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SoSPT I.:
IDENTIFYING FUNDAMENTAL SYSTEMS PROCESSES FOR A GENERAL THEORY OF SYSTEMS

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ABSTRACT

This paper is one of a series that further develops the System of Systems Processes Theory (SoSPT) which is an attempt at unification of the results of a wide range of systems theories and natural science experiments to enable development of a true “science” of systems. The central purpose of the SoSPT is to achieve a very detailed description of “how systems work.” In this paper we explain our work of identifying fundamental systems processes found in some form in many systems. We explain why we focus on isomorphic processes as a practical and useful framework for unifying diverse systems theories at the necessary abstraction level for a general theory. We begin with a definition of “process” in general and distinguish this from a “systems-level” process. We present arguments and evidence that support the position that systems-level processes are fundamental to the origin and maintenance of systems of all kinds and thus important for synthesizing the very fragmented systems literature. We argue that the natural science literature (e.g. astronomy, physics, chemistry, geology, biology, mathematics, computer science) constitutes studies of real, successful systems by the scientific method and so also are a key source that must be integrated with the synthesized systems literature to achieve a unified “science” of systems. Earlier versions of SoSPT presented ~110 systems processes. Here we introduce some of arguments used to determine if a candidate system process remained on the list or not to reduce the list to a more manageable 55 candidate systems processes. As examples of this procedure, we cover sixteen specific, individual, surviving candidate systems processes to illustrate the arguments used to decide whether or not to include each on the list. This is a work in progress and the list will continue to change as the concept of system processes is further examined and understood and new SPs are discovered and elucidated. It is important to note that this is a recursive process because puzzling over the candidate systems-level processes will discipline our definitions and criteria for recognizing new and judging current candidate systems processes. The paper concludes with insights gained from this effort and with a projection of work yet to be completed for a true “science” of systems to emerge.

Keywords: System of Systems Processes Theory, SoSPT, natural systems sciences, systems-level processes, science of systems, system of systems, how systems work

Capsule Outline:

- Brief History and Purpose of this Effort: How Systems Work
- Why Should A General Theory of Systems Focus on Processes?

- Definition of Process
    - ✓ What is A Systems-Level Process?
    - ✓ What Makes A Systems-Level Process Fundamental and Isomorphic?
    - ✓ Even Structural Patterns Result from Processes
    - ✓ Criteria for Selecting Processes
    - ✓ Table One: Original List of 110 SPs
- Sixteen “Representative” Systems-Level Processes -- Working Discussion
    - ✓ Boundaries
    - ✓ Chaos
    - ✓ Competition
    - ✓ Cycles
    - ✓ Duality
    - ✓ Emergence/Origins
    - ✓ Feedback
    - ✓ Fields
    - ✓ Flow
    - ✓ Fractal
    - ✓ Hierarchy
    - ✓ Networks
    - ✓ Self-Organization
    - ✓ Storage
    - ✓ Symmetry
    - ✓ Variation
    - ✓ Table Two: Recently Curated & Compacted List of 55 SPs
- Systems Process List as a “Framework” for Unifying the Systems Literature
- How Would SoSPT Qualify as A “Science” of Systems?
- Future Work: Reconciling SoSPT and the Natural Sciences Literature
- Literature Cited

Brief History and Purpose of this Effort: How Systems Work

In 1978, Troncale published the initial paper of this series as an attempt to formulate a framework for research efforts that could lead to an integrated general theory of systems. Earlier, he had attempted to explain the appearance of certain isomorphic structures (e.g. hierarchies) found widespread in natural systems by the interaction of what he then called “systems field axioms” (Troncale, 1972). The axioms were ultimately renamed systems processes and their very specific interactions called “linkage propositions.” The result was a highly specified network of general dynamics consistently found across many extant systems. Like the natural sciences, he emphasized increased resolution and specificity that he felt was missing in most systems approaches of the time. This resulted in subsequent papers that increased the number of systems processes to 110 with many more linkage propositions defining the mutual influences between the systems processes (Troncale, 1982, 1986, 2006). While detail, specificity and linkage to experimental testing/verification were the immediate goals, significant abstraction was simultaneously required to capture these similarities through the comparison of the particular nature of the processes across many different natural sciences and different size scales of real systems. Meanwhile, many other workers were beginning to identify systems processes true in their particular manifest systems although mostly not identified as part of the proposed field of systems science.

