General System Theory.

The origins of General System Theory (GST) date back to Ludwig von Bertalanffy's (1901–1972) interwar studies whose continuation after World War II found a friendly reception in the Anglo-American hemisphere, while there was also some debate with, partly, independent, partly, overlapping, developments in operations research, engineering science, management science and cybernetics all of which had some connection with United States think tanks like the *RAND Corporation* (cp. Davidson 1983, Hammond 2003).

The term "General System Theory" (GST) was coined by Bertalanffy himself. By that term his "Allgemeine Systemlehre" was translated into English (Bertalanffy 1950), after, for a long time, Bertalanffy himself had resisted to call his German "Lehre" ("doctrine") "Theory". Later on, during his stay at the *Center for Advanced Study in the Behavioral Sciences*, Stanford University, California (which had been formed with James Grier Miller as spearhead), from 1954 to 1955, he started to use "Systems" in plural too when, together with Kenneth E. Boulding (1910–1993), Ralph W. Gerard (1900–1974), and Anatol Rapoport (1911–2007), holding a seminar on "General Systems" and subsequently initiating the foundation of the *Society for the Advancement of General Systems Theory* (which after short time was renamed in *Society for General Systems Research* and since 1988 is known under the label of *International Society for the Systems Sciences*) and editing the *General Systems Yearbooks*. Bertalanffy used the old and the new term ("system" in singular and plural) interchangeably – as well as the German translation of "GST" into "Allgemeine Systemtheorie" – until he passed away (cp. Bertalanffy 1972, 1972 a).

The main reason why he initially hesitated to qualify GST as theory was that he wanted to make it distinct from traditional disciplinary theories in science which are used to having a rather restricted purpose, a rather restricted object of investigation and a rather restricted method by which they are constructed. GST, in contradistinction, was intended to be more than that: a theory of homologies/isomorphisms that are characteristic of the organisation of "wholes" – systems – wherever they might appear – in the domain of physico-chemical sciences, life sciences, social sciences and humanities as well. Because of that GST, as a theory of general principles of systems, was considered a kind of metatheory, cutting across, and capable of unifying, the diverse specialties, including a new *weltanschauung*, a new world view – hence a new paradigm for all sciences and humanities. (That's why Pouvreau and Drack 2007, 282-283, argue that "general systemology" would be a more appropriate name for GST.) However, *weltanschauung* goes beyond mere descriptions of the world which are known under the label of world pictures. It includes values and it tries to make world pictures consistent with values concerning the relationship of humans to the world, that is, humans to humans, humans to nature, humans to technology.

As a consequence, another reason to be skeptical about the name for Bertalanffy and for Rapoport as well was that at the times when Bertalanffy announced his GST it rather described a research programme and a framework than a fully-fledged body of theoretical knowledge though he had already made some, and would make further, substantial contributions to theorising systems along with other colleagues (cp. Bertalanffy 1972a, 186). Yet in 1968 Rapoport wrote: "General system theory is best described not as theory in the sense that this word is used in science but, rather, as a program or a direction in the contemporary philosophy of science." (Rapoport 1968, 452)

Still today critics bemoan that even Bertalanffy's book *General System Theory* (1968) and Anatol Rapoport's book *General System Theory* (1986) do by no way provide a concise overview and prove the rather unsystematic and unelaborated state of GST (cp. Müller 1996). Others argue, however, that in spite of that, a substantial body of knowledge has been achieved that paved the way for, if not anticipated, findings recently made known by the sciences of complexity (cp. Hammond 2003, Hofkirchner 2005). Kurt Richardson says in the introduction to the reprint of Boulding's article on General Systems Theory of 1956, "The modern complexity movement is in some ways quite different from the general systems movement". But "Complex systems thinkers share a lot of the aims and ambitions of the original general systems movement, such as the need for cross-disciplinary communication and the development of analytical tools and processes to interact with, and intervene in, a modern complex (systemic) world." (Richardson 2004, 127)

What are these aims and ambitions of GST, on closer scrutiny?

According to Rapoport, the central aim of GST is to integrate the analytical and "organismic" as well as the descriptive and normative tradition of systems thinking. "Our aim will be to show that far from being incompatible, these views are complementary, revealing different aspects of a unified approach to system theory." (Rapoport 1986, 7)

Regarding the difference between the analytical and the "organismic", Rapoport distinguished in his 1986 book *General System Theory* between two fundamentally different understandings of the term "system". On the one hand, there is the analytical comprehension that originates from the tradition of so-called exact natural as well as engineering sciences. A conception of a theory of systems in this tradition is tied to the use of mathematical models and methods that have originally been developed within the context of investigation of the non-living world. On the other hand, we have the so-called "organismic" approach to the system idea, a term originally introduced by Bertalanffy. Rapoport relates it to the diverse phenomena of the living but also social world as integrated wholes that are investigated by different life and social sciences respectively.

