Is Paul Weiss' and Ludwig von Bertalanffy's System Thinking still valid today?

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Abstract

The roots of what is today called general system theory (GST) can be traced back to the Vienna of the early 20th century. In the 1920s Paul Weiss performed experiments in the Viennese Prater Vivarium (a privately founded research institution in the area of experimental biology) and found that his results were totally incompatible with the prevailing mechanistic concepts dominating the biologists way of thinking. Therefore he proposed a system view. At about the same time Ludwig von Bertalanffy, coming from philosophical grounds, tried to overcome the dispute in biology of vitalism versus mechanism by developing an organismic concept. They met each other and discussed the biological concepts when von Bertalanffy was still a student.

Rupert Riedl knew both scholars personally and thought that their ideas are of paramount importance not only for the biologists world view. Thus he initiated a research project called "System Theory Today", in which the developments in system theory in the last three decades should be investigated. The focus of the project here described lies in the reception of system theory after von Bertalanffy's dead. Further developments as well as reductionistic tendencies are to be tackled. As our pre-studies have shown, a whole lot of disciplines have adopted system theory for their needs, but some of the modified theories sheer away from the original context. On the one side the development in the different disciplines is positive, on the other side it leads to contradictory positions followed by misunderstandings and building up new boarders that are weakening the prime intention of system theory. System theory was always meant to be an integrative tool for all sciences and was aiming for a dialog between scientific disciplines. Based on the theory arising from biology the developments in different disciplines (from mathematics to engineering, from medicine to economics, but especially life sciences) will be investigated. The key question is, whether von Bertalanffy's and Weiss' system thinking still plays a role in science today and especially if there are contributions that broaden or reduce the concept. To complete the picture the just recently found Bertalanffy estate, which is now hosted by the University of Vienna, will play an important role. The working hypothesis is that what was made out of GST is a considerable reduction of the original concept.

In this paper an overview of the research work in the project will be given. It starts with the system concepts in 1920s biology and the thoughts of Weiss and Bertalanffy. Therefrom the basic concepts are extracted to be compared with the contemporary developments of GST.

Keywords: Paul Weiss; Ludwig Bertalanffy; General System Theory; GST; History and Development of GST; Vienna; 1920s

Introduction

According to Rupert Riedl, who was the initiator of the here described research project, system theory is one of the most important issues when it comes to theory, not only in biology. Riedl was a student of zoology in Vienna where he took lectures in classes of Ludwig von Bertalanffy at the time just following World War II. Bertalanffy first presented his thoughts on general system theory in 1937 at the University of Chicago, but the first article was published only twelve years later in 1949 although it was meant to appear in 1945. Thus Rupert Riedl has, as he liked to say, "osmotically absorbed" the ideas of the founding father of GST. During his time as a professor in Chapel Hill, North Carolina, Riedl came in close contact with Paul Weiss from Rockefeller University. Weiss received his education, first in engineering and later on in biology, in Vienna. During the time working on his PhD thesis he found that the predominant approach to describe behavior in animals as a mere mechanistic phenomena is not sufficient and has to be replaced by a system view. The third person to whom Riedl liked to refer when concerned with system matters is Arthur Koestler. Koestler, who also spent part of his youth in Vienna, developed his own concept of a system theory some decades after Weiss' and von Bertalanffy's first notions. Furthermore he was the organizer of a symposium in Alpbach (Tyrol, Austria) in 1968 where he brought together scholars of various disciplines who thought "beyond reductionism" – which was also the title of the conference proceedings (Koestler and Smythies, 1969). Since the more important advocats of system theory, Weiss and von Bertalanffy came up with their ideas in the Austrian capital one could refer to their thinking as the "Viennese school" of system theory.

To the notion of Riedl system theory was ever more fragmented in the last decades, and as the systems approach is important to our world view with all its consequences he started a project for tracing back in detail the development of GST.

In the following the origin of the system thinking of Weiss, Bertalanffy and Koestler is roughly described. Thereafter an overview of the research project 'System Theory Today' is given with some first results. Furthermore the current state concerning the Bertalanffy archive is shortly mentioned.

