LUDWIG VON BERTALANFFY'S EARLY SYSTEM APPROACH

Manfred Drack
Department of Theoretical Biology, University of Vienna, Althanstraße 14, 1090 Vienna, Austria
and
Bertalanffy Center for the Study of Systems Science (BCSSS), Vienna, Austria
manfred.drack@univie.ac.at

ABSTRACT

Most of what Bertalanffy published in the field of "organismic" biology was written in German and is thus not widely known. In order to understand the development and meaning of his "general system theory" – which might more accurately be called "general systemology" – those early works are essential. In this talk I will therefore focus on key aspects of his "system theory" of life, both on the level of scientific concepts and philosophical considerations. This will also include a note on works that influenced Bertalanffy and motivated him to later establish a new transdisciplinary field. He was influenced by several philosophers as well as by results from experimental research. As a trained philosopher, Bertalanffy was clearly aware that the notion of systems has a long history going back at least to ancient Greek thinkers. As for the influences from science, the focus here will be on Paul A. Weiss and his experiments performed at the *Biologische Versuchsanstalt* in Vienna. Those two roots will be used to clarify Bertalanffy's unique contributions towards a system approach in biology and beyond, in which the aim was to free the term system from vague or even obscure metaphysical connotations and arrive at a framework that is useful for science.

Keywords: Ludwig von Bertalanffy, organismic biology, system theory of life

INTRODUCTION

The general system approach of Ludwig von Bertalanffy (1901–1972) appeared chronologically after he already applied a "system theory" in biology. Nevertheless, already at the beginning of his scientific career, he was trans-disciplinarily oriented and concerned himself with the idea of integrating various levels of sciences. A major part of his PhD thesis on Gustav Fechner is on biology, although physics, psychology and sociology are also dealt with. He points out the "perpetual recurrence of the same in all levels of integration [*Integrationsstufen*]" (Bertalanffy, 1926, p.49). Also in his later elaborations of his "general system theory" (GST), the levels of biology, psychology or psychiatry, and sociology resurface.

After graduating, Bertalanffy turned his focus on biology. Here, he developed what he called a "system theory of life" or "organismic" biology and made mayor contributions to establish the discipline of theoretical biology. Research in this field served as a nucleus for the later broadened system approach, and the early developments are thus important to understand the further research program of GST.

The current contribution is not comprehensive historical study, including discussions of critiques. Those who are interested in such details are referred to Pouvreau and Drack (2007), which describes why general systemology would be a more appropriate term than GST, and details influences on Bertalanffy and early developments made by him. Additional sources include Drack, Apfalter and Pouvreau (2007) and the PhD thesis of David Pouvreau. The focus here is rather on key aspects of the system approach in biology and how it is related to the further efforts in Bertalanffy's work.

THE SUBSTRATE FOR AN ORGANISMIC BIOLOGY

Biological problems in the early 20th century

Besides general cultural problems associated with progress, also recognized as crises in the time after World War I, there was a phase of reorientation in physics, induced by confusing findings in quantum physics. In biology as well, conflicting approaches appeared; they culminated in the mechanicism-vitalism-debate. The fundamental question was: Are biological appearances reducible to phenomena and laws of mechanics or physics and chemistry, or is life only explainable by assuming a specific vital entity?

The term "mechanicism" can refer to a complex of more or less coherently related positions. The more fundamental one is the "analytico-summative" approach to biological phenomena: the basis is the (methodological or metaphysical) postulate that any entity can be analysed in parts whose properties can be studied in isolation from the other ones without inconvenience (the relationships between the parts being "external," not "constitutive"). Through decomposition into "independent" causal chains and their "linear" composition, the properties of the whole are then supposed to be derivable from the knowledge thus acquired. "Mechanicism" would be represented in a biology which combines the "analytico-summative" approach with one or more of the following positions: physicalism (the idea that solely the concepts, methods, and laws of physics and chemistry enable biological phenomena to be grasped), determinism (each state is univocally derivable from previous states), and "reactivism" (the changes in the behaviour of an entity are ascribable to the sole action of its environment) (Pouvreau, 2005b; Drack, Apfalter and Pouvreau, 2007).