By the aims of bringing together the analytical and the organismic as well as the descriptive and the normative, GST was considered by its proponents a major step in the quest for a unity of science. "Its major goal is to generate a new type of unity of science: not a unity based on the reduction of the concepts, methods or even laws of all sciences to the ones of a single science regarded as more essential; but rather a formal unity based on the generality and ubiquity of the system concept and on the 'isomorphisms' it induces between sciences of which the logical and methodological autonomy is guaranteed." (Pouvreau Drack 283) "The need for general systems theory is accentuated by the present sociological situation in science", wrote Boulding in 1956 (1956/2004, 198). "The more science breaks into sub-groups, and the less communication is possible among the disciplines, ... the greater chance there is that the total growth of knowledge is being slowed down by the loss of relevant communications." (198-199) Therefore GST would develop generalised ears to provide specialists with advantages due to the awareness of the existence of similarities in widely different empirical fields. But in order to do so it had to pursue another aim too – that of acknowledging that "the total of observable phenomena … shows a structural uniformity" (Bertalanffy 1950/2008, 234) that is not only the result of construction but also an independent feature of the world.

Thus there are three aims of GST belonging to three different, albeit intricately interwoven fields which imply philosophical assumptions:

- the aim of bringing together the analytical method and a proper scientific method for investigating the organismic realm by postulating isomorphisms between different disciplines; this belongs to the field of epistemology (section 1);
- the aim of relating real-world systems of the same type or of a different type to each other by postulating isomorphisms between them; this belongs to the field of ontology (section 2);
- and the aim of reconciling the world of facts with the world of values by considering GST as tool for intervening in systems in a humane, humanistic, that is, nonmechanistic and nonreductionistic, way; this belongs to the field of ethics (section 3).

What then, from a today point of view, may be considered the lasting achievements of GST in these fields?

1 Epistemological Implications

Bertalanffy called his epistemological position “Perspectivism” which is kind of realism and includes, and is based upon, evolutionary thinking. This is a position neither naive materialistic nor radical constructivist. It seems to be a common denominator of GST and deserves attention, in particular, if compared with later developments of the systems movement.

Much can be learned from the way of thinking Bertalanffy and companions applied in their approach regarding reduction and its opposite, projection, which is rather idealistic and anthropomorphising.

The same is true when it comes to the role mathematical formalism can play in knowledge.

1.1 Realism, “Evolutionary Epistemology”, Perspectivism

Bertalanffy made his realism distinct from positivism and empirism. As he pointed out, “one cannot base and develop any science on sole experience and induction” (Bertalanffy 1927b, translation into English quoted after Pouvreau and Drack 2007, 304). “The determination of the natural laws is the product of a kind of alchemy between observation, ‘constructive activity of the reason‘ and an intuition ‘similar to the artistic vision’”. (Pouvreau and Drack 2007, 304) “A theoretical model is a conceptual construction”, “every scientific theory can be conceived as a conceptual model”. (Bertalanffy 1965, translation into English quoted after Pouvreau and Drack 2007, 300). However, “the actual world … does allow the application of our intellectual constructions.” (Bertalanffy 1950/2008, 222) Bertalanffy holds “that the world (i.e. the total of observable phenomena) shows a structural uniformity, manifesting itself by isomorphic traces of order in its different levels or realms.” (Bertalanffy 1968, 87) Knowledge about these isomorphies is made possible in as far as the structure of the cognitive ability is isomorph to the structure of reality. That is, there is a fundamental isomorphism adequacy of thought and reality. It is not required that the categories of experience fully correspond to the real universe, even less that they represent it completely. It is sufficient that a certain degree of isomorphism exists between the experienced world and the real world, so that experience can guide the organism in such a way as to preserve its existence (cp. Bertalanffy 1955, 257). Bertalanffy followed Konrad Lorenz in that the so-called “‘a priori’ forms of intuition and categories are organic functions, based upon corporeal and even machine-like structures in the sense organs and the nervous system, which have evolved as adaptation in the millions of years of evolution. Hence they are fitted to the ‘real’ world” (Bertalanffy 1955, 256). In this respect, it is worth stating that GST seemingly anticipated fundamental assumptions of what was later subsumed under the label of Evolutionary Epistemology.

Bertalanffy called his special epistemological view “perspectivism”. By that term he meant “that no knowledge grasps the ultimate reality, and that it can only mirror some aspects of reality in more or less appropriate models.” (Bertalanffy 1965, translation into English quoted after Pouvreau and Drack 2007, 301) Notwithstanding the fact that our experience and thinking appear to be determined by biological as well as cultural factors, this human bondage is stripped by a process of progressive de-anthropomorphisation of our world picture making our perspectivist knowledge of reality, though only relatively, true. E.g., physical constants such as Loschmidt’s number and the like “represent certain aspects of reality, independent of biological, theoretical or cultural biases.” (Bertalanffy 1955, 258; cp. 262) Bertalanffy developed such a stance against the constructivist view of Jacob von Uexküll (cp. Bertalanffy 1955, 255-256).

