

Systems Theory

Systems theory is the [transdisciplinary](#)^[1] study of [systems](#), i.e., cohesive groups of interrelated, interdependent components that can be [natural](#) or [artificial](#). Every system has causal boundaries, is influenced by its context, defined by its structure, function, and role, and expressed through its relations with other systems. A system is "more than the sum of its parts" when it expresses [synergy](#) or [emergent behavior](#).^[2]

Changing one component of a system may affect other components or the whole system. It may be possible to predict these changes in patterns of behavior. For systems that learn and adapt, the growth and the degree of [adaptation](#) depend upon how well the system is engaged with its environment and other contexts influencing its organization. Some systems support other systems, maintaining the other system to prevent failure. The goals of systems theory are to model a system's dynamics, [constraints](#), conditions, and relations; and to elucidate principles (such as purpose, measure, methods, tools) that can be discerned and applied to other systems at every level of nesting, and in a wide range of fields for achieving optimized [equifinality](#).^[3]

General systems theory is about developing broadly applicable concepts and principles, as opposed to concepts and principles specific to one domain of knowledge. It distinguishes dynamic or active systems from static or passive systems. Active systems are activity structures or components that interact in behaviours and processes or interrelate through formal contextual boundary conditions (attractors). Passive systems are structures and components that are being processed. For example, a computer program is passive when it is a file stored on the hard drive and active when it runs in memory.^[4] The field is related to [systems thinking](#), machine logic, and [systems engineering](#).

Overview

Systems theory is manifest in the work of practitioners in many disciplines, for example the works of physician [Alexander Bogdanov](#), biologist [Ludwig von Bertalanffy](#), linguist [Béla H. Bánáthy](#), and sociologist [Talcott Parsons](#); in the study of ecological systems by [Howard T. Odum](#), [Eugene Odum](#); in [Fritjof Capra's](#) study of [organizational theory](#); in the study of [management](#) by [Peter Senge](#); in interdisciplinary areas such as [human resource development](#) in the works of [Richard A. Swanson](#); and in the works of educators [Debra Hammond](#) and [Alfonso Montuori](#).

As a [transdisciplinary](#), interdisciplinary, and [multiperspectival](#) endeavor, systems theory brings together principles and concepts from [ontology](#), the [philosophy of science](#), [physics](#), [computer science](#), [biology](#), and [engineering](#), as well as [geography](#), [sociology](#), [political science](#), [psychotherapy](#) (especially [family systems therapy](#)), and [economics](#).

Systems theory promotes dialogue between autonomous areas of study as well as within [systems science](#) itself. In this respect, with the possibility of misinterpretations, von Bertalanffy^[5] believed a general theory of systems "should be an important regulative

device in science," to guard against superficial analogies that "are useless in science and harmful in their practical consequences."

Others remain closer to the direct systems concepts developed by the original systems theorists. For example, [Ilya Prigogine](#), of the [Center for Complex Quantum Systems](#) at the [University of Texas](#), has studied [emergent properties](#), suggesting that they offer [analogues](#) for [living systems](#). The [distinction](#) of [autopoiesis](#) as made by [Humberto Maturana](#) and [Francisco Varela](#) represent further developments in this field. Important names in contemporary systems science include [Russell Ackoff](#), [Ruzena Bajcsy](#), [Béla H. Bánáthy](#), [Gregory Bateson](#), [Anthony Stafford Beer](#), [Peter Checkland](#), [Barbara Grosz](#), [Brian Wilson](#), [Robert L. Flood](#), [Allenna Leonard](#), [Radhika Nagpal](#), [Fritjof Capra](#), [Warren McCulloch](#), [Kathleen Carley](#), [Michael C. Jackson](#), [Katia Sycara](#), and [Edgar Morin](#) among others.

With the modern foundations for a general theory of systems following World War I, [Ervin László](#), in the preface for Bertalanffy's book, *Perspectives on General System Theory*, points out that the [translation](#) of "general system theory" from German into English has "wrought a certain amount of havoc".^[6]

It (General System Theory) was criticized as pseudoscience and said to be nothing more than an admonishment to attend to things in a holistic way. Such criticisms would have lost their point had it been recognized that von Bertalanffy's general system theory is a perspective or paradigm, and that such basic conceptual frameworks play a key role in the development of exact scientific theory. .. Allgemeine Systemtheorie is not directly consistent with an interpretation often put on 'general system theory,' to wit, that it is a (scientific) "theory of general systems." To criticize it as such is to shoot at straw men. Von Bertalanffy opened up something much broader and of much greater significance than a single theory (which, as we now know, can always be falsified and has usually an ephemeral existence): he created a new paradigm for the development of theories.

Theorie (or *Lehre*) "has a much broader meaning in German than the closest English words 'theory' and 'science'," just as *Wissenschaft* (or 'Science').^[6] These ideas refer to an organized body of knowledge and "any systematically presented set of concepts, whether [empirically](#), [axiomatically](#), or [philosophically](#)" represented, while many associate *Lehre* with theory and science in the etymology of general systems, though it also does not translate from the German very well; its "closest equivalent" translates to 'teaching', but "sounds dogmatic and off the mark."^[6] An adequate overlap in meaning is found within the word "[nomothetic](#)", which can mean "having the capability to posit long-lasting sense." While the idea of a "general systems theory" might have lost many of its root meanings in the translation, by defining a new way of thinking about science and [scientific paradigms](#), systems theory became a widespread term used, for instance, to describe the interdependence of relationships created in [organizations](#).

