# FOOTPRINTS OF GENERAL SYSTEMS THEORY

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## ABSTRACT

In order to identify General Systems Theory (GST) or at least have a fuzzy idea of what it might look like, we shall look for its traces on different systems. We shall try to identify such an "animal" by its "footprints". First we mention some natural and artificial systems relevant for our search, than note the work of other people within cybernetics and identification of systems, and after that we are focused on what unification of different systems approaches and scientific disciplines should take into account (and whether or not it is possible). Axioms and principles are mentioned as an illustration of how to look for GST*. A related but still separate section is about Len Troncale and linkage propositions. After them there is another overview of different kinds of systems (life, consciousness, and physics). The documentary film Dangerous Knowledge and ideas of its characters Georg Cantor, Ludwig Boltzmann, Kurt Gödel, and Alan Turing are analyzed through systems worldview. "Patterns all the way down" and similar ideas by different authors are elaborated and followed by a section on Daniel Dennett's approach to real patterns. Two following sections are dedicated to Brian Josephson (a structural theory of everything) and Sunny Auyang. After that the author writes about cosmogony, archetypes, myths, and dogmas. The paper ends with a candidate for GST*.

**Keywords:** General Systems Theory, unification, patterns, principles, linkage propositions

## SYSTEMS IN NATURE AND ENGINEERING

The footprints manifest as phenomena and scientific disciplines. Different scientific disciplines often use different methodologies and terminologies for the same aspects of reality. Should they resemble more than it is the case nowadays and look for isomorphies and overlapping in order to have a broader insight into reality and avoid multiplication of research and terminology? If not, why not? Do different systems resemble each other more than modern science makes us believe? Is GST* (Rousseau, Wilby, Billingham, and Blachfellner, 2016a) a single set of rules or a presumably small number of such independent sets? A discussion about these and similar questions looks like a good way to identify the footprints and to try, if GST really is the skeleton of science, to reduce it to "bare bones". "Systemness" in nature can for instance be found in thermodynamics, chaos, science of life and consciousness (and anticipatory systems (Rosen, 2012; Nadin, 2010) and teleology), and quantum mechanics (regardless of which interpretation (Penrose, 2004; Price and Wharton, 2015) one votes for, double-slit experiments and quantum erasers (Walborn et al., 2002) do look like systems). More precisely, a strong candidate for GST should reveal whether or not the exemplars of systemness in nature from the previous sentence are relevant and whether they should be improved or replaced by some other systems (system processes) in nature. Also, perhaps such a theory with or without additional details could tell us something about Constructor Theory and the Universal Constructor (Deutsch, 2012), (in)determinism and causality, computation and computability (and similarities and differences between these concepts), etc. GST* might be an outcome of the process of abstraction (Troncale, 2009), i.e. reduction of different systems to their basic ingredients. If that were the case (without the consensus about GST or the set of such theories we can just make assumptions in the rest of this paper), the opposite process of deabstraction would describe specific systems (How long is the line of deabstraction from GST to a specific system/scientific concept?) within different aspects of reality or scientific disciplines. Moving back and forth between abstraction and deabstraction could allow us to assess different systems theories and compare their causal and explanatory power. Another way to assess the strength of a candidate for GST* would be its resemblance to publications by different authors and from different scientific disciplines (McNamara and Troncale, 2012). Systems mimicry (Troncale, 2014a) as an application of GST and insights about natural systems (emerged and selected by nature over millions and billions of years (Troncale, 1986)) to systems engineering (both hard and soft (Adcock, 2016) – including but not reduced to modeling and simulation, computation/computability, and control systems) would at the same time allow new understanding of how to improve engineering and to what extent natural systems such as life and consciousness (Perhaps even interpretations of quantum mechanics (Rosenblum and Kuttner, 2011; Kastner, 2015a)?) can be understood and simulated. A Structural Theory of Everything (Josephson, 2015) resembles aforementioned Constructor Theory (at least they are outcomes of similar mindsets) and the concept of Biomathics (Simeonov et al., 2012) resembles Systems Processes Theory (Friendshuh and Troncale, 2012; there are more systems processes than just more obvious feedback, synergy, and hierarchy) and Linkage Propositions. Those concepts, if they didn't significantly overlap, would at their mature stage communicate between each other.

There are many systems techniques and types of systems. This author is through his formal education (there is also extracurricular knowledge hopefully visible through the text) more familiar with control engineering, living systems, physics, and management than with others. The author actually has his, already published, candidate for GST* and it is difficult for him to write this paper without thinking about it. Hopefully this text is independent and unbiased enough to provide to the reader new insights about systems theory and systems thinking in general.

## CYBERNETICS AND IDENTIFICATION OF SYSTEMS

It should be explicated why this paper is less focused on cybernetics (for elaboration of cybernetics see Ashby (1956) and Wiener (1965)) and more on systems science. There is a confusion about what different people mean by systems theory and what by cybernetics (Troncale, 2009) and in this paper we shall approach to von Bertalanffy (1968) and Boulding (2004) as forefathers of systems science rather than systems theory/cybernetics.

The goal of systems science is looking for systems principles and asking why there are systems, while cybernetics tries to replicate the success in natural science and engineering (cybernetics in the narrow sense actually is engineering) onto systems in general. The success of cybernetics would for instance be nano-machines, enhanced control, computation, and telecommunications, or artificial consciousness and life and the success of systems science would be broader and deeper insights into systems worldview both in space and time (or for instance a proof that artificial consciousness isn't possible and why). Systems science is less successful in "stealing the spotlight" and even defining itself (and demonstrating results) as a respectful scientific discipline. On the other hand, if there are future breakthroughs waiting to happen in any of these disciplines (such as GST* or (in)determinism), they are more likely to happen within systems science. The cybernetic revolution has already happened. Wiener (1965) writes: “the present age is as truly the age of servomechanisms as the nineteenth century was the age of the steam engine and the eighteenth century the age of the clock.” Engineers from established subfields, even in big and interdisciplinary teams, rarely insist that they are doing cybernetics – unless they are developing robots or sensors. They do talk about systems theory and systems engineering as their interdisciplinarity intensifies and perspective broadens. The difference between cybernetics and systems science is similar to Deutsch and Marletto’s (2015) differentiation between predictions from initial data (and identification and modelling) and physical principles respectively (see also Simeonov (2015)).

Bateson (Bale, 1995) covers the middle ground between systems science and cybernetics and in his case it’s just a matter of choice that he writes about cybernetics (as a metaphor in the case of mind and learning) instead of systems science/worldview. He may be a useful source of information or inspiration for those who will try to unify different perspectives on systems and cybernetics. See also Rudan, Rudan, and Karabeg (2015), Simeonov (2002), and Ehresmann and Simeonov (2012) for examples of covering that middle ground.

## UNIFICATION

Von Bertalanffy (1968) and Boulding (2004) were pioneers in systems science. Boulding’s “skeleton of science” and Troncale’s systems processes are the main inspiration for the title of this paper. Von Bertalanffy is inconsistent in his use of the term General Systems Theory (GST), so Rousseau et al. (2016a) suggest GST* for “a theory articulating and inter-relating the principles underlying the systemic behaviours of all kinds of concrete systems”. That is the main topic of this paper. GST* and General Systems Worldview (GSW) could in principle develop a synergy and contribute to development of each other and to the scientific discipline systemology (Rousseau et al., 2016b).

For an overview of different systems approaches and institutions see Troncale (1988). This paper is more focused on unification and wondering why there are systems out there. Out of the lists included in that Troncale’s article, isomorphies are more relevant to the subject of this text than others. He includes isomorphies in many papers he has written, so frequently that isomorphies (systems processes) and linkage propositions could with the insistence on scientific rigour be considered the major part of his life work.

Since there is significant overlap between GST (transdisciplinarity) and Ladyman and Ross’ (2007) opinion of what modern metaphysics should contribute to (unification of scientific disciplines), let’s introduce principles they recommend for this task:

- PNC – Principle of Naturalistic Closure: “Any new metaphysical claim that is to be taken seriously at time *t* should be motivated by, and only by, the service it would perform, if true, in showing how two or more specific scientific hypotheses, at least one of which is drawn from fundamental physics, jointly explain more than the sum of what is explained by the two hypotheses taken separately.”

- PPC – Primacy of Physics Constraint: "special sciences at any time are discouraged from suggesting generalizations or causal relationships that violate the broad consensus in physics at that time"
  How does it work for metaphysics as usual? There are many mental constructs by philosophers of the past. What would happen to someone who doesn't understand and can't properly use Hegel's ideas (just one example among many) about subjective, objective, and absolute spirit (Hegel, 1977)? What kind of damage would I make if I mistreated absolute spirit as individual spirit? Do absolute and individual spirits occasionally leak into objective spirit? Do we owe something to scientific authorities who knew less about science and physics than we do? See Takahashi (2015) for a more enthusiastic interpretation of Hegel's philosophy.

