Systems theory is an interdisciplinary theory about the nature of complex systems in nature, society, and science, and is a framework by which one can investigate and/or describe any group of objects that work together to produce some result. This could be a single organism, any organization or society, or any electro-mechanical or informational artifact. As a technical and general academic area of study it predominantly refers to the science of systems that resulted from **Bertalanffy**'s **General System Theory** (GST), among others, in initiating what became a project of systems research and practice. Systems theoretical approaches were later appropriated in other fields, such as in the structural functionalist sociology of **Talcott Parsons** and **Niklas Luhmann**.

Contents

// Overview

Margaret Mead was an influential figure in systems theory.

Contemporary ideas from systems theory have grown with diversified areas, exemplified by the work of **Béla H. Bánáthy**, ecological systems with **Howard T. Odum, Eugene Odum** and **Fritj of Capra**, organizational theory and management with individuals such as **Peter Senge**, interdisciplinary study with areas like Human Resource Development from the work of **Richard A. Swanson**, and insights from educators such as **Debora Hammond** and **Alfonso Montuori**. As a transdisciplinary, interdisciplinary and multiperspectival domain, the area brings together principles and concepts from ontology, philosophy of science, physics, computer science, biology, and engineering as well as geography, sociology, political science, psychotherapy (within family systems therapy) and economics among others. Systems theory thus serves as a bridge for interdisciplinary dialogue between autonomous areas of study as well as within the area of systems science itself.

In this respect, with the possibility of misinterpretations, von Bertalanffy [1] 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 theorists. For example, **Ilya Prigogine**, of the Center for Complex Quantum Systems at the University of Texas, Austin, has studied emergent properties, suggesting that they offer analogues for living systems. The theories of autopoiesis of Francisco Varela and Humberto Maturana are a further development in this field. Important names in contemporary systems science include **Russell Ackoff, Béla H. Bánáthy, Anthony Stafford Beer, Peter Checkland, Robert L. Flood, Fritjof Capra, Michael C. Jackson, Edgar Morin** and **Werner Ulrich**

, among others.

With the modern foundations for a general theory of systems following the World Wars, Ervin Laszlo, in the preface for Bertalanffy's book ***Perspectives on General System Theory***, maintains that the translation of "general system theory" from German into English has "wrought a certain amount of havoc" [2]. The preface explains that the original concept of a general system theory was "*Allgemeine Systemtheorie* (or *Lehre*)", pointing out the fact that "Theorie" (or "Lehre") just as "Wissenschaft" (translated Scholarship), "has a much broader meaning in German than the closest English words 'theory' and 'science'" [2]. With these ideas referring to an organized body of knowledge and "any systematically presented set of concepts, whether they are empirical, axiomatic, or philosophical", "Lehre" is associated with theory and science in the etymology of general systems, but also does not translate from the German very well; "teaching" is the "closest equivalent", but "sounds dogmatic and off the mark" [2]. While many of the root meanings for the idea of a "general systems theory" might have been lost in the translation and many were led to believe that the systems theorists had articulated nothing but a pseudoscience, systems theory became a nomenclature that early investigators used to describe the interdependence of relationships in organization by defining a new way of thinking about science and scientific paradigms.

A system from this R**ussell Ackoff, Béla H. Bánáthy, Anthony Stafford Beer, Peter Checkland, Robert L. Flood, Fritjof Capra, Michael C. Jackson, Edgar Morin and Werner Ulrich** is composed of regularly interacting or interrelating groups of activities. For example, in noting the influence in organizational psychology as the field evolved from "an individually oriented industrial psychology to a systems and developmentally oriented organizational psychology," it was recognized that organizations are complex social systems; reducing the parts from the whole reduces the overall effectiveness of organizations [3