A system in this frame of reference can contain regularly interacting or interrelating groups of activities. For example, in noting the influence on the evolution of "an individually oriented [industrial psychology](#) [into] a systems and developmentally

oriented [organizational psychology](#)," some theorists recognize that organizations have complex social systems; separating the parts from the whole reduces the overall effectiveness of organizations.^[7] This difference, from conventional models that center on individuals, structures, departments and units, separates in part from the whole, instead of recognizing the interdependence between groups of individuals, structures, and processes that enable an organization to function.

László explains that the new systems view of organized complexity went "one step beyond the Newtonian view of organized simplicity," which reduced the parts from the whole, or understood the whole without relation to the parts. The relationship between organisations and their [environments](#) can be seen as the foremost source of complexity and interdependence. In most cases, the whole has properties that cannot be known from analysis of the constituent elements in isolation.^[8]

[Béla H. Bánáthy](#), who argued—along with the founders of the systems society—that "the benefit of humankind" is the purpose of science, has made significant and far-reaching contributions to the area of systems theory. For the Primer Group at the [International Society for the System Sciences](#), Bánáthy defines a perspective that iterates this view:^[9][full citation needed]

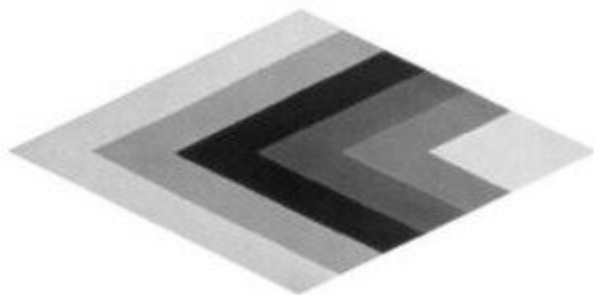
The systems view is a world-view that is based on the discipline of SYSTEM INQUIRY. Central to systems inquiry is the concept of SYSTEM. In the most general sense, a system means a configuration of parts connected and joined together by a web of relationships. The Primer Group defines a system as a family of relationships among the members acting as a whole. Von Bertalanffy defined a system as "elements in a standing relationship."

Applications

Art

Main article: [Systems art](#)

Systems art



[Kenneth Noland](#), Trans West, 1965.

Systems art is art influenced by [cybernetics](#) and [systems theory](#), reflecting on natural systems, social systems, and the social signs of the [art world](#) itself.^[1]

Systems art emerged as part of the first wave of the [conceptual art](#) movement in the 1960s and 1970s. Closely related and overlapping terms include *[anti-form](#)*

movement, cybernetic art, generative systems, process art, systems aesthetic, systemic art, systemic painting, and systems sculpture.

Related fields of systems art

Anti-form movement

By the early 1960s, [minimalism](#) had emerged as an abstract movement in art, with roots in [geometric abstraction](#) via [Malevich](#), [the Bauhaus](#), and [Mondrian](#). This movement rejected the ideas of relational and subjective painting, the complexity of [abstract expressionist](#) surfaces, and the emotional [zeitgeist](#) and polemics present in [action painting](#). Minimalism argued that extreme simplicity could capture all of the sublime representation needed in art. The term **Systematic art** was coined by [Lawrence Alloway](#) in 1966 to describe the method that artists such as [Kenneth Noland](#), [Al Held](#), and [Frank Stella](#) were using to compose [abstract paintings](#).^[2]

Associated with painters such as [Frank Stella](#), minimalism in painting, as opposed to other areas, is a modernist movement. Depending on the context, minimalism might be construed as a precursor to the postmodern movement. Some writers classify it as a postmodern movement, noting that early minimalism began and succeeded as a modernist movement, producing advanced works but partially abandoning this project when some artists shifted towards the anti-form movement.

In the late 1960s, the term [postminimalism](#) was coined by [Robert Pincus-Witten](#)^[3] to describe minimalist-derived art that incorporated content and contextual overtones that minimalism had rejected. This term was applied to the work of [Eva Hesse](#), [Keith Sonnier](#), [Richard Serra](#), and new work by former minimalists such as [Robert Smithson](#), [Robert Morris](#), [Bruce Nauman](#), [Sol LeWitt](#), [Barry Le Va](#), and others. Minimalists like [Donald Judd](#), [Dan Flavin](#), [Carl Andre](#), [Agnes Martin](#), [John McCracken](#), and others continued to produce their [late modernist](#) paintings and sculptures for the remainder of their careers.