- OSR – Ontic Structural Realism: structure and relations more fundamental than things, to the point of questioning objective reality of things
  Even though this approach looks bizarre from what we expect from reality, it is difficult to see why and when anyone would add things in themselves to a situation explained by relations. The insistence that relations are so fundamental might be problematic to the reader, especially because he/she usually thinks in terms of things. "Microbangings" (Ladyman and Ross, 2007) and spatiotemporally localized points with objects moving on space-time as background are notions inherited from classical physics (different from quantum mechanics and relativistic physics). For systems in quantum mechanics see Dugic and Jeknic (2006). This is a useful definition of things for those who hesitate to let things go: "'Things' are locators for correlations holding across less than the whole universe that manage not to fall apart instantly." Compare this approach to Prigogine's (1997) of state space and probabilities (rather than trajectories) as fundamental for complex systems. See also Bartels (1999) on quantum field theory.

- PII – Principle of the Identity of Indiscernibles
  It is about individual entities (see Bartels (1999) and Deutsch and Marletto (2015)). Ladyman and Ross (2007) discuss about its status (true or false) within quantum mechanics and how it affects the rest of reality.

PNC and PPC might look like very conservative approaches close to materialism and rationalism, but that is not the case. This worldview is faithful to its critique of the "counterintuitive" and open-minded just enough to allow new insights and forbid discussions about non-physical claims such as "The Big Bang was caused by Elvis" (Ladyman and Ross, 2007). PNC, PPC, and OSR are results of trying to provide a context for rigorous unification of science (transdisciplinarity) without prejudices and reliance on metaphysical and religious dogmas and they should be seen that way – as a methodology. In order to have a clearer insight of how to apply it to GST, it can be useful to read what Troncale (1988) has to say about "meso-science" and difficulties with confirmation of hypotheses within systems science. These principles are somewhere between Kuhn's (1996) paradigm shift and physical principles suggested by Deutsch (2012) because they are at the same time (again unification) about generation and assessment of new ideas and about what one can expect from reality. There are similarities between this approach and the AKG (Activity Scope, Knowledge Base, Guidance Framework) model by Rousseau et al. (2016c) that was also used as a checklist (see also Rousseau et al. (2016d)) as this paper was written (the influence of Activity Scope is more subtle but still present). The AKG model strengthened with Ladyman and Ross' work avoids complications with statements such as (What does it actually mean?):

"Nothing supernaturalistic exists, but concrete phenomena cannot all be reduced to Physics" (Rousseau et al., 2016b).

The role of metaphysics should be, according to Ladyman and Ross (2007), unification of disparate aspects of reality and scientific disciplines, the same (or similar) role GST* or an abstract enough systems theory would have in its developed form.

## AXIOMS AND PRINCIPLES

Axionetics (Rousseau et al., 2016d) studies the genesis of both natural and artificial systems (including epigenetics, the anthropic principle, and systems engineering) and "axionetic principles" behind them. It sees entities as wholes within different systemic environments/contexts.

How are we supposed to do abstraction? Abstraction and deabstraction are inspired by Troncale (2009). In his case, abstraction means figuring out the full set of systems processes and developing from them GST or at least allowing improved systems thinking. An example of too much abstraction (abstracting away) is von Neumann (Deutsch, 2012). He was using the term "universal constructor" before Deutsch, but cellular automata are isolated from physics (see also Wolfram (2002)). Considering Boulding's (2004) pessimistic claim that "all we can say about practically everything is almost nothing" and the fact that he was still interested in systems theory, we can compare it with Ladyman and Ross' (2007) patterns all the way down. If natural patterns are hopelessly disjointed, it makes sense to discuss about what keeps them apart. On the other hand, our worldviews and approaches to systems would be significantly affected if we found out that GST* or the universal constructor were real. Deabstraction is about specific systems and creation and understanding of different natural and artificial systems. It is about adding flesh to a (hopefully) properly understood skeleton (GST* or at least its footprints). If we deal with a seemingly too much abstracted candidate for GST* (not the whole skeleton) such as cellular automata or computer simulations (Bostrom, 2003), we might add up bones during the process of deabstraction. Some systems have some systems processes more obvious (exaggerated functions described by Troncale (1988)), but they could actually be (directly or indirectly) relevant not just to specific systems but also to GST. For instance, causation and goal-orientation (How and why animals seem to be goal-oriented?) might be less obvious within different systems but perhaps not totally absent.

Palmer (2014) calls levels of abstraction schemas. Besides of his initial idea and the need to support it with mathematical category theory, it is still in the developmental stage, especially because it is difficult to understand how nature is supposed to use schemas for emergence and maintenance of systems and how engineers could use them for systems mimicry (Troncale, 2014a). It is an open question whether his schemas are properly chosen and ordered and OSR-compatible (if not, why not). "I have had a thought on this situation concerning the GST* Universal Concrete Principles. Thinking about the fact that it is the two distinctions information/entropy and energy/matter which I have posited as the minimal set of principles that I could initially think of as being both universal and concrete.", says Palmer (2015). How do schemas and these principles communicate between each other and create reality?

Sowa (2000) has tried to develop a meta-ontology that he calls Diamond. Palmer's (2014) schemas theory might also reveal something about physical principles. Troncale's axioms are an outcome of a very similar mindset. Auyang (1998) mentions a few candidates for physical principles that are stronger (more fundamental) than physical laws: conservation of energy, symmetry and symmetry breaking, space-time, and causation. The principles that Auyang has found, without properly trying, look simpler than anything suggested by other authors. Jansen (2008) criticizes Sowa Diamond and their "unpolished edges" and thinks that an ontologist must include space-time in his theoretical system. Also, it seems that Ladyman and Ross (2007) criticize theoretical constructs from the past first and foremost in order to minimize noise created by random ideas by random authors focused on what "makes sense" and what is "intuitive" to them – rather than letting physics/empirical science and nature speak for itself.

Troncale is an important contributor to systems theory. He has always been interested in scientific rigour in systems science and continuity on previously published works, in attracting both relevant scientific concepts and scientists. For instance, he looks for systems processes in respectful publications (McNamara and Troncale, 2012). Linkage propositions are about connections between systems processes, an attempt to extract from nature systems principles and a very similar idea to Deutsch's constructor theory. Also, there is "a set of rules governing the system switch to the new level" according to Dodig-Crnkovic (2012). Troncale's work includes what one might expect from GST after "bumping" into it (Troncale, 1984), systems pathology (Troncale, 2013), systems mimicry (Troncale, 2014a; artificial systems inspired those developed and selected by nature over millions and billions of years), and even an idea that theory of everything is actually systems theory (Palmer, 2014; very similar to Ladyman and Ross (2007)). His work on isomorphies and linkage propositions will hopefully be developed by some future systems scientists.

Systems research differs from "regular" science because of its holism and it is challenging to set experiments/methodology and to define results that might affect hypotheses (an old system as the input and a different system as the outcome of experimentation with a real-life system). It is understandable why some people think that systems science should not go beyond engineering (i.e. not a new science) and mere systems thinking. On the other hand, we take natural systems for granted and the theory of emergence of already emerged and established systems is to us what water is to fish. Digital physics (Fredkin, 2003) and cellular automata resemble the idea of systems theory, but in their case it looks much more like information written by a programmer. In the case of systems theory it's more like information embodied within and stretched across patterns. Hence, perhaps any relevant candidate for GST* should from the get-go address real patterns (Dennett, 1991a; Ladyman and Ross, 2007) in order to demonstrate its strength and value.

The other difference between systems science and regular science, overlapping with the previous one, is transdisciplinarity (Rousseau et al., 2016a). Biophysics and physical chemistry are cross-disciplinary sciences (hybrid theories), but genuine transdisciplinarity insists even more on relations, it is more on the relational side of the relations-things divide. It is still in its early stage since it doesn't have its equivalent of the periodic table of elements used in chemistry. Specialization and jargon in scientific disciplines allows scientists (and other people interested in disciplined intellectual activities) to efficiently express their ideas and concepts and improve research and development, but this can also be an obstacle to share ideas and understand scientific ideas with different terminology for the same or similar phenomena or systems processes.

