

**On General System Theory's paradigm:
is the world hierarchically organized?**

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Thirty five years ago, in his *Foreword* to Erwin Lazslo's *Introduction to systems philosophy, toward a new paradigm of Contemporary thought*, Ludwig von Bertalanffy wrote that «the notion of "system" has gained central importance in contemporary science, society and life. In many fields of endeavor, the necessity of a «system approach» or «system thinking» is emphasized: new professions called «systems engineering», «systems analysis», and the like have come into being, and there can be little doubt that this concept marks a genuine necessary, and consequential development in science and world view»¹. Ludwig von Bertalanffy, known for his work in General System Theory and the founder of the «Society for General Systems Research», was at the beginning of his career a biologist who emphasized, in the late twenties, under the title of "organismic biology", the necessity of regarding the living organism as an «organized system» and defined the fundamental task of biology as discovery of the laws of biological systems at all levels of organization. It is this trend, raising in biology and other disciplines, which led him to conceive the idea of general systems theory, introduced in the 1930s and '40s, that is, as he said, an interdisciplinary doctrine, elaborating principles and models that apply to systems in general, irrespective of their particular kind, elements and «forces» involved. So, as we can see, the concept of system was closely related to the concept of model and the theory of general systems appeared more or less as a theory of the models we can build from these systems, the ultimate ontology of which remaining possibly never known. From this situation results a particular vision of nature, society and other systems to which the theory is supposed to apply. In this paper, I shall start from the definition of a system in General System Theory (GST). Then I shall point out that we cannot give GST an ontological meaning. It will result that we cannot prove the necessity of a natural hierarchical order in the world, because the set of all systems in GST is not necessarily a set hierarchically organized. It is not necessarily, as mathematicians say, a «non-circular» set. As the uses of hierarchy in social systems or networks is very often justified by the existence of natural hierarchies, my conviction is that we cannot take for granted that this kind of organization is the only one possible for human societies.

the whole.

A lot of concrete systems can be reduced to that. For example, we can find the system above in kinetics where it is a general expression of the mass action law. The same system, in a wider sense, is also used by Lotka (1925) to describe demographic problems in ecology: equations of biokinetics systems developed by Volterra and Lotka⁵ are particular cases of equations above.

Another definition of systems comes from cybernetics. As we shall see, it refers to cybernetic stability. So, let us explain now briefly what is systems cybernetics.

(b) *System-cybernetics* : The name of Norbert Wiener is attached to the study of self-stabilizing controls operating by error-reducing negative feedback⁶. Then, the “second cybernetics”, with Maruyama⁷, called attention to the importance of error (or deviation) *amplifying* control processes, which function by means of positive feedback.

The two currents, which deal with *open* systems in relation to a relevant environment, raised the concept of “cybernetic stability”. Cybernetic stability can be defined as the capacity of self-regulation by compensating for changing conditions in the environment through coordinate changes in the system's internal variables. This cybernetic stability is stated here as a rough model of adaptation.

Here the essential character of a system is its invariance as a whole, compared with the more variant fluctuation of its supposed constituting elements. Ordered wholes of this kind constitute systems in the only following sense, i.e. that within a given range of selected perturbations, their models return to the steady states characterized by the parameters of their constant internal constraints.

But there are other kinds of systems, which are, like the living beings, more complex systems and manifest a new property: adaptive self-organization. Let us explain what it is.

(c) *Adaptive self-organization*: When going from transient states to steady states, some systems do not only reestablish the parameters defining a previous steady state after perturbation but manifest sometimes a progressive development of new steady states which are more resistant to the perturbation than the former ones.

Ashby has shown that, in this case, the system organizes itself as a function of maximum resistance to the forces, which act on it in its environment. External constraints would lead to internal constraints, and then, to adaptive systems. Here would be a kind of natural selection leading from populations of relatively simple systems to hierarchically organized sets and clusters, and the evolution of any arbitrary complex system would be always in the direction of merging some characteristics, differentiating others, and developing partially autonomous subsystems in a hierarchical sequence.