Cybernetic art

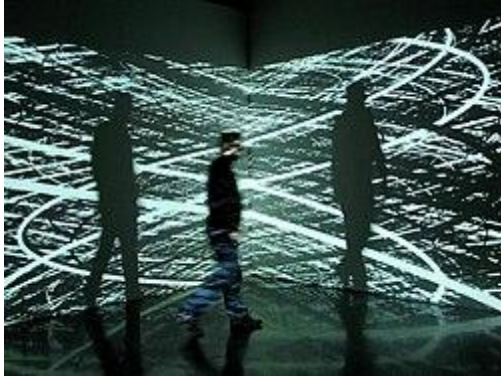
[Audio feedback](#), [tape loops](#), [sound synthesis](#), and computer-generated compositions reflect a cybernetic awareness of information, systems, and cycles. These techniques became widespread in the 1960s music industry. The visual effects of electronic feedback became a focus of artistic research in the late 1960s when video equipment first reached the consumer market. For example, [Steina and Woody Vasulka](#) used "all manner and combination of audio and video signals to generate electronic feedback in their respective media."^[4]

Related work by [Edward Ihnatowicz](#), [Wen-Ying Tsai](#), cybernetician [Gordon Pask](#), and the animist kinetics of [Robert Breer](#) and [Jean Tinguely](#) contributed to a strain of [cybernetic art](#) in the 1960s that was concerned with the shared circuits within and between the living and the technological. During this period, a line of cybernetic art theory also emerged. Writers such as [Jonathan Benthall](#) and [Gene Youngblood](#) drew on cybernetics. Notable contributors include British artist and theorist [Roy Ascott](#), with his essay

"Behaviourist Art and the Cybernetic Vision" published in the journal *Cybernetica* (1966–67), and American critic and theorist [Jack Burnham](#). In his 1968 work *Beyond Modern Sculpture*, Burnham develops a theory of cybernetic art that centers on art's drive to imitate and ultimately reproduce life.^[5] Additionally, in 1968, curator [Jasia Reichardt](#) organized the landmark exhibition *Cybernetic Serendipity* at the Institute of Contemporary Arts in London.

Generative systems

Main article: [Generative art](#)



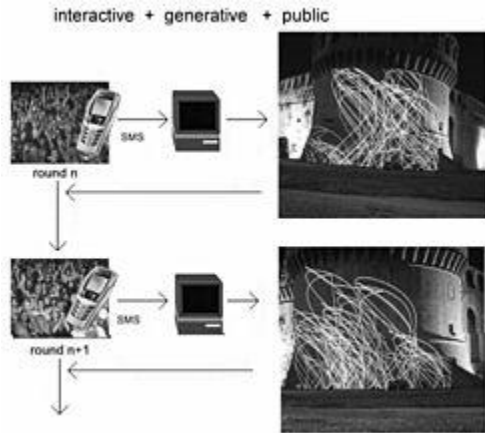
Installation view of *Irrational Geometrics* (2008)

by [Pascal Dombis](#)

Generative art is art that is created through algorithmic processes, using systems defined by computer software, algorithms, or similar mathematical, mechanical, or randomized autonomous methods. [Sonia Landy Sheridan](#) established the Generative Systems program at the [School of the Art Institute of Chicago](#) in 1970 in response to social changes brought about in part by the computer-robot communications revolution.^[6] The program, which brought artists and scientists together, aimed to transform the artist's role from passive to active by exploring contemporary scientific and technological systems and their relation to art and life. Unlike copier art, which was a commercial spin-off, Generative Systems was involved in developing elegant and simple systems intended for creative use by the general public. Generative Systems artists sought to bridge the gap between elite and novice by facilitating communication between the two, thus disseminating first-generation information to a broader audience and bypassing traditional commercial routes.^[6]

Process art

Main article: [Process art](#)



Maurizio Bolognini, *Collective Intelligence*

Machines series (CIMs, from 2000). These are generative and interactive installations using the mobile phone network and participation technologies from e-democracy.^[7]

Process art is an [artistic movement](#) and creative sentiment where the end product of *art* and *craft* is not the principal focus. The 'process' in process art refers to the act of creating art: the gathering, sorting, collating, associating, and patterning. Process art emphasizes the actual *doing*—art as a rite, [ritual](#), and performance. It often involves inherent motivation, rationale, and [intentionality](#). Thus, art is seen as a creative journey or process, rather than merely a final product.

In artistic discourse, the work of [Jackson Pollock](#) as a type of *action painting* is sometimes considered a precursor to process art. Process art, with its use of [serendipity](#), shares similarities with [Dada](#). Themes of change and transience are prominent in the process art movement. According to the [Solomon R. Guggenheim Museum](#), Robert Morris had a groundbreaking exhibition in 1968 that defined the movement. The museum's website notes that "Process artists were involved in issues attendant to the body, random occurrences, improvisation, and the liberating qualities of nontraditional materials such as [wax](#), [felt](#), and [latex](#). Using these, they created eccentric forms in erratic or irregular arrangements produced by actions such as cutting, hanging, and dropping, or organic processes such as growth, [condensation](#), [freezing](#), or [decomposition](#)".^[8]

Systemic art

According to Chilvers (2004), "earlier in 1966 the British art critic [Lawrence Alloway](#) had coined the term "Systemic art", to describe a type of abstract art characterized by the use of very simple standardized forms, usually [geometric](#) in character, either in a single concentrated image, or repeated in a system arranged according to a clearly visible principle of organization. He considered the chevron paintings of [Kenneth Noland](#) as examples of Systemic art, and considered this as a branch of [Minimal art](#)".^[9]