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. This is at difference to conventional models that center on individuals, structures, departments and units separate in part from the whole instead of recognizing the interdependence between groups of individuals, structures and processes that enable an organization to function. Laszlo [4] explains that the new systems view of organized complexity went "one step beyond the Newtonian view of organized simplicity" in reducing the parts from the whole, or in understanding the whole without relation to the parts. The relationship between organizations and their environments became recognized 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. 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 ISSS, Bánáthy defines a perspective that iterates this view:

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, system means a configuration of parts connected and joined together by a web of relationships. The Primer group defines system as a family of relationships among the members acting as a whole. Von Bertalanffy defined system as "elements in standing relationship. [5]

Similar ideas are found in learning theories that developed from the same fundamental concepts, emphasizing that 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. [6] Interdisciplinary perspectives are critical in breaking away from industrial age models and thinking where history is history and math is math segregated from the arts and music separate from the sciences and never the twain shall meet [7] . The influential contemporary work of Peter Senge [8] provides detailed discussion of the commonplace critique of educational systems grounded in conventional assumptions about learning, 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." It is in this way that systems theorists attempted to provide alternatives and an evolved ideation from orthodox theories with individuals such as Max Weber, Émile Durkheim in sociology and Frederick Winslow Taylor in scientific management, which were grounded in classical assumptions [9]. The theorists sought holistic methods by developing systems concepts that could be integrated with different areas.

The contradiction of reductionism in conventional theory (which has as its subject a single part) is simply an example of changing assumptions. The emphasis with systems theory shifts from parts to the organization of parts, recognizing interactions of the parts are not "static" and constant but "dynamic" processes. Conventional closed systems were questioned with the development of open systems perspectives. The shift was from absolute and universal authoritative principles and knowledge to relative and general conceptual and perceptual knowledge [10], still in the tradition of theorists that sought to provide means in organizing human life. Meaning, the history of ideas that preceded were rethought not lost. Mechanistic thinking was particularly critiqued, especially the industrial-age mechanistic metaphor of 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 [11]. Classical science had not been overthrown, but questions arose over core assumptions that historically influenced organized systems, within both social and technical sciences.

History

TIMELINE

Precursors

- Herbert Spencer (1820–1903), Vilfredo Pareto (1848–1923), Émile Durkheim (1858
Alexander Bogdanov
Nicolai Hartmann
Robert Maynard Hutchins

Pioneers

- 1946-1953 Macy conferences
- 1948 Norbert Wiener publishes *Cybernetics or Control and Comm*
- 1954 Ludwig von Bertalanffy, Anatol Rapoport,
Ralph W. Gerard
Society for General Systems Research
- 1955 W. Ross Ashby publishes *Introduction to Cybernetics*
- 1968 Ludwig von Bertalanffy publishes *General System theory: F*

Developments

- 1970-1980s Second-order cybernetics developed by Heinz von Foerster, Gregory Bateson,
Humberto Maturana

- 1970s Catastrophe theory (René Thom , E.C. Zeeman) D
- 1980s Chaos theory David Ruelle , Edward Lorenz, Mitchell Feigenbaum, Steve
- 1986 Context theory Anthony Wilden
- 1988 International Society for Systems Science
- 1990 Complex adaptive systems (CAS) John H. Holland ,
Murray Gell-Mann
W. Brian Arthur

Whether considering the first systems of written communication with Sumerian cuneiform to Mayan numerals, or the feats of engineering with the Egyptian pyramids, systems thinking in essence dates back to antiquity. 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 [12]. Von Bertalanffy traced systems concepts to the philosophy of G.W. von Leibniz and Nicholas of Cusa's *coincidentia oppositorum*. While modern systems are considerably more complicated, today's systems are embedded in history.

Systems theory as an area of study specifically developed following the World Wars from the work of Ludwig von Bertalanffy, Anatol Rapoport, Kenneth E. Boulding, William Ross Ashby, Margaret Mead, Gregory Bateson, C. West Churchman and others in the 1950s, specifically catalyzed by the cooperation in the Society for General Systems Research. 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*, Vol 1, No. 2, by 1950. Where assumptions in Western science from Greek thought with Plato and Aristotle to Newton's *Principia* 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 theorists explored the implications of twentieth century advances in terms of systems.

