles: User (computing) and End-user

A user is an agent, either a human agent (end-user) or software agent, who uses a computer or network service. A user often has a user account and is identified by a username (also user name), screen name (also screenname), nickname (also nick), or handle, which derives from the identical Citizen's Band radio term.

In hacker-related terminology, users are divided into "lusers" and "power users"[*citation needed*].

In projects where the system actor is another system or a software agent, there may be no end-user. In that case, the end-users for the system is indirect end-users.

Enthusiast computing[edit]

Main article: Enthusiast computing

Enthusiast computing refers to a sub-culture of personal computer users who focus on extremely high-performance computers. Manufacturers of performance-oriented parts typically include an enthusiast model in their offerings. Enthusiast computers (often referred to as a *box*, *build*, or *rig*) commonly feature extravagant cases, high-end components, and are sometimes liquid cooled.

Although high-end computers may be bought retail, enthusiasts often build their own systems to produce a computer that out-performs 'average' computers—for varied reasons that include enhanced game-play, faster video editing, improved high-end audio recording, and other applications.

Computer programming[edit]

Main articles: Computer programming and Software engineering

Computer programming in general is the process of writing, testing, debugging, and maintaining the source code and documentation of computer programs. This source code is written in a programming language, which is an artificial language often more restrictive or demanding than natural languages, but easily translated by the computer. The purpose of programming is to invoke the desired behaviour (customization) from the machine. The process of writing high quality source code requires knowledge of both the application's domain *and* the computer science domain. The highest-quality software is thus developed by a team of various domain experts, each person a specialist in some area of development. But the term *programmer* may apply to a range of program quality, from hacker to open source contributor to professional. And a single programmer could do most or all of the computer programming needed to generate the proof of concept to launch a new "killer" application.

Computer programmer[edit]

Main articles: Programmer, Software engineer, and Software developer

A programmer, computer programmer, or coder is a person who writes computer software. The term *computer programmer* can refer to a specialist in one area of computer programming or to a generalist who writes code for many kinds of software. One who practices or professes a formal approach to programming may also be known as a programmer analyst. A programmer's primary computer language (C, C++, Java, Lisp, Python, Smalltalk, etc.) is often prefixed to the above titles, and those who work in a web environment often prefix their titles with *web*. The term *programmer* can be used to refer to a software developer, software engineer, computer scientist, or software analyst. However, members of these professions typically[*citation needed*] possess other software engineering skills, beyond programming; for this reason, the term *programmer* is sometimes considered an insulting or derogatory oversimplification of these other professions[*citation needed*]. This has sparked much debate amongst developers, analysts, computer scientists, programmers, and outsiders who continue to be puzzled at the subtle differences in the definitions of these occupations.[8][9][10][11][12]

Computer industry[edit]

Main article: Computer industry

The computer industry is made up of all of the businesses involved in developing computer software, designing computer hardware and computer networking infrastructures, the manufacture of computer components and the provision of information technology services including system administration and maintenance.

Software industry[edit]

Main article: Software industry

The software industry includes businesses engaged in development, maintenance and publication of software. The industry also includes software services, such as training, documentation, and consulting.

Sub-disciplines of computing:

Computer engineering[edit]

Main article: Computer engineering

Computer engineering is a discipline that integrates several fields of Electrical engineering and computer science required to develop computer hardware and software.[13] Computer engineers usually have training in electronic engineering (or electrical engineering), software design, and hardware-software integration instead of only software engineering or electronic engineering. Computer engineers are involved in many hardware and software aspects of computing, from the design of individual microprocessors, personal computers, and supercomputers, to circuit design. This field of engineering not only focuses on how computer systems themselves work, but also how they integrate into the larger picture.[14]

Software engineering[edit]

Main article: Software engineering

Software engineering (SE) is the application of a systematic, disciplined, quantifiable approach to the design, development, operation, and maintenance of software, and the study of these approaches; that is, the application of engineering to software.[15][16][17] In layman's terms, it is the act of using insights to conceive, model and scale a solution to a problem. The first reference to the term is the 1968 NATO Software Engineering Conference and was meant to provoke thought regarding the perceived "software crisis" at the time.[18][19][20] *Software development*, a much used and more generic term, does not necessarily subsume the engineering paradigm. The generally accepted concepts of Software Engineering as an engineering discipline have been specified in the Guide to the Software Engineering Body of Knowledge (SWEBOK). The SWEBOK has become an internationally accepted standard ISO/IEC TR 19759:2005.[21]

Computer science[edit]

Main articles: Computer science and Computer scientist

Computer science or computing science (abbreviated CS or CompSci) is the scientific and practical approach to computation and its applications. A computer scientist specializes in the theory of computation and the design of computational systems.[22]

Its subfields can be divided into practical techniques for its implementation and application in computer systems and purely theoretical areas. Some, such as computational complexity theory, which studies fundamental properties of computational problems, are highly abstract, while others, such as computer graphics, emphasize real-world applications. Still others focus on the challenges in implementing computations. For example, programming language theory studies approaches to description of computations, while the study of computer programming itself investigates various aspects of the use of programming languages and complex systems, and human-computer interaction focuses on the challenges in making computers and computations useful, usable, and universally accessible to humans.

Information systems[edit]

Main article: Information systems

Information systems (IS) is the study of complementary networks of hardware and software (see information technology) that people and organizations use to collect, filter, process, create, and distribute data.[23][24][25][26][27] The study bridges business and computer science using the theoretical foundations of information and computation to study various business models and related algorithmic processes within a computer science discipline.[28][29][30][31][32][33][34][35][36] **Computer Information System(s)** (CIS) is a field studying computers and algorithmic processes, including their principles, their software and hardware designs, their applications, and their impact on society[37][38][39] while IS emphasizes functionality over design.[40]

Information technology[edit]

Main article: Information technology

Information technology (IT) is the application of computers and telecommunications equipment to store, retrieve, transmit and manipulate data,[41] often in the context of a business or other enterprise.[42] The term is commonly used as a synonym for computers and computer networks, but it also encompasses other information distribution technologies such as television and telephones. Several industries are associated with information technology, such as computer hardware, software, electronics, semiconductors, internet, telecom equipment, e-commerce and computer services.[43][44]

Computational (Syntax): (see computation & syntax)

Computational Biology

Summary:

Computational biology involves the development and application of data-analytical and theoretical methods, mathematical modeling and computational simulation techniques to the study of biological, behavioral, and social systems.[1] The field is broadly defined and includes foundations in computer science, applied mathematics, statistics, biochemistry, chemistry, biophysics, molecular biology, genetics, ecology, evolution, anatomy, neuroscience, and visualization.[2]

Introduction:

Computational Biology, sometimes referred to as bioinformatics, is the science of using biological data to develop algorithms and relations among various biological systems. Prior to the advent of computational biology, biologists were unable to have access to large amounts of data. Researchers were able to develop analytical methods for interpreting biological information, but were unable to share them quickly among colleagues.[3]

Bioinformatics began to develop in the early 1970s. It was considered the science of analyzing informatics processes of various biological systems. At this time, research in artificial intelligence was using network models of the human brain in order to generate new algorithms. This use of biological data to develop other fields pushed biological researchers to revisit the idea of using computers to evaluate and compare large data sets. By 1982, information was being shared amongst researchers through the use of punch cards. The amount of data being shared began to grow exponentially by the end of the 1980s. This required the development of new computational methods in order to quickly analyze and interpret relevant information.[3]

Since the late 1990s, computational biology has become an important part of developing emerging technologies for the field of biology.[4] The terms computational biology and evolutionary computation have a similar name, but are not to be confused. Unlike computational biology, evolutionary computation is not concerned with modeling and analyzing biological data. It instead creates algorithms based on the ideas of evolution across species. Sometimes referred to as genetic algorithms, the research of this field can be applied to computational biology. While evolutionary computation is not inherently a part of computational biology, Computational evolutionary biology is a subfield of it.[5]

Computational biology has been used to help sequence the human genome, create accurate models of the human brain, and assist in modeling biological systems.[3]

Subfields

Computational biomodeling:

Main article: Modelling biological systems

Computational biomodeling is a field concerned with building computer models of biological systems. Computational biomodeling aims to develop and use visual simulations in order to assess the complexity of biological systems. This is accomplished through the use of specialized algorithms, and visualization software. These models allow for prediction of how systems will react under different environments. This is useful for determining if a system is robust. A robust biological system is one that “maintain their state and functions against external and internal perturbations”,[6] which is essential for a biological system to survive. Computational biomodeling generates a large archive of such data, allowing for analysis from multiple users. While current techniques focus on small biological systems, researchers are working on approaches that will allow for larger networks to be analyzed and modeled. A majority of researchers believe that this will be essential in developing modern medical approaches to creating new drugs and gene therapy.[6]

Computational genomics:

Main article: Computational genomics

Computational genomics is a field within genomics which studies the genomes of cells and organisms. The Human Genome Project is one example of computational genomics. This project looks to sequence the entire human genome into a set of data. Once fully implemented, this could allow for doctors to analyze the genome of an individual patient.[7] This opens the possibility of personalized medicine, prescribing treatments based on an individual’s pre-existing genetic patterns. This project has created many similar programs. Researchers are looking to sequence the genomes of animals, plants, bacteria, and all other types of life.[8]

One of the main tools used in comparing the genomes is homology. Homology is observing the same organ across species and seeing what different functions they have. Research suggests that between 80 to 90% of sequences genes can be identified this way. In order to detect potential cures from genomes, comparisons between genome sequences of related species and mRNA sequences are drawn. This method is not completely accurate however. It may be necessary to include the genome of a primate in order to improve current methods of unique gene therapy.[8]

This field is still in development. An untouched project in the development in computational genomics is analyzing intergenic regions. Studies show that roughly 97% of the human genome consists of these regions. There are no current methods for determining possible implications of these sequences. Computational genomics will look to expand research in this area and develop new numerical and computational approaches to sequencing these regions.[8]

Computational neuroscience:

Main article: Computational neuroscience

Computational neuroscience is the study of brain function in terms of the information processing properties of the structures that make up the nervous system. It is a subset of the field of neuroscience, and looks to analyze brain data to create practical applications.[9] It looks to model the brain in order to examine specific types aspects of the neurological system. Various types of models of the brain include:

•Realistic Brain Models: These models look to represent every aspect of the brain, including as much detail at the cellular level as possible. Realistic models provide the most information about the brain, but also have the largest margin for error. More variables in a brain model create the possibility for more error to occur. These models do not account for parts of the cellular structure that scientists do not know about. Realistic brain models are the most computationally heavy and the most expensive to implement.[10]

•Simplifying Brain Models: These models look to limit the scope of a model in order to assess a specific physical property of the neurological system. This allows for the intensive computational problems to be solved, and reduces the amount of potential error from a realistic brain model.[10]

It is the work of computational neuroscientists to improve the algorithms and data structures currently used to increase the speed of such calculations.

Computational Evolutionary Biology

Computational biology has assisted the field of evolutionary biology in many capacities. This includes:

•Using DNA data to evaluate the evolutionary change of a species over time.

•Taking the results of computational genomics in order to evaluate the evolution of genetic disorders within a species.

•Build models of evolutionary systems in order predict what types of changes will occur in the future.[13]

One method of representing this subfield of computational biology is through the use of trees. A tree is a data structure that splits nodes based on a predefined rule. This tree, developed by M.R. Hezinger, V. King, and T.Warnow implements traversal of evolutionary information in less than polynomial time. This is a particularly quick method, as opposed to some modern methods that take longer than O(n^2) time. These tree have multiple applications to questions in computational evolutionary biology.[14]

Software & Tools:

Computational Biologists use a wide range of software. These range from command line arguments to graphical and web-based programs.

Open Source Software[edit]

Open source software provides a platform to develop computational biological methods. Specifically, open source means that anybody can access the software and modify it. This allows for computer scientists and biologists to work from anywhere to improve these programs. Organizations such as the Open Bioinformatics Foundation provides an environment that encourages open source development in computational biology and bioinformatics.[16] PLOS (Public Library of Science) computational biology supports the development of open source software. Becoming a member of the organization requires sharing of all publications and software developed in research. PLOS cites four main reasons for the use of open source software including:

•Reproducibility: This allows for researchers to use the exact methods used to calculate the relations between biological data.

•Faster Development: developers and researchers do not have to reinvent existing code for minor tasks. Instead they can use pre-existing programs to save time on the development and implementation of larger projects.

•Increased quality: Having input from multiple researchers studying the same topic provides a layer of assurance that errors will not be in the code.

•Long-term availability: Open source programs have no businesses or patents that they are tied too. This allows for them to be posted to multiple web pages and ensure that they are available in the future.[17]

Additional: Conferences, Journals & Related fields

Conferences[edit]

There are several large conferences that are concerned with computational biology. Some notable examples are Intelligent Systems for Molecular Biology (ISMB), European Conference on Computational Biology (ECCB) and Research in Computational Molecular Biology (RECOMB). MIT hosts a list of upcoming computational biology conferences including ISMB and RECOMB.[18]

Journals[edit]

Main article: List of bioinformatics journals

There are numerous journals dedicated to computational biology. Some notable examples include Journal of Computational Biology and PLoS Computational Biology. The PLOS computational biology journal is a peer-reviewed journal that has many notable research projects in the field of computational biology. They provide reviews on software, tutorials for open source software, and display information on upcoming computational biology conferences. PLOS Computational Biology is an open access journal. The publication may be openly used provided the author is cited.[19]

Related fields[edit]

Computational biology, bioinformatics and mathematical biology are all interdisciplinary approaches to the life sciences that draw from quantitative disciplines such as mathematics and information science. The NIH describes computational/mathematical biology as the use of computational/mathematical approaches to address theoretical and experimental questions in biology and, by contrast, bioinformatics as the application of information science to understand complex life-sciences data.[1]

Specifically, the NIH defines

Computational biology: The development and application of data-analytical and theoretical methods, mathematical modeling and computational simulation techniques to the study of biological, behavioral, and social systems.[1]

Bioinformatics: Research, development, or application of computational tools and approaches for expanding the use of biological, medical, behavioral or health data, including those to acquire, store, organize, archive, analyze, or visualize such data.[1]

While all three fields are distinct, there is necessarily significant overlap at their interface.[1]

Computational Chemistry

Computational Chemistry:

Computational chemistry is a branch of chemistry that uses principles of computer science to assist in solving chemical problems. It uses the results of theoretical chemistry, incorporated into efficient computer programs, to calculate the structures and properties of molecules and solids. Its necessity arises from the well-known fact that apart from relatively recent results concerning the hydrogen molecular ion (see references therein for more details), the quantum many-body problem cannot be solved analytically, much less in closed form. While its 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 distributions, dipoles and higher multipole moments, vibrational frequencies, reactivity or other spectroscopic quantities, and cross sections for collision with other particles.

The methods employed 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 a single molecule, a group of molecules, or a solid. Computational chemistry methods range from highly accurate to very approximate; highly accurate methods are typically feasible only for small systems. Ab initio methods are based entirely on theory from first principles. Other (typically less accurate) methods are called empirical or semi-empirical because they employ experimental results, often from acceptable models of atoms or related molecules, to approximate some elements of the underlying theory. Both *ab initio* and semi-empirical approaches involve approximations. These range from simplified forms of the first-principles equations that are easier or faster to solve, to approximations limiting the size of the system (for example, periodic boundary conditions), to fundamental approximations to the underlying equations that are required to achieve any solution to them at all. For example, most *ab initio* calculations make the Born–Oppenheimer approximation, which greatly simplifies the underlying Schrödinger equation by assuming that the nuclei remain in place during the calculation. In principle, ab initio methods eventually converge to the exact solution of the underlying equations as the number of approximations is reduced. In practice, however, it is impossible to eliminate all approximations, and residual error inevitably remains. The goal of computational chemistry is to minimize this residual error while keeping the calculations tractable.

In some cases, the details of electronic structure are less important than the long-time phase space behavior of molecules. This is the case in conformational studies of proteins and protein-ligand binding thermodynamics. Classical approximations to the potential energy surface are employed, as they are computationally less intensive than electronic calculations, to enable longer simulations of molecular dynamics. Furthermore, cheminformatics uses even more empirical (and computationally cheaper) methods like machine learning based on physicochemical properties. One typical problem in cheminformatics is to predict the binding affinity of drug molecules to a given target.

History:

Building on the founding discoveries and theories in the history of quantum mechanics, the first theoretical calculations in chemistry were those of Walter Heitler and Fritz London in 1927. The books that were influential in the early development of computational quantum chemistry include Linus Pauling and E. Bright Wilson's 1935 *Introduction to Quantum Mechanics – with Applications to Chemistry*, Eyring, Walter and Kimball's 1944 *Quantum Chemistry*, Heitler's 1945 *Elementary Wave Mechanics – with Applications to Quantum Chemistry*, and later Coulson's 1952 textbook *Valence*, each of which served as primary references for chemists in the decades to follow.

With the development of efficient computer technology in the 1940s, the solutions of elaborate wave equations for complex atomic systems began to be a realizable objective. In the early 1950s, the first semi-empirical atomic orbital calculations were carried out. Theoretical chemists became extensive users of the early digital computers. A very detailed account of such use in the United Kingdom is given by Smith and Sutcliffe.[1] The first *ab initio* Hartree–Fock calculations on diatomic molecules were carried out in 1956 at MIT, using a basis set of Slater orbitals. For diatomic molecules, a systematic study using a minimum basis set and the first calculation with a larger basis set were published by Ransil and Nesbet respectively in 1960.[2] The first polyatomic calculations using Gaussian orbitals were carried out in the late 1950s. The first configuration interaction calculations were carried out in Cambridge on the EDSAC computer in the 1950s using Gaussian orbitals by Boys and coworkers.[3] By 1971, when a bibliography of *ab initio* calculations was published,[4] the largest molecules included were naphthalene and azulene.[5][6] Abstracts of many earlier developments in *ab initio* theory have been published by Schaefer.[7]

In 1964, Hückel method calculations (using a simple linear combination of atomic orbitals (LCAO) method for the determination of electron energies of molecular orbitals of π electrons in conjugated hydrocarbon systems) of molecules ranging in complexity from butadiene and benzene to ovalene, were generated on computers at Berkeley and Oxford.[8] These empirical methods were replaced in the 1960s by semi-empirical methods such as CNDO.[9]

In the early 1970s, efficient *ab initio* computer programs such as ATMOL, Gaussian, IBMOL, and POLYAYTOM, began to be used to speed up *ab initio* calculations of molecular orbitals. Of these four programs, only GAUSSIAN, now massively expanded, is still in use, but many other programs are now in use. At the same time, the methods of molecular mechanics, such as MM2, were developed, primarily by Norman Allinger.[10]

One of the first mentions of the term "computational chemistry" can be found in the 1970 book *Computers and Their Role in the Physical Sciences* by Sidney Fernbach and Abraham Haskell Taub, where they state "It seems, therefore, that 'computational chemistry' can finally be more and more of a reality."[11] During the 1970s, widely different methods began to be seen as part of a new emerging discipline of *computational chemistry*.[12] The Journal of Computational Chemistry was first published in 1980.

Fields of Application:

The term *theoretical chemistry* may be defined as a mathematical description of chemistry, whereas *computational chemistry* is usually used when a mathematical method is sufficiently well developed that it can be automated for implementation on a computer. In theoretical chemistry, chemists, physicists and mathematicians develop algorithms and computer programs to predict atomic and molecular properties and reaction paths for chemical reactions. Computational chemists, in contrast, may simply apply existing computer programs and methodologies to specific chemical questions.

There are two different aspects to computational chemistry:

•Computational studies can be carried out to find a starting point for a laboratory synthesis, or to assist in understanding experimental data, such as the position and source of spectroscopic peaks.

•Computational studies can be used to predict the possibility of so far entirely unknown molecules or to explore reaction mechanisms that are not readily studied by experimental means.

Thus, computational chemistry can assist the experimental chemist or it can challenge the experimental chemist to find entirely new chemical objects.

Several major areas may be distinguished within computational chemistry:

•The prediction of the molecular structure of molecules by the use of the simulation of forces, or more accurate quantum chemical methods, to find stationary points on the energy surface as the position of the nuclei is varied.

•Storing and searching for data on chemical entities (see chemical databases).

•Identifying correlations between chemical structures and properties (see QSPR and QSAR).

•Computational approaches to help in the efficient synthesis of compounds.

•Computational approaches to design molecules that interact in specific ways with other molecules (e.g. drug design and catalysis).

Accuracy:

The words *exact* and *perfect* do not appear here, as very few aspects of chemistry can be computed exactly. However, almost every aspect of chemistry can be described in a qualitative or approximate quantitative computational scheme.

Molecules consist of nuclei and electrons, so the methods of quantum mechanics apply. Computational chemists often attempt to solve the non-relativistic Schrödinger equation, with relativistic corrections added, although some progress has been made in solving the fully relativistic Dirac equation. In principle, it is possible to solve the Schrödinger equation in either its time-dependent or time-independent form, as appropriate for the problem in hand; in practice, this is not possible except for very small systems. Therefore, a great number of approximate methods strive to achieve the best trade-off between accuracy and computational cost.

Accuracy can always be improved with greater computational cost. Significant errors can present themselves in ab initio models comprising many electrons, due to the computational expense of full relativistic-inclusive methods. This complicates the study of molecules interacting with high atomic mass unit atoms, such as transitional metals and their catalytic properties. Present algorithms in computational chemistry can routinely calculate the properties of molecules that contain up to about 40 electrons with sufficient accuracy. Errors for energies can be less than a few kJ/mol. For geometries, bond lengths can be predicted within a few picometres and bond angles within 0.5 degrees. The treatment of larger molecules that contain a few dozen electrons is computationally tractable by approximate methods such as density functional theory (DFT). There is some dispute within the field whether or not the latter methods are sufficient to describe complex chemical reactions, such as those in biochemistry. Large molecules can be studied by semi-empirical approximate methods. Even larger molecules are treated by classical mechanics methods that employ what are called molecular mechanics. In QM/MM methods, small portions of large complexes are treated quantum mechanically (QM), and the remainder is treated approximately (MM).

Methods:

Summary:

A single molecular formula can represent a number of molecular isomers. Each isomer is a local minimum on the energy surface (called the potential energy surface) created from the total energy (i.e., the electronic energy, plus the repulsion energy between the nuclei) as a function of the coordinates of all the nuclei. A stationary point is a geometry such that the derivative of the energy with respect to all displacements of the nuclei is zero. A local (energy) minimum is a stationary point where all such displacements lead to an increase in energy. The local minimum that is lowest is called the global minimum and corresponds to the most stable isomer. If there is one particular coordinate change that leads to a decrease in the total energy in both directions, the stationary point is a transition structure and the coordinate is the reaction coordinate. This process of determining stationary points is called geometry optimization.

The determination of molecular structure by geometry optimization became routine only after efficient methods for calculating the first derivatives of the energy with respect to all atomic coordinates became available. Evaluation of the related second derivatives allows the prediction of vibrational frequencies if harmonic motion is estimated. More importantly, it allows for the characterization of stationary points. The frequencies are related to the eigenvalues of the Hessian matrix, which contains second derivatives. If the eigenvalues are all positive, then the frequencies are all real and the stationary point is a local minimum. If one eigenvalue is negative (i.e., an imaginary frequency), then the stationary point is a transition structure. If more than one eigenvalue is negative, then the stationary point is a more complex one, and is usually of little interest. When one of these is found, it is necessary to move the search away from it if the experimenter is looking solely for local minima and transition structures.

The total energy is determined by approximate solutions of the time-dependent Schrödinger equation, usually with no relativistic terms included, and by making use of the Born–Oppenheimer approximation, which allows for the separation of electronic and nuclear motions, thereby simplifying the Schrödinger equation. This leads to the evaluation of the total energy as a sum of the electronic energy at fixed nuclei positions and the repulsion energy of the nuclei. A notable exception are certain approaches called direct quantum chemistry, which treat electrons and nuclei on a common footing. Density functional methods and semi-empirical methods are variants on the major theme. For very large systems, the relative total energies can be compared using molecular mechanics. The ways of determining the total energy to predict molecular structures are:

Types:

Ab initio **methods**[edit]

Main article: Ab initio quantum chemistry methods

The programs used in computational chemistry are based on many different quantum-chemical methods that solve the molecular Schrödinger equation associated with the molecular Hamiltonian. Methods that do not include any empirical or semi-empirical parameters in their equations – being derived directly from theoretical principles, with no inclusion of experimental data – are called ab initio methods. This does not imply that the solution is an exact one; they are all approximate quantum mechanical calculations. It means that a particular approximation is rigorously defined on first principles (quantum theory) and then solved within an error margin that is qualitatively known beforehand. If numerical iterative methods have to be employed, the aim is to iterate until full machine accuracy is obtained (the best that is possible with a finite word length on the computer, and within the mathematical and/or physical approximations made).

Diagram illustrating various *ab initio* electronic structure methods in terms of energy. Spacings are not to scale.

The simplest type of *ab initio* electronic structure calculation is the Hartree–Fock (HF) scheme, an extension of molecular orbital theory, in which the correlated electron–electron repulsion is not specifically taken into account; only its average effect is included in the calculation. As the basis set size is increased, the energy and wave function tend towards a limit called the Hartree–Fock limit. Many types of calculations (known as post-Hartree–Fock methods) begin with a Hartree–Fock calculation and subsequently correct for electron–electron repulsion, referred to also as electronic correlation. As these methods are pushed to the limit, they approach the exact solution of the non-relativistic Schrödinger equation. In order to obtain exact agreement with experiment, it is necessary to include relativistic and spin orbit terms, both of which are only really important for heavy atoms. In all of these approaches, in addition to the choice of method, it is necessary to choose a basis set. This is a set of functions, usually centered on the different atoms in the molecule, which are used to expand the molecular orbitals with the LCAO ansatz. Ab initio methods need to define a level of theory (the method) and a basis set.

The Hartree–Fock wave function is a single configuration or determinant. In some cases, particularly for bond breaking processes, this is quite inadequate, and several configurations need to be used. Here, the coefficients of the configurations and the coefficients of the basis functions are optimized together.

The total molecular energy can be evaluated as a function of the molecular geometry; in other words, the potential energy surface. Such a surface can be used for reaction dynamics. The stationary points of the surface lead to predictions of different isomers and the transition structures for conversion between isomers, but these can be determined without a full knowledge of the complete surface.

A particularly important objective, called computational thermochemistry, is to calculate thermochemical quantities such as the enthalpy of formation to chemical accuracy. Chemical accuracy is the accuracy required to make realistic chemical predictions and is generally considered to be 1 kcal/mol or 4 kJ/mol. To reach that accuracy in an economic way it is necessary to use a series of post-Hartree–Fock methods and combine the results. These methods are called quantum chemistry composite methods.

Density functional methods[edit]

Main article: Density functional theory

Density functional theory (DFT) methods are often considered to be ab initio methods for determining the molecular electronic structure, even though many of the most common functionals use parameters derived from empirical data, or from more complex calculations. In DFT, the total energy is expressed in terms of the total one-electron density rather than the wave function. In this type of calculation, there is an approximate Hamiltonian and an approximate expression for the total electron density. DFT methods can be very accurate for little computational cost. Some methods combine the density functional exchange functional with the Hartree–Fock exchange term and are known as hybrid functional methods.

Semi-empirical and empirical methods[edit]

Main article: Semi-empirical quantum chemistry methods

Semi-empirical quantum chemistry methods are based on the Hartree–Fock formalism, but make many approximations and obtain some parameters from empirical data. They are very important in computational chemistry for treating large molecules where the full Hartree–Fock method without the approximations is too expensive. The use of empirical parameters appears to allow some inclusion of correlation effects into the methods.

Semi-empirical methods follow what are often called empirical methods, where the two-electron part of the Hamiltonian is not explicitly included. For π-electron systems, this was the Hückel method proposed by Erich Hückel, and for all valence electron systems, the extended Hückel method proposed by Roald Hoffmann.

Molecular mechanics[edit]

Main article: Molecular mechanics

In many cases, large molecular systems can be modeled successfully while avoiding quantum mechanical calculations entirely. Molecular mechanics simulations, for example, use a single classical expression for the energy of a compound, for instance the harmonic oscillator. All constants appearing in the equations must be obtained beforehand from experimental data or *ab initio* calculations.

The database of compounds used for parameterization, i.e., the resulting set of parameters and functions is called the force field, is crucial to the success of molecular mechanics calculations. A force field parameterized against a specific class of molecules, for instance proteins, would be expected to only have any relevance when describing other molecules of the same class.

These methods can be applied to proteins and other large biological molecules, and allow studies of the approach and interaction (docking) of potential drug molecules (e.g. [1] and [2]).

Methods for solids[edit]

Main article: Computational chemical methods in solid state physics

Computational chemical methods can be applied to solid state physics problems. The electronic structure of a crystal is in general described by a band structure, which defines the energies of electron orbitals for each point in the Brillouin zone. Ab initio and semi-empirical calculations yield orbital energies; therefore, they can be applied to band structure calculations. Since it is time-consuming to calculate the energy for a molecule, it is even more time-consuming to calculate them for the entire list of points in the Brillouin zone.

Chemical dynamics[edit]

Once the electronic and nuclear variables are separated (within the Born–Oppenheimer representation), in the time-dependent approach, the wave packet corresponding to the nuclear degrees of freedom is propagated via the time evolution operator (physics) associated to the time-dependent Schrödinger equation (for the full molecular Hamiltonian). In the complementary energy-dependent approach, the time-independent Schrödinger equation is solved using the scattering theory formalism. The potential representing the interatomic interaction is given by the potential energy surfaces. In general, the potential energy surfaces are coupled via the vibronic coupling terms.

The most popular methods for propagating the wave packet associated to the molecular geometry are:

•the split operator technique,

•the Chebyshev (real) polynomial,

•the multi-configuration time-dependent Hartree method (MCTDH),

•the semiclassical method.

Molecular dynamics[edit]

Main article: Molecular dynamics

Molecular dynamics (MD) use either quantum mechanics, Newton's laws of motion or a mixed model to examine the time-dependent behavior of systems, including vibrations or Brownian motion and reactions. MD combined with density functional theory leads to hybrid models.

Interpreting Molecular Wave Functions:

The Atoms in molecules or QTAIM model of Richard Bader was developed in order to effectively link the quantum mechanical picture of a molecule, as an electronic wavefunction, to chemically useful concepts such as atoms in molecules, functional groups, bonding, the theory of Lewis pairs and the valence bond model. Bader has demonstrated that these empirically useful chemistry concepts can be related to the topology of the observable charge density distribution, whether measured or calculated from a quantum mechanical wavefunction. QTAIM analysis of molecular wavefunctions is implemented, for example, in the AIMAll software package.

Software Packages:

There are many self-sufficient software packages used by computational chemists. Some include many methods covering a wide range, while others concentrating on a very specific range or even a single method. Details of most of them can be found in:

•Biomolecular modelling programs: proteins, nucleic acid.

•Molecular mechanics programs.

•Quantum chemistry and solid state physics software supporting several methods.

•Molecular design software

•Semi-empirical programs.

•Valence bond programs.

Specialized Journals on Computational Chemistry:

•Reviews in Computational Chemistry

•Journal of Computational Chemistry

•Journal of Chemical Information and Modeling

•Journal of Computer-aided Molecular Design

•Journal of Chemical Information and Computer Sciences

•Journal of Chemical Theory and Computation

•Computational and Theoretical Polymer Science

•Theoretical and Computational Chemistry

•Journal of Theoretical and Computational Chemistry

•Journal of Cheminformatics

•Journal of Computer Chemistry Japan

•Annual Reports in Computational Chemistry

•Computers & Chemical Engineering

•Journal of Chemical Software

•Molecular Informatics

•Journal of Computer Aided Chemistry

Computer Science:

Summary:

Computer science or **computing science** (abbreviated **CS** or **CompSci**) is the scientific and practical approach to computation and its applications. A computer scientist specializes in the theory of computation and the design of computational systems.[1]

Its subfields can be divided into a variety of theoretical and practical disciplines. Some fields, such as computational complexity theory (which explores the fundamental properties of computational problems), are highly abstract, whilst fields such as computer graphics emphasize real-world visual applications. Still other fields focus on the challenges in implementing computation. For example, programming language theory considers various approaches to the description of computation, whilst the study of computer programming itself investigates various aspects of the use of programming language and complex systems. Human-computer interaction considers the challenges in making computers and computations useful, usable, and universally accessible to humans.

History:

Main article: History of computer science

Charles Babbage is credited with inventing the first mechanical computer.

Ada Lovelace is credited with writing the first algorithm intended for processing on a computer.

The earliest foundations of what would become computer science predate the invention of the modern digital computer. Machines for calculating fixed numerical tasks such as the abacus have existed since antiquity but they only supported the human mind, aiding in computations as complex as multiplication and division. Blaise Pascal designed and constructed the first working mechanical calculator, Pascal's calculator, in 1642. Two hundred years later, Thomas de Colmar launched the mechanical calculator industry[2] when he released his simplified arithmometer, which was the first calculating machine strong enough and reliable enough to be used daily in an office environment. Charles Babbage started the design of the first *automatic mechanical calculator*, his difference engine, in 1822, which eventually gave him the idea of the first *programmable mechanical calculator*, his Analytical Engine.[3] He started developing this machine in 1834 and "in less than

two years he had sketched out many of the salient features of the modern computer. A crucial step was the adoption of a punched card system derived from the Jacquard loom"[4] making it infinitely programmable.[5] In 1843, during the translation of a French article on the *analytical engine*, Ada Lovelace wrote, in one of the many notes she included, an algorithm to compute the Bernoulli numbers, which is considered to be the first computer program.[6] Around 1885, Herman Hollerith invented the tabulator which used punched cards to process statistical information; eventually his company became part of IBM. In 1937, one hundred years after Babbage's impossible dream, Howard Aiken convinced IBM, which was making all kinds of punched card equipment and was also in the calculator business[7] to develop his giant programmable calculator, the ASCC/Harvard Mark I, based on Babbage's *analytical engine*, which itself used cards and a central computing unit. When the machine was finished, some hailed it as "Babbage's dream come true".[8]
During the 1940s, as new and more powerful computing machines were developed, the term *computer* came to refer to the machines rather than their human predecessors.[9] As it became clear that computers could be used for more than just mathematical calculations, the field of computer science broadened to study computation in general. Computer science began to be established as a distinct academic discipline in the 1950s and early 1960s.[10][11] The world's first computer science degree program, the Cambridge Diploma in Computer Science, began at the University of Cambridge Computer Laboratory in 1953. The first computer science degree program in the United States was formed at Purdue University in 1962.[12] Since practical computers became available, many applications of computing have become distinct areas of study in their own right.

Although many initially believed it was impossible that computers themselves could actually be a scientific field of study, in the late fifties it gradually became accepted among the greater academic population.[13] It is the now well-known IBM brand that formed part of the computer science revolution during this time. IBM (short for International Business Machines) released the IBM 704[14] and later the IBM 709[15] computers, which were widely used during the exploration period of such devices. "Still, working with the IBM [computer] was frustrating...if you had misplaced as much as one letter in one instruction, the program would crash, and you would have to start the whole process over again".[13] During the late 1950s, the computer science discipline was very much in its developmental stages, and such issues were commonplace.

Time has seen significant improvements in the usability and effectiveness of computing technology. Modern society has seen a significant shift in the users of computer technology, from usage only by experts and professionals, to a near-ubiquitous user base. Initially, computers were quite costly, and some degree of human aid was needed for efficient use - in part from professional computer operators. As computer adoption became more widespread and affordable, less human assistance was needed for common usage.

Major achievements[edit]

The German military used the Enigma machine (shown here) during World War II for communication they thought to be secret. The large-scale decryption of Enigma traffic at Bletchley Park was an important factor that contributed to Allied victory in WWII.[16]

Despite its short history as a formal academic discipline, computer science has made a number of fundamental contributions to science and society - in fact, along with electronics, it is a founding science of the current epoch of human history called the Information Age and a driver of the Information Revolution, seen as the third major leap in human technological progress after the Industrial Revolution (1750-1850 CE) and the Agricultural Revolution (8000-5000 BCE).

These contributions include:

•The start of the "digital revolution," which includes the current Information Age and the Internet.[17]

•A formal definition of computation and computability, and proof that there are computationally unsolvable and intractable problems.[18]

•The concept of a programming language, a tool for the precise expression of methodological information at various levels of abstraction.[19]

•In cryptography, breaking the Enigma code was an important factor contributing to the Allied victory in World War II.[16]

•Scientific computing enabled practical evaluation of processes and situations of great complexity, as well as experimentation entirely by software. It also enabled advanced study of the mind, and mapping of the human genome became possible with the Human Genome Project.[17] Distributed computing projects such as Folding@home explore protein folding.

•Algorithmic trading has increased the efficiency and liquidity of financial markets by using artificial intelligence, machine learning, and other statistical and numerical techniques on a large scale.[20] High frequency algorithmic trading can also exacerbate volatility.[21]

•Computer graphics and computer-generated imagery have become almost ubiquitous in modern entertainment, particularly in television, cinema, advertising, animation and video games. Even films that feature no explicit CGI are usually "filmed" now on digital cameras, or edited or postprocessed using a digital video editor.[citation needed]

•Simulation of various processes, including computational fluid dynamics, physical, electrical, and electronic systems and circuits, as well as societies and social situations (notably war games) along with their habitats, among many others. Modern computers enable optimization of such designs as complete aircraft. Notable in electrical and electronic circuit design are SPICE, as well as software for physical realization of new (or modified) designs. The latter includes essential design software for integrated circuits.[citation needed]

•Artificial intelligence is becoming increasingly important as its getting smarter and more complex. There are many applications of the AI, some of which can be seen at homes, like the robotic vacuum cleaners and in video games or on the modern battlefield like drones, anti-missile systems and squad support robots.

Philosophy:

Main article: Philosophy of computer science

A number of computer scientists have argued for the distinction of three separate paradigms in computer science. Peter Wegner argued that those paradigms are science, technology, and mathematics.[22] Peter Denning's working group argued that they are theory, abstraction (modeling), and design.[23] Amnon H. Eden described them as the "rationalist paradigm" (which treats computer science as a branch of mathematics, which is prevalent in theoretical computer science, and mainly employs deductive reasoning), the "technocratic paradigm" (which might be found in engineering approaches, most prominently in software engineering), and the "scientific paradigm" (which approaches computer-related artifacts from the empirical perspective of natural sciences, identifiable in some branches of artificial intelligence).[24]

Name of the field[edit]

The term "computer science" appears in a 1959 article in Communications of the ACM,[25] in which Louis Fein argues for the creation of a *Graduate School in Computer Sciences* analogous to the creation of Harvard Business School in 1921, justifying the name by arguing that, like management science, it is applied and interdisciplinary in nature, yet at the same time, has all the characteristics of an academic discipline.[26] His efforts, and those of others such as numerical analyst George Forsythe, were rewarded: universities went on to create such programs, starting with Purdue in 1962.[27] Despite its name, a significant amount of computer science does not involve the study of computers themselves. Because of this, several alternative names have been proposed.[28] Certain departments of major universities prefer the term *computing science*, to emphasize precisely that difference. Danish scientist Peter Naur suggested the term *datalogy*,[29] to reflect the fact that the scientific discipline revolves around data and data treatment, while not necessarily involving computers. The first scientific institution to use the term was the Department of Datalogy at the University of Copenhagen, founded in 1969, with Peter Naur being the first professor in datalogy. The term is used mainly in the Scandinavian countries. Also, in the early days of computing, a number of terms for the practitioners of the field of computing were suggested in the *Communications of the ACM* – *turingineer*, *turologist*, *flow-charts-man*, *applied meta-mathematician*, and *applied* epistemologist.[30] Three months later in the same journal, *comptologist* was suggested, followed next year by *hypologist*.[31] The term *computics* has also been suggested.[32] In Europe, terms derived from contracted translations of the expression "automatic information" (e.g. "informazione automatica" in Italian) or "information and mathematics" are often used, e.g. *informatique* (French), *Informatik* (German), *informatica* (Italy), *informática* (Spain, Portugal) or *informatika* (Slavic languages) are also used and have also been adopted in the UK (as in *the School of Informatics of the University of Edinburgh*).[33]

A folkloric quotation, often attributed to—but almost certainly not first formulated by—Edsger Dijkstra, states that "computer science is no more about computers than astronomy is about telescopes."[note 1] The design and deployment of computers and computer systems is generally considered the province of disciplines other than computer science. For example, the study of computer hardware is usually considered part of computer engineering, while the study of commercial computer systems and their deployment is often called information technology or information systems. However, there has been much cross-fertilization of ideas between the various computer-related disciplines. Computer science research also often intersects other disciplines, such as philosophy, cognitive science, linguistics, mathematics, physics, statistics, and logic. Computer science is considered by some to have a much closer relationship with mathematics than many scientific disciplines, with some observers saying that computing is a mathematical science.[10] Early computer science was strongly influenced by the work of mathematicians such as Kurt Gödel and Alan Turing, and there continues to be a useful interchange of ideas between the two fields in areas such as mathematical logic, category theory, domain theory, and algebra.

The relationship between computer science and software engineering is a contentious issue, which is further muddied by disputes over what the term "software engineering" means, and how computer science is defined.[34] David Parnas, taking a cue from the relationship between other engineering and science disciplines, has claimed that the principal focus of computer science is studying the properties of computation in general, while the principal focus of software engineering is the design of specific computations to achieve practical goals, making the two separate but complementary disciplines.[35]

The academic, political, and funding aspects of computer science tend to depend on whether a department formed with a mathematical emphasis or with an engineering emphasis. Computer science departments with a mathematics emphasis and with a numerical orientation consider alignment with computational science. Both types of departments tend to make efforts to bridge the field educationally if not across all research.

Areas of Computer Science:

Summary:

As a discipline, computer science spans a range of topics from theoretical studies of algorithms and the limits of computation to the practical issues of implementing computing systems in hardware and software.[36][37] CSAB, formerly called *Computing Sciences Accreditation Board* – which is made up of representatives of the Association for Computing Machinery (ACM), and the IEEE Computer Society (IEEE-CS)[38] – identifies four areas that it considers crucial to the discipline of computer science: *theory of computation*, *algorithms and data structures*, *programming methodology and languages*, and *computer elements and architecture*. In addition to these four areas, CSAB also identifies fields such as software engineering, artificial intelligence, computer networking and communication, database systems, parallel computation, distributed computation, computer-human interaction, computer graphics, operating systems, and numerical and symbolic computation as being important areas of computer science.[36]

Theoretical Computer Science:

Main article: Theoretical computer science

The broader field of theoretical computer science encompasses both the classical theory of computation and a wide range of other topics that focus on the more abstract, logical, and mathematical aspects of computing.

Theory of Computation:

Main article: Theory of computation

According to Peter J. Denning, the fundamental question underlying computer science is, "*What can be (efficiently) automated?*"[10] The study of the theory of computation is focused on answering fundamental questions about what can be computed and what amount of resources are required to perform those computations. In an effort to answer the first question, computability theory examines which computational problems are solvable on various theoretical models of computation. The second question is addressed by computational complexity theory, which studies the time and space costs associated with different approaches to solving a multitude of computational problems.

The famous "P=NP?" problem, one of the Millennium Prize Problems,[39] is an open problem in the theory of computation.

Automata theoryComputability theoryComputational complexity theoryCryptographyQuantum computing theory

Information Theory:

Main articles: Information theory *and* Coding theory

Information theory is related to the quantification of information. This was developed by Claude E. Shannon to find fundamental limits on signal processing operations such as compressing data and on reliably storing and communicating data. Coding theory is the study of the properties of codes (systems for converting information from one form to another) and their fitness for a specific application. Codes are used for data compression, cryptography, error detection and correction, and more recently also for network coding. Codes are studied for the purpose of designing efficient and reliable data transmission methods.

Algorithms and Data Structures:

Analysis of algorithms

Algorithms

Data structures

Computational geometry

Programming Language Theory:

Main article: Programming language theory

Programming language theory (PLT) is a branch of computer science that deals with the design, implementation, analysis, characterization, and classification of programming languages and their individual features. It falls within the discipline of computer science, both depending on and affecting mathematics, software engineering and linguistics. It is an active research area, with numerous dedicated academic journals.

Type theoryCompiler designProgramming languages

Formal Methods:

Main article: Formal methods

Formal methods are a particular kind of mathematically based technique for the specification, development and verification of software and hardware systems. The use of formal methods for software and hardware design is motivated by the expectation that, as in other engineering disciplines, performing appropriate mathematical analysis can contribute to the reliability and robustness of a design. They form an important theoretical underpinning for software engineering, especially where safety or security is involved. Formal methods are a useful adjunct to software testing since they help avoid errors and can also give a framework for testing. For industrial use, tool support is required. However, the high cost of using formal methods means that they are usually only used in the development of high-integrity and life-critical systems, where safety or security is of utmost importance. Formal methods are best described as the application of a fairly broad variety of theoretical computer science fundamentals, in particular logic calculi, formal languages, automata theory, and program semantics, but also type systems and algebraic data types to problems in software and hardware specification and verification.

Applied Computer Science:

Artificial Intelligence:

Main article: Artificial intelligence

This branch of computer science aims to or is required to synthesise goal-orientated processes such as problem-solving, decision-making, environmental adaptation, learning and communication which are found in humans and animals. From its origins in cybernetics and in the Dartmouth Conference (1956), artificial intelligence (AI) research has been necessarily cross-disciplinary, drawing on areas of expertise such as applied mathematics, symbolic logic, semiotics, electrical engineering, philosophy of mind, neurophysiology, and social intelligence. AI is associated in the popular mind with robotic development, but the main field of practical application has been as an embedded component in areas of software development which require computational understanding and modeling such as finance and economics, data mining and the physical sciences. The starting-point in the late 1940s was Alan Turing's question "Can computers think?", and the question remains effectively unanswered although the "Turing Test" is still used to assess computer output on the scale of human intelligence. But the automation of evaluative and predictive tasks has been increasingly successful as a substitute for human monitoring and intervention in domains of computer application involving complex real-world data.Machine learningComputer visionImage processingPattern recognitionCognitive scienceData miningEvolutionary computationInformation retrievalKnowledge representationNatural language processingRoboticsMedical Image Computing

Computer Architecture and Engineering:

Main articles: Computer architecture *and* Computer engineering

Computer architecture, or digital computer organization, is the conceptual design and fundamental operational structure of a computer system. It focuses largely on the way by which the central processing unit performs internally and accesses addresses in memory. The field often involves disciplines of computer engineering and electrical engineering, selecting and interconnecting hardware components to create computers that meet functional, performance, and cost goals.Digital logicMicroarchitectureMultiprocessingOperating systemsComputer networksDatabasesInformation securityUbiquitous computingSystems architectureCompiler designProgramming languages

Computer Graphics and Visualization:

Main article: Computer graphics (computer science)

Computer graphics is the study of digital visual contents, and involves synthese and manipulations of image data. The study is connected to many other fields in computer science, including computer vision, image processing, and computational geometry, and is heavily applied in the fields of special effects and video games.

Computer Security and Cryptography:

Main articles: Computer security *and* Cryptography

Computer security is a branch of computer technology, whose objective includes protection of information from unauthorized access, disruption, or modification while maintaining the accessibility and usability of the system for its intended users. Cryptography is the practice and study of hiding (encryption) and therefore deciphering (decryption) information. Modern cryptography is largely related to computer science, for many encryption and decryption algorithms are based on their computational complexity.

Computational Science:

Computational science (or scientific computing) is the field of study concerned with constructing mathematical models and quantitative analysis techniques and using computers to analyze and solve scientific problems. In practical use, it is typically the application of computer simulation and other forms of computation to problems in various scientific disciplines.Numerical analysisComputational physicsComputational chemistryBioinformatics

Computer Networks:

Main article: Computer Network

This branch of computer science aims to manage networks between computers worldwide.

Concurrent, Parallel and Distributed Systems:

Main articles: Concurrency (computer science) *and* Distributed computing

Concurrency is a property of systems in which several computations are executing simultaneously, and potentially interacting with each other. A number of mathematical models have been developed for general concurrent computation including Petri nets, process calculi and the Parallel Random Access Machine model. A distributed system extends the idea of concurrency onto multiple computers connected through a network. Computers within the same distributed system have their own private memory, and information is often exchanged amongst themselves to achieve a common goal.

Databases and Information Retrieval:

Main articles: Database *and* Database management systems

A database is intended to organize, store, and retrieve large amounts of data easily. Digital databases are managed using database management systems to store, create, maintain, and search data, through database models and query languages.

Health Informatics:

Main article: Health Informatics

Health Informatics in computer science deals with computational techniques for solving problems in health care.

Information Science:

Main article: Information scienceInformation retrievalKnowledge representationNatural language processingHuman–computer interaction

Software Engineering:

Main article: Software engineering

Software engineering is the study of designing, implementing, and modifying software in order to ensure it is of high quality, affordable, maintainable, and fast to build. It is a systematic approach to software design, involving the application of engineering practices to software. Software engineering deals with the organizing and analyzing of software— it doesn't just deal with the creation or manufacture of new software, but its internal maintenance and arrangement. Both computer applications software engineers and computer systems software engineers are projected to be among the fastest growing occupations from 2008 and 2018.

Academia:

Conferences[edit]

Conferences are strategic events of the Academic Research in computer science. During those conferences, researchers from the public and private sectors present their recent work and meet. Proceedings of these conferences are an important part of the computer science literature.

Further information: List of computer science conferences

Journals[edit]

Further information: Category:Computer science journals

Construction: [Constructing]

Summary:

For other uses, see Construction (disambiguation).

In large construction projects, such as this skyscraper in Melbourne, cranes are essential.

In the fields of architecture and civil engineering, **construction** is a process that consists of the building or assembling of infrastructure. Far from being a single activity, large scale construction is a feat of human multitasking. Normally, the job is managed by a project manager, and supervised by a construction manager, design engineer, construction engineer or project architect.

For the successful execution of a project, effective planning is essential. Involved with the design and execution of the infrastructure in question must consider the environmental impact of the job, the successful scheduling, budgeting, construction site safety, availability of building materials, logistics, inconvenience to the public caused by construction delays and bidding, etc.

Data Collection:

Summary:

Data collection usually takes place early on in an improvement project, and is often formalised through a data collection plan[1] which often contains the following activity.

1.Pre collection activity — agree on goals, target data, definitions, methods

2.Collection — data collections

3.Present Findings — usually involves some form of sorting[2] analysis and/or presentation.

Prior to any data collection, pre-collection activity is one of the most crucial steps in the process. It is often discovered too late that the value of their interview information is discounted as a consequence of poor sampling of both questions and informants and poor elicitation techniques.[3] After pre-collection activity is fully completed, data collection in the field, whether by interviewing or other methods, can be carried out in a structured, systematic and scientific way.

A formal data collection process is necessary as it ensures that data gathered are both defined and accurate and that subsequent decisions based on arguments embodied in the findings are valid.[4] The process provides both a baseline from which to measure and in certain cases a target on what to improve.
Other main types of collection include census, sample survey, and administrative by-product and each with their respective advantages and disadvantages. A census refers to data collection about everyone or everything in a group or statistical population and has advantages, such as accuracy and detail and disadvantages, such as cost and time. A sampling is a data collection method that includes only part of the total population and has advantages, such as cost and time and disadvantages, such as accuracy and detail. Administrative by-product data are collected as a byproduct of an organization's day-to-day operations and has advantages, such as accuracy, time simplicity and disadvantages, such as no flexibility and lack of control.[5]

Other:

•Scientific data archiving

•Data management

•Experiment

•Observational study

•Sampling (statistics)

•Statistical survey

•Survey data collection

Types:

Designing studies

•Effect size Standard error Statistical power Sample size determination

Survey methodology

•Sampling Stratified sampling Opinion poll Questionnaire

Controlled experiment

•Design of experiments Randomized experiment Random assignment Replication Blocking Factorial experiment Optimal design

Uncontrolled studies

•Natural experiment Quasi-experiment Observational study

User Studies:

Survey methodology:

Observational study

Quantification

Sampling (statistics)

Usability Testing:

Documentation:

Evidence:

Summary:

Evidence, broadly construed, is anything presented in support of an assertion. This support may be strong or weak. The strongest type of evidence is that which provides direct proof of the truth of an assertion. At the other extreme is evidence that is merely consistent with an assertion but does not rule out other, contradictory assertions, as in circumstantial evidence.

In law, rules of evidence govern the types of evidence that are admissible in a legal proceeding, as well as the quality and quantity of evidence that are necessary to fulfill the legal burden of proof. Types of legal evidence include testimony, documentary evidence, and physical evidence.Scientific evidence consists of observations and experimental results that serve to support, refute, or modify a scientific hypothesis or theory, when collected and interpreted in accordance with the scientific method.

In philosophy, the study of evidence is closely tied to epistomology, which considers the nature of knowledge and how it can be acquired.

Types of Evidence:

•Anecdotal evidence

•Intuition

•Personal experience

•Scientific evidence

•Testimonial

In Science:

Main article: Scientific evidence

In scientific research evidence is accumulated through observations of phenomena that occur in the natural world, or which are created as experiments in a laboratory or other controlled conditions. Scientific evidence usually goes towards supporting or rejecting a hypothesis.

One must always remember that the burden of proof is on the person making a contentious claim. Within science, this translates to the burden resting on presenters of a paper, in which the presenters argue for their specific findings. This paper is placed before a panel of judges where the presenter must defend the thesis against all challenges.