This is the list of systems field axioms (primarily analyzed within hierarchies) suggested by Troncale (1972):

1. Counterparity – equal but opposite (e.g. spin, charge) entities within symmetrical organisms, double-helix DNA, antigen-antibody, etc.
2. Concrescence ratio – the ratio of the total sum of satisfied local counterparities/the total of unsatisfied local counterparities and how it affects stability
3. Neutrality quest – the tendency to satisfy counterparity and reach neutrality or the state of rest, according to Troncale a possible generalization of energy in systems (see also "work" in Deacon (2012))
4. Sphairicity – closing off of levels, sphere of interaction
5. Transgressive equilibration – residual peripheral instability or potential counterparity expressed in formation of new levels
6. Exclusion principle – related to sphaircity or closing off: "the new level experiences some sort of fresh freedom for variation"
7. Cyclicity or turnover – life cycles of cells and organisms, i.e. the cyclic nature of levels of hierarchies
8. Feedback, cybernetics – the output is fed back and modifies the subsequent output and generates stability or oscillations
9. The dynamic interaction of systems field axioms causes evolution of hierarchies

This is the list of physical principles proposed by Deutsch and Marletto (2015; the definitions rewritten word by word from their article and explanations and comments added by the author):

1. Basic principle of constructor theory: All other laws of physics are expressible entirely in terms of statements about which physical transformations are possible and which are impossible, and why. – Instead of making predictions from initial conditions, the focus of this approach is on physical principles behind reality (more fundamental than physical laws). On the other hand, Deutsch and Marletto don't miss the opportunity to claim that "principle I rules out any reference to probability in fundamental laws of physics", i.e. to make their opinion beyond dogmatic.
2. Principle of locality: There exists a mode of description such that the state of the combined system $S_1 \oplus S_2$ of any two substrates $S_1$ and $S_2$ is the pair $(x, y)$ of the states $x$ of $S_1$ and $y$ of $S_2$, and any construction undergone by $S_1$ and not $S_2$ can change only $x$ and not $y$. – Considering Wheeler (1983), Bartels (1999), and Dugic and Jeknic (2006), does "a mode of description" deserve its definition? "In constructor theory, the notion of time does not appear", say Deutsch and Marletto. Perhaps it appears on nature's list of principles (If not, why not?).
3. Interoperability principle: The combination of two substrates with information variables $S_1$ and $S_2$ is a substrate with information variable $S_1 \times S_2$.
4. If every pair of attributes in a variable $X$ is distinguishable, then so is $X$.
5. If every state with attribute $y$ is distinguishable from an attribute $x$, then so is $y$. – Considering this and the previous two principles, how does the hypothetical relevance of these and not some other principles affect Bartels' (1999) opinion that "two

indistinguishable objects are objects that are built up by the same set of Universals, and therefore actually appear to be one rather than two"?

6. Any number of instances of any information medium, with any one of its information-instantiating attributes, is preparable from naturally occurring substrates. – How about substrates preparable from information media (Wheeler, 1983; Bostrom, 2003; Kastner, 2015a)?
7. Composition principle: Every regular network of possible tasks is a possible task.
8. Principle of the consistency of measurement: Whenever a measurer of a variable $X$ would produce a sharp output when presented with the attribute $\{a\} \subseteq \bar{\bar{X}}$, all other measurers of $X$ would too. – Consistency and how to produce sharp outputs look like important aspects of reality and the concept of consistency deserves PNC and PPC compatible elaborations.
9. Any two disjoint, intrinsic attributes are ensemble distinguishable. – This and the previous principles are affected by Deutsch and Marletto's opinion that "probabilities are not allowed at the fundamental level in constructor theory". Would Prigogine (1997) approve it?

Conservation of energy is used as an inspiration. Why is it missing from that list, i.e. do those nine listed look like the most fundamental physical rules? Also, principles that are missing from the list should explain the Heisenberg uncertainty principle (Rosenblum and Kuttner, 2011) and why the idea of participatory universe (Wheeler, 1983) looks so real. How are physical principles imprinted within reality in order to achieve the appearance (Marletto, 2014) of design (explicitly named "design" by Kineman (2003), but actually "dumb" (without PhD in natural science) principles with intelligent-looking manifestations)? Have Deutsch and Marletto from parallel universes chosen the same set of principles?

There is another list from that same article (Deutsch and Marletto, 2015) named "properties of superinformation":

1. Not all information attributes of a superinformation medium are distinguishable
2. Undetectability of sharpness
3. Superinformation cannot be cloned
4. Pairs of observables not simultaneously preparable or measurable
5. Unpredictability of deterministic processes
6. Irreducible perturbation of one observable caused by measuring another
7. Consistency of consecutive measurements of a non-sharp observable
8. Quantization
9. Coherence and locally inaccessible information

There are other lists by Boulding (2004), Miller (1978), Palmer (2014), Sowa (2000), and others. The omission of their detailed descriptions in this paper doesn't make them less relevant and the reader is encouraged to read about them from the original papers. Let us, for the purpose of this text, stay for a while with Deutsch and Marletto's approach. It looks like the use of spheres for celestial mechanics – there is a need for additional explanations of explanations (two lists so far). How and where is nature supposed to remember and apply its principles? Also, conservation of energy mentioned as inspiration but not included on their lists doesn't require any thinking entity to be in charge. Perhaps other physical principles are equally "spontaneous" (conservation of energy is just about a constant amount of something) with containers, relations, and dynamics as everything they need for their manifestation (information embodied (Dodig-Crnkovic, 2012) instead of written). Troncale's approach with the axioms and linkage propositions is more about spontaneity that is difficult to comprehend by outside observers. On the other hand, Deutsch and Marletto's lists look that way because they are focused on (both classical and quantum) computation and avoidance of any doubt about the many worlds interpretation of quantum mechanics.

## LEN TRONCALE – LINKAGE PROPOSITIONS

We have already mentioned linkage propositions. Now we shall discuss about them in order to understand what they are about.

Note that Troncale calls them "linkage propositions" and not "linkages", i.e. they are open for discussion. They are sentence strings with linkages between phenomena such as "is a (partial) cause of", "is a (partial) result of", "inhibits", and "influences" that can be tested and developed by other methods (Friendshuh and Troncale, 2014). They resemble logical statements, but expressed in a way to explain systems-level processes (Friendshuh and Troncale, 2012). The idea is to keep scientific rigour and improve the concept through comparisons with natural sciences literature (McNamara and Troncale, 2012). The goal is to know natural systems and through this knowledge to enable better design of artificial systems (Troncale, 1986).

There is a challenge to form a critical mass of multidisciplinary teams of systems thinkers (Troncale, 1972) willing to dedicate themselves to this kind of uncertain (risking to never be taken seriously by established scientific fields) and long-term research. Simeonov et al. (2012) describe a like-minded team and its challenges and Rousseau et al. (2016e) express similar long-term thinking. See also Wiener's (1965; 1989) contemplation and disappointment about what could have happened, but did not (i.e. our differentiation between cyberneticists and systems scientists was somewhat exaggerated).

This author finds Troncale's approach very interesting and useful for future research. Further elaboration of linkage propositions, even those addressing the assumptions expressed here, would be too much within this specific paper (written by a one-man team).

## IDEAS AND CONCEPTS ABOUT LIFE, CONSCIOUSNESS, AND PHYSICS

Chalmers' hard problem of consciousness (Chalmers, 1996) underlines the need for unconventional interpretations of consciousness, but at the same time places those explanations in the more or less distant future rather than looking for its traces in already published works not admired by Chalmers. For instance, Carl Jung and Robert Rosen aren't mentioned in his book even though their inclusion would pose an important question about what one means by "non-physical" and how exactly non-physical phenomena are supposed to float around and be relevant to physical reality. By insisting on non-physicality and philosophy as the ultimate answer, Chalmers' work is very PPC-incompatible (one could do more justice to Chalmers' work and say that he actually fluctuates between different opinions) because, once we negate physical explanations (and discussions about physics of consciousness), any imaginary explanation would do. That is exactly the case with the inconsistency (being "crazy" as a methodology) of Chalmers' ideas as he fails to tell the difference between machines all the way up and patterns all the way down, i.e. for instance how we are supposed to differentiate between opposite worldviews of Wolfgang Pauli as just another mechanism and anecdotes of Wolfgang Pauli using his paranormal power to break machines (a radical form of panpsychism). The hard problem of consciousness can be an excuse to never try to be consistent and get closer to the solution. Or in Chalmers' words: "It is always possible that I am confused, or that there is a new and radical possibility that I have overlooked; but I can comfortably say that I think dualism is very likely true. I have also raised the possibility of a kind of panpsychism."

Qualia (phenomenal qualities, qualitative feels (Chalmers, 1996)) are hypothetical components/manifestations of consciousness, something that is allegedly non-physical, i.e. irreducible to physical epiphenomena. Although it is understandable why someone would make such an assumption, it is questionable how much explanatory power stays with the "non-physical" realm if we detach it from physical reality. Perhaps it makes sense to talk about a different kind of physical or physical but less obvious in the world without consciousness. For instance, even if the Copenhagen interpretation of quantum mechanics (the concept of qualia is actually more about the first-person experience) is about consciousness causing collapse of the wave function, it makes consciousness deeply involved in physical phenomena (participatory (Wheeler, 1983)) rather than non-physical. A better description would be sub-empirical (Kastner, 2013). Jung's ideas about psychoid components of the psyche are inspired by alchemy and mysticism, but they still belong to physical reality (especially because Jung (1996a) was willing to include causation and quantum mechanics into consciousness research).

Life and consciousness are important exemplars of systems in nature, not just because we are alive and conscious but also because they are difficult to explain. It seems reasonable to assume systems theory or theories behind these difficulties. Chalmers (1996) encourages "crazy" ideas for explaining consciousness, but he goes all over the place with descriptions of what it feels like to be a thermostat and without any organized (instead of getting crazy) attempt to track footprints of GST*. Chalmers' work is, in a way similar to Hillman (1997), good for starting anew and getting rid of dysfunctional metaphysical ideas. They are better in questioning old ideas and methodologies than creating new ones (unless one likes to talk to thermostats). Rosen (2012) on the other hand has interesting suggestions about what makes alive and conscious (anticipatory) systems so special.