1.2 Antireductionism, Antiholism (Antimechanicism, Antivitalism)

Bertalanffy's work on a theoretical biology lies at the very basic of the modern scientific approach of systems thinking. GST was born when Bertalanffy – in the attempt to overcome the deep cleft between the controversial theoretical approaches to biology at his time, that is, mechanicism and vitalism (mechanicism is the materialistic approach that tries to reduce life phenomena to phenomena that can be explained by physics, while vitalism was the idealistic conviction that that which transcends being explained by physics is something metaphysical) – formulated laws of organisation ruling biota as well as other ordered entities. By deliberating on the shortcomings of both positions, Bertalanffy developed a third view that tried to integrate the reasonable aspects of each of the two perspectives on life. He called it the "organismic" perspective. This view took over the notion of wholeness from the vitalist standpoint by fundamentally accepting the relative autonomy of the living world. Thus, it refused the neo-positivist notion of a mechanistic generation of form in organisms (as Friedrich Waismann most prominently put it forward) and the possibility of a complete reduction of life to physico-chemical processes. However, at the same time Bertalanffy's organismic stance adopted the mechanistic critique regarding the special vitalistic idea of a super-material, transcendent entelechy (as Hans Driesch most prominently advanced it). Actually, by searching for a tenable notion of wholeness Bertalanffy cleared this concept from its anthropomorphic implications and tried to put it on the firm grounds of exact scientific thinking.

Bertalanffy laid the cornerstone for such an understanding within the problem setting of a theoretical biology. Within this context, he referred to and advanced essential categories regarding the relation between open and closed systems, between causality and organised complexity, as well as the notion of entropy. In doing so, he generalised the laws formulated to grasp biota as organised systems and found himself in the position to make them successfully apply to different domains such as medicine, psychology, psychotherapy, and so on. "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 …, irrespective of whether they are of physical, biological or sociological nature." (Bertalanffy 1955a, 31)

Bertalanffy disavowed the assumption that science, "in order to state exact laws for any field, and to render it an exact science, ... had to be reduced to physics and chemistry" as "methodological principle of the so-called mechanistic view." (Bertalanffy 1950/2008, 224) This made him find himself in sharp contrast to attempts *en vogue* in the Vienna Circle. But he did not only reject physicalism. He explicitly repudiated biologism in relation to the explanation of social phenomena. This becomes clear from the following quote: "This does not imply 'bologism', i.e., reduction of social to biological concepts, but indicates system principles applying in both fields." (Bertalanffy 1968, 125) Besides his disapproval of, so to say, vertical reductionism regarding social science, he argued against, so to say, horizontal reductionism as well. In discarding the summative concept of systems as aggregates, he criticised the methodological individualism abound in social sciences as doomed to fail because of the practically unsurmountable number of elements and interactions they might be involved in and because of its losing sight of the autonomy of systems due to the feedback the system exerts on the elements. (cp. Müller 1996, 72-73)

That is to say, that at the same time when Bertalanffy opposed reductionism he did not fall into the trap of holism. He was aware that there is a delicate relationship or balance between these two ways of approaching the world. Regarding living systems, he described the situation as follows: "What we can do is only: firstly, isolate the single process and determine it in a physico-chemical way… But this just gives us no knowledge about the biological problem, the reciprocal dependence of the single processes; or secondly, we can at one swoop define the whole event in the organism by an integral law …, with which we nonetheless again have to forego the physico-chemical determination in the detail…" (Bertalanffy 1932, translation into English quoted after Pouvreau and Drack 2007, 307)

1.3 Mathematics and Nonformalism

This antireductionist as well as antiholist stance has consequences for devisinig the relationship between the analytical method and its use of mathematics, on the one hand, and the exclusive use of ordinary language in case "the general principles … cannot be formulated in mathematical terms" (Bertalanffy 1950/2008, 221) as a scientific method as well, on the other hand. Bertalanffy shared this conviction with other representatives of GST, above all, with Rapoport.

Concerning the integration of the analytical and organismic approach, GST tried to achieve unity on an abstract level of valid analogy building based on structural similarities between diverse kinds of real world systems. Hence, the language of mathematics plays an important role in this integration process. As Rapoport put it in the so far last big synopsis of the GST programme (1986, 30): "There is no escaping the conclusion that understanding (at least in its scientific sense) entails analysis." GST aims at extracting principal formal system properties that all kinds of real world systems (as investigated in the empirical sciences) have in common and tries to categorise abstract types of systems according to these formal properties.

In this context, new mathematical techniques were developed to cover all classes of real-world systems on a formal basis of representation. Regarding goal-seeking and self-controlling forms of behaviour, mathematical models of cybernetics based on the concept of various forms of information-controlled feedback became available. Additionally, the information concept opened up new directions to develop general notions of order and disorder, thus, to gain new formal measures of organisation. Generally, the information concept became the central unifying concept underlying the working of organismic systems. It reintroduced teleological ideas into the theory of physical processes, and established itself as a second unifying dimension alongside with the energy concept.