Subjects like complexity, self-organization, connectionism and adaptive systems had already been studied in the 1940s and 1950s. In fields like cybernetics, researchers like Norbert Wiener, William Ross Ashby, John von Neumann and Heinz von Foerster examined complex systems using mathematics. John 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 computer at all. At the same time

Howard T. Odum, the radiation ecologist, recognised that the study of general systems required a language that could depict energetics and kinetics at any system scale. Odum developed a general systems, or Universal language, based on the circuit language of electronics to fulfill this role, known as the Energy Systems Language. Between 1929-1951, 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 interdisciplinary Division of the Social Sciences established in 1931 [13]. Numerous scholars had been actively engaged in ideas before (Tectology of Alexander Bogdanov published in 1912-1917 is a remarkable example), but in 1937 von Bertalanffy presented the general theory of systems for a conference at the University of Chicago.

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 can be understood and used to develop greater insight into the behavior of complex phenomena and to move closer toward a unity of science. System philosophy, methodology and application are complementary to this science [2]. By 1956, the Society for General Systems Research was established, renamed the International Society for Systems Science in 1988. The Cold War affected the research project for systems theory in ways that sorely disappointed many of the seminal theorists. Some began to recognize theories defined in association with systems theory had deviated from the initial General Systems Theory (GST) view [14]. The 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 [15]. Since the end of the Cold War, there has been a renewed interest in systems theory with efforts to strengthen an ethical view.

Developments in system theories

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. The term goes back to Bertalanffy's book titled "*General System theory: Foundations, Development, Applications*" from 1968 [

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. Von Bertalanffy tells that he developed the "allgemeine Systemtheorie" since 1937 in talks and since 1946 with publications.
[16]

Von Bertalanffy's objective was to bring together under one heading the organismic science that he had observed in his work as a biologist. His desire was to use the word "system" to describe those principles which are common to systems in general. In GST, he writes:

...there 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. [17]

Ervin Laszlo [18] in the preface of von Bertalanffy's book *Perspectives on General System Theory..* [19]

Thus when von Bertalanffy spoke of Allgemeine Systemtheorie 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.

Ludwig von 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:

Domain	Description
Philosophy	the ontology, epistemology, and axiology of systems;
Theory	a set of interrelated concepts and principles applying to all systems
Methodology	the set of models, strategies, methods, and tools that instrumentalize syster
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 then is knowledgeable action. [20]

Cybernetics

The term cybernetics derives from a Greek word which meant steersman, and which is the origin of English words such as "govern". Cybernetics is the study of feedback and derived concepts such as communication and control in living organisms, machines and organisations. Its focus is how anything (digital, mechanical or biological) processes information, reacts to information, and changes or can be changed to better accomplish the first two 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. According to Jackson (2000), von Bertalanffy promoted an embryonic form of general system theory (GST) as early as the 1920s and 1930s but it was not until the early 1950s it became more widely known in scientific circles.

Threads of cybernetics began in the late 1800s that led toward the publishing of seminal works (e.g., Wiener's *Cybernetics* in 1948 and von Bertalanffy's *General Systems 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. Von Bertalanffy (1969) specifically makes 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;" then reiterates: "the model is of wide application but should not be identified with 'systems theory' in general", and that "warning is necessary against its incautious expansion to fields for which its concepts are not made." (17-23). Jackson (2000) also claims von Bertalanffy was informed by Alexander Bogdanov's three volume *Tectology* that was published in Russia between 1912 and 1917, and was translated into German in 1928. He also states it is clear to Gorelik (1975) that the "conceptual part" of general system theory (GST) had first been put in place by Bogdanov. The similar position is held by Mattessich (1978) and Capra (1996). Ludwig von Bertalanffy never even mentioned Bogdanov in his works, which Capra (1996) finds "surprising".