Are hermeneutical interpretations (Juarrero, 1999) PNC and PPC-compatible? They partially are because OSR-compatible relations might be so complex and redundant that for instance it makes more sense to talk about how emotions and situations (or morale of a story we've heard) affect our behaviour than about neural inputs and outputs. On the other hand, compatibilism of free will and deterministic physics is seemingly supported by Juarrero (1999) and Deacon (2012) and they both claim that their books explain how it happens. Perhaps this understanding of human freedom isn't directly incompatible with PNC and PPC, but rather with some other principle between them and friendly to both (don't use stronger constraints to what is physically possible than to what is mentally possible – it can also be applied to Chalmers' work).

A layperson is more likely to hear about strangeness of quantum mechanics by a new age guru than through formal education. On the other hand, respectful physicists should be blamed for claiming that quantum mechanics implies consciousness (Kastner (2015b) writes about it but doesn't see her work as quantum physics implying consciousness). Perhaps a systems researcher looking for GST* should consider the possibility that the footprints can be found in works of physicists interested in both quantum mechanics and systems.

Jeknic-Dugic, Dugic, and Francom (2014) use systems approach to criticize the many worlds interpretation of quantum mechanics. It looks like a very strong argument against the interpretation preferred by Deutsch all the while this approach (systems, what is physically possible) is compatible with Deutsch's ideas of constructor theory. In that sense, if their and/or Kastner's work really provides enough reasons to eliminate Everett's interpretation, perhaps it is not just armchair intuitions (Ladyman and Ross, 2007) that have prejudices about what makes sense. Examples of quantum mechanics from the systems perspective such as the Born rule, the aforementioned Dugic and Jeknic-Dugic's articles, and the double-slit and similar experiments are serious challenges for the many worlds interpretation. Without anything resembling collapse of the wave function we would just by pure coincidence end up *every time* in reality compatible with other (not many worlds) interpretations. Perhaps the reason for relative popularity of the many worlds interpretation is difficulties to deal with a very counterintuitive quantum realm – some people choose to kick the can down the road (and turn the Copenhagen interpretation upside down because it looks uncomfortably panpsychic) with an ad hoc pseudo-explanation. According to some proponents of this interpretation, it is computationally simpler. That doesn't seem to be the case because it is actually different (even though we might be persistent in denial of this difference, including refusal to note that experimental results from double-slit experiments with and without interference are different) when we talk about waves (interactions) and an infinite number of coexisting particles (Cantor's big and even bigger infinities is hardly a simpler explanation). Also, Everettian quantum randomness would make us totally random and without any control over our decisions and lives (instead of predeterminism we would be hopelessly random in our infinitesimal corner of the multiverse). And the principle of conservation of energy that was so useful to Pauli would require additional principles and explanations. The discussion about Everett's interpretation inspired by Jeknic-Dugic et al.'s (2014) and Kastner's (2013) papers could be read as a reversal of PNC principle: Out of competing physical theories, eliminate those that do not unify.

Different systems thinkers see differently the arrows of time and causation and their roles in complex natural systems. It is usually about the role of the second law of thermodynamics and how it affects determinism. Prigogine (1997) is a proponent of an idea of indeterminism (Lebowitz (1993) disagrees) among complex (alive and conscious) systems and Auyang (1998) sees it as misleading. They do generally agree that it as an open question. Ladyman and Ross (2007) see causation and thermodynamics as (not) a part of fundamental physics that could only be properly addressed by future physics and physicists. Only (compatibility with) physics can according to this view provide a proper seal of approval. That doesn't mean that non-physicists are inferior, but that institutionalized paradigm shifts are the only viable way of making progress in science and metaphysics (especially about "counterintuitive" issues).

Strange loop (Hofstadter, 1979) resembles an algorithm, but such that refers to itself and creates self-awareness (consciousness). Inspired by Gödel and Turing, Hofstadter claims that self-reference will be incorporated in future artificial intelligence. If we apply Ladyman and Ross (2007) to this concept, it seems that we should ask for physics of strange loops and wonder whether classical physics (and classical computers) is a good enough approximation – especially because Hofstadter is more comfortable with the concept of causation than Ladyman and Ross. Are causal loops realizable on computers that do not permit temporal loops? The first thing computers learn about the world around them is how to do mathematics (to compute – hence their name), but that is not the case with animals and humans. Also, it is strange that, even though his concept of strange loops looks like the origin of free will (see about free will in Kastner (2013) and Price and Wharton (2015)), Hofstadter (2007) denies that we have free will (and writes very little about something so "obvious"). More than three decades after the concept of strange loops was published, we still wait for conscious computers. According to Rosen (2012), that will never happen. Either Hofstadter is a creator of an interesting idea stuck in his refusal to acknowledge that artificial computers will never be capable of that task (Penrose, 1989) or we just have to be patient and wait for a while.

Constructor theory is a physical theory that is more about what is physically possible rather than predictions from initial and boundary conditions. It comes from a similar worldview as structural theory of everything (Josephson, 2015) also elaborated in this text. Constructors are constraints (reductions of degrees of freedom in order to have something coherent instead of a pile of randomness), tasks, or algorithms embedded in nature. They are explanations and reasons why reality looks this way (and what one can expect to experience within it) instead of another. Catalysts (Deutsch, 2012) are a good example and analogy of constructors. Constructor theory is inspired by Pauli's discovery of antineutrinos. In order to explain beta decay and what at the time looked like violation of conservation of energy, Pauli hypothesized mass-less particles. In that situation, the law of conservation was like a physical principle, a rule more fundamental than some other physical laws. Deutsch and Marletto (2015) assume there are other similar principles, laws below laws that tell the difference between the physically possible and impossible. The goal of their research is to understand on a deeper level information and computation on both classical and quantum levels. Important components of constructor theory are knowledge and tasks and genetics and biology are also valuable sources of inspiration and potential insights. This work is still in its early stage and what interests us here in the first place is the universal constructor – the constructor that unifies other programmable constructors and that is presumably short.

The reader might complain about the omission of some big names in systems theory (a long list of those dealing with systems thinking and those who have perhaps tried and failed with GST*) in this paper (lesser known ideas by big names in physics Einstein (a letter (Einstein, 2011)) and Pauli (Jung, 1978b) are used). This is not an overview of who has written what, but rather in the true spirit of transdisciplinarity looking for traces of systems theory in surprising places. Those places are among authors who, instead of having a sense that GST* is real and taking a pen in order to write something (and each time create their own hierarchy, diagram, and/or axioms), "bump" (Troncale, 1984) into its footprints on the wall of a specialized silo and see in unification the only way to move forward (instead of being stuck in the dangerousness of their knowledge (Malone, 2007), radical problems (Rousseau et al., 2016a), and unexpected insights). If we look at something the same way everyone else looks at it, we shall see what everyone else sees (there is a similar statement attributed to Einstein). The approach to unification of scientific disciplines and development of GST encouraged in this paper is compatible with PNC principle by Ladyman and Ross (2007). Also: "These diagrams are very useful as teaching aids, conveying the evolution of the systems field and the contributions of its leading figures, as well as showing the synergies between different systems disciplines and orthodox ones. We contend however that they are inadequate as research aids for developing the subject matter further, which is the area this paper aims to support." (Rousseau et al. 2016c).

Children have causal expectations about events they have never experienced (Ladyman and Ross, 2007). They expect causal dependence even when they still know nothing about scientific logic and experiments. Proper systems thinking would provide us insights we wouldn't have otherwise. Make your own comments and comparisons about thinkers from Table 1 and aforementioned children. Can proper systems thinking help us to provide for them the future they deserve?

**Table 1. A 3-Year-Old child as a Systems Thinker**

| Issue | Systems thinker | Rival |
|---|---|---|
| slavery | Aristotle | 3-year-old child |
| Nazism | Martin Heidegger | 3-year-old child |
| war | a systems thinker | 3-year-old child |
| 2 * 2 = ? | the latest computer | 3-year-old child |

## DANGEROUS KNOWLEDGE

The TV documentary "Dangerous Knowledge" (Malone, 2007) is about the life works of Cantor, Boltzmann, Gödel, and Turing. They had "counterintuitive" insights about reality: Cantor in mathematical sets and infinity (Zenkin, 2004), Boltzmann in thermodynamics, Gödel (1931) in logic, and Turing (1950) in computation. Turing was the most establishment-friendly: he was slightly more on the pro side about computability of consciousness and during the Second World War actively helping the winning side. At the later stage of his life he was betrayed by society (as a homosexual) and the other three scientists were more "betrayed" by their unfinished work (one reason why "danger" is in the title of the documentary). Gödel had demonstrated that there are truths that cannot be proven with specified axioms. On the other hand, later he tried to mathematically prove intuition and seemingly contradicted his own proof against finitism (Tait, 2013). Cantor's work is about the size of infinitesimally small and infinitely big objects (numbers, amounts). Boltzmann's work challenges physical certainty and determinism in a way that is still unresolved within scientific community (Is Prigogine (1997) right or wrong with his notion of indeterminism?) All of them represented "counterintuitive" (Ladyman and Ross, 2007) ideas at the time when other people didn't have them. In this author's opinion, those ideas without taking care about physical reality and without attempts of unification of scientific disciplines are flawed in a way analogous to von Neumann's cellular automata (mathematics disconnected from the rest of reality). An interesting detail is that Turing (1950) saw extrasensory perception (ESP) as a potentially real phenomenon.