"Vitalism" can have two meanings, a metaphysical or a methodological one. Metaphysically, it asserts that biological phenomena cannot be explained without the action of a nonspatial principle harmonizing the matter and energies involved in living phenomena. Methodologically, it is not antinaturalistic and only asserts that, at least provisionally, biology should have its own categories, methods, and laws (Pouvreau, 2005b; Drack, Apfalter and Pouvreau, 2007). Metaphysical vitalism renounces a scientific explanation.

This conflict was one motivation for Bertalanffy. Moreover, the ever growing number of results from experimental research in biology, which were rarely linked together let alone ordered in a comprehensive way, was a core incentive for him to establish a theoretical biology.

Some influences on Bertalanffy

Bertalanffy was influenced by many people from various disciplines. Those who are interesting here stem mainly from philosophy and biology. The PhD thesis of Bertalanffy was not only supervised by Moritz Schlick, the leading figure of the neo-positivist "Vienna Circle," but also by Robert Reininger, a prominent neo-Kantian. Bertalanffy was also in close contact with another neo-Kantian: Hans Vaihinger. Besides others, he was interested in Heraclitus, who said that "[a]ll things come about through opposition, and the universe flows like a river" (Barnes, 1987, p.107); in Cusanus, who wrote that in all parts the whole is reflected (Cusanus, 2002, p.45) and anticipated perspectivism (cf. coincidentia oppositorum); in Leibniz, who amongst other relevant issues anticipated a perspectivist approach when providing the example of one and the same town which looks different from different angles (Leibniz, 1998, §57); in Goethe, who was also important for many morphologists; and also in Nicolai Hartmann, who was writing about a stratified structure of the real world.

Bertalanffy was influenced by certain themes of philosophies of life (*Lebensphilosophie*) which comprised process, dynamics, creativity, and criticism of mechanistic thoughts. But he also distanced himself from certain other aspects in the philosophies of life and philosophies of wholeness (*Ganzheitsphilosophie*).

As for the influences from sciences, a few people can be mentioned. The considerations and experiments performed in the *Biologische Versuchsanstalt* by Paul Weiss, whom Bertalanffy personally knew, underlined the system theory of life. Weiss performed experiments in the field of animal behaviour and developmental biology.

The work in the field of *Gestalt* psychology was important, and here especially Wolfgang Köhler must be mentioned. Beyond psychology he introduced the concept of *Gestalt* also to physical problems (Köhler, 1924). This was important not only for "organismic" biology but also for the broadened "general systemology." As a precursor of "general systemology", the work of the mathematician Alfred Lotka (1925) was also important.

OUTLINE OF THE SYSTEM THEORY OF LIFE

General remarks

The conflict between "mechanicism" and "vitalism" is, for Bertalanffy, essentially metaphysical, and thus cannot be solved by means of empirical sciences.

Although there are machine-like structures or reactions in the organism, those are insufficient to explain life. In particular the experiments of Hans Driesch on early developmental stages of sea urchins were proving that the contemporary machine theory in biology must be false. He clearly demonstrated the equifinality of development, i.e., the arriving at similar final stages from different starting conditions. But his neo-vitalism based on those experiments soon disappeared.

What ultimately makes an organism an organism, or what is the difference between the living and the non-living? Bertalanffy was not satisfied with the mechanicists' approach on the one side and vitalistic currents on the other side. He notes that there are no "living" substances; rather, the basic trait of the living is the organisation of substances (Bertalanffy, 1934a, p.346). It is thus attempted to approach the core problems of life, namely order and organisation (a derivation of wholeness) in the organism. He concluded from analyzing theories of development, that "wholeness [*Ganzheit*], Gestalt, is the primary attribute of life" (Bertalanffy, 1928, p.225). Expressed in another way:

"The characteristic of life does not lie in a distinctiveness of single life processes [*Lebensvorgänge*], but rather in a certain *order* among all the processes" (Bertalanffy, 1934a). Observing events only separately will not reveal anything about the organisation of the organism. And biology must grasp the organism as a whole.