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 (CA), neural networks (NN), artificial intelligence (AI), and artificial life (ALife) are related fields, but they 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 now. 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.

Complex adaptive systems

Complex adaptive systems are special cases of complex systems. They are *complex* in that they are diverse and made up of multiple interconnected elements and *adaptive* in that they have the capacity to change and learn from experience. The term *complex adaptive systems* was coined at the interdisciplinary Santa Fe Institute (SFI), by John H. Holland, Murray Gell-Mann and others. However, the approach of the complex adaptive systems does not take into account the adoption of information which enables people to use it.

CAS ideas and models are essentially evolutionary. Accordingly, the theory of complex adaptive systems bridges developments of the system theory with the ideas of 'generalized Darwinism', which suggests that Darwinian principles of evolution help explain a wide range of phenomena.

Applications of system theories

Living systems theory

Living systems theory is an offshoot of von Bertalanffy's general systems theory, created by James Grier Miller, which was intended to formalize the concept of "life". According to Miller's original conception as spelled out in his magnum opus *Living Systems*, a "living system" must contain each of 20 "critical subsystems", which are defined by their functions and visible in numerous systems, from simple cells to organisms, countries, and societies. In *Living Systems* Miller provides a detailed look at a number of systems in order of increasing size, and identifies his subsystems in each.

James Grier Miller (1978) wrote a 1,102-page volume to present his living systems theory. He constructed a general theory of living systems by focusing on concrete systems—nonrandom accumulations of matter-energy in physical space-time organized into interacting, interrelated subsystems or components. Slightly revising the original model a dozen years later, he distinguished eight "nested" hierarchical levels in such complex structures. Each level is "nested" in the sense that each higher level contains the next lower level in a nested fashion.

Organizational theory

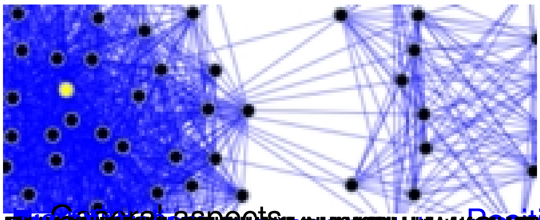
Software and computing

In the 1960s, systems theory was adopted by the post John Von Neumann computing and information technology field and, in fact, formed the basis of structured analysis and structured design (see also Larry Constantine, Tom DeMarco and Ed Yourdon). It was also the basis for early software engineering and computer-aided software engineering principles.

By the 1970s, General Systems Theory (GST) was the fundamental underpinning of most commercial software design techniques, and by the 1980, W. Vaughn Frick and Albert F. Case, Jr. had used GST to design the "missing link" transformation from system analysis (defining what's needed in a system) to system design (what's actually implemented) using the Yourdon/DeMarco notation. These principles were incorporated into computer-aided software engineering tools delivered by Nastec Corporation, Transform Logic, Inc., KnowledgeWare (see Fran Tarkenton and James Martin), Texas Instruments, Arthur Andersen and ultimately IBM Corporation.

Sociology and Sociocybernetics

Sociology



System dynamics

System Dynamics was founded in the late 1950s by Jay W. Forrester of the MIT Sloan School of Management with the establishment of the MIT System Dynamics Group. At that time, he began applying what he had learned about systems during his work in electrical engineering to everyday kinds of systems. Determining the exact date of the founding of the field of system dynamics is difficult and involves a certain degree of arbitrariness. Jay W. Forrester joined the faculty of the Sloan School at MIT in 1956, where he then developed what is now System Dynamics. The first published article by Jay W. Forrester in the Harvard Business Review on "Industrial Dynamics", was published in 1958. The members of the System Dynamics Society have chosen 1957 to mark the occasion as it is the year in which the work leading to that article, which described the dynamics of a manufacturing supply chain, was done.