A main difference between this and other approaches to systems theory and systems thinking (systems analysis, systems simulations, systems management, soft systems methodology) was the focus on answering the simple question: “how do systems work, particularly natural systems?” For example, while systems management and soft systems techniques seek to understand specific systems of interest to humans, made of humans, or how to intervene to improve human systems, or even how to define one system boundary vs. another, this approach seeks understanding of how systems work in general; how systemness comes into being, not just human systems. The point was to explain the observed similarities of natural systems that self-organized and remained stable from 14 billion years ago up to those appearing today using the same set of isomorphic or universal processes. Since these systems were in perpetual existence and sustainability long before human consciousness came into being (a mere 1 thru 7 million years ago), SoSPT avoids the endless and seemingly fruitless philosophical and political debates over whether we create systems in our minds or they exist, out there, objectively.

The purpose of this paper is to report on and extend the discussions of which processes to include in the SoSPT model and which to exclude or condense. What is the smallest number or minimal set of systems processes needed to provide a strong explanation of how systems work? Another purpose is to develop an explicit set of criteria for judging what to include or exclude as the work continues.

Why Should A General Theory of Systems Focus on Processes?

It is interesting to note that the many successes of natural science have derived mostly from increases in understanding how nature works, that is, by what processes it works that we then turn to our use. The natural sciences study phenomena and the way they study phenomena is to do experiments whereby nature tells us details about the processes by which the phenomena work. The list of systems ranges from the first sub-atomic systems that emerged from the big bang, across astronomical systems such as the galaxies and solar systems emerging from the big bang, through chemical, geological, and biological systems to social/human systems. Especially in the vast literature of the natural sciences, focus on process has resulted in reliable detail. Consider such processes as continental drift, gravitational collapse, the standard energy interactions of subatomic particles, valence in chemistry, photosynthesis, DNA synthesis and genetic inheritance, and many more. All of these are processes that were elucidated in great detail by experimentation and measurement. One could say science is the accumulated knowledge of processes across these many systems. They tell us the mechanics of how many things work.

In the SoSPT we are looking for the “mechanics” of how systems in general work -- why they are able to exist as systems. We are not seeking an answer to a philosophical “why” as much as an answer to a process “how”. Notice we are not using the term “mechanics” in its original sense, either in science, industry or human discourse. Our use involves non-linear causation, elements of indeterminancy and chaos that were not part of the traditional logical positivism school of thought.

Some in the systems field react negatively to mechanical reductionist methods of understanding nature. They see it as an obsolete way of looking at the world. We understand this position, but find it to be an over-reaction. These methods still provide a lot of value. The way things work provides valuable insights at a more fundamental level than other descriptions. Understanding how systems work increases our ability to structure a better quality of life, especially human life. It should be obvious that increases in quality of life, even species survival depends on our future ability to solve our current crisis problems of social and hybrid human-natural systems. We are asking, what can study of systems and their ways of accomplishing change (process mechanisms) tell us about improving those hybrid systems?

By its very nature and definition, as enshrined in the four original purposes of the ISSS (International Society for the Systems Sciences)[go to http://isss.org], a general theory of systems (GTS) results from extensive comparisons between many different scales of reality, different disciplines, different domains, and different tools. In other words, ISSS is more than interdisciplinary, it is transdisciplinary by its covenant and the nature of what it seeks to do. SoSPT posits that it is most productive to look for commonalities of "<u>process</u>" across these disciplines, domains, tools and scales. Since the natural sciences have focused centuries of work on elucidating processes on each scalar level of reality, the huge literature of the natural sciences provides a rich treasure ripe for harvesting vital and fundamental information on universal processes from comparative study of non-human and man-made systems. Understanding systems processes and their mutual impacts and influences in one context should help us understand them in other systems contexts. So for (1) better applications; (2) better documentation; (3) better potential for synthesis and integration; (4) better diagnosis of malfunctioning systems (which we call top-down systems pathology; Troncale, 2011a); (5) better design of new systems of all kinds, it would be helpful to have a deeper understanding of how healthy systems work or have worked in the long past. And SoSPT posits that the best way to do this is to identify and document universal or general systems processes.

Definition of Process

We define a process as a series of steps of change through which a set of objects proceeds. This includes the modern concept of parallel processes or a network of processes such that the steps are not necessarily linear. SoSPT suggests widening the concept of process to all cases wherein an entity is subject to detectable influence and change. We can identify the process from the background because of the regularity with which the steps or identifiable changes occur across the many duplications of the system.