He tried to get closer to the problem by liberating "wholeness" [*Ganzheit*] from its metaphysical connotations and setting it to work at scientifically grasping life. Bertalanffy's "organismic" biology or "system theory of life" was an attempt to overcome the conflict between mechanicism and vitalism in the realm of science (not ontology), and also to overcome the lack of a scientific theory of life. Accordingly, the organismic perspective also serves as a keystone in his effort to establish a theoretical biology, whose aim is to establish natural laws (system laws) for the phenomena of life. Those laws should be exact (as in other natural sciences) and reached deductively with the aid of mathematics. The organismic approach must be seen as a working hypothesis and not as an explanation; it raises a problem but is not a problem solution (Bertalanffy, 1934a; 1941a).

In this regard, note that wholeness and holism is not the same. Bertalanffy insists that his "organismic" biology is not in line with holism. A leading figure of holism in Germany (A. Meyer) also points out the difference (Bertalanffy, 1941a, pp.341f.). In the same paper, however, Bertalanffy also chums up to the German regime and certain attitudes thereof.

"The organic wholeness [*Ganzheit*] is neither a metaphysical concept nor an asylum of ignorance, but a problem which can and must be investigated with the methods of exact science." (Bertalanffy, 1930; 1937a)

Although Bertalanffy already writes about wholeness and systems in early papers, the meaning of the term system remained implicit for a long time. The explicit definition of the term was not presented before 1945, when a system was defined as a complex of elements in interaction (Bertalanffy, 1945).

In the Aristotelian "the whole is more than the sum of its parts," the "more" is seen in the relations between the parts, which again shows the attempt to make way for a scientific approach: "The properties and modes of action of the higher levels are not explainable by the summation of the properties and modes of action of *their components as studied only in isolation*. But if we know *all* the components brought together and *all the relations existing between them*, then the higher levels are derivable from their components." (Bertalanffy, 1932, p.99 and 1949a, p.140)

As knowing all the parts and their relations may sometimes be hard to achieve or even practically impossible, the search for laws of higher order is proposed. System laws should in this case show characters similar to statistical thermodynamics, where, although not dealing with causal events at the level of single parts, natural laws were found.

Above this system approach, the life sciences also ask for other perspectives which are beyond prevailing physicalistic issues. Thus, biology needs to be approached from different methodological perspectives, which are: physico-chemical, *ganzheitlich* or organismic, teleological, and historical (Bertalanffy, 1928, p.88).

Concerning the problem of finality, which is an ongoing problem in biology, Bertalanffy makes an interesting statement that reflects the different perspectives one can take: "What in the whole denotes a causal equilibrium process, appears for the part as a teleological event." (Bertalanffy, 1929a, p.390; 1929b, p.102)

Basic concepts

Bertalanffy formulates what he terms two general organismic "principles" or "working hypotheses" (Bertalanffy 1932:331), which are rather conceptual models of biological organization. These "principles" had already been previously mentioned by several thinkers, but Bertalanffy unifies them and extends their scope from the single organism to biological organizations in general – from cell to biocoenose. He thereby opened the way from organicism to systemism (cf. Drack, Apfalter and Pouvreau, 2007; Pouvreau and Drack, 2007).

The first is the "principle" of the organized system as an "open system" in "flux equilibrium" [*Fließgleichgewicht*] (Bertalanffy, 1929b, p.87; 1932, pp.83f., 116, 197; 1940a, p.521; 1940b, p.43). This equilibrium is different from the chemical equilibriums because the latter are characterized by a minimum of free energy. The organism, in contrast, is an open system that maintains itself through a continuous flux of matter and energy, by assimilation and dissimilation, and is distant from true equilibrium, and able to supply work. Thus metabolism appears as an essential property of the organism (cf. Drack, Apfalter and Pouvreau, 2007).

The second "principle" is the "striving of the organic *Gestalt* for a maximum of formness [*Gestaltetheit*]" (Bertalanffy, 1929b, p.104). This is meant to play a role in ontogenesis as well as in phylogeny, and later becomes the "principle of hierarchization" or "principle of progressive organization (or individualization)" (Bertalanffy, 1932, pp.269-274, 300-320). The dynamic interactions in the system give rise to order. This principle is very much related to epigenetic phenomena and comprises the development from an initial equipotential state (with maximum regulation abilities) over segregation processes. This is followed by differentiation and specialization, where some sort of centralization, with "leading parts" that control the development of other subsystems, can also occur. Characteristic is the inherent trend toward an ever-increasing complexity – a trend that he later (Bertalanffy, 1949a) calls "anamorphosis," after Richard Woltereck had coined the term in 1940 (cf. Drack, Apfalter and Pouvreau, 2007). The "hierarchical" or stratified organisation was also used synonymously with the more neutral term Enkapsis (Bertalanffy, 1934a, pp.351f.).