John G. Harries identified common ground in the ideas underlying developments in 20th-century art, such as [Serial art](#), Systems art, [Constructivism](#), and [Kinetic art](#). These forms of art often do not stem directly from observations of the external natural environment but from the observation of depicted shapes and their

relationships.^[10] According to Harries, Systems art represents a deliberate attempt by artists to develop a more flexible frame of reference. Rather than being a cognitive system that leads to the institutionalization of an imposed model, it uses its frame of reference as a model to be emulated. However, transferring the meaning of a picture to its location within a systemic structure does not eliminate the need to define the constitutive elements of the system. Without these definitions, constructing the system becomes challenging.^[10]



Newschool [ASCII art](#) Screenshot

Systemic painting

Systemic Painting, according to Auping (1989), "was the title of a highly influential exhibition at the [Guggenheim Museum](#) in 1966 assembled and introduced by [Lawrence Alloway](#) as curator. The show contained numerous works that many critics today would consider part of the [Minimal art](#)".^[11] In the catalogue, Alloway noted that "...paintings, such as those in this exhibition, are not, as has been often claimed, impersonal. The personal is not expunged by using a neat technique: anonymity is not a consequence of highly finishing a painting".^[12] The term "Systemic Painting" later came to refer to artists who employ systems to make a number of aesthetic decisions before commencing to paint.^[13]

Systems sculpture

According to Feldman (1987), "[serial art](#), serial painting, systems sculpture, and [ABC art](#) were art styles of the 1960s and 1970s in which simple geometric configurations are repeated with little or no variation. Sequences become important in mathematics and linguistic contexts. These works rely on simple arrangements of basic volumes and voids, mechanically produced surfaces, and algebraic permutations of form. The impact on the viewer, however, is anything but simple".^[14]

- [Algorithmic art](#)
- [Computer art](#)
- [Conceptual art](#)
- [Design](#)
- [Evolutionary art](#)
- [Fractal art](#)
- [Generative art](#)
- [Information art](#)

- [Interactive art](#)
- [Media art](#)
- [Participatory art](#)
- [Process music](#)
- [Software art](#)
- [Sustainable art](#)
- [Systems thinking](#)
- [Systems music](#)
- [Systems Group](#)

Biology

Main article: [Systems biology](#)

Systems biology is a movement that draws on several trends in [bioscience](#) research. Proponents describe systems biology as a biology-based interdisciplinary study field that focuses on complex interactions in [biological systems](#), claiming that it uses a new perspective ([holism](#) instead of [reduction](#)).

Particularly from the year 2000 onwards, the biosciences have used the term widely and in a variety of contexts. An often stated ambition of systems biology is the modelling and discovery of [emergent properties](#), which represent properties of a system whose theoretical description requires the only possible useful techniques to fall under the remit of systems biology. It is thought that [Ludwig von Bertalanffy](#) may have created the term *systems biology* in 1928.^[1]

Subdisciplines of systems biology include:

- [Systems neuroscience](#)
- [Systems pharmacology](#)

Ecology

Main article: [Systems ecology](#)

Systems ecology is an [interdisciplinary](#) field of [ecology](#) that takes a [holistic](#) approach to the study of [ecological systems](#), especially [ecosystems](#);^{[1][2][3]} it can be seen as an application of general systems theory to ecology.

Central to the systems ecology approach is the idea that an ecosystem is a [complex system](#) exhibiting [emergent properties](#). Systems ecology focuses on interactions and transactions within and between biological and ecological systems, and is especially concerned with the way the functioning of ecosystems can be influenced by human interventions. It uses and extends concepts from [thermodynamics](#) and develops other macroscopic descriptions of complex systems.

Chemistry

Main article: [Systems chemistry](#)

Systems chemistry is the science of studying [networks](#) of interacting molecules to create new functions from a set (or library) of molecules with different hierarchical levels and emergent properties.^[14] Systems chemistry is also related to the origin of life ([abiogenesis](#)).^[15]

Engineering

Main article: [Systems engineering](#)

Systems engineering is an [interdisciplinary](#) approach and means for enabling the realization and deployment of successful [systems](#). It can be viewed as the application of engineering techniques to the engineering of systems, as well as the application of a systems approach to engineering efforts.^[16] Systems engineering integrates other disciplines and specialty groups into a team effort, forming a structured development process that proceeds from concept to production to operation and disposal. Systems engineering considers both the business and the technical needs of all customers, with the goal of providing a quality product that meets the user's needs.^{[17][18]}

User-centered design process

Systems thinking is a crucial part of [user-centered design](#) processes and is necessary to understand the whole impact of a new [human-computer interaction](#) (HCI) [information system](#).^[19] Overlooking this and developing software without insights from the future users (mediated by user experience designers) is a serious design flaw that can lead to complete failure of information systems, increased stress and mental illness for users of information systems, leading to increased costs and a huge waste of resources.^[20] It is currently surprisingly uncommon for organizations and governments to investigate the project management decisions leading to serious design flaws and a lack of usability.^[citation needed]

The [Institute of Electrical and Electronics Engineers](#) estimates that roughly 15% of the estimated \$1 trillion used to develop information systems every year is completely wasted, and the produced systems are discarded before implementation due to entirely preventable mistakes.^[21] According to the CHAOS report published in 2018 by the Standish Group, a vast majority of information systems fail or partly fail according to their survey:

Pure success is the combination of high customer satisfaction with high return on value to the organization. Related figures for the year 2017 are: successful: 14%, challenged: 67%, failed: 19%.^[22]

Mathematics

Main article: [System dynamics](#)

System dynamics is an approach to understanding the [nonlinear](#) behavior of [complex systems](#) over time using [stocks](#), [flows](#), internal [feedback loops](#), and time delays.^[23]

Social sciences and humanities

- [Systems theory in anthropology](#)
- [Systems theory in archaeology](#)
- [Systems theory in political science](#)

Psychology

Main article: [Systems psychology](#)

Systems psychology is a branch of [psychology](#) that studies [human behaviour](#) and [experience](#) in [complex systems](#).