When evidence is contradictory to predicted expectations, the evidence and the ways of making it are often closely scrutinized (see experimenter's regress) and only at the end of this process is the hypothesis rejected: this can be referred to as 'refutation of the hypothesis'. The rules for evidence used by science are collected systematically in an attempt to avoid the bias inherent to anecdotal evidence.

Additional Research:

•Argument

•Belief

•Empiricism

•Falsifiability

•Logical positivism

•Mathematical proof

•Proof (truth)

•Reason

•Skepticism

•Theory of justification

•Validity

Additional Reference:

Ecology:

Summary:

Additional Reference:

Effects:

Additional Resource:

Electronic Music:

Summary:

Electronic music is music that employs electronic musical instruments and electronic music technology in its production. In general a distinction can be made between sound produced using electromechanical means and that produced using electronic technology.[1] Examples of electromechanical sound producing devices include the telharmonium, Hammond organ, and the electric guitar. Purely electronic sound production can be achieved using devices such as the Theremin, sound synthesizer, and computer.[2]

Electronic music was once associated almost exclusively with Western art music but from the late 1960s on the availability of affordable music technology meant that music produced using electronic means became increasingly common in the popular domain.[3] Today electronic music includes many varieties and ranges from experimental art music to popular forms such as electronic dance music.

Engineering: (further research is required)

Summary:

Engineering is the application of scientific, economic, social, and practical knowledge in order to design, build, and maintain structures, machines, devices, systems, materials and processes. It may encompass using insights to conceive, model and scale an appropriate solution to a problem or objective. The discipline of engineering is extremely broad, and encompasses a range of more specialized fields of engineering, each with a more specific emphasis on particular areas of technology and types of application.

The American Engineers' Council for Professional Development (ECPD, the predecessor of ABET)[1] has defined "engineering" as:

The creative application of scientific principles to design or develop structures, machines, apparatus, or manufacturing processes, or works utilizing them singly or in combination; or to construct or operate the same with full cognizance of their design; or to forecast their behavior under specific operating conditions; all as respects an intended function, economics of operation or safety to life and property.[2][3]

One who practices engineering is called an engineer, and those licensed to do so may have more formal designations such as Professional Engineer, FAA Designated Engineering Representative, Chartered Engineer, Incorporated Engineer, Ingenieur or European Engineer.

Evolution:

Summary:

Evolution is the change in the inherited characteristics of biological populations over successive generations. Evolutionary processes give rise to diversity at every level of biological organisation, including species, individual organisms and molecules such as DNA and proteins.[1]

All life on earth is descended from a last universal ancestor that lived approximately 3.8 billion years ago. Repeated speciation and the divergence of life can be inferred from shared sets of biochemical and morphological traits, or by shared DNA sequences.[2] These homologous traits and sequences are more similar among species that share a more recent common ancestor, and can be used to reconstruct evolutionary histories, using both existing species and the fossil record. Existing patterns of biodiversity have been shaped both by speciation and by extinction.[3]Charles Darwin was the first to formulate a scientific argument for the theory of evolution by means of natural selection. Evolution by natural selection is a process that is inferred from three facts about populations: 1) more offspring are produced than can possibly survive, 2) traits vary among individuals, leading to different rates of survival and reproduction, and 3) trait differences are heritable.[4] Thus, when members of a population die they are replaced by the progeny of parents that were better adapted to survive and reproduce in the environment in which natural selection took place. This process creates and preserves traits that are seemingly fitted for the functional roles they perform.[5] Natural selection is the only known cause of adaptation, but not the only known cause of evolution. Other, nonadaptive causes of evolution include mutation and genetic drift.[6]

In the early 20th century, genetics was integrated with Darwin's theory of evolution by natural selection through the discipline of population genetics. The importance of natural selection as a cause of evolution was accepted into other branches of biology. Moreover, previously held notions about evolution, such as orthogenesis and "progress" became obsolete.[7] Scientists continue to study various aspects of evolution by forming and testing hypotheses, constructing scientific theories, using observational data, and performing experiments in both the field and the laboratory. Biologists agree that descent with modification is one of the most reliably established facts in science.[8] Discoveries in evolutionary biology have made a significant impact not just within the traditional branches of biology, but also in other academic disciplines (e.g., anthropology and psychology) and on society at large.[9][10] *For a generally accessible and less technical introduction to the topic, see* Introduction to evolution*.*

Introduction:

Evolution is the process of change in all forms of life over generations, and evolutionary biology is the study of how evolution occurs. Life evolves by means of mutations (changes in an organism's hereditary information), genetic drift (random change in the genetic variation of a population from generation to generation), and natural selection (the non-random and gradual process of natural variation by which observable traits (such as eye color) become more or less common in a population).

All individuals have hereditary material in the form of genes that are received from their parents, then passed on to their offspring. Among offspring there are variations of genes due to the introduction of new genes via random changes called mutations or via reshuffling of existing genes during sexual reproduction.[1][2] The offspring differs from the parent in minor random ways. If those differences are helpful, the offspring is more likely to survive and reproduce. This means that more offspring in the next generation will have that helpful difference and individuals will not have equal chances of reproductive success. In this way, traits that result in organisms being better adapted to their living conditions become more common in descendant populations.[1][2] These differences accumulate resulting in changes within the population. This process is responsible for the many diverse life forms in the world.

The forces of evolution are most evident when populations become isolated, either through geographic distance or by other mechanisms that prevent genetic exchange. Over time, isolated populations can branch off into new species.[3][4]

The majority of genetic mutations neither assist, change the appearance of, nor bring harm to individuals. Through the process of genetic drift, these mutated genes are neutrally sorted among populations and survive across generations by chance alone. In contrast to genetic drift, natural selection is not a random process because it acts on traits that are necessary for survival.[5] Natural selection and random genetic drift are constant and dynamic parts of life and over time this has shaped the branching structure in the tree of life.[6]

The modern understanding of evolution began with the 1859 publication of Charles Darwin's On the Origin of Species. In addition, Gregor Mendel's work with plants helped to explain the hereditary patterns of genetics.[7] Fossil discoveries in paleontology, advances in population genetics and a global network of scientific research have provided further details into the mechanisms of evolution. Scientists now have a good understanding of the origin of new species (speciation) and have observed the speciation process in the laboratory and in the wild. Evolution is the principal theory that biologists use to understand life and is used in many disciplines, including medicine, psychology, conservation biology, anthropology, forensics, agriculture and other social-cultural applications.

Evolutionary Developmental Biology:

Summary:

(Redirected from Evodevo)

Evolutionary developmental biology (**evolution of development** or informally, **evo-devo**) is a field of biology that compares the developmental processes of different organisms to determine the ancestral relationship between them, and to discover how developmental processes evolved. It addresses the origin and evolution of embryonic development; how modifications of development and developmental processes lead to the production of novel features, such as the evolution of feathers;[1] the role of developmental plasticity in evolution; how ecology impacts development and evolutionary change; and the developmental basis of homoplasy and homology.[2]

Although interest in the relationship between ontogeny and phylogeny extends back to the nineteenth century, the contemporary field of evo-devo has gained impetus from the discovery of genes regulating embryonic development in model organisms. General hypotheses remain hard to test because organisms differ so much in shape and form.[3]

Nevertheless, it now appears that just as evolution tends to create new genes from parts of old genes (molecular economy), evo-devo demonstrates that evolution alters developmental processes to create new and novel structures from the old gene networks (such as bone structures of the jaw deviating to the ossicles of the middle ear) or will conserve (molecular economy) a similar program in a host of organisms such as eye development genes in molluscs, insects, and vertebrates.[4] [5] Initially the major interest has been in the evidence of homology in the cellular and molecular mechanisms that regulate body plan and organ development. However subsequent approaches include developmental

Basic principles:

Charles Darwin's theory of evolution is based on three principles: natural selection, heredity, and variation. At the time that Darwin wrote, the principles underlying heredity and variation were poorly understood. In the 1940s, however, biologists incorporated Gregor Mendel's principles of genetics to explain both, resulting in the modern synthesis. It was not until the 1980s and 1990s, however, when more comparative molecular sequence data between different kinds of organisms was amassed and detailed, that an understanding of the molecular basis of the developmental mechanisms has arisen.

Currently, it is well understood how genetic mutation occurs. However, developmental mechanisms are not understood sufficiently to explain which kinds of phenotypic variation can arise in each generation from variation at the genetic level. Evolutionary developmental biology studies how the dynamics of development determine the phenotypic variation arising from genetic variation and how that affects phenotypic evolution (especially its direction). At the same time evolutionary developmental biology also studies how development itself evolves.

Thus, the origins of evolutionary developmental biology come from both an improvement in molecular biology techniques as applied to development, and the full appreciation of the limitations of classic neo-Darwinism as applied to phenotypic evolution. Some evo-devo researchers see themselves as extending and enhancing the modern synthesis by incorporating into it findings of molecular genetics and developmental biology. Others, drawing on findings of discordances between genotype and phenotype and epigenetic mechanisms of development, are mounting an explicit challenge to neo-Darwinism.[citation needed]

Evolutionary developmental biology is not yet a unified discipline, but can be distinguished from earlier approaches to evolutionary theory by its focus on a few crucial ideas. One of these is modularity: as has been long recognized, plants and animal bodies are modular: they are organized into developmentally and anatomically distinct parts. Often these parts are repeated, such as fingers, ribs, and body segments. Evo-devo seeks the genetic and evolutionary basis for the division of the embryo into distinct modules, and for the partly independent development of such modules.

Another central idea is that some gene products function as switches whereas others act as diffusible signals. Genes specify proteins, some of which act as structural components of cells and others as enzymes that regulate various biochemical pathways within an organism. Most biologists working within the modern synthesis assumed that an organism is a straightforward reflection of its component genes. The modification of existing, or evolution of new, biochemical pathways (and, ultimately, the evolution of new species of organisms) depended on specific genetic mutations. In 1961, however, Jacques Monod, Jean-Pierre Changeux and François Jacob discovered within the bacterium Escherichia coli a gene that functioned only when "switched on" by an environmental stimulus.[7] Later, scientists discovered specific genes in animals, including a subgroup of the genes which contain the homeobox DNA motif, called Hox genes, that act as switches for other genes, and could be induced by other gene products, morphogens, that act analogously to the external stimuli in bacteria. These discoveries drew biologists' attention to the fact that genes can be selectively turned on and off, rather than being always active, and that highly disparate organisms (for example, fruit flies and human beings) may use the same genes for embryogenesis (e.g., the genes of the "developmental-genetic toolkit", see below), just regulating them differently.

Similarly, organismal form can be influenced by mutations in promoter regions of genes, those DNA sequences at which the products of some genes bind to and control the activity of the same or other genes, not only protein-specifying sequences. This finding suggested that the crucial distinction between different species (even different orders or phyla) may be due less to differences in their content of gene products than to differences in spatial and temporal *expression* of conserved genes. The implication that large evolutionary changes in body morphology are associated with changes in gene regulation, rather than the evolution of new genes, suggested that Hox and other "switch" genes may play a major role in evolution, something that contradicts the neo-darwinian synthesis.

Another focus of evo-devo is developmental plasticity, the basis of the recognition that organismal phenotypes are not uniquely determined by their genotypes. If generation of phenotypes is conditional, and dependent on external or environmental inputs, evolution can proceed by a "phenotype-first" route,[3][8] with genetic change following, rather than initiating, the formation of morphological and other phenotypic novelties.[clarification needed] The case for this was argued for by Mary Jane West-Eberhard in her 2003 book *Developmental plasticity and evolution*.[8]

History:

An early version of recapitulation theory, also called the *biogenetic law* or *embryological parallelism*, was put forward by Étienne Serres in 1824–26 as what became known as the "Meckel-Serres Law" which attempted to provide a link between comparative embryology and a "pattern of unification" in the organic world. It was supported by Étienne Geoffroy Saint-Hilaire as part of his ideas of idealism, and became a prominent part of his version of Lamarckism leading to disagreements with Georges Cuvier. It was widely supported in the Edinburgh and London schools of higher anatomy around 1830, notably by Robert Edmond Grant, but was opposed by Karl Ernst von Baer's embryology of divergence in which embryonic parallels only applied to early stages where the embryo took a general form, after which more specialised forms diverged from this shared unity in a branching pattern. The anatomist Richard Owen used this to support his idealist concept of species as showing the unrolling of a divine plan from an archetype, and in the 1830s attacked the transmutation of species proposed by Lamarck, Geoffroy and Grant.[9] In the 1850s Owen began to support an evolutionary view that the history of life was the gradual unfolding of a teleological divine plan,[10] in a continuous "ordained becoming", with new species appearing by natural birth.[11]

In On the Origin of Species (1859), Charles Darwin proposed evolution through natural selection, a theory central to modern biology. Darwin recognised the importance of embryonic development in the understanding of evolution, and the way in which von Baer's branching pattern matched his own idea of descent with modification[12]:

“

We can see why characters derived from the embryo should be of equal importance with those derived from the adult, for a natural classification of course includes all ages.[13]

”Ernst Haeckel (1866), in his endeavour to produce a synthesis of Darwin's theory with Lamarckism and Naturphilosophie, proposed that "ontogeny recapitulates phylogeny," that is, the development of the embryo of every species (ontogeny) fully repeats the evolutionary development of that species (phylogeny), in Geoffroy's linear model rather than Darwin's idea of branching evolution.[12] Haeckel's concept explained, for example, why humans, and indeed all vertebrates, have gill slits and tails early in embryonic development. His theory has since been discredited. However, it served as a backdrop for a renewed interest in the evolution of development after the modern evolutionary synthesis was established (roughly 1936 to 1947).Stephen Jay Gould called this approach to explaining evolution as *terminal addition*; as if every evolutionary advance was added as new stage by reducing the duration of the older stages. The idea was based on observations of neoteny.[14] This was extended by the more general idea of heterochrony (changes in timing of development) as a mechanism for evolutionary change.[15]D'Arcy Thompson postulated that differential growth rates could produce variations in form in his 1917 book *On Growth and Form*. He showed the underlying similarities in *body plans* and how geometric *transformations* could be used to explain the variations.Edward B. Lewis discovered homeotic genes, rooting the emerging discipline of evo-devo in molecular genetics. In 2000, a special section of the Proceedings of the National Academy of Sciences (PNAS) was devoted to "evo-devo",[16] and an entire 2005 issue of the Journal of Experimental Zoology Part B: Molecular and Developmental Evolution was devoted to the key evo-devo topics of evolutionary innovation and morphological novelty.[17]John R. Horner began his project "How to Build a Dinosaur" in 2009 in conjunction with his published book of the same name. Using the principles and theories of evolutionary developmental biology, he took a chick embryo and attempted to change the development so it grew components similar to a dinosaur.[18] He successfully grew buds of teeth, and is currently continuing work on growing a tail, and changing the wings to claws. Horner used evolutionary developmental biology on a chick embryo because he knew he couldn't make an exact replica of a dinosaur since there is no more DNA so instead he just took the framework still in the chick's DNA that allowed it to evolve from a dinosaur.[19]

The developmental-genetic toolkit

The developmental-genetic toolkit consists of a small fraction of the genes in an organism's genome whose products control its development. These genes are highly conserved among Phyla. Differences in deployment of toolkit genes affect the body plan and the number, identity, and pattern of body parts. The majority of toolkit genes are components of signaling pathways, and encode for the production of transcription factors, cell adhesion proteins, cell surface receptor proteins, and secreted morphogens, all of these participate in defining the fate of undifferentiated cells, generating spatial and temporal patterns, which in turn form the body plan of the organism. Among the most important of the toolkit genes are those of the **Hox** gene cluster, or complex. Hox genes, transcription factors containing the more broadly distributed homeobox protein-binding DNA motif, function in patterning the body axis. Thus, by combinatorial specifying the identity of particular body regions, Hox genes determine where limbs and other body segments will grow in a developing embryo or larva. A paragon of a toolbox gene is *Pax6/eyeless*, which controls eye formation in all animals. It has been found to produce eyes in mice and Drosophila, even if mouse *Pax6/eyeless* was expressed in *Drosophila*.[20]

This means that a big part of the morphological evolution undergone by organisms is a product of variation in the genetic toolkit, either by the genes changing their expression pattern or acquiring new functions. A good example of the first is the enlargement of the beak in Darwin's Large Ground-finch (Geospiza magnirostris), in which the gene BMP is responsible for the larger beak of this bird, relative to the other finches.[21]

The loss of legs in snakes and other squamates is another good example of genes changing their expression pattern. In this case the gene Distal-less is very under-expressed, or not expressed at all, in the regions where limbs would form in other tetrapods.[22] This same gene determines the spot pattern in butterfly wings,[23] which shows that the toolbox genes can change their function.

Toolbox genes, as well as being highly conserved, also tend to evolve the same function convergently or in parallel. Classic examples of this are the already mentioned *Distal-less* gene, which is responsible for appendage formation in both tetrapods and insects, or, at a finer scale, the generation of wing patterns in the butterflies Heliconius erato and Heliconius melpomene. These butterflies are Müllerian mimics whose coloration pattern arose in different evolutionary events, but is controlled by the same genes.[24] The previous supports Kirschner and Gerhart's theory of Facilitated Variation, which states that morphological evolutionary novelty is generated by regulatory changes in various members of a large set of conserved mechanisms of development and physiology.[25]

Development and the origin of novelty:

Among the more surprising and, perhaps, counterintuitive (from a neo-Darwinian viewpoint) results of recent research in evolutionary developmental biology is that the diversity of body plans and morphology in organisms across many phyla are not necessarily reflected in diversity at the level of the sequences of genes, including those of the developmental genetic toolkit and other genes involved in development. Indeed, as Gerhart and Kirschner have noted, there is an apparent paradox: "where we most expect to find variation, we find conservation, a lack of change".[26]

Even within a species, the occurrence of novel forms within a population does not generally correlate with levels of genetic variation sufficient to account for all morphological diversity. For example, there is significant variation in limb morphologies amongst salamanders and in differences in segment number in centipedes, even when the respective genetic variation is low.

A major question then, for evo-devo studies, is: If the morphological novelty we observe at the level of different clades is not always reflected in the genome, where does it come from? Apart from neo-Darwinian mechanisms such as mutation, translocation and duplication of genes, novelty may also arise by mutation-driven changes in gene regulation. The finding that much biodiversity is not due to differences in genes, but rather to alterations in gene regulation, has introduced an important new element into evolutionary theory.[27][28] Diverse organisms may have highly conserved developmental genes, but highly divergent regulatory mechanisms for these genes. Changes in gene regulation are "second-order" effects of genes, resulting from the interaction and timing of activity of gene networks, as distinct from the functioning of the individual genes in the network.

The discovery of the homeotic Hox gene family in vertebrates in the 1980s allowed researchers in developmental biology to empirically assess the relative roles of gene duplication and gene regulation with respect to their importance in the evolution of morphological diversity. Several biologists, including Sean B. Carroll of the University of Wisconsin–Madison suggest that "changes in the cis-regulatory systems of genes" are more significant than "changes in gene number or protein function".[29] These researchers argue that the combinatorial nature of transcriptional regulation allows a rich substrate for morphological diversity, since variations in the level, pattern, or timing of gene expression may provide more variation for natural selection to act upon than changes in the gene product alone.Epigenetic alterations of gene regulation or phenotype generation that are subsequently consolidated by changes at the gene level constitute another class of mechanisms for evolutionary innovation. Epigenetic changes include modification of the genetic material due to methylation and other reversible chemical alteration,[30] as well as nonprogrammed remolding of the organism by physical and other environmental effects due to the inherent plasticity of developmental mechanisms.[8] The biologists Stuart A. Newman and Gerd B. Müller have suggested that organisms early in the history of multicellular life were more susceptible to this second category of epigenetic determination than are modern organisms, providing a basis for early macroevolutionary changes.[31]

Evolutionary Mechanisms: (see: evolution)

Fabrication: (further research is required)

Four-dimensional space (see: mathematics)

Geometric Language: (see: mathematics)

HCI (Human Computer Interaction): [participatory responses]

Summary:

Human–computer Interaction (**HCI**) involves the study, planning, and design of the interaction between people (users) and computers. It is often regarded as the intersection of computer science, behavioral sciences, design and several other fields of study. The term was popularized by Card, Moran, and Newell in their seminal 1983 book, "The Psychology of Human-Computer Interaction", although the authors first used the term in 1980,[1] and the first known use was in 1975.[2] The term connotes that, unlike other tools with only limited uses (such as a hammer, useful for driving nails, but not much else), a computer has many affordances for use and this takes place in an open-ended dialog between the user and the computer.
Because human–computer interaction studies a human and a machine in conjunction, it draws from supporting knowledge on both the machine and the human side. On the machine side, techniques in computer graphics, operating systems, programming languages, and development environments are relevant. On the human side, communication theory, graphic and industrial design disciplines, linguistics, social sciences, cognitive psychology, and human factors such as computer user satisfaction are relevant. Engineering and design methods are also relevant. Due to the multidisciplinary nature of HCI, people with different backgrounds contribute to its success. HCI is also sometimes referred to as **man–machine interaction** (**MMI**) or **computer–human interaction** (**CHI**).

Attention to human-machine interaction is important because poorly designed human-machine interfaces can lead to many unexpected problems. A classic example of this is the Three Mile Island accident, a nuclear meltdown accident, where investigations concluded that the design of the human–machine interface was at least partially responsible for the disaster.[3][4][5] Similarly, accidents in aviation have resulted from manufacturers' decisions to use non-standard flight instrument and/or throttle quadrant layouts: even though the new designs were proposed to be superior in regards to basic human–machine interaction, pilots had already ingrained the "standard" layout and thus the conceptually good idea actually had undesirable results.

Goals:

A basic goal of HCI is to improve the interactions between users and computers by making computers more usable and receptive to the user's needs. Specifically, HCI is concerned with:

•Methodologies and processes for designing interfaces (i.e., given a task and a class of users, design the best possible interface within given constraints, optimizing for a desired property such as learnability or efficiency of use)

•Methods for implementing interfaces (e.g. software toolkits and libraries; efficient algorithms)

•Techniques for evaluating and comparing interfaces

•Developing new interfaces and interaction techniques

•Developing descriptive and predictive models and theories of interaction

A long term goal of HCI is to design systems that minimize the barrier between the human's cognitive model of what they want to accomplish and the computer's understanding of the user's task.

Professional practitioners in HCI are usually designers concerned with the practical application of design methodologies to real-world problems. Their work often revolves around designing graphical user interfaces and web interfaces.

Researchers in HCI are interested in developing new design methodologies, experimenting with new hardware devices, prototyping new software systems, exploring new paradigms for interaction, and developing models and theories of interaction.

Differences in Related Fields:

HCI differs from human factors (or ergonomics) as HCI focuses more on users working specifically with computers, rather than other kinds of machines or designed artifacts. There is also a focus in HCI on how to implement the computer software and hardware mechanisms to support human–computer interaction. Thus, human factors is a broader term; HCI could be described as the human factors of computers – although some experts try to differentiate these areas.

HCI also differs from human factors in that there is less of a focus on repetitive work-oriented tasks and procedures, and much less emphasis on physical stress and the physical form or industrial design of the user interface, such as keyboards and mouse devices.

Three areas of study have substantial overlap with HCI even as the focus of inquiry shifts. In the study of personal information management (PIM), human interactions with the computer are placed in a larger informational context – people may work with many forms of information, some computer-based, many not (e.g., whiteboards, notebooks, sticky notes, refrigerator magnets) in order to understand and effect desired changes in their world. In computer-supported cooperative work (CSCW), emphasis is placed on the use of computing systems in support of the collaborative work of a group of people. The principles of human interaction management (HIM) extend the scope of CSCW to an organizational level and can be implemented without use of computer systems.

Design:

Principles:

When evaluating a current user interface, or designing a new user interface, it is important to keep in mind the following experimental design principles:

•Early focus on user(s) and task(s): Establish how many users are needed to perform the task(s) and determine who the appropriate users should be; someone who has never used the interface, and will not use the interface in the future, is most likely not a valid user. In addition, define the task(s) the users will be performing and how often the task(s) need to be performed.

•Empirical measurement: Test the interface early on with real users who come in contact with the interface on an everyday basis. Keep in mind that results may vary with the performance level of the user and may not be an accurate depiction of the typical human-computer interaction. Establish quantitative usability specifics such as: the number of users performing the task(s), the time to complete the task(s), and the number of errors made during the task(s).

•Iterative design: After determining the users, tasks, and empirical measurements to include, perform the following iterative design steps:

1.Design the user interface

2.Test

3.Analyze results

4.Repeat

Repeat the iterative design process until a sensible, user-friendly interface is created.[6]

Methodologies:

A number of diverse methodologies outlining techniques for human–computer interaction design have emerged since the rise of the field in the 1980s. Most design methodologies stem from a model for how users, designers, and technical systems interact. Early methodologies, for example, treated users' cognitive processes as predictable and quantifiable and encouraged design practitioners to look to cognitive science results in areas such as memory and attention when designing user interfaces. Modern models tend to focus on a constant feedback and conversation between users, designers, and engineers and push for technical systems to be wrapped around the types of experiences users want to have, rather than wrapping user experience around a completed system.

•Activity theory: used in HCI to define and study the context in which human interactions with computers take place. Activity theory provides a framework to reason about actions in these contexts, analytical tools with the format of checklists of items that researchers should consider, and informs design of interactions from an activity-centric perspective.[7]

•User-centered design: user-centered design (UCD) is a modern, widely practiced design philosophy rooted in the idea that users must take center-stage in the design of any computer system. Users, designers and technical practitioners work together to articulate the wants, needs and limitations of the user and create a system that addresses these elements. Often, user-centered design projects are informed by ethnographic studies of the environments in which users will be interacting with the system. This practice is similar but not identical to participatory design, which emphasizes the possibility for end-users to contribute actively through shared design sessions and workshops.

•Principles of user interface design: these are seven principles of user interface design that may be considered at any time during the design of a user interface in any order: tolerance, simplicity, visibility, affordance, consistency, structure and feedback.[8]

Heuristic Evaluation:

A **heuristic evaluation** is a usability inspection method for computer software that helps to identify usability problems in the user interface (UI) design. It specifically involves evaluators examining the interface and judging its compliance with recognized usability principles (the "heuristics"). These evaluation methods are now widely taught and practiced in the New Media sector, where UIs are often designed in a short space of time on a budget that may restrict the amount of money available to provide for other types of interface testing.

Introduction:

The main goal of heuristic evaluations is to identify any problems associated with the design of user interfaces. Usability consultant Jakob Nielsen developed this method on the basis of several years of experience in teaching and consulting about usability engineering.Heuristic evaluations are one of the most informal methods[1] of usability inspection in the field of human-computer interaction. There are many sets of usability design heuristics; they are not mutually exclusive and cover many of the same aspects of user interface design.

Quite often, usability problems that are discovered are categorized—often on a numeric scale—according to their estimated impact on user performance or acceptance. Often the heuristic evaluation is conducted in the context of use cases (typical user tasks), to provide feedback to the developers on the extent to which the interface is likely to be compatible with the intended users' needs and preferences.

The simplicity of heuristic evaluation is beneficial at the early stages of design. This usability inspection method does not require user testing which can be burdensome due to the need for users, a place to test them and a payment for their time. Heuristic evaluation requires only one expert, reducing the complexity and expended time for evaluation. Most heuristic evaluations can be accomplished in a matter of days. The time required varies with the size of the artifact, its complexity, the purpose of the review, the nature of the usability issues that arise in the review, and the competence of the reviewers. Using heuristic evaluation prior to user testing will reduce the number and severity of design errors discovered by users. Although heuristic evaluation can uncover many major usability issues in a short period of time, a criticism that is often leveled is that results are highly influenced by the knowledge of the expert reviewer(s). This "one-sided" review repeatedly has different results than software performance testing, each type of testing uncovering a different set of problems.

Nielsen's Heuristics:

Jakob Nielsen's heuristics are probably the most-used usability heuristics for user interface design. Nielsen developed the heuristics based on work together with Rolf Molich in 1990.[1][2] The final set of heuristics that are still used today were released by Nielsen in 1994.[3] The heuristics as published in Nielsen's book *Usability Engineering* are as follows[4]

Visibility of system status:

The system should always keep users informed about what is going on, through appropriate feedback within reasonable time.

Match between system and the real world:

The system should speak the user's language, with words, phrases and concepts familiar to the user, rather than system-oriented terms. Follow real-world conventions, making information appear in a natural and logical order.

User control and freedom:

Users often choose system functions by mistake and will need a clearly marked "emergency exit" to leave the unwanted state without having to go through an extended dialogue. Support undo and redo.

Consistency and standards:

Users should not have to wonder whether different words, situations, or actions mean the same thing. Follow platform conventions.

Error prevention:

Even better than good error messages is a careful design which prevents a problem from occurring in the first place. Either eliminate error-prone conditions or check for them and present users with a confirmation option before they commit to the action.

Recognition rather than recall:

Minimize the user's memory load by making objects, actions, and options visible. The user should not have to remember information from one part of the dialogue to another. Instructions for use of the system should be visible or easily retrievable whenever appropriate.

Flexibility and efficiency of use:

Accelerators—unseen by the novice user—may often speed up the interaction for the expert user such that the system can cater to both inexperienced and experienced users. Allow users to tailor frequent actions.

Aesthetic and minimalist design:

Dialogues should not contain information which is irrelevant or rarely needed. Every extra unit of information in a dialogue competes with the relevant units of information and diminishes their relative visibility.

Help users recognize, diagnose, and recover from errors:

Error messages should be expressed in plain language (no codes), precisely indicate the problem, and constructively suggest a solution.

Help and documentation:

Even though it is better if the system can be used without documentation, it may be necessary to provide help and documentation. Any such information should be easy to search, focused on the user's task, list concrete steps to be carried out, and not be too large.

Gerhardt-Powals' Cognitive Engineering Principles:

Although Nielsen is considered the expert and field leader in heuristics, Jill Gerhardt-Powals also developed a set of cognitive principles for enhancing computer performance.[5] These heuristics, or principles, are similar to Nielsen's heuristics but take a more holistic approach to evaluation. Gerhardt Powals' principles[6] are listed below.

•**Automate unwanted workload**:

•free cognitive resources for high-level tasks.

•eliminate mental calculations, estimations, comparisons, and unnecessary thinking.

•**Reduce uncertainty**:

•display data in a manner that is clear and obvious.

•**Fuse data**:

•reduce cognitive load by bringing together lower level data into a higher-level summation.

•**Present new information with meaningful aids to interpretation**:

•use a familiar framework, making it easier to absorb.

•use everyday terms, metaphors, etc.

•**Use names that are conceptually related to function**:

•Context-dependent.

•Attempt to improve recall and recognition.

•Group data in consistently meaningful ways to decrease search time.

•**Limit data-driven tasks**:

•Reduce the time spent assimilating raw data.

•Make appropriate use of color and graphics.

•**Include in the displays only that information needed by the user at a given time**.

•**Provide multiple coding of data when appropriate**.

•**Practice judicious redundancy**.

Weinschenk and Barker Classification :

Susan Weinschenk and Dean Barker created a categorization of heuristics and guidelines by several major providers into the following twenty types:[7]

1. User Control: heuristics that check whether the user has enough control of the interface.

2. Human Limitations: the design takes into account human limitations, cognitive and sensorial, to avoid overloading them.

3. Modal Integrity: the interface uses the most suitable modality for each task: auditory, visual, or motor/kinesthetic.

4. Accommodation: the design is adequate to fulfill the needs and behaviour of each targeted user group.

5. Linguistic Clarity: the language used to communicate is efficient and adequate to the audience.

6. Aesthetic Integrity: the design is visually attractive and tailored to appeal to the target population.

7. Simplicity: the design will not use unnecessary complexity.

8. Predictability: users will be able to form a mental model of how the system will behave in response to actions.

9. Interpretation: there are codified rules that try to guess the user intentions and anticipate the actions needed.

10. Accuracy: There are no errors, i.e. the result of user actions correspond to their goals.

11. Technical Clarity: the concepts represented in the interface have the highest possible correspondence to the domain they are modeling.

12. Flexibility: the design can be adjusted to the needs and behaviour of each particular user.

13. Fulfillment: the user experience is adequate.

14. Cultural Propriety: user's cultural and social expectations are met.

15. Suitable Tempo: the pace at which users works with the system is adequate.

16. Consistency: different parts of the system have the same style, so that there are no different ways to represent the same information or behavior.

17. User Support: the design will support learning and provide the required assistance to usage.

18. Precision: the steps and results of a task will be what the user wants.

19. Forgiveness: the user will be able to recover to an adequate state after an error.

20.Responsiveness: the interface provides enough feedback information about the system status and the task completion.

Display Designs:

Displays are human-made artifacts designed to support the perception of relevant system variables and to facilitate further processing of that information. Before a display is designed, the task that the display is intended to support must be defined (e.g. navigating, controlling, decision making, learning, entertaining, etc.). A user or operator must be able to process whatever information that a system generates and displays;

therefore, the information must be displayed according to principles in a manner that will support perception, situation awareness, and understanding.

Thirteen Principles of Display Design:

Christopher Wickens et al. defined 13 principles of display design in their book *An Introduction to Human Factors Engineering*.[9]

These principles of human perception and information processing can be utilized to create an effective display design. A reduction in errors, a reduction in required training time, an increase in efficiency, and an increase in user satisfaction are a few of the many potential benefits that can be achieved through utilization of these principles.

Certain principles may not be applicable to different displays or situations. Some principles may seem to be conflicting, and there is no simple solution to say that one principle is more important than another. The principles may be tailored to a specific design or situation. Striking a functional balance among the principles is critical for an effective design.[10]

Perceptual Principles:

1. Make displays legible (or audible). A display's legibility is critical and necessary for designing a usable display. If the characters or objects being displayed cannot be discernible, then the operator cannot effectively make use of them.

2. Avoid absolute judgment limits. Do not ask the user to determine the level of a variable on the basis of a single sensory variable (e.g. color, size, loudness). These sensory variables can contain many possible levels.

3. Top-down processing. Signals are likely perceived and interpreted in accordance with what is expected based on a user's past experience. If a signal is presented contrary to the user's expectation, more physical evidence of that signal may need to be presented to assure that it is understood correctly.

4. Redundancy gain. If a signal is presented more than once, it is more likely that it will be understood correctly. This can be done by presenting the signal in alternative physical forms (e.g. color and shape, voice and print, etc.), as redundancy does not imply repetition. A traffic light is a good example of redundancy, as color and position are redundant.

5. Similarity causes confusion: Use discriminable elements. Signals that appear to be similar will likely be confused. The ratio of similar features to different features causes signals to be similar. For example, A423B9 is more similar to A423B8 than 92 is to 93. Unnecessary similar features should be removed and dissimilar features should be highlighted.

Mental Model Principles:

6. Principle of pictorial realism. A display should look like the variable that it represents (e.g. high temperature on a thermometer shown as a higher vertical level). If there are multiple elements, they can be configured in a manner that looks like it would in the represented environment.

7. Principle of the moving part. Moving elements should move in a pattern and direction compatible with the user's mental model of how it actually moves in the system. For example, the moving element on an altimeter should move upward with increasing altitude.

Principles based on Attention:

8. Minimizing information access cost. When the user's attention is diverted from one location to another to access necessary information, there is an associated cost in time or effort. A display design should minimize this cost by allowing for frequently accessed sources to be located at the nearest possible position. However, adequate legibility should not be sacrificed to reduce this cost.

9. Proximity compatibility principle. Divided attention between two information sources may be necessary for the completion of one task. These sources must be mentally integrated and are defined to have close mental proximity. Information access costs should be low, which can be achieved in many ways (e.g. proximity, linkage by common colors, patterns, shapes, etc.). However, close display proximity can be harmful by causing too much clutter.

10. Principle of multiple resources. A user can more easily process information across different resources. For example, visual and auditory information can be presented simultaneously rather than presenting all visual or all auditory information.

Memory Principles:

11. Replace memory with visual information: knowledge in the world. A user should not need to retain important information solely in working memory or retrieve it from long-term memory. A menu, checklist, or another display can aid the user by easing the use of their memory. However, the use of memory may sometimes benefit the user by eliminating the need to reference some type of knowledge in the world (e.g. an expert computer operator would rather use direct commands from memory than refer to a manual). The use of knowledge in a user's head and knowledge in the world must be balanced for an effective design.

12. Principle of predictive aiding. Proactive actions are usually more effective than reactive actions. A display should attempt to eliminate resource-demanding cognitive tasks and replace them with simpler perceptual tasks to reduce the use of the user's mental resources. This will allow the user to not only focus on current conditions, but also think about possible future conditions. An example of a predictive aid is a road sign displaying the distance from a certain destination.

13. Principle of consistency. Old habits from other displays will easily transfer to support processing of new displays if they are designed in a consistent manner. A user's long-term memory will trigger actions that are expected to be appropriate. A design must accept this fact and utilize consistency among different displays.

Human-computer interface

Main article: User interface

The human–computer interface can be described as the point of communication between the human user and the computer. The flow of information between the human and computer is defined as the loop of interaction. The loop of interaction has several aspects to it including:

•*Task environment*: The conditions and goals set upon the user.
•*Machine environment*: The environment that the computer is connected to, e.g. a laptop in a college student's dorm room.
•*Areas of the interface*: Non-overlapping areas involve processes of the human and computer not pertaining to their interaction. Meanwhile, the overlapping areas only concern themselves with the processes pertaining to their interaction.
•*Input flow*: The flow of information that begins in the task environment, when the user has some task that requires using their computer.
•*Output*: The flow of information that originates in the machine environment.
•*Feedback*: Loops through the interface that evaluate, moderate, and confirm processes as they pass from the human through the interface to the computer and back.

Current Research:

User Customization:

End-user development studies how ordinary users could routinely tailor applications to their own needs and use this power to invent new applications based on their understanding of their own domains. With their deeper knowledge of their own knowledge domains, users could increasingly be important sources of new applications at the expense of generic systems programmers (with systems expertise but low domain expertise).

Embedded Computation:

Computation is passing beyond computers into every object for which uses can be found. Embedded systems make the environment alive with little computations and automated processes, from computerized cooking appliances to lighting and plumbing fixtures to window blinds to automobile braking systems to greeting cards. To some extent, this development is already taking place. The expected difference in the future is the addition of networked communications that will allow many of these embedded computations to coordinate with each other and with the user. Human interfaces to these embedded devices will in many cases be very different from those appropriate to workstations.

Augmented Reality:

A common staple of science fiction, augmented reality refers to the notion of layering relevant information into our vision of the world. Existing projects show real-time statistics to users performing difficult tasks, such as manufacturing. Future work might include augmenting our social interactions by providing additional information about those we converse with.

Factors of Change:

Traditionally, as explained in a journal article discussing user modeling and user-adapted interaction, computer usage was modeled as a human-computer dyad in which the two were connected by a narrow explicit communication channel, such as text-based terminals. Much work has been done to make the interaction between a computing system and a human. However, as stated in the introduction, there is much room for mishaps and failure. Because of this, human-computer interaction shifted focus beyond the inter-face (to respond to observations as articulated by D. Engelbart: "If ease of use was the only valid criterion, people would stick to tricycles and never try bicycles."[11]

The means by which humans interact with computers continues to evolve rapidly. Human–computer interaction is affected by the forces shaping the nature of future computing. These forces include:

•Decreasing hardware costs leading to larger memory and faster systems

•Miniaturization of hardware leading to portability

•Reduction in power requirements leading to portability

•New display technologies leading to the packaging of computational devices in new forms

•Specialized hardware leading to new functions

•Increased development of network communication and distributed computing

•Increasingly widespread use of computers, especially by people who are outside of the computing profession

•Increasing innovation in input techniques (e.g., voice, gesture, pen), combined with lowering cost, leading to rapid computerization by people previously left out of the "computer revolution."

•Wider social concerns leading to improved access to computers by currently disadvantaged groups

The future for HCI, based on current promising research, is expected[12] to include the following characteristics:

•Ubiquitous communication. Computers are expected to communicate through high speed local networks, nationally over wide-area networks, and portably via infrared, ultrasonic, cellular, and other technologies. Data and computational services will be portably accessible from many if not most locations to which a user travels.

•*High-functionality systems*. Systems can have large numbers of functions associated with them. There are so many systems that most users, technical or non-technical, do not have time to learn them in the traditional way (e.g., through thick manuals).

•*Mass availability of computer graphics*. Computer graphics capabilities such as image processing, graphics transformations, rendering, and interactive animation are becoming widespread as inexpensive chips become available for inclusion in general workstations and mobile devices.

•*Mixed media*. Commercial systems can handle images, voice, sounds, video, text, formatted data. These are exchangeable over communication links among users. The separate worlds of consumer electronics (e.g., stereo sets, VCRs, televisions) and computers are partially merging. Computer and print worlds are expected to cross-assimilate each other.

•*High-*bandwidth *interaction*. The rate at which humans and machines interact is expected to increase substantially due to the changes in speed, computer graphics, new media, and new input/output devices.

This can lead to some qualitatively different interfaces, such as virtual reality or computational video.

•*Large and thin* displays. New display technologies are finally maturing, enabling very large displays and displays that are thin, lightweight, and low in power consumption. This is having large effects on portability and will likely enable the development of paper-like, pen-based computer interaction systems very different in feel from desktop workstations of the present.

•*Information utilities*. Public information utilities (such as home banking and shopping) and specialized industry services (e.g., weather for pilots) are expected to proliferate. The rate of proliferation can accelerate with the introduction of high-bandwidth interaction and the improvement in quality of interfaces.

Scientific Conferences:

One of the top conferences for new research in human-computer interaction is the annually held ACM's Conference on Human Factors in Computing Systems, usually referred to by its short name CHI (pronounced *kai*, or *khai*). CHI is organized by ACM SIGCHI Special Interest Group on Computer–Human Interaction. CHI is a large, highly competitive conference, with thousands of attendants, and is quite broad in scope. It is broadly attended by academics, practitioners and industry people, with top companies (Google; Microsoft; Paypal) as sponsors.

There are also dozens of other smaller, regional or specialized HCI-related conferences held around the world each year, the most important of which include:[13]

Special purpose[edit]

•ASSETS: ACM International Conference on Computers and Accessibility

•CSCW: ACM conference on Computer Supported Cooperative Work.

•DIS: ACM conference on Designing Interactive Systems.

•ECSCW: European Conference on Computer-Supported Cooperative Work. Every second year.

•GROUP: ACM conference on supporting group work.

•HRI: ACM/IEEE International Conference on Human–robot interaction.

•ICMI: International Conference on Multimodal Interfaces.

•ITS: ACM conference on Interactive Tabletops and Surfaces.

•IUI: International Conference on Intelligent User Interfaces.

•MobileHCI: International Conference on Human–Computer Interaction with Mobile Devices and Services.

•NIME: International Conference on New Interfaces for Musical Expression.

•Ubicomp: International Conference on Ubiquitous computing

•UIST: ACM Symposium on User Interface Software and Technology.

•i-USEr: International Conference on User Science and Engineering.

•INTERACT: IFIP TC13 Conference on Human-Computer Interaction.

Heuristic:

Etymology:

Heuristic (Template:(IPAc-en); Greek: "Εὑρίσκω", **"find"** or **"discover"**)

Summary:

Heuristic (Template:(IPAc-en); Greek: "Εὑρίσκω", **"find"** or **"discover"**) refers to experience-based techniques for problem solving, learning, and discovery that give a solution which is not guaranteed to be optimal. Where the exhaustive search is impractical, heuristic methods are used to speed up the process of finding a satisfactory solution via mental shortcuts to ease the cognitive load of making a decision. Examples of this method include using a rule of thumb, an educated guess, an intuitive judgment, stereotyping, or common sense.

In more precise terms, heuristics are strategies using readily accessible, though loosely applicable, information to control problem solving in human beings and machines.[1]

Example:

The most fundamental heuristic is trial and error, which can be used in everything from matching nuts and bolts to finding the values of variables in algebra problems.

Here are a few other commonly used heuristics, from George Pólya's 1945 book, How to Solve It:[2]

•If you are having difficulty understanding a problem, try drawing a picture.

•If you can't find a solution, try assuming that you have a solution and seeing what you can derive from that ("working backward").

•If the problem is abstract, try examining a concrete example.

•Try solving a more general problem first (the "inventor's paradox": the more ambitious plan may have more chances of success).

Psychology:

Summary:

Main article: Heuristics in judgment and decision making

In psychology, heuristics are simple, efficient rules, learned or hard-coded by evolutionary processes, that have been proposed to explain how people make decisions, come to judgments, and solve problems typically when facing complex problems or incomplete information. These rules work well under most circumstances, but in certain cases lead to systematic errors or cognitive biases.[3]

Although much of the work of discovering heuristics in human decision-makers was done by the Israeli psychologists Amos Tversky and Daniel Kahneman,[4] the concept was originally introduced by Nobel laureate Herbert A. Simon. Simon's original, primary object of research was problem solving, showed that we operate within what he calls bounded rationality. He coined the term "satisficing", which denotes the situation where people seek solutions or accept choices or judgments that are "good enough" for their purposes, but could be optimized.[5]Gerd Gigerenzer focused on the "fast and frugal" properties of heuristics, i.e., using heuristics in a way that is principally accurate and thus eliminating most cognitive bias.[6] From one particular batch of research, Gigerenzer and Wolfgang Gaissmaier found that both individuals and organizations rely on heuristics in an adaptive way. They also found that ignoring part of the information [with a decision], rather than weighing all the options, can actually lead to more accurate decisions.[7]

Heuristics, through greater refinement and research, have begun to be applied to other theories, or be explained by them. For example: the Cognitive-Experiential Self-Theory (CEST) also an adaptive view of heuristic processing. CEST breaks down two systems that process information. At some times, roughly speaking, individuals consider issues rationally, systematically, logically, deliberately, effortfully, and verbally. On other occasions, individuals consider issues intuitively, effortlessly, globally, and emotionally.[8] From this perspective, heuristics are part of a larger experiential processing system that is often adaptive, but vulnerable to error in situations that require logical analysis.[9]

In 2002, Daniel Kahneman and Shane Frederick proposed that cognitive heuristics work by a process called attribute substitution, which happens without conscious awareness.[10] According to this theory, when somebody makes a judgment (of a "target attribute") that is computationally complex, a rather easier calculated "heuristic attribute" is substituted. In effect, a cognitively difficult problem is dealt with by answering a rather simpler problem, without being aware of this happening.[10] This theory explains cases where judgments fail to show regression toward the mean.[11] Heuristics can be considered to reduce the complexity of clinical judgements in healthcare.[12]

Theorized Psychological Heuristics:

Well known[edit]

•Anchoring and adjustment – Describes the common human tendency to rely too heavily on the first piece of information offered (the "anchor") when making decisions.

•Availability heuristic – A mental shortcut that occurs when people make judgments about the probability of events by the ease with which examples come to mind.

•Representativeness heuristic – A mental shortcut used when making judgments about the probability of an event under uncertainty.

•Naïve diversification – When asked to make several choices at once, people tend to diversify more than when making the same type of decision sequentially.

•Escalation of commitment – Describes the phenomenon where people justify increased investment in a decision, based on the cumulative prior investment, despite new evidence suggesting that the cost, starting today, of continuing the decision outweighs the expected benefit.

•Familiarity heuristic – A mental shortcut applied to various situations in which individuals assume that the circumstances underlying the past behavior still hold true for the present situation and that the past behavior thus can be correctly applied to the new situation. Especially prevalent when the individual experiences a high cognitive load.

Lesser known[edit]

•Affect heuristic

•Contagion heuristic

•Effort heuristic

•Fluency heuristic

•Gaze heuristic

•Peak-end rule

•Recognition heuristic

•Scarcity heuristic

•Similarity heuristic

•Simulation heuristic

•Social proof

•Take-the-best heuristic

Cognitive Maps:

Heuristics were also found to be used in the manipulation and creation of cognitive maps. Cognitive maps are internal representations of our physical environment, particularly associated with spacial relationships. These internal representations of our environment are used as memory as a guide in our external environment. It was found that when questioned about maps imaging, distancing, and etc., people commonly made distortions to images. These distortions took shape in the regularization of images (i.e., images are represented as more like pure abstract geometric images, though they are irregular in shape).

There are several ways that humans form and use cognitive maps. Visual intake is a key part of mapping. The first is by using *landmarks*. This is where a person uses a mental image to estimate a relationship, usually distance, between two objects. Second, is *route-road* knowledge, and this is generally developed after a person has performed a task and is relaying the information of that task to another person. Third, is survey. A person estimates a distance based on a mental image that, to them, might appear like an actual map. This image is generally created when a person's brain begins making image corrections. These are presented in five ways: 1. *Right-angle bias* is when a person straightens out an image, like mapping an intersection, and begins to give everything 90-degree angles, when in reality it may not be that way. 2. *Symmetry heuristic* is when people tend to think of shapes, or buildings, as being more symmetrical than they really are. 3. *Rotation heuristic* is when a person takes a naturally (realistically) distorted image and straightens it out for their mental image. 4. *Alignment heuristic* is similar to the pervious, where people align objects mentally to make them straighter than they really are. 5. *Relative-position heuristic* people do not accurately distance landmarks in their mental image based on how well they remember that particular item.

Another method of creating cognitive maps is by means of auditory intake based on verbal descriptions.

Using the mapping based from a person's visual intake, another person can create a mental image, such as directions to a certain location.[13]

Philosophy:

"Heuristic device" is used when an entity X exists to enable understanding of, or knowledge concerning, some other entity Y. A good example is a model that, as it is never identical with what it models, is a heuristic device to enable understanding of what it models. Stories, metaphors, etc., can also be termed heuristic in that sense. A classic example is the notion of utopia as described in Plato's best-known work, The Republic. This means that the "ideal city" as depicted in *The Republic* is not given as something to be pursued, or to present an orientation-point for development; rather, it shows how things would have to be connected, and how one thing would lead to another (often with highly problematic results), if one would opt for certain principles and carry them through rigorously.

"Heuristic" is also often used as a noun to describe a rule-of-thumb, procedure, or method.[14] Philosophers of science have emphasized the importance of heuristics in creative thought and constructing scientific theories.[15] (See The Logic of Scientific Discovery, and philosophers such as Imre Lakatos,[16] Lindley Darden, William C. Wimsatt, and others.)

Law: (further research is required)

Mass Communication: (further research is required)

Heuristics and Science Opinions: (further research is required)

Stereotyping:

Stereotyping is a type of heuristic that all people use to for opinions or make judgments about things they have never seen or experienced. They work as a mental shortcut to access everything from social status of a person from their actions to assumptions that a plant that is tall has a trunk and leaves, is a tree even though we have never seen that particular type of tree before. Stereotypes as described by Lippman are the pictures we have in our heads which are built around experiences as well as what we are told about the world. These "pictures in our heads" allow us to make judgments without having first-hand experience on the topics, which is what heuristics are all about.

Stereotypes get a bad rap as being a tool used in racism but we all use stereotypes, and they are an effective way to form opinions or to pass judgment on things we do not fully understand.

Explanation of how we can identify a plant in another country as being a tree with stereotypes: Because we have been told what a tree looks like and we have seen many types of trees we have images in our brains of what different characteristics make up a tree. So when we see something that has similar characteristics even though we have never been told that that plant is in fact a tree we can pass judgment that most likely that plant is in fact a tree. Thus we have used a mental shortcut to make a decision on something, instead of going to a native of the region and asking, "Is this a tree".

Computer Science:

Main article: Heuristic (computer science)

In computer science, a heuristic is a technique designed for solving a problem more quickly when classic methods are too slow, or for finding an approximate solution when classic methods fail to find any exact solution. By trading optimality, completeness, accuracy, and/or precision for speed, a heuristic can quickly produce a solution that is good enough for solving the problem at hand, as opposed to finding all exact solutions in a prohibitively long time.

For example, many real-time anti-virus scanners use heuristic signatures for detecting viruses and other forms of malware.

One way of achieving this computational performance gain consists in solving a simpler problem whose solution is also a solution to the more complex problem.

Heuristics is used in the A* algorithm whose intent is to find a short path from one node to another. A high-value heuristic computes a path quickly, but the path might not be the shortest. A low-value heuristic computes a path more slowly, but the path becomes shorter.

Human Computer Interaction:

In human-computer interaction, heuristic evaluation is a usability-testing technique devised by expert usability consultants. In heuristic evaluation, the user interface is reviewed by experts and its compliance to *usability heuristics* (broadly stated characteristics of a good user interface, based on prior experience) is assessed, and any violating aspects are recorded.

In software development, the use of a heuristic approach can facilitate a well-designed user interface, enabling users to navigate complex systems intuitively and without difficulty. The interface may guide the user when necessary using tooltips, help buttons, invitations to chat with support, etc., providing help when needed. However, in practice, the designer of the user interface may not find it easy to strike the optimum balance for assistance of the user. An example of a heuristic approach is the search product of Google. Google's primary product, search, involves incredibly complex algorithms searching a massive amount of data. The User Interface is simplified hugely to make for an intuitive experience; the requested search data is entered into a box and submitted with a single click. Data is organised by searching both the precise term submitted and also by applying fuzzy logic; searching for near-matches and associations (e.g., a search for 'Jonathan Smith' also returns results for 'John Smith'). This means that Google is able to return the information that the user wants, but may not have asked for, with an incredibly simple and intuitive user interface. If, however, the results returned are incorrect, you are given the option of performing an "advanced search" to provide more information for a more targeted response.Software developers and targeted end-users alike disregard heuristics at their own peril. End users often need to increase their understanding of the basic framework that a project entails (so that their expectations are realistic), and developers often need to push to learn more about their target audience (so that their learning styles can be judged). Business rules crucial to the organization are often so obvious to the end-user that they are not conveyed to the developer, who may lack domain knowledge in the particular field of endeavor the application is meant to serve. A proper Software Requirements Specification (SRS) models the heuristics of how a user processes information on-screen. An SRS is ideally shared with the end-user well before the actual Software Design Specification (SDS) is written and the application is developed, so users' feedback about their experience can be used to adapt the design of the application. This saves much time in the Software Development Life Cycle (SDLC). Unless heuristics are adequately considered, the project will likely suffer many implementation problems and setbacks.