Besides those two "principles," a third one, namely that of primary activity of the organism, becomes explicit only later when Bertalanffy's organismic thinking has matured (Bertalanffy, 1937b, pp.14, 133-134). It was nonetheless implicit in many of his writings between 1927 and 1932, and also has ancient roots. This concept must be viewed in opposition to a mere passive concept of organisms that merely react to the outside world.

We can thus numerate key issues of Bertalanffy's thinking: "wholeness" was already mentioned in the last section; the open system in flux equilibrium; hierarchy and hierarchisation; primary activity; and, furthermore, the "conservation" of the integrity of the state of a system when it is disturbed from the outside, which is related to equifinality. All the issues reflect the dynamic understanding of the organism.

Some fields of application

Before testing the usefulness of his system approach in a broad field of sciences, Bertalanffy already applied his organismic perspective to deal with biological phenomena on various levels. He did not himself prove the usefulness in all fields of biology, but provided a means to approach phenomena differently. He gave the following explicit examples.

Morphology and physiology seemed to be two separate disciplines within biology. They therefore provided an area of tension to test the usefulness of the organismic approach. The origin of form in the organism is a key issue in biology. It is therefore understandable that Bertalanffy was interested in problems of morphology and developmental biology, and came up with a dynamic view in morphology (Bertalanffy, 1932, 1941a). He interpreted the phenomena as a hierarchic order of processes in a dynamic equilibrium, where the higher level system seems to be persistent [*beharrend*] while the subordinate level is in transition [*im Wechsel*]. He did not restrict this approach to the morphogenesis of an organism On the one hand he applied it to lower levels, where the cells are persistent while the chemical components are in transition. On the other hand, he also applied it to higher levels where, for instance, a biocoenose is persistent while there is a transition of individual organisms (Bertalanffy, 1941a). He claimed that the old distinction between form and function can essentially be reduced to the velocity of the processes in the organism: structures are prolonged and slow; functions are transitory and fast events (Bertalanffy, 1941a). The organismic form thus appears as a temporal cross section of a flow of events [*Geschehensfluss*] in space and time.

But this qualitative model was still unsatisfactory to him. Within a dynamic morphology, Bertalanffy strove for exact quantitative laws. And he achieved this by connecting growth to the concept of open systems: An organism is growing as long as assimilation is higher than dissimilation, and a steady state [*Fließgleichgewicht*] is reached once assimilation and dissimilation become equally high. Through this approach, Bertalanffy tried to connect morphology, developmental biology, and physiology by means of a formal mathematical approach.

The single events, the exchange of components which are investigated by physiology, leave open the problem of organisation. This problem revolves around how all the processes are ordered, the connectedness amongst the processes. And a key problem of metabolism is that it is self controlled [*Selbststeuerung*] (Bertalanffy, 1941a, p.255). This calls for combining the issues. Although Bertalanffy's work in this direction is not sufficient to explain all the phenomena, it was an important step towards investigating the order arising out of the single events.

The open systems approach was also a means to overcome the problem of equifinality, a problem raised by the experiments of Driesch which led to discussions about vitalism. Bertalanffy claimed that when an open system reaches a steady state, this state is equifinal or independent of the initial condition (Bertalanffy, 1940a); but there is some weakness in his related model, which in the premises already anticipates the results (Pouvreau and Drack, 2007, p.319). A closed system cannot behave in an equifinal way.

Bertalanffy also approached the problem of homology, an important issue in biology. Transplantation experiments in developmental biology, especially Hans Spemann's works on the "organizers of development," are interesting in this regard. They show the dependency of each part on the position in the whole during the first developmental stages of the embryo. This demonstrates that the embryo must be grasped as a whole. The finding that in the experiment the same organ can develop from different material (taken from another place in the embryo) challenges the classical view, which holds that homologous organs stem from similar dispositions [*Anlagen*]. Bertalanffy tried to overcome this difficulty by means of a dynamic developmental homology concept [*dynamisch-entwicklungsgeschichtlicher Homologiebegriff*]. This states that not the material from which the organ originates is decisive, but rather the organizing relationships through which the material is imprinted [*geprägt*] (Bertalanffy, 1941a, p.251).