In fact, the proof that we are interpreting what happens is that the reorganized system is not necessarily a more stable system. The model shows that it is just the opposite. When one says that adaptive self-organization occurs by means of a complexification of structure, we try to translate, in ordinary language, the physical and statistic fact that the system becomes thermodynamically «improbable», and hence, structurally instable, so, prone to physical disorganization.

If S is the entropy function, we can say that disorder in systems grows at a rate dS/dt , which is the dissipation function Y . If Y is zero, the system is in a stationary state. If Y is positive, the system is in a

⁵ A. Lotka, *Elements of Mathematical Biology* (1925), New York, 1957. V. Volterra, *Leçons sur la théorie mathématique de la lutte pour la vie* (1931), rééd. Paris, Gauthier-villars, 1990.

⁶ N. Wiener, *Cybernetics*, 2nd ed. Cambridge, Mass. 1961; *The Human Use of Human Beings : Cybernetics and Society*, Garden City, New York, 1954.

⁷ M. Maruyama, «The Second Cybernetics : Deviation-Amplifying Mutual Causal Process», *American Scientist*, 1963.

state of progressive disorganization. If Y is negative, the system is in a state of progressive physical organization. But, personally, I would not say that the system gathers information when it actually decreases its entropy⁸. This is an interpretation. All we can say is that the positive, negative or zero entropy change (dS) is governed by the relative values of terms in the Prigogine equation:

$$dS = dS_e + dS_i \quad (2)$$

where dS_i denotes entropy change through the input, and dS_e entropy change due to irreversible processes within the system⁹.

A simple comment here : (2) is not a universal property but a local one. Of course, we know that no open systems violate the Second Law of Thermodynamics (since the decrease of entropy within an open system is always offset by the increase of entropy in its surroundings). But we cannot infer from this fact that :

$$dS_e/dt > dS_i/dt \quad (3)$$

within the complex as a whole. Nobody knows what happens at the level of the observable universe itself because nobody knows whether the observable universe is an open system or not¹⁰.

This allows another comment: speaking of levels refer to a new property of systems, the hierarchy property. Let us explain what it is..

(d) *Hierarchy property*: According to Herbert Simon¹¹, the father of Artificial Intelligence, complex systems used to evolve from simple systems much more rapidly if there are stable intermediate forms than if there are not. The resulting complex is, as he points out, hierarchic. In that case, any failure in the organization will not destroy the system as a whole but only decompose it to the next stable subsystem assembly. It is the reason why, in favorable environment, systems not only maintain their already attained level of organization but continuously evolve toward more highly organized states. So, systems sharing a common environment will tend to form hierarchical supra-systems, and consequently, an environment composed of such systems itself becomes a system, with subsystems introducing the fixed forces which define its parameters. Provide that the environment is likewise populated with other systems of the corresponding level of organization, the supra-systems adapt to one another and jointly constitute systems of the second level order. For Laszlo, «the concept of natural hierarchy is an entailment of the concept of self-stabilizing and self-organizing ordered wholes in common environments»¹². This suggests a vertical law of organization, by deduction from horizontal laws of interaction. At each level, systems contain systems of all lower levels plus their combination within the whole formed at that level. Hence the possibility of a diversity of structures and functions increasing with the levels. The higher we raise our sights on the hierarchy, the more diversity of functions and properties would be found, manifested by a smaller number of actualized systems.

⁸ See D. Parrochia, *Cosmologie de l'information*, Paris, Hermès, 1994.

⁹ E. Laszlo, *op.cit.*, p. 44.

¹⁰ The french philosopher Henri Bergson was always aware of that. See H. Bergson, *L'évolution créatrice*, Paris, P.U.F., 1970 pp.701-703.