Engineering:

Main article: Heuristic (engineering)

In engineering, a heuristic is an experience-based method that can be used as an aid to solve process design problems, varying from size of equipment to operating conditions. By using heuristics, time can be reduced when solving problems. Several methods are available to engineers. These include Failure mode and effects analysis and Fault tree analysis. The former relies on a group of qualified engineers to evaluate problems, rank them in order of importance and then recommend solutions. The methods of forensic engineering are an important source of information for investigating problems, especially by elimination of unlikely causes and using the weakest link principle. Because heuristics are fallible, it is important to understand their limitations. They are aids that facilitate quick estimates and preliminary process designs.

Additional Heuristic References:

Immersion: (virtual reality)

Summary:

"Immersion" into virtual reality is a metaphoric use of the experience of submersion into water applied to representation, fiction or simulation. Immersion can also be defined as the state of consciousness where a "visitor" (Maurice Benayoun) or "immersant" (Char Davies)'s awareness of physical self is transformed by being surrounded in an engrossing environment; often artificial, creating a perception of Presence in a non-physical world. The term is widely used for describing partial or complete suspension of disbelief enabling action or reaction to stimulations encountered in a virtual or artistic environment. The degree to which the virtual or artistic environment faithfully reproduces reality determines the degree of suspension of disbelief. The greater the suspension of disbelief, the greater the degree of Presence achieved.

Types of Immersion:

Tactical Immersion:

Tactical immersion is experienced when performing tactile operations that involve skill. Players feel "in the zone" while perfecting actions that result in success.

Strategic Immersion:

Strategic immersion is more cerebral, and is associated with mental challenge. Chess players experience strategic immersion when choosing a correct solution among a broad array of possibilities.

Narrative Immersion:

Narrative immersion occurs when players become invested in a story, and is similar to what is experienced while reading a book or watching a movie.

Staffan Björk and Jussi Holopainen, in *Patterns In Game Design*,[2] divide immersion into similar categories, but call them **sensory-motoric immersion**, **cognitive immersion** and **emotional immersion**, respectively. In addition to these, they add a new category:

Spatial Immersion:

Spatial immersion occurs when a player feels the simulated world is perceptually convincing. The player feels that he or she is really "there" and that a simulated world looks and feels "real".

Immersive Virtual Reality:

Immersive virtual reality is a hypothetical future technology that exists today as virtual reality art projects, for the most part.[3] It consists of immersion in an artificial environment where the user feels just as immersed as they usually feel in consensus reality.

Direct Interaction of the Nervous System:

The most considered method would be to induce the sensations that made up the virtual reality in the nervous system directly. In functionalism/conventional biology we interact with consensus reality through the nervous system. Thus we receive all input from all the senses as nerve impulses. It gives your neurons a feeling of heightened sensation. It would involve the user receiving inputs as artificially stimulated nerve impulses, the system would receive the CNS outputs (natural nerve impulses) and process them allowing the user to interact with the virtual reality. Natural impulses between the body and central nervous system would need to be prevented. This could be done by blocking out natural impulses using nanorobots which attach themselves to the brain wiring, whilst receiving the digital impulses of which describe the virtual world, which could then be sent into the wiring of the brain. A feedback system between the user and the computer which stores the information would also be needed. Considering how much information would be required for such a system, it's likely it would be based on quantum computers.

Requirements:

Understanding of the Nervous System:

A comprehensive understanding of which nerve impulses correspond to which sensations, and which motor impulses correspond to which muscle contractions will be required. This will allow the correct sensations in the user, and actions in the virtual reality to occur. The Blue Brain Project is the current, most promising research with the idea of understanding how the brain works by building very large scale computer models.

Ability to Manipulate CNS:

The nervous system would obviously need to be manipulated. Whilst non-invasive devices using radiation have been postulated, invasive cybernetic implants are likely to become available sooner and be more accurate. Manipulation could occur at any stage of the nervous system - the spinal cord is likely to be simplest; as all nerves pass through here, this could be the only site of manipulation. Molecular Nanotechnology is likely to provide the degree of precision required and could allow the implant to be built inside the body rather than be inserted by an operation.

Computer Hardware/Software to Process Inputs/Outputs:

A very powerful and probably (but not necessarily) Strong AI would be required to process all the inputs from the CNS, run a simulation of a virtual reality approaching the complexity of consensus reality, and translate its events to a complete set of nerve impulses for the user. Strong artificial intelligence may also be required to write the program for a decent alternate reality.

Immersive Digital Environments:

Summary:

An **immersive digital environment** is an artificial, interactive, computer-created scene or "world" within which a user can immerse themselves.[4]

Immersive digital environments could be thought of as synonymous with Virtual reality, but without the implication that actual "reality" is being simulated. An immersive digital environment could be a model of reality, but it could also be a complete fantasy user interface or abstraction, as long as the user of the environment is immersed within it. The definition of immersion is wide and variable, but here it is assumed to mean simply that the user feels like they are part of the simulated "universe". The success with which an immersive digital environment can actually immerse the user is dependent on many factors such as believable 3D computer graphics, surround sound, interactive user-input and other factors such as simplicity, functionality and potential for enjoyment. New technologies are currently under development which claim to bring realistic environmental effects to the players' environment - effects like wind, seat vibration and ambient lighting.

Perception:

To create a sense of full immersion, the 5 senses (sight, sound, touch, smell, taste) must perceive the digital environment to be physically real. Immersive technology can perceptually fool the senses through:

•Panoramic 3D displays (visual)

•Surround sound acoustics (auditory)

•Haptics and force feedback (tactile)

•Smell replication (olfactory)

•Taste replication (gustation)

Interaction:

Once the senses reach a sufficient belief that the digital environment is real, the user must then be able to interact with the environment in a natural, intuitive manner. Various immersive technologies such as gestural controls, motion tracking, and computer vision respond to the user's actions and movements. Brain control interfaces (BCI) respond to the user's brainwave activity.

Examples and Applications:

Training and rehearsal simulations run the gamut from part task procedural training (often buttonology, for example: which button do you push to deploy a refueling boom) through situational simulation (such as crisis response or convoy driver training) to full motion simulations which train pilots or soldiers and law enforcement in scenarios that are too dangerous to train in actual equipment using live ordinance.Computer games from simple arcade to Massively multiplayer online game and training programs such as flight and driving simulators. Entertainment environments such as motion simulators that immerse the riders/players in a virtual digital environment enhanced by motion, visual and aural cues. There is a motion simulators of the Virunga Mountains in Rwanda to meet a tribe of Mountain Gorillas,[5] or a ride that takes a journey through the arteries and heart to witness the build up of plaque and thus learn about cholesterol and health.[6]

In parallel with scientist, artists like Knowbotic Research, Donna Cox, Rebecca Allen, Robbie Cooper, Maurice Benayoun, Char Davies, and Jeffrey Shaw use the potential of immersive virtual reality to create physiologic or symbolic experiences and situations.

Other examples of immersion technology include physical environment / immersive space with surrounding digital projections and sound such as the CAVE, and the use of head-mounted displays for viewing movies, with head-tracking and computer control of the image presented, so that the viewer appears to be inside the scene.. The next generation is VIRTSIM, which achieves total immersion through motion capture and wireless head mounted displays for teams of up to thirteen immersants enabling natural movement through space and interaction in both the virtual and physical space simultaneously.

Practical Applications at Ford Motor Company

The developmental process used at Ford Motor Company may seem unusual to anyone who is not familiar with virtual reality, but this does not mean it is not impressive. The innovative concepts being used in the Virtual Reality lab at Ford have even sparked the interest of NASA. Ford's Virtual Reality lab is led by technical expert, Elizabeth Baron. Along with her team, she promotes some of the most advanced car designs in the auto industry.

Ford Motor Company uses 3D imaging to help them construct the interior of their vehicles. Inside the iVE lab, Ford has a test car that supports the motion software. The test car is built to resemble an actual car and has doors, seats, and a steering wheel. The test car is fixed to a platform which has built in overhead cameras that face the driver. Through the software, engineers are able to develop the interior of cars and display it through the virtual reality headset of the person sitting in the test car. The cameras that are facing the test car allow the user full visual mobility while looking at the interior of the vehicle. The motion sensing is able to tell when the user turns their head and gives them a three hundred and sixty degree view. The appearance of the interior can be switched from a Mustang to an Escape in as quickly as five minutes which allows easy comparison of concept designs.

The Cave Automated Virtual Environment (CAVE) is also used by developers to look at the exterior as well as the interior of concept designs. While standing in the CAVE, 3D glasses fixed with motion sensors are needed to control the view. Images developed in design software are projected over the walls of the room to give users an idea as to what future products are intended to look like. To change the view of the car from exterior to interior, the person wearing the 3D glasses just has to sit atop a chair that is positioned in the center of the room.

Although Ford has state of the art equipment in their labs, engineers are able to duplicate the same visual experience with their mobile station. This allows Ford to do public demonstrations at events like the North American International Auto Show and at various universities across the country. Ms. Baron is a key note speaker who has traveled with the mobile station to give demonstrations on the work being done with this type of technology. Ford's mobile station consists of some of the same components that are found in their onsite company lab. The station has seats, pedals, and a steering wheel which give the user an opportunity to physically grasp what they are seeing through their virtual reality headset. Ford's mobile station also consists of two, top of the line, 3D televisions that display the same images as the virtual reality headset which is useful when demonstrating to larger audiences.

This software gives engineers real life data on the overall appearance of their future products. Engineers are able to make recommendations and suggest that certain components be placed in a more convenient position. Being able to suggest these ideas before production allows the company to make full use of their resources. These innovative concepts that have been applied in the virtual reality lab have sped up production and reduced costs, thus ultimately making better products for their customers. The technology of virtual reality has become state of the art when compared to where it was five years ago; it is only imaginable as to what will be the next advancement.

Immersive Environments: (see: immersion & environment)

Immersive Worlds: (see: immersion & world)

Intelligence: (further research is required)

Summary:

Intelligence has been defined in many different ways including, but not limited to, abstract thought, understanding, self-awareness, communication, reasoning, learning, having emotional knowledge, retaining, planning, and problem solving.

Intelligence is most widely studied in humans, but has also been observed in animals and in plants. Artificial intelligence is the simulation of intelligence in machines.

Within the discipline of psychology, various approaches to human intelligence have been adopted. The psychometric approach is especially familiar to the general public, as well as being the most researched and by far the most widely used in practical settings.[1]

Interaction: (further research is required)

Summary:

Interaction is a kind of action that occurs as two or more objects have an effect upon one another. The idea of a two-way effect is essential in the concept of interaction, as opposed to a one-way causal effect. A closely related term is interconnectivity, which deals with the interactions of interactions within systems: combinations of many simple interactions can lead to surprising emergent phenomena. *Interaction* has different tailored meanings in various sciences.[citation needed] Changes can also involve interaction.

Casual examples of interaction outside of science include:[citation needed]

•Communication of any sort, for example two or more people talking to each other, or communication among groups, organizations, nations or states: trade, migration, foreign relations, transportation,

•The feedback during the operation of machines such as a computer or tool, for example the interaction between a driver and the position of his or her car on the road: by steering the driver influences this position, by observation this information returns to the driver.

Invention:

Summary:

An **invention** is a unique or novel device, method, composition or process. It may be an improvement upon a machine or product, or a new process for creating an object or a result. An invention that achieves a completely unique function or result may be a radical breakthrough. Such works are novel and not obvious to others skilled in the same field.

Some inventions can be patented. A Patent legally protects the intellectual property rights of the inventor and legally recognizes that a claimed invention is actually an invention. The rules and requirements for patenting an invention vary from country to country, and the process of obtaining a patent is often expensive.

Another meaning of invention is **cultural invention**, which is an innovative set of useful social behaviours adopted by people and passed on to others.[1] The Institute for Social Inventions collected many such ideas in magazines and books.[2] Invention is also an important component of artistic and design creativity. Inventions often extend the boundaries of human knowledge, experience or capability.

Knowledge:

Summary:

Knowledge is a familiarity with someone or something, which can include facts, information, descriptions, or skills acquired through experience or education. It can refer to the theoretical or practical understanding of a subject. It can be implicit (as with practical skill or expertise) or explicit (as with the theoretical understanding of a subject); it can be more or less formal or systematic.[1] In philosophy, the study of knowledge is called epistemology; the philosopher Plato famously defined knowledge as "justified true belief." However, no single agreed upon definition of knowledge exists, though there are numerous theories to explain it.

Knowledge acquisition involves complex cognitive processes: perception, communication, association and reasoning; while knowledge is also said to be related to the capacity of *acknowledgment* in human beings.[2]

Theories:

See also: Epistemology

“

The eventual demarcation of philosophy from science was made possible by the notion that philosophy's core was "theory of knowledge," a theory distinct from the sciences because it was their *foundation*… Without this idea of a "theory of knowledge," it is hard to imagine what "philosophy" could have been in the age of modern science.

”

— Richard Rorty, *Philosophy and the Mirror of Nature*

The definition of knowledge is a matter of ongoing debate among philosophers in the field of epistemology. The classical definition, described but not ultimately endorsed by Plato,[3] specifies that a statement must meet three criteria in order to be considered knowledge: it must be justified, true, and believed. Some claim that these conditions are not sufficient, as Gettier case examples allegedly demonstrate. There are a number of alternatives proposed, including Robert Nozick's arguments for a requirement that knowledge 'tracks the truth' and Simon Blackburn's additional requirement that we do not want to say that those who meet any of these conditions 'through a defect, flaw, or failure' have knowledge. Richard Kirkham suggests that our definition of knowledge requires that the evidence for the belief necessitates its truth.[4]

In contrast to this approach, Wittgenstein observed, following Moore's paradox, that one can say "He believes it, but it isn't so," but not "He knows it, but it isn't so." [5] He goes on to argue that these do not correspond to distinct mental states, but rather to distinct ways of talking about conviction. What is different here is not the mental state of the speaker, but the activity in which they are engaged. For example, on this account, to *know* that the kettle is boiling is not to be in a particular state of mind, but to perform a particular task with the statement that the kettle is boiling. Wittgenstein sought to bypass the difficulty of definition by looking to the way "knowledge" is used in natural languages. He saw knowledge as a case of a family resemblance. Following this idea, "knowledge" has been reconstructed as a cluster concept that points out relevant features but that is not adequately captured by any definition.[6]

Epistemology:

Epistemology (i/ɨˌpɪstɨˈmɒlədʒi/ from Greek ἐπιστήμη - *epistēmē*, meaning "knowledge, understanding", and λόγος - logos, meaning "study of") is the branch of philosophy concerned with the nature and scope of knowledge[1][2] and is also referred to as "theory of knowledge". It questions what knowledge is and how it can be acquired, and the extent to which any given subject or entity can be known.

Much of the debate in this field has focused on analyzing the nature of knowledge and how it relates to connected notions such as truth, belief, and justification.

The term "epistemology" was introduced by the Scottish philosopher James Frederick Ferrier (1808–1864).[3]

Etymology:

Summary:

"Etymologies" redirects here. For the encyclopedia, see Etymologiae*. For the Elvish dictionary, see* The Etymologies (Tolkien)*.*

Not to be confused with Entomology *or* Etiology*.*

Etymology is the study of the history of words, their origins, and how their form and meaning have changed over time. By an extension, the term "the etymology of [a word]" means the origin of the particular word.

For languages with a long written history, etymologists make use of texts in these languages and texts about the languages to gather knowledge about how words were used during earlier periods of their history and when they entered the languages in question. Etymologists also apply the methods of comparative linguistics to reconstruct information about languages that are too old for any direct information to be available.

By analyzing related languages with a technique known as the comparative method, linguists can make inferences about their shared parent language and its vocabulary. In this way, word roots have been found that can be traced all the way back to the origin of, for instance, the Indo-European language family.

Even though etymological research originally grew from the philological tradition, currently much etymological research is done on language families where little or no early documentation is available, such as Uralic and Austronesian.

The word *etymology* is derived from the Greek *etymon*, meaning "true sense" and the suffix *-logia*, denoting "the study of".[1]

Etymon is also used in English to refer to the source word of a given word. For example, Latin *candidus*, which means "white", is the etymon of English *candid*.

Methods:

Etymologists apply a number of methods to study the origins of words, some of which are:

•Philological research. Changes in the form and meaning of the word can be traced with the aid of older texts, if such are available.

•Making use of dialectological data. The form or meaning of the word might show variations between dialects, which may yield clues about its earlier history.

•The comparative method. By a systematic comparison of related languages, etymologists may often be able to detect which words derive from their common ancestor language and which were instead later borrowed from another language.

•The study of semantic change. Etymologists must often make hypotheses about changes in the meaning of particular words. Such hypotheses are tested against the general knowledge of semantic shifts. For example, the assumption of a particular change of meaning may be substantiated by showing that the same type of change has occurred in other languages as well.

Experience (Experiential):

Summary:

Experience comprises knowledge of or skill of some thing or some event gained through involvement in or exposure to that thing or event.[1] The history of the word *experience* aligns it closely with the concept of experiment. For example, the word experience could be used in a statement like: "I have experience in fishing".

The concept of experience generally refers to know-how or procedural knowledge, rather than propositional knowledge: on-the-job training rather than book-learning. Philosophers dub knowledge based on experience "empirical knowledge" or "*a posteriori* knowledge".

The interrogation of experience has a long tradition in continental philosophy. Experience plays an important role in the philosophy of Søren Kierkegaard. The German term Erfahrung, often translated into English as "experience", has a slightly different implication, connoting the coherency of life's experiences.

A person with considerable experience in a specific field can gain a reputation as an expert.

Certain religious traditions (such as types of Buddhism, Surat Shabd Yoga, mysticism and Pentecostalism) and educational paradigms with, for example, the conditioning of military recruit-training (also known as "boot camps"), stress the experiential nature of human epistemology. This stands in contrast to alternatives: traditions of dogma, logic or reasoning. Participants in activities such as tourism, extreme sports and recreational drug-use also tend to stress the importance of experience.

Types:

Language:

Language:

Summary:

Language is the human capacity for acquiring and using complex systems of communication, and **a language** is any specific example of such a system. The scientific study of language is called linguistics. Estimates of the number of languages in the world vary between 6,000 and 7,000. However, any precise estimate depends on a partly arbitrary distinction between languages and dialects. Natural languages are spoken or signed, but any language can be encoded into secondary media using auditory, visual, or tactile stimuli, for example, in graphic writing, braille, or whistling. This is because human language is modality-independent. When used as a general concept, "language" may refer to the cognitive ability to learn and use systems of complex communication, or to describe the set of rules that makes up these systems, or the set of utterances that can be produced from those rules. All languages rely on the process of semiosis to relate signs with particular meanings. Oral and sign languages contain a phonological system that governs how symbols are used to form sequences known as words or morphemes, and a syntactic system that governs how words and morphemes are combined to form phrases and utterances.

Human language is unique because it has the properties of productivity, recursivity, and displacement, and because it relies entirely on social convention and learning. Its complex structure therefore affords a much wider range of possible expressions and uses than any known system of animal communication. Language is thought to have originated when early hominins started gradually changing their primate communication systems, acquiring the ability to form a theory of other minds and a shared intentionality.

This development is sometimes thought to have coincided with an increase in brain volume, and many linguists see the structures of language as having evolved to serve specific communicative and social functions. Language is processed in many different locations in the human brain, but especially in Broca's and Wernicke's areas. Humans acquire language through social interaction in early childhood, and children generally speak fluently when they are approximately three years old. The use of language is deeply entrenched in human culture. Therefore, in addition to its strictly communicative uses, language also has many social and cultural uses, such as signifying group identity, social stratification, as well as for social grooming and entertainment.

Languages evolve and diversify over time, and the history of their evolution can be reconstructed by comparing modern languages to determine which traits their ancestral languages must have had in order for the later stages to have occurred. A group of languages that descend from a common ancestor is known as a language family. The languages that are most spoken in the world today belong to the Indo-European family, which includes languages such as English, Spanish, Portuguese, Russian, and Hindi; the Sino-Tibetan languages, which include Mandarin Chinese, Cantonese, and many others; the Afro-Asiatic family, which include Arabic, Amharic, Somali, and Hebrew; and the Bantu languages, which include Swahili, Zulu, Shona, and hundreds of other languages spoken throughout Africa. The consensus is that between 50 and 90% of languages spoken today will probably have become extinct by the year 2100.[1][2]

Definitions:

Main article: Philosophy of language

The English word "language" derives ultimately from Indo-European *dn̥ǵ^{h}wéh$_{2}$s "tongue, speech, language" through Latin *lingua*, "language; tongue", and Old French *langage* "language".[3] The word is sometimes used to refer to codes, ciphers, and other kinds of artificially constructed communication systems such as those used for computer programming. A language in this sense is a system of signs for encoding and decoding information. This article specifically concerns the properties of natural human language as it is studied in the discipline of linguistics.

As an object of linguistic study, "language" has two primary meanings: an abstract concept, and a specific linguistic system, e.g. "French". The Swiss linguist Ferdinand de Saussure, who defined the modern discipline of linguistics, first explicitly formulated the distinction using the French word *langage* for language as a concept, langue as a specific instance of a language system, and *parole* for the concrete usage of speech in a particular language.[4]

When speaking of language as a general concept, definitions can be used which stress different aspects of the phenomenon.[5] These definitions also entail different approaches and understandings of language, and they inform different and often incompatible schools of linguistic theory.[6]

Mental faculty, organ or instinct:

One definition sees language primarily as the mental faculty that allows humans to undertake linguistic behavior: to learn languages and to produce and understand utterances. This definition stresses the universality of language to all humans and it emphasizes the biological basis for the human capacity for language as a unique development of the human brain. Proponents of the view that the drive to language acquisition is innate in humans often argue that this is supported by the fact that all cognitively normal children raised in an environment where language is accessible will acquire language without formal instruction. Languages may even spontaneously develop in environments where people live or grow up together without a common language, for example, creole languages and spontaneously developed sign languages such as Nicaraguan Sign Language. This view, which can be traced back to Kant and Descartes, often understands language to be largely innate, for example, in Chomsky's theory of Universal Grammar, or American philosopher Jerry Fodor's extreme innatist theory. These kinds of definitions are often applied by studies of language within a cognitive science framework and in neurolinguistics.[7][8]

Formal Symbolic System:

Another definition sees language as a formal system of signs governed by grammatical rules of combination to communicate meaning. This definition stresses that human languages can be described as closed structural systems consisting of rules that relate particular signs to particular meanings.[9] This structuralist view of language was first introduced by Ferdinand de Saussure,[10] and his structuralism remains foundational for most approaches to language today.[11]

Some proponents of this view of language have advocated a formal approach which studies language structure by identifying its basic elements and then by formulating a formal account of the rules according to which the elements combine in order to form words and sentences. The main proponent of such a theory is Noam Chomsky, the originator of the generative theory of grammar, who has defined language as a particular set of sentences that can be generated from a particular set of rules.[12] Chomsky considers these rules to be an innate feature of the human mind and to constitute the essence of what language is.[13] Formal definitions of language are commonly used in formal logic, in formal theories of grammar, and in applied computational linguistics.[14][15]

Tool for Communication:

Yet another definition sees language as a system of communication that enables humans to cooperate. This definition stresses the social functions of language and the fact that humans use it to express themselves and to manipulate objects in their environment. Functional theories of grammar explain grammatical structures by their communicative functions, and understand the grammatical structures of language to be the result of an adaptive process by which grammar was "tailored" to serve the communicative needs of its users.[16][17] This view of language is associated with the study of language in pragmatic, cognitive, and interactive frameworks, as well as in socio-linguistics and linguistic anthropology. Functionalist theories tend to study grammar as dynamic phenomena, as structures that are always in the process of changing as they are employed by their speakers. This view places importance on the study of linguistic typology, or the classification of languages according to structural features, as it can be shown that processes of grammaticalization tend to follow trajectories that are partly dependent on typology. In the philosophy of language, these views are often associated with Wittgenstein's later works and with ordinary language philosophers such as Paul Grice, John Searle and J. L. Austin.[15]

The Unique Status of Human Language:

Main articles: Animal language *and* Great ape language

Human language is unique in comparison to other forms of communication, such as those used by non-human animals. Communication systems used by other animals such as bees or non-human apes are closed systems that consist of a closed number of possible things that can be expressed.[18]

In contrast, human language is open-ended and productive, meaning that it allows humans to produce an infinite set of utterances from a finite set of elements and to create new words and sentences. This is possible because human language is based on a dual code, where a finite number of meaningless elements (e.g. sounds, letters or gestures) can be combined to form units of meaning (words and sentences).[19]

Furthermore, the symbols and grammatical rules of any particular language are largely arbitrary, meaning that the system can only be acquired through social interaction.[20] The known systems of communication used by animals, on the other hand, can only express a finite number of utterances that are mostly genetically transmitted.[21]

Several species of animals have proven able to acquire forms of communication through social learning, such as the Bonobo Kanzi, which learned to express itself using a set of symbolic lexigrams. Similarly, many species of birds and whales learn their songs by imitating other members of their species. However, while some animals may acquire large numbers of words and symbols,[notes 1] none have been able to learn as many different signs as is generally known by an average 4 year old human, nor have any acquired anything resembling the complex grammar of human language.[22]

Human languages also differ from animal communication systems in that they employ grammatical and semantic categories, such as noun and verb, present and past, to express exceedingly complex meanings.[22] Human language is also unique in having the property of recursivity: the way in which, for example, a noun phrase is able to contain another noun phrase (as in "[[the chimpanzee]'s lips]") or a clause is able to contain a clause (as in "[I see [the dog is running]]").[23] Human language is also the only known natural communication system that is *modality independent*, meaning that it can be used not only for communication through one channel or medium, but through several - for example, spoken language uses the auditive modality, whereas sign languages and writing use the visual modality, and braille writing uses the tactile modality.[24]

With regard to the meaning that it may convey and the cognitive operations that it builds on, human language is also unique in being able to refer to abstract concepts and to imagined or hypothetical events as well as events that took place in the past or may happen in the future. This ability to refer to events that are not at the same time or place as the speech event is called displacement, and while some animal communication systems can use displacement (such as the communication of bees that can communicate the location of sources of nectar that are out of sight), the degree to which it is used in human language is also considered unique.[19]

Origin:

Main articles: Origin of language *and* Origin of speech

75–80,000-year-old artefacts from Blombos cave, South Africa, including a piece of ochre engraved with diagonal cross-hatch patterns, perhaps the oldest known example of symbols.

"The Tower of Babel" by Pieter Bruegel the Elder. Oil on board, 1563.

Humans have speculated about the origins of language throughout history. The Biblical myth of the Tower of Babel is one such account; other cultures have different stories of how language arose.[25]

Theories about the origin of language can be divided according to their basic assumptions. Some theories are based on the idea that language is so complex that one cannot imagine it simply appearing from nothing in its final form, but that it must have evolved from earlier pre-linguistic systems among our pre-human ancestors. These theories can be called continuity-based theories. The opposite viewpoint is that language is such a unique human trait that it cannot be compared to anything found among non-humans and that it must therefore have appeared suddenly in the transition from pre-hominids to early man. These theories can be defined as discontinuity-based. Similarly, theories based on Chomsky's Generative view of language see language mostly as an innate faculty that is largely genetically encoded, whereas functionalist theories see it as a system that is largely cultural, learned through social interaction.[26]

Currently, the only prominent proponent of a discontinuity-based theory of human language origins is linguist and philosopher Noam Chomsky. Chomsky proposes that "some random mutation took place, maybe after some strange cosmic ray shower, and it reorganized the brain, implanting a language organ in an otherwise primate brain."[27] Though cautioning against taking this story too literally, Chomsky insists that "it may be closer to reality than many other fairy tales that are told about evolutionary processes, including language."[27]

Continuity-based theories are currently held by a majority of scholars, but they vary in how they envision this development. Those who see language as being mostly innate, for example, psychologist Steven Pinker, hold the precedents to be animal cognition,[8] whereas those who see language as a socially learned tool of communication, such as psychologist Michael Tomasello, see it as having developed from animal communication, either primate gestural or vocal communication to assist in cooperation.[21] Other continuity-based models see language as having developed from music, a view already espoused by Rousseau, Herder, Humboldt, and Charles Darwin. A prominent proponent of this view today is archaeologist

Steven Mithen.[28]

Because the emergence of language is located in the early prehistory of man, the relevant developments have left no direct historical traces, and no comparable processes can be observed today. Theories that stress continuity often look at animals to see if, for example, primates display any traits that can be seen as analogous to what pre-human language must have been like. Alternatively, early human fossils can be inspected to look for traces of physical adaptation to language use or for traces of pre-linguistic forms of symbolic behaviour.[29]

It is mostly undisputed that pre-human australopithecines did not have communication systems significantly different from those found in great apes in general, but scholarly opinions vary as to the developments since the appearance of the genus Homo some 2.5 million years ago. Some scholars assume the development of primitive language-like systems (proto-language) as early as Homo habilis (2.3 million years ago), while others place the development of primitive symbolic communication only with Homo erectus (1.8 million years ago) or Homo heidelbergensis (0.6 million years ago), and the development of language proper with Anatomically Modern Homo sapiens with the Upper Paleolithic revolution less than 100,000 years ago.[30][31]

The Study of Language:

The study of language, linguistics, has been developing into a science since the first grammatical descriptions of particular languages in India more than 2000 years ago. Today, linguistics is a science that concerns itself with all aspects of language, examining it from all of the theoretical viewpoints described above.[32]

Subdisciplines:

The academic study of language is conducted within many different disciplinary areas and from different theoretical angles, all of which inform modern approaches to linguistics. For example, descriptive linguistics examines the grammar of single languages, theoretical linguistics develops theories on how best to conceptualize and define the nature of language based on data from the various extant human languages, sociolinguistics studies how languages are used for social purposes informing in turn the study of the social functions of language and grammatical description, neurolinguistics studies how language is processed in the human brain and allows the experimental testing of theories, computational linguistics builds on theoretical and descriptive linguistics to construct computational models of language often aimed at processing natural language or at testing linguistic hypotheses, and historical linguistics relies on grammatical and lexical descriptions of languages to trace their individual histories and reconstruct trees of language families by using the comparative method.[33]

Early history:

The formal study of language is often considered to have started in India with Pāṇini, the 5th century BC grammarian who formulated 3,959 rules of Sanskrit morphology. However, Sumerian scribes already studied the differences between Sumerian and Akkadian grammar around 1900 BC. Subsequent grammatical traditions developed in all of the ancient cultures that adopted writing.[34]

In the 17th century AD, the French Port-Royal Grammarians developed the idea that the grammars of all languages were a reflection of the universal basics of thought, and therefore that grammar was universal. In the 18th century, the first use of the comparative method by British philologist and expert on ancient India William Jones sparked the rise of comparative linguistics.[35] The scientific study of language was broadened from Indo-European to language in general by Wilhelm von Humboldt. Early in the 20th century, Ferdinand de Saussure introduced the idea of language as a static system of interconnected units, defined through the oppositions between them.[10]

By introducing a distinction between diachronic and synchronic analyses of language, he laid the foundation of the modern discipline of linguistics. Saussure also introduced several basic dimensions of linguistic analysis that are still fundamental in many contemporary linguistic theories, such as the distinctions between syntagm and paradigm, and the Langue-parole distinction, distinguishing language as an abstract system (*langue*), from language as a concrete manifestation of this system (*parole*).[36]

Contemporary Linguistics:

In the 1960s, Noam Chomsky formulated the generative theory of language. According to this theory, the most basic form of language is a set of syntactic rules that is universal for all humans and which underlies the grammars of all human languages. This set of rules is called Universal Grammar; for Chomsky, describing it is the primary objective of the discipline of linguistics. Thus, he considered that the grammars of individual languages are only of importance to linguistics insofar as they allow us to deduce the universal underlying rules from which the observable linguistic variability is generated.[37]

In opposition to the formal theories of the generative school, functional theories of language propose that since language is fundamentally a tool, its structures are best analyzed and understood by reference to their functions. Formal theories of grammar seek to define the different elements of language and describe the way they relate to each other as systems of formal rules or operations, while functional theories seek to define the functions performed by language and then relate them to the linguistic elements that carry them out.[15][notes 2] The framework of cognitive linguistics interprets language in terms of the concepts (which are sometimes universal, and sometimes specific to a particular language) which underlie its forms.[38] Cognitive linguistics is primarily concerned with how the mind creates meaning through language.

Physiological and Neural Architecture of Language and Speech:

Summary:

Speaking is the default modality for language in all cultures. The production of spoken language depends on sophisticated capacities for controlling the lips, tongue and other components of the vocal apparatus, the ability to acoustically decode speech sounds, and the neurological apparatus required for acquiring and producing language.[39] The study of the genetic bases for human language is still on a fairly basic level, and the only gene that has been positively implied in language production is FOXP2, which may cause a kind of congenital language disorder if affected by mutations.[40]

The Brain and Language:

Main article: Neurolinguistics

Language Areas of the brain. The Angular Gyrus is represented in orange, Supramarginal Gyrus is represented in yellow, Broca's area is represented in blue, Wernicke's area is represented in green, and the Primary Auditory Cortex is represented in pink.

The brain is the coordinating center of all linguistic activity; it controls both the production of linguistic cognition and of meaning and the mechanics of speech production. Nonetheless, our knowledge of the neurological bases for language is quite limited, though it has advanced considerably with the use of modern imaging techniques. The discipline of linguistics dedicated to studying the neurological aspects of language is called neurolinguistics.[41]

Early work in neurolinguistics involved the study of language in people with brain lesions, to see how lesions in specific areas affect language and speech. In this way, neuroscientists in the 19th century discovered that two areas in the brain are crucially implicated in language processing. The first area is Wernicke's area, which is located in the posterior section of the superior temporal gyrus in the dominant cerebral hemisphere. People with a lesion in this area of the brain develop receptive aphasia, a condition in which there is a major impairment of language comprehension, while speech retains a natural-sounding rhythm and a relatively normal sentence structure. The second area is Broca's area, located in the posterior inferior frontal gyrus of the dominant hemisphere. People with a lesion to this area develop expressive aphasia, meaning that they know what they want to say, they just cannot get it out.[42] They are typically able to understand what is being said to them, but unable to speak fluently. Other symptoms that may be present in Broca's aphasia include problems with fluency, articulation, word-finding, word repetition, and producing and comprehending complex grammatical sentences, both orally and in writing. Those with this aphasia also exhibit ungrammatical speech and show inability to use syntactic information to determine the meaning of sentences. Both Broca's and Wenicke's aphasia also affect the use of sign language, in analogous ways to how they affect speech, with Broca's aphasia causing signers to sign slowly and with incorrect grammar, whereas a signer with Wernicke's aphasia will sign fluently, but make little sense to others and have difficulties comprehending others' signs. This shows that the impairment is specific to the ability to use language, not to the physiology used for speech production.[43][44]

With technological advances in the late 20th century, neurolinguists have also adopted non-invasive techniques such as functional magnetic resonance imaging (fMRI) and electrophysiology to study language processing in individuals without impairments.[41]

Anatomy of Speech:

Main articles: Speech production, Phonetics, and Articulatory phonetics

The human vocal tract.Spectrogram of American English vowels [i, u, ɑ] showing the formants f_1 and f_2

Spoken language relies on human physical ability to produce sound, which is a longitudinal wave propagated through the air at a frequency capable of vibrating the ear drum. This ability depends on the physiology of the human speech organs. These organs consist of the lungs, the voice box (larynx), and the upper vocal tract - the throat, the mouth, and the nose. By controlling the different parts of the speech apparatus, the airstream can be manipulated to produce different speech sounds.[45]

The sound of speech can be analyzed into a combination of segmental and suprasegmental elements. The segmental elements are those that follow each other in sequences, which are usually represented by distinct letters in alphabetic scripts, such as the Roman script. In free flowing speech, there are no clear boundaries between one segment and the next, nor usually are there any audible pauses between words. Segments therefore are distinguished by their distinct sounds which are a result of their different articulations, and they can be either vowels or consonants. Suprasegmental phenomena encompass such elements as stress, phonation type, voice timbre, and prosody or intonation, all of which may have effects across multiple segments.[46]Consonants and vowel segments combine to form syllables, which in turn combine to form utterances; these can be distinguished phonetically as the space between two inhalations. Acoustically, these different segments are characterized by different formant structures, that are visible in a spectrogram of the recorded sound wave (See illustration of Spectrogram of the formant structures of three English vowels). Formants are the amplitude peaks in the frequency spectrum of a specific sound.[46][47]

Vowels are those sounds that have no audible friction caused by the narrowing or obstruction of some part of the upper vocal tract. They vary in quality according to the degree of lip aperture and the placement of the tongue within the oral cavity.[46] Vowels are called close when the lips are relatively closed, as in the pronunciation of the vowel [i] (English "ee"), or open when the lips are relatively open, as in the vowel [a] (English "ah"). If the tongue is located towards the back of the mouth, the quality changes, creating vowels such as [u] (English "oo"). The quality also changes depending on whether the lips are rounded as opposed to unrounded, creating distinctions such as that between [i] (unrounded front vowel such as English "ee") and [y] (rounded front vowel such as German "ü").[48]

Consonants are those sounds that have audible friction or closure at some point within the upper vocal tract. Consonant sounds vary by place of articulation, i.e. the place in the vocal tract where the airflow is obstructed, commonly at the lips, teeth, alveolar ridge, palate, velum, uvula, or glottis. Each place of articulation produces a different set of consonant sounds, which are further distinguished by manner of articulation, or the kind of friction, whether full closure, in which case the consonant is called occlusive or stop, or different degrees of aperture creating fricatives and approximants. Consonants can also be either voiced or unvoiced, depending on whether the vocal cords are set in vibration by airflow during the production of the sound. Voicing is what separates English [s] in *bus* (unvoiced sibilant) from [z] in *buzz* (voiced sibilant).[49]

Some speech sounds, both vowels and consonants, involve release of air flow through the nasal cavity, and these are called nasals or nasalized sounds. Other sounds are defined by the way the tongue moves within the mouth: such as the l-sounds (called laterals, because the air flows along both sides of the tongue), and the r-sounds (called rhotics) that are characterized by how the tongue is positioned relative to the air stream.[47]

By using these speech organs, humans can produce hundreds of distinct sounds: some appear very often in the world's languages, whereas others are much more common in certain language families, language areas, or even specific to a single language.[50]

Structure:

Summary:

When described as a system of symbolic communication, language is traditionally seen as consisting of three parts: signs, meanings, and a code connecting signs with their meanings. The study of the process of semiosis, how signs and meanings are combined, used, and interpreted is called semiotics. Signs can be composed of sounds, gestures, letters, or symbols, depending on whether the language is spoken, signed, or written, and they can be combined into complex signs, such as words and phrases. When used in communication, a sign is encoded and transmitted by a sender through a channel to a receiver who decodes it.[51]

Ancient Tamil inscription at Thanjavur

Some of the properties that define human language as opposed to other communication systems are the arbitrariness of the linguistic sign, meaning that there is no predictable connection between a linguistic sign and its meaning, the duality of the linguistic system, meaning that linguistic structures are built by combining elements into larger structures that can be seen as layered, e.g. how sounds build words and words build phrases, the discreteness of the elements of language, meaning that the elements out of which linguistic signs are constructed are discrete units, e.g. sounds and words, that can be distinguished from each other and rearranged in different patterns, and the productivity of the linguistic system, meaning that the finite number of linguistic elements can be combined into a theoretically infinite number of combinations.[51]

The rules by which signs can be combined to form words and phrases are called syntax or grammar. The meaning that is connected to individual signs, morphemes, words, phrases, and texts is called semantics.[52]

The division of language into separate but connected systems of sign and meaning goes back to the first linguistic studies of de Saussure and is now used in almost all branches of linguistics.[53]

Semantics:

Main articles: Semantics, Semiotics, and Meaning (linguistics)

Languages express meaning by relating a sign form to a meaning, or its content. Sign forms must be something that can be perceived, for example, in sounds, images, or gestures, and then related to a specific meaning by social convention. Because the basic relation of meaning for most linguistic signs is based on social convention, linguistic signs can be considered arbitrary, in the sense that the convention is established socially and historically, rather than by means of a natural relation between a specific sign form and its meaning.

Thus, languages must have a vocabulary of signs related to specific meaning. The English sign "dog" denotes, for example, a member of the species Canis familiaris. In a language, the array of arbitrary signs connected to specific meanings is called the lexicon, and a single sign connected to a meaning is called a lexeme. Not all meanings in a language are represented by single words. Often, semantic concepts are embedded in the morphology or syntax of the language in the form of grammatical categories.[54]

All languages contain the semantic structure of predication: a structure that predicates a property, state, or action. Traditionally, semantics has been understood to be the study of how speakers and interpreters assign truth values to statements, so that meaning is understood to be the process by which a predicate can be said to be true or false about an entity, e.g. "[x [is y]]" or "[x [does y]]". Recently, this model of semantics has been complemented with more dynamic models of meaning that incorporate shared knowledge about the context in which a sign is interpreted into the production of meaning. Such models of meaning are explored in the field of pragmatics.[54]

Sounds and Symbols:

Main articles: Phonology *and* Writing

A spectrogram showing the sound of the spoken English word "man", which is written phonetically as [mæn]. Note that in flowing speech, there is no clear division between segments, only a smooth transition as the vocal apparatus moves.

The letter "wi" in the Hangul script.

The sign for "wi" in Korean Sign Language

Depending on modality, language structure can be based on systems of sounds (speech), gestures (sign languages), or graphic or tactile symbols (writing). The ways in which languages use sounds or signs to construct meaning are studied in phonology.[55] The study of how humans produce and perceive vocal sounds is called phonetics.[56] In spoken language, meaning is produced when sounds become part of a system in which some sounds can contribute to expressing meaning and others do not. In any given language, only a limited number of the many distinct sounds that can be created by the human vocal apparatus contribute to constructing meaning.[57]

Sounds as part of a linguistic system are called phonemes.[58] Phonemes are abstract units of sound, defined as the smallest units in a language that can serve to distinguish between the meaning of a pair of minimally different words, a so-called minimal pair. In English, for example, the words */bat/* [bat] and */pat/* [pʰat] form a minimal pair, in which the distinction between /b/ and /p/ differentiates the two words, which have different meanings. However, each language contrasts sounds in different ways. For example, in a language that does not distinguish between voiced and unvoiced consonants, the sounds [p] and [b] would be considered a single phoneme, and consequently, the two pronunciations would have the same meaning. Similarly, the English language does not distinguish phonemically between aspirated and non-aspirated pronunciations of consonants, as many other languages do: the unaspirated /p/ in */spin/* [spin] and the aspirated /p/ in */pin/* [pʰin] are considered to be merely different ways of pronouncing the same phoneme (such variants of a single phoneme are called allophones), whereas in Mandarin Chinese, the same difference in pronunciation distinguishes between the words [pʰá] "crouch" and [pá] "eight" (the accent above the á means that the vowel is pronounced with a high tone).[59]

All spoken languages have phonemes of at least two different categories, vowels and consonants, that can be combined to form syllables.[46] As well as segments such as consonants and vowels, some languages also use sound in other ways to convey meaning. Many languages, for example, use stress, pitch, duration, and tone to distinguish meaning. Because these phenomena operate outside of the level of single segments, they are called suprasegmental.[60] Some languages have only a few phonemes, for example, Rotokas and Pirahã language with 11 and 10 phonemes respectively, whereas languages like Taa may have as many as 141 phonemes.[59] In sign languages, the equivalent to phonemes (formerly called cheremes) are defined by the basic elements of gestures, such as hand shape, orientation, location, and motion, which correspond to manners of articulation in spoken language.[61]Writing systems represent language using visual symbols, which may or may not correspond to the sounds of spoken language. The Latin alphabet (and those on which it is based or that have been derived from it) was originally based on the representation of single sounds, so that words were constructed from letters that generally denote a single consonant or vowel in the structure of the word. In syllabic scripts, such as the Inuktitut syllabary, each sign represents a whole syllable. In logographic scripts, each sign represents an entire word,[62] and will generally bear no relation to the sound of that word in spoken language.

Because all languages have a very large number of words, no purely logographic scripts are known to exist. Written language represents the way spoken sounds and words follow one after another by arranging symbols according to a pattern that follows a certain direction. The direction used in a writing system is entirely arbitrary and established by convention. Some writing systems use the horizontal axis (left to right as the Latin script or right to left as the Arabic script), while others such as traditional Chinese writing use the vertical dimension (from top to bottom). A few writing systems use opposite directions for alternating lines, and others, such as the ancient Maya script, can be written in either direction and rely on graphic cues to show the reader the direction of reading.[63]

In order to represent the sounds of the world's languages in writing, linguists have developed the International Phonetic Alphabet, designed to represent all of the discrete sounds that are known to contribute to meaning in human languages.[64]

Grammar:

Summary: Abbreviated Summary:

Main article: Grammar

Grammar is the study of how meaningful elements called morphemes within a language can be combined into utterances. Morphemes can either be *free* or *bound*. If they are free to be moved around within an utterance, they are usually called words, and if they are bound to other words or morphemes, they are called affixes. The way in which meaningful elements can be combined within a language is governed by rules. The rules for the internal structure of words are called morphology. The rules of the internal structure of phrases and sentences are called *syntax*.[65]

Etymology:

Further information: Grapheme

The word *grammar* derives from Greek γραμματικὴ τέχνη (*grammatikē technē*), which means "art of letters", from γράμμα (*gramma*), "letter", itself from γράφειν (*graphein*), "to draw, to write".[7]

Summary: Full Article Summary:

In linguistics, **grammar** is the set of structural rules that governs the composition of clauses, phrases and words in any given natural language. The term refers also to the study of such rules, and this field includes morphology, syntax, and phonology, often complemented by phonetics, semantics, and pragmatics. Linguists do not normally use the term to refer to orthographical rules, although usage books and style guides that call themselves grammars may also refer to spelling and punctuation.[citation needed]

Grammar Categories:

Grammar can be described as a system of categories and a set of rules that determine how categories combine to form different aspects of meaning.[66] Languages differ widely in whether they are encoded through the use of categories or lexical units. However, several categories are so common as to be nearly universal. Such universal categories include the encoding of the grammatical relations of participants and predicates by grammatically distinguishing between their relations to a predicate, the encoding of temporal and spatial relations on predicates, and a system of grammatical person governing reference to and distinction between speakers and addressees and those about whom they are speaking.[67]

Word Classes:

Languages organize their parts of speech into classes according to their functions and positions relative to other parts. All languages, for instance, make a basic distinction between a group of words that prototypically denotes things and concepts and a group of words that prototypically denotes actions and events. The first group, which includes English words such as "dog" and "song", are usually called nouns. The second, which includes "run" and "sing", are called verbs. Another common category is the adjective: words that describe properties or qualities of nouns, such as "red" or "big". Word classes can be "open" if new words can continuously be added to the class, or relatively "closed" if there is a fixed number of words in a class. In English, the class of pronouns is closed, whereas the class of adjectives is open, since infinite numbers of adjectives can be constructed from verbs (e.g. "saddened") or nouns (e.g. with the -like suffix "noun-like"). In other languages such as Korean, the situation is the opposite, and new pronouns can be constructed, whereas the number of adjectives is fixed.[68]

The word classes also carry out differing functions in grammar. Prototypically, verbs are used to construct predicates, while nouns are used as arguments of predicates. In a sentence such as "Sally runs", the predicate is "runs", because it is the word that predicates a specific state about its argument "Sally". Some verbs such as "curse" can take two arguments, e.g. "Sally cursed John.". A predicate that can only take a single argument is called intransitive, while a predicate that can take two arguments is called transitive.[69]

Many other word classes exist in different languages, such as conjunctions that serve to join two sentences, articles that introduce a noun, interjections such as "agh!" or "wow!", or ideophones that mimic the sound of some event. Some languages have positionals that describe the spatial position of an event or entity. Many languages have classifiers that identify countable nouns as belonging to a particular type or having a particular shape. For instance, in Japanese, the general noun classifier for humans is *nin* (人), and it is used for counting humans, whatever they are called:

san-nin no gakusei (三人の学生) lit. "3 human-classifier of student" — three students

For trees, it would be:

san-bon no ki (三本の木) lit. "3 classifier-for-long-objects of tree" — three trees

Morphology:

In linguistics, the study of the internal structure of complex words and the processes by which words are formed is called morphology. In most languages, it is possible to construct complex words that are built of several morphemes. For instance, the English word "unexpected" can be analyzed as being composed of the three morphemes "un-", "expect" and "-ed".[70]

Morphemes can be classified according to whether they are independent morphemes, so-called roots, or whether they can only co-occur attached to other morphemes. These bound morphemes or affixes can be classified according to their position in relation to the root: prefixes precede the root, suffixes follow the root, and infixes are inserted in the middle of a root. Affixes serve to modify or elaborate the meaning of the root.

Some languages change the meaning of words by changing the phonological structure of a word, for example, the English word "run", which in the past tense is "ran". This process is called ablaut. Furthermore, morphology distinguishes between the process of inflection, which modifies or elaborates on a word, and the process of derivation, which creates a new word from an existing one. In English, the verb "sing" has the inflectional forms "singing" and "sung", which are both verbs, and the derivational form "singer", which is a noun derived from the verb with the agentive suffix "-er".[71][72]

Languages differ widely in how much they rely on morphological processes of word formation. In some languages, for example, Chinese, there are no morphological processes, and all grammatical information is encoded syntactically by forming strings of single words. This type of morpho-syntax is often called isolating, or analytic, because there is almost a full correspondence between a single word and a single aspect of meaning. Most languages have words consisting of several morphemes, but they vary in the degree to which morphemes are discrete units. In many languages, notably in most Indo-European languages, single morphemes may have several distinct meanings that cannot be analyzed into smaller segments. For example, in Latin, the word *bonus*, or "good", consists of the root *bon-*, meaning "good", and the suffix *-us*, which indicates masculine gender, singular number, and nominative case. These languages are called fusional languages, because several meanings may be fused into a single morpheme. The opposite type of fusional languages are agglutinative languages, which construct words by stringing morphemes together in chains, but with each morpheme as a discrete semantic unit. An example of such a language is Turkish, where for example, the word *evlerinizden*, or "from your houses", consists of the morphemes, *ev-ler-iniz-den* with the meanings *house-plural-your-from*. The languages that rely on morphology to the greatest extent are traditionally called polysynthetic languages. They may express the equivalent of an entire English sentence in a single word. For example, in the Yupik word *tuntussuqatarniksaitengqiggtuq*, which means "He had not yet said again that he was going to hunt reindeer", the word consists of the morphemes *tuntu-ssur-qatar-ni-ksaite-ngqiggte-uq* with the meanings, "reindeer-hunt-future-say-negation-again-third.person.singular.indicative", and except for the morpheme *tuntu* ("reindeer") none of the other morphemes can appear in isolation.[73]

Many languages use morphology to cross-reference words within a sentence. This is sometimes called agreement. For example, in many Indo-European languages, adjectives must cross-reference the noun they modify in terms of number, case, and gender, so that the Latin adjective *bonus*, or "good", is inflected to agree with a noun that is masculine gender and singular. In many polysynthetic languages, verbs cross-reference their subjects and objects. In these types of languages, a single verb may include information that would require an entire sentence in English. For example, in the Basque phrase *ikusi nauzu*, or "you saw me", the past tense auxiliary verb *n-au-zu* (similar to English "do") agrees with both the subject (you) expressed by the *n-* prefix, and with the object (me) expressed by the *-zu* suffix. The sentence could be directly transliterated as "see you-did-me"[74]

Morpheme:

In linguistics, a **morpheme** is the smallest grammatical unit in a language. The field of study dedicated to morphemes is called morphology. A morpheme is not identical to a word, and the principal difference between the two is that a morpheme may or may not stand alone, whereas a word, by definition, is freestanding. Every word comprises one or more morphemes.

Syntax:

Main article: Syntax

In addition to word classes, a sentence can be analyzed in terms of grammatical functions: "The cat" is the subject of the phrase, "on the mat" is a locative phrase, and "sat" is the core of the predicate.