The example with particles in a box and how long we should wait in order to experience all particles to spontaneously move towards one half (Poincare recurrence time (Bricmont, 1996)) resembles the question how fast will be the fastest person ever. A non-systemic answer would be: "Somewhere between Usain Bolt and the speed of light." It's more likely that such a person will with his (at the moment male humans are faster) speed be closer to Bolt than to light. But we can't tell for sure the lowest impossible speed or how tall will be the smallest professional basketball player. For that box we can never be sure what deviation from equilibrium is "reasonable" (One, two, even ten particles don't have pressure and diffusion, but "many particles" have it). Gaussian curves are approximations of reality, but that doesn't mean just that we can't properly compute. In the same way it's difficult based on empirical data to tell the difference between determinism and indeterminism. That's where some theory may improve our understanding of life, consciousness, and other forms of systemness even if it's difficult to prove.

The problem of halting a Turing machine is important for comparison of artificial computation/intelligence with our consciousness. How does our "Turing machine" halt when it achieves a satisfying result? It is interesting that Hofstadter (1979) analyzes this problem from the point of view of computation and Penrose (1989) does it from the point of view of physics and mathematics. May we use PNC and combine them? Let's quote Penrose (2004; OR means objective reduction):
"A standard position is that of computational functionalism, according to which it is merely computational activity (of some suitable but yet unspecified nature) that gives rise to conscious mentality. I have argued strongly against this view (partly using reasoning based on Gödel's theorem and the notion of Turing computability—see §16.6), and I have indeed suggested that consciousness actually depends upon the missing (gravitational) OR theory. My arguments demand that this missing theory must be a non-computational theory (i.e. its actions lie outside the scope of Turing machine simulation, §16.6). Theoretical ideas for producing an OR model of this type are in a very preliminary stage, at present, but possibly there are some clues here."
It seems that, according to Penrose's view, there is an analogy between collapse of the wave function by gravity and "halting" of something more advanced than Turing machine. Is this the place to look for GST, for a theory that addresses that either directly (just GST) or indirectly (deabstraction after we have added flesh to the bones)? How far is your favourite candidate for GST away from addressing this task and why? This Turing's (1950) quote is about minds, but it can also be read as if it refers to other systems and to Boulding's skeleton (Boulding, 2004), abstraction (Troncale), and GST* (Rousseau et al., 2016a): "In considering the functions of the mind or the brain we find certain operations which we can explain in purely mechanical terms. This we say does not correspond to the real mind: it is a sort of skin which we must strip off if we are to find the real mind. But then in what remains we find a further skin to be stripped off, and so on. Proceeding in this way do we ever come to the 'real' mind, or do we eventually come to the skin which has nothing in it? In the latter case the whole mind is mechanical."

## PATTERNS ALL THE WAY DOWN

Embodied (strongly coupled) information is difficult to comprehend because it isn't written anywhere (see also Maturana and Varela (1980) on autopoiesis and embodiment). Proto-information or potential information has a property of being able to become information in an infinite number of ways. That is a different kind of reality than Cantor's infinite number of dividing a line and it's less "dangerous" (unify-able science and reality beyond mathematics of written equations) than in the documentary Dangerous Knowledge. Although the author has difficulties to elaborate this statement in a way that would be satisfying to each reader and point out where Dodig-Crnkovic (2012) claims the same thing (similarly to patterns all the way down, that insight is spread all over Dodig-Crnkovic's article), that doesn't make the conclusion less accurate. We are not computer simulations and artificial self-awareness isn't possible, but there will still be people who aren't willing to accept that "I am not a computer simulation" is also information. Every human being would understand that the Earth, if observed from distance, isn't flat. The same kind of proof just isn't possible for systems (applications rather than experiments (Troncale, 1988)), especially if claims that we can do something and soon enough are more attractive to potential sponsors with a surplus of money and deficit of understanding. Information contained within complex systems can be read in the infinite number of ways and naysayers are free to read it in a way that fits their skepticism, especially if (PNC) the concept of teleodynamics is still missing (the consensus about) physics of teleodynamics. The neologism "teleodynamics" and some other concepts used by Dodig-Crnkovic are inspired by Deacon (2012). Even if she is proven wrong by future systems researchers for choosing Deacon's ideas as GST* (exoskeleton), she may still be important for systems science.

This is a definition of real patterns rewritten from Ladyman and Ross (2007): "To be is to be a real pattern; and a pattern $x \to y$ is real iff
(i) it is projectible; and
(ii) it has a model that carries information about at least one pattern P in an encoding that has logical depth less than the bit-map encoding of P, and where P is not projectible by a physically possible device computing information about another real pattern of lower logical depth than $x \to y$."
This definition relies heavily on OSR-principle. It is difficult to elaborate what it says (for instance, logical depth is similar to length of a causal chain), but hopefully one can get some idea about its meaning and what makes it relevant to this paper by comparing it with Dodig-Crnkovic's (2012) strongly coupled information and this quote by Ladyman and Ross (2007): "As noted, clause (ii) of the analysis expresses the principle of Occam's razor, in restricting ontological commitment to what is *required* for a maximally empirically adequate science. The razor has sometimes been interpreted in a stronger way, as suggesting that ontologies should be not just restricted but *small.*" Compare these ideas to a radically different worldview by Bostrom (2003) who thinks that, if reality can be simulated, we and the world around us are probably within a computer simulation. It seems that the only way for someone to come to this conclusion is to ignore (among other details) strong coupling of information in nature ("a perfect simulation of a perspective (namely one that has all the same information content as the target) thereby just *is* that perspective and *physics* should not be expected to distinguish them" (Ladyman and Ross, 2007)) and turn OSR-principle upside down. Also, the definition presumes the possibility of unification into metaphysics/GST.

Projection from that definition is about information transfer (Troncale, 1988) and: "'Projectibility' is the concept of information-carrying possibility—applied now not to channels but to models of real patterns and ultimately to real patterns themselves" (Ladyman and Ross, 2007). Projection and projectibility are synonymous to Dodig-Crnkovic's (2012) natural computation. Also note similarities to constructor theory (Deutsch, 2012). Due to complexity of the concept and in order to provide a clearer insight what it is about, let's quote Ladyman and Ross' (2007) explanation: "$x_L \to y_L$ is *projectible* if (i) there is a physically possible M that could perform the projection $x_L \to y_L$ given some *R* and (ii) there is at least one other projection $x_L \to z_L$ that M can perform without changing its program. (Condition (ii) is necessary to avoid trivialization of projectibility by reference to an M that simply implements the one-step inference rule 'Given input $x_L$, output $y_L$'. Projectibility, unlike projection, is a modal notion and so has stronger conditions for applicability.) Intuitively, then, projectibility is just better-than-chance estimatability by a physically possible computer running a non-trivial program. Estimatability should be understood as estimatability in the actual world that science aims to describe, not as estimatability in some class of merely possible worlds."

There is a strong analogy between computation described this way ("Any physical system that a mind could use for processing information, if there were any minds around, is to count as a computer." (Ladyman and Ross, 2007)) and computation we expect from computers. Because of this confusion one can easily face while trying to understand similarities and differences, let's try to explain it in a less rigorous (but hopefully equally serious in attempting to address something that seems to be important to General Systems Theory) way in the next paragraph.

We are obviously processing information each time we think and our inability to comprehend how we are doing it doesn't make it less real. The first thing computers do is mathematics. Ladyman and Ross (2007) in their book mention Dennett who mentions (imagine a computer mentioning another computer quoting another computer... without frying its chips) an idea by the artificial intelligence researcher Patrick Hayes that computers or robots should be "naïve" and wrong about physics just like we tend to be. We begin our conscious lives as terrible mathematicians and amoebas are even worse. But, the fact that we are open systems is an important piece of information about what we do and how. Neurons do have something that looks like bits of information or weight within a neural network, but not really. Information processing and the substrate where it takes place are much more mashed together than in the case of computers (Bostrom (2003) disagrees). The only way to delete physically embodied information is to physically destroy it (including its witnesses). It's information regardless of whether or not someone can take it and carry around. We aren't built and the fact there is a continuum between us and our common ancestors is also important information, even if it isn't written anywhere. We are self-aware from the get-go, even when we don't understand that we are self-aware. The fact that I slept last night in order to be able to write a (hopefully) coherent text isn't my flaw – it's a very important part of how I'm doing it. So, a computer prone to making errors, forgetting birthdays and anniversaries, and "naïve" as we are would just be a very bad computer.