¹¹ H. A. Simon, «The Architecture of Complexity», *Proceedings of The American Philosophical Society*, 106 (1962).

Thus, atoms exist in greater numbers than molecules but have fewer properties and variations of structure; organisms exist in fewer numbers than molecules but have an enormously wide repertory of functions, and properties exist in untold variety of structural forms (the ten million species of plants are but a fraction of all the possible species which could be capable of existence). And we can say also that the number of ecologies and societies is smaller than that of organisms but manifest a greater diversity and flexibility than biological phenomena.

According to Laszlo¹³, the hierarchy relation may be expressed like that: a given system a has component subsystems c_1, c_2, \dots, c_n , in determinate association, the sum of which is expressed as R . But system a is a part of a hierarchy when its components are likewise systems and when it is itself a component in a more encompassing system, say b . We have:

$$[a = (c_1, c_2, \dots, c_n)^R] \subset b$$

where a is a subsystem of b and the c 's are comparable systems in relation to which a is a supra-system.

The problem is that the confirmation of existence of these intra-systemic and inter-systemic hierarchies encounters serious difficulties: Laszlo himself recognized that the identification of different levels with empirically known entities is often problematic and unclear. I would personally add that I am not convinced that hierarchies (and taxonomies in general) are more than useful tools that allow us to simplify our representation of a reality, which has also non-hierarchical properties.

So I should resume the first point like that: GST studies different kinds of systems which have different properties : state properties, cybernetic stability, adaptive self organization and hierarchy properties. But are they actual systems or only useful models of them? My conviction is that GST cannot give any ontological meaning to its descriptions. I would like to explain why.

2

The ontology of the systems described by GST is not supposed to be known for several reasons:

First, because of the GST method: against classical science in its diverse disciplines (chemistry, biology, psychology, social sciences...), which tried to isolate the elements of the observed universe (chemical compounds, and enzymes, cells, elementary sensations, freely competing individuals...), GST expected that, by putting them together again, conceptually or experimentally, the whole of system – cell, mind, society, and so on – would result to be intelligible. But in order to do that, the most important is no more to be aware of the nature of the elements but, as we have seen, to understand their interrelations: say, the interplay of enzymes in a cell or of many mental processes conscious and unconscious in mind, or also the structure and dynamics of social processes, etc.

Secondly, as Bertalanffy said¹⁴, it turned out that there were correspondences, parallelisms or isomorphisms in certain general aspects of systems which appear, sometimes surprisingly, in totally different systems. So, the actual aim of the theory was the exploration of «wholes» and «wholeness», i.e. of notions which, not so long ago, were perhaps considered metaphysical notions transcending the

¹² E. Laszlo, *op.cit.*, pp. 48-49.

¹³ *Ibid.*, p. 51.

¹⁴ L. von Bertalanffy, *op.cit.*, p. 79.

boundary of science, but that can be now described in terms of scientific explanations. So are hierarchy structure, stability, teleology, differentiation, approach to and maintenance of steady states, goal-directedness, and so on. Henceforward, novel conceptions and mathematical fields had been developed to deal with them : dynamic system theory, automata theory, system analysis by sets, networks¹⁵ or graph theory, and others. So, through this interdisciplinary endeavor, the theory did not aim at the description of systems themselves but at the elaboration of principles and models applying to «systems» in general, providing at the same time a possible approach toward unification of science.