As an aspect of systems theory, *system dynamics* is a method for understanding the dynamic behavior of complex systems. The basis of the method is the recognition that the structure of any system — the many circular, interlocking, sometimes time-delayed relationships among its components — is often just as important in determining its behavior as the individual components themselves. Examples are chaos theory and social dynamics. It is also claimed that, because there are often properties-of-the-whole which cannot be found among the properties-of-the-elements, in some cases the behavior of the whole cannot be explained in terms of the behavior of the parts. An example is the properties of these letters which when considered together can give rise to meaning which does not exist in the letters by themselves. This further explains the integration of tools, like language, as a more parsimonious process in the human application of easiest path adaptability through interconnected systems.

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. [22] 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 needs. [23]

Systems psychology

Systems psychology is a branch of psychology that studies human behaviour and experience in complex systems. It is inspired by systems theory and systems thinking, and based on the theoretical work of Roger Barker, Gregory Bateson, Humberto Maturana and others. It is an approach in psychology, in which groups and individuals, are considered as systems in homeostasis. Systems psychology "includes the domain of engineering psychology, but in addition is more concerned with societal systems and with the study of motivational, affective, cognitive and group behavior than is engineering psychology." [24] In systems psychology "characteristics of organizational behaviour for example individual needs, rewards, expectations, and attributes of the people interacting with the systems are considered in the process in order to create an effective system". [25]. The Systems psychology includes an illusion of homeostatic systems, although most of the living systems are in a continuous disequilibrium of various degrees.

See also

- List of types of systems theory
- Cybernetics
- Emergence
- Glossary of systems theory
- Holism
- Meta-systems
- Open and Closed Systems in Social Science
- Social rule system theory
- Sociology and complexity science
- Systemantics

- System engineering
- Systems psychology
- Systemics
- Systems theory in archaeology
- Systems theory in anthropology
- Systems theory in political science
- Systems thinking
- World-systems theory
- Systematics - study of multi-term systems

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2. ^ a b c d (Laszlo 1974)
3. ^ (Schein 1980: 4-11)
4. ^ Laslo (1972: 14-15)
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7. ^ (see Steiss 1967; Buckley, 1967)
8. ^ Peter Senge (2000: 27-49)
9. ^ (Bailey 1994: 3-8; see also Owens 2004)
10. ^ (Bailey 1994: 3-8)

11. ^ (Bailey 1994; Flood 1997; Checkland 1999; Laszlo 1972)
12. ^ (Hammond 2003: 12-13)
13. ^ Hammond 2003: 5-9
14. ^ Hull 1970
15. ^ (Hammond 2003: 229-233)
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External links

- Systems theory at Principia Cybernetica Web

Organizations

- International Society for the System Sciences
- New England Complex Systems Institute
- System Dynamics Society

Systems and systems science

Systems categories

Systems theory · Systems science · Systems scientists (
Conceptual
Physical
Social

Systems

Biological · Complex · Complex adaptive ·
Conceptual
Database management
Dynamical
Economical
Ecosystem · Formal · Global Positioning System ·
Human anatomy
Systems of measurement
Metric system
Multi-agent system
Nervous system
Operating system
Physical system
Political system
Sensory system
Social structure
Solar System
Systems art

Theoretical fields

Chaos theory · Complex systems · Control theory ·
Cybernetics
Living systems
Systems biology
System dynamics
Systems ecology
Systems engineering
Systems psychology
Systems science

Systems scientists

Russell L. Ackoff · William Ross Ashby · Béla H. Bánáthy ·
Gregory Bateson
Richard E. Bellman
Stafford Beer
Ludwig von Bertalanffy
Murray Bowen
Kenneth E. Boulding
C. West Churchman
George Dantzig
Heinz von Foerster
Jay Wright Forrester
George Klir
Edward Lorenz
Niklas Luhmann
Humberto Maturana
Margaret Mead
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