## DANIEL DENNETT – REAL PATTERNS

We have already included concepts explained in this section (hopefully the reader had some idea about meaning of the expressions "pattern" and "bit map"). We use these belated detailed explanations of Dennett's work for further elaboration of patterns (relevant to GST), computation (especially its natural equivalent), and computability.

Ladyman and Ross' (2007) work on real patterns is inspired by Dennett (1991a) who writes: "I want to show that mild realism is the doctrine that makes the most sense when what we are talking about is real patterns, such as the real patterns discernible from the intentional stance." Bit maps and real patterns are related to randomness: a truly random phenomenon is incompressible and nothing short of a complete bit map can be used for its description. Ladyman and Ross are inspired by Dennett as they try to unify his work on real patterns with logical depth (a measure of computational complexity) and thermodynamic depth (the minimum amount of entropy that must be produced during a state's evolution; logical depth is preferred).

This theory is both about patterns in nature and our inherent capacity to recognize patterns even in a noisy environment. This spontaneous ability of humans to notice patterns within data Dennett calls folk psychology (Dennett, 1991a). It is very difficult to understand (regular folk has it and experts can hardly understand it) how it emerges in our minds in order to replicate it in computers and artificial intelligence. He adds intentional (and not just physical and chemical) terms to the list of entities with causal power and even mentions Aristotle's final cause (extensively elaborated by Deacon (2012) and Juarrero (1999)) in a footnote. He also assumes that beliefs and language (our inner dialogue) have an important role in how we discern patterns.

For illustrations of patterns Dennett (1991a) uses pixilated images (algorithms for drawing images) with added noise and Game of Life (cellular automata). A universal Turing machine can be in principle constructed on cellular automata (and Game of Life). Dennett uses them as an illustration of (in)compressibility of information contained within patterns. His work is like a middle ground between Deacon and Juarrero, although they go deeper into abstraction and speculations. Dennett's mention of real patterns seems to be more on Deacon's (his love for neologisms) side and intentional stance (a noise emitter as an agent with beliefs and desires and intentionality or "aboutness" (Dennett, 1991b)) is more on the side of Juarrero's hermeneutics.

The topic of rival interpretations in that Dennett's article is very relevant to systems science and opportunities and limitations to experimentation within systems. It makes sense that Ladyman and Ross (2007) are so much inspired by Dennett.

This quote is a good illustration of what Dennett's ideas are about because it captures real patterns (systems), minds, and self-awareness (Dennett, 1991a): "These intermediate regularities are those which are preserved under selection pressure: the regularities dictated by principles of good design and hence homed in on by self-designing systems. That is, a 'rule of thought' may be much more than a mere regularity; it may be a wise rule, a rule one would design a system by if one were a system designer, and hence a rule one would expect self-designing systems to 'discover' in the course of settling into their patterns of activity. Such rules no more need be explicitly represented than do the principles of aerodynamics that are honored in the design of birds' wings."
There is something about that quote that reminds of Troncale.

## BRIAN JOSEPHSON – A STRUCTURAL THEORY OF EVERYTHING AND LAW WITHOUT LAW

Josephson's structural theory of everything (Josephson, 2015) goes further than other (with an exclusion of Deutsch and Marletto, although they differ already at the level of physical principles) attempts of unification of quantum and systems theory. His approach is based upon Wheeler's (1983) ideas (Josephson, 2012) of participatory universe and conscious observers as an important part of a genuine theory of everything. In order to understand where Josephson's ideas are coming from and are focused on, one should note that he was trying as a young Nobel Prize laureate to connect people with different backgrounds in order to research consciousness. Systems worldview has been present in both his attempts to bring together different people and where to look for answers about consciousness. His more recent work is a continuation in that direction.

Instead of being satisfied with a statistical approach to quantum mechanics, Josephson (2015) wonders what happens within individual quantum events and sees Barad's agential realism and Kastner's reality of possibility as the most promising attempts, i.e. starting points for his research. He sees in the unification of self-organization and emergence with Barad's and Kastner's ideas the beginning of a theory more fundamental than quantum mechanics.

Barad's agential realism is a development of Niels Bohr's concept of indeterminacy that sees quantum phenomena as indeterminate (instead of uncertain) and context-dependent. The difference is that Barad (according to Josephson (2015)) goes further than Bohr in not being focused just on what happens during experimentation, but sees lack of autonomy among structures as fundamental, i.e. "relationships precede relata" (note similarities to aforementioned Ladyman and Ross (2007) and Dennett (1991a)). He introduces into quantum mechanics discursive practice used in other mechanisms and control and the active aspect of matter (configurability and self-organization) known from biology. The active aspect of matter is analogous to Eigen's hypercycles and Josephson compares it to learning (he sees similarities between development of objects and development of object concepts). It is responsible for self-sustaining changes.

Kastner's possibilist interpretation of quantum mechanics sees observations as outcomes of transactions with possibilities. Possibilities are considered physically real, but not necessarily manifested. Josephson (2015) sees possibilities "as *aspects of discourse* rather than something real" (emphasis Josephson), but this author fails to understand the disagreement between Kastner and Josephson (they *are* different individuals with similar and different interests and Josephson is more focused on cosmic possibilities). Wheeler (1983) writes about unobserved reality "of a paler and more theoretic hue", so it isn't clear on what kind of disagreement between him and Kastner Josephson insists.

Evolutionary agential realism is Josephson's attempt to combine the aforementioned ideas with Wheeler's observer-participancy of quantum mechanics. Participatory universe is analogous to measurement in quantum mechanics, but goes much farther into cosmology and emergence of everything that exists. Josephson compares it to cultural evolution within a different context.

Josephson (2015) sees parallels between this primordial matter organizing itself and mathematical and musical intuition. In a way his ideas resemble Dennett's intentional stance (Dennett, 1989), i.e. both authors have hints about something that is fundamental to information in nature and difficult to investigate and explain. There is a feeling that both point to something (GST*?) that is missing from their theories.

In a way similar to Rosen (2012), Josephson (2012) claims that non-quantitative science such as biology is more fundamental (this approach doesn't seem to contradict Ladyman and Ross (2007) – the difference is what one means by "more fundamental") than quantitative physics. Wheeler's observer-participation and emergent laws appear naturally within this, non-quantitative, framework. It seems from this point of view that dynamics and attunement and even signs and meaning (influenced by Peirce's semiosis, just like Deacon (2012)) are more fundamental than a theory trying to explain the smallest physical objects. He suggests the scheme: primordial reality → circular mechanics → semiotics and structure → technological development → regulatory mechanisms → emergent laws. "Technological development" from the scheme should not be understood as panpsychic and anthropocentric, but rather in terms of dynamics in action from the title of Juarrero's (1999) book. Josephson (2012) clarifies it when he writes (about the three components sign, object, and interpretant used by Peirce): "With such a grouping there is no essential difference between the three components, and all three can be considered interpretants, each interpreting signs originating in the other two systems, and also the interactions between these two."

There are moments in Josephson's writings that look like footprints and a sketch of GST* (it's up to future systems researchers to tell whether or not that really is the case). He doesn't see it as a fully developed theory, but rather announces it when he writes (Josephson, 2012) about coupling of systems and reduced degrees of freedom of a joint system. Such systems are difficult to describe in quantitative terms. This situation reminds him of Gödel's incompletes theorem and true statements that cannot be proven with specified axioms. Their viability is the criterion biological systems (and other systems that are outcomes of dynamics in action) need to pass the test.

It is interesting that structural theory of everything as a still incomplete idea initiated by Josephson at this stage looks strikingly similar to Deacon's (2012) and Juarrero's (1999) work, although they both hesitate to see it as something that might contribute to physical theory and emergence of physical laws. That doesn't necessarily mean, considering Deacon's and Juarrero's approaches, that GST* has anything to do with Aristotle's four causes, but that could be the case.

Combined with Prigogine's conclusions, if they are right, it seems that observer participation with other related or isomorphic systems processes is responsible for the arrow of time and "the end of certainty" (Prigogine, 1997). If this is the path GST* or some theory strongly connected to GST* will take, the arrow (symmetry breaking) of time and the difference between determinism and causality (whether or not retrocausality (Peijnenburg, 2006; Kineman, 2011; Price and Wharton, 2015) is real and possible and what it means for our participation within reality) needs to be elaborated by future researchers.

Josephson's (and Wheeler's) and Deutsch and Marletto's ideas come from similar mindsets even though it seems they disagree on plausible interpretations of quantum mechanics. Everett's many worlds interpretation looks like a forced attempt to get of rid of any notion that consciousness collapses wave functions and Wheeler is known for going into the opposite direction. Which reality looks friendlier towards conscious/self-aware inhabitants: the one where the cosmic Turing machine halts/collapses the wave function or the one where it explodes into an infinite number of states?

Let's end this section in the spirit of the claim that different people occasionally bump into footprints of GST* and quote Josephson (2012) when he sounds like Troncale: "Nature is pervaded by patterns (signs) which through practice we have become expert in interpreting, a process that has pragmatic value even if it is not amenable to the traditional quantitative methodology. If the picture developed here is correct, there is much more in the way of meaning to be found in the natural world by such means than can be found through the traditional methodology of science."