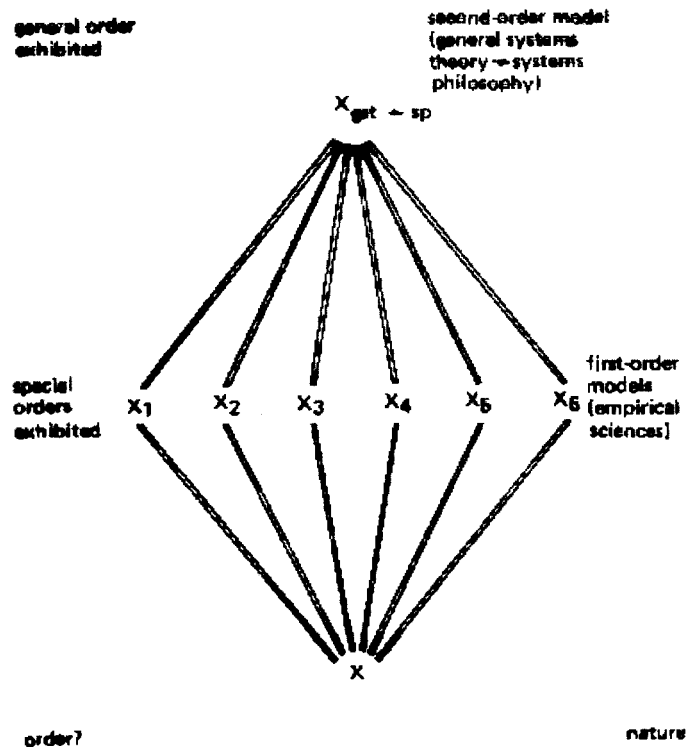
However, GST was more ambitious. Bertalanffy and Laszlo hoped to embrace empirical knowledge in a «systems philosophy». For them, GST constituted a new paradigm, in the sense of Thomas Kuhn, and ended in a new philosophy of nature, with an “organismic” outlook of the world as a great organization. Of course, according to Laszlo, «we may never know whether the "real" world, that ultimate reality which surely underlies our observations and constitutes our very existence is truly ordered, and if so, whether it is divided into distinct types of special orders or manifests one overarching type of systematic order»¹⁶. And so, the only thing we do know is that «our rational mind seeks order and that when it finds it, it validates its own presuppositions»¹⁷. But Laszlo made clear too that not all kinds of worlds could validate all kinds of order, and so, there was to be something about the world we experienced which permitted the validation of certain types of envisaged order. This hope, which was the basic assumption of empirical sciences was also the hope of GST. So Laszlo made some difference between two kinds of models: first order models, which were empirical models of the many sciences and other disciplines dealing with aspects of the experienced world, and second order models, for the building of which systems constructs were possibly the best contemporary instruments. Of course, the objects of GST were first order models of the experienced world. The basic assumption of the theory was then that first order models refer to some common underlying core termed «reality», and that this core was generally ordered. So, special orders elucidated by the many empirical-level models serving as data were integrated into a second-order model exhibiting a species of general order¹⁸.

¹⁵ On the philosophy of network theory, see D. Parrochia, *Philosophie des réseaux*, Paris, P.U.F., 1993.

¹⁶ E. Laszlo, *op. cit.*, p. 139.

¹⁷ *Ibid.*

¹⁸ *Ibid.*, p. 19-21.



GST was supposed to be the optimally consistent framework built «in view of the fitness of systems concepts to remain invariant when passing from one first order model to another, thereby permitting the translation of terms and concepts as particular transformation of the invariance stated in the systems language»¹⁹. Though, as it was said, we had not the capability of knowing what the «real world» could be, however, by building these second-order meta-models, and on the basic assumption which is no more than the one of empirical sciences, GST was able to put in evidence the existence of an overarching type of systematic order.

Certainly, as one can guess it, the argument of an ordering of second-order meta-models holds if holds the argument that there is at least a limited order in nature, so that the regularities we can find are sufficient to allow the applicability of any special scientific theory. But this notion of a «limited order in nature» remains full of vagueness as long as we never know what systems are but only guess what models may be associated to them and compared one another by the use of some big mathematical tools like, for instance, categories and functors²⁰.