Beyond the fields or problems where Bertalanffy utilized system concepts to a greater extent (e.g., growth), he also suggested an approach of wholeness or a system approach in other biological areas.

He for instance challenged the summative view in cell theory. This theory supposes that the organism is morphologically and physiologically the sum of cells and cell performances (*Zelleistungen*). Multicellular organisms appear as an aggregate of building blocks (*Bausteins*) termed cells. Of course, the cell is a basic structural element, but the organisation of a whole organism can be found in a single cell (unicellular organisms) as well as in the coordination of several cells (multicellular organisms). In the latter, the single cell plays another role, i.e., it is a part of a unit of higher order. Seen physiologically, life is not the sum of single cell performances. Those cell performances are also joined together to a unity on a higher level, e.g., by means of nerves or hormones (Bertalanffy, 1934a, pp.350f.).

Also on the level of the biocoenose or ecosystem, Bertalanffy envisages the wholeness of components that are interacting, although the degree of connectedness here is much lower than in the organism. The equilibrium in a biocoenose also involves a sort of steady state [*Fließgleichgewicht*], not of physico-chemical entities, but rather of units beyond the individual on a higher level of the system (Bertalanffy, 1941a, p.257).

The Darwinian selection scheme of evolution also appears to be "analytico-summative" (selection and summation of single modifications of separated traits) and "reactivist" (the phylogenetic adaptation of the organism is a mere reaction to the environment). If Darwin's thinking were applied to organ systems, then those should be decomposable to little parts, so that each part can change randomly, and those parts must have a value of selection (*Selektionswert*). In the eye, for example, Bertalanffy (1934a) describes each part as necessary, and senseless in isolation. Darwin's theory is based on small changes of properties of an organisation and presupposes the organisation. Bertalanffy (1934a, p.345) also points out that Darwin overlooked the difference in principle between property and part.

In this regard, note that Rupert Riedl, a former student of Bertalanffy, introduced a "system theory of evolution" which elaborates on the significance of the interdependence of genes by insertion of superimposed genes to transfer the functional dependencies within the structure of the phenotype to the genotype. A feedback between genotype and phenotype thereby increases the chances of successful adaptation (Riedl, 1977).

This brings us to genetics, where Bertalanffy also advocated a new view on empirical results. The prevailing summative interpretation should thereby be overcome by an organismic point of view: The chromosomes should not be seen as a chain of genes for red eyes and small wings (here he refers to early gene maps of the fruit fly), but rather the whole organism emerges [*wird hervorgebracht*] out of the whole genome; and genes are certain differences in the genome that account for different traits. Not the single gene itself creates a wing of this or that form. Rather the wing emerges out of the whole genome, and the shape can vary according to certain molecular differences in the chromosomes. Such a notion would circumvent contemporary problems of genetics, like the positions of the genes, while at the same time the results of genetics would not be contradicted (Bertalanffy, 1934a, p.359).

A field within biology which Bertalanffy surely influenced from a very early time on is what became known as ethology. This is a topic which he probably discussed with Paul Weiss already in the 1920s (Weiss, 1977; Drack, Apfalter and Pouvreau, 2007). Weiss was working in the *Biologische Versuchsanstalt*, a privately founded institution in Vienna devoted to grasp the big problems of biology experimentally. Weiss did research on animal behaviour, and falsified the mechanicist tropism theory of Jacques Loeb (which comprises all four traits of mechanicism mentioned above) with experiments on the resting posture of butterflies with respect to light and gravity. What Weiss has basically shown is that the animal does not behave like a reacting "machine," and that the resting posture can not be predicted by merely knowing the outside factors. The translated results of this PhD thesis from 1922 were published in the *General Systems* yearbook (Weiss, 1959). Weiss did not restrict himself to a systems approach in animal behaviour. He also used it in the area of developmental biology (e.g., Weiss, 1926) which influenced Bertalanffy who categorized the "field theory" in Weiss's developmental biology as an organismic theory (Bertalanffy, 1928, pp.189f.). Weiss also extended his system thinking. Some articles should be mentioned which are still worthwhile reading: Weiss (1970, 1971). Also interesting are the contributions of Weiss, Bertalanffy and others in Koestler and Smythies (1969).