The "Viennese school" of System Theory

Paul A. Weiss

In 1918 Paul Weiss began his studies in mechanical engineering at the Vienna's *Technische Hochschule*, now called Vienna University of Technology, but one year later he decided to study biology at the University of Vienna. For Weiss' background and professional career see, e.g. Brauckmann (2003). Soon Weiss optained one of the highly demanded workplaces at the 'Prater Vivarium' laboratories – a privately founded research institution situated in the Prater, a Viennese recreation area.

Supervised by Hans Przibram and Berthold Hatschek, Paul Weiss received his PhD for experimental studies on the resting postures of butterflies in response to light and gravity (Weiss, 1922) from the University of Vienna. The results contradicted the rather mechanistic tropism theory of Jacques Loeb, which Weiss later expressed as follows: The results from studies on the living organism "proved totally incompatible with the mechanistic doctrines – or rather rationalizations – of animal behavior prevailing at that time." Moreover, Weiss "saw a way of reconciling them [his findings] fully with the then flourishing epistemology of modern physics" (Weiss, 1977). "The experiments totally confirmed theoretical conclusions. It could be demonstrated that knowing the efficacy of single factors within a complex allowed for unequivocally drawing conclusions about the efficacy of the entirety from which we previously isolated single parts; all positions [of the butterflies] turned out to be demonstrable as coming off the entirety of those partial effects, an exclusive efficacy of one single factor was never observed" (Weiss, 1922, 19, own translation). An elaborated version of his PhD thesis was published in German (Weiss, 1925) and 34 years later translated to English (Weiss, 1959). Paul Weiss explained in 1977: "The 80-page article stated the basic premises and principles of a holistic systems-theory which I could derive cogently from my own studies of animal behavior and from cognate trends such as 'Gestalt' Psychology so as to define in detail the scientific characteristics by which a singled-out fraction of nature can rightfully be accorded the designation of 'system'" (Weiss, 1977, 18).

Paul Weiss' first formulations of a biological system theory dealt especially with the determination of phases in which dramatic changes in the phenotype are still possible. He consequently understood the step by step and dynamic explication of the body plan as a product of increasing networking between interacting and thereby developing systems and not, like Hans Driesch (a former student of Ernst Haeckel) in his so-called vitalism, as a product of an organizing power about which Driesch spoke in terms of an unobservable entelechistic principle of life. However, it actually was Driesch himself who referred to developing organisms as 'systems' and their specific developmental behaviors as system behaviors as early as in 1899 (Mocek, 1998, 321-322). The notion of cascaded hierarchies of developmental dynamics was broadly debated in the Vivarium laboratories and was incorporated as a concept in Bertalanffy's vision of theoretical biology. Bertalanffy participated in those discussions. (Hofer, 2002, 160-161)

In his work of 1925, Paul Weiss contradicted the idea that activities in life could be explained by physics and chemistry alone without further requirements: Whether or not physical or chemical terms could replace biological ones, the laws of complex issues will never be fully replaced (Weiss, 1925, 170). In his early work we can already find the basis of a hierarchical order necessary to allow actions (like locomotion) of an animal as a whole. With each level (physical or chemical reaction, single muscle fiber contraction, contraction of a muscle, movement of an organ, motion of the organism) new characteristics would appear that could not be described simply by the lower levels alone. By only quantitatively splitting the whole into the lower-level elements, these characteristics would be lost. This would also be true for inorganic entities like molecules or atoms. In the chapter 'laws of systems' Paul Weiss proposed: "As a system we want to define each complex that, when parts of it are modified, displays an effort to stay constant with regard to its outside" (Weiss, 1925, 183, own translation). In other words, the state of a system should be stable, that is, distinct to and within the outside conditions. As he interprets, a constant system state in the whole, when parts are altered, could only be achieved by inverse changes in other parts, which is done by the system itself (system reaction). He continued: "The cases of regulation and adaptation are typical system reactions of the organism. They are so widespread that their mere existence suffices to make the organism being recognizable as a system" (Weiss, 1925, 183, own translation). Consequently, he described organisms as systems.