It received inspiration from systems theory and systems thinking, as well as the basics of theoretical work from [Roger Barker](#), [Gregory Bateson](#), [Humberto Maturana](#), and others. It makes an approach in [psychology](#) in which groups and individuals receive consideration as [systems](#) in [homeostasis](#). Systems psychology "includes the domain of [engineering psychology](#), but in addition seems more concerned with societal systems^[24] and with the study of motivational, affective, cognitive, and group behavior that holds the name engineering psychology."^[25]

In systems psychology, characteristics of [organizational behaviour](#) (such as individual needs, rewards, [expectations](#), and attributes of the people interacting with the [systems](#)) are considered in this process in order to create an effective system."^[26]

Informatics

Systems theory has been applied in the field of neuroinformatics and connectionist cognitive science. Attempts are being made in neurocognition to merge connectionist cognitive neuroarchitectures with the approach of systems theory and [dynamical systems theory](#).^[27]

History

Precursors

Timeline
Predecessors
<ul style="list-style-type: none">• Baron d'Holbach (1723/1789), Saint-Simon (1760–1825), Auguste Comte (1798–1857), Karl Marx (1818–1883), Friedrich Engels (1820–1895), Herbert Spencer (1820–

1903), [Rudolf Clausius](#) (1822–1888), [Vilfredo Pareto](#) (1848–1923), [Émile Durkheim](#) (1858–1917), [Alexander Bogdanov](#) (1873–1928), [Nicolai Hartmann](#) (1882–1950), [Robert Maynard Hutchins](#) (1929–1951), among others

Founders

- 1946–1953: [Macy conferences](#)
- 1948: [Norbert Wiener](#) publishes *Cybernetics: Or Control and Communication in the Animal and the Machine*
- 1951: [Talcott Parsons](#) publishes *The Social System*^[28]
- 1954: The [Society for the Advancement of General Systems Theory](#) is established by [Ludwig von Bertalanffy](#), [Anatol Rapoport](#), [Ralph W. Gerard](#), [Kenneth Boulding](#).
- 1955: [William Ross Ashby](#) publishes *Introduction to Cybernetics*
- 1968: [Bertalanffy](#) publishes *General System Theory: Foundations, Development, Applications*

Other contributors

- 1970–1990 [Second-order cybernetics](#) ([Heinz von Foerster](#), [Gregory Bateson](#), [Humberto Maturana](#), and others)
- 1971–1973 [Cybersyn](#), rudimentary internet and cybernetic system for democratic economic planning developed by [Stafford Beer](#) in Chile under the [Allende government](#)
- 1970s: [Catastrophe theory](#) ([René Thom](#), [E.C. Zeeman](#)) [Dynamical systems](#) in mathematics.
- 1977: [Ilya Prigogine](#) received the Nobel Prize for his works on [self-organization](#), conciliating important *systems theory* concepts with [system thermodynamics](#).
- 1980s: [Chaos theory](#) ([David Ruelle](#), [Edward Lorenz](#), [Mitchell Feigenbaum](#), [Steve Smale](#), [James A. Yorke](#))
- 1986: [Context theory](#) ([Anthony Wilden](#))

- 1988: [International Society for Systems Science](#) is established.
- 1990: [Complex adaptive systems](#) (John H. Holland, Murray Gell-Mann, W. Brian Arthur)

Systems thinking can date back to antiquity, whether considering the first systems of written communication with Sumerian [cuneiform](#) to [Maya numerals](#), or the feats of engineering with the [Egyptian pyramids](#). Differentiated from Western [rationalist](#) traditions of philosophy, [C. West Churchman](#) often identified with the [I Ching](#) as a systems approach, sharing a frame of reference similar to [pre-Socratic](#) philosophy and [Heraclitus](#).^{[29]:12–13} [Ludwig von Bertalanffy](#) traced systems concepts to the philosophy of [Gottfried Leibniz](#) and [Nicholas of Cusa's](#) *coincidentia oppositorum*. While modern systems can seem considerably more complicated, they may embed themselves in history.

Figures like [James Joule](#) and [Sadi Carnot](#) represent an important step in introducing the *systems approach* into the (rationalist) hard sciences of the 19th century, also known as the [energy transformation](#). Then, the [thermodynamics](#) of this century, by [Rudolf Clausius](#), [Josiah Gibbs](#), and others, established the *system reference model* as a formal scientific object.