Konrad Lorenz, Nobel Prize winning ethologist, had a friendly relationship with Bertalanffy, as we can see from letters in the Bertalanffy archive (Bertalanffy papers). When writing a textbook on ethology (Lorenz, 1978) he very much stresses the system character and the importance of being aware of the wholeness when studying animal behaviour. Lorenz is not satisfied with behaviourism and he describes phenomena in animal behaviour that are not reactions to any outside stimulus and which can thus be interpreted as primary activity.

So already in the biological realm it is clear that Bertalanffy tries to apply system thinking on several levels. Interaction, hierarchization and steady state [*Fließgleichgewicht*] are utilized in areas from molecules to ecosystems.

Mathematical modelling

In the early writings of Bertalanffy mathematics was not seen as a proper means to deal with the complex problems in biology. Mathematics was looked upon as a tool to reduce biological problems to physics and chemistry. But this attitude changed considerably when recognizing that the mathematic approach is not necessarily connected to a reduction, but can rather serve as a tool to formulate system laws similar to the prominent example of Boltzmann's statistical thermodynamics. Bertalanffy aims at the determination of "higher order statistics," where the causalities driving the single parts are ignored, and "exact laws" are nevertheless derived without reduction to the realm of physics and chemistry. With his growth equations, Bertalanffy (1934b, 1941b) shows how a mathematical approach in that direction can be implemented in the field of the dynamics of morphogenesis (Pouvreau 2005a,b).

His approach was one beyond a mere data fitting and detecting correlation, but rather it was a hypothetic-deductive search for interrelations between relevant parameters, revealing the principles that underlie the processes, and finally arriving at natural laws instead of empirical rules.

Parallels in the models for individual animal growth and population development were already pointed out by several authors. But Bertalanffy found in Lotka (1925) (who was also influenced by Boltzmann's statistical thermodynamics) an important precursor for his mathematical works and especially for the formal generalization when dealing with different empirical problems in a similar mathematical way towards exact system laws. This was approach was an important step in the way towards a "general systemology."

The fact that Bertalanffy's "organismic" biology was not an empty program is exemplified by his theory of organic growth, which even today remains a central reference. In this theory, the problems of global growth and relative (allometric) growth are tackled not only by finding growth constants, but also by linking growth with anabolism and catabolism. Animal growth is demonstrated to be the outcome of the openness of the system and of the dynamic interplay of internal driving "forces." This step had not been made before, and combines the open system concept with equifinality and serves also as a bridge between morphogenesis and physiology (see Pouvreau 2005a,b; Pouvreau and Drack 2007). Furthermore, it was demonstrated that finding naturals laws in biology, independently of physics and chemistry, is feasible, and that thus biology stays as an autonomous discipline.

Epistemology

The "organismic" biology of Bertalanffy and further on his "general systemology" must primarily be seen as an epistemological program and not as a task of metaphysics. Nevertheless, certain objectivity is claimed to be reachable by means of a perspectivist epistemology. Perspectivism is a term coined by Nietzsche, and the approach finds its predecessors in Cusanus and Leibniz. Influences also came from Kant, Spengler, Vaihinger, Cassirer, Helmholtz, and also Piaget (Pouvreau and Drack, 2007).

The perspectivist approach is critical towards empiricism and must also be distinguished from realism. According to Bertalanffy it is possible to arrive at statements about some aspects of "reality" by looking at a "thing" from different points of view, like in perspectivism. In his own words:

"We are aware that no knowledge grasps the ultimate reality, and that it can only mirror some aspects of reality in more or less appropriate models. In the idea that every science is a mere reflection of certain traits of reality in necessarily limited symbols and models lie at the same time the limit and the fruitfulness of the creative scientific thought. In contrast with the dogmatism of earlier times, we can call 'perspectivist' this world view and in that sense, the model represents the essence of every knowledge in general" (Bertalanffy, 1965).