## SUNNY AUYANG – A PROTOTYPE OF A MODERN SYSTEMS THINKER

Auyang is a physicist with a broad interest in systems: economics, evolutionary biology, statistical physics, quantum field theory, engineering, and mind. Her work includes an equal amount of systems thinking and speculations about systems theories. She is the only author mentioned by Troncale (2014b) with publications about complex systems and natural science focused on several systems processes.

It is difficult to write an overview that would do justice to her work because her writing style is challenging to follow, but worth the effort. She is competent enough to use rapid back and forth movements between abstraction and deabstraction and a patient reader can really have insights of what a system (either natural or engineered) feels like. She seems to be mentioning many different footprints of GST* (depending on what GST* turns out to look like) either as hints or more explicitly. It is difficult to capture the spirit of her books in texts such as this one.

In her book on foundations of complex-systems theories Auyang (1998) combines economics, evolutionary biology, and statistical physics. She is focused on synthesis of these scientific disciplines and looking for general structures and she is curious about the same mathematics applicable to different topics. She criticizes “the tinkering process” (reductionism and focus on smaller and smaller details) as insufficient because it distracts us from seeing the holistic nature of (for instance) evolution of organisms and the outcome is a failure to understand novelties such as wings. She writes about stochastic and ergodic (ensembles of objects) systems, (arrows of) time, and the role of causation and probability in physical reality. She reaches von Bertalanffy’s level of curiosity and dedication to systems research without a single mention of his name in this specific book (he is mentioned in her book from the following paragraph).

Her book on engineering (Auyang, 2004) is at the same time a historical overview of engineering and description of systems worldview applied to engineering (engineering of different systems, engineering and society, formal and informal education, teams, entrepreneurship and leadership, and relationship to science, research and development). She is focused on electrical engineering, information and control, energy, mechanical engineering, chemical engineering, aircrafts, materials, and bioengineering. A significant part is about systems thinking in engineering. It is also about ways to access and deal with information about both technical/physical and human aspects of problems. She uses historical examples to illustrate what present and future engineers might experience. The book can be useful to engineers as a reminder and inspiration for getting adequate knowledge needed for different requirements and ethical engineering and to keep in mind systems perspective.

Her book on quantum field theory (Auyang, 1995) is the most difficult to follow. It contains densely written philosophy. It is the first published book out of four and their chronological order makes sense (they are ordered here from arguably the most relevant for systems science and with the broadest perspective) as she was distancing herself from thinking and writing just about strictly physical systems. Auyang wonders why there is quantum field theory at all. Instead of choosing her favourite interpretation she builds a complex theoretical and mathematical structure needed for people to set aside their everyday thinking and properly articulate quantum phenomena (just as we easily comprehend classical physics in all its inaccuracy). At least that is her idea because one may assume that her writing style and elaboration of concepts such as fiber bundles (it reminds of Deutsch and Marletto’s (2015) search for physical principles) would be overwhelming even to experts.

Auyang in her book on mind (Auyang, 2001) writes about “open mind” that emerges within its environment and as such differs from designed artificial “minds”. This model includes the open mind, mind’s infrastructure, and emergence (i.e. relations between them). It is less difficult to read and on the surface less rigorous than her other books. But, as usual for Auyang, she includes a wide range of topics. The strength of that book is its breadth, but it is like a long announcement of GST* of minds that never happens. For some reason, Einstein's (2011) four types of thinking from another Auyang's book (Auyang, 2004) is about creativity and includes a detailed description of something that looks like a candidate for GST* of consciousness. There are publications that go deeper than Auyang into mind (Thompson, 2007; Dennett, 1991b; Chalmers, 1996) and open mind (Turchin 1977; Ogle, 2007; Clark and Chalmers; 1998).

Auyang leaves open the question of time and causation. She does address everything relevant to these topics, but doesn't provide conclusions. She barely mentions Prigogine and calls him "misleading". In the debate about free will (Auyang, 1998) she for some reason sees compatibilism (deterministic physics and non-deterministic mind somehow sharing the same reality) as a genuine idea on the same level with determinism and indeterminism.

Her approach to systems resembles Ladyman and Ross (2007) as they begin with non-classical physics and its "counter-intuitive" aspects and wonder about unification and synthesis. On the other hand, they refuse to make any opinions and conclusions about determinism and interpretations of quantum mechanics. Dennett (1989) prefers beliefs and interpretations as a predictive strategy (the intentional stance in his case) and a way to move forward and either confirm or refute an approach.

Auyang is a competent systems thinker. Still, when she writes about systems engineering (Auyang, 2004), she uses extensively jet fighters as an example. If readers didn't already know, they wouldn't learn from her book what it looks like when jet fighters fight. Do not look for systems view on conscience in Auyang's writings. Our increasing human capability to "fight" isn't followed by our maturity to avoid conflicts. Wiener (1965) was working on shooting down enemies during the Second World War and refused to participate in such activities during the Cold War (Wiener, 1989). But, to be honest, aggression and altruism *are both* legit systems perspectives (the more you fight, the more you get).

## COSMOGONY, ARCHETYPES, MYTHS, AND DOGMAS

Are symbols and myths manifestations of the system Jung calls the collective unconscious? They are supposed to provide relatively universal narratives and lessons abstracted from different individual and societal situations. In the age of astrophysics and the theory of evolution, is there any place left for a reasonable person to be religious and/or spiritual and care about myths and metaphors?

Ancient mythologies and cosmogonies look like accurate or inaccurate systems theories. Ladyman and Ross (2007) encourage radical breaking away from metaphysics of the past exactly because of irrelevant mythology and its equivalents hidden behind the veil of peer-review and publications. Still, that doesn't mean that daydreaming, poetry, and metaphors should be forbidden, but rather that we shouldn't learn about flying machines from the myth of Icarus or about the Big Bang from myths about genesis.

Archetypes (Jung, 1996b) resemble instincts but in a more conscious way, as if they have minds of their own. They are components of the collective unconscious, images of objects of admiration or threat waiting to appear in our conscious lives. Stories and myths may contain universal messages and wisdom, but that seems to be rarely if ever (in an obvious way) affected by GST*. On the other hand: "a GST* would have to encompass all kinds of concrete systems, and thus also ones with properties that are still mysterious from the perspective of physical science e.g. agency, will, intentionality, volition, consciousness, creativity, and self-awareness" (Rousseau et al., 2016d).

If GST is real, it is the one and only most complete metaphysics (others can either join during deabstraction and specific life-cycles and situations or be applied to a narrower set of systems). That is exactly what a fundamentalist would say about his religion or cult (see also Dennett (1991a) on beliefs and perception of patterns). That is one more reason to use PPC and PNC – to have scientific ammunition for fighting against (and winning or losing) or trying to unify already established scientific and religious/spiritual ideas. Regardless of how GST* looks like (if it exists), it will be up to the systems of many humans to decide in a democratic and peer-reviewed manner whether or not it should be used. If it addresses a significant number of issues included in this paper (and perhaps some others), that will be an overload of insights and serious questioning of already habitual ways of thinking and doing. Inclusion instead of reductionism (Troncale, 1988) would have opponents on many fronts, regardless of its quality. One must be familiar with many scientific disciplines in order to create and assess a candidate for GST*. Its success in reaching consensus also depends on different individuals and how much they are willing to gamble and bet on a single theory.

Ancient cosmogonies are stories of emergence, evolution, and systems. They are also about creation for those who believe in a creative, conscious, and/or goal directed entity behind or above reality. There are deities (or Holy Trinity in Christianity) in religions and mythologies and also Enneagram, Sephirot (the tree of life), analogies between human body and animals in anthroposophical view of human body and consciousness, the tetragrammaton (the four letters in the true name of God and their Kabbalistic/mystical interpretations), five Chinese elements, tattvas, Pythagoreans who believed in mystical powers of numbers, people looking for the Golden Mean and Fibonacci numbers in both natural and artificial patterns and proportions, etc. Some of these ideas are less frequently mentioned in scientific publications (hence the omission of references in the previous sentence – that doesn't necessarily mean that they are irrelevant), but that shouldn't be the sole criterion for differentiation between more and less scientific or serious ideas. Humans are not novices in looking for systems and patterns and finding either genuine systems or just figments of their imagination. There is something inherently human in looking for systemness, just as in looking for fragmentation. It is more difficult to tell differences between right and wrong ideas about systems theory or metaphysics than in case of some other fragments of reality with either clearly defined inputs and outputs or with written down contents, hence the number of candidates. The market of more or less arbitrary candidates for GST is saturated and that was probably the main reason why Ladyman and Ross (2007) are "rude" towards metaphysics of the past or why Marletto (2014) talks about appearance of design without intentional design.