In addition to the application of mechanistic concepts of interacting single parts he considered it to be essential to deal with a system as a whole, because system reactions (e.g. concerning functions and development) could only be adequately understood by taking into account the system as a whole. In his work on 'morphodynamics' (Weiss, 1926), published six years before Bertalanffy's 'Theoretical Biology' (Bertalanffy, 1932), Paul Weiss consequently defined biological form as "the typical localization, i.e., arrangement and allocation of different sub-processes within the respective material systems", so that already the fact "that at this location these and only these and at that location those and only those processes are introduced is 'form' for us; we do not have to wait until those different processes actually create a certain spatial gestalt" (Hofer, 2000, 149, own translations). In this context he developed a field theory in developmental biology ('morphogenetic fields of organization') and programmatically declared: "All field laws can be conceived as special cases of general system laws" (Weiss, 1926, 27, own translation), using the word 'field' as a term for prospective terrains of organ-formation.

Paul Weiss advocated system thinking on a broad and deep basis, as this quotation demonstrates: "It is an urgent task for the future to raise man's sights, his thinking and his acting, from his preoccupation with segregated things, phenomena, and processes to greater familiarity and concern with their natural connectedness, to the 'total context'. To endow the epistemological foundations for such a turn of outlook with the credentials of validation by modern scientific experience, is thus a major step toward that goal" (Weiss, 1977, 19). Weiss was also a member of the Club of Rome (Brauckmann, 2003).

Ludwig von Bertalanffy

In his youth Bertalanffy lived in his mother's estate outside of Vienna next to Paul Kammerer, one of the most prominent experimenters of the 'Prater Vivarium'. Being a neighbor and friend to the family, Kammerer time and again talked to the young Ludwig Bertalanffy about biological matters and introduced him in vivisection and anatomy of plants and animals. Therefore, Bertalanffy was probably well aware of the attitude in which science was performed at the Vivarium laboratories. At the end of World War I, the family, due to financial losses, temporarily left Vienna and moved to Zell am See (Salzburg, Austria). In 1924 Ludwig Bertalanffy returned to Vienna and lived there until 1937 when a Rockefeller scholarship was granted to him for one year. He came back from America in 1938 and lived in Vienna until 1948 when he decided to permanently go to North America.

Bertalanffy studied history of art and philosophy in Innsbruck (Tyrol, Austria) from 1920 to 1924 and in Vienna from 1924 to 1926. In the course of his studies he focused mainly on philosophy, where his teachers were Robert Reininger and Moritz Schlick, he also attended Rudolf Carnap's study group; for details see Brauckmann (2000), Hammond (2003) or Hofer (1996). Having personally participated in the discussions of the Vienna Circle, he concluded that the logical positivist's scientism was not valid. In contrast, he himself referred to Immanuel Kant (Critique of Pure Reason A51/B75) and liked to say that, though theory without experience is mere intellectual play, experience without theory is blind (Bertalanffy, 1969, 101). But Bertalanffy recognized the 1920s in Vienna as a time of high intellectual intensity from which many developments started that later became important (Bertalanffy, 1967).

Already during his days as a student in Vienna Ludwig von Bertalanffy met Paul Weiss. They discussed system issues in biology, Weiss with an experimental and Bertalanffy with a philosophical background. Five years after Bertalanffy's death, the 79-year old Paul Weiss remembered these times: "It was in those days that a sparkling Viennese student, a little more than three years my junior, approached me for a meeting – Ludwig von Bertalanffy. We met in coffeehouses and 'milked' each other. I soon found that his thinking and mine moved on the same wavelength – his coming from philosophical speculation, mine from logical evaluation of practical experience. And so it remained for half a century, each of us hewing his separate path according to his predilection. That is, I kept on as the empirical experimental explorer, interpreter, and integrator, for whom the 'system' concept remained simply a silent intellectual guide and helper in the conceptual ordering of experience, while he, more given to extrapolations and broad generalizations, and bent on encompassing the cosmos of human knowledge, made the theory [General System Theory] itself and the applicability of it to many areas of human affairs his prime concern. Does not this confluence here, once again, prove the 'hybrid vigor' of the merger of ideas that, coming from a common source, have converged upon common ground, albeit by separate routes – the one offering a distillate of a life of study of living systems, the other the extensive elaboration of an intuitive philosophical ideology, tested in its pertinence to human evolution?" (Weiss, 1977, 18-19)

In his summary book on GST, Ludwig Bertalanffy put it this way: "The present author, in the early [19]20s, became puzzled about obvious lacunae in the research and theory of biology. The then prevalent mechanistic approach (...) appeared to neglect or actively deny just what is essential in the phenomena of life. He advocated an 'organismic' conception in biology, which emphasizes consideration of the organism as a whole or system, and sees the main objective of biological sciences in the discovery of the principles of organization at its various levels. The authors first statements go back to 1925–26" (Bertalanffy, 1969, 12).