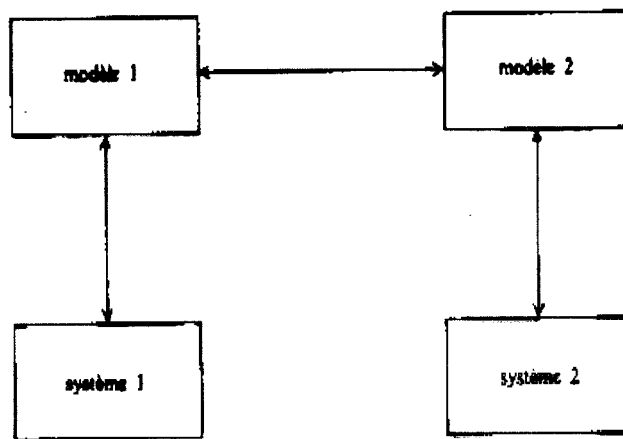
We must see in fact that the concept of system is inseparable of the concept of model. A model may be defined as a representative system of a concrete system²¹. The concept of «representation» has to be understood in the sense of group theory, i.e. as a mathematical mapping. Between systems and models, there is a mapping which can be an isomorphism (one-to-one correspondance), but non necessarily. Generally, it is only a homomorphism (i.e. an injective or a surjective correspondance), so a model may be more precisely defined as a set of properties, which a family of homomorphic systems have in common. Anyway, two systems or two families of homomorphic systems may be compared

¹⁹ *Ibid.*, p. 20.

²⁰ Categories, functors and natural transformations were introduced by Eilenberg and MacLane in the 1940's and describe relations between mathematical objects.

²¹ B. Walliser, *Systèmes et Modèles, introduction critique à l'analyse des systèmes*, Paris, Seuil, 1977, pp. 116 sq.

through their respective models, which can be isomorphic.

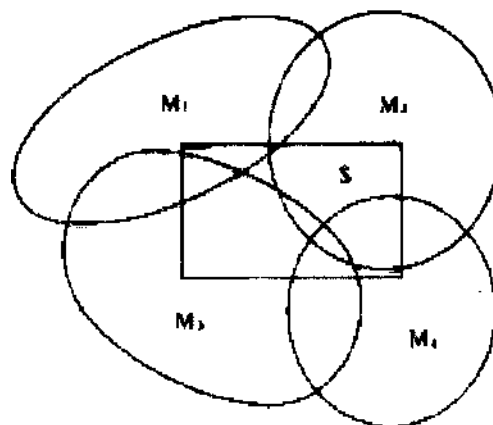


These relations, which suppose that we compare some properties of the systems and some of their models, raise a lot of problems.

First, there are different kinds of properties: some are simultaneously present in the model and in the system (compatible properties); some exist in the system but not in the model (real properties); and some exist only in the model (formal properties).

Secondly, on this basis, we shall say that a model is *perfect* if every property of the model is also a property of the system (in this case, there is no formal property in the model); a model is *complete* if every property of the system is also a property of the model (in this case, there is no real properties in the system). In practice, every model is incomplete and imperfect.

So, for every system S , according to the properties we select to describe it, there are generally a large set of models $\{M_1, M_2, \dots\}$ more or less complete or perfect, the intersections of which being not empty, and making a covering of the system²²:



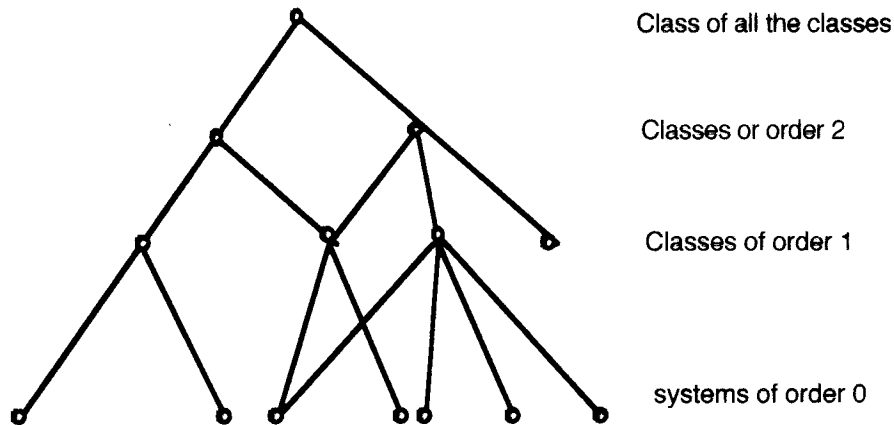
So, in this way, models cannot be easily integrated in a partial or total order.