Similar ideas are found in [learning theories](#) that developed from the same fundamental concepts, emphasising how understanding results from knowing concepts both in part and as a whole. In fact, Bertalanffy's organismic psychology paralleled the learning theory of [Jean Piaget](#).^[30] Some consider interdisciplinary perspectives critical in breaking away from [industrial age](#) models and thinking, wherein history represents history and math represents math, while the arts and sciences [specialization](#) remain separate, and many treat teaching as [behaviorist](#) conditioning.^[31]

The contemporary work of [Peter Senge](#) provides a detailed discussion of the commonplace critique of educational systems grounded in conventional assumptions about learning,^[32] including the problems with fragmented knowledge and lack of holistic learning from the "machine-age thinking" that became a "model of school separated from daily life." In this way, some systems theorists attempt to provide alternatives to, and evolved ideation from orthodox theories which have grounds in classical assumptions, including individuals such as [Max Weber](#) and [Émile Durkheim](#) in sociology and [Frederick Winslow Taylor](#) in [scientific management](#).^[33] The theorists sought holistic methods by developing systems concepts that could integrate with different areas.

Some may view the contradiction of [reductionism](#) in conventional theory (which has as its subject a single part) as simply an example of changing assumptions. The emphasis with systems theory shifts from parts to the organization of parts, recognizing interactions of the parts as not static and constant but dynamic processes. Some questioned the conventional [closed systems](#) with the development of [open systems](#) perspectives. The shift originated from [absolute](#) and universal authoritative principles and knowledge to relative and

general [conceptual](#) and [perceptual](#) knowledge^[34] and still remains in the tradition of theorists that sought to provide means to organize human life. In other words, theorists rethought the preceding [history of ideas](#); they did not lose them. Mechanistic thinking was particularly critiqued, especially the industrial-age mechanistic [metaphor](#) for the mind from [interpretations](#) of [Newtonian mechanics](#) by [Enlightenment](#) philosophers and later psychologists that laid the foundations of modern organizational theory and management by the late 19th century.^[35]

Founding and early development

Where assumptions in Western science from [Plato](#) and [Aristotle](#) to [Isaac Newton's *Principia*](#) (1687) have historically influenced all areas from the [hard](#) to [social](#) sciences (see [David Easton's](#) seminal development of the "[political system](#)" as an analytical construct), the original systems theorists explored the implications of 20th-century advances in terms of systems.

Between 1929 and 1951, [Robert Maynard Hutchins](#) at the [University of Chicago](#) had undertaken efforts to encourage innovation and interdisciplinary research in the social sciences, aided by the [Ford Foundation](#), with the university's interdisciplinary [Division of the Social Sciences](#) established in 1931.^{[29]:5-9}

Many early systems theorists aimed at finding a general systems theory that could explain all systems in all fields of science.

"[General systems theory](#)" (GST; [German: *allgemeine Systemlehre*](#)) was coined in the 1940s by [Ludwig von Bertalanffy](#), who sought a new approach to the study of [living systems](#).^[36] Bertalanffy developed the theory via lectures beginning in 1937 and then via publications beginning in 1946.^[37] According to [Mike C. Jackson](#) (2000), Bertalanffy promoted an embryonic form of GST as early as the 1920s and 1930s, but it was not until the early 1950s that it became more widely known in scientific circles.^[38]

Jackson also claimed that Bertalanffy's work was informed by [Alexander Bogdanov's](#) three-volume [Tectology](#) (1912–1917), providing the conceptual base for GST.^[38] A similar position is held by [Richard Mattessich](#) (1978) and [Fritjof Capra](#) (1996). Despite this, Bertalanffy never even mentioned Bogdanov in his works.

The systems view was based on several fundamental ideas. First, all phenomena can be viewed as a web of relationships among elements, or a [system](#). Second, all systems, whether [electrical](#), [biological](#), or [social](#), have common [patterns](#), [behaviors](#), and [properties](#) that the observer can analyze and use to develop greater insight into the behavior of complex phenomena and to move closer toward a unity of the sciences. System philosophy, methodology, and application are complementary to this science.^[6]

Cognizant of advances in science that questioned classical assumptions in the organizational sciences, Bertalanffy's idea to develop a theory of systems began as early as the [interwar period](#), publishing "An Outline for General Systems Theory" in the [British Journal for the Philosophy of Science](#) by 1950.^[39]

In 1954, von Bertalanffy, along with [Anatol Rapoport](#), [Ralph W. Gerard](#), and [Kenneth Boulding](#), came together at the [Center for Advanced Study in the Behavioral Sciences](#) in Palo Alto to discuss the creation of a "society for the advancement of General Systems Theory." In December that year, a meeting of around 70 people was held in [Berkeley](#) to form a society for the exploration and development of GST.^[40] The [Society for General Systems Research](#) (renamed the International Society for Systems Science in 1988) was established in 1956 as an affiliate of the [American Association for the Advancement of Science](#) (AAAS),^[40] specifically catalyzing systems theory as an area of study. The field developed from the work of Bertalanffy, Rapoport, Gerard, and Boulding, as well as other theorists in the 1950s, like [William Ross Ashby](#), [Margaret Mead](#), [Gregory Bateson](#), and [C. West Churchman](#), among others.