Supervised by Moritz Schlick, Ludwig Bertalanffy wrote his PhD thesis (Bertalanffy, 1926) about concepts of the German physicist and philosopher Gustav Fechner. This thesis was concerned with intriguing questions, namely whether higher units, which from Fechner's point of view on nature would actually integrate the living organism, could be methodically investigated in a quite abstract manner, whether they could be empirically verified, and to what degree an inductive metaphysics would be reasonable for sciences (Brauckmann, 2000, 2). Although coming from philosophical grounds, a bigger part in his thesis is dealing with biological questions.

After graduating he wrote many articles in the field of theoretical biology. In 1928, for example, he published a book on a 'critical theory of morphogenesis' (Bertalanffy, 1928), which acquainted him especially with the Berlin Society for Scientific Philosophy around Hans Reichenbach – a counterpart to the Vienna Circle around Moritz Schlick – and opened contacts to Gestalt psychologists. His way of thinking was probably based on Weiss' 'morphodynamics' (Weiss, 1926), but Bertalanffy did not mention it (Hofer, 2000, 152). Brauckmann (2000, IX) describes the attitude of Bertalanffy towards a theoretical biology: When he started his theoretical program he actually was convinced that biology's right to exist as a science asks for a theoretical background which was not established yet. For him, biology of this time was not much more than some kind of natural history in a pre-critical stage. This he wanted to change with the aid of his organismic system theory.

Having developed his own approach to theoretical biology during the 1920s, he was the first academic receiving a habilitation (postdoctoral lecture qualification) in 'theoretical biology' at the University of Vienna in 1934 (Hofer, 1996, 12-15). The basis for this habilitation was volume 1 of his book on 'theoretical biology' (Bertalanffy, 1932). Therein, after having criticized mechanism and vitalism in biology he argued for an organismic biology.

The organismic viewpoint emphasized that organisms are highly organized entities, meticulously embedded in their respective environments, and biologists should find out how this is performed. Ludwig von Bertalanffy tried to implement his organismic program in various studies on metabolism, growth, and the biophysics of the organism. One step in this direction was the so-called theory of open systems and steady states, which essentially was an expansion of conventional physical chemistry, kinetics, and thermodynamics. As he says, he did not stop on the way once taken and so he developed an even more comprehensive generalization that he called 'General System Theory'. Some years later, Ludwig Bertalanffy put it this way: "I presented it [GST] first in 1937 in Charles Morris' philosophy seminar at the University of Chicago. However, at that time theory was in bad repute in biology, and I was afraid of what Gauss, the mathematician, called the 'clamor of the Boeotians'. So I left my drafts in the drawer, and it was only after the war that my first publications on the subject appeared" (Bertalanffy, 1969, 90). Actually, it appeared in 1949 in German language (Bertalanffy, 1949).

In his definition of what a system is he only later included the environment: "A system may be defined as a set of elements standing in interrelation among themselves and with [the] environment." (Bertalanffy, 1969, 252) This definition is very general and differs from the definition of Weiss, who refers to a behavioral reaction (see above).

Arthur Koestler

Koestler can not be assigned directly to a "Viennese school" of system theory, although he studied engineering in Vienna at the same time when Weiss and Bertalanffy already discussed system matters. He is mentioned here because he also was concerned about the prevailing reductionism and thus developed an own concept of system thinking. Discussing system theory Rupert Riedl often refered to Koestler and the Alpbach Symposium Koestler organized in 1968 (Koestler and Smythies, 1969). Although he was not a scientist and without academic degree, thus often seen as "story teller", Koestler managed to bring together many important thinkers, such as L. v. Bertalanffy, V. E. Frankl, F. A. Hayek, J. Piaget, W. H. Thorpe, C. H. Waddington and P. A. Weiss. Riedl acknowledged the conference as an important intellectual basis for further thinking.