Furthermore, the general scheme of a system of differential equations as formal representation of real-world systems became an ever more refined tool. In this regard, there are essentially two things to mention. First, by using such a representation of the concept of a whole the latter lost its metaphysical connotations. This becomes immediately clear when referring to A.D. Hall and R.E. Fagan's classical paper *Definition of system*. "The degree of 'wholeness' of the system is determined by the nature of the functions $f_1,\ldots, f_n$. If each of these functions depends strongly on each of the variables, the system shows a high degree of wholeness; a change in any variable then affects appreciable changes in the rest." (Fagan/Hall 1956, 26) Thus, the idea of interdependence became the central criterion for comprehending wholeness. "The more tightly interwoven is the network, the more organized is the system comprised by the relations." (Rapoport 1970, 5)

Second, the scheme of a system of differential equations gave rise to further formal representation of important additional characteristics of organised systems. In this regard, Bertalanffy gave some examples that are derivable from such a mathematical expression of systems (cp. Bertalanffy 1968, chapter 3). Among others, he referred to the phenomenon of segregation, where an initial system splits up in a group of independent units; a process he called "progressive mechanization". The subsystem that has so far acted as the leading hub looses its organising capacity. The opposite case is "progressive centralization" denoting development of new dependencies, leading to new functional units. In the course of the evolution of a system, both processes can combine such that a functional differentiation occurs; specialised and relatively autonomous subsystems coalesce on a more comprehensive level to a more effective structure. Related to these processes is also the essential concept of hierarchy. Together with further examples (growth, competition, finality) Bertalnaffy showed how some general system ideas beyond the mechanistic level could be subject to formal consideration as well.

Finally, the concept of mathematical equilibrium that is tied to the identification of the extreme values of system equations has to be mentioned here. This procedure was equated with the definition of various general stability conditions related to the solution character of the system equations. Thus, the methods of calculus were used in the GST programme for attaining general schemes for the solution of extreme value tasks. Such schemes opened up new possibilities for the analysis of the stability of systems by asking for the robustness of equation systems in terms of varying initial values as well as of fluctuations of parametric boundary conditions. Consequently, the analysis of stability provided a general characterisation of systems behaviour as well.

As Rapoport pointed out in discussing stability in terms of equifinality related to the open systems aspect, "The question of the existence of a steady state independent of initial conditions is only one of many questions one can ask with reference to the behaviour of a system." (Rapoport 1970, 8) Other crucial questions were related to the stability of steady states, to the number of stable states, and to the various types of steady states. The notion of equilibrium/stability as an exact concept was not related to the constituent entities of a system but referred to its overall organisation. As W. R. Ashby (1952, 57) put it, "The fact that the stability of a system is a property of the system as a whole is related to the fact, that the presence of stability always implies some co-ordination of the actions between the parts." Additionally, as mathematical idea with a clear appeal to wholeness it did not any longer refer to any of the teleological and metaphysialc connotations the concept of wholeness was traditionally confronted with.

The representation of systems as mathematical models in form of differential equations together with the possibility of a rigorous formal characterisation of a system's organisation as a holistic attribute made this method a central instrument of choice within the GST. Representative for the overall programme and its proponents is the following quote of Bertalanffy: "... systems can be defined by certain families of differential equations and if, in the usual way of mathematical reasoning, more specified conditions are introduced, many important properties can be found of systems in general and more special cases." (Bertalanffy 1968, 38)

This leads us, finally, to the central philosophy of science aim that the GST programme was pursueing – the possibility of an integration of all fields of science that an abstract mathematical representation of real-world systems brought forward. Due to the highest degree of abstraction a generalised mathematical model of the above mentioned form does not represent a specific system, but the set of all systems with the same structural and dynamic relations. Thus, the method of mathematical analogy building seemed to be the most natural foundation of GST, as this implies analogy construction according to the most rigorous, i.e. formal, standards. This method was denoted as “isomorphism”. Rapoport (1968, 455) gave the following definition of the term: “Two mathematical objects are isomorphic if there exists a one-to-one correspondence between the elements of one and those of the other and if the relations among the elements are preserved by the same correspondence.” Thus, a system that is specified as a particular mathematical model is isomorphic to all systems that are specified by the models of the same type; and consequentially, a general classification of systems derives form a classification of mathematical models.

The mathematical aspect of GST provided a shift from the specific nature of systems to their mathematical structure. It should lead to a new integration of knowledge on an abstract level of consideration; specialised concepts and terminology regarding the investigation of real world systems in the diverse fields of science should become interchangeable in the sense of a mutual translation on the structural level. “If a term enters as a homologous variable or parameter in two or more isomorphic models, then the term plays the same part in the respective theories.” (Rapoport 1968, 456) GST regarded the reoccurrence of identical structural patterns in the theories of diverse disciplines as a sign of common organisation; they are not visible on the specialised level of scientific practice.

Nevertheless, GST was also fully aware of the fact that mathematical analysis does not reach into all fields of science, as formal-mathematical description has limits in terms of adequate representation of highly complex phenomena. Hence, GST considered the relationship of the analytical and organismic approach as a complementary one. Although achieving formal validity of analogies through reliance on mathematics is a central goal, this programme also acknowledges qualitative ways of analogy construction. Organismic phenomena often escape a reasonable mathematical representation, nonetheless analogous comparisons in a qualitative form can still bring about a high heuristic potential for hypotheses generation. Thus, proponents of the modern framework of GST also referred to the heuristics of a non-formal analogy building regarding the complexity of organismic systems (cp. Gerard 1958a, and b).