Another way in which languages convey meaning is through the order of words within a sentence. The grammatical rules for how to produce new sentences from words that are already known is called syntax. The syntactical rules of a language determine why a sentence in English such as "I love you" is meaningful, but "*love you I" is not.[notes 3] Syntactical rules determine how word order and sentence structure is constrained, and how those constraints contribute to meaning.[75] For example, in English, the two sentences "the slaves were cursing the master" and "the master was cursing the slaves" mean different things, because the role of the grammatical subject is encoded by the noun being in front of the verb, and the role of object is encoded by the noun appearing after the verb. Conversely, in Latin, both *Dominus servos vituperabat* and *Servos vituperabat dominus* mean "the master was reprimanding the slaves", because *servos*, or "slaves", is in the accusative case, showing that they are the grammatical object of the sentence, and *dominus*, or "master", is in the nominative case, showing that he is the subject.[76]

Latin uses morphology to express the distinction between subject and object, whereas English uses word order. Another example of how syntactic rules contribute to meaning is the rule of inverse word order in questions, which exists in many languages. This rule explains why when in English, the phrase "John is talking to Lucy" is turned into a question, it becomes "Who is John talking to?", and not "John is talking to who?". The latter example may be used as a way of placing special emphasis on "who", thereby slightly altering the meaning of the question. Syntax also includes the rules for how complex sentences are structured by grouping words together in units, called phrases, that can occupy different places in a larger syntactic structure. Sentences can be described as consisting of phrases connected in a tree structure, connecting the phrases to each other at different levels.[77] To the right is a graphic representation of the syntactic analysis of the English sentence "the cat sat on the mat". The sentence is analyzed as being constituted by a noun phrase, a verb, and a prepositional phrase; the prepositional phrase is further divided into a preposition and a noun phrase, and the noun phrases consist of an article and a noun.[78]

The reason sentences can be seen as being composed of phrases is because each phrase would be moved around as a single element if syntactic operations were carried out. For example, "the cat" is one phrase, and "on the mat" is another, because they would be treated as single units if a decision was made to emphasize the location by moving forward the prepositional phrase: "[And] on the mat, the cat sat".[78] There are many different formalist and functionalist frameworks that propose theories for describing syntactic structures, based on different assumptions about what language is and how it should be described. Each of them would analyze a sentence such as this in a different manner.[15]

Typology and Universals:

Main articles: Linguistic typology *and* Linguistic universal

Languages can be classified in relation to their grammatical types. Languages that belong to different families nonetheless often have features in common, and these shared features tend to correlate.[79] For example, languages can be classified on the basis of their basic word order, the relative order of the verb, and its constituents in a normal indicative sentence. In English, the basic order is SVO: "The snake(S) bit(V) the man(O)", whereas for example, the corresponding sentence in the Australian language Gamilaraay would be *ḍuyugu ṇama ḍayn yi:y* (Snake Man Bit), SOV.[80] Word order type is relevant as a typological parameter, because basic word order type corresponds with other syntactic parameters, such as the relative order of nouns and adjectives, or of the use of prepositions or postpositions. Such correlations are called implicational universals. For example, most (but not all) languages that are of the SOV type have postpositions rather than prepositions, and have adjectives before nouns.[81]

Through the study of various types of word order, it has been discovered that not all languages group the relations between actors and actions into Subject, Object and Verb, as English does. This type is called the nominative-accusative type. Some languages called ergative, Gamilaraay among them, distinguish between Agents and Patients. In English transitive clauses, both the subject of intransitive sentences ("I run") and transitive sentences ("I love you") are treated in the same way, shown here by the nominative pronoun *I*. In ergative languages, the single participant in an intransitive sentence, such as "I run", is treated the same as the patient in a transitive sentence, giving the equivalent of "me run" and "you love me". Only in transitive sentences would the equivalent of the pronoun "I" be used.[80] In this way the semantic roles can map onto the grammatical relations in different ways, grouping an intransitive subject either with Agents (accusative type) or Patients (ergative type) or even making each of the three roles differently, which is called the tripartite type.[82]

The shared features of languages which belong to the same typological class type may have arisen completely independently. Their co-occurrence might be due to the universal laws governing the structure of natural languages, "language universals", or they might be the result of languages evolving convergent solutions to the recurring communicative problems that humans use language to solve.[16]

Social Contexts of Use and Transmission:

While all humans have the ability to learn any language, they only do so if they grow up in an environment in which language exists and is used by others. Language is therefore dependent on communities of speakers in which children learn language from their elders and peers and themselves transmit language to their own children. Languages are used by those who speak them to communicate and to solve a plethora of social tasks. Many aspects of language use can be seen to be adapted specifically to these purposes.[16] Due to the way in which language is transmitted between generations and within communities, language perpetually changes, diversifying into new languages or converging due to language contact. The process is similar to the process of evolution, where the process of descent with modification leads to the formation of a phylogenetic tree.[83]

However, languages differ from a biological organisms in that they readily incorporate elements from other languages through the process of diffusion, as speakers of different languages come into contact. Humans also frequently speak more than one language, acquiring their first language or languages as children, or learning new languages as they grow up. Because of the increased language contact in the globalizing world, many small languages are becoming endangered as their speakers shift to other languages that afford the possibility to participate in larger and more influential speech communities.[84]

Additional Categories:

Linguistics:

Outline of Linguistics:

Summary:

See also: Index of linguistics articles

The following outline is provided as an overview of and topical guide to linguistics:Linguistics is the scientific study of natural language. Someone who engages in this study is called a linguist. Linguistics can be theoretical or applied.

Questions In Linguistics:

1.What is language?

2.How did it/does it evolve?

3.How does language serve as a medium of communication?

4.How does language serve as a medium of thinking?

5.What is common to all languages?

6.How do languages differ?

Basic Concepts:

What basic concepts / terms do I have to know to talk about linguistics?

•Morphology

•morpheme, inflection, paradigm, declension, derivation, compound

•Phonology

•phoneme, allophone, segment, mora, syllable, foot, stress, tone

•Grammar

•tense, aspect, mood and modality, grammatical number, grammatical gender, case

•Syntax

•phrase, clause, grammatical function, grammatical voice

•Lexicology

•word, lexeme, lemma, lexicon, vocabulary, terminology

•Semantics

•meaning, sense, entailment, truth condition, compositionality

•Pragmatics

•presupposition, implicature, deixis

History of Linguistics:

Timeline of Basic Linguistic Concepts:

Main article: History of linguistics

•Unsolved problems in linguistics

Timeline of discovery of basic linguistics concepts[edit]

When were the basic concepts first described and by whom?

•Ancient Sanskrit grammarians

•Ancient Greek study of language

•Roman elaborations of Greek study

•Medieval philosophical work in Latin

•Beginnings of modern linguistics in the 19th century

•Behaviorism and mental *tabula rasa* hypothesis

•Chomsky and functionalism

•Generative grammar leads to generative phonology and semantics

•Alternate syntactic systems develop in 80s

•Computational linguistics becomes feasible the late 80s

•Neurolinguistics and the biological basis of cognition

Nature of Linguistics:

Linguistics can be described as all of the following:

•Academic discipline – body of knowledge given to - or received by - a disciple (student); a branch or sphere of knowledge, or field of study, that an individual has chosen to specialise in.

•Field of science – widely-recognized category of specialized expertise within science, and typically embodies its own terminology and nomenclature. Such a field will usually be represented by one or more scientific journals, where peer reviewed research is published. There are many sociology-related scientific journals.

•Social science – field of academic scholarship that explores aspects of human society related to the language it speaks.

Branches of Linguistics:

•Theoretical linguistics

•Cognitive linguistics

•Generative linguistics

•Functional theories of grammar

•Quantitative linguistics

•Phonology

•Graphemics

•Morphology

•Syntax
•Lexis
•Semantics
•Pragmatics
•Descriptive linguistics
•Anthropological linguistics
•Comparative linguistics
•Historical linguistics
•Phonetics
•Graphetics
•Etymology
•Sociolinguistics
•Applied linguistics
•Computational linguistics
•Evolutionary linguistics
•Forensic linguistics
•Internet linguistics
•Language acquisition
•Language assessment
•Language development
•Language education
•Linguistic anthropology
•Neurolinguistics
•Psycholinguistics
•Second-language acquisition

Subfields by Linguistic Structures Studied:

Sub-fields of structure-focused linguistics include:

•Phonetics – study of the physical properties of speech (or signed) production and perception

•Phonology – study of sounds (or signs) as discrete, abstract elements in the speaker's mind that distinguish meaning

•Morphology – study of internal structures of words and how they can be modified

•Syntax – study of how words combine to form grammatical sentences

•Semantics – study of the meaning of words (lexical semantics) and fixed word combinations (phraseology), and how these combine to form the meanings of sentences

•Pragmatics – study of how utterances are used in communicative acts – and the role played by context and nonlinguistic knowledge in the transmission of meaning

•Discourse analysis – analysis of language use in texts (spoken, written, or signed)

Subfields, By Nonlinguistic Factors Studied:

•Applied linguistics – study of language-related issues applied in everyday life, notably language policies, planning, and education. (Constructed language fits under Applied linguistics.)

•Biolinguistics – study of natural as well as human-taught communication systems in animals, compared to human language.

•Clinical linguistics – application of linguistic theory to the field of Speech-Language Pathology.

•Computational linguistics – study of linguistic issues in a way that is 'computationally responsible', i.e., taking careful note of computational consideration of algorithmic specification and computational complexity, so that the linguistic theories devised can be shown to exhibit certain desirable computational properties implementations.

•Developmental linguistics – study of the development of linguistic ability in individuals, particularly the acquisition of language in childhood.

•Evolutionary linguistics – study of the origin and subsequent development of language by the human species.

•Historical linguistics – study of language change over time. Also called diachronic linguistics.

•Language geography – study of the geographical distribution of languages and linguistic features.

•Linguistic typology – study of the common properties of diverse unrelated languages, properties that may, given sufficient attestation, be assumed to be innate to human language capacity.

•Neurolinguistics – study of the structures in the human brain that underlie grammar and communication.

•Psycholinguistics – study of the cognitive processes and representations underlying language use.

•Sociolinguistics – study of variation in language and its relationship with social factors.

•Stylistics – study of linguistic factors that place a discourse in context.

Additional Article References:

Other subfields of linguistics[edit]

•Contrastive linguistics

•Corpus linguistics

•Dialectology

•Discourse analysis

•Grammar

•Interlinguistics

•Language didactics

•Language learning

•Language teaching

•Language for specific purposes

•Lexicology

•Linguistic statistics

•Orthography

•Rhetoric

•Text linguistics

Schools, movements, and approaches of linguistics[edit]

•Cognitive linguistics

•Danish School

•Functionalism

•Generative linguistics

•Geneva School

•Neo-Grammarians

•Prague School

•Prescription and description

•Soviet linguistics

•Stratificational linguistics

•Structuralism

•Systemic linguistics

•SIL International

•Tagmemics

Summary:

Linguistics is the scientific study of human language.[1][2][3][4][5] Linguistics can be broadly broken into three categories or subfields of study: language form, language meaning, and language in context. The earliest known activities in descriptive linguistics have been attributed to Pāṇini around 500 BCE, with his analysis of Sanskrit in *Ashtadhyayi*.[6]

One subfield of linguistics is the study of language structure, or grammar. This focuses on the system of rules followed by the users of a language. It includes the study of morphology (the formation and composition of words), syntax (the formation and composition of phrases and sentences from these words), and phonology (sound systems). Phonetics is a related branch of linguistics concerned with the actual properties of speech sounds and nonspeech sounds, and how they are produced and perceived.

The study of language meaning is concerned with how languages employ logical structures and real-world references to convey, process, and assign meaning, as well as to manage and resolve ambiguity. This category includes the study of semantics (how meaning is inferred from words and concepts) and pragmatics (how meaning is inferred from context).

Linguistics also looks at the broader context in which language is influenced by social, cultural, historical and political factors. This includes the study of evolutionary linguistics, which investigates into questions related to the origins and growth of languages; historical linguistics, which explores language change; sociolinguistics, which looks at the relation between linguistic variation and social structures; psycholinguistics, which explores the representation and function of language in the mind; neurolinguistics, which looks at language processing in the brain; language acquisition, on how children or adults acquire language; and discourse analysis, which involves the structure of texts and conversations.

Although linguistics is the scientific study of language, a number of other intellectual disciplines are relevant to language and intersect with it. Semiotics, for example, is the general study of signs and symbols both within language and without. Literary theorists study the use of language in literature. Linguistics additionally draws on and informs work from such diverse fields as acoustics, anthropology, biology, computer science, human anatomy, informatics, neuroscience, philosophy, psychology, sociology, and speech-language pathology.

Terminology:

Before the 20th century, the term philology, first attested in 1716,[7] was commonly used to refer to the science of language, which was then predominantly historical in focus.[8] Since Ferdinand de Saussure's insistence on the importance of synchronic analysis, however, this focus has shifted[9] and the term "philology" is now generally used for the "study of a language's grammar, history, and literary tradition", especially in the United States,[10] where it was never as popular as it was elsewhere (in the sense of the "science of language").[7]

Although the term "linguist" in the sense of "a student of language" dates from 1641,[11] the term "linguistics" is first attested in 1847.[11] It is now the usual academic term in English for the scientific study of language.

The term *linguist* applies within the field to someone who studies language, or specific languages. Outside the field, this term is commonly used to refer to people who speak many languages fluently.[12]

Fundamental Questions:

Linguistics concerns itself with describing and explaining the nature of human language. Fundamental questions include what is universal to language, how language can vary, and how human beings come to know languages. Linguistic research can broadly be divided into the descriptive analysis of structure and grammar on the one hand and the study of non-linguistic influences on language on the other.

Formal and Functional Approaches:

One major debate in linguistics concerns how language should be defined and understood. One prominent group of linguists use the term "language" primarily to refer to a hypothesised, innate module in the human brain that allows people to undertake linguistic behaviour. This "Universal grammar" is considered to guide children when they learn languages and to constrain what sentences are considered grammatical in any language. Proponents of this view, which is predominant in those schools of linguistics that are based on the generative theory of Noam Chomsky, do not necessarily consider that language evolved for communication in particular. They consider instead that it has more to do with the process of structuring human thought (see also formal grammar).

Another group of linguists, by contrast, use the term "language" to refer to a communication system that developed to support cooperative activity and extend cooperative networks. Such functional theories of grammar view language as a tool that emerged and is adapted to the communicative needs of its users, and the role of cultural evolutionary processes are often emphasised over that of biological evolution.

Variation and Universality:

While some theories on linguistics focus on the different varieties that language produces, among different sections of society, others focus on the universal properties that are common to all given languages at one given time on the planet. The theory of variation therefore would elaborate on the different usages of popular languages like French and English across the globe, as well as its smaller dialects and regional permutations within their national boundaries. The theory of variation looks at the cultural stages that a particular language undergoes, and these include the following. The first stage is pidgin, or that phase in the creation of a language's variation when new, non-native speakers undertake a mainstream language and use its phrases and words in a broken manner that often attempts to be overly literal in meaning. At this junction, many of the linguistic characteristics of the native speakers' own language or mother tongue influence their use of the mainstream language, and that is when it arrives at the stage of being called a creole. Hence, this process in the creation of dialects and varieties of languages as globally popular as English and French, as well as others like Spanish, for instance, is one that is rooted in the changing evolution and growth of each language. These variating factors are studied in order to understand the different usages and dialects that a language develops over time.

Dialects:

A dialect is a variety of a language that is a characteristic of a particular group of the language's speakers.[13] The group of people who are the speakers of a dialect are usually bound to each other by social identity. This is what differentiates a dialect from a discourse. These are speech varieties that have not been given an official status as a language. Dialects often get the status of a language due to political and social reasons. The popular saying that a "language is a dialect with an army and navy" is attributed as a definition of a language to Max Weinreich.

A discourse is a way of speaking that emerges within a certain social setting, and is based on a certain subject matter. There are certain lexical additions (new words) that are brought into play because of the expertise of the community of people within a certain domain of specialisation. People in the medical fraternity, for example, may use some medical terminology in their communication that is specialised to the field of medicine. This is often referred to as being part of the medical discourse, and so on and so forth.

Universal grammar takes into account general formal structures and features that are common to all languages (official as well as those that are considered as dialects), and the template of which pre-exists in the mind of an infant child. This idea is based on the theory of generative grammar and the formal school of linguistics, whose proponents include Noam Chomsky and those who follow his theory and work.

"We may as individuals be rather fond of our own dialect. This should not make us think, though, that it is actually any better than any other dialect. Dialects are not good or bad, nice or nasty, right or wrong – they are just different from one another, and it is the mark of a civilised society that it tolerates different dialects just as it tolerates different races, religions and sexes." [14]

Schools of Thought:

Early Grammarians:

Historicism:

Structuralism:

Main article: Structuralism (linguistics)

Early in the 20th century, Saussure introduced the idea of language as a static system of interconnected units, defined through the oppositions between them. By introducing a distinction between diachronic to synchronic analyses of language, he laid the foundation of the modern discipline of linguistics. Saussure also introduced several basic dimensions of linguistic analysis that are still foundational in many contemporary linguistic theories, such as the distinctions between syntagm and paradigm, and the langue- parole distinction, distinguishing language as an abstract system (*langue*) from language as a concrete manifestation of this system (*parole*).[20] Substantial additional contributions following Saussure's definition of a structural approach to language came from The Prague school, Leonard Bloomfield, Charles F. Hockett, Louis Hjelmslev, Émile Benveniste and Roman Jakobson.[21]

Generativism:

Main article: Generative linguistics

During the last half of the 20th century, following the work of Noam Chomsky, linguistics was dominated by the generativist school. While formulated by Chomsky in part as a way to explain how human beings acquire language and the biological constraints on this acquisition, in practice it has largely been concerned with giving formal accounts of specific phenomena in natural languages. Generative theory is modularist and formalist in character. Chomsky built on earlier work of Zellig Harris to formulate the generative theory of language. According to this theory the most basic form of language is a set of syntactic rules universal for all humans and underlying the grammars of all human languages. This set of rules is called Universal Grammar, and for Chomsky describing it is the primary objective of the discipline of linguistics. For this reason the grammars of individual languages are of importance to linguistics only in so far as they allow us to discern the universal underlying rules from which the observable linguistic variability is generated.

In the classic formalization of generative grammars first proposed by Noam Chomsky in the 1950s,[22][23] a grammar *G* consists of the following components:

•A finite set *N* of nonterminal symbols, none of which appear in strings formed from *G*.

•A finite set of terminal symbols that is disjoint from *N*.

•A finite set *P* of *production rules*, that map from one string of symbols to another.

A formal description of language attempts to replicate a speaker's knowledge of the rules of their language, and the aim is to produce a set of rules that is minimally sufficient to successfully model valid linguistic forms.

Functionalism:

Main article: Functional theories of grammar

Functional theories of language propose that since language is fundamentally a tool, it is reasonable to assume that its structures are best analyzed and understood with reference to the functions they carry out. Functional theories of grammar differ from formal theories of grammar, in that the latter seeks to define the different elements of language and describe the way they relate to each other as systems of formal rules or operations, whereas the former defines the functions performed by language and then relates these functions to the linguistic elements that carry them out. This means that functional theories of grammar tend to pay attention to the way language is actually used, and not just to the formal relations between linguistic elements.[24]

Functional theories then describe language in term of functions existing on all levels of language.

•Phonological function: the function of the phoneme is to distinguish between different lexical material.

•Semantic function: (Agent, Patient, Recipient, etc.), describing the role of participants in states of affairs or actions expressed.

•Syntactic functions: (e.g. subject and Object), defining different perspectives in the presentation of a linguistic expression

•Pragmatic functions: (Theme and Rheme, Topic and Focus, Predicate), defining the informational status of constituents, determined by the pragmatic context of the verbal interaction. Functional descriptions of grammar strive to explain how linguistic functions are performed in communication through the use of linguistic forms.

Cognitive Linguistics:

Main article: Cognitive linguistics

In the 1970s and 1980s, a new school of thought known as cognitive linguistics emerged as a reaction to generativist theory. Led by theorists such as Ronald Langacker and George Lakoff, linguists working within the realm of cognitive linguistics propose that language is an emergent property of basic, general-purpose cognitive processes. In contrast to the generativist school of linguistics, cognitive linguistics is non-modularist and functionalist in character. Important developments in cognitive linguistics include cognitive grammar, frame semantics, and conceptual metaphor, all of which are based on the idea that form-function correspondences based on representations derived from embodied experience constitute the basic units of

language.
Cognitive linguistics interprets language in terms of the concepts, sometimes universal, sometimes specific to a particular tongue, which underlie its forms. It is thus closely associated with semantics but is distinct from psycholinguistics, which draws upon empirical findings from cognitive psychology in order to explain the mental processes that underlie the acquisition, storage, production and understanding of speech and writing. Cognitive linguistics denies that there is an *autonomous linguistic faculty* in the mind; it understands grammar in terms of *conceptualization*; and it claims that knowledge of language arises out of *language use*.[25] Because of its conviction that knowledge of language is learned through use, cognitive linguistics is sometimes considered to be a functional approach, but it differs from other functional approaches in that it is primarily concerned with how the mind creates meaning through language, and not with the use of language as a tool of communication.
Sub-disciplines:
Linguistic Structures:
Linguistic structures are pairings of meaning and form. Any particular pairing of meaning and form is a Saussurean sign. For instance, the meaning "cat" is represented worldwide with a wide variety of different sound patterns (in oral languages), movements of the hands and face (in sign languages), and written symbols (in written languages).
Linguists focusing on structure attempt to understand the rules regarding language use that native speakers know (not always consciously). All linguistic structures can be broken down into component parts that are combined according to (sub)conscious rules, over multiple levels of analysis. For instance, consider the structure of the word "tenth" on two different levels of analysis. On the level of internal word structure (known as morphology), the word "tenth" is made up of one linguistic form indicating a number and another form indicating ordinality. The rule governing the combination of these forms ensures that the ordinality marker "th" follows the number "ten." On the level of sound structure (known as phonology), structural analysis shows that the "n" sound in "tenth" is made differently from the "n" sound in "ten" spoken alone. Although most speakers of English are consciously aware of the rules governing internal structure of the word pieces of "tenth", they are less often aware of the rule governing its sound structure. Linguists focused on structure find and analyze rules such as these, which govern how native speakers use language.
Linguistics has many sub-fields concerned with particular aspects of linguistic structure. These sub-fields range from those focused primarily on form to those focused primarily on meaning. They also run the gamut of level of analysis of language, from individual sounds, to words, to phrases, up to discourse.
Sub-fields that focus on a structure-focused study of language:
•Phonetics, the study of the physical properties of speech (or signed) production and perception.
•Phonology, the study of sounds (or signs) as discrete, abstract elements in the speaker's mind that distinguish meaning (phonemes).

•Morphology, the study of morphemes, or the internal structures of words and how they can be modified
•Syntax, the study of how words combine to form grammatical sentences
•Semantics, the study of the meaning of words (lexical semantics) and fixed word combinations (phraseology), and how these combine to form the meanings of sentences
•Pragmatics, the study of how utterances are used in communicative acts, and the role played by context and non-linguistic knowledge in the transmission of meaning
•Discourse analysis, the analysis of language use in texts (spoken, written, or signed)
•Stylistics, the study of linguistic factors (rhetoric, diction, stress) that place a discourse in context.
•Semiotics, the study of signs and sign processes (semiosis), indication, designation, likeness, analogy, metaphor, symbolism, signification, and communication.

Many linguists would agree that these divisions overlap considerably, and the independent significance of each of these areas is not universally acknowledged. Regardless of any particular linguist's position, each area has core concepts that foster significant scholarly inquiry and research.

Inter-disciplinary Factors:

Alongside the structurally motivated domains of study, are other fields within the domain of linguistics. These fields are often distinguished by external factors that influence the study of language.

•Applied linguistics, the study of language-related issues applied in everyday life, notably language policies, planning, and education. (Constructed language fits under Applied linguistics.)
•Biolinguistics, the study of natural as well as human-taught communication systems in animals, compared to human language.
•Clinical linguistics, the application of linguistic theory to the field of Speech-Language Pathology.
•Computational linguistics, the study of linguistic issues in a way that is 'computationally responsible', i.e., taking careful note of computational consideration of algorithmic specification and computational complexity, so that the linguistic theories devised can be shown to exhibit certain desirable computational properties implementations.
•Developmental linguistics, the study of the development of linguistic ability in individuals, particularly the acquisition of language in childhood.
•Evolutionary linguistics, the study of the origin and subsequent development of language by the human species.
•Historical linguistics or diachronic linguistics, the study of language change over time.
•Language geography, the study of the geographical distribution of languages and linguistic features.
•Linguistic typology, the study of the common properties of diverse unrelated languages, properties that may, given sufficient attestation, be assumed to be innate to human language capacity.
•Neurolinguistics, the study of the structures in the human brain that underlie grammar and communication.
•Psycholinguistics, the study of the cognitive processes and representations underlying language use.

•Sociolinguistics, the study of variation in language and its relationship with social factors.Semiotics is a larger discipline that investigates the relationship between signs and what they signify more broadly. From the perspective of semiotics, language can be seen as a sign or symbol, with the world as its representation.[citation needed]

Sub-fields:

Historical Linguistics:

Main article: Historical linguistics

Historical linguists study the history of specific languages as well as general characteristics of language change. One aim of historical linguistics is to classify languages in language families descending from a common ancestor, an enterprise that relies primarily on the comparative method. This involves comparison of elements in different languages to detect possible cognates in order to be able to reconstruct how different languages have changed over time. Some historical linguists, along with non-linguists interested in language change, have also employed such tools as computational phylogenetics. The study of language change is also referred to as "diachronic linguistics", which can be distinguished from "synchronic linguistics", the study of a given language at a given moment in time without regard to its previous stages. Historical linguistics was among the first linguistic disciplines to emerge and was the most widely practised form of linguistics in the late 19th century. However, a shift in focus to the synchronic perspective began in the early twentieth century with Saussure and became predominant in western linguistics through the work of Noam Chomsky.

Semiotics:

Main article: SemioticsSemiotics is the study of sign processes (semiosis), or signification and communication, signs, and symbols, both individually and grouped into sign systems, including the study of how meaning is constructed and understood. Semioticians often do not restrict themselves to linguistic communication when studying the use of signs but extend the meaning of "sign" to cover all kinds of cultural symbols. Nonetheless, semiotic disciplines closely related to linguistics are literary studies, discourse analysis, text linguistics, and philosophy of language. Semiotics, within the linguistics paradigm, is the study of the relationship between language and culture. Historically, Edward Sapir and Ferdinand De Saussure's structuralist theories influenced the study of signs extensively until the late part of the 20th century, but later, post-modern and post-structural thought, through language philosophers including Jacques Derrida, Mikhail Bakhtin, Michel Foucault, and others, have also been a considerable influence on the discipline in the late part of the 20th century and early 21st century[citation needed]. These theories emphasise the role of language variation, and the idea of subjective usage, depending on external elements like social and cultural factors, rather than merely on the interplay of formal elements.

Language Documentation:

Main article: Language documentation

Since the inception of the discipline of linguistics, linguists have been concerned with describing and analysing previously undocumented languages. Starting with Franz Boas in the early 1900s, this became the main focus of American linguistics until the rise of formal structural linguistics in the mid-20th century. This focus on language documentation was partly motivated by a concern to document the rapidly disappearing languages of indigenous peoples. The ethnographic dimension of the Boasian approach to language description played a role in the development of disciplines such as sociolinguistics, anthropological linguistics, and linguistic anthropology, which investigate the relations between language, culture, and society.

The emphasis on linguistic description and documentation has also gained prominence outside North America, with the documentation of rapidly dying indigenous languages becoming a primary focus in many university programs in linguistics. Language description is a work-intensive endeavour, usually requiring years of field work in the language concerned, so as to equip the linguist to write a sufficiently accurate reference grammar. Further, the task of documentation requires the linguist to collect a substantial corpus in the language in question, consisting of texts and recordings, both sound and video, which can be stored in an accessible format within open repositories, and used for further research.[26]

Applied Linguistics:

Main article: Applied linguistics

Linguists are largely concerned with finding and describing the generalities and varieties both within particular languages and among all languages. Applied linguistics takes the results of those findings and "applies" them to other areas. Linguistic research is commonly applied to areas such as language education, lexicography, and translation. "Applied linguistics" has been argued to be something of a misnomer[who?], since applied linguists focus on making sense of and engineering solutions for real-world linguistic problems, not simply "applying" existing technical knowledge from linguistics; moreover, they commonly apply technical knowledge from multiple sources, such as sociology (e.g., conversation analysis) and anthropology.

Today, computers are widely used in many areas of applied linguistics. Speech synthesis and speech recognition use phonetic and phonemic knowledge to provide voice interfaces to computers. Applications of computational linguistics in machine translation, computer-assisted translation, and natural language processing are areas of applied linguistics that have come to the forefront. Their influence has had an effect on theories of syntax and semantics, as modeling syntactic and semantic theories on computers constraints.

Linguistic analysis is a sub-discipline of applied linguistics used by many governments to verify the claimed nationality of people seeking asylum who do not hold the necessary documentation to prove their claim.[27] This often takes the form of an interview by personnel in an immigration department. Depending on the country, this interview is conducted either in the asylum seeker's native language through an interpreter or in an international lingua franca like English.[27] Australia uses the former method, while Germany employs the latter; the Netherlands uses either method depending on the languages involved.[27] Tape recordings of the interview then undergo language analysis, which can be done either by private contractors or within a department of the government. In this analysis, linguistic features of the asylum seeker are used by analysts to make a determination about the speaker's nationality. The reported findings of the linguistic analysis can play a critical role in the government's decision on the refugee status of the asylum seeker.[27]

Translation:

The sub-field of translation includes the translation of written and spoken texts across mediums, from digital to print and spoken. To translate literally means to transmute the meaning from one language into another. Translators are often employed by organisations, such as travel agencies as well as governmental embassies to facilitate communication between two speakers who do not know each other's language. Translators are also employed to work within computational linguistics setups like Google Translate for example, which is an automated, programmed facility to translate words and phrases between any two or more given languages. Translation is also conducted by publishing houses, who convert works of writing from one language to another in order to reach varied audiences.

Phonology:

Summary:

Phonology is a branch of linguistics concerned with the systematic organization of sounds in languages. It has traditionally focused largely on study of the systems of phonemes in particular languages, but it may also cover any linguistic analysis either at a level beneath the word (including syllable, onset and rhyme, articulatory gestures, articulatory features, mora, etc.) or at all levels of language where sound is considered to be structured for conveying linguistic meaning. Phonology also includes the study of equivalent organizational systems in sign languages.

The word *phonology* (as in *the phonology of English*) can also refer to the phonological system (sound system) of a given language. This is one of the fundamental systems which a language is considered to comprise, like its syntax and its vocabulary.

Phonology is often distinguished from *phonetics*. While phonetics concerns the physical production, acoustic transmission and perception of the sounds of speech,[1][2] phonology describes the way sounds function within a given language or across languages to encode meaning. For many linguists, phonetics belongs to descriptive linguistics, and phonology to theoretical linguistics, although establishing the phonological system of a language is necessarily an application of theoretical principles to analysis of phonetic evidence. Note that this distinction was not always made, particularly before the development of the modern concept of phoneme in the mid 20th century. Some subfields of modern phonology have a crossover with phonetics in descriptive disciplines such as psycholinguistics and speech perception, resulting in specific areas like articulatory phonology or laboratory phonology.

Phoneme:

Summary:

A **phoneme** is a basic unit of a language's phonology, which is combined with other phonemes to form meaningful units such as words or morphemes. The phoneme can be described as "The smallest contrastive linguistic unit which may bring about a change of meaning".[1] In this way the difference in meaning between the English words *kill* and *kiss* is a result of the exchange of the phoneme /l/ for the phoneme /s/. Two words that differ in meaning through a contrast of a single phoneme are called minimal pairs.

Within linguistics there are differing views as to exactly what phonemes are and how a given language should be analyzed in phonemic terms. However, a phoneme is generally regarded as an abstraction of a set (or equivalence class) of speech sounds (phones) which are perceived as equivalent to each other in a given language. For example, in English, the "k" sounds in the words *kit* and *skill* are not identical (as described below), but they are distributional variants of a single phoneme, /k/. Different speech sounds representing the same phoneme are known as allophones, and such variation may be conditioned, in which case a certain phoneme is realized as a certain allophone in particular phonological environments, or it may be free in which case it may vary randomly. In this way, phonemes are often considered to constitute an abstract underlying representation for words, while speech sounds make up the corresponding phonetic realization, or surface form.

Writing:

Writing System:

Summary:

A **writing system** is an organized regular method (typically standardized) of information storage and transfer for the communication of messages (expressing thoughts or ideas) in a language by visually (or possibly tactilely) encoding and decoding (known as writing and reading) with a set of signs or symbols, both known generally as characters (with the set collective referred to as a 'script').[1] These characters, often including letters and numbers, are usually recorded onto a durable medium such as paper or electronic storage/display, although non-durable methods may also be used, such as writing in sand or skywriting.

The general attributes of writing systems can be placed into broad categories such as alphabets, syllabaries, or logographies. Any particular system can have attributes of more than one category. In the alphabetic category, there is a standard set of letters (basic written symbols or graphemes) of consonants and vowels that encode based on the general principle that the letters (or letter pair/groups) represent phonemes (basic significant sounds) of the spoken language. A syllabary typically correlates a symbol to a syllable (which can be a pairing or group of phonemes, and are considered the building blocks of words). In a logography, each character represents a word, morpheme or semantic unit (which themselves can be pairings or groups of syllables). Other categories include abjads (which is an alphabet where vowels are not indicated at all) and abugidas, also called alphasyllabaries (where vowels are shown by diacritics or other modification of consonants). A system's category can often be determined just by identifying the number of symbols used within the system. Alphabets typically use a set of 20-to-35 symbols to fully express a language, whereas syllabaries can have 80-to-100, and logographies can have several hundreds of symbols.

Most systems will typically have an ordering of its symbol elements so that groups of them can be coded into larger clusters like words or acronyms (generally lexemes), giving rise to many more possibilities (permutations) in meanings than the symbols can convey by themselves. Systems will also enable the concatenation (a "stringing together") of these smaller groupings (sometimes referred to by the generic term 'character strings') in order to enable a full expression of the language. The reading step can be accomplished by the reader purely in the mind as an internal process, or expressed verbally (typically, 'reading aloud'). Historically, writing systems have developed after a spoken language has been established, although the individual symbols used (typically an ideogram) may have preceded the spoken word. A special set of symbols known as punctuation is used to aid in structure and organization of many writing systems and can be used to help capture nuances and variations in the message's meaning that are communicated verbally by cues in timing, tone, accent, inflection or intonation.

A writing system will also typically have a method for formatting recorded messages that follows the spoken version's rules like its grammar and syntax so that the reader will have the meaning of the intended message accurately preserved. Writing systems were preceded by proto-writing, which used pictograms, ideograms and other mnemonic symbols. Proto-writing lacked the ability to capture and express a full range of thoughts and ideas. The invention of writing systems, which dates back to the beginning of the Bronze Age in the late Neolithic Era of the late 4th millennium BCE, enabled the accurate durable recording of human history in a manner that was not prone to the same types of error to which oral history is vulnerable. Soon after, it provided a reliable form of long distance communication. And with the advent of publishing, it provided the medium for an early form of mass communication. Secure written communications were also made more reliable with the invention of encryption.

Grapheme:

A **grapheme** is the smallest semantically distinguishing unit in a written language, analogous to the phonemes of spoken languages. A grapheme may or may not carry meaning by itself, and may or may not correspond to a single phoneme. Graphemes include alphabetic letters, typographic ligatures, Chinese characters, numerical digits, punctuation marks, and other individual symbols of any of the world's writing systems.

The word *grapheme* is derived from Greek γράφω *gráphō* ("write"), and the suffix -*eme*, by analogy with phoneme and other names of emic units. The study of graphemes is called graphemics.

A grapheme is an abstract concept, similar to a character in computing. A glyph is a specific shape that represents that grapheme, in a specific typeface. For example, the abstract concept of "the Arabic numeral one" is a grapheme, which would have two different glyphs (allographs) in the fonts Times New Roman and Helvetica.

Additional Detailed Research:

Syntax:

Machine:

Etymology:

The word machine derives from the Latin word *machina*,[1] which in turn derives from the Greek (Doric μαχανά *makhana*, Ionic μηχανή *mekhane* "contrivance, machine, engine",[2] a derivation from μῆχος *mekhos* "means, expedient, remedy"[3]).

A wider meaning of "fabric, structure" is found in classical Latin, but not in Greek usage. This meaning is found in late medieval French, and is adopted from the French into English in the mid-16th century. In the 17th century, the word could also mean a scheme or plot, a meaning now expressed by the derived machination. The modern meaning develops out of specialized application of the term to stage engines used in theater and to military siege engines, both in the late 16th and early 17th centuries. The OED traces the formal, modern meaning to John Harris' Lexicon Technicum (1704), which has:

Machine, or Engine, in Mechanicks, is whatsoever hath Force sufficient either to raise or stop the Motion of a Body... Simple Machines are commonly reckoned to be Six in Number, viz. the Ballance, Leaver, Pulley, Wheel, Wedge, and Screw... Compound Machines, or Engines, are innumerable.

The word engine used as a (near-)synonym both by Harris and in later language derives ultimately (via Old French) from Latin *ingenium* "ingenuity, an invention".

Summary:

Further information: Equipment (disambiguation)

James Albert Bonsack's cigarette rolling machine, invented in 1880 and patented in 1881.

A **machine** is a tool that consists of one or more parts, and uses energy to achieve a particular goal. Machines are usually powered by mechanical, chemical, thermal, or electrical means, and are frequently motorized. Historically, a powered tool also required moving parts to classify as a machine; however, the advent of electronics technology has led to the development of powered tools without moving parts that are considered machines.[1]

A simple machine is a device that simply transforms the direction or magnitude of a force, but a large number of more complex machines exist. Examples include vehicles, electronic systems, molecular machines, computers, television, and radio.

Manufacturing: (further research is required)

Summary:

Manufacturing is the production of goods for use or sale using labor and machines, tools, chemical and biological processing, or formulation. The term may refer to a range of human activity, from handicraft to high tech, but is most commonly applied to industrial production, in which raw materials are transformed into finished goods on a large scale. Such finished goods may be used for manufacturing other, more complex products, such as aircraft, household appliances or automobiles, or sold to wholesalers, who in turn sell them to retailers, who then sell them to end users – the "consumers".

Manufacturing takes turns under all types of economic systems. In a free market economy, manufacturing is usually directed toward the mass production of products for sale to consumers at a profit. In a collectivist economy, manufacturing is more frequently directed by the state to supply a centrally planned economy. In mixed market economies, manufacturing occurs under some degree of government regulation.

Modern manufacturing includes all intermediate processes required for the production and integration of a product's components. Some industries, such as semiconductor and steel manufacturers use the term *fabrication* instead.

The manufacturing sector is closely connected with engineering and industrial design. Examples of major manufacturers in North America include General Motors Corporation, General Electric, and Pfizer. Examples in Europe include Volkswagen Group, Siemens, and Michelin. Examples in Asia include Toyota, Samsung, and Bridgestone.

Mathematics:

Mathematics:

Etymology:

The word *mathematics* comes from the Greek μάθημα (*máthēma*), which, in the ancient Greek language, means "that which is learnt",[24] "what one gets to know," hence also "study" and "science", and in modern Greek just "lesson." The word *máthēma* is derived from μανθάνω (*manthano*), while the modern Greek equivalent is μαθαίνω (*mathaino*), both of which mean "to learn." In Greece, the word for "mathematics" came to have the narrower and more technical meaning "mathematical study" even in Classical times.[25] Its adjective is μαθηματικός (*mathēmatikós*), meaning "related to learning" or "studious", which likewise further came to mean "mathematical". In particular, μαθηματικὴ τέχνη (*mathēmatikḗ tékhnē*), Latin: *ars mathematica*, meant "the mathematical art".

In Latin, and in English until around 1700, the term *mathematics* more commonly meant "astrology" (or sometimes "astronomy") rather than "mathematics"; the meaning gradually changed to its present one from about 1500 to 1800. This has resulted in several mistranslations: a particularly notorious one is Saint Augustine's warning that Christians should beware of *mathematici* meaning astrologers, which is sometimes mistranslated as a condemnation of mathematicians.

The apparent plural form in English, like the French plural form *les mathématiques* (and the less commonly used singular derivative *la mathématique*), goes back to the Latin neuter plural *mathematica* (Cicero), based on the Greek plural τα μαθηματικά (*ta mathēmatiká*), used by Aristotle (384–322 BC), and meaning roughly "all things mathematical"; although it is plausible that English borrowed only the adjective *mathematic(al)* and formed the noun *mathematics* anew, after the pattern of physics and metaphysics, which were inherited from the Greek.[26] In English, the noun *mathematics* takes singular verb forms. It is often shortened to *maths* or, in English-speaking North America, *math*.[27]

Summary:

Mathematics is the abstract study of topics such as quantity (numbers),[2] structure,[3] space,[2] and change.[4][5][6] There is a range of views among mathematicians and philosophers as to the exact scope and definition of mathematics.[7][8]Mathematicians seek out patterns[9][10] and formulate new conjectures. Mathematicians resolve the truth or falsity of conjectures by mathematical proof. When mathematical structures are good models of real phenomena, then mathematical reasoning can provide insight or predictions about nature. Through the use of abstraction and logic, mathematics developed from counting, calculation, measurement, and the systematic study of the shapes and motions of physical objects. Practical mathematics has been a human activity for as far back as written records exist. The research required to solve mathematical problems can take years or even centuries of sustained inquiry.Rigorous arguments first appeared in Greek mathematics, most notably in Euclid's Elements. Since the pioneering work of Giuseppe Peano (1858–1932), David Hilbert (1862–1943), and others on axiomatic systems in the late 19th century, it has become customary to view mathematical research as establishing truth by rigorous deduction from appropriately chosen axioms and definitions. Mathematics developed at a relatively slow pace until the Renaissance, when mathematical innovations interacting with new scientific discoveries led to a rapid increase in the rate of mathematical discovery that has continued to the present day.[11]Galileo Galilei (1564–1642) said, "The universe cannot be read until we have learned the language and become familiar with the characters in which it is written. It is written in mathematical language, and the letters are triangles, circles and other geometrical figures, without which means it is humanly impossible to comprehend a single word. Without these, one is wandering about in a dark labyrinth."[12] Carl Friedrich Gauss (1777–1855) referred to mathematics as "the Queen of the Sciences".[13] Benjamin Peirce (1809–1880) called mathematics "the science that draws necessary conclusions".[14] David Hilbert said of mathematics: "We are not speaking here of arbitrariness in any sense. Mathematics is not like a game whose tasks are determined by arbitrarily stipulated rules. Rather, it is a conceptual system possessing internal necessity that can only be so and by no means otherwise."[15] Albert Einstein (1879–1955) stated that "as far as the laws of mathematics refer to reality, they are not certain; and as far as they are certain, they do not refer to reality."[16] French mathematician Claire Voisin states "There is creative drive in mathematics, it's all about movement trying to express itself." [17]

Mathematics is used throughout the world as an essential tool in many fields, including natural science, engineering, medicine, finance and the social sciences. Applied mathematics, the branch of mathematics concerned with application of mathematical knowledge to other fields, inspires and makes use of new mathematical discoveries, which has led to the development of entirely new mathematical disciplines, such as statistics and game theory. Mathematicians also engage in pure mathematics, or mathematics for its own sake, without having any application in mind. There is no clear line separating pure and applied mathematics, and practical applications for what began as pure mathematics are often discovered.[18]

History:

Evolution:

Main article: History of mathematics

Greek mathematician Pythagoras (c. 570 – c. 495 BC), commonly credited with discovering the Pythagorean theorem.

The evolution of mathematics might be seen as an ever-increasing series of abstractions, or alternatively an expansion of subject matter. The first abstraction, which is shared by many animals,[19] was probably that of numbers: the realization that a collection of two apples and a collection of two oranges (for example) have something in common, namely quantity of their members.

Mayan numerals

Evidenced by tallies found on bone, in addition to recognizing how to count physical objects, prehistoric peoples may have also recognized how to count abstract quantities, like time – days, seasons, years.[20]

More complex mathematics did not appear until around 3000 BC, when the Babylonians and Egyptians began using arithmetic, algebra and geometry for taxation and other financial calculations, for building and construction, and for astronomy.[21] The earliest uses of mathematics were in trading, land measurement, painting and weaving patterns and the recording of time.

In Babylonian mathematics elementary arithmetic (addition, subtraction, multiplication and division) first appears in the archaeological record. Numeracy pre-dated writing and numeral systems have been many and diverse, with the first known written numerals created by Egyptians in Middle Kingdom texts such as the Rhind Mathematical Papyrus.[citation needed]

Between 600 and 300 BC the Ancient Greeks began a systematic study of mathematics in its own right with Greek mathematics.[22]

Mathematics has since been greatly extended, and there has been a fruitful interaction between mathematics and science, to the benefit of both. Mathematical discoveries continue to be made today. According to Mikhail B. Sevryuk, in the January 2006 issue of the Bulletin of the American Mathematical Society, "The number of papers and books included in the Mathematical Reviews database since 1940 (the first year of operation of MR) is now more than 1.9 million, and more than 75 thousand items are added to the database each year. The overwhelming majority of works in this ocean contain new mathematical theorems and their proofs."[23]

Definitions:

Main article: Definitions of mathematicsAristotle defined mathematics as "the science of quantity", and this definition prevailed until the 18th century.[28] Starting in the 19th century, when the study of mathematics increased in rigor and began to address abstract topics such as group theory and projective geometry, which have no clear-cut relation to quantity and measurement, mathematicians and philosophers began to propose a variety of new definitions.[29] Some of these definitions emphasize the deductive character of much of mathematics, some emphasize its abstractness, some emphasize certain topics within mathematics. Today, no consensus on the definition of mathematics prevails, even among professionals.[7] There is not even consensus on whether mathematics is an art or a science.[8] A great many professional mathematicians take no interest in a definition of mathematics, or consider it undefinable.[7] Some just say, "Mathematics is what mathematicians do."[7]

Three leading types of definition of mathematics are called logicist, intuitionist, and formalist, each reflecting a different philosophical school of thought.[30] All have severe problems, none has widespread acceptance, and no reconciliation seems possible.[30]

An early definition of mathematics in terms of logic was Benjamin Peirce's "the science that draws necessary conclusions" (1870).[31] In the Principia Mathematica, Bertrand Russell and Alfred North Whitehead advanced the philosophical program known as logicism, and attempted to prove that all mathematical concepts, statements, and principles can be defined and proven entirely in terms of symbolic logic. A logicist definition of mathematics is Russell's "All Mathematics is Symbolic Logic" (1903).[32]Intuitionist definitions, developing from the philosophy of mathematician L.E.J. Brouwer, identify mathematics with certain mental phenomena. An example of an intuitionist definition is "Mathematics is the mental activity which consists in carrying out constructs one after the other."[30] A peculiarity of intuitionism is that it rejects some mathematical ideas considered valid according to other definitions. In particular, while other philosophies of mathematics allow objects that can be proven to exist even though they cannot be constructed, intuitionism allows only mathematical objects that one can actually construct.Formalist definitions identify mathematics with its symbols and the rules for operating on them. Haskell Curry defined mathematics simply as "the science of formal systems".[33] A formal system is a set of symbols, or *tokens*, and some *rules* telling how the tokens may be combined into *formulas*. In formal systems, the word *axiom* has a special meaning, different from the ordinary meaning of "a self-evident truth". In formal systems, an axiom is a combination of tokens that is included in a given formal system without needing to be derived using the rules of the system.

Inspiration, Pure and Applied Mathematics, and Aesthetics:

Main article: Mathematical beauty

Sir Isaac Newton (1643–1727), an inventor of infinitesimal calculus.

Mathematics arises from many different kinds of problems. At first these were found in commerce, land measurement, architecture and later astronomy; today, all sciences suggest problems studied by mathematicians, and many problems arise within mathematics itself. For example, the physicist Richard Feynman invented the path integral formulation of quantum mechanics using a combination of mathematical reasoning and physical insight, and today's string theory, a still-developing scientific theory which attempts to unify the four fundamental forces of nature, continues to inspire new mathematics.[34] Some mathematics is only relevant in the area that inspired it, and is applied to solve further problems in that area. But often mathematics inspired by one area proves useful in many areas, and joins the general stock of mathematical concepts. A distinction is often made between pure mathematics and applied mathematics. However pure mathematics topics often turn out to have applications, e.g. number theory in cryptography. This remarkable fact that even the "purest" mathematics often turns out to have practical applications is what Eugene Wigner has called "the unreasonable effectiveness of mathematics".[35] As in most areas of study, the explosion of knowledge in the scientific age has led to specialization: there are now hundreds of specialized areas in mathematics and the latest Mathematics Subject Classification runs to 46 pages.[36] Several areas of applied mathematics have merged with related traditions outside of mathematics and become disciplines in their own right, including statistics, operations research, and computer science.

For those who are mathematically inclined, there is often a definite aesthetic aspect to much of mathematics. Many mathematicians talk about the *elegance* of mathematics, its intrinsic aesthetics and inner beauty. Simplicity and generality are valued. There is beauty in a simple and elegant proof, such as Euclid's proof that there are infinitely many prime numbers, and in an elegant numerical method that speeds calculation, such as the fast Fourier transform. G.H. Hardy in A Mathematician's Apology expressed the belief that these aesthetic considerations are, in themselves, sufficient to justify the study of pure mathematics. He identified criteria such as significance, unexpectedness, inevitability, and economy as factors that contribute to a mathematical aesthetic.[37] Mathematicians often strive to find proofs that are particularly elegant, proofs from "The Book" of God according to Paul Erdős.[38][39] The popularity of recreational mathematics is another sign of the pleasure many find in solving mathematical questions.

Notation, Language and Rigor:

Main article: Mathematical notation

Leonhard Euler, who created and popularized much of the mathematical notation used today

Most of the mathematical notation in use today was not invented until the 16th century.[40] Before that, mathematics was written out in words, a painstaking process that limited mathematical discovery.[41] Euler (1707–1783) was responsible for many of the notations in use today. Modern notation makes mathematics much easier for the professional, but beginners often find it daunting. It is extremely compressed: a few symbols contain a great deal of information. Like musical notation, modern mathematical notation has a strict syntax (which to a limited extent varies from author to author and from discipline to discipline) and encodes information that would be difficult to write in any other way.

Mathematical language can be difficult to understand for beginners. Words such as *or* and *only* have more precise meanings than in everyday speech. Moreover, words such as open and field have been given specialized mathematical meanings. Technical terms such as homeomorphism and integrable have precise meanings in mathematics. Additionally, shorthand phrases such as *iff* for "if and only if" belong to mathematical jargon. There is a reason for special notation and technical vocabulary: mathematics requires more precision than everyday speech. Mathematicians refer to this precision of language and logic as "rigor".Mathematical proof is fundamentally a matter of rigor. Mathematicians want their theorems to follow from axioms by means of systematic reasoning. This is to avoid mistaken "theorems", based on fallible intuitions, of which many instances have occurred in the history of the subject.[42] The level of rigor expected in mathematics has varied over time: the Greeks expected detailed arguments, but at the time of Isaac Newton the methods employed were less rigorous. Problems inherent in the definitions used by Newton would lead to a resurgence of careful analysis and formal proof in the 19th century. Misunderstanding the rigor is a cause for some of the common misconceptions of mathematics. Today, mathematicians continue to argue among themselves about computer-assisted proofs. Since large computations are hard to verify, such proofs may not be sufficiently rigorous.[43]Axioms in traditional thought were "self-evident truths", but that conception is problematic. At a formal level, an axiom is just a string of symbols, which has an intrinsic meaning only in the context of all derivable formulas of an axiomatic system. It was the goal of Hilbert's program to put all of mathematics on a firm axiomatic basis, but according to Gödel's incompleteness theorem every (sufficiently powerful) axiomatic system has undecidable formulas; and so a final axiomatization of mathematics is impossible. Nonetheless mathematics is often imagined to be (as far as its formal content) nothing but set theory in some axiomatization, in the sense that every mathematical statement or proof could be cast into formulas within set theory.[44]

Fields of Mathematics:

Foundation and Philosophy:

See also: Areas of mathematics *and* Glossary of areas of mathematics

An abacus, a simple calculating tool used since ancient times.

Mathematics can, broadly speaking, be subdivided into the study of quantity, structure, space, and change (i.e. arithmetic, algebra, geometry, and analysis). In addition to these main concerns, there are also subdivisions dedicated to exploring links from the heart of mathematics to other fields: to logic, to set theory (foundations), to the empirical mathematics of the various sciences (applied mathematics), and more recently to the rigorous study of uncertainty.

In order to clarify the foundations of mathematics, the fields of mathematical logic and set theory were developed. Mathematical logic includes the mathematical study of logic and the applications of formal logic to other areas of mathematics; set theory is the branch of mathematics that studies sets or collections of objects. Category theory, which deals in an abstract way with mathematical structures and relationships between them, is still in development. The phrase "crisis of foundations" describes the search for a rigorous foundation for mathematics that took place from approximately 1900 to 1930.[45] Some disagreement about the foundations of mathematics continues to the present day. The crisis of foundations was stimulated by a number of controversies at the time, including the controversy over Cantor's set theory and the

Brouwer–Hilbert controversy.

Mathematical logic is concerned with setting mathematics within a rigorous axiomatic framework, and studying the implications of such a framework. As such, it is home to Gödel's incompleteness theorems which (informally) imply that any effective formal system that contains basic arithmetic, if *sound* (meaning that all theorems that can be proven are true), is necessarily *incomplete* (meaning that there are true theorems which cannot be proved *in that system*). Whatever finite collection of number-theoretical axioms is taken as a foundation, Gödel showed how to construct a formal statement that is a true number-theoretical fact, but which does not follow from those axioms. Therefore no formal system is a complete axiomatization of full number theory. Modern logic is divided into recursion theory, model theory, and proof theory, and is closely linked to theoretical computer science,[citation needed] as well as to category theory.Theoretical computer science includes computability theory, computational complexity theory, and information theory.