So, systems theory and its equivalents under different names enter a terrain of mythology and religion. Even though in this case the story of genesis is supposed to be based on a more scientific basis, there is a chance of cultic behaviour, especially if the same GST* manages to reveal broader and deeper insights (a conflict with reductionist "heretics"). Politics resembles a cult when a politician is someone more often seen on TV and it could just as well happen to someone whose ideas about better systems are backed-up by scientific publications. That is, it can happen if we don't include delusion and manipulation into systems worldview.

An interesting variation of Jungian ideas is Hillman's (1997) work. He supports random imagination (letting the soul speak for itself) with very little or totally without conscious control (he even calls it "pathologizing") and allowing that realm wherever consciousness emerges from (i.e. refusal to make any real or delusional guesses about GST* of consciousness) to spontaneously express itself. He was interested in systems thinking, but without any obvious prejudices (starting every day anew without any sense of discipline and responsibility is also a prejudice or habit). Since he didn't have any artistic talent or something entertaining that would attract laypersons to his point of view, he chose Persona (a mask, a role played in front of other people) of an eternally young eccentric individual and turned a lack of dogma into a new nihilistic and escapist dogma. Mind you, this is just one way of interpreting Hillman and the other would be that he exaggerates some Jung's ideas about imagination and fantasies in order to bring them "to the streets". He insists on spontaneous dynamics of the psyche and promotes a life-style as if the collective unconscious is self-regulatory and inherently good (Hillman, 1992) or as if he doesn't care about consequences. Violence and misunderstanding in nature and society as manifestations of unconstrained imagination and fantasies tell a different story. Hillman's approach is neither good nor bad. It all depends on how we apply it (or not). See a critique of Hillman's work by Winther (1999).

## A CANDIDATE FOR GST*

The author hopes that this section will be seen as separate (as much as it can be) from the rest of the text. Without the consensus from scientific community, it is just speculations.

Deacon (2012) and Juarrero (1999) have similar (to the point of accusations for plagiarism) ideas about Aristotle's four causes and their application to the theory of consciousness. They prefer to apply their work to consciousness (and life in Deacon's case) than to systems in general, but Wurzman and Giordano (2009) and Dodig-Crnkovic (2012) disagree. It is interesting that Aristotle's four causes are mentioned by multiple authors such as Kineman (2011; inspired by Rosen (2012)), Auyang (2004), Ladyman and Ross (2007), and Heidegger (1977). Hence, if one looked for General Systems Theory in already published scientific work, Aristotle and his four causes would be "the lowest-hanging fruit" and as such it should be at least considered.

Rosen (2012) claims that biology is a more fundamental scientific discipline than physics. In order to make this statement compatible with PNC, it should be seen as:

(i) real patterns all the way down, but also all the way up,
(ii) a need to expand physics and causation (whatever that might be (Ladyman and Ross, 2007)) in order to include life, consciousness, and anticipatory systems.

Deacon's concept of absence (that is, depending on how some future scientific community will see it) is a way to eliminate non-physical or non-materialistic ideas about consciousness. Constraints (Deacon, 2012; Juarrero 1999) reduce degrees of freedom, but they do that in such a way that matter can become goal-directed. At least that is what Deacon claims – that Newtonian physics allows non-Newtonian behaviour of consciousness. Since natural phenomena are indifferent about whether or not they are within limits of human comprehension, it is for them irrelevant what a creator of an interesting idea (Deacon) thinks about its compatibility with classical physics. It would be compatible with PNC to conclude that non-determinism of teleodynamics (in life and consciousness) is incompatible with physics reduced to determinism. Ladyman and Ross (2007) insist that physics should have the last word in explanation of phenomena and unification of science. Deacon stops just a step before he reveals interesting insights about causation in physics.

How to compare Deacon's and Juarrero's ideas to other attempts? First of all, they don't even call their work General Systems Theory (although Juarrero is very familiar with the concept). If someone else, independently or not, wrote again Miller's (1978) or Boulding's (2004) theory or Sowa's (2000) diagram (lattice of categories, i.e. "diamond"), the accusation of plagiarism would be much stronger. It would be even stronger if someone wrote that Elvis is behind the Big Bang without mentioning Ladyman and Ross (2007). That is, the real GST (and metaphysics) is something that might be figured out independently by different authors and even by extraterrestrials from another galaxy.

Carl Jung insists on the primordial nature of the quaternion – four elements of reality as hinted to him through his visions and conversations with his patients. He (1978a) describes four psychological types (more precisely eight if we multiply by two: extraverted and introverted). Since those who have come after Jung had failed to empirically prove their existence as psychological types, it would be more accurate to call them four psychological functions: thought, emotion, senses, and intuition.

Einstein's "four types of thinking" are elaborated by Auyang (2004): experience ($E$), creation ($E \rightarrow A$), deduction ($A \rightarrow S$), and experimentation ($S \rightarrow E$). $A$ are axioms and $S$ resultant propositions. It resembles both Jung's psychological functions and Aristotle's four causes, but not in a straightforward way (the reason why this text is the first time someone addresses the similarity; it deserves a separate publication): effective cause/thought is spread over deduction and experimentation, material cause/senses is about experience, and formal cause/emotion is spread over experimentation and experience (how one feels about the outcome of experimentation and whether the context (constraints on thoughts) should be improved). This lack of straightforwardness hopefully doesn't pose doubt (in this specific model of mind) about the permutation of psychological functions and Aristotle's four causes (such as thought and efficient cause in the same column) used in Table 1. On the creation ($E \rightarrow A$) part Auyang writes: "Einstein explained that the leap is intuitive; logical methods such as induction may help but are never sufficient. This point he stressed in many writings, as in examples of atomic theories: 'The theoretical idea (atomism in this case) does not arise apart from and independent of experience; nor can it be derived from experience by a purely logical procedure. It is produced by a creative act.'" What is missing from (Auyang's interpretation of) Einstein's (2011) approach is a PNC-compatible theory of intuition and creativity (The same phenomena as in Gödel's unfinished work (Sieg, 2006; Tait, 2013)?).

As far as we know, there are also four physical interactions. Ladyman and Ross' (2007) concept of patterns all the way down is especially influenced by quantum mechanics and fundamental physics.

If we add to them, hopefully accurately chosen, physical principles (we shall use here something similar to Auyang's "principles" from the section about axioms), perhaps we have all that we need in order to figure out the universal constructor (Deutsch, 2012). This is a candidate for GST* (or at least a theory strongly related to GST*) created by this author and already published (Malecic, 2015). It is interesting that the row in the table with the physical principles (Jung, 1978b) is developed by Pauli (from Jung's suggestion) – the very same scientist (Nobel Prize laureate) who had inspired Deutsch (2012) for his constructor theory (and physical principles).

**Table 2. Self-Referential Complex Systems (Copyright © 2015 [IGI Global]). Reprinted by permission of the publisher.**

| | | | | |
|---|---|---|---|---|
| **Cause (Aristotle)** | material | formal | efficient | final |
| **Psychological function (Jung)** | senses | emotion | thought | intuition |
| **Physical principle (Jung and Pauli)** | conservation of energy | space-time | causality | synchronicity |
| **Physical interaction** | electromagnetic | weak | strong | gravitation |
| **Explication** | **billiard balls** | **orthograde** | **contragrade** | **teleology** |

Is that table compatible with PPC, PNC, and OSR? It gives a priority to relations over things (OSR). It is motivated by modern science and fundamental physics and, if we consider it as a real possibility, it suggests new insights about reality (PNC). Hopefully it doesn't violate PPC especially because this author (Malecic, 2015) was writing about the most fundamental scientific discipline and claiming that properly developed General Systems Theory would be more fundamental than other sciences. It is more about how we define "fundamental" than any genuine disagreement, especially because it is difficult to draw a line between metaphysics according to Ladyman and Ross (2007) and GST*.

Palmer (2014) warns about falling apart of the theory in Kineman's (2011) approach if we see Aristotle's four causes as axioms or a completely circular meta-causation (arrows and holon sequences in Kineman's diagrams). Table 2 looks like an algorithm, but of a special kind – that describes itself (see also Hofstadter (2007)).

This approach at the same time addresses Prigogine's (1997) indeterminism, Josephson's (2015) structural theory, and consciousness/creativity. It "tames" each aspect of dangerous knowledge: Gödel and Turing on mind and computation, Boltzmann's on thermodynamics and (in)determinism, and Cantor's infinity as an outcome of reduction to efficient cause (abstracting away other causes, i.e. the difference between potential and actual (Zenkin, 2004)). Also compare the infinitesimally small (or infinitely precise) and seeming indeterminism of the second law of thermodynamics as seemingly an outcome of coarse graining and our incomplete knowledge (Bricmont, 1996). An author similar-minded to the author of this paper (a similar worldview and different descriptions) is Jargodzki (2009).

Many living authors mentioned in this paper are informed by the author and they had enough time to express their disagreement. On the other hand, this author agrees that only physics and physicists should approve the ideas presented here. Hopefully the inclusion of the table will not spoil the reading experience that readers had before the arrival to this section. The author eagerly awaits critique, especially if it is merciless.

Considering Tegmark (1998) and the ultimate ensemble, what kind of physical/mathematical reality does permit systems?


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