2 Ontological Implications

For Bertalanffy it was a fact that all sciences, eventually, are concerned with systems, as he wrote for the British Journal for the Philosophy of Science (cp. Bertalanffy 1950/2008, 223). He distinguished real-world systems from systems in the mind. “What is to be defined and described as system is not a question with an obvious or trivial answer. It will be readily agreed that a galaxy, a dog, a cell and an atom are *real systems*; that is, entities perceived in or inferred from observation, and existing independently from an observer. On the other hand there are *conceptual systems* such as logic, mathematics … which essentially are symbolic constructs; with *abstracted systems* (science) as a subclass of the latter, i.e. conceptual systems corresponding with reality.” (Bertalanffy 1968, XIX-XX) It is worth noting that this in contradistinction to some subjectivistic, constructivistic system theoretical concepts of today that exclude real-world systems from scientific endeavour.

What are the features of these real-world systems after GST?

2.1 Self-organisation, Organised Complexity

Though the term “self-organisation” entered the scientific discourse only at the turn from the fifties to the sixties of the last century, it might well be said that the concept itself was anticipated by Bertalanffy years before. Pouvreau and Drack mention that Bertalanffy was strongly influenced by Julius Schaxel in Jena “who strives from 1919 on for the development of a theoretical biology worthy of this name and able to open a third way between ‘mechanicism’ and ‘vitalism’.” Publications he edited in *Abhandlungen zur theoretischen Biologie* recognised “self-organization as an inherent and materially immanent principle of life” (Pouvreau and Drack 2007, 302). Müller writes that Bertalanffy interpreted phenomena in question as self-organisation processes (Müller 1996, 87).

Rapoport’s notion of “organized complexity” may also be regarded as term for depicting the essential feature of self-organising systems not to be found in mechanical systems. Rapoport came up with a simple general classification scheme of real world systems that also became the starting point for the further unfolding of the GST programme. It represents a triadic classification that builds upon principal kinds of phenomena that have been subject to scientific investigation according to the crucial criterion of organisation. The three groups are the following:

- organised simplicity,
- organised complexity, and
- chaotic complexity.

Actually, it should be possible that any phenomenon investigated by an empirical science can be subsumed under one of these categories.

Regarding organised simplicity, Rapoport and Horvath gave the following description. “The organization of a system is simple if the system is a serial of an additive complex of components, each of which is understood.” (Rapoport & Horvath, 1959, 89) As examples, they referred to the notion of a machine as a deterministic time-linear chain of events and to a propagating wave, consisting of additively super-imposed sinusoidal components. On the other hand, concerning systems of chaotic complexity, “... the number of entities involved is so vast that the interactions can be described in terms of continuously distributed quantities or gradients, i.e., do not need to be specifically identified with regard to the individual entities.” (ibid., 89) (Such systems are a matter of an exact treatment by applying the methods of mathematical probability, as it has been the case, for example, in statistical mechanics.)

The crucial point here is that science in the tradition of the mathematical methodology developed in physics had only comprised systems in terms of organised simplicity as well as chaotic complexity. Thus, the exact science approach in its classical form did not cover the phenomena comprising the category of organised complexity. It is obvious that this class covered all the diverse phenomena of the living world that have been the early starting point of systems thinking in the organismic understanding of Bertalanffy. Concepts like a living organism, survival, reproduction, development, life cycle, etc. simply had no place within the early exact sciences. In fact, they had to be excluded from research to free educated thinking from the teleological Aristotelian philosophy and to prepare the ground for modern science (see Rapoport 1966, 3). Thus, we can associate the category of organised complexity as the genuine field of the system idea.

GST faced the problem of defining systems in a way that did not exclude systems exhibiting organised complexity. In a first step, Rapoport came up with a working definition of "system" that relates to the analytical tradition of this concept: "I accept the definition of a system as (1) something consisting of a set (finite or infinite) of entities (2) among which a set of relations is specified, so that (3) deductions are possible from some relations to others or from the relations among entities to the behavior or the history of the system." (Rapoport 1968, 453) The analytical bias of this definition is due to the following characteristics. First, it carries out a total separation of substance and form; the criteria for something being a system are that it consists of definable sets of constituent parts as well as of their relations that together make up a certain structural form, regardless of the specific content of the phenomenon in question. Second, this comprehension, then, makes it possible to come up with the application of formal mathematical language for a more or less rigorous representation of a system's structure and dynamics via deductive means. Thus, in the exact sciences, a material system is defined by series of numbers that change in time, i.e. by the variables ascribed to the constituent parts (e.g. mass, distance, concentration); and the technique of differential calculus is used to make precise statements about how these quantities and their rate of change are related. Together, these two things make up a mathematical model in form of a system of differential equations.

For sure, such an analytical approach understands phenomena as systems by breaking up the whole into measurable quantities and their deterministic or probabilistic law-governed interactions; therefore, the analytical approach to the notion of system does not, in principle, differ from the exact mathematised science procedures.