Bertalanffy's ideas were adopted by others working in mathematics, psychology, biology, [game theory](#), and [social network analysis](#). Subjects that were studied included those of [complexity](#), [self-organization](#), [connectionism](#), and [adaptive systems](#). In fields like [cybernetics](#), researchers such as Ashby, [Norbert Wiener](#), [John von Neumann](#), and [Heinz von Foerster](#) examined complex systems mathematically; Von Neumann discovered [cellular automata](#) and self-reproducing systems, again with only pencil and paper. [Aleksandr Lyapunov](#) and [Jules Henri Poincaré](#) worked on the foundations of [chaos theory](#) without any [computers](#) at all. At the same time, [Howard T. Odum](#), known as a radiation ecologist, recognized that the study of general systems required a language that could depict [energetics](#), [thermodynamics](#), and [kinetics](#) at any system scale. To fulfill this role, Odum developed a general system, or [universal language](#), based on the circuit language of [electronics](#), known as the [Energy Systems Language](#).

The [Cold War](#) affected the research project for systems theory in ways that sorely disappointed many of the seminal theorists. Some began to recognize that theories defined in association with systems theory had deviated from the initial general systems theory view.^[41] Economist Kenneth Boulding, an early researcher in systems theory, had concerns over the manipulation of systems concepts. Boulding concluded from the effects of the Cold War that abuses of [power](#) always prove consequential and that systems theory might address such issues.^{[29]:229–233} Since the end of the Cold War, a renewed interest in systems theory emerged, combined with efforts to strengthen an [ethical](#)^[42] view on the subject.

In sociology, systems thinking also began in the 20th century, including [Talcott Parsons' action theory](#)^[43] and [Niklas Luhmann's social systems theory](#).^{[44][45]} According to Rudolf Stichweh (2011):^{[43]:2}

Since its beginnings, the [social sciences](#) have been an important part of the establishment of systems theory... [T]he two most influential suggestions were the comprehensive sociological versions of systems theory, which were proposed by Talcott Parsons since the 1950s and by Niklas Luhmann since the 1970s.

Elements of systems thinking can also be seen in the work of [James Clerk Maxwell](#), particularly [control theory](#).

General systems research and systems inquiry

Many early systems theorists aimed at finding a general systems theory that could explain all systems in all fields of science. [Ludwig von Bertalanffy](#) began developing his 'general systems theory' via lectures in 1937 and then via publications from 1946.^[37] The concept received extensive focus in his 1968 book, *General System Theory: Foundations, Development, Applications*.^[30]

There are many definitions of a general system. Some properties that definitions include are: an overall [goal of the system](#), [parts of the system](#), and [relationships between these parts](#), and [emergent properties](#) of the interaction between the parts of the system that are not performed by any part on its own.^{[46]:58} [Derek Hitchins](#) defines a system in terms of [entropy](#) as a collection of parts and relationships between the parts where the parts of their interrelationships decrease entropy.^{[46]:58}

Bertalanffy aimed to bring together under one heading the organismic science that he had observed in his work as a biologist. He wanted to use the word *system* for those principles that are common to systems in general. In *General System Theory* (1968), he wrote:^{[30]:32}

[T]here exist models, principles, and laws that apply to generalized systems or their subclasses, irrespective of their particular kind, the nature of their component elements, and the relationships or "forces" between them. It seems legitimate to ask for a theory, not of systems of a more or less special kind, but of universal principles applying to systems in general.

In the preface to von Bertalanffy's *Perspectives on General System Theory*, [Ervin László](#) stated:^[6]

Thus, when von Bertalanffy spoke of Allgemeine System Source, it was consistent with his view that he was proposing a new perspective, a new way of doing science. It was not directly consistent with an interpretation often put on "general system theory", to wit, that it is a (scientific) "theory of general systems." To criticize it as such is to shoot at straw men. Von Bertalanffy opened up something much broader and of much greater significance than a single theory (which, as we now know, can always be falsified and has usually an ephemeral existence): he created a new paradigm for the development of theories.

Bertalanffy outlines systems inquiry into three major domains: [philosophy](#), [science](#), and [technology](#). In his work with the Primer Group, [Béla H. Bánáthy](#) generalized the domains into four integratable domains of systemic inquiry:

1. philosophy: the [ontology](#), [epistemology](#), and [axiology](#) of systems
2. theory: a set of interrelated concepts and principles applying to all systems
3. methodology: the set of models, strategies, methods, and tools that instrumentalize systems theory and philosophy
4. Application: the application and interaction of the domains

These operate in a recursive relationship, he explained; integrating 'philosophy' and 'theory' as knowledge, and 'method' and 'application' as action; systems inquiry is thus knowledgeable action.^[47]^[failed verification]

Properties of general systems

General systems may be split into a [hierarchy](#) of systems, where there are fewer interactions between the different systems than there are between the components in the system. The alternative is [heterarchy](#), where all components within the system interact with one another.^{[46]:65} Sometimes an entire system will be represented inside another system as a part, sometimes referred to as a holon.^[46] These hierarchies of systems are studied in [hierarchy theory](#).^[48] The amount of interaction between parts of systems higher in the hierarchy and parts of the system lower in the hierarchy is reduced. If all the parts of a system are tightly [coupled](#) (interact with one another a lot) then the system cannot be decomposed into different systems. The amount of coupling between parts of a system may differ temporally, with some parts interacting more often than others, or for different processes in a system.^{[49]:293} [Herbert A. Simon](#) distinguished between decomposable, nearly decomposable, and nondecomposable systems.^{[46]:72}