Computability theory examines the limitations of various theoretical models of the computer, including the most well-known model – the Turing machine. Complexity theory is the study of tractability by computer; some problems, although theoretically solvable by computer, are so expensive in terms of time or space that solving them is likely to remain practically unfeasible, even with the rapid advancement of computer hardware. A famous problem is the "P = NP?" problem, one of the Millennium Prize Problems.[46] Finally, information theory is concerned with the amount of data that can be stored on a given medium, and hence deals with concepts such as compression and entropy.

Mathematical logicSet theoryCategory theoryTheory of computation

Pure Mathematics:

Quantity:

The study of quantity starts with numbers, first the familiar natural numbers and integers ("whole numbers") and arithmetical operations on them, which are characterized in arithmetic. The deeper properties of integers are studied in number theory, from which come such popular results as Fermat's Last Theorem. The twin prime conjecture and Goldbach's conjecture are two unsolved problems in number theory.

As the number system is further developed, the integers are recognized as a subset of the rational numbers ("fractions"). These, in turn, are contained within the real numbers, which are used to represent continuous quantities. Real numbers are generalized to complex numbers. These are the first steps of a hierarchy of numbers that goes on to include quarternions and octonions. Consideration of the natural numbers also leads to the transfinite numbers, which formalize the concept of "infinity". Another area of study is size, which leads to the cardinal numbers and then to another conception of infinity: the aleph numbers, which allow meaningful comparison of the size of infinitely large sets.

Natural numbersIntegersRational numbersReal numbersComplex numbers

Structure:

Many mathematical objects, such as sets of numbers and functions, exhibit internal structure as a consequence of operations or relations that are defined on the set. Mathematics then studies properties of those sets that can be expressed in terms of that structure; for instance number theory studies properties of the set of integers that can be expressed in terms of arithmetic operations. Moreover, it frequently happens that different such structured sets (or structures) exhibit similar properties, which makes it possible, by a further step of abstraction, to state axioms for a class of structures, and then study at once the whole class of structures satisfying these axioms. Thus one can study groups, rings, fields and other abstract systems; together such studies (for structures defined by algebraic operations) constitute the domain of abstract algebra. By its great generality, abstract algebra can often be applied to seemingly unrelated problems; for instance a number of ancient problems concerning compass and straightedge constructions were finally solved using Galois theory, which involves field theory and group theory. Another example of an algebraic theory is linear algebra, which is the general study of vector spaces, whose elements called vectors have both quantity and direction, and can be used to model (relations between) points in space. This is one example of the phenomenon that the originally unrelated areas of geometry and algebra have very strong interactions in modern mathematics. Combinatorics studies ways of enumerating the number of objects that fit a given structure.

CombinatoricsNumber theoryGroup theoryGraph theoryOrder theoryAlgebra

Space:

The study of space originates with geometry – in particular, Euclidean geometry. Trigonometry is the branch of mathematics that deals with relationships between the sides and the angles of triangles and with the trigonometric functions; it combines space and numbers, and encompasses the well-known Pythagorean theorem. The modern study of space generalizes these ideas to include higher-dimensional geometry, non-Euclidean geometries (which play a central role in general relativity) and topology. Quantity and space both play a role in analytic geometry, differential geometry, and algebraic geometry. Convex and discrete geometry were developed to solve problems in number theory and functional analysis but now are pursued with an eye on applications in optimization and computer science. Within differential geometry are the concepts of fiber bundles and calculus on manifolds, in particular, vector and tensor calculus. Within algebraic geometry is the description of geometric objects as solution sets of polynomial equations, combining the concepts of quantity and space, and also the study of topological groups, which combine structure and space. Lie groups are used to study space, structure, and change. Topology in all its many ramifications may have been the greatest growth area in 20th century mathematics; it includes point-set topology, set-theoretic topology, algebraic topology and differential topology. In particular, instances of modern day topology are metrizability theory, axiomatic set theory, homotopy theory, and Morse theory. Topology also includes the now solved Poincaré conjecture, and the still unsolved areas of the Hodge conjecture. Other results in geometry and topology, including the four color theorem and Kepler conjecture, have been proved only with the help of computers.GeometryTrigonometryDifferential geometryTopologyFractal geometryMeasure theory

Change:

Understanding and describing change is a common theme in the natural sciences, and calculus was developed as a powerful tool to investigate it. Functions arise here, as a central concept describing a changing quantity. The rigorous study of real numbers and functions of a real variable is known as real analysis, with complex analysis the equivalent field for the complex numbers. Functional analysis focuses attention on (typically infinite-dimensional) spaces of functions. One of many applications of functional analysis is quantum mechanics. Many problems lead naturally to relationships between a quantity and its rate of change, and these are studied as differential equations. Many phenomena in nature can be described by dynamical systems; chaos theory makes precise the ways in which many of these systems exhibit unpredictable yet still deterministic behavior.CalculusVector calculusDifferential equationsDynamical systemsChaos theoryComplex analysis

Applied:

Applied mathematics concerns itself with mathematical methods that are typically used in science, engineering, business, and industry. Thus, "applied mathematics" is a mathematical science with specialized knowledge. The term *applied mathematics* also describes the professional specialty in which mathematicians work on practical problems; as a profession focused on practical problems, *applied mathematics* focuses on the "formulation, study, and use of mathematical models" in science, engineering, and other areas of mathematical practice.

In the past, practical applications have motivated the development of mathematical theories, which then became the subject of study in pure mathematics, where mathematics is developed primarily for its own sake. Thus, the activity of applied mathematics is vitally connected with research in pure mathematics.

Statistics and Other Decision Sciences:

Applied mathematics has significant overlap with the discipline of statistics, whose theory is formulated mathematically, especially with probability theory. Statisticians (working as part of a research project) "create data that makes sense" with random sampling and with randomized experiments;[47] the design of a statistical sample or experiment specifies the analysis of the data (before the data be available). When reconsidering data from experiments and samples or when analyzing data from observational studies, statisticians "make sense of the data" using the art of modelling and the theory of inference – with model selection and estimation; the estimated models and consequential predictions should be tested on new data.[48]Statistical theory studies decision problems such as minimizing the risk (expected loss) of a statistical action, such as using a procedure in, for example, parameter estimation, hypothesis testing, and selecting the best. In these traditional areas of mathematical statistics, a statistical-decision problem is formulated by minimizing an objective function, like expected loss or cost, under specific constraints: For example, designing a survey often involves minimizing the cost of estimating a population mean with a given level of confidence.[49] Because of its use of optimization, the mathematical theory of statistics shares concerns with other decision sciences, such as operations research, control theory, and mathematical economics.[50]

Computational Mathematics:

Computational mathematics proposes and studies methods for solving mathematical problems that are typically too large for human numerical capacity. Numerical analysis studies methods for problems in analysis using functional analysis and approximation theory; numerical analysis includes the study of approximation and discretization broadly with special concern for rounding errors. Numerical analysis and, more broadly, scientific computing also study non-analytic topics of mathematical science, especially algorithmic matrix and graph theory. Other areas of computational mathematics include computer algebra and symbolic computation.Mathematical physicsFluid dynamicsNumerical analysisOptimizationProbability theoryStatisticsCryptographyMathematical financeGame theoryMathematical biologyMathematical chemistryMathematical economicsControl theory

Combinatorics:

Combinatorics is a branch of mathematics concerning the study of finite or countable discrete structures. Aspects of combinatorics include counting the structures of a given kind and size (enumerative combinatorics), deciding when certain criteria can be met, and constructing and analyzing objects meeting the criteria (as in combinatorial designs and matroid theory), finding "largest", "smallest", or "optimal" objects (extremal combinatorics and combinatorial optimization), and studying combinatorial structures arising in an algebraic context, or applying algebraic techniques to combinatorial problems (algebraic combinatorics). Combinatorial problems arise in many areas of pure mathematics, notably in algebra, probability theory, topology, and geometry,[1] and combinatorics also has many applications in optimization, computer science, ergodic theory and statistical physics. Many combinatorial questions have historically been considered in isolation, giving an *ad hoc* solution to a problem arising in some mathematical context. In the later twentieth century, however, powerful and general theoretical methods were developed, making combinatorics into an independent branch of mathematics in its own right. One of the oldest and most accessible parts of combinatorics is graph theory, which also has numerous natural connections to other areas. Combinatorics is used frequently in computer science to obtain formulas and estimates in the analysis of algorithms.

A mathematician who studies combinatorics is called a *combinatorialist*.

Geometry:

Etymology:

Summary:

Geometry (Ancient Greek: *γεωμετρία*; geo- "earth", -metron "measurement") is a branch of mathematics concerned with questions of shape, size, relative position of figures, and the properties of space. A mathematician who works in the field of geometry is called a geometer. Geometry arose independently in a number of early cultures as a body of practical knowledge concerning lengths, areas, and volumes, with elements of a formal mathematical science emerging in the West as early as Thales (6th Century BC). By the 3rd century BC geometry was put into an axiomatic form by Euclid, whose treatment—Euclidean geometry—set a standard for many centuries to follow.[1] Archimedes developed ingenious techniques for calculating areas and volumes, in many ways anticipating modern integral calculus. The field of astronomy, especially mapping the positions of the stars and planets on the celestial sphere and describing the relationship between movements of celestial bodies, served as an important source of geometric problems during the next one and a half millennia. Both geometry and astronomy were considered in the classical world to be part of the Quadrivium, a subset of the seven liberal arts considered essential for a free citizen to master.

The introduction of coordinates by René Descartes and the concurrent developments of algebra marked a new stage for geometry, since geometric figures, such as plane curves, could now be represented analytically, i.e., with functions and equations. This played a key role in the emergence of infinitesimal calculus in the 17th century. Furthermore, the theory of perspective showed that there is more to geometry than just the metric properties of figures: perspective is the origin of projective geometry. The subject of geometry was further enriched by the study of intrinsic structure of geometric objects that originated with Euler and Gauss and led to the creation of topology and differential geometry.

In Euclid's time there was no clear distinction between physical space and geometrical space. Since the 19th-century discovery of non-Euclidean geometry, the concept of space has undergone a radical transformation, and the question arose: which geometrical space best fits physical space? With the rise of formal mathematics in the 20th century, also 'space' (and 'point', 'line', 'plane') lost its intuitive contents, so today we have to distinguish between physical space, geometrical spaces (in which 'space', 'point' etc. still have their intuitive meaning) and abstract spaces. Contemporary geometry considers manifolds, spaces that are considerably more abstract than the familiar Euclidean space, which they only approximately resemble at small scales. These spaces may be endowed with additional structure, allowing one to speak about length. Modern geometry has multiple strong bonds with physics, exemplified by the ties between pseudo-Riemannian geometry and general relativity. One of the youngest physical theories, string theory, is also very geometric in flavour.

While the visual nature of geometry makes it initially more accessible than other parts of mathematics, such as algebra or number theory, geometric language is also used in contexts far removed from its traditional, Euclidean provenance (for example, in fractal geometry and algebraic geometry).[2]

Geometry (Ancient Greek: *γεωμετρία*; geo- "earth", -metron "measurement") is a branch of mathematics concerned with questions of shape, size, relative position of figures, and the properties of space.

Resources:

Mathematica:

Wolfram Alpha

Mechanism: (see: engineering)

Models:

Non Physical

Abstract:

•Conceptual model, a nonphysical model

•Conceptual model (computer science), also called a domain model

•Interpretation (logic), a model is (part of) an interpretation of facts in logic, a mapping of truth values to sentences.

•Mathematical model, an abstract model that uses mathematical language

•Structure (mathematical logic), in model theory often called just a model or semantic model

Modeling Biological Systems:

Summary:

Modelling biological systems is a significant task of systems biology and mathematical biology. Computational systems biology aims to develop and use efficient algorithms, data structures, visualization and communication tools with the goal of computer modelling of biological systems. It involves the use of computer simulations of biological systems, including cellular subsystems (such as the networks of metabolites and enzymes which comprise metabolism, signal transduction pathways and gene regulatory networks), to both analyze and visualize the complex connections of these cellular processes.Artificial life or virtual evolution attempts to understand evolutionary processes via the computer simulation of simple (artificial) life forms.

Overview:

It is understood that an unexpected emergent property of a complex system is a result of the interplay of the cause-and-effect among simpler, integrated parts (see biological organisation). Biological systems manifest many important examples of emergent properties in the complex interplay of components. Traditional study of biological systems requires reductive methods in which quantities of data are gathered by category, such as concentration over time in response to a certain stimulus. Computers are critical to analysis and modelling of these data. The goal is to create accurate real-time models of a system's response to environmental and internal stimuli, such as a model of a cancer cell in order to find weaknesses in its signalling pathways, or modelling of ion channel mutations to see effects on cardiomyocytes and in turn, the function of a beating heart.

A monograph on this topic summarizes an extensive amount of published research in this area up to 1987,[1] including subsections in the following areas: computer modelling in biology and medicine, arterial system models, neuron models, biochemical and oscillation networks, quantum automata, quantum computers in molecular biology and genetics, cancer modelling, neural nets, genetic networks, abstract relational biology, metabolic-replication systems, category theory[2] applications in biology and medicine,[3] automata theory, cellular automata, tessallation models[4][5] and complete self-reproduction, chaotic systems in organisms, relational biology and organismic theories.[6][7] This published report also includes 390 references to peer-reviewed articles by a large number of authors.[8][9][10]

Standards[edit]

By far the most widely accepted standard format for storing and exchanging models in the field is the Systems Biology Markup Language (SBML)[11] The SBML.org website includes a guide to many important software packages used in computational systems biology. Other markup languages with different emphases include BioPAX and CellML.

Tasks:

Cellular model[edit]

Main article: Cellular model Part of the Cell Cycle Summerhayes and Elton's 1923 food web of Bear Island (*Arrows represent an organism being consumed by another organism*). A sample time-series of the Lotka-Volterra model. Note that the two populations exhibit cyclic behaviour.

Creating a cellular model has been a particularly challenging task of systems biology and mathematical biology. It involves the use of computer simulations of the many cellular subsystems such as the networks of metabolites and enzymes which comprise metabolism, signal transduction pathways and gene regulatory networks to both analyze and visualize the complex connections of these cellular processes.

The complex network of biochemical reaction/transport processes and their spatial organization make the development of a predictive model of a living cell a grand challenge for the 21st century.

In 2006, the National Science Foundation (NSF) put forward a grand challenge for systems biology in the 21st century to build a mathematical model of the whole cell.[12] E-Cell Project aims "to make precise whole cell simulation at the molecular level possible".[13] CytoSolve - developed by V. A. Shiva Ayyadurai and C. Forbes Dewey, Jr., of the Department of Biological Engineering at the Massachusetts Institute of Technology - provided a method to model the whole cell by dynamically integrating multiple molecular pathway models.[14][15]

A whole cell computational model for the bacterium Mycoplasma genitalium, including all its 525 genes, gene products, and their interactions, was built by scientists from Stanford University and the J. Craig Venter Institute and published on 20 July 2012 in Cell.[16]

A dynamic computer model of intracellular signaling was the basis for Merrimack Pharmaceuticals to discover the target for their cancer medicine MM-111.[17]Membrane computing is the task of modelling specifically a cell membrane.

Protein folding[edit]

Main article: Protein folding problem

Protein structure prediction is the prediction of the three-dimensional structure of a protein from its amino acid sequence—that is, the prediction of a protein's tertiary structure from its primary structure. It is one of the most important goals pursued by bioinformatics and theoretical chemistry. Protein structure prediction is of high importance in medicine (for example, in drug design) and biotechnology (for example, in the design of novel enzymes). Every two years, the performance of current methods is assessed in the CASP experiment.

Human biological systems[edit]

Brain model[edit]

The Blue Brain Project is an attempt to create a synthetic brain by reverse-engineering the mammalian brain down to the molecular level. The aim of the project, founded in May 2005 by the Brain and Mind Institute of the École Polytechnique in Lausanne, Switzerland, is to study the brain's architectural and functional principles. The project is headed by the Institute's director, Henry Markram. Using a Blue Gene supercomputer running Michael Hines's NEURON software, the simulation does not consist simply of an artificial neural network, but involves a partially biologically realistic model of neurons.[18][19] It is hoped by its proponents that it will eventually shed light on the nature of consciousness. There are a number of sub-projects, including the Cajal Blue Brain, coordinated by the Supercomputing and Visualization Center of Madrid (CeSViMa), and others run by universities and independent laboratories in the UK, U.S., and Israel. The Human Brain Project builds on the work of the Blue Brain Project.[20][21] It is one of six pilot projects in the Future Emerging Technologies Research Program of the European Commission,[22] competing for a billion euro funding.

Model of the immune system[edit]

The last decade has seen the emergence of a growing number of simulations of the immune system.[23][24]

Virtual liver[edit]

The Virtual Liver project is a 43 million euro research program funded by the German Government, made up of seventy research group distributed across Germany. The goal is to produce a virtual liver, a dynamic mathematical model that represents human liver physiology, morphology and function.[25]

Tree model[edit]

Main article: Simulated growth of plants

Electronic trees (e-trees) usually use L-systems to simulate growth. L-systems are very important in the field of complexity science and A-life. A universally accepted system for describing changes in plant morphology at the cellular or modular level has yet to be devised.[26] The most widely implemented tree generating algorithms are described in the papers "Creation and Rendering of Realistic Trees", and Real-Time Tree Rendering

Ecological models[edit]

Main article: Ecosystem model

Ecosystem models are mathematical representations of ecosystems. Typically they simplify complex foodwebs down to their major components or trophic levels, and quantify these as either numbers of organisms, biomass or the inventory/concentration of some pertinent chemical element (for instance, carbon or a nutrient species such as nitrogen or phosphorus).

Models in ecotoxicology[edit]

The purpose of models in ecotoxicology is the understanding, simulation and prediction of effects caused by toxicants in the environment. Most current models describe effects on one of many different levels of biological organization (e.g. organisms or populations). A challenge is the development of models that predict effects across biological scales. Ecotoxicology and models discusses some types of ecotoxicological models and provides links to many others.

Modelling of infectious disease[edit]

Main articles: Mathematical modelling of infectious disease *and* Epidemic model

It is possible to model the progress of most infectious diseases mathematically to discover the likely outcome of an epidemic or to help manage them by vaccination. This field tries to find parameters for various infectious diseases and to use those parameters to make useful calculations about the effects of a mass vaccination programme.

Standard Model:

This article is about the Standard Model of particle physics. For other uses, see Standard model (disambiguation).

This article is a non-mathematical general overview of the Standard Model. For a mathematical description, see the article Standard Model (mathematical formulation).

The **Standard Model** of particle physics is a theory concerning the electromagnetic, weak, and strong nuclear interactions, which mediate the dynamics of the known subatomic particles. It was developed throughout the latter half of the 20th century, as a collaborative effort of scientists around the world.[1] The current formulation was finalized in the mid-1970s upon experimental confirmation of the existence of quarks. Since then, discoveries of the bottom quark (1977), the top quark (1995), and the tau neutrino (2000) have given further credence to the Standard Model. More recently (2011–2012), the possible detection of the Higgs boson would complete the set of predicted particles upon its verification. Because of its success in explaining a wide variety of experimental results, the Standard Model is sometimes regarded as a "theory of almost everything".

The Standard Model falls short of being a complete theory of fundamental interactions because it makes certain simplifying assumptions. It does not incorporate the full theory of gravitation as described by general relativity, or predict the accelerating expansion of the universe (as possibly described by dark energy). The theory does not contain any viable dark matter particle that possesses all of the required properties deduced from observational cosmology. It also does not correctly account for neutrino oscillations (and their non-zero masses). Although the Standard Model is believed to be theoretically self-consistent[2] and has demonstrated huge and continued successes in providing experimental predictions, it does leave some unexplained phenomena.

The development of the Standard Model was driven by theoretical and experimental particle physicists alike. For theorists, the Standard Model is a paradigm of a quantum field theory, which exhibits a wide range of physics including spontaneous symmetry breaking, anomalies, non-perturbative behavior, etc. It is used as a basis for building more exotic models that incorporate hypothetical particles, extra dimensions, and elaborate symmetries (such as supersymmetry) in an attempt to explain experimental results at variance with the Standard Model, such as the existence of dark matter and neutrino oscillations.

Multisensory Integration: (Multisensorial)

Musical Compostion: (further research is required)

Natural Processes: (see nature & process)

Nature: (further research is required)

Summary:

Nature, in the broadest sense, is equivalent to the **natural world**, **physical world**, or **material world**. "Nature" refers to the phenomena of the physical world, and also to life in general. It ranges in scale from the subatomic to the cosmic.

The word *nature* is derived from the Latin word *natura*, or "essential qualities, innate disposition", and in ancient times, literally meant "birth".[1] *Natura* was a Latin translation of the Greek word physis (φύσις), which originally related to the intrinsic characteristics that plants, animals, and other features of the world develop of their own accord.[2][3] The concept of nature as a whole, the physical universe, is one of several expansions of the original notion; it began with certain core applications of the word φύσις by pre-Socratic philosophers, and has steadily gained currency ever since. This usage was confirmed during the advent of modern scientific method in the last several centuries.[4][5]

Within the various uses of the word today, "nature" often refers to geology and wildlife. Nature may refer to the general realm of various types of living plants and animals, and in some cases to the processes associated with inanimate objects – the way that particular types of things exist and change of their own accord, such as the weather and geology of the Earth, and the matter and energy of which all these things are composed. It is often taken to mean the "natural environment" or wilderness–wild animals, rocks, forest, beaches, and in general those things that have not been substantially altered by human intervention, or which persist despite human intervention. For example, manufactured objects and human interaction generally are not considered part of nature, unless qualified as, for example, "human nature" or "the whole of nature". This more traditional concept of natural things which can still be found today implies a distinction between the natural and the artificial, with the artificial being understood as that which has been brought into being by a human consciousness or a human mind. Depending on the particular context, the term "natural" might also be distinguished from the unnatural, the supernatural, or synthetic.

Patterns

Pattern

A **pattern**, apart from the term's use to mean "Template"[a], is a discernible regularity in the world or in a manmade design. As such, the elements of a pattern repeat in a predictable manner.

Any of the five senses may directly observe patterns. Conversely, abstract patterns in science, mathematics, or language may be observable only by analysis. Direct observation in practice means seeing visual patterns, which are widespread in nature and in art. Visual patterns in nature are often chaotic, never exactly repeating, and often involve fractals. Natural patterns include spirals, meanders, waves, foams, tilings, cracks, and those created by symmetries of rotation and reflection. All such patterns have an underlying mathematical structure; indeed, mathematics can be seen as the search for regularities, and the output of any function is a mathematical pattern. Similarly in the sciences, theories explain and predict regularities in the world.

In art and architecture, decorations or visual motifs may be combined and repeated to form patterns designed to have a chosen effect on the viewer. In computer science, a software design pattern is a known solution to a class of problems in programming. In fashion, the pattern is a template used to create any number of similar garments.

Pattern formation

Patterns in nature

Patterns in nature:

Patterns in nature are visible regularities of form found in the natural world. These **patterns** recur in different contexts and can sometimes be **modelled mathematically**. Natural patterns include symmetries, trees, spirals, meanders, waves, foams, arrays, cracks and stripes.[1] Early Greek philosophers studied pattern, with **Plato**, **Pythagoras** and **Empedocles** attempting to explain order in nature. The modern understanding of visible patterns developed gradually over time.

In the 19th century, Belgian physicist **Joseph Plateau** examined **soap films**, leading him to formulate the concept of a **minimal surface**. German biologist and artist **Ernst Haeckel** painted hundreds of marine organisms to emphasise their **symmetry**. Scottish biologist **D'Arcy Thompson** pioneered the study of growth patterns in both plants and animals, showing that simple equations could explain spiral growth. In the 20th century, British mathematician **Alan Turing** predicted mechanisms of **morphogenesis** which give rise to patterns of spots and stripes. Hungarian biologist **Aristid Lindenmayer** and French American mathematician **Benoît Mandelbrot** showed how the mathematics of **fractals** could create plant growth patterns.**Mathematics**, **physics** and **chemistry** can explain patterns in nature at different levels. Patterns in living things are explained by the **biological** processes of **natural selection** and **sexual selection**. Studies of **pattern formation** make use of **computer models** to simulate a wide range of patterns.

Types of patterns

Philosophy:

Summary:

Philosophy is the study of general and fundamental problems, such as those connected with reality, existence, knowledge, values, reason, mind, and language.[1][2] Philosophy is distinguished from other ways of addressing such problems by its critical, generally systematic approach and its reliance on rational argument.[3] In more casual speech, by extension, "philosophy" can refer to "the most basic beliefs, concepts, and attitudes of an individual or group".[4]

The word "philosophy" comes from the Ancient Greek φιλοσοφία (*philosophia*), which literally means "love of wisdom".[5][6][7] The introduction of the terms "philosopher" and "philosophy" has been ascribed to the Greek thinker Pythagoras.[8]

Areas of Inquiry:

Epistemology:

Etymology:

Epistemology (i/ɨˌpɪstɨˈmɒlədʒi/ from Greek ἐπιστήμη - *epistēmē*, meaning "knowledge, understanding", and λόγος - logos, meaning "study of") is the branch of philosophy concerned with the nature and scope of knowledge[1][2] and is also referred to as "theory of knowledge". It questions what knowledge is and how it can be acquired, and the extent to which any given subject or entity can be known.

Much of the debate in this field has focused on analyzing the nature of knowledge and how it relates to connected notions such as truth, belief, and justification.

The term "epistemology" was introduced by the Scottish philosopher James Frederick Ferrier (1808–1864).[3]

Summary:

Main article: Epistemology

Epistemology is concerned with the nature and scope of knowledge,[11] such as the relationships between truth, belief, and theories of justification.Skepticism is the position which questions the possibility of completely justifying any truth. The regress argument, a fundamental problem in epistemology, occurs when, in order to completely prove any statement P, its justification itself needs to be supported by another justification. This chain can do three possible options, all of which are unsatisfactory according to the Münchhausen trilemma. One option is infinitism, where this chain of justification can go on forever. Another option is foundationalism, where the chain of justifications eventually relies on basic beliefs or axioms that are left unproven. The last option, such as in coherentism, is making the chain circular so that a statement is included in its own chain of justification.Rationalism is the emphasis on reasoning as a source of knowledge. Empiricism is the emphasis on observational evidence via sensory experience over other evidence as the source of knowledge. Rationalism claims that every possible object of knowledge can be deduced from coherent premises without observation. Empiricism claims that at least some knowledge is only a matter of observation. For this, Empiricism often cites the concept of tabula rasa, where individuals are not born with mental content and that knowledge builds from experience or perception. Epistemological solipsism is the idea that the existence of the world outside the mind is an unresolvable question.

René DescartesParmenides (fl. 500 BC) argued that it is impossible to doubt that thinking actually occurs. But thinking must have an object, therefore something *beyond* thinking really exists. Parmenides deduced that what really exists must have certain properties—for example, that it cannot come into existence or cease to exist, that it is a coherent whole, that it remains the same eternally (in fact, exists altogether outside time). This is known as the third man argument. Plato (427–347 BC) combined rationalism with a form of realism. The philosopher's work is to consider being, and the essence (ousia) of things. But the characteristic of essences is that they are universal. The nature of a man, a triangle, a tree, applies to all men, all triangles, all trees. Plato argued that these essences are mind-independent "forms", that humans (but particularly philosophers) can come to know by reason, and by ignoring the distractions of sense-perception.

Modern rationalism begins with Descartes. Reflection on the nature of perceptual experience, as well as scientific discoveries in physiology and optics, led Descartes (and also Locke) to the view that we are directly aware of ideas, rather than objects. This view gave rise to three questions:

1.Is an idea a true copy of the real thing that it represents? Sensation is not a direct interaction between bodily objects and our sense, but is a physiological process involving representation (for example, an image on the retina). Locke thought that a "secondary quality" such as a sensation of green could in no way resemble the arrangement of particles in matter that go to produce this sensation, although he thought that "primary qualities" such as shape, size, number, were really in objects.

2.How can physical objects such as chairs and tables, or even physiological processes in the brain, give rise to mental items such as ideas? This is part of what became known as the mind-body problem.

3.If all the contents of awareness are ideas, how can we know that anything exists apart from ideas?

Descartes tried to address the last problem by reason. He began, echoing Parmenides, with a principle that he thought could not coherently be denied: I *think*, therefore I *am* (often given in his original Latin: Cogito ergo sum). From this principle, Descartes went on to construct a complete system of knowledge (which involves proving the existence of God, using, among other means, a version of the ontological argument).[12] His view that reason alone could yield substantial truths about reality strongly influenced those philosophers usually considered modern rationalists (such as Baruch Spinoza, Gottfried Leibniz, and Christian Wolff), while provoking criticism from other philosophers who have retrospectively come to be grouped together as empiricists.

Logic:

Main article: Logic

Logic is the study of the principles of correct reasoning. Arguments use either deductive reasoning or inductive reasoning. Deductive reasoning is when, given certain statements (called premises), other statements (called conclusions) are unavoidably implied. Rules of inferences from premises include the most popular method, modus ponens, where given “A” and “If A then B”, then “B” must be concluded. A common convention for a deductive argument is the syllogism. An argument is termed valid if its conclusion does indeed follow from its premises, whether the premises are true or not, while an argument is sound if its conclusion follows from premises that are true. Propositional logic uses premises that are propositions, which are declarations that are either true or false, while predicate logic uses more complex premises called formulae that contain variables. These can be assigned values or can be quantified as to when they apply with the universal quantifier (always apply) or the existential quantifier (applies at least once). Inductive reasoning makes conclusions or generalizations based on probabilistic reasoning. For example, if “90% of humans are right-handed” and “Joe is human” then “Joe is probably right-handed”. Fields in logic include mathematical logic (formal symbolic logic) and philosophical logic.

Metaphysics:

Main article: Metaphysics

Metaphysics is the study of the most general features of reality, such as existence, time, the relationship between mind and body, objects and their properties, wholes and their parts, events, processes, and causation. Traditional branches of metaphysics include cosmology, the study of the world in its entirety, and ontology, the study of being.

Within metaphysics itself there are a wide range of differing philosophical theories. Idealism, for example, is the belief that reality is mentally constructed or otherwise immaterial while realism holds that reality, or at least some part of it, exists independently of the mind. Subjective idealism describes objects as no more than collections or "bundles" of sense data in the perceiver. The 18th century philosopher George Berkeley contended that existence is fundamentally tied to perception with the phrase *Esse est aut percipi aut percipere* or "To be is to be perceived or to perceive".[13]

In addition to the aforementioned views, however, there is also an ontological dichotomy within metaphysics between the concepts of particulars and universals as well. Particulars are those objects that are said to exist in space and time, as opposed to abstract objects, such as numbers. Universals are properties held by multiple particulars, such as redness or a gender. The type of existence, if any, of universals and abstract objects is an issue of serious debate within metaphysical philosophy. Realism is the philosophical position that universals do in fact exist, while nominalism is the negation, or denial of universals, abstract objects, or both.[14] Conceptualism holds that universals exist, but only within the mind's perception.[15]

The question of whether or not existence is a predicate has been discussed since the Early Modern period. Essence is the set of attributes that make an object what it fundamentally is and without which it loses its identity. Essence is contrasted with accident: a property that the substance has contingently, without which the substance can still retain its identity.

Ethics:

Summary:

Ethics, also known as **moral philosophy**, is a branch of philosophy that involves systematizing, defending and recommending concepts of right and wrong conduct.[1] The term comes from the Greek word ethos, which means "character". Ethics is a complement to Aesthetics in the philosophy field of Axiology. In philosophy, ethics studies the moral behavior in humans and how one should act. Ethics may be divided into four major areas of study:[1]

- Meta-ethics, about the theoretical meaning and reference of moral propositions and how their truth values (if any) may be determined;
- Normative ethics, about the practical means of determining a moral course of action;
- Applied ethics, about how moral outcomes can be achieved in specific situations;
- Descriptive ethics, also known as comparative ethics, is the study of people's beliefs about morality;

Ethics seeks to resolve questions dealing with human morality—concepts such as good and evil, right and wrong, virtue and vice, justice and crime.

Moral & Political Philosophy:

Main articles: Ethics and Political philosophy

Ethics, or "moral philosophy," is concerned primarily with the question of the best way to live, and secondarily, concerning the question of whether this question can be answered. The main branches of ethics are meta-ethics, normative ethics, and applied ethics. Meta-ethics concerns the nature of ethical thought, such as the origins of the words good and bad, and origins of other comparative words of various ethical systems, whether there are absolute ethical truths, and how such truths could be known. Normative ethics are more concerned with the questions of how one ought to act, and what the right course of action is. This is where most ethical theories are generated. Lastly, applied ethics go beyond theory and step into real world ethical practice, such as questions of whether or not abortion is correct. Ethics is also associated with the idea of morality, and the two are often interchangeable.

Jeremy Bentham

One debate that has commanded the attention of ethicists in the modern era has been between consequentialism (actions are to be morally evaluated solely by their *consequences*) and deontology (actions are to be morally evaluated solely by consideration of agents' *duties*, the *rights* of those whom the action concerns, or both). Jeremy Bentham and John Stuart Mill are famous for propagating utilitarianism, which is the idea that the fundamental moral rule is to strive toward the "greatest happiness for the greatest number". However, in promoting this idea they also necessarily promoted the broader doctrine of consequentialism. Adopting a position opposed to consequentialism, Immanuel Kant argued that moral principles were simply products of reason. Kant believed that the incorporation of consequences into moral deliberation was a deep mistake, since it denies the necessity of practical maxims in governing the working of the will. According to Kant, reason requires that we conform our actions to the categorical imperative, which is an absolute duty. An important 20th-century deontologist, W.D. Ross, argued for weaker forms of duties called prima facie duties. More recent works have emphasized the role of character in ethics, a movement known as the aretaic turn (that is, the *turn towards virtues*). One strain of this movement followed the work of Bernard Williams. Williams noted that rigid forms of consequentialism and deontology demanded that people behave impartially. This, Williams argued, requires that people abandon their personal projects, and hence their personal integrity, in order to be considered moral. G.E.M. Anscombe, in an influential paper, "Modern Moral Philosophy" (1958), revived virtue ethics as an alternative to what was seen as the entrenched positions of Kantianism and consequentialism. Aretaic perspectives have been inspired in part by research of ancient conceptions of virtue. For example, Aristotle's ethics demands that people follow the *Aristotelian mean*, or balance between two vices; and Confucian ethics argues that virtue consists largely in striving for harmony with other people. Virtue ethics in general has since gained many adherents, and has been defended by such philosophers as Philippa Foot, Alasdair MacIntyre, and Rosalind Hursthouse.

Thomas HobbesPolitical philosophy is the study of government and the relationship of individuals (or families and clans) to communities including the state. It includes questions about justice, law, property, and the rights and obligations of the citizen. Politics and ethics are traditionally inter-linked subjects, as both discuss the question of what is good and how people should live. From ancient times, and well beyond them, the roots of justification for political authority were inescapably tied to outlooks on human nature. In *The*

Republic, Plato presented the argument that the ideal society would be run by a council of philosopher-kings, since those best at philosophy are best able to realize the good. Even Plato, however, required philosophers to make their way in the world for many years before beginning their rule at the age of fifty. For Aristotle, humans are political animals (i.e. social animals), and governments are set up to pursue good for the community. Aristotle reasoned that, since the state (polis) was the highest form of community, it has the purpose of pursuing the highest good. Aristotle viewed political power as the result of natural inequalities in skill and virtue. Because of these differences, he favored an aristocracy of the able and virtuous. For Aristotle, the person cannot be complete unless he or she lives in a community. His *The Nicomachean Ethics* and *The Politics* are meant to be read in that order. The first book addresses virtues (or "excellences") in the person as a citizen; the second addresses the proper form of government to ensure that citizens will be virtuous, and therefore complete. Both books deal with the essential role of justice in civic life.Nicolas of Cusa rekindled Platonic thought in the early 15th century. He promoted democracy in Medieval Europe, both in his writings and in his organization of the Council of Florence. Unlike Aristotle and the Hobbesian tradition to follow, Cusa saw human beings as equal and divine (that is, made in God's image), so democracy would be the only just form of government. Cusa's views are credited by some as sparking the Italian Renaissance, which gave rise to the notion of "Nation-States".

Georg Wilhelm Friedrich Hegel

Later, Niccolò Machiavelli rejected the views of Aristotle and Thomas Aquinas as unrealistic. The ideal sovereign is not the embodiment of the moral virtues; rather the sovereign does whatever is successful and necessary, rather than what is morally praiseworthy. Thomas Hobbes also contested many elements of Aristotle's views. For Hobbes, human nature is essentially anti-social: people are essentially egoistic, and this egoism makes life difficult in the natural state of things. Moreover, Hobbes argued, though people may have natural inequalities, these are trivial, since no particular talents or virtues that people may have will make them safe from harm inflicted by others. For these reasons, Hobbes concluded that the state arises from a common agreement to raise the community out of the state of nature. This can only be done by the establishment of a sovereign, in which (or whom) is vested complete control over the community, and is able to inspire awe and terror in its subjects.[16]

David Hume

Many in the Enlightenment were unsatisfied with existing doctrines in political philosophy, which seemed to marginalize or neglect the possibility of a democratic state. Jean-Jacques Rousseau was among those who attempted to overturn these doctrines: he responded to Hobbes by claiming that a human is by nature a kind of "noble savage", and that society and social contracts corrupt this nature. Another critic was John Locke. In Second Treatise on Government he agreed with Hobbes that the nation-state was an efficient tool for raising humanity out of a deplorable state, but he argued that the sovereign might become an abominable institution compared to the relatively benign unmodulated state of nature.[17]

Following the doctrine of the fact-value distinction, due in part to the influence of David Hume and his student Adam Smith, appeals to human nature for political justification were weakened. Nevertheless, many political philosophers, especially moral realists, still make use of some essential human nature as a basis for their arguments.Marxism is derived from the work of Karl Marx and Friedrich Engels. Their idea that capitalism is based on exploitation of workers and causes alienation of people from their human nature, the historical materialism, their view of social classes, etc., have influenced many fields of study, such as sociology, economics, and politics. Marxism inspired the Marxist school of communism, which brought a huge impact on the history of the 20th century.

Philosophy of Science:

Summary:

The **philosophy of science** is concerned with all the assumptions, foundations, methods, implications of science, and with the use and merit of science. This discipline sometimes overlaps metaphysics, ontology and epistemology, viz., when it explores whether scientific results comprise a study of truth. In addition to these central problems of science as a whole, many philosophers of science consider problems that apply to particular sciences (e.g. philosophy of biology or philosophy of physics). Some philosophers of science also use contemporary results in science to reach conclusions about philosophy.

Philosophy of science has historically been met with mixed response from the scientific community. Though scientists often contribute to the field, many prominent scientists have felt that the practical effect on their work is limited.

Grounds of validity of scientific reasoning:

Physical: (See: Physics & Particle Physics)

Physics:

Etymology:

Physics (from Greek φυσική (ἐπιστήμη), i.e. "knowledge, science of nature", from φύσις, *physis*, i.e. "nature"[1][2][3][4][5])

Summary:

Physics (from Greek φυσική (ἐπιστήμη), i.e. "knowledge, science of nature", from φύσις, *physis*, i.e. "nature"[1][2][3][4][5]) is a part of natural philosophy and a natural science that involves the study of matter[6] and its motion through space and time, along with related concepts such as energy and force.[7] More broadly, it is the general analysis of nature, conducted in order to understand how the universe behaves.[8][9][10]

Physics is one of the oldest academic disciplines, perhaps the oldest through its inclusion of astronomy.[11] Over the last two millennia, physics was a part of natural philosophy along with chemistry, certain branches of mathematics, and biology, but during the Scientific Revolution in the 17th century, the natural sciences emerged as unique research programs in their own right.[12] Physics intersects with many interdisciplinary areas of research, such as biophysics and quantum chemistry, and the boundaries of physics are not rigidly defined. New ideas in physics often explain the fundamental mechanisms of other sciences, while opening new avenues of research in areas such as mathematics and philosophy.

Physics also makes significant contributions through advances in new technologies that arise from theoretical breakthroughs. For example, advances in the understanding of electromagnetism or nuclear physics led directly to the development of new products which have dramatically transformed modern-day society, such as television, computers, domestic appliances, and nuclear weapons; advances in thermodynamics led to the development of industrialization; and advances in mechanics inspired the development of calculus.

History:

Main article: History of physicsNatural philosophy has its origins in Greece during the Archaic period, (650 BCE – 480 BCE), when Pre-Socratic philosophers like Thales rejected non-naturalistic explanations for natural phenomena and proclaimed that every event had a natural cause.[13] They proposed ideas verified by reason and observation and many of their hypotheses proved successful in experiment,[14] for example atomism.Classical physics became a separate science when early modern Europeans used these experimental and quantitative methods to discover what are now considered to be the laws of physics.[15][16] Kepler, Galileo and more specifically Newton discovered and unified the different laws of motion.[17] During the industrial revolution, as energy needs increased, so did research, which led to the discovery of new laws in thermodynamics, chemistry and electromagnetics.Modern physics started with the works of Max Planck in quantum theory and Einstein in relativity, and continued in quantum mechanics pioneered by Heisenberg, Schrödinger and Paul Dirac.

Philosophy:

Main article: Philosophy of physics

In many ways, physics stems from ancient Greek philosophy. From Thales' first attempt to characterize matter, to Democritus' deduction that matter ought to reduce to an invariant state, the Ptolemaic astronomy of a crystalline firmament, and Aristotle's book Physics (an early book on physics, which attempted to analyze and define motion from a philosophical point of view), various Greek philosophers advanced their

own theories of nature. Physics was known as natural philosophy until the late 18th century.
By the 19th century physics was realized as a discipline distinct from philosophy and the other sciences. Physics, as with the rest of science, relies on philosophy of science to give an adequate description of the scientific method.[18] The scientific method employs a priori reasoning as well as a posteriori reasoning and the use of Bayesian inference to measure the validity of a given theory.[19]

The development of physics has answered many questions of early philosophers, but has also raised new questions. Study of the philosophical issues surrounding physics, the philosophy of physics, involves issues such as the nature of space and time, determinism, and metaphysical outlooks such as empiricism, naturalism and realism.[20]

Many physicists have written about the philosophical implications of their work, for instance Laplace, who championed causal determinism,[21] and Erwin Schrödinger, who wrote on quantum mechanics.[22] The mathematical physicist Roger Penrose has been called a Platonist by Stephen Hawking,[23] a view Penrose discusses in his book, The Road to Reality.[24] Hawking refers to himself as an "unashamed reductionist" and takes issue with Penrose's views.[25]

Core Theories:

Summary:

Further information: Branches of physics*,* Outline of physics

Though physics deals with a wide variety of systems, certain theories are used by all physicists. Each of these theories were experimentally tested numerous times and found correct as an approximation of nature (within a certain domain of validity). For instance, the theory of classical mechanics accurately describes the motion of objects, provided they are much larger than atoms and moving at much less than the speed of light. These theories continue to be areas of active research, and a remarkable aspect of classical mechanics known as chaos was discovered in the 20th century, three centuries after the original formulation of classical mechanics by Isaac Newton (1642–1727).

These central theories are important tools for research into more specialized topics, and any physicist, regardless of his or her specialization, is expected to be literate in them. These include classical mechanics, quantum mechanics, thermodynamics and statistical mechanics, electromagnetism, and special relativity.

Classical Physics:

Main article: Classical physics Classical physics implemented in an acoustic engineering model of sound reflecting from an acoustic diffuserClassical physics includes the traditional branches and topics that were recognized and well-developed before the beginning of the 20th century—classical mechanics, acoustics, optics, thermodynamics, and electromagnetism. Classical mechanics is concerned with bodies acted on by forces and bodies in motion and may be divided into statics (study of the forces on a body or bodies at rest), kinematics (study of motion without regard to its causes), and dynamics (study of motion and the forces that affect it); mechanics may also be divided into solid mechanics and fluid mechanics (known together as continuum mechanics), the latter including such branches as hydrostatics, hydrodynamics, aerodynamics, and pneumatics. Acoustics is the study of how sound is produced, controlled, transmitted and received.[26] Important modern branches of acoustics include ultrasonics, the study of sound waves of very high frequency beyond the range of human hearing; bioacoustics the physics of animal calls and hearing[27], and electroacoustics, the manipulation of audible sound waves using electronics.[28] Optics, the study of light, is concerned not only with visible light but also with infrared and ultraviolet radiation, which exhibit all of the phenomena of visible light except visibility, e.g., reflection, refraction, interference, diffraction, dispersion, and polarization of light. Heat is a form of energy, the internal energy possessed by the particles of which a substance is composed; thermodynamics deals with the relationships between heat and other forms of energy. Electricity and magnetism have been studied as a single branch of physics since the intimate connection between them was discovered in the early 19th century; an electric current gives rise to a magnetic field and a changing magnetic field induces an electric current. Electrostatics deals with electric charges at rest, electrodynamics with moving charges, and magnetostatics with magnetic poles at rest.

Modern Physics:

Main article: Modern physics

Solvay Conference of 1927, with prominent physicists such as Albert Einstein, Werner Heisenberg, Max Planck, Hendrik Lorentz, Niels Bohr, Marie Curie, Erwin Schrödinger and Paul Dirac.

Classical physics is generally concerned with matter and energy on the normal scale of observation, while much of modern physics is concerned with the behavior of matter and energy under extreme conditions or on the very large or very small scale. For example, atomic and nuclear physics studies matter on the smallest scale at which chemical elements can be identified. The physics of elementary particles is on an even smaller scale, as it is concerned with the most basic units of matter; this branch of physics is also known as high-energy physics because of the extremely high energies necessary to produce many types of particles in large particle accelerators. On this scale, ordinary, commonsense notions of space, time, matter, and energy are no longer valid.

The two chief theories of modern physics present a different picture of the concepts of space, time, and matter from that presented by classical physics. Quantum theory is concerned with the discrete, rather than continuous, nature of many phenomena at the atomic and subatomic level, and with the complementary aspects of particles and waves in the description of such phenomena. The theory of relativity is concerned with the description of phenomena that take place in a frame of reference that is in motion with respect to an observer; the special theory of relativity is concerned with relative uniform motion in a straight line and the general theory of relativity with accelerated motion and its connection with gravitation. Both quantum theory and the theory of relativity find applications in all areas of modern physics.

Differences Between Classical and Modern Physics:

While physics aims to discover universal laws, its theories lie in explicit domains of applicability. Loosely speaking, the laws of classical physics accurately describe systems whose important length scales are greater than the atomic scale and whose motions are much slower than the speed of light. Outside of this domain, observations do not match their predictions. Albert Einstein contributed the framework of special relativity, which replaced notions of absolute time and space with spacetime and allowed an accurate description of systems whose components have speeds approaching the speed of light. Max Planck, Erwin Schrödinger, and others introduced quantum mechanics, a probabilistic notion of particles and interactions that allowed an accurate description of atomic and subatomic scales. Later, quantum field theory unified quantum mechanics and special relativity. General relativity allowed for a dynamical, curved spacetime, with which highly massive systems and the large-scale structure of the universe can be well-described. General relativity has not yet been unified with the other fundamental descriptions; several candidate theories of quantum gravity are being developed.

Relation to Other Fields:

Prerequisites:

Mathematics is the language used for compact description of the order in nature, especially the laws of physics. This was noted and advocated by Pythagoras,[29] Plato,[30] Galileo,[31] and Newton.

Physics theories use mathematics[32] to obtain order and provide precise formulas, precise or estimated solutions, quantitative results and predictions. Experiment results in physics are numerical measurements. Technologies based on mathematics, like computation have made computational physics an active area of research.

The distinction between mathematics and physics is clear-cut, but not always obvious, especially in mathematical physics.Ontology is a prerequisite for physics, but not for mathematics. It means physics is ultimately concerned with descriptions of the real world, while mathematics is concerned with abstract patterns, even beyond the real world. Thus physics statements are synthetic, while math statements are analytic. Mathematics contains hypotheses, while physics contains theories. Mathematics statements have to be only logically true, while predictions of physics statements must match observed and experimental data. The distinction is clear-cut, but not always obvious. For example, mathematical physics is the application of mathematics in physics. Its methods are mathematical, but its subject is physical.[33] The problems in this field start with a "math model of a physical situation" and a "math description of a physical law". Every math statement used for solution has a hard-to-find physical meaning. The final mathematical solution has an easier-to-find meaning, because it is what the solver is looking for.

Physics is a branch of fundamental science, not practical science.[34] Physics is also called "the fundamental science" because the subject of study of all branches of natural science like chemistry, astronomy, geology and biology are constrained by laws of physics.[35] For example, chemistry studies properties, structures, and reactions of matter (chemistry's focus on the atomic scale distinguishes it from physics). Structures are formed because particles exert electrical forces on each other, properties include physical characteristics of given substances, and reactions are bound by laws of physics, like conservation of energy, mass and charge. Physics is applied in industries like engineering and medicine.

Application and Influence:

Main article: Applied physicsApplied physics is a general term for physics research which is intended for a particular use. An applied physics curriculum usually contains a few classes in an applied discipline, like geology or electrical engineering. 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 a problem.

The approach is similar to that of applied mathematics. Applied physicists can also be interested in the use of physics for scientific research. For instance, people working on accelerator physics might seek to build better particle detectors for research in theoretical physics.

Physics is used heavily in engineering. For example, statics, a subfield of mechanics, is used in the building of bridges and other static structures. The understanding and use of acoustics results in sound control and better concert halls; similarly, the use of optics creates better optical devices. An understanding of physics makes for more realistic flight simulators, video games, and movies, and is often critical in forensic investigations.

With the standard consensus that the laws of physics are universal and do not change with time, physics can be used to study things that would ordinarily be mired in uncertainty. For example, in the study of the origin of the earth, one can reasonably model earth's mass, temperature, and rate of rotation, as a function of time allowing one to extrapolate forward and backward in time and so predict prior and future conditions. It also allows for simulations in engineering which drastically speed up the development of a new technology.

But there is also considerable interdisciplinarity in the physicist's methods and so many other important fields are influenced by physics, e.g. the fields of econophysics and sociophysics.

Research:

Scientific Method:

Physicists use the scientific method to test the validity of a physical theory, using a methodical approach to compare the implications of the theory in question with the associated conclusions drawn from experiments and observations conducted to test it. Experiments and observations are collected and compared with the predictions and hypotheses made by a theory, thus aiding in the determination or the validity/invalidity of the theory.

A scientific law is a concise verbal or mathematical statement of a relation that expresses a fundamental principle of a theory, like Newton's law of universal gravitation. [36]

Theory and Experiment:

Theoretical Physics:

Experimental Physics:

Main articles: Theoretical physics *and* Experimental physics

The astronaut and Earth are both in free-fall

Lightning is an electric current

Theorists seek to develop mathematical models that both agree with existing experiments and successfully predict future experimental results, while experimentalists devise and perform experiments to test theoretical predictions and explore new phenomena. Although theory and experiment are developed separately, they are strongly dependent upon each other. Progress in physics frequently comes about when experimentalists make a discovery that existing theories cannot explain, or when new theories generate experimentally testable predictions, which inspire new experiments.Physicists who work at the interplay of theory and experiment are called phenomenologists. Phenomenologists look at the complex phenomena observed in experiment and work to relate them to fundamental theory.

Theoretical physics has historically taken inspiration from philosophy; electromagnetism was unified this way.[37] Beyond the known universe, the field of theoretical physics also deals with hypothetical issues,[38] such as parallel universes, a multiverse, and higher dimensions. Theorists invoke these ideas in hopes of solving particular problems with existing theories. They then explore the consequences of these ideas and work toward making testable predictions.Experimental physics expands, and is expanded by, engineering and technology. Experimental physicists involved in basic research design and perform experiments with equipment such as particle accelerators and lasers, whereas those involved in applied research often work in industry, developing technologies such as magnetic resonance imaging (MRI) and transistors. Feynman has noted that experimentalists may seek areas which are not well-explored by theorists.[39]

Scope and Aims:

Physics covers a wide range of phenomena, from elementary particles (such as quarks, neutrinos and electrons) to the largest superclusters of galaxies. Included in these phenomena are the most basic objects composing all other things. Therefore physics is sometimes called the "fundamental science".[35] Physics aims to describe the various phenomena that occur in nature in terms of simpler phenomena. Thus, physics aims to both connect the things observable to humans to root causes, and then connect these causes together.

For example, the ancient Chinese observed that certain rocks (lodestone) were attracted to one another by some invisible force. This effect was later called magnetism, and was first rigorously studied in the 17th century. A little earlier than the Chinese, the ancient Greeks knew of other objects such as amber, that when rubbed with fur would cause a similar invisible attraction between the two. This was also first studied rigorously in the 17th century, and came to be called electricity. Thus, physics had come to understand two observations of nature in terms of some root cause (electricity and magnetism). However, further work in the 19th century revealed that these two forces were just two different aspects of one force—electromagnetism.

This process of "unifying" forces continues today, and electromagnetism and the weak nuclear force are now considered to be two aspects of the electroweak interaction. Physics hopes to find an ultimate reason (Theory of Everything) for why nature is as it is (see section *Current research* below for more information).

Research Fields:

Contemporary research in physics can be broadly divided into condensed matter physics; atomic, molecular, and optical physics; particle physics; astrophysics; geophysics and biophysics. Some physics departments also support research in Physics education.