However, in oder to include systems of organised complexity too, a second step was necessary to get rid of shortcomings of the traditional approach due to the one-sided hypostatising of deterministic relations. This aspect refers to the disentanglement of the analytic approach from the idea of a mere additive and linear thinking. In this regard, Rapoport clearly pointed out that the classical *dictum* of the holists – "the whole is greater than the sum of its parts" – can be interpreted as a rejection of the additivity notion. But at the same time he conceded that the additive way of thinking should not be equated with analytical thinking *per se*, but with "pitfalls of elementalism" that are often used for a mistaken interpretation of analytic thinking (Rapoport 1986, 9-11). Especially, these pitfalls comprise the linkage of causes and effects in a simple chain of consecutive events, a neglect of the context dependency of stated causal relationships, and a fixation on unidirectionality of causation, thus, a non-awareness of the fact that cause-effect relations are often invertible. The origins of these pitfalls probably lie in an indefensible generalisation of the exact analytical mathematical techniques of classical mechanics. In this context, the idea of analysis was to isolate and understand the parts of a phenomenon and, subsequently, to add up the results in a mathematically linear way. Rapoport and Horvath stressed that "... in presenting the analytical view, it is natural to fall into the language appropriate for describing a mechanism – 'the working of the parts'. The implied hope is that it is possible to 'build up' the understanding of a complexity by 'superimposing' the workings of the various parts." (Rapoport & Horvath, 1959, 87) This hope of the classical picture can be fulfilled in the case of rather simple mechanical systems. Typically, the latter can be exemplified as wholes where the operation can be broken up into a temporal chain of events, all connected by determinate causal relations (like machines); or where the possibility to add up the fundamental quantities is given, as perturbing influences are so small that they may be widely neglected (as in the solar system case).

Thus, concerning the system category of organised complexity, Rapoport stressed that the emphasis lies "... on the circumstances that the addition of a new entity introduces not only the relation of this entity to all others but also modifies the relations among all the other entities." (Rapoport 1966, 5) Consequently, we have the notion of a system as an interwoven network of relations beyond linearity and additivity. Nonetheless, a mathematical approach to such a notion is possible and brought forward by Rapoport as well. "Mathematically an 'organized complexity' can be viewed as a set of objects or events whose description involves many variables, among which there are strong mutual interdependencies, so that the resulting system of equations cannot be solved 'piece-meal' ..." (ibid., 4)

A complex organised system – standing in the organismic tradition of system thinking – might be comprised by a qualitative approach to systems. From this "soft" perspective, Rapoport defines: "According to a 'soft' definition, a system is a portion of the world that is perceived as a unit and that is able to maintain its 'identity' in spite of change going on in it." (Rapoport 1970, 22) We can notice the instant difference compared to the analytic notion. Whereas in the latter an ascription of specific values to an analytical mathematical structure constituting a state is the central definition criterion, the organismic conception stresses the idea of identity. A system in this regard is essentially an identity-preserving phenomenon, something that keeps constancy amidst change; this idea underlies the organisimic notion of a whole and it reveals itself in an act of cognition.

From this standpoint, the living organism is the prototype of a system. The material composition of an organism is constantly changing through metabolism, yet the organism maintains its identity. In fact, this is true of organisations and institutions of the human social realm too.

While the comprehension of organismic phenomena in a teleological way explicitly brought into focus the whole, it had to be replaced since its anthropomorphic underpinning did not conform to scientific standards of thinking. The question, then, was how the essential idea of goal directedness could be represented in a formal way and, such, be freed from the teleological connotations. In this regard, "A goal in its general sense is simply some end state to which a system tends by virtue of its structural organization ..." (Rapoport 1970, 8)

2.2 Evolution

Self-organisation has a diachronous and a synchronous aspect. The diachronous aspect refers to the evolution of systems, the synchronous aspect to systems' hierarchies.

Regarding the diachronous aspect, it goes without saying that Bertalanffy shared the basic assumption that reality is dynamical. As biologist he supported the idea of evolution.

Concerning development as part of evolution, Bertalanffy describes an inherent trend toward the rise of complexity. He does so by framing his second organismic principle. It is the "principle of progressive organization". It comprises a segregation process as a disintegrative trend (specialisation or differentiation which is well-known in Niklas Luhmann's social systems theory) and centralisation as an integrative trend. Later, Bertalanffy called these processes, after Richard Woltereck, "anamorphosis" (Bertalanffy 1949).

As Davidson (1983) points out, Bertalanffy said that both the scientific view and a religious, mystic view reveal the same idea when the first is referring to *homo sapiens* as by now the ultimate product of terrestrial evolution and the second is underlining that it is God who becomes aware of himself in the course of evolution. This assumption anticipates the idea of system theorist Bela H. Banathy and others that circumscribes the shift from the evolution of consciousness towards a conscious evolution (cp. 2000).

2.3 Hierarchy, Emergence and Downward Causation

Regarding the basic structural assumption of Bertalanffy's early GST, it is clear that he laid the foundations for what was later called "hierarchical system theory". Hierarchy has two fields of application:

- one field is within a system where the term circumscribes the part-whole relationship (intrasystemic aspect) and
- another field comprises the relation between systems that represent different stages of the overall evolution of nature and society (intersystemic aspect).