We maintain that each of the steps, and even the sequence of steps, as well as the observed change conditions are obligatory in the ideal, abstracted case, which might be called the "representative" or the "typological" case. We recognize that we may encounter in nature a possible diversity of what might be called "flavors" or "variants" on a particular sequence of steps with some individual steps excluded, exaggerated, or transmuted for particular functions. But we want to emphasize that the identity and function of a process depends on the existence and recognition of a set of steps and their sequence. Without recognition of this basal condition, we would not be able to integrate across the set. This is typical of the human condition. In order to recognize the genus or family of a species, we first had to recognize the consistent pattern across the whole range of individual species phenotypic variation.

Usually a process has evolved in nature to accomplish some necessary function. So identifying the function of a process is as important as identifying its recognition features. We have to be careful about changes in function through the processes of cooption or exaptation across long-term evolution (Gould & Vrba, 1982). Functions may change over time. If the function of current focus was not necessary at the time of the original system origin, it must have subsequently become necessary to the new systems that were derived from the original system. For example, from current interpretation of paleontological data, swim bladders and feathers had one function at one point in evolutionary time, but their presence enabled their use for a future function (air breathing lungs, flight) that enabled an entire new lineage of descendent systems. This may be true for systems in general beyond the biological example. In fact, the entire unbroken sequence of origins from cosmos to now is replete with examples of new systems originating with new functions enabled by the many systems preceding them with other functions.

A process is dynamic. It causes change while it is based on change. But since the identity and sequence of changes are always the same, we see it as a regularity that is constant despite the many different entities in which it is found or variants that it subsequently produces. There are several different types of photosynthesis or chemosynthesis, but all are variants on the same dynamic process. So despite its dynamic and active nature, it is also meta-stable when compared across many particular systems.

A more modern view of the old word "process" is algorithm. It is used more in computer science and mathematics. An algorithm is some expression of the finite set of changes that must be performed to transform a given set of inputs into a defined output. One can express this set of changes in language, computer programming, or mathematics. But, in a sense, nature has been performing "algorithms" of change for 14 billion years.

We compared definitions of "process" from some 31 different domains of study, from natural systems (the natural sciences) to human to artificial systems to get a general definition. The surviving or consistent 9 hallmarks recognizing "process" anywhere were: "dynamic," "change," "from finite & defined," "starting to ending state," via a "required/obligate sequence," "of steps," "reproducible," "algorithmic," and yielding "a definable systems-level function."

What is A Systems-Level Process?

Chemosynthesis, photosynthesis, continental drift etc. are processes in nature that exhibit the above 7 characteristics, but they are not what we mean by "systems processes." In the SoSPT model, a "systems" process is defined as that series of steps typical of surviving systems that adequately fulfills a needed systems function when considered at the abstract systems level. All three natural processes just cited work on entities on their level (bacteria, plants, vast crustal plates), but all also have feedbacks, cycles, boundaries as part of the process at the material level. Notice that our emphasis here is on "systems" function, not function on the "particulars" level. While a process in a natural science phenomenon (continental drift, metabolism, subatomic particle interactions) is defined by the action of the particulars on that scale, a systems level process is not dependent on the particulars at all. It is the "pattern" of interaction (perhaps we could call it the shape or "architecture" of interaction on the abstracted general level) that is the defining element. So the pattern might be what we call "positive feedback" but the particulars manifesting the positive feedback might be cosmic dust on one scalar level, sound waves on another, reproducing organisms on another, or financial instruments on still another. The particulars interact with the mechanisms of their particular scales of objects, but it's the general relationship of interacting parts that we focus on for the systems-level description. This requires abstraction from the particulars – exactly the opposite of the focus of the natural sciences. The "systems-level" process fulfills a different set of "functions" on the abstract systems level than the functions fulfilled by the interaction of the particulars on the local level. For example, one systems-level-function might be recognized as "sustaining systemness" on the systems level whatever the particulars of the system are.

In addition, the general pattern of interaction is exactly similar (isomorphic) across the many different log scales and types of manifest systems (i.e. natural entities) in which it occurs. One cannot find the sub-atomic particle interaction on the climate level or the ecosystem level. In fact, it is subsumed and nonactive by one of the lost four "E's" of the original GST writings – the Exclusion Principle. But when one captures the class or type of structure of interaction on the abstract level, this allows comparison and recognition of similarity. Isomorphic systems processes are Discipline-independent, Domain-independent, Tool-independent and Scale-independent. That is what makes them systems-level. Recognition of systems-level processes saves us from the DDTs poison, that is, restricting our attention to isolated Disciplines, Domains, Tools, and Scales. Remaining on the DDTs level is "poison" to any attempts to perceive the general systems level.