Since the 20th century, the individual fields of physics have become increasingly specialized, and today most physicists work in a single field for their entire careers. "Universalists" such as Albert Einstein (1879–1955) and Lev Landau (1908–1968), who worked in multiple fields of physics, are now very rare.[40]

Table: Fields, Subfields & Theories

Table of the major fields of physics, along with their subfields and the theories they employ

[hide]

Field

Subfields

Major theories

Concepts

AstrophysicsAstronomy, Astrometry, Cosmology, Gravitation physics, High-energy astrophysics, Planetary astrophysics, Plasma physics, Solar Physics, Space physics, Stellar astrophysicsBig Bang, Cosmic inflation, General relativity, Newton's law of universal gravitation, Lambda-CDM model, MagnetohydrodynamicsBlack hole, Cosmic background radiation, Cosmic string, Cosmos, Dark energy, Dark matter, Galaxy, Gravity, Gravitational radiation, Gravitational singularity, Planet, Solar system, Star, Supernova, Universe

Atomic, molecular, and optical physicsAtomic physics, Molecular physics, Atomic and Molecular astrophysics, Chemical physics, Optics, PhotonicsQuantum optics, Quantum chemistry, Quantum information sciencePhoton, Atom, Molecule, Diffraction, Electromagnetic radiation, Laser, Polarization (waves), Spectral line, Casimir effect

Particle physicsNuclear physics, Nuclear astrophysics, Particle astrophysics, Particle physics phenomenologyStandard Model, Quantum field theory, Quantum electrodynamics, Quantum chromodynamics, Electroweak theory, Effective field theory, Lattice field theory, Lattice gauge theory, Gauge theory, Supersymmetry, Grand unification theory, Superstring theory, M-theoryFundamental force (gravitational, electromagnetic, weak, strong), Elementary particle, Spin, Antimatter, Spontaneous symmetry breaking, Neutrino oscillation, Seesaw mechanism, Brane, String, Quantum gravity, Theory of everything, Vacuum energy

Condensed matter physicsSolid state physics, High pressure physics, Low-temperature physics, Surface Physics, Nanoscale and Mesoscopic physics, Polymer physicsBCS theory, Bloch wave, Density functional theory, Fermi gas, Fermi liquid, Many-body theory, Statistical MechanicsPhases (gas, liquid, solid), Bose-Einstein condensate, Electrical conduction, Phonon, Magnetism, Self-organization, Semiconductor, superconductor, superfluid, Spin,

Applied PhysicsAccelerator physics, Acoustics, Agrophysics, Biophysics, Chemical Physics, Communication Physics, Econophysics, Engineering physics, Fluid dynamics, Geophysics, Laser Physics, Materials physics, Medical physics, Nanotechnology, Optics, Optoelectronics, Photonics, Photovoltaics, Physical chemistry, Physics of computation, Plasma physics, Solid-state devices, Quantum chemistry, Quantum electronics, Quantum information science, Vehicle dynamics

High Energy Physics (Particle Physics) and Nuclear Physics:

Main articles: Particle physics *and* Nuclear Physics A simulated event in the CMS detector of the Large Hadron Collider, featuring a possible appearance of the Higgs boson.Particle physics is the study of the elementary constituents of matter and energy, and the interactions between them.[51] In addition, particle physicists design and develop the high energy accelerators,[52] detectors,[53] and computer programs[54] necessary for this research. The field is also called "high-energy physics" because many elementary particles do not occur naturally, but are created only during high-energy collisions of other particles.[55]

Currently, the interactions of elementary particles and fields are described by the Standard Model.[56] The model accounts for the 12 known particles of matter (quarks and leptons) that interact via the strong, weak, and electromagnetic fundamental forces.[56] Dynamics are described in terms of matter particles exchanging gauge bosons (gluons, W and Z bosons, and photons, respectively).[57] The Standard Model also predicts a particle known as the Higgs boson,[56] the existence of which has not yet been verified. In July 2012 CERN, the European laboratory for particle physics, announced the detection of a particle consistent with the Higgs boson.[58]Nuclear Physics is the field of physics that studies the constituents and interactions of atomic nuclei. The most commonly known applications of nuclear physics are nuclear power generation and nuclear weapons technology, but the research has provided application in many fields, including those in nuclear medicine and magnetic resonance imaging, ion implantation in materials engineering, and radiocarbon dating in geology and archaeology.

Condensed Matter Physics:

Main article: Condensed matter physics

Velocity-distribution data of a gas of rubidium atoms, confirming the discovery of a new phase of matter, the Bose–Einstein condensateCondensed matter physics is the field of physics that deals with the macroscopic physical properties of matter.[41] In particular, it is concerned with the "condensed" phases that appear whenever the number of particles in a system is extremely large and the interactions between them are strong.[42]

The most familiar examples of condensed phases are solids and liquids, which arise from the bonding by way of the electromagnetic force between atoms.[43] More exotic condensed phases include the superfluid[44] and the Bose–Einstein condensate[45] found in certain atomic systems at very low temperature, the superconducting phase exhibited by conduction electrons in certain materials,[46] and the ferromagnetic and antiferromagnetic phases of spins on atomic lattices.[47]

Condensed matter physics is by far the largest field of contemporary physics.[48] Historically, condensed matter physics grew out of solid-state physics, which is now considered one of its main subfields.[49] The term *condensed matter physics* was apparently coined by Philip Anderson when he renamed his research group—previously *solid-state theory*—in 1967.[50] In 1978, the Division of Solid State Physics of the American Physical Society was renamed as the Division of Condensed Matter Physics.[49] Condensed matter physics has a large overlap with chemistry, materials science, nanotechnology and engineering.[42]

Atomic, Molecular and Optical Physics:

Main article: Atomic, molecular, and optical physicsAtomic, molecular, and optical physics (AMO) is the study of matter–matter and light–matter interactions on the scale of single atoms and molecules. The three areas are grouped together because of their interrelationships, the similarity of methods used, and the commonality of the energy scales that are relevant. All three areas include both classical, semi-classical and quantum treatments; they can treat their subject from a microscopic view (in contrast to a macroscopic view).Atomic physics studies the electron shells of atoms. Current research focuses on activities in quantum control, cooling and trapping of atoms and ions,[citation needed] low-temperature collision dynamics and the effects of electron correlation on structure and dynamics. Atomic physics is influenced by the nucleus (see, e.g., hyperfine splitting), but intra-nuclear phenomena such as fission and fusion are considered part of high-energy physics.Molecular physics focuses on multi-atomic structures and their internal and external interactions with matter and light. Optical physics is distinct from optics in that it tends to focus not on the control of classical light fields by macroscopic objects, but on the fundamental properties of optical fields and their interactions with matter in the microscopic realm.

Applied Physics:

Applied physics is a general term for physics which is intended for a particular technological or practical use.[1] It is usually considered as a bridge or a connection between "pure" physics and engineering.[2] "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.[3] 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.[4]

Otherwise Applied Physics or Engineering Physics is no more different from Engineering in the chosen area of speciality eg if one choses to major in High Speed networks and Mobile Communication as electives and an Electronic Engineering student chooses the same there is no substantial perceivable difference. National University of Science and Technology NUST Zimbabwe offers both Engineering Physics/Applied Physics and Electronic Engineering with similar content but having Engineering Physics/Applied Physics having a thorough grounding in both Engineering and Natural Science, hence the common perception that Engineering Physics/Applied Physics is a bridge between natural sciences and engineering.

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 enabling design and construction of high-energy colliders.

Astrophysics:

Main articles: Astrophysics *and* Physical cosmology

The deepest visible-light image of the universe, the Hubble Ultra Deep FieldAstrophysics and astronomy are the application of the theories and methods of physics to the study of stellar structure, stellar evolution, the origin of the solar system, and related problems of cosmology. Because astrophysics is a 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.

The discovery by Karl Jansky in 1931 that radio signals were emitted by celestial bodies initiated the science of radio astronomy. Most recently, the frontiers of astronomy have been expanded by space exploration. Perturbations and interference from the earth's atmosphere make space-based observations necessary for infrared, ultraviolet, gamma-ray, and X-ray astronomy.Physical cosmology is the study of the formation and evolution of the universe on its largest scales. Albert Einstein's theory of relativity plays a central role in all modern cosmological theories. In the early 20th century, Hubble's discovery that the universe was expanding, as shown by the Hubble diagram, prompted rival explanations known as the steady state universe and the Big Bang.

The Big Bang was confirmed by the success of Big Bang nucleosynthesis and the discovery of the cosmic microwave background in 1964. The Big Bang model rests on two theoretical pillars: Albert Einstein's general relativity and the cosmological principle. Cosmologists have recently established the ΛCDM model of the evolution of the universe, which includes cosmic inflation, dark energy and dark matter.

Numerous possibilities and discoveries are anticipated to emerge from new data from the Fermi Gamma-ray Space Telescope over the upcoming decade and vastly revise or clarify existing models of the universe.[59][60] In particular, the potential for a tremendous discovery surrounding dark matter is possible over the next several years.[61] Fermi will search for evidence that dark matter is composed of weakly interacting massive particles, complementing similar experiments with the Large Hadron Collider and other underground detectors.IBEX is already yielding new astrophysical discoveries: "No one knows what is creating the ENA (energetic neutral atoms) ribbon" along the termination shock of the solar wind, "but everyone agrees that it means the textbook picture of the heliosphere — in which the solar system's enveloping pocket filled with the solar wind's charged particles is plowing through the onrushing 'galactic wind' of the interstellar medium in the shape of a comet — is wrong."[62]

Current Research:

Further information: List of unsolved problems in physics

Feynman diagram signed by R.P. Feynman

A typical event described by physics: a magnet levitating above a superconductor demonstrates the Meissner effect.

Research in physics is continually progressing on a large number of fronts.

In condensed matter physics, an important unsolved theoretical problem is that of high-temperature superconductivity. Many condensed matter experiments are aiming to fabricate workable spintronics and quantum computers.

In particle physics, the first pieces of experimental evidence for physics beyond the Standard Model have begun to appear. Foremost among these are indications that neutrinos have non-zero mass. These experimental results appear to have solved the long-standing solar neutrino problem, and the physics of massive neutrinos remains an area of active theoretical and experimental research. Particle accelerators have begun probing energy scales in the TeV range, in which experimentalists are hoping to find evidence for the Higgs boson and supersymmetric particles.[63]

Theoretical attempts to unify quantum mechanics and general relativity into a single theory of quantum gravity, a program ongoing for over half a century, have not yet been decisively resolved. The current leading candidates are M-theory, superstring theory and loop quantum gravity.

Many astronomical and cosmological phenomena have yet to be satisfactorily explained, including the existence of ultra-high energy cosmic rays, the baryon asymmetry, the acceleration of the universe and the anomalous rotation rates of galaxies.

Although much progress has been made in high-energy, quantum, and astronomical physics, many everyday phenomena involving complexity, chaos, or turbulence are still poorly understood.[citation needed] Complex problems that seem like they could be solved by a clever application of dynamics and mechanics remain unsolved; examples include the formation of sandpiles, nodes in trickling water, the shape of water droplets, mechanisms of surface tension catastrophes, and self-sorting in shaken heterogeneous collections.[citation needed]

These complex phenomena have received growing attention since the 1970s for several reasons, including the availability of modern mathematical methods and computers, which enabled complex systems to be modeled in new ways. Complex physics has become part of increasingly interdisciplinary research, as exemplified by the study of turbulence in aerodynamics and the observation of pattern formation in biological systems. In 1932, Horace Lamb said:[64]

I am an old man now, and when I die and go to heaven there are two matters on which I hope for enlightenment. One is quantum electrodynamics, and the other is the turbulent motion of fluids. And about the former I am rather optimistic.

Unsolved Problems:

Some of the major unsolved problems in physics are theoretical, meaning that existing theories seem incapable of explaining a certain observed phenomenon or experimental result. The others are experimental, meaning that there is a difficulty in creating an experiment to test a proposed theory or investigate a phenomenon in greater detail.

Additional References:

General

•Glossary of classical physics

•Glossary of physics

•Index of physics articles

•List of elementary physics formulae, Elementary physics formulae

•List of important publications in physics

•List of physicists

•List of physics concepts in primary and secondary education curricula

•Perfection in physics and chemistry

•Timeline of developments in theoretical physics

•Timeline of fundamental physics discoveries

Main branches

•Classical Mechanics

•Electricity and Magnetism

•Modern Physics

•Optics

•Thermodynamics

Related fields

•Astronomy

•Chemistry

•Engineering

•Mathematics

•Quantum Mechanics

•Science

Interdisciplinary fields incorporating physics

•Acoustics

•Biophysics

•Econophysics

•Geophysics

•Nanotechnology

•Neurophysics

•Psychophysics

Process: (further research is required)

Research:[Investigate]

Research:

Summary:

This article is about the search for knowledge. For the suburb of Melbourne, Australia, see Research, Victoria.

For the publisher, see RE/Search.

For information on using Wikipedia for research, see Wikipedia:Researching with Wikipedia.

Basrelief sculpture "Research holding the torch of knowledge" (1896) by Olin Levi Warner. Library of Congress Thomas Jefferson Building, Washington, D.C.

"**Research** and experimental development (R&D) comprise creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications." (OECD (2002) Frascati Manual: proposed standard practice for surveys on research and experimental development, 6th edition.)[1] It is used to establish or confirm facts, reaffirm the results of previous work, solve new or existing problems, support theorems, or develop new theories. A research project may also be an expansion on past work in the field. To test the validity of instruments, procedures, or experiments, research may replicate elements of prior projects, or the project as a whole. The primary purposes of basic research (as opposed to applied research) are documentation, discovery, interpretation, or the research and development of methods and systems for the advancement of human knowledge. Approaches to research depend on epistemologies, which vary considerably both within and between humanities and sciences. There are several forms of research: scientific, humanities, artistic, economic, social, business, marketing, practitioner research, etc.

Forms of Research:

Scientific research relies on the application of the scientific method, a harnessing of curiosity. This research provides scientific information and theories for the explanation of the nature and the properties of the world. It makes practical applications possible. Scientific research is funded by public authorities, by charitable organizations and by private groups, including many companies. Scientific research can be subdivided into different classifications according to their academic and application disciplines. Scientific research is a widely used criterion for judging the standing of an academic institution, such as business schools, but some argue that such is an inaccurate assessment of the institution, because the quality of research does not tell about the quality of teaching (these do not necessarily correlate totally).[2]

Research in the humanities involves different methods such as for example hermeneutics and semiotics, and a different, more relativist epistemology. Humanities scholars usually do not search for the ultimate correct answer to a question, but instead explore the issues and details that surround it. Context is always important, and context can be social, historical, political, cultural or ethnic. An example of research in the humanities is historical research, which is embodied in historical method. Historians use primary sources and other evidence to systematically investigate a topic, and then to write histories in the form of accounts of the past.

Artistic research, also seen as 'practice-based research', can take form when creative works are considered both the research and the object of research itself. It is the debatable body of thought which offers an alternative to purely scientific methods in research in its search for knowledge and truth.

The phrase *my research* is also used loosely to describe a person's entire collection of information about a particular subject.

Etymology:

The word *research* is derived from the Middle French "*recherche*", which means "to go about seeking", the term itself being derived from the Old French term "*recerchier*" a compound word from "re-" + "cerchier", or "sercher", meaning 'search'.[4] The earliest recorded use of the term was in 1577.[4]

Definitions:

Research has been defined in a number of different ways.

A broad definition of research is given by Martyn Shuttleworth - "In the broadest sense of the word, the definition of research includes any gathering of data, information and facts for the advancement of knowledge."[5]

Another definition of research is given by Creswell who states - "Research is a process of steps used to collect and analyze information to increase our understanding of a topic or issue". It consists of three steps: Pose a question, collect data to answer the question, and present an answer to the question.[6]

The Merriam-Webster Online Dictionary defines research in more detail as "a studious inquiry or examination; especially : investigation or experimentation aimed at the discovery and interpretation of facts, revision of accepted theories or laws in the light of new facts, or practical application of such new or revised theories or laws".[4]

Steps in Conducting Research:

Research is often conducted using the hourglass model structure of research.[7] The hourglass model starts with a broad spectrum for research, focusing in on the required information through the method of the project (like the neck of the hourglass), then expands the research in the form of discussion and results. The major steps in conducting research are:[8]

•Identification of research problem

•Literature review

•Specifying the purpose of research

•Determine specific research questions or hypotheses

•Data collection

•Analyzing and interpreting the data

•Reporting and evaluating research

The steps generally represent the overall process, however they should be viewed as an ever-changing process rather than a fixed set of steps.[9] Most researches begin with a general statement of the problem, or rather, the purpose for engaging in the study.[10] The literature review identifies flaws or holes in previous research which provides justification for the study. Often, a literature review is conducted in a given subject area before a research question is identified. A gap in the current literature, as identified by a researcher, then engenders a research question. The research question may be parallel to the hypothesis. The hypothesis is the supposition to be tested. The researcher(s) collects data to test the hypothesis. The researcher(s) then analyzes and interprets the data via a variety of statistical methods, engaging in what is known as Empirical research. The results of the data analysis in confirming or failing to reject the Null hypothesis are then reported and evaluated. At the end the researcher may discuss avenues for further research.Rudolph Rummel says, "... no researcher should accept any one or two tests as definitive. It is only when a range of tests are consistent over many kinds of data, researchers, and methods can one have confidence in the results."[11]

Scientific Research:

Main article: Scientific method

Primary scientific research being carried out at the Microscopy Laboratory of the Idaho National Laboratory.

Scientific research equipment at MIT.

Generally, research is understood to follow a certain structural process. Though step order may vary depending on the subject matter and researcher, the following steps are usually part of most formal research, both basic and applied:

1.Observations and Formation of the topic: Consists of the subject area of ones interest and following that subject area to conduct subject related research. The subject area should not be randomly chosen since it requires reading a vast amount of literature on the topic to determine the gap in the literature the researcher intends to narrow. A keen interest in the chosen subject area is advisable. The research will have to be justified by linking its importance to already existing knowledge about the topic.

2.Hypothesis: A testable prediction which designates the relationship between two or more variables.

3.Conceptual definition: Description of a concept by relating it to other concepts.

4.Operational definition: Details in regards to defining the variables and how they will be measured/assessed in the study.

5.Gathering of data: Consists of identifying a population and selecting samples, gathering information from and/or about these samples by using specific research instruments. The instruments used for data collection must be valid and reliable.

6.Analysis of data: Involves breaking down the individual pieces of data in order to draw conclusions about it.

7.Data Interpretation: This can be represented through tables, figures and pictures, and then described in words.

8.Test, revising of hypothesis

9.Conclusion, reiteration if necessary

A common misconception is that a hypothesis will be proven (see, rather, Null hypothesis). Generally a hypothesis is used to make predictions that can be tested by observing the outcome of an experiment. If the outcome is inconsistent with the hypothesis, then the hypothesis is rejected (see falsifiability). However, if the outcome is consistent with the hypothesis, the experiment is said to support the hypothesis. This careful language is used because researchers recognize that alternative hypotheses may also be consistent with the observations. In this sense, a hypothesis can never be proven, but rather only supported by surviving rounds of scientific testing and, eventually, becoming widely thought of as true.

A useful hypothesis allows prediction and within the accuracy of observation of the time, the prediction will be verified. As the accuracy of observation improves with time, the hypothesis may no longer provide an accurate prediction. In this case a new hypothesis will arise to challenge the old, and to the extent that the new hypothesis makes more accurate predictions than the old, the new will supplant it. Researchers can also use a null hypothesis, which state no relationship or difference between the independent or dependent variables. A null hypothesis uses a sample of all possible people to make a conclusion about the population.[12]

Historical Method:

Main article: Historical method

German historian Leopold von Ranke (1795-1886), considered to be one of the founders of modern source-based history.

The historical method comprises the techniques and guidelines by which historians use historical sources and other evidence to research and then to write history. There are various history guidelines commonly used by historians in their work, under the headings of external criticism, internal criticism, and synthesis. This includes lower criticism and sensual criticism. Though items may vary depending on the subject matter and researcher, the following concepts are part of most formal historical research:[13]

- Identification of origin date
- Evidence of localization
- Recognition of authorship
- Analysis of data

•Identification of integrity

•Attribution of credibility

Methods:

Summary:

The goal of the research process is to produce new knowledge or deepen understanding of a topic or issue. This process takes three main forms (although, as previously discussed, the boundaries between them may be obscure):

•Exploratory research, which helps to identify and define a problem or question.

•Constructive research, which tests theories and proposes solutions to a problem or question.

•Empirical research, which tests the feasibility of a solution using empirical evidence.

The research room at the New York Public Library, an example of secondary research in progress.

There are two major types of research design: qualitative research and quantitative research. Researchers choose qualitative or quantitative methods according to the nature of the research topic they want to investigate and the research questions they aim to answer:

Maurice Hilleman is credited with saving more lives than any other scientist of the 20th century.[14]Qualitative research

Understanding of human behavior and the reasons that govern such behavior. Asking a broad question and collecting data in the form of words, images, video etc that is analyzed searching for themes. This type of research aims to investigate a question without attempting to quantifiably measure variables or look to potential relationships between variables. It is viewed as more restrictive in testing hypotheses because it can be expensive and time consuming, and typically limited to a single set of research subjects[citation needed]. Qualitative research is often used as a method of exploratory research as a basis for later quantitative research hypotheses[citation needed]. Qualitative research is linked with the philosophical and theoretical stance of social constructionism.Quantitative research

Systematic empirical investigation of quantitative properties and phenomena and their relationships. Asking a narrow question and collecting numerical data to analyze utilizing statistical methods. The quantitative research designs are experimental, correlational, and survey (or descriptive).[15] Statistics derived from quantitative research can be used to establish the existence of associative or causal relationships between variables. Quantitative research is linked with the philosophical and theoretical stance of positivism.

The Quantitative data collection methods rely on random sampling and structured data collection instruments that fit diverse experiences into predetermined response categories[citation needed]. These methods produce results that are easy to summarize, compare, and generalize[citation needed]. Quantitative research is concerned with testing hypotheses derived from theory and/or being able to estimate the size of a phenomenon of interest. Depending on the research question, participants may be randomly assigned to different treatments (this is the only way that a quantitative study can be considered a true experiment)[citation needed]. If this is not feasible, the researcher may collect data on participant and situational characteristics in order to statistically control for their influence on the dependent, or outcome, variable. If the intent is to generalize from the research participants to a larger population, the researcher will employ probability sampling to select participants.[16]

In either qualitative or quantitative research, the researcher(s) may collect primary or secondary data. Primary data is data collected specifically for the research, such as through interviews or questionnaires. Secondary data is data that already exists, such as census data, which can be re-used for the research. It is good ethical research practice to use secondary data wherever possible.[17]

Mixed-method research, i.e. research that includes qualitative and quantitative elements, using both primary and secondary data, is becoming more common.[18]

Research Process:

Exploratory Research:

Summary:

Constructive Research:

Summary:

Empirical Research:

Summary:

Research Design:

Qualitative Research:

Summary:

Qualitative research is a method of inquiry employed in many different academic disciplines, traditionally in the social sciences, but also in market research and further contexts.[1] Qualitative researchers aim to gather an in-depth understanding of human behavior and the reasons that govern such behavior. The qualitative method investigates the *why* and *how* of decision making, not just *what*, *where*, *when*. Hence, smaller but focused samples are more often needed than large samples.

In the conventional view, qualitative methods produce information only on the particular cases studied, and any more general conclusions are only propositions (informed assertions). Quantitative methods can then be used to seek empirical support for such research hypotheses.

Quantitative Research:

Summary:

In sociology, **quantitative research** refers to the systematic empirical investigation of social phenomena via statistical, mathematical or computational techniques.[1] The objective of quantitative research is to develop and employ mathematical models, theories and/or hypotheses pertaining to phenomena. The process of measurement is central to quantitative research because it provides the fundamental connection between empirical observation and mathematical expression of quantitative relationships. Quantitative data is any data that is in numerical form such as statistics, percentages, etc.[1] In layman's terms, this means that the quantitative researcher asks a specific, narrow question and collects a sample of numerical data from participants to answer the question. The researcher analyzes the data with the help of statistics. The researcher is hoping the numbers will yield an unbiased result that can be generalized to some larger population. Qualitative research, on the other hand, asks broad questions and collects word data from participants. The researcher looks for themes and describes the information in themes and patterns exclusive to that set of participants.

More generally, quantitative research is widely used in social sciences such as psychology, economics, sociology, marketing, and political science, and less frequently in anthropology and history. Research in mathematical sciences such as physics is also 'quantitative' by definition, though this use of the term differs in context. In the social sciences, the term relates to empirical methods, originating in both philosophical positivism and the history of statistics, which contrast with qualitative research methods.

Qualitative methods produce information only on the particular cases studied, and any more general conclusions are only hypotheses. Quantitative methods can be used to verify which of such hypotheses are true.

A comprehensive analysis of 1274 articles published in the top two American sociology journals between 1935 and 2005 found that roughly two thirds of these articles used quantitative methods.[2]

Discovery: (observation) [Investigate]

Summary:

Discovery is the act of detecting something new, or something "old" that had been unknown. With reference to science and academic disciplines, discovery is the observation of new phenomena, new actions, or new events and providing new reasoning to explain the knowledge gathered through such observations with previously acquired knowledge from abstract thought and everyday experiences. Visual discoveries are often called **sightings**.[citation needed]

Discovery:

Summary:

New discoveries are acquired through various senses and are usually assimilated, merging with pre-existing knowledge and actions. Questioning is a major form of human thought and interpersonal communication, and plays a key role in discovery.[citation needed] Discoveries are often made due to questions. Some discoveries lead to the invention of objects, processes, or techniques. A discovery may sometimes be based on earlier discoveries, collaborations or ideas, and the process of discovery requires at least the awareness that an existing concept or method can be modified or transformed.[citation needed] However, some discoveries also represent a radical breakthrough in knowledge.

Within Science:

Within scientific disciplines, discovery is the observation of new phenomena, actions, or events which helps explain knowledge gathered through previously acquired scientific evidence. In science, exploration is one of three purposes of research,[citation needed] the other two being description and explanation. Discovery is made by providing observational evidence and attempts to develop an initial, rough understanding of some phenomenon.

Discovery within the field of particle physics has an accepted definition for what constitutes a discovery: a five-sigma level of certainty.[1] Such a level defines statistically how unlikely it is that an experimental result is due to chance. The combination of a five-sigma level of certainty, and independent confirmation by other experiments, turns findings into accepted discoveries.[1]

Investigation:

Science

Science

Experiment:

Summary:

An **experiment** is an orderly procedure carried out with the goal of verifying, refuting, or establishing the validity of a hypothesis. Experiments provide insight into cause-and-effect by demonstrating what outcome occurs when a particular factor is manipulated. Experiments vary greatly in their goal and scale, but always rely on repeatable procedure and logical analysis of the results. A child may carry out basic experiments to understand the nature of gravity, while teams of scientists may take years of systematic investigation to advance the understanding of a phenomenon. Experiments can vary from personal and informal (e.g. tasting a range of chocolates to find a favorite), to highly controlled (e.g. tests requiring complex apparatus overseen by many scientists that hope to discover information about subatomic particles). Uses of experiments vary considerably between the natural and social sciences.

Overview:

In the scientific method, an **experiment** is an empirical method that arbitrates between competing models or hypotheses.[1][2] Experimentation is also used to test existing theories or new hypotheses in order to support them or disprove them.[3][4]

An experiment usually tests a hypothesis, which is an expectation about how a particular process or phenomenon works. However, an experiment may also aim to answer a "what-if" question, without a specific expectation about what the experiment will reveal, or to confirm prior results. If an experiment is carefully conducted, the results usually either support or disprove the hypothesis. According to some Philosophies of science, an experiment can never "prove" a hypothesis, it can only add support. Similarly, an experiment that provides a counterexample can disprove a theory or hypothesis. An experiment must also control the possible confounding factors—any factors that would mar the accuracy or repeatability of the experiment or the ability to interpret the results. Confounding is commonly eliminated through scientific control and/or, in randomized experiments, through random assignment.

In engineering and other physical sciences, experiments are a primary component of the scientific method. They are used to test theories and hypotheses about how physical processes work under particular conditions (e.g., whether a particular engineering process can produce a desired chemical compound). Typically, experiments in these fields will focus on replication of identical procedures in hopes of producing identical results in each replication. Random assignment is uncommon.

In medicine and the social sciences, the prevalence of experimental research varies widely across disciplines. When used, however, experiments typically follow the form of the clinical trial, where experimental units (usually individual human beings) are randomly assigned to a treatment or control condition where one or more outcomes are assessed.[5] In contrast to norms in the physical sciences, the focus is typically on the average treatment effect (the difference in outcomes between the treatment and control groups) or another test statistic produced by the experiment.[6] A single study will typically not involve replications of the experiment, but separate studies may be aggregated through systematic review and meta-analysis.

Of course, these differences between experimental practice in each of the branches of science have exceptions. For example, agricultural research frequently uses randomized experiments (e.g., to test the comparative effectiveness of different fertilizers). Similarly, experimental economics often involves experimental tests of theorized human behaviors without relying on random assignment of individuals to treatment and control conditions.[7]

Types:

Summary:

Experiments might be categorized according to a number of dimensions, depending upon professional norms and standards in different fields of study. In some disciplines (e.g., Psychology or Political Science), a 'true experiment' is a method of social research in which there are two kinds of variables. The independent variable is manipulated by the experimenter, and the dependent variable is measured. The signifying characteristic of a true experiment is that it randomly allocates the subjects in order to neutralize the potential for experimenter bias and ensures, over a large number of iterations of the experiment, that all confounding factors are controlled for.[12][13]

Timeline of Scientific Discoveries:

The Scientific Method:

Main article: Scientific method

The scientific method seeks to explain the events of nature in a reproducible way.[53] An explanatory thought experiment or hypothesis is put forward, as explanation, using principles such as parsimony (also known as "Occam's Razor") and are generally expected to seek consilience—fitting well with other accepted facts related to the phenomena.[54] This new explanation is used to make falsifiable predictions that are testable by experiment or observation. The predictions are to be posted before a confirming experiment or observation is sought, as proof that no tampering has occurred. Disproof of a prediction is evidence of progress.[55][56] This is done partly through observation of natural phenomena, but also through experimentation, that tries to simulate natural events under controlled conditions, as appropriate to the discipline (in the observational sciences, such as astronomy or geology, a predicted observation might take the place of a controlled experiment). Experimentation is especially important in science to help establish causal relationships (to avoid the correlation fallacy).

When a hypothesis proves unsatisfactory, it is either modified or discarded.[57] If the hypothesis survived testing, it may become adopted into the framework of a scientific theory. This is a logically reasoned, self-consistent model or framework for describing the behavior of certain natural phenomena. A theory typically describes the behavior of much broader sets of phenomena than a hypothesis; commonly, a large number of hypotheses can be logically bound together by a single theory. Thus a theory is a hypothesis explaining various other hypotheses. In that vein, theories are formulated according to most of the same scientific principles as hypotheses. In addition to testing hypotheses, scientists may also generate a model based on observed phenomena. This is an attempt to describe or depict the phenomenon in terms of a logical, physical or mathematical representation and to generate new hypotheses that can be tested.[58]

While performing experiments to test hypotheses, scientists may have a preference for one outcome over another, and so it is important to ensure that science as a whole can eliminate this bias.[59][60] This can be achieved by careful experimental design, transparency, and a thorough peer review process of the experimental results as well as any conclusions.[61][62] After the results of an experiment are announced or published, it is normal practice for independent researchers to double-check how the research was performed, and to follow up by performing similar experiments to determine how dependable the results might be.[63] Taken in its entirety, the scientific method allows for highly creative problem solving while minimizing any effects of subjective bias on the part of its users (namely the confirmation bias).[64]

Summary:

This article is about the general term, particularly as it refers to experimental sciences. For other uses, see Science (disambiguation).

Science (from Latin *scientia*, meaning "knowledge"[1]) is a systematic enterprise that builds and organizes knowledge in the form of testable explanations and predictions about the universe.[2][3] In an older and closely related meaning, "science" also refers to a body of knowledge itself, of the type that can be rationally explained and reliably applied. A practitioner of science is known as a scientist.

Since classical antiquity, science as a type of knowledge has been closely linked to philosophy. In the early modern period the words "science" and "philosophy" were sometimes used interchangeably.[4] By the 17th century, natural philosophy (which is today called "natural science") was considered a separate branch of philosophy.[5] However, "science" continued to be used in a broad sense denoting reliable knowledge about a topic, in the same way it is still used in modern terms such as library science or political science.

In modern use, "science" more often refers to a way of pursuing knowledge, not only the knowledge itself. It is often treated as synonymous with 'natural and physical science', and thus restricted to those branches of study that relate to the phenomena of the material universe and their laws, sometimes with implied exclusion of pure mathematics. This is now the dominant sense in ordinary use.[6] This narrower sense of "science" developed as scientists such as Johannes Kepler, Galileo Galilei and Isaac Newton began formulating laws of nature such as Newton's laws of motion. In this period[vague] it became more common to refer to natural philosophy as "natural science". Over the course of the 19th century, the word "science" became increasingly associated with the scientific method, a disciplined way to study the natural world, including physics, chemistry, geology and biology.

It is in the 19th century also that the term scientist was created by the naturalist-theologian William Whewell to distinguish those who sought knowledge on nature from those who sought knowledge on other disciplines. The *Oxford English Dictionary* dates the origin of the word "scientist" to 1834. This sometimes left the study of human thought and society in a linguistic limbo, which was resolved by classifying these areas of academic study as social science. Similarly, several other major areas of disciplined study and knowledge exist today under the general rubric of "science", such as formal science and applied science.

Causality:

Summary:

Causality (also referred to as **causation**[1]) is the relation between an event (the *cause*) and a second event (the effect), where the second event is understood as a consequence of the first.[2]

In common usage, causality is also the relation between a set of factors (causes) and a phenomenon (the effect). Anything that affects an effect is a factor of that effect. A direct factor is a factor that affects an effect directly, that is, without any intervening factors. (Intervening factors are sometimes called "intermediate factors".) The connection between a cause(s) and an effect in this way can also be referred to as a *causal nexus*.

Though the causes and effects are typically related to changes or events, candidates include objects, processes, properties, variables, facts, and states of affairs; characterizing the causal relation can be the subject of much debate.

The philosophical treatment on the subject of causality extends over millennia. In the Western philosophical tradition, discussion stretches back at least to Aristotle, and the topic remains a staple in contemporary philosophy.

Authors:

Thomas Kuhn:

Semiotics:

Outline of Semiotics:

Semiotics – study of signs and sign processes (semiosis), indication, designation, likeness, analogy, metaphor, symbolism, signification, and communication. Semiotics is closely related to the field of linguistics, which, for its part, studies the structure and meaning of language more specifically. Also called semiotic studies, or semiology (in the Saussurean tradition).

Branches of Semiotics:

Main Branch:

•Semantics – relation between signs and the things to which they refer; their *denotata*, or meaning

•Syntactics – relations among signs in formal structures

•Pragmatics – relation between signs and the effects they have on the people who use them

Subfields

•Biosemiotics – growing field that studies the production, action and interpretation of signs and codes [1] in the biological realm. Biosemiotics attempts to integrate the findings of scientific biology and semiotics, representing a paradigmatic shift in the occidental scientific view of life, demonstrating that semiosis (sign process, including meaning and interpretation) is its immanent and intrinsic feature.

•Cognitive semiotics – study of meaning-making by employing and integrating methods and theories developed in the cognitive sciences as well as in the human sciences. It involves conceptual and textual analysis as well as experimental and ethnographic investigations.

•Computational semiotics – attempts to engineer the process of semiosis, in the study of and design for Human-Computer Interaction, and mimic aspects of human cognition through artificial intelligence and knowledge representation.

•Cultural semiotics –

•Design Semiotics –

•Product Semiotics – study of the use of signs in the design of physical products. Introduced by Rune Monö while teaching Industrial Design at the Institute of Design, Umeå University, Sweden.

•Law and Semiotics –

•Literary semiotics – approach to literary criticism informed by the theory of signs or semiotics. Semiotics, tied closely to the structuralism pioneered by Ferdinand de Saussure, was extremely influential in the development of literary theory out of the formalist approaches of the early twentieth century.

•Music semiology – "There are strong arguments that music inhabits a semiological realm which, on both ontogenetic and phylogenetic levels, has developmental priority over verbal language." (Middleton 1990, p. 172) See Nattiez (1976, 1987, 1989), Stefani (1973, 1986), Baroni (1983), and *Semiotica* (66: 1–3 (1987)).

•Gregorian chant semiology – current avenue of palaeographical research in Gregorian chant which is revising the Solesmes school of interpretation.

•Organisational semiotics – examines the nature, characteristics and features of information, and studies how information can be best used in the context of organised activities and business domains. Organisational semiotics treats organisations as information systems in which information is created, processed, distributed, stored and used.

•Semiotic anthropology – semiotics of Charles Sanders Peirce and Roman Jakobson applied to anthropology.

•Semiotic engineering – views HCI as computer-mediated communication between designers and users at interaction time. The system speaks for its designers in various types of conversations specified at design time. These conversations communicate the designers' understanding of who the users are, what they know the users want or need to do, in which preferred ways, and why.

•Semiotic information theory – considers the information content of signs and expressions as it is conceived within the semiotic or sign-relational framework developed by Charles Sanders Peirce.

•Social semiotics – expands the interpretable semiotic landscape to include all cultural codes, such as in slang, fashion, and advertising. It considers social connotations, including meanings related to ideology and power structures, in addition to denotative meanings of signs.

•Urban semiotics – study of meaning in urban form as generated by signs, symbols, and their social connotations.[1] It focuses on material objects of the built environment, such as streets, squares, parks, and buildings, but also abstract cultural constructs such as building codes, planning documents, unbuilt designs, real estate advertising, and popular discourse about the city,[2] such as architectural criticism and real estate blogs.

•Theatre Semiotics – extends or adapts semiotics onstage. Key theoricians include Keir Elam.

•Visual semiotics – analyses visual signs. See also visual rhetoric.[3]

History of Semiotics:

•History of semiotics

•Tartu-Moscow Semiotic School – scientific school of thought that was formed since 1964 and led by Juri Lotman. Among the other members of this school were Boris Uspensky, Vyacheslav Vsevolodovich Ivanov, Vladimir Toporov, Mikhail Gasparov, Alexander Piatigorsky, Isaak I. Revzin, and others. As a result of their collective work, they established a theoretical framework around the semiotics of culture.

Methods of Semiotics:

•Commutation test –

•Paradigmatic analysis –

•Syntagmatic analysis –

Semiotic Analysis:

•Semiotic democracy

•Semiotic elements and classes of signs

•Semiotics of interactive media

•Semiotics of music videos

•Semiotics of photography

•Semiotics of social networking

•Semiotics of wrestling characters

General Semiotics Concepts:

•Biosemiotics –

•Code –

•Computational semiotics –

•Connotation –

•Decode –

•Denotation –

•Encode –

•Lexical –

•Literary semiotics –

•Modality –

•Representation (arts) –

•Salience –

•Semeiotic –

•Semiosis –

•Semiotic square –

•Semiosphere –

•Semiotic elements & sign classes –

•Sign –

•Sign relational complex –

•Sign relation –

•Umwelt –

•Value –

Additional Article References: Organizations, Publications, Influential Persons, Cognitive Semioticians, & Other

Semiotics organizations[edit]

•International Association for Semiotic Studies

•International Association for the Semiotics of Law

•International Society for Biosemiotic Studies

•Semiotic Society of America

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•The American Journal of Semiotics

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•Semiotica

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•Sign Systems Studies

•Versus

Persons influential in semiotics[edit]

•Mikhail Bakhtin –

•Roland Barthes –

•Marcel Danesi –

•John Deely –

•Umberto Eco –

•Algirdas Julien Greimas –

•Félix Guattari –

•Louis Hjelmslev –

•Vyacheslav Ivanov –

•Roman Jakobson –

•Roberta Kevelson –

•Kalevi Kull –

•Juri Lotman –

•Charles S. Peirce –

•Augusto Ponzio –

•Ferdinand de Saussure –

•Thomas Sebeok –

•Michael Silverstein –

•Eero Tarasti –

•Vladimir Toporov –

•Jakob von Uexküll –

Cognitive semioticians[edit]

•Per Aage Brandt –

•Peer Bundgård –

•Riccardo Fusaroli –

•Svend Østergaard –

•Frederik Stjernfelt –

•Kristian Tylén –

•Mikkel Wallentin –

•Jordan Zlatev –

Literary semioticians[edit]

•Roland Barthes –

•Marcel Danesi –

•Juri Lotman –

Social semioticians[edit]

•Roland Barthes –

•Michael Halliday –

•Bob Hodge –

•Christian Metz –

See also[edit]Semiotics portal

•Structuralism

•Post-structuralism

•Aestheticization of violence

•Postmodernity

Summary:

Semiotics, also called **semiotic studies** and including (in the Saussurean tradition) **semiology**, is the study of signs and sign processes (semiosis), indication, designation, likeness, analogy, metaphor, symbolism, signification, and communication. Semiotics is closely related to the field of linguistics, which, for its part, studies the structure and meaning of language more specifically. However, as different from linguistics, semiotics studies also non-linguistic sign systems. Semiotics is often divided into three branches:

•Semantics: Relation between signs and the things to which they refer; their *denotata*, or meaning

•Syntactics: Relations among signs in formal structures

•Pragmatics: Relation between signs and sign-using agents

Semiotics is frequently seen as having important anthropological dimensions; for example, Umberto Eco proposes that every cultural phenomenon can be studied as communication.[1] However, some semioticians focus on the logical dimensions of the science. They examine areas belonging also to the natural sciences – such as how organisms make predictions about, and adapt to, their semiotic niche in the world (see semiosis). In general, semiotic theories take *signs* or sign systems as their object of study: the communication of information in living organisms is covered in biosemiotics (including zoosemiotics).

Syntactics is the branch of semiotics that deals with the formal properties of signs and symbols.[2] More precisely, syntactics deals with the "rules that govern how words are combined to form phrases and sentences."[3] Charles Morris adds that semantics deals with the relation of signs to their designata and the

objects which they may or do denote; and, pragmatics deals with the biotic aspects of semiosis, that is, with all the psychological, biological, and sociological phenomena which occur in the functioning of signs.
Sense:
Summary:

"Five senses" redirects here. For other uses, see Five senses (disambiguation).

Senses are physiological capacities of organisms that provide data for perception. The senses and their operation, classification, and theory are overlapping topics studied by a variety of fields, most notably neuroscience, cognitive psychology (or cognitive science), and philosophy of perception. The nervous system has a specific sensory system or organ, dedicated to each sense.

Humans have a multitude of senses. Sight (ophthalmoception), hearing (audioception), taste (gustaoception), smell (olfacoception or olfacception), and touch (tactioception) are the five traditionally recognized. While the ability to detect other stimuli beyond those governed by the traditional senses exists, including temperature (thermoception), kinesthetic sense (proprioception), pain (nociception), balance (equilibrioception), acceleration (kinesthesioception)[citation needed], and various internal stimuli (e.g. the different chemoreceptors for detecting salt and carbon dioxide concentrations in the blood), only a small number of these can safely be classified as separate senses in and of themselves. What constitutes a sense is a matter of some debate, leading to difficulties in defining what exactly a sense is.

Animals also have receptors to sense the world around them, with degrees of capability varying greatly between species. Humans have a comparatively weak sense of smell, while some animals may lack one or more of the traditional five senses. Some animals may also intake and interpret sensory stimuli in very different ways. Some species of animals are able to sense the world in a way that humans cannot, with some species able to sense electrical and magnetic fields, and detect water pressure and currents.

Definition:

There is no firm agreement among neurologists as to the number of senses because of differing definitions of what constitutes a sense. One definition states that an exteroceptive sense is a faculty by which outside stimuli are perceived. According to Aristotle, humans possess five senses: sight, hearing, touch, smell and taste.[1] Humans are considered to have at least five additional senses that include: nociception (pain); equilibrioception (balance); proprioception and kinaesthesia (joint motion and acceleration); sense of time; thermoception (temperature differences); and possibly an additional weak magnetoception (direction),[2] and six more if interoceptive senses (see *other internal senses* below) are also considered.

One commonly recognized categorisation for human senses is as follows: chemoreception; photoreception; mechanoreception; and thermoception. This categorisation has been criticized as too restrictive, however, as it does not include categories for accepted senses such as the sense of time and sense of pain.

Non-human animals may possess senses that are absent in humans, such as electroreception and detection of polarized light.

A broadly acceptable definition of a sense would be "A system that consists of a group of sensory cell types that responds to a specific physical phenomenon, and that corresponds to a particular group of regions within the brain where the signals are received and interpreted." Disputes about the number of senses typically arise around the classification of the various cell types and their mapping to regions of the brain.

In Buddhist philosophy, Ayatana or "sense-base" includes the mind as a sense organ, in addition to the traditional five. This addition to the commonly acknowledged senses may arise from the psychological orientation involved in Buddhist thought and practice. The mind considered by itself is seen as the principal gateway to a different spectrum of phenomena that differ from the physical sense data. This way of viewing the human sense system indicates the importance of internal sources of sensation and perception that complements our experience of the external world.

Traditional Senses:

Sight[edit]

In this painting by Pietro Paolini, each individual represents one of the five senses.[3] The Walters Art Museum.Sight or **vision** is the capability of the eye(s) to focus and detect images of visible light on photoreceptors in the retina of each eye that generates electrical nerve impulses for varying colors, hues, and brightness. There are two types of photoreceptors: rods and cones. Rods are very sensitive to light, but do not distinguish colors. Cones distinguish colors, but are less sensitive to dim light. There is some disagreement as to whether this constitutes one, two or three senses. Neuroanatomists generally regard it as two senses, given that different receptors are responsible for the perception of color and brightness. Some argue[citation needed] that stereopsis, the perception of depth using both eyes, also constitutes a sense, but it is generally regarded as a cognitive (that is, post-sensory) function of the visual cortex of the brain where patterns and objects in images are recognized and interpreted based on previously learned information. This is called visual memory.

The inability to see is called blindness. Blindness may result from damage to the eyeball, especially to the retina, damage to the optic nerve that connects each eye to the brain, and/or from stroke (infarcts in the brain). Temporary or permanent blindness can be caused by poisons or medications.

People who are blind from degradation or damage to the visual cortex, but still have functional eyes, are actually capable of some level of vision and reaction to visual stimuli but not a conscious perception; this is known as blindsight. People with blindsight are usually not aware that they are reacting to visual sources, and instead just unconsciously adapt their behaviour to the stimulus.

Hearing[edit]Hearing or **audition** is the sense of sound perception. Hearing is all about vibration. Mechanoreceptors turn motion into electrical nerve pulses, which are located in the inner ear. Since sound is vibrations propagating through a medium such as air, the detection of these vibrations, that is the sense of the hearing, is a mechanical sense because these vibrations are mechanically conducted from the eardrum through a series of tiny bones to hair-like fibers in the inner ear, which detect mechanical motion of the fibers within a range of about 20 to 20,000 hertz,[4] with substantial variation between individuals. Hearing at high frequencies declines with an increase in age. Inability to hear is called deafness or hearing impairment. Sound can also be detected as vibrations conducted through the body by tactition. Lower frequencies than can be heard are detected this way.

Taste[edit]Taste (or, the more formal term, **gustation**; adjectival form: "gustatory") is one of the traditional five senses. It refers to the capability to detect the taste of substances such as food, certain minerals, and poisons, etc. The sense of taste is often confused with the "sense" of flavor, which is a combination of taste and smell perception. Flavor depends on odor, texture, and temperature as well as on taste. Humans receive tastes through sensory organs called taste buds, or gustatory calyculi, concentrated on the upper surface of the tongue. There are five basic tastes: sweet, bitter, sour, salty and umami. Other tastes such as calcium[5] and free fatty acids[6] may be other basic tastes but have yet to receive widespread acceptance.

Smell[edit]Smell or **olfaction** is the other "chemical" sense. Unlike taste, there are hundreds of olfactory receptors (388 according to one source[7]), each binding to a particular molecular feature. Odor molecules possess a variety of features and, thus, excite specific receptors more or less strongly. This combination of excitatory signals from different receptors makes up what we perceive as the molecule's smell. In the brain, olfaction is processed by the olfactory system. Olfactory receptor neurons in the nose differ from most other neurons in that they die and regenerate on a regular basis. The inability to smell is called anosmia. Some neurons in the nose are specialized to detect pheromones.[8]

Touch[edit]Touch or somatosensory, also called tactition or mechanoreception, is a perception resulting from activation of neural receptors, generally in the skin including hair follicles, but also in the tongue, throat, and mucosa. A variety of pressure receptors respond to variations in pressure (firm, brushing, sustained, etc.). The touch sense of itching caused by insect bites or allergies involves special itch-specific neurons in the skin and spinal cord.[9] The loss or impairment of the ability to feel anything touched is called tactile anesthesia. Paresthesia is a sensation of tingling, pricking, or numbness of the skin that may result from nerve damage and may be permanent or temporary.

Other Senses:

Balance and acceleration[edit]

Main article: Vestibular systemBalance, equilibrioception, or **vestibular sense** is the sense that allows an organism to sense body movement, direction, and acceleration, and to attain and maintain postural equilibrium and balance. The organ of equilibrioception is the vestibular labyrinthine system found in both of the inner ears. In technical terms, this organ is responsible for two senses of angular momentum acceleration and linear acceleration (which also senses gravity), but they are known together as equilibrioception.

The vestibular nerve conducts information from sensory receptors in three ampulla that sense motion of fluid in three semicircular canals caused by three-dimensional rotation of the head. The vestibular nerve also conducts information from the utricle and the saccule, which contain hair-like sensory receptors that bend under the weight of otoliths (which are small crystals of calcium carbonate) that provide the inertia needed to detect head rotation, linear acceleration, and the direction of gravitational force.

Temperature[edit]Thermoception is the sense of **heat** and the absence of heat (**cold**) by the skin and including internal skin passages, or, rather, the heat flux (the rate of heat flow) in these areas. There are specialized receptors for cold (declining temperature) and for heat. The cold receptors play an important part in the animal's sense of smell, telling wind direction. The heat receptors are sensitive to infrared radiation and can occur in specialized organs, for instance in pit vipers. The thermoceptors in the skin are quite different from the homeostatic thermoceptors in the brain (hypothalamus), which provide feedback on internal body temperature. (see temperature receptor)

Kinesthetic sense[edit]Proprioception, the **kinesthetic sense**, provides the parietal cortex of the brain with information on the relative positions of the parts of the body. Neurologists test this sense by telling patients to close their eyes and touch their own nose with the tip of a finger. Assuming proper proprioceptive function, at no time will the person lose awareness of where the hand actually is, even though it is not being detected by any of the other senses. Proprioception and touch are related in subtle ways, and their impairment results in surprising and deep deficits in perception and action.[10]

Pain[edit]Nociception (physiological pain) signals nerve-damage or damage to tissue. The three types of pain receptors are cutaneous (skin), somatic (joints and bones), and visceral (body organs). It was previously believed that pain was simply the overloading of pressure receptors, but research in the first half of the 20th century indicated that pain is a distinct phenomenon that intertwines with all of the other senses, including touch. Pain was once considered an entirely subjective experience, but recent studies show that pain is registered in the anterior cingulate gyrus of the brain.[11] The main function of pain is to attract our attention to dangers and motivate us to avoid them. For example, humans avoid touching a sharp needle, or hot object, or extending an arm beyond a safe limit because it is dangerous, and thus hurts. Without pain, people could do many dangerous things without being aware of the dangers.

Time[edit]Chronoception refers to how the passage of time is perceived and experienced. Although the sense of time is not associated with a specific sensory system the work of psychologists and neuroscientists indicates that human brains do have a system governing the perception of time,[12] composed of a highly distributed system involving the cerebral cortex, cerebellum and basal ganglia. One particular component, the suprachiasmatic nucleus, is responsible for the circadian (or daily) rhythm, while other cell clusters appear to be capable of shorter-range (ultradian) timekeeping.

Other internal senses[edit]

An **internal sense** also known as **interoception** is "any sense that is normally stimulated from within the body".[13] These involve numerous sensory receptors in internal organs, such as stretch receptors that are neurologically linked to the brain. Some examples of specific receptors are:

•Pulmonary stretch receptors are found in the lungs and control the respiratory rate.

•Peripheral chemoreceptors in the brain monitor the carbon dioxide and oxygen levels in the brain to give a feeling of suffocation if carbon dioxide levels get too high.[14]

•The chemoreceptor trigger zone is an area of the medulla in the brain that receives inputs from blood-borne drugs or hormones, and communicates with the vomiting center.

•Chemoreceptors in the circulatory system also measure salt levels and prompt thirst if they get too high (they can also respond to high sugar levels in diabetics[15]).

•Cutaneous receptors in the skin not only respond to touch, pressure, and temperature, but also respond to vasodilation in the skin such as blushing.

•Stretch receptors in the gastrointestinal tract sense gas distension that may result in colic pain.

•Stimulation of sensory receptors in the esophagus result in sensations felt in the throat when swallowing, vomiting, or during acid reflux.

•Sensory receptors in pharynx mucosa, similar to touch receptors in the skin, sense foreign objects such as food that may result in a gag reflex and corresponding gagging sensation.

•Stimulation of sensory receptors in the urinary bladder and rectum may result in sensations of fullness.

•Stimulation of stretch sensors that sense dilation of various blood vessels may result in pain, for example headache caused by vasodilation of brain arteries.

Non Human Senses:

Analogous to human senses[edit]

Other living organisms have receptors to sense the world around them, including many of the senses listed above for humans. However, the mechanisms and capabilities vary widely.