2.3.1 Intrasystemic Hierarchy

Bertalanffy takes Nicholas of Cusa's idea "*ex omnibus partibus relucet totum*" ("each part reflects the whole") as point of departure. It is well justified to look upon this assumption as something that later on became known as "downward causation" (cp. Campbell 1974) which is closely related to emergent effects. As early as in 1928 Bertalanffy wrote with regard to the organism: "The characteristic of the organism is first that it is more than the sum of its parts and second that the single processes are ordered for the maintenance of the whole" (Bertalanffy 1928, translation into English quoted after Pouvreau and Drack 2007, 305). Bertalanffy discovered that there is "maintenance of the organized system in a dynamical pseudo-equilibrium through the change of its components" (Bertalanffy 1932, translation into English quoted after Pouvreau and Drack 2007, 309). By that he was aware of what Hermann Haken (cp., e.g., 1996) called later, initially, the "enslaving principle" and the ordering of parameters along different levels evident not only in living systems but also in material ones like the Laser light – the higher the level the slower the development of the respective parameter. It is noteworthy that this has also been partly paralleled by Humberto Maturana and Francisco Varela's concept of autopoiesis by which they referred to living systems – the difference is that they abandon the hierarchical perspective, since they talk about networks of nodes only that produce each other and leave out the question of the whole (cp., e.g., Varela et al. 1974). But here Bertalanffy gets quite clear: organismic conceptions in biology "assert the necessity of investigating not only parts but also the relations of organization resulting from a dynamic interaction and manifesting themselves by the difference in behavior of parts in isolation and in the whole organism." (Bertalanffy 1950 in 2008, 219-220) Thus Bertalanffy distinguishes in this respect between two levels, that is,

– the level of parts
– and the level of the whole,

and he distinguishes between

– the dynamic interaction of parts,
– and the relations of organisation.

And it seems obvious that he locates the interaction on the parts' level and the relations on the whole's level. And he considers the following relationship between the interaction and the relations: The relations, on the one hand, result from the interaction and, on the other, are manifest in the behaviour of the parts in that the behaviour is different from the behaviour when in isolation. From that follows there are two processes in organisms/organisations/systems:

– one bottom-up in which interaction on the level of the parts result in relations on the level of the whole,
– and one top-down in which relations on the level of the whole manifest themselves on the level of the parts, viz., in their behaviour.

Hence Bertalanffy shared both the concept of emergence and the concept of downward causation in the following ways.

– As to emergence, he repudiated its metaphysical connotation. But nevertheless he emphasises the difference in quality between the two levels and supposes the irreducibility of the quality of the higher level to the quality of the lower level when he claims "with assurance that even if we would completely know the single substances in the organism, this problem of organization, the essential trait of life, would not yet be solved" (Bertalanffy 1932, translation into English quoted after Pouvreau and Drack 2007, 306) "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, translation into English quoted after Pouvreau and Drack 2007, 308) which is obvious since the relations express the new quality and belong thus to the higher levels.
– As to the dominance exerted from the higher levels on the lower levels, he reinstated final causality in a certain respect only, for he equally discountenanced teleology. "What in the whole denotes a causal equilibrium process, appears for the part as a teleological event", says Bertalanffy (1929, translation into English quoted after Pouvreau and Drack 2007, 306).

2.3.2 Intersystemic Hierarchy

Bertalanffy abstracted these ideas from applying to living systems exclusively and conceded "we are certainly able to establish scientific laws for the different levels or strata of reality." (Bertalanffy 1950/2008, 233-234) So he could arrive at the conclusion: "Reality, in the modern conception, appears as a tremendous hierarchical order of organized entities, leading, in a superposition of many levels, from physical and chemical to biological and sociological systems." "When emphasizing general structural isomorphies of different levels, it asserts, at the same time, their autonomy and possession of specific laws." (Bertalanffy 1950/2008, 234) "Speaking in the way of gross oversimplification", Bertalanffy conceived of three major levels: "physical nature; organisms; and human behavior, individual and social." And here "the notion of emergence is essentially correct: each higher level presents new features that surpass those of the lower levels." (Bertalanffy 1959, 67)

In that way his idea of the hierarchical ordering of processes within living systems extended to the conception of a hierarchical order of system classes, based on their level of organisation and complexity which is, in turn, related to the evolutionary stage systems inhabit. For example, Boulding suggested an accordant hierarchical scheme, comprising an eleven-level construction (cp. Boulding 1956, 14-16). According to Boulding, one central function of such a scheme was to give some ideas of gaps in both theoretical and empirical knowledge. Regarding the question of the availability of adequate formal theoretical models, it is worth stating that according to him such representations merely extended up to the fourth level of his scheme – i.e. from the level of static structure over the clockwork level of simple dynamic systems over the level of the control mechanism to the level of self-maintaining structure. The realm of definitive living systems started not before the fifth level; hence, that meant that no genuine formal theoretical model for the higher levels existed. Nevertheless, as each level incorporates those below it, "... much valuable information and insights can be obtained by applying low-level systems to high-level subject matter." (Boulding 1956, 17)

In 1967 Arthur Koestler made a remarkable contribution to the conceiving of the synchronous aspect of self-organisation regarding the totality of real-world systems when coining the terms "holarchy" and "holon". "Holarchy" denotes the hierarchy of "holons". A holon is a self-contained whole made up of its subordinate parts, while, in return, it is itself a part dependent of another whole.