Koestler is very much concerned over behaviorism and the stimulus-response theory which he completely rejected and liked to replace by a non-mechanistic concept of the human being and other systems. Central to his system thinking is the concept of the 'autonomous holon': "The organism in its structural aspect is not an aggregation of elementary parts, and in its functional aspects not a chain of elementary units of behavior. (...) The organism is to be regarded as a multileveled hierarchy of semi-autonomous sub-wholes, branching into sub-wholes of a lower order, and so on. Sub-wholes on any level of the hierarchy are referred to as holons." (Koestler, 1978, 304)

No evidence was found that Arthur Koestler got in touch with Paul Weiss and Ludwig Bertalanffy much earlier than in the 1960s. Nevertheless, at the Alpbach Symposium Koestler's theory of 'holons' was well accepted by Ludwig von Bertalanffy, and Paul Weiss stated that he was agreeing with almost everything that Koestler had said, with the only exception of Koestler's tree-like model of holon genealogy (Koestler and Smythies, 1969).

What was made of GST?

First of all it can be said that GST influenced many scientific fields and is still widely known, which is also reflected by the fact that there are still conferences held by ISSS. But system theory is used in different fields often in a very different way. Especially in German speaking countries system theory is often connected to sociology because Luhmann used to refer to GST.

To this day the development of system theory since 1970 has not been systematically described. Although there are some attempts, for instance the one of Kratky et al. (1989) which tried to point out the new reductionism in system theory. Thereby the supposition was verified that scientific research across disciplines, especially concerning system theory, does not play a big role and the dialog between disciplines even next to each other is rather sparse. Thinking about a common theory like GST is not widespread at the moment. But still there are attempts to bridge the gap between various scientific fields like the one of Riedl (2000), which is sort of a 'Längsschnitt-Theorie' (longitudinal section theory).

Riedl (personal communication) once stated, that there are three aspects which have to be addressed within further research on the development of the system theory:
1. GST was developed further in different ways. Thus expansions as well as incompleteness must be pointed out.
2. It can be expected that the boom of inorganic paradigms went on which possibly led to an ontological reductionism that has to be corrected.
3. Investigations must show how system theory can confirm, correct and complete evolutionary epistemology and the theory of evolution.

The working hypotheses in the current project is that what was made of GST in the last three decades is a considerable reduction of the original conception.

Our pre-studies have shown that the terminus system theory is widely and internationally spread among various disciplines, but in some fields the concepts already differ from the originators attitude. The linkage between various disciplines – usually thought to be made by GST – is not often visible. There are just a few institutions around the globe trying to integrate thoughts of various disciplines. Yet it seems that here also the behavior of the whole is merely explained by its subunit properties which is conferred to as complexity. This might fit into Bertalanffy's definition of what a system is, but Weiss probably would not be comfortable with it. He once stated that a living system can not be characterized only by complexity, "meaning simplicity in large numbers, which could be more profitably studied singly and then added up." Furthermore: "Organization has exactly the opposite connotation." (Weiss, 1977, 43)

The aim of this project is to draw a picture of the development of GST especially since the 1970s. Based on the theory arising from biology the developments in different areas will be investigated, the key question being, whether Bertalanffy's and Weiss' system theory still plays a role in science today and especially if there are contributions that broaden or reduce the concept. The overview of the developments will show where and in which direction the theory was developed further and where it was simplified.

The result of the study will contribute to a better understanding of the problems at the interfaces between disciplines, which is important because nature itself is not divided into physics, chemistry, biology, and what ever disciplines man has invented. Anyhow, the interdisciplinary and transdisciplinary character seems to have been overcome by the accelerating developments in the single disciplines with clear and sharp boarders to the neighboring research areas.

In his Ross Ashby memorial lecture at this years European Meetings on Cybernetics and Systems Research (EMCSR) Matjaž Mulej clearly pointed out this problem of overspecialization also within the systems researchers community (Mulej, 2006). By refering to Bertalanffy he mentioned that this current development might lead to big problems on a large scale.