Smell[edit]

Most non-human mammals have a much keener sense of smell than humans, although the mechanism is similar. Sharks combine their keen sense of smell with timing to determine the direction of a smell. They follow the nostril that first detected the smell.[16] Insects have olfactory receptors on their antennae.

Vomeronasal organ[edit]

Many animals (salamanders, reptiles, mammals) have a vomeronasal organ that is connected with the mouth cavity. In mammals it is mainly used to detect pheromones of marked territory, trails, and sexual state. Reptiles like snakes and monitor lizards make extensive use of it as a smelling organ[17] by transferring scent molecules to the vomeronasal organ with the tips of the forked tongue. In mammals, it is often associated with a special behavior called flehmen characterized by uplifting of the lips. The organ is vestigial in humans, because associated neurons have not been found that give any sensory input in humans.[citation needed]

Taste[edit]Flies and butterflies have taste organs on their feet, allowing them to taste anything they land on. Catfish have taste organs across their entire bodies, and can taste anything they touch, including chemicals in the water.[18]

Vision[edit]Cats have the ability to see in low light due to muscles surrounding their irises to contract and expand pupils as well as the tapetum lucidum, a reflective membrane that optimizes the image. Pitvipers, pythons and some boas have organs that allow them to detect infrared light, such that these snakes are able to sense the body heat of their prey. The common vampire bat may also have an infrared sensor on its nose.[19] It has been found that birds and some other animals are tetrachromats and have the ability to see in the ultraviolet down to 300 nanometers. Bees and dragonflies[20] are also able to see in the ultraviolet.

Balance[edit]

Many invertebrates have a statocyst, which is a sensor for acceleration and orientation that works very differently from the mammalian's semi-circular canals.

Sensing gravity[edit]

Some plants (such as mustard) have genes that are necessary for the plant to sense the direction of gravity. If these genes are disabled by a mutation, a plant cannot grow upright.[21]

Not analogous to human senses[edit]

In addition, some animals have senses that humans do not, including the following:

Echolocation[edit]

Main article: Animal echolocation

Certain animals, including bats and cetaceans, have the ability to determine orientation to other objects through interpretation of reflected sound (like sonar). They most often use this to navigate through poor lighting conditions or to identify and track prey. There is currently an uncertainty whether this is simply an extremely developed post-sensory interpretation of auditory perceptions or it actually constitutes a separate sense. Resolution of the issue will require brain scans of animals while they actually perform echolocation, a task that has proven difficult in practice.

Blind people report they are able to navigate and in some cases identify an object by interpreting reflected sounds (especially their own footsteps), a phenomenon known as human echolocation.

Electroreception[edit]Electroreception (or **electroception**) is the ability to detect electric fields. Several species of fish, sharks, and rays have the capacity to sense changes in electric fields in their immediate vicinity. Some fish passively sense changing nearby electric fields; some generate their own weak electric fields, and sense the pattern of field potentials over their body surface; and some use these electric field generating and sensing capacities for social communication. The mechanisms by which electroceptive fish construct a spatial representation from very small differences in field potentials involve comparisons of spike latencies from different parts of the fish's body.

The only orders of mammals that are known to demonstrate electroception are the dolphin and monotreme orders. Among these mammals, the platypus[22] has the most acute sense of electroception.

A dolphin can detect electric fields in water using electroreceptors in vibrissal crypts arrayed in pairs on its snout and which evolved from whisker motion sensors.[23] These electroreceptors can detect electric fields as weak as 4.6 microvolts per centimeter, such as those generated by contracting muscles and pumping gills of potential prey. This permits the dolphin to locate prey from the seafloor where sediment limits visibility and echolocation.Body modification enthusiasts have experimented with magnetic implants to attempt to replicate this sense.[24] However, in general humans (and it is presumed other mammals) can detect electric fields only indirectly by detecting the effect they have on hairs. An electrically charged balloon, for instance, will exert a force on human arm hairs, which can be felt through tactition and identified as coming from a static charge (and not from wind or the like). This is not electroception, as it is a post-sensory cognitive action.

Magnetoception[edit]Magnetoception (or **magnetoreception**) is the ability to detect the direction one is facing based on the Earth's magnetic field. Directional awareness is most commonly observed in birds.[25] It has also been observed in insects such as bees. Although there is no dispute that this sense exists in many avians (it is essential to the navigational abilities of migratory birds), it is not a well-understood phenomenon.[26] One study has found that cattle make use of magnetoception, as they tend to align themselves in a north-south direction.[27] Magnetotactic bacteria build miniature magnets inside themselves and use them to determine their orientation relative to the Earth's magnetic field.[citation needed] The question of how useful magnetoception may be to human beings is subject of ongoing research.[28]

Other[edit]

•**Pressure detection** uses the organ of Weber, a system consisting of three appendages of vertebrae transferring changes in shape of the gas bladder to the middle ear. It can be used to regulate the buoyancy of the fish. Fish like the weather fish and other loaches are also known to respond to low pressure areas but they lack a swim bladder.

•**Current detection** The lateral line in fish and aquatic forms of amphibians is a detection system of water currents, consisting mostly of vortices. The lateral line is also sensitive to low-frequency vibrations. The mechanoreceptors are hair cells, the same mechanoreceptors for vestibular sense and hearing. It is used primarily for navigation, hunting, and schooling. The receptors of the electrical sense are modified hair cells of the lateral line system.

•Polarized light **direction/detection** is used by bees to orient themselves, especially on cloudy days. Cuttlefish can also perceive the polarization of light. Most sighted humans can in fact learn to roughly detect large areas of polarization by an effect called Haidinger's brush, however this is considered an entoptic phenomenon rather than a separate sense.

•Slit sensillae **of spiders** detect mechanical strain in the exoskeleton, providing information on force and vibrations.

Plant Senses:

Some plants have sensory organs, for example the Venus fly trap, that respond to vibration, light, water, scents, or specific chemicals. Some plants sense the location of other plants and attack and eat part of them. Plants have no pain receptors that can travel through neural cell as having no electro-neuro electroreception as confirmed through various experiments.[29]

Culture:

Further information: Five wits*,* Ṣaḍāyatana*,* Ayatana*, and* Indriya

In the time of William Shakespeare, there were commonly reckoned to be **five wits** or **five senses**.[30] At that time, the words "sense" and "wit" were synonyms,[30] so the senses were known as the five outward wits.[31][32] This traditional concept of five senses is common today.

The traditional five senses are enumerated as the "five material faculties" (*pañcannaṃ indriyānaṃ avakanti*) in Buddhist literature. They appear in allegorical representation as early as in the Katha Upanishad (roughly 6th century BC), as five horses drawing the "chariot" of the body, guided by the mind as "chariot driver".

Depictions of the five traditional senses as allegory became a popular subject for seventeenth-century artists, especially among Dutch and Flemish Baroque painters. A typical example is Gérard de Lairesse's *Allegory of the Five Senses* (1668), in which each of the figures in the main group allude to a sense: Sight is the reclining boy with a convex mirror, hearing is the cupid-like boy with a triangle, smell is represented by the girl with flowers, taste is represented by the woman with the fruit, and touch is represented by the woman holding the bird.Tamil Literature, Tholkappiyam is said to be the first in the world to describe six senses which related to external body parts. One of its verses says "beings with one sense are those that have the sense of TOUCH. Beings with two senses are those that have the sense of TASTE along with the above. Beings with three senses, have sense of SMELL in addition. Beings with four senses, have sense of SIGHT, along with the above. Beings with five senses, have sense of HEARING, in addition. The beings with six senses, have a MIND, along with the above."[33][34]

Shape: [Forms] (see: Mathematics & Geometry)

Summary:

This article is about describing the shape of an object. For common shapes, see list of geometric shapes*. For other uses, see* Shape (disambiguation)*.*

The **shape** (Old English: *gesceap*, *created thing*) of an object located in some space is a geometrical description of the part of that space occupied by the object, as determined by its external boundary – abstracting from location and orientation in space, size, and other properties such as colour, content, and material composition.

Mathematician and statistician David George Kendall writes:[1]

In this paper 'shape' is used in the vulgar sense, and means what one would normally expect it to mean. [...] We here define 'shape' informally as 'all the geometrical information that remains when location, scale[2] and rotational effects are filtered out from an object.'

Simple shapes can be described by basic geometry objects such as a set of two or more points, a line, a curve, a plane, a plane figure (e.g. square or circle), or a solid figure (e.g. cube or sphere). Most shapes occurring in the physical world are complex. Some, such as plant structures and coastlines, may be so arbitrary as to defy traditional mathematical description – in which case they may be analyzed by differential geometry, or as fractals.

Simulation:

Summary:

Simulation is the imitation of the operation of a real-world process or system over time.[1] The act of simulating something first requires that a model be developed; this model represents the key characteristics or behaviors/functions of the selected physical or abstract system or process. The model represents the system itself, whereas the simulation represents the operation of the system over time.

Simulation is used in many contexts, such as simulation of technology for performance optimization, safety engineering, testing, training, education, and video games. Often, computer experiments are used to study simulation models. Simulation is also used with scientific modelling of natural systems or human systems to gain insight into their functioning.[2] Simulation can be used to show the eventual real effects of alternative conditions and courses of action. Simulation is also used when the real system cannot be engaged, because it may not be accessible, or it may be dangerous or unacceptable to engage, or it is being designed but not yet built, or it may simply not exist.[3]

Key issues in simulation include acquisition of valid source information about the relevant selection of key characteristics and behaviours, the use of simplifying approximations and assumptions within the simulation, and fidelity and validity of the simulation outcomes.

Sound: (further research is required)

Psychoacoustics:

Psychoacoustics is the scientific study of sound perception. More specifically, it is the branch of science studying the psychological and physiological responses associated with sound (including speech and music). It can be further categorized as a branch of psychophysics.

Background:

Hearing is not a purely mechanical phenomenon of wave propagation, but is also a sensory and perceptual event; in other words, when a person hears something, that something arrives at the ear as a mechanical sound wave traveling through the air, but within the ear it is transformed into neural action potentials. These nerve pulses then travel to the brain where they are perceived. Hence, in many problems in acoustics, such as for audio processing, it is advantageous to take into account not just the mechanics of the environment, but also the fact that both the ear and the brain are involved in a person's listening experience.

The inner ear, for example, does significant signal processing in converting sound waveforms into neural stimuli, so certain differences between waveforms may be imperceptible.[1] Data compression techniques, such as MP3, make use of this fact.[2] In addition, the ear has a nonlinear response to sounds of different intensity levels; this nonlinear response is called loudness. Telephone networks and audio noise reduction systems make use of this fact by nonlinearly compressing data samples before transmission, and then expanding them for playback.[3] Another effect of the ear's nonlinear response is that sounds that are close in frequency produce phantom beat notes, or intermodulation distortion products.[4]

Limits of Perception:

The human ear can nominally hear sounds in the range 20 Hz (0.02 kHz) to 20,000 Hz (20 kHz). The upper limit tends to decrease with age; most adults are unable to hear above 16 kHz. The lowest frequency that has been identified as a musical tone is 12 Hz under ideal laboratory conditions.[5] Tones between 4 and 16 Hz can be perceived via the body's sense of touch.

Frequency resolution of the ear is 3.6 Hz within the octave of 1000 – 2000 Hz. That is, changes in pitch larger than 3.6 Hz can be perceived in a clinical setting.[5] However, even smaller pitch differences can be perceived through other means. For example, the interference of two pitches can often be heard as a (low-)frequency difference pitch. This effect of phase variance upon the resultant sound is known as beating.

The semitone scale used in Western musical notation is not a linear frequency scale but logarithmic. Other scales have been derived directly from experiments on human hearing perception, such as the mel scale and Bark scale (these are used in studying perception, but not usually in musical composition), and these are approximately logarithmic in frequency at the high-frequency end, but nearly linear at the low-frequency end.

The intensity range of audible sounds is enormous. Human ear drums are sensitive to variations in the sound pressure, and can detect pressure changes from as small as a few micropascals to greater than 1 bar. For this reason, sound pressure level is also measured logarithmically, with all pressures referenced to 20 μPa (or 1.97385×10^{-10} atm). The lower limit of audibility is therefore defined as 0 dB, but the upper limit is not as clearly defined. The upper limit is more a question of the limit where the ear will be physically harmed or with the potential to cause noise-induced hearing loss.

A more rigorous exploration of the lower limits of audibility determines that the minimum threshold at which a sound can be heard is frequency dependent. By measuring this minimum intensity for testing tones of various frequencies, a frequency dependent absolute threshold of hearing (ATH) curve may be derived. Typically, the ear shows a peak of sensitivity (i.e., its lowest ATH) between 1 - 5 kHz, though the threshold changes with age, with older ears showing decreased sensitivity above 2 kHz.[6]

The ATH is the lowest of the equal-loudness contours. Equal-loudness contours indicate the sound pressure level (dB), over the range of audible frequencies, which are perceived as being of equal loudness.

Equal-loudness contours were first measured by Fletcher and Munson at Bell Labs in 1933 using pure tones reproduced via headphones, and the data they collected are called Fletcher-Munson curves. Because subjective loudness was difficult to measure, the Fletcher-Munson curves were averaged over many subjects. Robinson and Dadson refined the process in 1956 to obtain a new set of equal-loudness curves for a frontal sound source measured in an anechoic chamber. The Robinson-Dadson curves were standardized as ISO 226 in 1986. In 2003, ISO 226 was revised as equal-loudness contour using data collected from 12 international studies.

Sound Localization:

Main article: Sound localizationSound localization is the process of determining the location of a sound source. The brain utilizes subtle differences in intensity, spectral, and timing cues to allow us to localize sound sources.[7] Localization can be described in terms of three-dimensional position: the azimuth or horizontal angle, the zenith or vertical angle, and the distance (for static sounds) or velocity (for moving sounds).[8] The basis of localization is based on the slight difference in loudness, tone and timing between the two ears. Humans as most four legged animals are adept at detecting direction in the horizontal, but less so in the vertical due to the ears being placed symmetrically. Some species of owls have their ears placed asymmetrically, and can detect sound in all three planes, an adaption to hunt small mammals in the dark.[9]

Sound Localization:

Main article: Auditory masking Audio Masking Graph

In some situations an otherwise clearly audible sound can be masked by another sound. For example, conversation at a bus stop can be completely impossible if a loud bus is driving past. This phenomenon is called masking. A weaker sound is masked if it is made inaudible in the presence of a louder sound.

Missing Fundamental:

ain article: Missing fundamental

A harmonic series of pitches that are related 2×f, 3×f, 4×f, 5×f, etc., give human hearing the psychoacoustic impression that the pitch 1×f is present.

Summary:

Sound is a mechanical wave that is an oscillation of pressure transmitted through some medium (like air or water), composed of frequencies within the range of hearing.[1]

Acoustics:

Main articles: Acoustics *and* Acoustical Engineering

Audio engineers in R&D design audio equipmentAcoustics is the interdisciplinary science that deals with the study of all mechanical waves in gases, liquids, and solids including vibration, sound, ultrasound and infrasound. A scientist who works in the field of acoustics is an acoustician while someone working in the field of acoustical engineering may be called an acoustic or audio engineer. The application of acoustics can be seen in almost all aspects of modern society, subdisciplines include: Aeroacoustics, Audio signal processing, Architectural acoustics, Bioacoustics, Electroacoustics, Environmental noise, Musical acoustics, Noise control, Psychoacoustics, Speech, Ultrasound, Underwater acoustics and vibration.[2]

Physics of Sound:

Propagation of Sound:

Sound is a sequence of waves of pressure that propagates through compressible media such as air or water. (Sound can propagate through solids as well, but there are additional modes of propagation). Sound that is perceptible by humans has frequencies from about 20 Hz to 20,000 Hz. In air at standard temperature and pressure, the corresponding wavelengths of sound waves range from 17 m to 17 mm. During propagation, waves can be reflected, refracted, or attenuated by the medium.[3]

The behavior of sound propagation is generally affected by three things:

•A relationship between density and pressure. This relationship, affected by temperature, determines the speed of sound within the medium.

•The propagation is also affected by the motion of the medium itself. For example, sound moving through wind. Independent of the motion of sound through the medium, if the medium is moving, the sound is further transported.

•The viscosity of the medium also affects the motion of sound waves. It determines the rate at which sound is attenuated. For many media, such as air or water, attenuation due to viscosity is negligible.

When sound is moving through a medium that does not have constant physical properties, it may be refracted (either dispersed or focused).[3]

Spherical compression waves

The mechanical vibrations that can be interpreted as sound are able to travel through all forms of matter: gases, liquids, solids, and plasmas. The matter that supports the sound is called the medium. Sound cannot travel through a vacuum.

Longitudinal and Transverse Waves:

Sound is transmitted through gases, plasma, and liquids as longitudinal waves, also called compression waves. Through solids, however, it can be transmitted as both longitudinal waves and transverse waves. Longitudinal sound waves are waves of alternating pressure deviations from the equilibrium pressure, causing local regions of compression and rarefaction, while transverse waves (in solids) are waves of alternating shear stress at right angle to the direction of propagation.

Matter in the medium is periodically displaced by a sound wave, and thus oscillates. The energy carried by the sound wave converts back and forth between the potential energy of the extra compression (in case of longitudinal waves) or lateral displacement strain (in case of transverse waves) of the matter and the kinetic energy of the oscillations of the medium.

Sound Wave Properties and Characteristics:

Sound waves are often simplified to a description in terms of sinusoidal plane waves, which are characterized by these generic properties:

•Frequency, or its inverse, the period

•Wavelength

•Wavenumber

•Amplitude

•Sound pressure

•Sound intensity

•Speed of sound

•Direction

Sometimes speed and direction are combined as a velocity vector; wavenumber and direction are combined as a wave vector.Transverse waves, also known as shear waves, have the additional property, polarization, and are not a characteristic of sound waves.

Speed of Sound:

Main article: Speed of sound

The speed of sound depends on the medium the waves pass through, and is a fundamental property of the material. In general, the speed of sound is proportional to the square root of the ratio of the elastic modulus (stiffness) of the medium to its density. Those physical properties and the speed of sound change with ambient conditions. For example, the speed of sound in gases depends on temperature. In 20 °C (68 °F) air at sea level, the speed of sound is approximately 343 m/s (1,230 km/h; 767 mph) using the formula "v = (331 + 0.6 T) m/s". In fresh water, also at 20 °C, the speed of sound is approximately 1,482 m/s (5,335 km/h; 3,315 mph). In steel, the speed of sound is about 5,960 m/s (21,460 km/h; 13,330 mph).[6] The speed of sound is also slightly sensitive (a second-order anharmonic effect) to the sound amplitude, which means that there are nonlinear propagation effects, such as the production of harmonics and mixed tones not present in the original sound (see parametric array).

Perception of Sound:

Summary:

The perception of sound in any organism is limited to a certain range of frequencies. For humans, hearing is normally limited to frequencies between about 20 Hz and 20,000 Hz (20 kHz),[7] although these limits are not definite. The upper limit generally decreases with age. Other species have a different range of hearing. For example, dogs can perceive vibrations higher than 20 kHz, but are deaf to anything below 40 Hz. As a signal perceived by one of the major senses, sound is used by many species for detecting danger, navigation, predation, and communication. Earth's atmosphere, water, and virtually any physical phenomenon, such as fire, rain, wind, surf, or earthquake, produces (and is characterized by) its unique sounds. Many species, such as frogs, birds, marine and terrestrial mammals, have also developed special organs to produce sound. In some species, these produce song and speech. Furthermore, humans have developed culture and technology (such as music, telephone and radio) that allows them to generate, record, transmit, and broadcast sound. The scientific study of human sound perception is known as psychoacoustics.

Noise:

Main article: Noise

Noise is a term often used to refer to an unwanted sound. In science and engineering, noise is an undesirable component that obscures a wanted signal.

Sound Pressure:

Main article: Sound pressure

Sound pressure is the difference, in a given medium, between average local pressure and the pressure in the sound wave. A square of this difference (i.e., a square of the deviation from the equilibrium pressure) is usually averaged over time and/or space, and a square root of this average provides a root mean square (RMS) value. For example, 1 Pa RMS sound pressure (94 dBSPL) in atmospheric air implies that the actual pressure in the sound wave oscillates between (1 atm Pa) and (1 atm Pa), that is between 101323.6 and 101326.4 Pa. Such a tiny (relative to atmospheric) variation in air pressure at an audio frequency is perceived as a deafening sound, and can cause hearing damage, according to the table below.

As the human ear can detect sounds with a wide range of amplitudes, sound pressure is often measured as a level on a logarithmic decibel scale. The **sound pressure level** (SPL) or L_p is defined as

where *p* is the root-mean-square sound pressure and is a reference sound pressure. Commonly used reference sound pressures, defined in the standard ANSI S1.1-1994, are 20 µPa in air and 1 µPa in water. Without a specified reference sound pressure, a value expressed in decibels cannot represent a sound pressure level.

Since the human ear does not have a flat spectral response, sound pressures are often frequency weighted so that the measured level matches perceived levels more closely. The International Electrotechnical Commission (IEC) has defined several weighting schemes. A-weighting attempts to match the response of the human ear to noise and A-weighted sound pressure levels are labeled dBA. C-weighting is used to measure peak levels.

Equipment for Dealing with Sound

Sound Measurement:

Sound measurements Sound pressure *p*, SPLParticle velocity *v*, SVLParticle displacement *ξ*Sound intensity *I*, SILSound power P_{ac}Sound power level SWLSound energySound energy density *E*Sound energy flux *q*Acoustic impedance *Z*Speed of sound *c*Audio frequency AF

•v t e

•Decibel, Sone, mel, Phon, Hertz

•Sound pressure level, Sound pressure

•Particle velocity, Acoustic velocity

•Particle displacement, Particle amplitude, Particle acceleration

•Sound power, Acoustic power, Sound power level

•Sound energy flux

•Sound intensity, Acoustic intensity, Sound intensity level

•Acoustic impedance, Sound impedance, Characteristic impedance

•Speed of sound, Amplitude

Space:

Summary:

Space is the boundless three-dimensional extent in which objects and events have relative position and direction.[1] Physical space is often conceived in three linear dimensions, although modern physicists usually consider it, with time, to be part of a boundless four-dimensional continuum known as spacetime. In mathematics, "spaces" are examined with different numbers of dimensions and with different underlying structures. The concept of space is considered to be of fundamental importance to an understanding of the physical universe. However, disagreement continues between philosophers over whether it is itself an entity, a relationship between entities, or part of a conceptual framework.

Debates concerning the nature, essence and the mode of existence of space date back to antiquity; namely, to treatises like the *Timaeus* of Plato, or Socrates in his reflections on what the Greeks called khora (i.e. "space"), or in the *Physics* of Aristotle (Book IV, Delta) in the definition of *topos* (i.e. place), or even in the later "geometrical conception of place" as "space *qua* extension" in the *Discourse on Place* (*Qawl fi al-Makan*) of the 11th century Arab polymath Alhazen.[2] Many of these classical philosophical questions were discussed in the Renaissance and then reformulated in the 17th century, particularly during the early development of classical mechanics. In Isaac Newton's view, space was absolute—in the sense that it existed permanently and independently of whether there were any matter in the space.[3] Other natural philosophers, notably Gottfried Leibniz, thought instead that space was in fact a collection of relations between objects, given by their distance and direction from one another. In the 18th century, the philosopher and theologian George Berkeley attempted to refute the "visibility of spatial depth" in his *Essay Towards a New Theory of Vision*. Later, the metaphysician Immanuel Kant said neither space nor time can be empirically perceived, they are elements of a systematic framework that humans use to structure all experiences. Kant referred to "space" in his *Critique of Pure Reason* as being: a subjective "pure a priori form of intuition", hence it is an unavoidable contribution of our human faculties.

In the 19th and 20th centuries mathematicians began to examine non-Euclidean geometries, in which space can be said to be *curved*, rather than *flat*. According to Albert Einstein's theory of general relativity, space around gravitational fields deviates from Euclidean space.[4] Experimental tests of general relativity have confirmed that non-Euclidean space provides a better model for the shape of space.

Philosophy of Space:

Leibniz and Newton:

In the seventeenth century, the philosophy of space and time emerged as a central issue in epistemology and metaphysics. At its heart, Gottfried Leibniz, the German philosopher-mathematician, and Isaac Newton, the English physicist-mathematician, set out two opposing theories of what space is. Rather than being an entity that independently exists over and above other matter, Leibniz held that space is no more than the collection of spatial relations between objects in the world: "space is that which results from places taken together".[5] Unoccupied regions are those that *could* have objects in them, and thus spatial relations with other places. For Leibniz, then, space was an idealised abstraction from the relations between individual entities or their possible locations and therefore could not be continuous but must be discrete.[6] Space could be thought of in a similar way to the relations between family members. Although people in the family are related to one another, the relations do not exist independently of the people.[7] Leibniz argued that space could not exist independently of objects in the world because that implies a difference between two universes exactly alike except for the location of the material world in each universe. But since there would be no observational way of telling these universes apart then, according to the identity of indiscernibles, there would be no real difference between them. According to the principle of sufficient reason, any theory of space that implied that there could be these two possible universes, must therefore be wrong.[8]

Isaac Newton

Newton took space to be more than relations between material objects and based his position on observation and experimentation. For a relationist there can be no real difference between inertial motion, in which the object travels with constant velocity, and non-inertial motion, in which the velocity changes with time, since all spatial measurements are relative to other objects and their motions. But Newton argued that since non-inertial motion generates forces, it must be absolute.[9] He used the example of water in a spinning bucket to demonstrate his argument. Water in a bucket is hung from a rope and set to spin, starts with a flat surface. After a while, as the bucket continues to spin, the surface of the water becomes concave. If the bucket's spinning is stopped then the surface of the water remains concave as it continues to spin. The concave surface is therefore apparently not the result of relative motion between the bucket and the water.[10] Instead, Newton argued, it must be a result of non-inertial motion relative to space itself. For several centuries the bucket argument was decisive in showing that space must exist independently of matter.

Kant:

In the eighteenth century the German philosopher Immanuel Kant developed a theory of knowledge in which knowledge about space can be both *a priori* and synthetic.[11] According to Kant, knowledge about space is *synthetic*, in that statements about space are not simply true by virtue of the meaning of the words in the statement. In his work, Kant rejected the view that space must be either a substance or relation. Instead he came to the conclusion that space and time are not discovered by humans to be objective features of the world, but are part of an unavoidable systematic framework for organizing our experiences.[12]

Non-Euclidean Geometry:

Euclid's *Elements* contained five postulates that form the basis for Euclidean geometry. One of these, the parallel postulate has been the subject of debate among mathematicians for many centuries. It states that on any plane on which there is a straight line L_1 and a point P not on L_1, there is only one straight line L_2 on the plane that passes through the point P and is parallel to the straight line L_1. Until the 19th century, few doubted the truth of the postulate; instead debate centered over whether it was necessary as an axiom, or whether it was a theory that could be derived from the other axioms.[13] Around 1830 though, the Hungarian János Bolyai and the Russian Nikolai Ivanovich Lobachevsky separately published treatises on a type of geometry that does not include the parallel postulate, called hyperbolic geometry. In this geometry, an infinite number of parallel lines pass through the point P. Consequently the sum of angles in a triangle is less than 180° and the ratio of a circle's circumference to its diameter is greater than pi. In the 1850s, Bernhard Riemann developed an equivalent theory of elliptical geometry, in which no parallel lines pass through P. In this geometry, triangles have more than 180° and circles have a ratio of circumference-to-diameter that is less than pi.

Type of geometry

Number of parallels

Sum of angles in a triangle

Ratio of circumference to diameter of circle

Measure of curvature

Hyperbolic

Infinite

< 180°

> π

< 0

Euclidean

1

180°

π

0

Elliptical

0

> 180°

< π

> 0

Gauss & Poincare:

Although there was a prevailing Kantian consensus at the time, once non-Euclidean geometries had been formalised, some began to wonder whether or not physical space is curved. Carl Friedrich Gauss, a German mathematician, was the first to consider an empirical investigation of the geometrical structure of space. He thought of making a test of the sum of the angles of an enormous stellar triangle and there are reports he actually carried out a test, on a small scale, by triangulating mountain tops in Germany.[14]Henri Poincaré, a French mathematician and physicist of the late 19th century introduced an important insight in which he attempted to demonstrate the futility of any attempt to discover which geometry applies to space by experiment.[15] He considered the predicament that would face scientists if they were confined to the surface of an imaginary large sphere with particular properties, known as a sphere-world. In this world, the temperature is taken to vary in such a way that all objects expand and contract in similar proportions in different places on the sphere. With a suitable falloff in temperature, if the scientists try to use measuring rods to determine the sum of the angles in a triangle, they can be deceived into thinking that they inhabit a plane, rather than a spherical surface.[16] In fact, the scientists cannot in principle determine whether they inhabit a plane or sphere and, Poincaré argued, the same is true for the debate over whether real space is Euclidean or not. For him, which geometry was used to describe space, was a matter of convention.[17] Since Euclidean geometry is simpler than non-Euclidean geometry, he assumed the former would always be used to describe the 'true' geometry of the world.[18]

Einstein:

In 1905, Albert Einstein published a paper on a special theory of relativity, in which he proposed that space and time be combined into a single construct known as *spacetime*. In this theory, the speed of light in a vacuum is the same for all observers—which has the result that two events that appear simultaneous to one particular observer will not be simultaneous to another observer if the observers are moving with respect to one another. Moreover, an observer will measure a moving clock to tick more slowly than one that is stationary with respect to them; and objects are measured to be shortened in the direction that they are moving with respect to the observer.

Over the following ten years Einstein worked on a general theory of relativity, which is a theory of how gravity interacts with spacetime. Instead of viewing gravity as a force field acting in spacetime, Einstein suggested that it modifies the geometric structure of spacetime itself.[19] According to the general theory, time goes more slowly at places with lower gravitational potentials and rays of light bend in the presence of a gravitational field. Scientists have studied the behaviour of binary pulsars, confirming the predictions of Einstein's theories and non-Euclidean geometry is usually used to describe spacetime.

Mathematics:

In modern mathematics spaces are defined as sets with some added structure. They are frequently described as different types of manifolds, which are spaces that locally approximate to Euclidean space, and where the properties are defined largely on local connectedness of points that lie on the manifold. There are however, many diverse mathematical objects that are called spaces. For example, vector spaces such as function spaces may have infinite numbers of independent dimensions and a notion of distance very different to Euclidean space, and topological spaces replace the concept of distance with a more abstract idea of nearness.

Physics:

Classical mechanics

Space is one of the few fundamental quantities in physics, meaning that it cannot be defined via other quantities because nothing more fundamental is known at the present. On the other hand, it can be related to other fundamental quantities. Thus, similar to other fundamental quantities (like time and mass), space can be explored via measurement and experiment.

Relativity

Main article: Theory of relativity

Before Einstein's work on relativistic physics, time and space were viewed as independent dimensions. Einstein's discoveries showed that due to relativity of motion our space and time can be mathematically combined into one object — spacetime. It turns out that distances in space or in time separately are not invariant with respect to Lorentz coordinate transformations, but distances in Minkowski space-time along space-time intervals are—which justifies the name.

In addition, time and space dimensions should not be viewed as exactly equivalent in Minkowski space-time. One can freely move in space but not in time. Thus, time and space coordinates are treated differently both in special relativity (where time is sometimes considered an imaginary coordinate) and in general relativity (where different signs are assigned to time and space components of spacetime metric).

Furthermore, in Einstein's general theory of relativity, it is postulated that space-time is geometrically distorted- *curved* -near to gravitationally significant masses.[20]

Experiments are ongoing to attempt to directly measure gravitational waves. This is essentially solutions to the equations of general relativity, which describe moving ripples of spacetime. Indirect evidence for this has been found in the motions of the Hulse-Taylor binary system.

Cosmology

Main article: Shape of the universe

Relativity theory leads to the cosmological question of what shape the universe is, and where space came from. It appears that space was created in the Big Bang, 13.8 billion years ago[21] and has been expanding ever since. The overall shape of space is not known, but space is known to be expanding very rapidly due to the Cosmic Inflation.

Spatial Measurement:

Main article: Measurement

The measurement of *physical space* has long been important. Although earlier societies had developed measuring systems, the International System of Units, (SI), is now the most common system of units used in the measuring of space, and is almost universally used.

Currently, the standard space interval, called a standard meter or simply meter, is defined as the distance traveled by light in a vacuum during a time interval of exactly 1/299,792,458 of a second. This definition coupled with present definition of the second is based on the special theory of relativity in which the speed of light plays the role of a fundamental constant of nature.

Geographic Space:

See also: Spatial analysisGeography is the branch of science concerned with identifying and describing the Earth, utilizing spatial awareness to try to understand why things exist in specific locations. Cartography is the mapping of spaces to allow better navigation, for visualization purposes and to act as a locational device. Geostatistics apply statistical concepts to collected spatial data to create an estimate for unobserved phenomena.

Geographical space is often considered as land, and can have a relation to ownership usage (in which space is seen as property or territory). While some cultures assert the rights of the individual in terms of ownership, other cultures will identify with a communal approach to land ownership, while still other cultures such as Australian Aboriginals, rather than asserting ownership rights to land, invert the relationship and consider that they are in fact owned by the land. Spatial planning is a method of regulating the use of space at land-level, with decisions made at regional, national and international levels. Space can also impact on human and cultural behavior, being an important factor in architecture, where it will impact on the design of buildings and structures, and on farming.

Ownership of space is not restricted to land. Ownership of airspace and of waters is decided internationally. Other forms of ownership have been recently asserted to other spaces—for example to the radio bands of the electromagnetic spectrum or to cyberspace.Public space is a term used to define areas of land as collectively owned by the community, and managed in their name by delegated bodies; such spaces are open to all, while private property is the land culturally owned by an individual or company, for their own use and pleasure.Abstract space is a term used in geography to refer to a hypothetical space characterized by complete homogeneity. When modeling activity or behavior, it is a conceptual tool used to limit extraneous variables such as terrain.

In Psychology:

Psychologists first began to study the way space is perceived in the middle of the 19th century. Those now concerned with such studies regard it as a distinct branch of psychology. Psychologists analyzing the perception of space are concerned with how recognition of an object's physical appearance or its interactions are perceived, see, for example, visual space.

Other, more specialized topics studied include amodal perception and object permanence. The perception of surroundings is important due to its necessary relevance to survival, especially with regards to hunting and self preservation as well as simply one's idea of personal space.

Several space-related phobias have been identified, including agoraphobia (the fear of open spaces), astrophobia (the fear of celestial space) and claustrophobia (the fear of enclosed spaces).

Spacetime: [See: space, mathematics & physics]

Summary:

In physics, **spacetime** (also **space–time**, **space time** or **space–time continuum**) is any mathematical model that combines space and time into a single continuum. Spacetime is usually interpreted with space as existing in three dimensions and time playing the role of a fourth dimension that is of a different sort from the spatial dimensions. From a Euclidean space perspective, the universe has three dimensions of space and one of time. By combining space and time into a single manifold, physicists have significantly simplified a large number of physical theories, as well as described in a more uniform way the workings of the universe at both the supergalactic and subatomic levels.

In non-relativistic classical mechanics, the use of Euclidean space instead of spacetime is appropriate, as time is treated as universal and constant, being independent of the state of motion of an observer. In relativistic contexts, time cannot be separated from the three dimensions of space, because the observed rate at which time passes for an object depends on the object's velocity relative to the observer and also on the strength of gravitational fields, which can slow the passage of time.

In cosmology, the concept of spacetime combines space and time to a single abstract universe. Mathematically it is a manifold consisting of "events" which are described by some type of coordinate system. Typically three spatial dimensions (length, width, height), and one temporal dimension (time) are required. Dimensions are independent components of a coordinate grid needed to locate a point in a certain defined "space". For example, on the globe the latitude and longitude are two independent coordinates which together uniquely determine a location. In spacetime, a coordinate grid that spans the 3+1 dimensions locates events (rather than just points in space), i.e. time is added as another dimension to the coordinate grid. This way the coordinates specify *where* and *when* events occur. However, the unified nature of spacetime and the freedom of coordinate choice it allows imply that to express the temporal coordinate in one coordinate system requires both temporal and spatial coordinates in another coordinate system. Unlike in normal spatial coordinates, there are still restrictions for how measurements can be made spatially and temporally (see Spacetime intervals). These restrictions correspond roughly to a particular mathematical model which differs from Euclidean space in its manifest symmetry.

Until the beginning of the 20th century, time was believed to be independent of motion, progressing at a fixed rate in all reference frames; however, later experiments revealed that time slows at higher speeds of the reference frame relative to another reference frame. Such slowing, called time dilation, is explained in special relativity theory. Many experiments have confirmed time dilation, such as the relativistic decay of muons from cosmic ray showers and the slowing of atomic clocks aboard a Space Shuttle relative to synchronized Earth-bound inertial clocks. The duration of time can therefore vary according to events and reference frames.

When dimensions are understood as mere components of the grid system, rather than physical attributes of space, it is easier to understand the alternate dimensional views as being simply the result of coordinate transformations.

The term *spacetime* has taken on a generalized meaning beyond treating spacetime events with the normal 3+1 dimensions. It is really the combination of space and time. Other proposed spacetime theories include additional dimensions—normally spatial but there exist some speculative theories that include additional temporal dimensions and even some that include dimensions that are neither temporal nor spatial (e.g. superspace). How many dimensions are needed to describe the universe is still an open question. Speculative theories such as string theory predict 10 or 26 dimensions (with M-theory predicting 11 dimensions: 10 spatial and 1 temporal), but the existence of more than four dimensions would only appear to make a difference at the subatomic level.[1]

In Literature:

Incas regarded space and time as a single concept, referred to as ***pacha*** (Quechua: *pacha*, Aymara: *pacha*).[2][3] The peoples of the Andes maintain a similar understanding.[4]Arthur Schopenhauer wrote in §18 of On the Fourfold Root of the Principle of Sufficient Reason (1813): "...the representation of coexistence is impossible in Time alone; it depends, for its completion, upon the representation of Space; because, in mere Time, all things follow one another, and in mere Space all things are side by side; it is accordingly only by the **combination of Time and Space** that the representation of coexistence arises."

The idea of a unified spacetime is stated by Edgar Allan Poe in his essay on cosmology titled Eureka (1848) that "Space and duration are one." In 1895, in his novel The Time Machine, H.G. Wells wrote, "There is no difference between time and any of the three dimensions of space except that our consciousness moves along it", and that "any real body must have extension in four directions: it must have Length, Breadth, Thickness, and Duration."Marcel Proust, in his novel Swann's Way (published 1913), describes the village church of his childhood's Combray as "... a building which occupied, so to speak, four dimensions of space—the name of the fourth being Time..."

Mathematical concept[edit]

The first reference to spacetime as a mathematical concept was in 1754 by Jean le Rond d'Alembert in the article *Dimension* in Encyclopedie. Another early venture was by Joseph Louis Lagrange in his *Theory of Analytic Functions* (1797, 1813). He said, "One may view mechanics as a geometry of four dimensions, and mechanical analysis as an extension of geometric analysis".[5]

After discovering quaternions,[6] William Rowan Hamilton commented, "Time is said to have only one dimension, and space to have three dimensions. ... The mathematical quaternion partakes of both these elements; in technical language it may be said to be 'time plus space', or 'space plus time': and in this sense it has, or at least involves a reference to, four dimensions. And how the One of Time, of Space the Three, Might in the Chain of Symbols girdled be." Hamilton's biquaternions, which have algebraic properties sufficient to model spacetime and its symmetry, were in play for more than a half-century before formal relativity. For instance, William Kingdon Clifford noted their relevance.

Another important antecedent to spacetime was the work of James Clerk Maxwell as he used partial differential equations to develop electrodynamics with the four parameters. Lorentz discovered some invariances of Maxwell's equations late in the 19th century which were to become the basis of Albert Einstein's theory of special relativity. Fiction authors were also involved, as mentioned above. It has always been the case that time and space are measured using real numbers, and the suggestion that the dimensions of space and time are comparable could have been raised by the first people to have formalized physics, but ultimately, the contradictions between Maxwell's laws and Galilean relativity had to come to a head with the realization of the import of finitude of the speed of light.

While spacetime can be viewed as a consequence of Einstein's 1905 theory of special relativity, it was first explicitly proposed mathematically by one of his teachers, the mathematician Hermann Minkowski, in a 1908 essay[7] building on and extending Einstein's work. His concept of Minkowski space is the earliest treatment of space and time as two aspects of a unified whole, the essence of special relativity. (For an English translation of Minkowski's article, see Lorentz et al. 1952.) The 1926 thirteenth edition of the Encyclopædia Britannica included an article by Einstein titled "Space–Time".[8]) The idea of Minkowski space led to special relativity being viewed in a more geometrical way.

However, the most important contribution of Minkowski's geometric viewpoint of spacetime turned out to be in Einstein's later development of general relativity, since the correct description of the effect of gravitation on space and time was found to be most easily visualized as a "warp" or stretching in the geometrical fabric of space and time, in a smooth and continuous way that changed smoothly from point-to-point along the spacetime fabric.

Basic Concepts:

Summary:

Spacetimes are the arenas in which all physical events take place—an event is a point in spacetime specified by its time and place. For example, the motion of planets around the sun may be described in a particular type of spacetime, or the motion of light around a rotating star may be described in another type of spacetime. The basic elements of spacetime are events. In any given spacetime, an event is a unique position at a unique time. Because events are spacetime points, an example of an event in classical relativistic physics is , the location of an elementary (point-like) particle at a particular time. A spacetime itself can be viewed as the union of all events in the same way that a line is the union of all of its points, formally organized into a manifold, a space which can be described at small scales using coordinates systems.

A spacetime is independent of any observer.[9] However, in describing physical phenomena (which occur at certain moments of time in a given region of space), each observer chooses a convenient metrical coordinate system. Events are specified by four real numbers in any such coordinate system. The trajectories of elementary (point-like) particles through space and time are thus a continuum of events called the world line of the particle. Extended or composite objects (consisting of many elementary particles) are thus a union of many world lines twisted together by virtue of their interactions through spacetime into a "world-braid". However, in physics, it is common to treat an extended object as a "particle" or "field" with its own unique (e.g. center of mass) position at any given time, so that the world line of a particle or light beam is the path that this particle or beam takes in the spacetime and represents the history of the particle or beam. The world line of the orbit of the Earth (in such a description) is depicted in two spatial dimensions *x* and *y* (the plane of the Earth's orbit) and a time dimension orthogonal to *x* and *y*. The orbit of the Earth is an ellipse in space alone, but its world line is a helix in spacetime.[10]

The unification of space and time is exemplified by the common practice of selecting a metric (the measure that specifies the interval between two events in spacetime) such that all four dimensions are measured in terms of units of distance: representing an event as (in the Lorentz metric) or (in the original Minkowski metric)[11] where is the speed of light. The metrical descriptions of Minkowski Space and spacelike, lightlike, and timelike intervals given below follow this convention, as do the conventional formulations of the Lorentz transformation.

Spacetime Intervals:

Spacetime intervals[edit]

In a Euclidean space, the separation between two points is measured by the distance between the two points. The distance is purely spatial, and is always positive. In spacetime, the separation between two events is measured by the *invariant interval* between the two events, which takes into account not only the spatial separation between the events, but also their temporal separation. The interval, s^2, between two events is defined as:

(spacetime interval),

where *c* is the speed of light, and Δ*r* and Δ*t* denote differences of the space and time coordinates, respectively, between the events. (Note that the choice of signs for above follows the space-like convention (−+++). Other treatments reverse the sign of .)

Certain types of world lines (called geodesics of the spacetime) are the shortest paths between any two events, with *distance* being defined in terms of spacetime intervals. The concept of geodesics becomes critical in general relativity, since geodesic motion may be thought of as "pure motion" (inertial motion) in spacetime, that is, free from any external influences.

Spacetime intervals may be classified into three distinct types, based on whether the temporal separation ()

or the spatial separation () of the two events is greater.

Time-like interval[edit]

For two events separated by a time-like interval, enough time passes between them that there could be a cause–effect relationship between the two events. For a particle traveling through space at less than the speed of light, any two events which occur to or by the particle must be separated by a time-like interval. Event pairs with time-like separation define a negative squared spacetime interval () and may be said to occur in each other's future or past. There exists a reference frame such that the two events are observed to occur in the same spatial location, but there is no reference frame in which the two events can occur at the same time.

The measure of a time-like spacetime interval is described by the proper time, :

(proper time).

The proper time interval would be measured by an observer with a clock traveling between the two events in an inertial reference frame, when the observer's path intersects each event as that event occurs. (The proper time defines a real number, since the interior of the square root is positive.)

Light-like interval[edit]

In a light-like interval, the spatial distance between two events is exactly balanced by the time between the two events. The events define a squared spacetime interval of zero (). Light-like intervals are also known as "null" intervals.

Events which occur to or are initiated by a photon along its path (i.e., while traveling at , the speed of light) all have light-like separation. Given one event, all those events which follow at light-like intervals define the propagation of a light cone, and all the events which preceded from a light-like interval define a second (graphically inverted, which is to say "*pastward*") light cone.

Space-like interval[edit]

When a space-like interval separates two events, not enough time passes between their occurrences for there to exist a causal relationship crossing the spatial distance between the two events at the speed of light or slower. Generally, the events are considered not to occur in each other's future or past. There exists a reference frame such that the two events are observed to occur at the same time, but there is no reference frame in which the two events can occur in the same spatial location.

For these space-like event pairs with a positive squared spacetime interval (), the measurement of space-like separation is the proper distance, :

(proper distance).

Like the proper time of time-like intervals, the proper distance of space-like spacetime intervals is a real number value.

Mathematics of Spacetimes:

Summary:

For physical reasons, a spacetime continuum is mathematically defined as a four-dimensional, smooth, connected Lorentzian manifold . This means the smooth Lorentz metric has signature . The metric determines the geometry of spacetime, as well as determining the geodesics of particles and light beams. About each point (event) on this manifold, coordinate charts are used to represent observers in reference frames. Usually, Cartesian coordinates are used. Moreover, for simplicity's sake, the speed of light is usually assumed to be unity.

A reference frame (observer) can be identified with one of these coordinate charts; any such observer can describe any event . Another reference frame may be identified by a second coordinate chart about . Two observers (one in each reference frame) may describe the same event but obtain different descriptions. Usually, many overlapping coordinate charts are needed to cover a manifold. Given two coordinate charts, one containing (representing an observer) and another containing (representing another observer), the intersection of the charts represents the region of spacetime in which both observers can measure physical quantities and hence compare results. The relation between the two sets of measurements is given by a non-singular coordinate transformation on this intersection. The idea of coordinate charts as local observers who can perform measurements in their vicinity also makes good physical sense, as this is how one actually collects physical data—locally.

For example, two observers, one of whom is on Earth, but the other one who is on a fast rocket to Jupiter, may observe a comet crashing into Jupiter (this is the event). In general, they will disagree about the exact location and timing of this impact, i.e., they will have different 4-tuples (as they are using different coordinate systems). Although their kinematic descriptions will differ, dynamical (physical) laws, such as momentum conservation and the first law of thermodynamics, will still hold. In fact, relativity theory requires more than this in the sense that it stipulates these (and all other physical) laws must take the same form in all coordinate systems. This introduces tensors into relativity, by which all physical quantities are represented.

Geodesics are said to be time-like, null, or space-like if the tangent vector to one point of the geodesic is of this nature. Paths of particles and light beams in spacetime are represented by time-like and null (light-like) geodesics, respectively.

Topology:

Main article: Spacetime topology

The assumptions contained in the definition of a spacetime are usually justified by the following considerations.

The connectedness assumption serves two main purposes. First, different observers making measurements (represented by coordinate charts) should be able to compare their observations on the non-empty intersection of the charts. If the connectedness assumption were dropped, this would not be possible. Second, for a manifold, the properties of connectedness and path-connectedness are equivalent, and one requires the existence of paths (in particular, geodesics) in the spacetime to represent the motion of particles and radiation.

Every spacetime is paracompact. This property, allied with the smoothness of the spacetime, gives rise to a smooth linear connection, an important structure in general relativity. Some important theorems on constructing spacetimes from compact and non-compact manifolds include the following:[citation needed]

- A compact manifold can be turned into a spacetime if, and only if, its Euler characteristic is 0. (Proof idea: the existence of a Lorentzian metric is shown to be equivalent to the existence of a nonvanishing vector field.)
- Any non-compact 4-manifold can be turned into a spacetime.

Spacetime Symmetries:

Main article: Spacetime symmetries

Often in relativity, spacetimes that have some form of symmetry are studied. As well as helping to classify spacetimes, these symmetries usually serve as a simplifying assumption in specialized work. Some of the most popular ones include:

- Axisymmetric spacetimes
- Spherically symmetric spacetimes
- Static spacetimes
- Stationary spacetimes.

Causal Structure:

Main article: Causal structure

See also: Causality (physics) *and* Causality

The causal structure of a spacetime describes causal relationships between pairs of points in the spacetime based on the existence of certain types of curves joining the points.

Spacetime in General Relativity:

Main article: Spacetime in General relativity

In general relativity, it is assumed that spacetime is curved by the presence of matter (energy), this curvature being represented by the Riemann tensor. In special relativity, the Riemann tensor is identically zero, and so this concept of "non-curvedness" is sometimes expressed by the statement *Minkowski spacetime is flat.*

The earlier discussed notions of time-like, light-like and space-like intervals in special relativity can similarly be used to classify one-dimensional curves through curved spacetime. A time-like curve can be understood as one where the interval between any two infinitesimally close events on the curve is time-like, and likewise for light-like and space-like curves. Technically the three types of curves are usually defined in terms of whether the tangent vector at each point on the curve is time-like, light-like or space-like. The world line of a slower-than-light object will always be a time-like curve, the world line of a massless particle such as a photon will be a light-like curve, and a space-like curve could be the world line of a hypothetical tachyon. In the local neighborhood of any event, time-like curves that pass through the event will remain inside that event's past and future light cones, light-like curves that pass through the event will be on the surface of the light cones, and space-like curves that pass through the event will be outside the light cones. One can also define the notion of a 3-dimensional "spacelike hypersurface", a continuous 3-dimensional "slice" through the 4-dimensional property with the property that every curve that is contained entirely within this hypersurface is a space-like curve.[12]

Many spacetime continua have physical interpretations which most physicists would consider bizarre or unsettling. For example, a compact spacetime has closed timelike curves, which violate our usual ideas of causality (that is, future events could affect past ones). For this reason, mathematical physicists usually consider only restricted subsets of all the possible spacetimes. One way to do this is to study "realistic" solutions of the equations of general relativity. Another way is to add some additional "physically reasonable" but still fairly general geometric restrictions and try to prove interesting things about the resulting spacetimes. The latter approach has led to some important results, most notably the Penrose–Hawking singularity theorems.

Quantized Spacetime:

Main article: Quantum spacetime

In general relativity, spacetime is assumed to be smooth and continuous—and not just in the mathematical sense. In the theory of quantum mechanics, there is an inherent discreteness present in physics. In attempting to reconcile these two theories, it is sometimes postulated that spacetime should be quantized at the very smallest scales. Current theory is focused on the nature of spacetime at the Planck scale. Causal sets, loop quantum gravity, string theory, and black hole thermodynamics all predict a quantized spacetime with agreement on the order of magnitude. Loop quantum gravity makes precise predictions about the geometry of spacetime at the Planck scale.

Priviledged Character of 3 + 1 spacetime:

See also: Kairos*,* Time perception*, and* Dreamtime

There are two kinds of dimensions, spatial (bidirectional) and temporal (unidirectional). Let the number of spatial dimensions be N and the number of temporal dimensions be T. That $N = 3$ and $T = 1$, setting aside the compactified dimensions invoked by string theory and undetectable to date, can be explained by appealing to the physical consequences of letting N differ from 3 and T differ from 1. The argument is often of an anthropic character.

The implicit notion that the dimensionality of the universe is special is first attributed to Gottfried Wilhelm Leibniz, who in the Discourse on Metaphysics suggested[13] that the world is "the one which is at the same time the simplest in hypothesis and the richest in phenomena." Immanuel Kant argued that 3-dimensional space was a consequence of the inverse square law of universal gravitation. While Kant's argument is historically important, John D. Barrow says that it "...gets the punch-line back to front: it is the three-dimensionality of space that explains why we see inverse-square force laws in Nature, not vice-versa." (Barrow 2002: 204). This is because the law of gravitation (or any other inverse-square law) follows from the concept of flux and the proportional relationship of flux density and the strength of field. If $N = 3$, then 3-dimensional solid objects have surface areas proportional to the square of their size in any selected spatial dimension. In particular, a sphere of radius r has area of $4\pi r^2$. More generally, in a space of N dimensions, the strength of the gravitational attraction between two bodies separated by a distance of r would be inversely proportional to rN^{-1}.

In 1920, Paul Ehrenfest showed that if we fix $T = 1$ and let $N > 3$, the orbit of a planet about its sun cannot remain stable. The same is true of a star's orbit around the center of its galaxy.[14] Ehrenfest also showed that if N is even, then the different parts of a wave impulse will travel at different speeds. If $N > 3$ and odd, then wave impulses become distorted. Only when $N = 3$ or 1 are both problems avoided. In 1922, Hermann Weyl showed that Maxwell's theory of electromagnetism works only when $N = 3$ and $T = 1$, writing that this fact "...not only leads to a deeper understanding of Maxwell's theory, but also of the fact that the world is four dimensional, which has hitherto always been accepted as merely 'accidental,' become intelligible through it."[15] Finally, Tangherlini[16] showed in 1963 that when $N > 3$, electron orbitals around nuclei cannot be stable; electrons would either fall into the nucleus or disperse.