[Russell L. Ackoff](#) distinguished general systems by how their goals and subgoals could change over time. He distinguished between goal-maintaining, [goal-seeking](#), multi-goal, and reflective (or goal-changing) systems.^{[46]:73}

System types and fields

Theoretical fields

Main article: [List of types of systems theory](#)

- [Chaos theory](#)
- [Complex system](#)
- [Control theory](#)
- [Dynamical systems theory](#)
- [Earth system science](#)
- [Ecological systems theory](#)
- [Industrial ecology](#)
- [Living systems theory](#)^[48]
- [Sociotechnical system](#)
- [Systemics](#)
- [Telecoupling](#)
- [Urban metabolism](#)
- [World-systems theory](#)

Cybernetics

Main article: [Cybernetics](#)

[Cybernetics](#) is the study of the [communication](#) and control of regulatory [feedback](#) both in living and lifeless systems (organisms, organizations, machines), and in combinations of those. Its focus is on how anything (digital, mechanical, or biological) controls its behavior, processes information, reacts to information, and changes or can be changed to better accomplish those three primary tasks.

The terms *systems theory* and *cybernetics* have been widely used as synonyms. Some authors use the term *cybernetic systems* to denote a proper subset of the class of general systems, namely those systems that include [feedback loops](#). However, [Gordon Pask](#)'s differences of eternal interacting actor loops (that produce finite products) makes general systems a proper subset of cybernetics. In cybernetics, complex systems have been examined mathematically by such researchers as [W. Ross Ashby](#), [Norbert Wiener](#), [John von Neumann](#), and [Heinz von Foerster](#).

Threads of cybernetics began in the late 1800s, which led toward the publishing of seminal works (such as Wiener's *Cybernetics* in 1948 and [Bertalanffy](#)'s *General System Theory* in 1968). Cybernetics arose more from engineering fields, and GST from biology. If anything, it appears that although the two probably mutually influenced each other, cybernetics had the greater influence. Bertalanffy specifically made the point of distinguishing between the areas in noting the influence of cybernetics:

Systems theory is frequently identified with cybernetics and control theory. This again is incorrect. Cybernetics, as the theory of control mechanisms in technology and nature, is founded on the concepts of information and feedback, but as part of a general theory of systems.... [T]he model is of wide application but should not be identified with 'systems theory' in general ... [and] warning is necessary against its incautious expansion to fields for which its concepts are not made.^{[30]:17–23}

Cybernetics, [catastrophe theory](#), [chaos theory](#), and [complexity theory](#) have the common goal to explain complex systems that consist of a large number of mutually interacting and interrelated parts in terms of those interactions. [Cellular automata](#), [neural networks](#), [artificial intelligence](#), and [artificial life](#) are related fields, but do not try to describe general (universal) complex (singular) systems. The best context to compare the different "C"-Theories about complex systems is historical, which emphasizes different tools and methodologies, from [pure mathematics](#) in the beginning to pure [computer science](#) today. Since the beginning of chaos theory, when [Edward Lorenz](#) accidentally discovered a [strange attractor](#) with his computer, computers have become an indispensable source of information. One could not imagine the study of complex systems without the use of computers today.

System types

Complex adaptive systems

Main article: [Complex adaptive system](#)

Complex adaptive systems (CAS), coined by [John H. Holland](#), [Murray Gell-Mann](#), and others at the interdisciplinary [Santa Fe Institute](#), are special cases of [complex systems](#): they

are *complex* in that they are diverse and composed of multiple, interconnected elements; they are *adaptive* in that they have the capacity to change and learn from experience.

In contrast to [control systems](#), in which [negative feedback](#) dampens and reverses disequilibria, CAS are often subject to [positive feedback](#), which magnifies and perpetuates changes, converting local irregularities into global features.

See also

Systems science portal

- [Glossary of systems theory](#)
- [List of types of systems theory](#)
- [Autonomous agency theory](#)
- [Bibliography of sociology](#)
- [Cellular automata](#)
- [Chaos theory](#)
 - [Complexity](#)
- [Dependency theory](#)
- [Emergence](#)
- [Engaged theory](#)
- [Fractal](#)
- [Grey box model](#)
- [Hierarchy theory](#)
- [Irreducible complexity](#)
- [Meta-systems](#)
- [Multidimensional systems](#)
- [Open and closed systems in social science](#)
- [Pattern language](#)
- [Recursion \(computer science\)](#)
- [Reductionism](#)
- [Redundancy \(engineering\)](#)
- [Reversal theory](#)
- [Social rule system theory](#)
- [Sociology and complexity science](#)
- [Sociotechnical system](#)
- [Structuralist economics](#)
- [Structure–organization–process](#)
- [System identification](#)
- [Systemantics](#)
- [Systematics – study of multi-term systems](#)

- Systemics
- Systemography
- Systems science
- Tektology
- Theoretical ecology
- User-in-the-loop
- Viable system theory
- Viable systems approach
- World-systems theory

Organizations

- [List of systems sciences organizations](#)