For a quick overview towards the influence of GST we were looking at the library of the University of Vienna and in online book shops for items found with the keyword "system theory" ("general system theory" would have brought too few results) both in English and German up to the year 2004. This serves only for a rough insight into the dispersal of GST and more detailed analysis are needed for an elaborated examination. We tried to classify the more than 120 book titles found and allocated them to their scientific disciplines. Although GST is meant to overcome the gap between scientific disciplines this allocation was possible because most of the books are focusing only on one discipline. Figure 1 shows the distribution of the texts with regard to the various disciplines. What attracts attention is the high number of publications in the area of sociology. This is due to the fact, that Niklas Luhmann used the term "Allgemeine Systemtheorie" for his sociological theory which triggered quite a lot of publications also from other authors – mostly in German. Also areas like politics or religion are more or less directly connected to Luhmann with little reference to the GST founders. Prominent also is the mathematical thread of system theory, but the use of system theory in mathematics is very much different from the concepts considered in sociology. These two areas can easily be distinguished from one another and also the influence of GST in both of them is different. Interestingly enough the biological area is rather small – although this is the science where GST stems from.

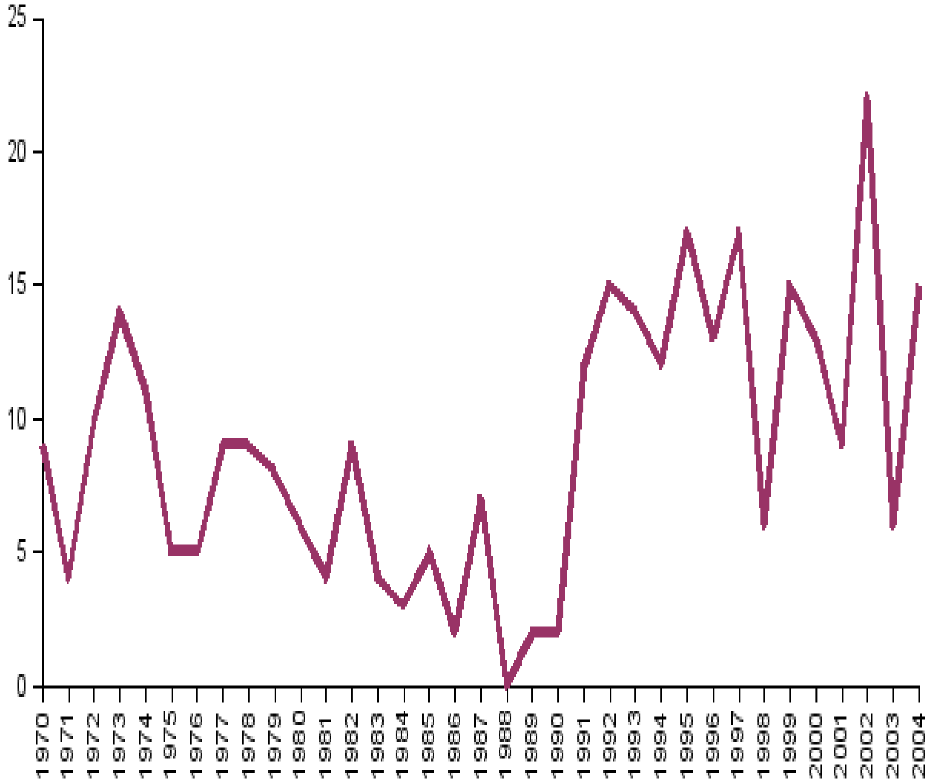

Figure 1. To get a first impression about the influence of GST we performed a keyword search for

recent books in the area of system theory and tried to allocate the 123 items to the according disciplines. (For further notes see text.)

To examine the significance of GST in the scientific world an investigation of the appearance of GST in journal articles of the last three centuries was done. For this purpose the General Search of the ISI Web of Knowledge was used, looking for the topic "general system$ theory", i.e. the singular 'system' as well as the plural 'systems' are included. As seen in Figure 2 the number of citations of GST was never really high (compared to e.g. "systems biology" which shows 278 results for the year 2004 alone) and reached a first peak in 1973 the year after Bertalanffy died. A slow decrease followed until 1990. But in 1991 the number of references increased again and seems to have reached a stable plateau until today. Of course it is of interest how this considerable increase in 1991 can be explained. Before 1991 there was only one year in which there were more results than in 1991. Why did the term become fashionable again? When investigating the works that appeared in 1991 which in one way or another referred to GST there is not a single event that could explain the jump. Articles from different areas, computer sciences as well as sociology, refer to GST. Interestingly enough, at the same time the use of the term "organismic" is sharply increasing as well.