"[...] perception is not a reflection of 'real things' (whatever their metaphysical status), and knowledge not a simple approximation to 'truth' or 'reality.' It is an interaction between knower and known, this dependent on a multiplicity of factors of a biological, psychological, cultural, linguistic, etc., nature. [...] This leads to a 'perspective' philosophy [...]" (Bertalanffy, 1969, p.xxii).

Physical constants are an example in which certain aspects of reality are represented (Bertalanffy, 1955, pp.258-259; 1937b, p.156). Taking into account different perspectives, i.e., different approaches, which all result in the same constants, an objective aspect of reality can be revealed. With his growth equations Bertalanffy exactly tried to find such constants in the realm of biology.

WAY TOWARDS A GENERAL SYSTEMOLOGY

The described concepts, methods, and epistemological background were opening the way for developing a general system approach.

With the formalism developed through the organismic program in theoretical biology, and the appearance of formal similarities in different fields, a broader, generalized scope could be taken into account. Though not all of the basic concepts of life are applicable broadly, at least some seemed to have the potential to be generalized and mathematically formulated. The open system concept is one example for a possible generalization; from the organismic realm towards systems in general. "General systemology" was presented first in 1937, its first print was in German (Bertalanffy, 1945; 1949b).

ACKNOWLEDGEMENT

Thanks goes to Rupert Riedl (1925–2005), who initiated a research project which was supported by Austrian Science Fund (FWF) Grant P18149-G04, to David Pouvreau for eminent contributions and profound discussions, and to Gerd B. Müller. Thanks also go to The University of Chicago Press for permission to reprint parts of an article.

REFERENCES

Barnes, J. (1987). *Early Geek Philosophy*. Penguin, London.

Bertalanffy papers. Archive of the Bertalanffy Center for the Study of Systems Science (BCSSS). Department of Theoretical Biology, University of Vienna, Austria. http://www.bertalanffy.org

Bertalanffy, L.v. (1926). *Fechner und das Problem der Integration höherer Ordnung*. PhD thesis, University of Vienna.

Bertalanffy, L.v. (1928). Kritische Theorie der Formbildung, in *Abhandlungen zur theoretischen Biologie*, (J. Schaxel, ed.), Gebrüder Borntraeger, Berlin.

Bertalanffy, L.v. (1929a). Die Teleologie des Lebens. Eine kritische Erörterung, *Biologia Generalis*, 5:379-394.

Bertalanffy, L.v. (1929b). Vorschlag zweier sehr allgemeiner biologischer Gesetze – Studien über theoretische Biologie III, *Biologisches Zentralblatt*, 49:83-111.

Bertalanffy, L.v. (1930). *Lebenswissenschaft und Bildung*. Stenger, Erfurt.

Bertalanffy, L.v. (1932). *Theoretische Biologie: Band 1: Allgemeine Theorie, Physikochemie, Aufbau und Entwicklung des Organismus*. Gebrüder Borntraeger, Berlin.

Bertalanffy, L.v. (1934a). Wandlungen des biologischen Denkens, *Neue Jahrbücher für Wissenschaft und Jugendbildung*, 10:339-366.

Bertalanffy L.v. (1934b). Untersuchungen über die Gesetzlichkeit des Wachstums I. Allgemeine Grundlagen der Theorie. Mathematisch-physiologische Gesetzlichkeiten des Wachstums bei Wassertieren, *Wilhelm Roux' Archiv für Entwicklungsmechanik der Organismen*, 131:613-652.

Bertalanffy, L.v. (1937a). Biologische Gesetzlichkeit im Lichte der organismischen Auffassung, in *Travaux du IX^{e} Congrès International de Philosophie*, Hermann, Paris.

Bertalanffy, L.v. (1937b). *Das Gefüge des Lebens*. Teubner, Leipzig.

Bertalanffy, L.v. (1940a). Der Organismus als physikalisches System betrachtet, *Die Naturwissenschaften*, 28:521-531.

Bertalanffy, L.v. (1940b). *Vom Molekül zur Organismenwelt – Grundfragen der modernen Biologie*. Akademische Verlagsgesellschaft Athenaion, Potsdam.

Bertalanffy, L.v. (1941a). Die organismische Auffassung und ihre Auswirkungen, *Der Biologe*, 10:247-258 and 337-345.