3 Ethical Implications

Concerning the integration of the descriptive and normative approach, GST was from the outset considered a tool for intervention in the world we live in. In the social sphere it is social systems that are to be blamed for consequences undesired and unintended so far. "Contemplating contemporary history in the making, it is difficult to ascribe its irrationality and bestiality solely to individuals. Rather we seem to be victims of 'historical forces' – whatever this may mean. Events seem to involve more than just individual decisions and actions and to be determined more by sociocultural 'systems', be these prejudices, ideologies, pressure groups, social trends, growth and decay of civilizations, or what not", says late Bertalanffy (Bertalanffy 1968, 6).

Since Bertalanffy grew up in the Viennese post-*fin-de-siècle* atmosphere of cultural criticism, it comes not as a surprise that he shared the descriptions of crises that were said to abound in all spheres of life and the norms that were implicit in these descriptions. For Bertalanffy crisis also got a grip on science. In 1927 he wrote, "the mechanistic epoch …, whose hope it was to create a happy future for mankind by means of mechanics and technology", "may today come to its end" (Bertalanffy 1927, translation into English quoted after Pouvreau and Drack 2007, 285). When announcing what we today, after Kuhn, would term a paradigm shift in scientific thinking, albeit one that comprises all science – natural sciences and social and human sciences –, Bertalanffy expresses 1928 in his *Kritische Theorie der Formbildung* his value-laden stance and his conviction that there is an intrinsic link between science and society: "The technical age is about to become disgusted with itself – let us hope that it will be followed by an organismic one, which opens new doors to the future of mankind" (translation into English quoted after Pouvreau and Drack 2007, 288). The mediator between science and society is *Weltanschauung*. "The organismic conception, first grown on the ground of biology, is in the position to broaden to a general world view" (Bertalanffy 1934, translation into English quoted after Pouvreau and Drack 2007, 288).

At the end of his life, and after the atrocities of Nazi provoked World War II which he meanwhile had had to witness, Bertalanffy shared the very same idea: "The nineteenth and first half of the twentieth century conceived of the *world as chaos*. … The mechanistic world view, taking the play of physical particles as ultimate reality, found its expression in a civilization which glorifies physical technology that has led eventually to the catastrophes of our time" (Bertalanffy 1968, 198). Bertalanffy devoted his thoughts to the future of humanity. However, he grew more pessimistic as to the fate of civilisation and humankind at all. He admitted that Oswald Spengler in his writings had omitted that our civilisation is disposing over the technologies required for overcoming any plague that has beleaguered mankind so far and that we are empowered today to act upon the global challenges globally. But he did not rule out the possibility of extinction. "We know precisely and scientifically what the effects of pollution, waste of natural resources, the population explosion, the armaments race, etc., are going to be." (Bertalanffy 1968, 6). However: "We seem to follow some tragic historical necessity," though there would be an evolutionary necessity to fight the dangers coming along with utilitarian common sense and the military-industrial complex.

This possible design of future humanity is the meaning of "unity-through-diversity" in the context of the social task of the GST. Bertalanffy identified the causes of environmental pollution, waste of natural resources, population explosion, arms race, and so on, not in psychic features of wicked people that are in power but in systemic features of the civilisation, in the design of socio-cultural systems. System theoretical insights are to be applied to contribute to that aim. Bertalanffy's GST is a humanistic one. Thus all his descriptions of humans and social systems serve the function to help to formulate guidelines for acting towards humane norms and values.

In that respect, Bertalanffy's co-workers in GST joined him. According to Bertalanffy it was the reductionistic robot view of humans in behaviourism that was closely connected to the militarism of the post-war era. GST inspired the development of peace research. Boulding and Rapoport established the Center for Peace Research and Conflict Resolution at the University of Michigan in 1956 (cp. Hammond 2003). Both are well-known for their protests against the Vietnam War and for their criticism of the military-industrial complex of the United States. Rapoport is known for his development of non-zero sum models in game theory. Boulding was among the first economists to include ecological considerations in economic theory. By that it is clear that GST did not abide by the *dictum* of value-free science.

Conclusion

"GST" turns out to be the name for systems science *in statu nascendi* from which many ramifications followed in the course of the history of systems science. The complex systems approach as the most recent development of the new paradigm seems to have more in common with the original ideas than other ramifications and more than today acknowledged. This holds for epistemological, ontological and ethical aspects of philosophical implications as well.

In its attempt for generalisations, GST is thus heading towards a state of science called in our days "transdisciplinarity". The term "transdisciplinarity" is used to define a concept that goes beyond the meaning of multi- and even interdisciplinarity. While multidisciplinarity would mean the unrelated coexistence of monodisciplinary accounts and interdisciplinarity the casual establishment of relations between monodisciplines without having feedback loops that have a lasting impact on their repertoire of methods and concepts, transdisciplinarity comes into play when each discipline is engaged in the collaborative undertaking of constructing a common base of methods and concepts, of which its own methods and concepts can be understood as kind of instantiations. Transdisciplinarity does thereby not mean the abolishment of disciplinary knowledge but grasping for a bigger picture.

Actually, GST and systems science aware of the aims set out by GST are the transdisciplinary science *per se*.

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