Properties of $n+m$-dimensional spacetimesMax Tegmark[17] expands on the preceding argument in the following anthropic manner. If T differs from 1, the behavior of physical systems could not be predicted reliably from knowledge of the relevant partial differential equations. In such a universe, intelligent life capable of manipulating technology could not emerge. Moreover, if $T > 1$, Tegmark maintains that protons and electrons would be unstable and could decay into particles having greater mass than themselves. (This is not a problem if the particles have a sufficiently low temperature.) If $N > 3$, Ehrenfest's argument above holds; atoms as we know them (and probably more complex structures as well) could not exist. If $N < 3$, gravitation of any kind becomes problematic, and the universe is probably too simple to contain observers. For example, when $N < 3$, nerves cannot cross without intersecting.

In general, it is not clear how physical law could function if T differed from 1. If $T > 1$, subatomic particles which decay after a fixed period would not behave predictably, because time-like geodesics would not be necessarily maximal.[18] $N = 1$ and $T = 3$ has the peculiar property that the speed of light in a vacuum is a *lower bound* on the velocity of matter; all matter consists of tachyons.[17] However, signature (1,3) and (3,1) are physically equivalent. To call vectors with positive Minkowski "length" timelike is just a convention that depends on the convention for the sign of the metric tensor. Indeed, particle phyicists tend to use a metric with signature (+−−−) that results in positive Minkowski "length" for timelike intervals and energies while spatial separations have negative Minkowski "length". Relativists, however, tend to use the opposite convention (−+++) so that spatial separations have positive Minkowski length.

Hence anthropic and other arguments rule out all cases except $N = 3$ and $T = 1$ (or $N = 1$ and $T = 3$ in different conventions) — which happens to describe the world about us. Curiously, the cases $N = 3$ or 4 have the richest and most difficult geometry and topology. There are, for example, geometric statements whose truth or falsity is known for all N except one or both of 3 and 4.[citation needed] $N = 3$ was the last case of the Poincaré conjecture to be proved.

For an elementary treatment of the privileged status of $N = 3$ and $T = 1$, see chpt. 10 (esp. Fig. 10.12) of Barrow;[19] for deeper treatments, see §4.8 of Barrow and Tipler (1986) and Tegmark.[17] Barrow has repeatedly cited the work of Whitrow.[20]String theory hypothesizes that matter and energy are composed of tiny vibrating strings of various types, most of which are embedded in dimensions that exist only on a scale no larger than the Planck length. Hence $N = 3$ and $T = 1$ do not characterize string theory, which embeds vibrating strings in coordinate grids having 10, or even 26, dimensions.

The Causal dynamical triangulation (CDT) theory is a background independent theory which derives the observed 3+1 spacetime from a minimal set of assumptions, and needs no adjusting factors. It does not assume any pre-existing arena (dimensional space), but rather attempts to show how the spacetime fabric itself evolves. It shows spacetime to be 2-d near the Planck scale, and reveals a fractal structure on slices of constant time, but spacetime becomes 3+1-d in scales significantly larger than Planck. So, CDT may become the first theory which doesn't postulate but really explains observed number of spacetime dimensions.[21]

Spatialization: (further research is required)

Summary:

Spatialization (*spatialisation*) can refer to the spatial forms that social activities and material things, phenomena or processes take on.[1] This term related to geography, sociology, urban planning and cultural studies. Generally the term refers to an overall sense of social space typical of a time, place or culture.Cognitive maps are one aspect of spatialization, which also includes everyday practice, institutionalized representations (i.e., maps, see cartography) and the imagination of possible spatial worlds (as in the visual puns of the work of the Surrealist painter, René Magritte). See also geographical space, Henri Lefebvre. The origins of the term are in Rob Shields 1985, *Introduction* to a Précis of Henri Lefebvre's *La Production de l'espace*.[2] where *social spatialization* is proposed as an English translation of Henri Lefebvre's French term "l'espace". However, Shields embues the concept with a sense of being a general, socio-cultural attribute, as in the work of Michel Foucault who makes 1 mention of the term but does not theorize it) rather than a spatial regime that is dialectically produced as part of a Marxist mode of production.[3]

Social spatializations are virtual but manifest materially, in discourse and as frames through which problems are understood.[4] Following Foucault they are *cultural formations* relevant at many scales, from gestures and bodily comportment to geopolitical relationships between States (see also Critical Geopolitics).[citation needed] On one hand, spatializations are achieved, hegemonic regimes which place and space activities in sites and regions. But on the other hand, spatializations are continually in change as they depend on and reflect peoples' ongoing performative actualizations of these spatial orders or regimes. However they are contested and the focus of struggles over the meaning of places, or manners, or over the reputation of neighbourhoods.[citation needed]

Spatializations are therefore both ways of fixing in place cultural values and important social meanings, but also change over time. Globalization is an example of the changing spatialization of the world. Examples might include cases where a region becomes stereotyped and idolized as part of the identity of a nation state or culture: the Canadian North (Arctic) and Canadian identity; Karelia and Finnish identity.[citation needed] These are often taken up in the media, for example the British North and late 20th-century British working class identity portrayed in the long-running television series Coronation Street.[citation needed] These place-images and regional- and place-myths take on meanings through their similarity or difference from other places we know. Spatialization is argued[weasel words] to be a regime of "spacings" and "placings" of people and activities. Given activities or behaviours are related to "places-for-this" and "places-for-that." Several typical spatializations can be detected: centre-margin, mosaics of different identities, binary divisions (black-white, civilized-barbarian, etc.), near-far continua (local-foreign).[citation needed]

Spatialization offers a way of talking about how place-images and regional- and place-myths, cognitive mappings and so on are part of wider "formations" and come to have an economic impact by being put into practice, such as through the marketing of tourism destinations, and the way that the reputations of places and regions becomes a conceptual shorthand which lends credibility to claims and beliefs, such as the truthfulness of a scientific finding (e.g., "Cambridge" - whether USA or UK), the believability of a religious claim or an event (e.g., "Mecca"), or the trustworthiness of a product (e.g., "Swiss" watches). For these reasons, the identities of places are durable and city-marketing fails, place-marketing does not work or city-branding is unsuccessful: the entire network of place-myths has to be reworked if one place-myth is to be altered relative to others.[citation needed]

Spatializations are important for governance by linking *affect* and emotion to place and region. They can be referenced in architecture and interior design, for example, in escapist consumer environments such as the West Edmonton Mall[5]

Spatial Music:

Summary:

Spatial music is composed music that intentionally exploits sound localization. Though present in Western music from biblical times in the form of the antiphon, as a component specific to new musical techniques the concept of spatial music (*Raummusik*, usually translated as "space music") was introduced as early as 1928 in Germany.[1]

The term *spatialisation* is connected especially with electroacoustic music to denote the projection and localization of sound sources in physical or virtual space or sound's spatial movement in space.

Context:

The term "spatial music" indicates music in which the location and movement of sound sources is a primary compositional parameter and a central feature for the listener. It may involve a single, mobile sound source, or multiple, simultaneous, stationary or mobile sound events in different locations.

There are at least three distinct categories when plural events are treated spatially:[2]

1.essentially independent events separated in space, like simultaneous concerts, each with a strong signaling character

2.one or several such signaling events, separated from more "passive" reverberating background complexes

3.separated but coordinated performing groups.

Examples:

Examples of spatiality include more than seventy works by Giovanni Pierluigi da Palestrina (canticles, litanies, masses, Marian antiphons, psalm- and sequence-motets),[3] the five-choir, forty- and sixty-voice Missa sopra Ecco sì beato giorno by Alessandro Striggio and the possibly related eight-choir, forty-voice motet Spem in alium by Thomas Tallis, as well as a number of other Italian—mainly Florentine—works dating between 1557 and 1601,[4] Charles Ives's Fourth Symphony (1912–18),[5] Edgard Varèse's Poème électronique (Expo '58), Henryk Górecki's *Scontri*, op. 17 (1960), which unleashes a volume of sound with a "tremendous orchestra" for which the composer precisely dictates the placement of each player onstage, including fifty-two percussion instruments,[6] Karlheinz Stockhausen's Helicopter String Quartet (1992–93/95), which is "arguably the most extreme experiment involving the spatial motility of live performers",[7] and Henry Brant's Ice Field, a "'spatial narrative,'"[8] or "spatial organ concerto,"[9] awarded the 2002 Pulitzer Prize for Music.

Additional References:

•3D audio effect

•Auditory spatial attention

•Audium (theater)

•Directional sound

•Octophonic sound

•Holophones

•Planephones

•Quadraphonic sound

•Stereophonic sound

•Surround sound

•Ton de Leeuw

•Wave field synthesis

Synthesis:

Etymology:

In general, the noun **synthesis** (from the ancient Greek σύνθεσις, σύν "with" and θέσις "placing") refers to a combination of two or more entities that together form something new; alternately, it refers to the creating of something by artificial means. The corresponding verb, **to synthesize** (or synthesise), means *to make or form a synthesis*.

Synthetic Life: (see: artificial life)

Synthetic: (further research is required)

Technology

Etymology:

Technology (from Greek τέχνη, *techne*, "art, skill, cunning of hand"; and -λογία, -logia[1])

Summary:

Technology (from Greek τέχνη, *techne*, "art, skill, cunning of hand"; and -λογία, -logia[1]) is the making, modification, usage, and knowledge of tools, machines, techniques, crafts, systems, and methods of organization, in order to solve a problem, improve a preexisting solution to a problem, achieve a goal, handle an applied input/output relation or perform a specific function. It can also refer to the collection of such tools, including machinery, modifications, arrangements and procedures. Technologies significantly affect human as well as other animal species' ability to control and adapt to their natural environments. The term can either be applied generally or to specific areas: examples include *construction technology*, *medical technology*, and *information technology*.

The human species' use of technology began with the conversion of natural resources into simple tools. The prehistorical discovery of the ability to control fire increased the available sources of food and the invention of the wheel helped humans in travelling in and controlling their environment. Recent technological developments, including the printing press, the telephone, and the Internet, have lessened physical barriers to communication and allowed humans to interact freely on a global scale. However, not all technology has been used for peaceful purposes; the development of weapons of ever-increasing destructive power has progressed throughout history, from clubs to nuclear weapons.

Technology has affected society and its surroundings in a number of ways. In many societies, technology has helped develop more advanced economies (including today's global economy) and has allowed the rise of a leisure class. Many technological processes produce unwanted by-products, known as pollution, and deplete natural resources, to the detriment of the Earth and its environment. Various implementations of technology influence the values of a society and new technology often raises new ethical questions. Examples include the rise of the notion of efficiency in terms of human productivity, a term originally applied only to machines, and the challenge of traditional norms.

Philosophical debates have arisen over the present and future use of technology in society, with disagreements over whether technology improves the human condition or worsens it. Neo-Luddism, anarcho-primitivism, and similar movements criticise the pervasiveness of technology in the modern world, opining that it harms the environment and alienates people; proponents of ideologies such as transhumanism and techno-progressivism view continued technological progress as beneficial to society and the human condition. Indeed, until recently, it was believed that the development of technology was restricted only to human beings, but recent scientific studies indicate that other primates and certain dolphin communities have developed simple tools and learned to pass their knowledge to other generations.

Definition and Usage:

The use of the term *technology* has changed significantly over the last 200 years. Before the 20th century, the term was uncommon in English, and usually referred to the description or study of the useful arts.[2] The term was often connected to technical education, as in the Massachusetts Institute of Technology (chartered in 1861).[3] "Technology" rose to prominence in the 20th century in connection with the Second Industrial Revolution. The meanings of technology changed in the early 20th century when American social scientists, beginning with Thorstein Veblen, translated ideas from the German concept of Technik into "technology." In German and other European languages, a distinction exists between *Technik* and *Technologie* that is absent in English, as both terms are usually translated as "technology." By the 1930s, "technology" referred not to the study of the industrial arts, but to the industrial arts themselves.[4] In 1937, the American sociologist Read Bain wrote that "technology includes all tools, machines, utensils, weapons, instruments, housing, clothing, communicating and transporting devices and the skills by which we produce and use them."[5] Bain's definition remains common among scholars today, especially social scientists. But equally prominent is the definition of technology as applied science, especially among scientists and engineers, although most social scientists who study technology reject this definition.[6] More recently, scholars have borrowed from European philosophers of "technique" to extend the meaning of technology to various forms of instrumental reason, as in Foucault's work on technologies of the self ("techniques de soi").

Dictionaries and scholars have offered a variety of definitions. The Merriam-Webster dictionary offers a definition of the term: "the practical application of knowledge especially in a particular area" and "a capability given by the practical application of knowledge".[7] Ursula Franklin, in her 1989 "Real World of Technology" lecture, gave another definition of the concept; it is "practice, the way we do things around here".[8] The term is often used to imply a specific field of technology, or to refer to high technology or just consumer electronics, rather than technology as a whole.[9] Bernard Stiegler, in Technics and Time, 1, defines technology in two ways: as "the pursuit of life by means other than life", and as "organized inorganic matter."[10]

Technology can be most broadly defined as the entities, both material and immaterial, created by the application of mental and physical effort in order to achieve some value. In this usage, technology refers to tools and machines that may be used to solve real-world problems. It is a far-reaching term that may include simple tools, such as a crowbar or wooden spoon, or more complex machines, such as a space station or particle accelerator. Tools and machines need not be material; virtual technology, such as computer software and business methods, fall under this definition of technology.[11]

The word "technology" can also be used to refer to a collection of techniques. In this context, it is the current state of humanity's knowledge of how to combine resources to produce desired products, to solve problems, fulfill needs, or satisfy wants; it includes technical methods, skills, processes, techniques, tools and raw materials. When combined with another term, such as "medical technology" or "space technology", it refers to the state of the respective field's knowledge and tools. "State-of-the-art technology" refers to the high technology available to humanity in any field. The invention of integrated circuits and the microprocessor (here, an Intel 4004 chip from 1971) led to the modern computer revolution.

Technology can be viewed as an activity that forms or changes culture.[12] Additionally, technology is the application of math, science, and the arts for the benefit of life as it is known. A modern example is the rise of communication technology, which has lessened barriers to human interaction and, as a result, has helped spawn new subcultures; the rise of cyberculture has, at its basis, the development of the Internet and the computer.[13] Not all technology enhances culture in a creative way; technology can also help facilitate political oppression and war via tools such as guns. As a cultural activity, technology predates both science and engineering, each of which formalize some aspects of technological endeavor.

Science, Engineering and Technology:

The distinction between science, engineering and technology is not always clear. Science is the reasoned investigation or study of phenomena, aimed at discovering enduring principles among elements of the phenomenal world by employing formal techniques such as the scientific method.[14] Technologies are not usually exclusively products of science, because they have to satisfy requirements such as utility, usability and safety.

Engineering is the goal-oriented process of designing and making tools and systems to exploit natural phenomena for practical human means, often (but not always) using results and techniques from science. The development of technology may draw upon many fields of knowledge, including scientific, engineering, mathematical, linguistic, and historical knowledge, to achieve some practical result.

Technology is often a consequence of science and engineering — although technology as a human activity precedes the two fields. For example, science might study the flow of electrons in electrical conductors, by using already-existing tools and knowledge. This new-found knowledge may then be used by engineers to create new tools and machines, such as semiconductors, computers, and other forms of advanced technology. In this sense, scientists and engineers may both be considered technologists; the three fields are often considered as one for the purposes of research and reference.[15]

The exact relations between science and technology in particular have been debated by scientists, historians, and policymakers in the late 20th century, in part because the debate can inform the funding of basic and applied science. In the immediate wake of World War II, for example, in the United States it was widely considered that technology was simply "applied science" and that to fund basic science was to reap technological results in due time. An articulation of this philosophy could be found explicitly in Vannevar Bush's treatise on postwar science policy, *Science—The Endless Frontier*: "New products, new industries, and more jobs require continuous additions to knowledge of the laws of nature ... This essential new knowledge can be obtained only through basic scientific research." In the late-1960s, however, this view came under direct attack, leading towards initiatives to fund science for specific tasks (initiatives resisted by the scientific community). The issue remains contentious—though most analysts resist the model that technology simply is a result of scientific research.[16][17]

History: (further research is required)

Technology and Philosophy: (further research is required)

Dimension: (mathematics & physics)

Summary:

In physics and mathematics, the **dimension** of a space or object is informally defined as the minimum number of coordinates needed to specify any point within it.[1][2] Thus a line has a dimension of one because only one coordinate is needed to specify a point on it (for example, the point at 5 on a number line). A surface such as a plane or the surface of a cylinder or sphere has a dimension of two because two coordinates are needed to specify a point on it (for example, to locate a point on the surface of a sphere you need both its latitude and its longitude). The inside of a cube, a cylinder or a sphere is three-dimensional because three coordinates are needed to locate a point within these spaces.

In physical terms, *dimension* refers to the constituent structure of all space (cf. volume) and its position in time (perceived as a scalar dimension along the *t*-axis), as well as the spatial constitution of objects within—structures that correlate with both particle and field conceptions, interact according to relative properties of mass—and are fundamentally mathematical in description. These, or other axes, may be referenced to uniquely identify a point or structure in its attitude and relationship to other objects and occurrences. Physical theories that incorporate time, such as general relativity, are said to work in 4-dimensional "spacetime", (defined as a Minkowski space). Modern theories tend to be "higher-dimensional" including quantum field and string theories. The state-space of quantum mechanics is an infinite-dimensional function space.

The concept of dimension is not restricted to physical objects. High-dimensional spaces occur in mathematics and the sciences for many reasons, frequently as configuration spaces such as in Lagrangian or Hamiltonian mechanics; these are abstract spaces, independent of the physical space we live in.

Time: (further research is required)

Summary:

Time is a dimension in which events can be ordered from the past through the present into the future,[1][2][3][4][5][6] and also the measure of durations of events and the intervals between them.[3][7][8] Time has long been a major subject of study in religion, philosophy, and science, but defining it in a manner applicable to all fields without circularity has consistently eluded scholars.[3][7][8][9][10][11] Nevertheless, diverse fields such as business, industry, sports, the sciences, music, dance, and the live theater all incorporate some notion of time into their respective measuring systems.[12][13][14] Some simple, relatively uncontroversial definitions of time include "time is what clocks measure"[7][15] and "time is what keeps everything from happening at once".[16][17][18][19]

Two contrasting viewpoints on time divide many prominent philosophers. One view is that time is part of the fundamental structure of the universe — a dimension independent of events, in which events occur in sequence. Sir Isaac Newton subscribed to this realist view, and hence it is sometimes referred to as Newtonian time.[20][21] The opposing view is that *time* does not refer to any kind of "container" that events and objects "move through", nor to any entity that "flows", but that it is instead part of a fundamental intellectual structure (together with space and number) within which humans sequence and compare events. This second view, in the tradition of Gottfried Leibniz[15] and Immanuel Kant,[22][23] holds that *time* is neither an event nor a thing, and thus is not itself measurable nor can it be travelled.

Time is one of the seven fundamental physical quantities in the International System of Units. Time is used to define other quantities — such as velocity — so defining time in terms of such quantities would result in circularity of definition.[24] An operational definition of time, wherein one says that observing a certain number of repetitions of one or another standard cyclical event (such as the passage of a free-swinging pendulum) constitutes one standard unit such as the second, is highly useful in the conduct of both advanced experiments and everyday affairs of life. The operational definition leaves aside the question whether there is something called time, apart from the counting activity just mentioned, that flows and that can be measured. Investigations of a single continuum called spacetime bring questions about space into questions about time, questions that have their roots in the works of early students of natural philosophy. Furthermore, it may be that there is a subjective component to time, but whether or not time itself is "felt", as a sensation or an experience, has never been settled.[3][7][8][25][26]

Temporal measurement has occupied scientists and technologists, and was a prime motivation in navigation and astronomy. Periodic events and periodic motion have long served as standards for units of time. Examples include the apparent motion of the sun across the sky, the phases of the moon, the swing of a pendulum, and the beat of a heart. Currently, the international unit of time, the second, is defined in terms of radiation emitted by caesium atoms (see below). Time is also of significant social importance, having economic value ("time is money") as well as personal value, due to an awareness of the limited time in each day and in human life spans.

Time in Greek Mythology:

The Greek language denotes two distinct principles, Chronos and Kairos. The former refers to numeric, or chronological, time. The latter, literally "the right or opportune moment", relates specifically to metaphysical or Divine time. In theology, Kairos is qualitative, as opposed to quantitative.
In Greek mythology, Chronos (Ancient Greek: Χρόνος) is identified as the Personification of Time. His name in Greek means "time" and is alternatively spelled Chronus (Latin spelling) or Khronos. Chronos is usually portrayed as an old, wise man with a long, gray beard, such as "Father Time". Some English words whose etymological root is khronos/chronos include *chronology*, *chronometer*, *chronic*, *anachronism*, *synchronize*, and *chronicle*.
Philosophy: (further research is required)
Main articles: Philosophy of space and time *and* Temporal finitism
Two distinct viewpoints on time divide many prominent philosophers. One view is that time is part of the fundamental structure of the universe, a dimension in which events occur in sequence. Sir Isaac Newton subscribed to this realist view, and hence it is sometimes referred to as Newtonian time.[21] An opposing view is that *time* does not refer to any kind of actually existing dimension that events and objects "move through", nor to any entity that "flows", but that it is instead an intellectual concept (together with space and number) that enables humans to sequence and compare events[43] This second view, in the tradition of Gottfried Leibniz[15] and Immanuel Kant,[22][23] holds that space and time "do not exist in and of themselves, but ... are the product of the way we represent things", because we can know objects only as they appear to us.
The Vedas, the earliest texts on Indian philosophy and Hindu philosophy dating back to the late 2nd millennium BC, describe ancient Hindu cosmology, in which the universe goes through repeated cycles of creation, destruction and rebirth, with each cycle lasting 4320 million years.[44] Ancient Greek philosophers, including Parmenides and Heraclitus, wrote essays on the nature of time.[45] Plato, in the Timaeus, identified time with the period of motion of the heavenly bodies. Aristotle, in Book IV of his Physica defined time as the number of change with respect to before and after.
In Book 11 of his Confessions, St. Augustine of Hippo ruminates on the nature of time, asking, "What then is time? If no one asks me, I know: if I wish to explain it to one that asketh, I know not." He begins to define time by what it is not rather than what it is,[46] an approach similar to that taken in other negative definitions. However, Augustine ends up calling time a “distention” of the mind (Confessions 11.26) by which we simultaneously grasp the past in memory, the present by attention, and the future by expectation.
In contrast to ancient Greek philosophers who believed that the universe had an infinite past with no beginning, medieval philosophers and theologians developed the concept of the universe having a finite past with a beginning. This view is shared by Abrahamic faiths as they believe time started by creation, therefore the only thing being infinite is God and everything else, including time, is finite.Isaac Newton believed in absolute space and absolute time; Leibniz believed that time and space are relational.[47] The differences

between Leibniz's and Newton's interpretations came to a head in the famous Leibniz-Clarke Correspondence.

"Time is not an empirical concept. For neither co-existence nor succession would be perceived by us, if the representation of time did not exist as a foundation *a priori*. Without this presupposition we could not represent to ourselves that things exist together at one and the same time, or at different times, that is, contemporaneously, or in succession."Immanuel Kant, Critique of Pure Reason (1781), trans. Vasilis Politis (London: Dent., 1991), p.54.Immanuel Kant, in the Critique of Pure Reason, described time as an a priori intuition that allows us (together with the other *a priori* intuition, space) to comprehend sense experience.[48] With Kant, neither space nor time are conceived as substances, but rather both are elements of a systematic mental framework that necessarily structures the experiences of any rational agent, or observing subject. Kant thought of time as a fundamental part of an abstract conceptual framework, together with space and number, within which we sequence events, quantify their duration, and compare the motions of objects. In this view, *time* does not refer to any kind of entity that "flows," that objects "move through," or that is a "container" for events. Spatial measurements are used to quantify the extent of and distances between objects, and temporal measurements are used to quantify the durations of and between events. (See Ontology).Henri Bergson believed that time was neither a real homogeneous medium nor a mental construct, but possesses what he referred to as Duration. Duration, in Bergson's view, was creativity and memory as an essential component of reality.[49]

According to Martin Heidegger we do not exist inside time, *we are time*. Hence, the relationship to the past is a present awareness of *having been*, which allows the past to exist in the present. The relationship to the future is the state of anticipating a potential possibility, task, or engagement. It is related to the human propensity for caring and being concerned, which causes "being ahead of oneself" when thinking of a pending occurrence. Therefore, this concern for a potential occurrence also allows the future to exist in the present. The present becomes an experience, which is qualitative instead of quantitative. Heidegger seems to think this is the way that a linear relationship with time, or temporal existence, is broken or transcended.[50] We are not stuck in sequential time. We are able to remember the past and project into the future - we have a kind of random access to our representation of temporal existence --- we can, in our thoughts, step out of (ecstasis) sequential time.[51]

Time as "unreal"[edit]

In 5th century BC Greece, Antiphon the Sophist, in a fragment preserved from his chief work *On Truth*, held that: "*Time is not a reality (hypostasis), but a concept (noêma) or a measure (metron).*" Parmenides went further, maintaining that time, motion, and change were illusions, leading to the paradoxes of his follower Zeno.[52] Time as an illusion is also a common theme in Buddhist thought.[53][54]J. M. E. McTaggart's 1908 The Unreality of Time argues that, since every event has the characteristic of being both present and not present (i.e., future or past), that time is a self-contradictory idea (see also The flow of time).

These arguments often center around what it means for something to be *unreal*. Modern physicists generally believe that time is as *real* as space—though others, such as Julian Barbour in his book The End of Time, argue that quantum equations of the universe take their true form when expressed in the timeless realm containing every possible *now* or momentary configuration of the universe, called 'platonia' by Barbour.[55] (See also: Eternalism (philosophy of time))

Physical Definition: (further research is required)

Main article: Time in physics

Until Einstein's profound reinterpretation of the physical concepts associated with time and space, time was considered to be the same everywhere in the universe, with all observers measuring the same time interval for any event.[56] Non-relativistic classical mechanics is based on this Newtonian idea of time.

Einstein, in his special theory of relativity,[57] postulated the constancy and finiteness of the speed of light for all observers. He showed that this postulate, together with a reasonable definition for what it means for two events to be simultaneous, requires that distances appear compressed and time intervals appear lengthened for events associated with objects in motion relative to an inertial observer.

The theory of special relativity finds a convenient formulation in Minkowski spacetime, a mathematical structure that combines three dimensions of space with a single dimension of time. In this formalism, distances in space can be measured by how long light takes to travel that distance, e.g., a light-year is a measure of distance, and a meter is now defined in terms of how far light travels in a certain amount of time. Two events in Minkowski spacetime are separated by an invariant interval, which can be either space-like, light-like, or time-like. Events that are time-like cannot be simultaneous in any frame of reference, there must be a temporal component (and possibly a spatial one) to their separation. Events that are space-like could be simultaneous in some frame of reference, and there is no frame of reference in which they do not have a spatial separation. People travelling at different velocities between two events measure different spatial and temporal separations between the events, but the *invariant interval* is constant and independent of velocity.

Classical mechanics[edit]

In non-relativistic classical mechanics, Newton's concept of "relative, apparent, and common time" can be used in the formulation of a prescription for the synchronization of clocks. Events seen by two different observers in motion relative to each other produce a mathematical concept of time that works sufficiently well for describing the everyday phenomena of most people's experience. In the late nineteenth century, physicists encountered problems with the classical understanding of time, in connection with the behavior of electricity and magnetism. Einstein resolved these problems by invoking a method of synchronizing clocks using the constant, finite speed of light as the maximum signal velocity. This led directly to the result that observers in motion relative to one another measure different elapsed times for the same event.

Two-dimensional space depicted in three-dimensional spacetime. The past and future light cones are absolute, the "present" is a relative concept different for observers in relative motion.

Spacetime[edit]

Main article: Spacetime

Time has historically been closely related with space, the two together merging into spacetime in Einstein's special relativity and general relativity. According to these theories, the concept of time depends on the spatial reference frame of the observer, and the human perception as well as the measurement by instruments such as clocks are different for observers in relative motion. For example, if a spaceship carrying a clock flies through space at (very nearly) the speed of light, its crew does not notice a change in the speed of time on board their vessel because everything traveling at the same speed slows down at the same rate (including the clock, the crew's thought processes, and the functions of their bodies). However, to a stationary observer watching the spaceship fly by, the spaceship appears flattened in the direction it is traveling and the clock on board the spaceship appears to move very slowly. On the other hand, the crew on board the spaceship also perceives the observer as slowed down and flattened along the spaceship's direction of travel, because both are moving at very nearly the speed of light relative to each other. Because the outside universe appears flattened to the spaceship, the crew perceives themselves as quickly traveling between regions of space that (to the stationary observer) are many light years apart. This is reconciled by the fact that the crew's perception of time is different from the stationary observer's; what seems like seconds to the crew might be hundreds of years to the stationary observer. In either case, however, causality remains unchanged: the past is the set of events that can send light signals to an entity and the future is the set of events to which an entity can send light signals.[58][59][60]

Time dilation[edit]

Relativity of simultaneity: Event B is simultaneous with A in the green reference frame, but it occurred before in the blue frame, and occurs later in the red frame.

Main article: Time dilation

Einstein showed in his thought experiments that people travelling at different speeds, while agreeing on cause and effect, measures different time separations between events, and can even observe different chronological orderings between non-causally related events. Though these effects are typically minute in the human experience, the effect becomes much more pronounced for objects moving at speeds approaching the speed of light. Many subatomic particles exist for only a fixed fraction of a second in a lab relatively at rest, but some that travel close to the speed of light can be measured to travel farther and survive much longer than expected (a muon is one example). According to the special theory of relativity, in the high-speed particle's frame of reference, it exists, on the average, for a standard amount of time known as its mean lifetime, and the distance it travels in that time is zero, because its velocity is zero. Relative to a frame of reference at rest, time seems to "slow down" for the particle. Relative to the high-speed particle, distances seem to shorten. Einstein showed how both temporal and spatial dimensions can be altered (or "warped") by high-speed motion.

Einstein (*The Meaning of Relativity*): "Two events taking place at the points A and B of a system K are simultaneous if they appear at the same instant when observed from the middle point, M, of the interval AB. Time is then defined as the ensemble of the indications of similar clocks, at rest relatively to K, which register the same simultaneously."

Einstein wrote in his book, *Relativity*, that simultaneity is also relative, i.e., two events that appear simultaneous to an observer in a particular inertial reference frame need not be judged as simultaneous by a second observer in a different inertial frame of reference.

Relativistic time versus Newtonian time[edit]

Views of spacetime along the world line of a rapidly accelerating observer in a relativistic universe. The events ("dots") that pass the two diagonal lines in the bottom half of the image (the past light cone of the observer in the origin) are the events visible to the observer.

The animations visualise the different treatments of time in the Newtonian and the relativistic descriptions. At the heart of these differences are the Galilean and Lorentz transformations applicable in the Newtonian and relativistic theories, respectively.

In the figures, the vertical direction indicates time. The horizontal direction indicates distance (only one spatial dimension is taken into account), and the thick dashed curve is the spacetime trajectory ("world line") of the observer. The small dots indicate specific (past and future) events in spacetime.

The slope of the world line (deviation from being vertical) gives the relative velocity to the observer. Note how in both pictures the view of spacetime changes when the observer accelerates.

In the Newtonian description these changes are such that *time* is absolute: the movements of the observer do not influence whether an event occurs in the 'now' (i.e., whether an event passes the horizontal line through the observer).

However, in the relativistic description the *observability of events* is absolute: the movements of the observer do not influence whether an event passes the "light cone" of the observer. Notice that with the change from a Newtonian to a relativistic description, the concept of *absolute time* is no longer applicable: events move up-and-down in the figure depending on the acceleration of the observer.

Arrow of time[edit]

Main article: Arrow of time

Time appears to have a direction – the past lies behind, fixed and immutable, while the future lies ahead and is not necessarily fixed. Yet for the most part the laws of physics do not specify an arrow of time, and allow any process to proceed both forward and in reverse. This is generally a consequence of time being modeled by a parameter in the system being analyzed, where there is no "proper time": the direction of the arrow of time is sometimes arbitrary. Examples of this include the Second law of thermodynamics, which states that entropy must increase over time (see Entropy); the cosmological arrow of time, which points away from the Big Bang, CPT symmetry, and the radiative arrow of time, caused by light only traveling forwards in time (see light cone). In particle physics, the violation of CP symmetry implies that there should be a small counterbalancing time asymmetry to preserve CPT symmetry as stated above. The standard description of measurement in quantum mechanics is also time asymmetric (see Measurement in quantum mechanics).

Quantized time[edit]

See also: Chronon

Time quantization is a hypothetical concept. In the modern established physical theories (the Standard Model of Particles and Interactions and General Relativity) time is not quantized.Planck time (~ 5.4 × 10−44 seconds) is the unit of time in the system of natural units known as Planck units. Current established physical theories are believed to fail at this time scale, and many physicists expect that the Planck time might be the smallest unit of time that could ever be measured, even in principle. Tentative physical theories that describe this time scale exist; see for instance loop quantum gravity.

Time as Big Bang:

Stephen Hawking in particular has addressed a connection between time and the Big Bang. In A Brief History of Time and elsewhere, Hawking says that even if time did not begin with the Big Bang and there were another time frame before the Big Bang, no information from events then would be accessible to us, and nothing that happened then would have any effect upon the present time-frame.[61] Upon occasion, Hawking has stated that time actually began with the Big Bang, and that questions about what happened *before* the Big Bang are *meaningless*.[62][63][64] This less-nuanced, but commonly repeated formulation has received criticisms from philosophers such as Aristotelian philosopher Mortimer J. Adler.[65][66]

Scientists have come to some agreement on descriptions of events that happened 10^{-35} seconds after the Big Bang, but generally agree that descriptions about what happened before one Planck time (5×10^{-44} seconds) after the Big Bang are likely to remain pure speculation.

Speculative physics beyond the Big Bang[edit]

A graphical representation of the expansion of the universe with the inflationary epoch represented as the dramatic expansion of the metric seen on the left

While the Big Bang model is well established in cosmology, it is likely to be refined in the future. Little is known about the earliest moments of the universe's history. The Penrose–Hawking singularity theorems require the existence of a singularity at the beginning of cosmic time. However, these theorems assume that general relativity is correct, but general relativity must break down before the universe reaches the Planck temperature, and a correct treatment of quantum gravity may avoid the singularity.[67]

There may also be parts of the universe well beyond what can be observed in principle. If inflation occurred this is likely, for exponential expansion would push large regions of space beyond our observable horizon.

Some proposals, each of which entails untested hypotheses, are:

•models including the Hartle–Hawking boundary condition in which the whole of space-time is finite; the Big Bang does represent the limit of time, but without the need for a singularity.[68]

•brane cosmology models[69] in which inflation is due to the movement of branes in string theory; the pre-big bang model; the ekpyrotic model, in which the Big Bang is the result of a collision between branes; and the cyclic model, a variant of the ekpyrotic model in which collisions occur periodically.[70][71][72]

•chaotic inflation, in which inflation events start here and there in a random quantum-gravity foam, each leading to a *bubble universe* expanding from its own big bang.[73]

Proposals in the last two categories see the Big Bang as an event in a much larger and older universe, or multiverse, and not the literal beginning.

Time Travel:

Main article: Time travel

See also: Time travel in fiction*,* Wormhole*, and* Twin paradox

Time travel is the concept of moving backwards and/or forwards to different points in time, in a manner analogous to moving through space, and different from the normal "flow" of time to an earthbound observer. In this view, all points in time (including future times) "persist" in some way. Time travel has been a plot device in fiction since the 19th century. Traveling backwards in time has never been verified, presents many theoretic problems, and may be an impossibility.[74] Any technological device, whether fictional or hypothetical, that is used to achieve time travel is known as a time machine.

A central problem with time travel to the past is the violation of causality; should an effect precede its cause, it would give rise to the possibility of a temporal paradox. Some interpretations of time travel resolve this by accepting the possibility of travel between branch points, parallel realities, or universes.

Another solution to the problem of causality-based temporal paradoxes is that such paradoxes cannot arise simply because they have not arisen. As illustrated in numerous works of fiction, free will either ceases to exist in the past or the outcomes of such decisions are predetermined. As such, it would not be possible to enact the grandfather paradox because it is a historical fact that your grandfather was not killed before his child (your parent) was conceived. This view doesn't simply hold that history is an unchangeable constant, but that any change made by a hypothetical future time traveler would already have happened in his or her past, resulting in the reality that the traveler moves from. More elaboration on this view can be found in the Novikov self-consistency principle.

Time Perception:

Main article: Time perception

The specious present refers to the time duration wherein one's perceptions are considered to be in the present. The experienced present is said to be ‘specious’ in that, unlike the objective present, it is an interval and not a durationless instant. The term *specious present* was first introduced by the psychologist E.R. Clay, and later developed by William James.[75]

Biopsychology[edit]

The brain's judgement of time is known to be a highly distributed system, including at least the cerebral cortex, cerebellum and basal ganglia as its components. One particular component, the suprachiasmatic nuclei, is responsible for the circadian (or daily) rhythm, while other cell clusters appear capable of shorter-range (ultradian) timekeeping.

Psychoactive drugs can impair the judgement of time. Stimulants can lead both humans and rats to overestimate time intervals,[76][77] while depressants can have the opposite effect.[78] The level of activity in the brain of neurotransmitters such as dopamine and norepinephrine may be the reason for this.[79] Such chemicals will either excite or inhibit the firing of neurons in the brain, with a greater firing rate allowing the brain to register the occurrence of more events within a given interval (speed up time) and a decreased firing rate reducing the brain's capacity to distinguish events occurring within a given interval (slow down time).[80]Mental chronometry is the use of response time in perceptual-motor tasks to infer the content, duration, and temporal sequencing of cognitive operations.

Alterations[edit]

In addition to psychoactive drugs, judgements of time can be altered by temporal illusions (like the kappa effect[81]), age,[82] and hypnosis.[83] The sense of time is impaired in some people with neurological diseases such as Parkinson's disease and attention deficit disorder.

Psychologists assert that time seems to go faster with age, but the literature on this age-related perception of time remains controversial.[84] Those who support this notion argue that young people, having more excitatory neurotransmitters, are able to cope with faster external events.[80]

Virtual Reality:

Summary:

Virtual reality (**VR**) is a term that applies to computer-simulated environments that can simulate physical presence in places in the real world, as well as in imaginary worlds. Most current virtual reality environments are primarily visual experiences, displayed either on a computer screen or through special stereoscopic displays, but some simulations include additional sensory information, such as sound through speakers or headphones. Some advanced, haptic systems now include tactile information, generally known as force feedback, in medical and gaming applications. Furthermore, virtual reality covers remote communication environments which provide virtual presence of users with the concepts of telepresence and telexistence or a virtual artifact (VA) either through the use of standard input devices such as a keyboard and mouse, or through multimodal devices such as a wired glove, the Polhemus, and omnidirectional treadmills. The simulated environment can be similar to the real world in order to create a lifelike experience—for example, in simulations for pilot or combat training—or it can differ significantly from reality, such as in VR games. In practice, it is currently very difficult to create a high-fidelity virtual reality experience, due largely to technical limitations on processing power, image resolution, and communication bandwidth; however, the technology's proponents hope that such limitations will be overcome as processor, imaging, and data communication technologies become more powerful and cost-effective over time.

Virtual reality is often used to describe a wide variety of applications commonly associated with immersive, highly visual, 3D environments. The development of CAD software, graphics hardware acceleration, head-mounted displays, database gloves, and miniaturization have helped popularize the notion. In the book *The Metaphysics of Virtual Reality* by Michael R. Heim, seven different concepts of virtual reality are identified: simulation, interaction, artificiality, immersion, telepresence, full-body immersion, and network communication. People often identify VR with head mounted displays and data suits.[citation needed]

The possibility exists to have films and television programmes which are watched with a head-mounted display and computer control of the image so that the viewer appears to be inside the scene with the action going all round. The computer presents the view which corresponds to the direction the viewer is facing, through a system of head-tracking. This would give the viewers the feeling that they are actually going to the scene in person instead of looking at pictures on a screen. The term "virtual space" has been suggested as more specific for this technology, which is described in detail in the article Virtual Space - the movies of the future.

The term "artificial reality", coined by Myron Krueger, has been in use since the 1970s; however, the origin of the term "virtual reality" can be traced back to the French playwright, poet, actor, and director Antonin Artaud. In his seminal book *The Theatre and Its Double* (1938), Artaud described theatre as "*la réalité virtuelle*", a virtual reality in which, in Erik Davis's words, "characters, objects, and images take on the phantasmagoric force of alchemy's visionary internal dramas".[1] Artaud claimed that the "perpetual allusion to the materials and the principle of the theater found in almost all alchemical books should be understood as the expression of an identity [...] existing between the world in which the characters, images, and in a general way all that constitutes the *virtual reality* of the theater develops, and the purely fictitious and illusory world in which the symbols of alchemy are evolved".[2]

The term has also been used in The Judas Mandala, a 1982 science-fiction novel by Damien Broderick, where the context of use is somewhat different from that defined above. The earliest use cited by the Oxford English Dictionary is in a 1987 article titled "*Virtual reality*",[3] but the article is not about VR technology. The concept of virtual reality was popularized in mass media by movies such as Brainstorm and The Lawnmower Man. The VR research boom of the 1990s was accompanied by the non-fiction book *Virtual Reality* (1991) by Howard Rheingold.[4] The book served to demystify the subject, making it more accessible to less technical researchers and enthusiasts.

Multimedia: from Wagner to Virtual Reality, edited by Randall Packer and Ken Jordan and first published in 2001, explores the term and its history from an avant-garde perspective. Philosophical implications of the concept of VR are discussed in books including Philip Zhai's *Get Real: A Philosophical Adventure in Virtual Reality* (1998) and *Digital Sensations: Space, Identity and Embodiment in Virtual Reality* (1999), written by Ken Hillis.

Timeline:

Virtual reality can trace its roots to the 1860s, when 360-degree art through panoramic murals began to appear. An example of this would be Baldassare Peruzzi's piece titled, *Sala delle Prospettive*. In the 1920s, vehicle simulators were introduced.[citation needed] Morton Heilig wrote in the 1950s of an "Experience Theatre" that could encompass all the senses in an effective manner, thus drawing the viewer into the onscreen activity. He built a prototype of his vision dubbed the Sensorama in 1962, along with five short films to be displayed in it while engaging multiple senses (sight, sound, smell, and touch). Predating digital computing, the Sensorama was a mechanical device, which reportedly still functions today. Around this time, Douglas Englebart uses computer screens as both input and output devices. In 1966, Thomas A. Furness III introduces a visual flight stimulator for the Air Force. In 1968, Ivan Sutherland, with the help of his student Bob Sproull, created what is widely considered to be the first virtual reality and augmented reality (AR) head-mounted display (HMD) system. It was primitive both in terms of user interface and realism, and the HMD to be worn by the user was so heavy it had to be suspended from the ceiling. The graphics comprising the virtual environment were simple wire-frame model rooms. The formidable appearance of the device inspired its name, The Sword of Damocles. Also notable among the earlier hypermedia and virtual reality systems was the Aspen Movie Map, which was created at MIT in 1977. The program was a crude virtual simulation of Aspen, Colorado in which users could wander the streets in one of three modes: summer, winter, and polygons. The first two were based on photographs—the researchers actually photographed every possible movement through the city's street grid in both seasons—and the third was a basic 3-D model of the city. In the late 1980s, the term "virtual reality" was popularized by Jaron Lanier, one of the modern pioneers of the field. Lanier had founded the company VPL Research in 1985, which developed and built some of the seminal "goggles and gloves" systems of that decade. In 1991, Antonio Medina, a MIT graduate and NASA scientist, designed a virtual reality system to "drive" Mars rovers from Earth in apparent real time despite the substantial delay of Mars-Earth-Mars signals. The system, termed "Computer-Simulated Teleoperation" as published by Rand, is an extension of virtual reality.[5]

Impact:

There has been an increase in interest in the potential social impact of new technologies, such as virtual reality. In the book *Infinite Reality: Avatars, Eternal Life, New Worlds, and the Dawn of the Virtual Revolution,* Blascovich and Bailenson review the literature on the psychology and sociology behind life in virtual reality. In addition, Mychilo S. Cline, in his book *Power, Madness, and Immortality: The Future of Virtual Reality*, argues that virtual reality will lead to a number of important changes in human life and activity.[6] He argues that:

•Virtual reality will be integrated into daily life and activity, and will be used in various human ways. Another such speculation has been written up on how to reach ultimate happiness via virtual reality.[7]

•Techniques will be developed to influence human behavior, interpersonal communication, and cognition.[8]

•As we spend more and more time in virtual space, there will be a gradual "migration to virtual space", resulting in important changes in economics, worldview, and culture.[9]

Examples: Environments

AlloSphere

Cave automatic virtual environment:

Virtual: (See: Virtual Reality) (further research is required)

World: (further research is required)

Summary:

World is a common name for the whole of human civilization, specifically human experience, history, or the human condition in general, *worldwide*, i.e. anywhere on Earth.[2]

In a philosophical context it may refer to:

1.the whole of the physical Universe, or

2.an ontological world (*see* world disclosure).

In a theological context, *world* usually refers to the material or the profane sphere, as opposed to the celestial, spiritual, transcendent or sacred. The "end of the world" refers to scenarios of the final end of human history, often in religious contexts.World history is commonly understood as spanning the major geopolitical developments of about five millennia, from the first civilizations to the present.World population is the sum of all human populations at any time; similarly, world economy is the sum of the economies of all societies (all countries), especially in the context of globalization. Terms like world championship, gross world product, world flags etc. also imply the sum or combination of all current-day sovereign states.

In terms such as world religion, world language, and world war, *world* suggests international or intercontinental scope without necessarily implying participation of the entire world.

In terms such as world map and world climate, *world* is used in the sense detached from human culture or civilization, referring to the planet Earth physically.

Etymology:

The English word world comes from the Old English *weorold (-uld), weorld, worold (-uld, -eld)*, a compound of wer "man" and *eld* "age," which thus means roughly "Age of Man."[3] The Old English is a reflex of the Common Germanic **wira-alđiz*, also reflected in Old Saxon *werold*, Old High German *weralt*, Old Frisian *warld* and Old Norse *verǫld* (whence the Icelandic veröld).[4]

The corresponding word in Latin is *mundus*, literally "clean, elegant", itself a loan translation of Greek cosmos "orderly arrangement." While the Germanic word thus reflects a mythological notion of a "domain of Man" (compare Midgard), presumably as opposed to the divine sphere on the one hand and the chthonic sphere of the underworld on the other, the Greco-Latin term expresses a notion of creation as an act of establishing order out of chaos.

'World' distinguishes the entire planet or population from any particular country or region: *world affairs* pertain not just to one place but to the whole world, and world history is a field of history that examines events from a global (rather than a national or a regional) perspective. *Earth*, on the other hand, refers to the planet as a physical entity, and distinguishes it from other planets and physical objects.

'*World*' can also be used attributively, to mean 'global', 'relating to the whole world', forming usages such as world community or world canonical texts.[5]

By extension, a '*world*' may refer to any planet or heavenly body, especially when it is thought of as inhabited, especially in the context of science fiction or futurology.

'*World*', in original sense, when qualified, can also refer to a particular domain of human experience.

•The *world of work* describes paid work and the pursuit of career, in all its social aspects, to distinguish it from home life and academic study.

•The *fashion world* describes the environment of the designers, fashion houses and consumers that make up the fashion industry.

•historically, the New World vs. the Old World, referring to the parts of the world colonized in the wake of the age of discovery. Now mostly used in zoology and botany, as New World monkey.

Philosophy:

In philosophy, the term world has several possible meanings. In some contexts, it refers to everything that makes up reality or the physical universe. In others, it can mean have a specific ontological sense (see world disclosure). While clarifying the concept of world has arguably always been among the basic tasks of Western philosophy, this theme appears to have been raised explicitly only at the start of the twentieth century[6] and has been the subject of continuous debate. The question of what the world is has by no means been settled.

Parmenides

The traditional interpretation of Parmenides' work is that he argued that the every-day perception of reality of the physical world (as described in doxa) is mistaken, and that the reality of the world is 'One Being' (as described in aletheia): an unchanging, ungenerated, indestructible whole.

Plato

In his Allegory of the Cave, Plato distinguishes between forms and ideas and imagines two distinct worlds : the sensible world and the intelligible world.

Hegel

In Hegel's philosophy of history, the expression *Weltgeschichte ist Weltgericht* (World History is a tribunal that judges the World) is used to assert the view that History is what judges men, their actions and their opinions. Science is born from the desire to transform the World in relation to Man; its final end is technical application.

SchopenhauerThe World as Will and Representation is the central work of Arthur Schopenhauer.

Schopenhauer saw the human will as our one window to the world behind the representation; the Kantian thing-in-itself. He believed, therefore, that we could gain knowledge about the thing-in-itself, something Kant said was impossible, since the rest of the relationship between representation and thing-in-itself could be understood by analogy to the relationship between human will and human body.

Wittgenstein

Two definitions that were both put forward in the 1920s, however, suggest the range of available opinion. "The world is everything that is the case," wrote Ludwig Wittgenstein in his influential Tractatus Logico-Philosophicus, first published in 1922. This definition would serve as the basis of logical positivism, with its assumption that there is exactly one world, consisting of the totality of facts, regardless of the interpretations that individual people may make of them.

HeideggerMartin Heidegger, meanwhile, argued that "the surrounding world is different for each of us, and notwithstanding that we move about in a common world".[7] The world, for Heidegger, was that into which we are always already "thrown" and with which we, as beings-in-the-world, must come to terms. His conception of "world disclosure" was most notably elaborated in his 1927 work Being and Time.

Freud

In response, Sigmund Freud proposed that we do not move about in a common world, but a common thought process. He believed that all the actions of a person are motivated by one thing: lust. This led to numerous theories about reactionary consciousness.

Other

Some philosophers, often inspired by David Lewis, argue that metaphysical concepts such as possibility, probability and necessity are best analyzed by comparing *the* world to a range of possible worlds; a view commonly known as modal realism.

Religion and Mythology:

"Carnal" redirects here. It is not to be confused with Carneal or Karnal.

Yggdrasil, a modern attempt to reconstruct the Norse world tree which connects the heavens, the world, and the underworld.Mythological cosmologies often depict the world as centered around an axis mundi and delimited by a boundary such as a world ocean, a world serpent or similar. In some religions, worldliness (also called carnality) is that which relates to this world as opposed to other worlds or realms.

Buddhism

In Buddhism, the world means society, as distinct from the monastery. It refers to the material world, and to worldly gain such as wealth, reputation, jobs, and war. The spiritual world would be the path to enlightenment, and changes would be sought in what we could call the psychological realm.

Christianity

In Christianity, the term often connotes the concept of the fallen and corrupt world order of human society, in contrast to the World to Come. The world is frequently cited alongside *the* flesh and *the* Devil as a source of temptation that Christians should flee. Monks speak of striving to be "*in* this world, but not *of* this world"--as Jesus said, and the term "worldhood" has been distinguished from "monkhood", the former being the status of merchants, princes, and others who deal with "worldly" things.

This view is clearly expressed by king Alfred the Great of England (d. 899) in his famous Preface to the Cura Pastoralis:

"Therefore I command you to do as I believe you are willing to do, that you free yourself from worldly affairs *(*Old English*: woruldðinga)* as often as you can, so that wherever you can establish that wisdom that God gave you, you establish it. Consider what punishments befell us in this world when we neither loved wisdom at all ourselves, nor transmitted it to other men; we had the name alone that we were Christians, and very few had the practices."

Although Hebrew and Greek words meaning "world" are used in Scripture with the normal variety of senses, many examples of its use in this particular sense can be found in the teachings of Jesus according to the Gospel of John, e.g. 7:7, 8:23, 12:25, 14:17, 15:18-19, 17:6-25, 18:36. For contrast, a relatively newer concept is Catholic imagination.Contemptus mundi is the name given to the recognition that the world, in all its vanity, is nothing more than a futile attempt to hide from God by stifling our desire for the good and the holy.[8] This view has been criticized as a "pastoral of fear" by modern historian Jean Delumeau.[9]

During the Second Vatican Council, there was a novel attempt to develop a positive theological view of the World, which is illustrated by the pastoral optimism of the constitutions Gaudium et Spes, Lumen Gentium, Unitatis Redintegratio and Dignitatis Humanae.

Eastern Christianity

In Eastern Christian monasticism or asceticism the world of mankind is driven by passions. Therefore the passions of the World are simply called "the world". Each of these passions are a link to the world of mankind or order of human society. Each of these passions must be overcome in order for a person to receive salvation (theosis). The process of theosis is a personal relationship with God. This understanding is taught within the works of ascetics like Evagrius Ponticus, and the most seminal ascetic works read most widely by Eastern Christians, the Philokalia and the Ladder of Divine Ascent (the works of Evagrius and John Climacus are also contained within the Philokalia). At the highest level of world transcendence is hesychasm which culminates into the Vision of God.

Orbis Catholicus

Orbis Catholicus is a Latin phrase meaning *Catholic world*, per the expression Urbi et Orbi, and refers to that area of Christendom under papal supremacy. It is somewhat similar to the phrases secular world, Jewish world and Islamic world.

Judaism

Main article: Olam HaZeh