Bertalanffy, L.v. (1941b). Untersuchungen über die Gesetzlichkeit des Wachstums, VII. Teil: Stoffwechseltypen und Wachstumstypen, *Biologisches Zentralblatt*, 61:510-532.

Bertalanffy, L.v. (1945). Zu einer allgemeinen Systemlehre. *Blätter für deutsche Philosophie*, 18, unpublished, but preserved in the Bertalanffy papers.

Bertalanffy, L.v. (1949a). *Das biologische Weltbild – Die Stellung des Lebens in Natur und Wissenschaft*. Francke AG, Bern.

Bertalanffy, L.v. (1949b). Zu einer allgemeinen Systemlehre, *Biologia Generalis*, 19:114-129.

Bertalanffy, L.v. (1955). An essay on the relativity of categories, *Philosophy of Science*, 225:243-263.

Bertalanffy, L.v. (1965). Zur Geschichte theoretischer Modelle in der Biologie, *Studium Generale*, 18:290-298.

Bertalanffy, L.v. (1969). *General System Theory: Foundations, Development, Applications*. Braziller, New York.

Cusanus (Nikolaus von Kues) (2002). Philosophisch-theologische Werke, Band 3: *Gespräch über das Globusspiel* or *Dialogus de ludo globi*. Meiner, Hamburg. 1st ed. 1463.

Drack, M., Apfalter, W., and Pouvreau, D. (2007) On the Making of a System Theory of Life: Paul A Weiss and Ludwig von Bertalanffy's Conceptual Connection, *The Quarterly Review of Biology*, 82(4):349-373.

Koestler, A. and Smythies, J.R. (eds.) (1969). *Beyond reductionism*. Hutchinson, London.

Köhler, W. (1924). *Die physischen Gestalten in Ruhe und im stationären Zustand*. Vieweg, Braunschweig.

Leibniz, G.W. (1998). *Monadologie*. Reclam, Stuttgart. 1st French ed. 1714.

Lorenz, K. (1978). *Vergleichende Verhaltensforschung – Grundlagen der Ethologi*e. Springer, Wien.

Lotka, A.J. (1925). *Elements of Physical Biology*. William & Wilkins, Baltimore.

Pouvreau, D. (2005a). Vers une histoire de la "théorie générale des systèmes" de Ludwig von Bertalanffy, in *Mémoire de DEA*, E.H.E.S.S., Paris.

Pouvreau, D. (2005b). Eléments d'histoire d'une fécondation mutuelle entre "Holisme" et biologie mathématique. *Sciences et Techniques en Perspective*, 9(2e série, fascicule 2):143-242.

Pouvreau, D., and Drack, M. (2007). On the history of Ludwig von Bertalanffy's "General Systemology", and on its relationship to Cybernetics – Part I : elements on the origins and genesis of Ludwig von Bertalanffy's "General Systemology", *International Journal of General Systems*, 36(3):281-337.

Riedl, R. (1977). A Systems-Analytical Approach to Macro-Evolutionary Phenomena, *The Quarterly Review of Biology*, 52(4):351-370.

Weiss, P. A. (1926). Morphodynamik: Ein Einblick in die Gesetzte der organischen Gestaltung an Hand von experimentellen Ergebnissen, in *Abhandlungen zur theoretischen Biologie*, (J. Schaxel, ed.), Gebrüder Borntraeger, Berlin.

Weiss, P. A. (1959). Animal behavior as system reaction: Orientation toward light and gravity in the resting postures of butterflies (Vanessa), *General Systems: Yearbook of the Society for General Systems Research*, 4:19-44.

Weiss, P.A. (1970). Life, Order, and Understanding: A Theme in Three Variations. *The Graduate Journal*, Volume 8 supplement. Austin (TX): University of Texas.

Weiss, P.A. (ed.) (1971). *Hierarchically organized systems in theory and practice*. Hafner, New York.

Weiss, P. A. (1977). The system of nature and the nature of systems: Empirical holism and practical reductionism harmonized, in *A New Image of Man in Medicine, Vol. I: Towards a Man-Centered Medical Science*, (K. E. Schaefer, H. Hensel, and R. Brady, eds.), Futura, New York.