First, for every model M of a given system S , we have to choose the most representative model of S (but there could be more than one);

Second, these models (graphs, lattices, trees, matrices, analytical curves, etc.), though very

²² *Ibid.*, p. 123.

different from one another, could be integrated in a taxonomy, which lead to some kind of hierarchy or partial order like the following²³:



But in fact, building this kind of structure depends on a lot of choices about index of distances, criteria of aggregation for classes or clusters, and so on.

So, the partial order, if it exists, cannot be unique.

There is also another problem, which is a more basic one: the view of a hierarchically organized reality is logically, if not ontologically, very controversial.

3

I want to draw the attention of the reader on the following fact: until the beginning of the 20th century, at least, the western view of nature, societies, bodies and minds has been founded on the concepts of ranks, hierarchies and the metaphor of tree. Even in mathematics, where we may progressively “strip away” algebraic, topological or ordered structures until all that is left are pure sets, the basic theory of these sets, the so-called Zermelo-Fraenkel theory (or ZF in abbreviated form) is still hierarchic. In the same way, Russell's theory of types, analytical and arithmetical hierarchies manifest partial or total orders.

Since the 1920's, and the new approach of sets by Paul Finsler²⁴, thought up again by Peter Aczel²⁵ in the 80's, a non hierarchical conception of sets has been invented, which is more permissive than Zermelo's one. In ZF theory, we cannot speak of certain kind of sets, the existence of which being however very widespread all over the world, I mean «circular sets». In particular, we cannot write formulas like $B \in B$, or $a_1 \in a_2 \in \dots \in a_n \in a_1$. This is made for avoiding a very well know paradox : the paradox of Mirimanoff.

However, in computer science, economics or linguistics, it is getting steadily harder to avoid dealing with such sets in a formal and rigorous manner. To do so, we use graphic representations. When the sets are not circular, we can represent them by graphs with no loops. Consider, for example,

²³ *Ibid.*, p. 144.

²⁴ Cf. D. Booth and R. Ziegler, *Finsler Set Theory :Platonism and Circularity*, translation of Paul Finsler's Papers on set theory with introductory comments, Basel, Birkhäuser Verlag, 1996. See also D. Parrochia, *Mathématiques et métaphysique chez Paul Finsler*, introduction à P. Finsler, *De la vie après la mort*, Fougères, Encre Marine, 1998.

the very simple sets which could be some sets like that :

$$a = \{a_1, a_2\}$$

$$b = \{b_1, b_2\}$$

We can represent them by some hereditary graphs like the following ones, where a_1, a_2, b_1, b_2 are atoms :



The method is : when some elements is contained in a set, you must draw an arrow between the set and the element.

So, consider now the set $J = \{J\}$. As the element contained in the set is the set itself, in this case, you can draw a loop between the set and itself to represent it. So you have:



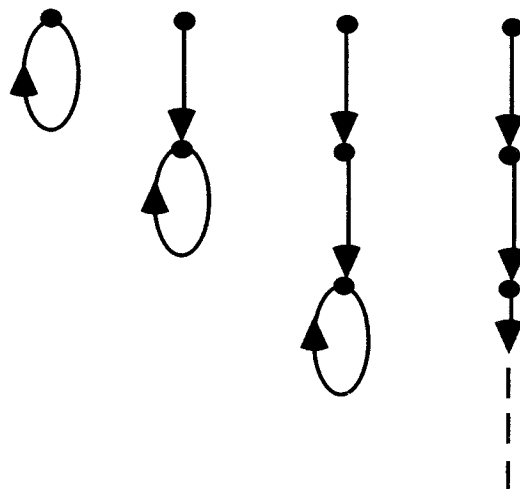
But you can infer from the definition of the that that you have also :

$$\{J\} = \{\{J\}\}$$

$$\{\{J\}\} = \{\{\{J\}\}\}$$

etc.