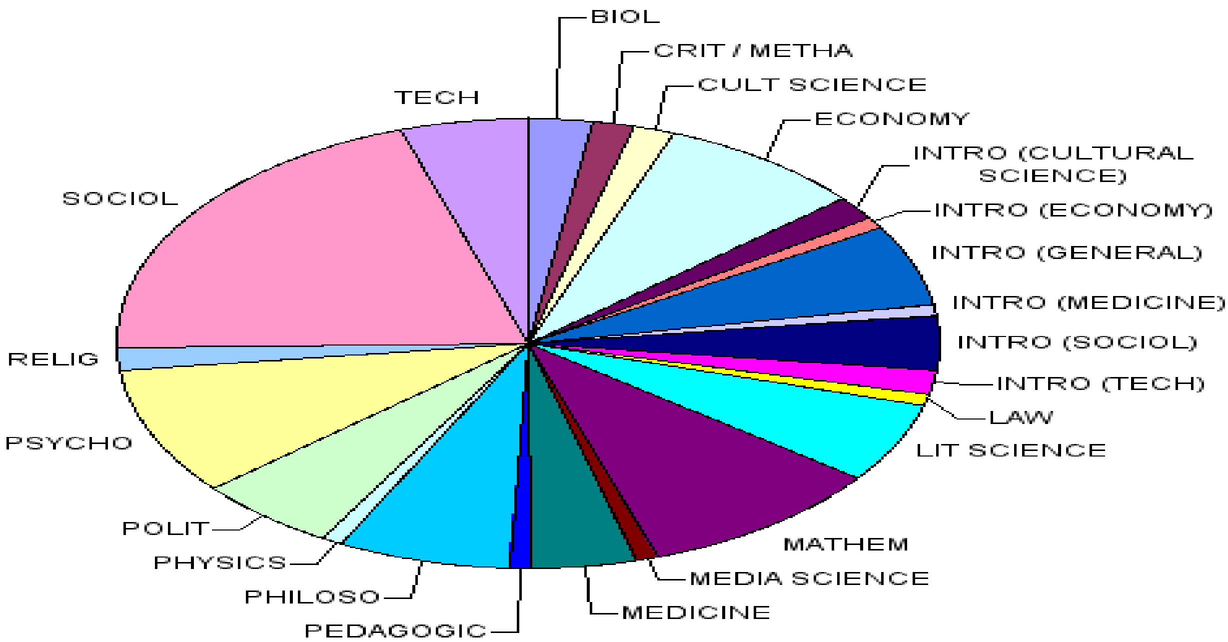

Figure 2. Citations of "general system$ theory" (General Search / ISI Web of Knowledge) showing the number of articles containing "general system$ theory".

From the overall 314 articles since 1970, 133 appeared in the ten years between 1995 and 2004. These 133 articles are an import source for further investigations in the project. Although they do not reflect similar concepts under different names the articles are at least directly referring to GST and thus serve for an insight on elaborating of reducing contributions.

Bertalanffy Estate

In 2004 the Bertalanffy estate was found in a book store in Buffalo, New York. When sent to Vienna it consisted of six banana boxes full of books and letters. The archiving is not fully completed yet, but as it turns out the probably most interesting items are the nearly 600 letters from and to Bertalanffy dating from 1945 to his death. Correspondences with many important scholars of that time were found, and most of them are of valuable, i.e. scientific, content. Besides that many books that belonged to Bertalanffy were found. Until now it is not quite clear whether the estate is complete or items were lost, particularly concerning the letters. To take care of the newly established archive and foster systems research the 'Bertalanffy Center for the Study of Systems Science' (BCSSS), based in Vienna, was founded in 2005.

The letters will tell about the connection and debate of Bertalanffy with colleagues in the field of biology as well as experts from other disciplines. This exchange of ideas may contribute to the investigation of the further developments of GST. Hopefully, there will also be detailed information about contradicting points of view in the correspondences. In any case the archive will contribute much for tracing back the development of system theory not only for the current project but also for any further research.

Acknowledgment

This research is supported by Austrian Science Foundation Grant P18149-G04 to Rupert Riedl. Unfortunately Rupert Riedl (22.2.1925-18.9.2005) passed away shortly after the start of the project. We like to thank Ludwig Huber for providing the infrastructure for the work.

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