So, different graphs are depicting this set ant the last is an infinite chain²⁶:



²⁵ P. Aczel, *Non well founded set theory*, CSLI Lecture Notes, Vol.14, CSLI publications, Stanford, California, 1988.

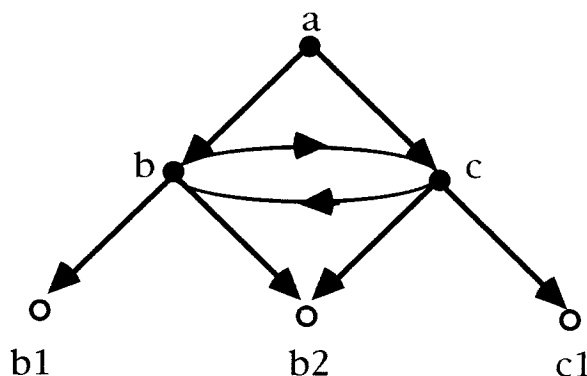
Finally, consider now the sets a, b, c, defined as follows:

$$a = \{b, c\}$$

$$b = \{b_1, b_2, c\}$$

$$c = \{c_1, b_2, b\}$$

Here we have both circularity and atoms. A graph depicting the set a is like that:



Now, in a version of ZF set theory proposed by John von Neumann, there is an additional axiom, the Axiom of Foundation (AF), which explicitly rules out the formation of circular sets like the one above, that is, it rules out sets having themselves as members. ZF set theory is said to be “well-founded”.

But following the proposal of Paul Finsler, Peter Aczel invented a new theory named «non well founded set theory», which is an extension of ZF, and which allows the existence of circular sets or sets with infinite paths, on the ground of an explicit axiom named «anti-foundation axiom» (AFA): every graph depicts exactly one set.

Then, the main result is one can prove that, if ZF is consistent, ZF + AFA is consistent too. In order to prove that, one requires a generalization of the concept of graph, which is a very general notion of system, and this notion can obviously take place in GST.

By a system, one means, here, a class of nodes together with a class of (directed) edges, each edge being an ordered pair (n, n') of nodes. One writes $n \in n'$ if (n, n') is an edge of M. Any graph is a system and any system belongs to GST.

Now we may ask an interesting question: is the set of all the systems of GST circular or non circular? For Bertalanffy, Lazslo, Mesarovic and most of scientists working in GST²⁷, the answer is “non circular”. This is the traditional view of a hierarchical universe. But we can also support an alternative approach, based on the anti-foundation axiom and the non-well founded set theory.

In this way, you are not required to see minds, societies, nature and world as hierarchically organized. In fact, you are not required to see anything at all as hierarchically organized. As surprising it could be, this way of thinking is, in mathematics, a consistent one. Perhaps many people will think it is not very plausible to consider that non well founded sets may apply to domains like sociology or politics. But who knows? Modern societies are very complicated ones and the relations between their members often show graphs with loops. In the same way, computer science, economics, linguistic or natural

²⁶ See K. Devlin, *The joy of sets, Fundamental of Contemporary Set Theory*, 2nd edition, New York, Berlin, Springer Verlag, p. 149.

sciences now commonly deal with circularity. Perhaps the world to come will be a non-hierarchical one.

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²⁷ See, for instance, M. Mesarovic, D. Macko, Y. Takahara, *Theory of hierarchical multilevel systems*, New York, Academic Press, 1970.