What Makes A Systems-Level Process Fundamental and Isomorphic?

Heraclitus never really said exactly "Nothing is permanent except change" but that is the most economical expression of his insight, "you can never step into the same river twice," that we most like. If everything experiences change, then everything is consistently subject to processes that cause the change. That is why science is so successful when it focuses on studying and measuring processes with its method and tools. The universality of change processes renders them fundamental.

A process is isomorphic if its abstracted, generalized "form" or "pattern" can be found at many scales in many phenomena (Gr. iso- = same as, equal; morpho- = form). The system processes that we have identified can be found from the subatomic particles to galaxies and in fields as diverse as economics, biology and physics (see Auyang, 1998 for example). In each of these scales and domains, there is something fundamentally the same when one's viewpoint is at the system level, i.e. process level of abstraction. We are speculating that some system processes may be limited to some minimum level of domain complexity. So it will be very important to specify and document precisely in which (disciplines, domains, scales) a systems processes is found and applicable in the cases when it is not fully transdisciplinary, and in which it is not. In addition, some currently identified system processes may just be more complex forms of more fundamental processes found in all domains. We have found that some systems processes are prerequisites for others. These corollaries need to be further explored and their associated fertile questions remain to be answered. Until that time, a key working tenet of SoSPT is to regard ALL candidate systems processes as fundamental enough to be regarded as axiomatic – this to avoid the widespread tendency to make one's favorite or best known isomorphy the single most fundamental process.

Structural Patterns Result from Processes: SoSPT Focuses on the Process That Causes Structure, not just on the Structure

Sometimes the regularity or demonstrated pattern or isomorphy found across different systems appears to be a structure, such as fractal form (Mandelbrot, xxxx) or hierarchies (Salthe, 1985; Simon, 1996; Wilson, xxxx). While the SoSPT focuses on <u>processes</u> that are the same across different particulars (so integrative or synthetic), it also includes <u>structures</u> like these that are common to many systems. So what is the relationship between regular and similar "structures" in nature and regular and similar "processes?" SoSPT treats structures and processes as transforms of each other, like phases of the same system (water, gas, ice), or like energy and matter are transforms of each other. Thus, we sometimes use the word "structurprocess" to transcend what we consider an artificial duality based on limitations and traditions in human perception and thinking. Although we have not found the direct quote, we understand that Bertalanffy (the father of general systems theory) once wrote that structure is "slow" process, and process is merely “fast” structure. This is essentially the same idea. So we include seemingly isomorphic structures with isomorphic processes in our listings.

Both structures and processes can be similar across many different systems. SoSPT insists on tracing isomorphic “structures” to the processes that give rise to the structure. It is interesting that in many cases, certainly for hierarchy and fractals, the literature is far more informative about the “structure” found across different particular systems than revealing the process that gives rise to the structure. In biology, there exists a huge literature on the interdependence of “form and function” (~9 million hits on Google) which to us, in this transdisciplinary field of general theories of systems, translates into “form and process.” Future research needs to allocate more time to revealing the process generating the structure.

Criteria for Selecting Processes

SoSPT endeavors to produce and work on the most parsimonious list of isomorphic systems processes, yet miss none that are relevant. We continue to use the seven criteria for limiting the Integrative Themes to Principal Systems Concepts (PSCs) of the original paper in this series (Troncale, 1978) or its educational applications (Troncale, 1993). But we have added additional criteria. The current list includes the following (not in order of importance):

(1) fulfills the working definition of “process;”
(2) fulfills the working definition of “systems-level;”
(3) can be proven to be isomorphic; found in all mature systems; all sciences
(4) can be demonstrated to increase persistence or sustainability of manifest systems;
(5) has very rich associations or influences on the other systems processes;
(6) exhibits all of the identifying features for that process;
(7) rich in associated literature of empirical or experimental or formal data;
(8) is domain-independent, discipline-independent, tool-independent, and scale-independent;
(9) illustrates key disciplinary phenomena for each case study;
(10) understood in sufficient detail;
(11) recognized by workers in relevant specialties;
(12) has exemplars of application to improve systems functions in defined contexts;
(13) enables citation of the range of systems for which it is present or valid;
(14) represents an intriguing advance in human knowledge in itself;
(15) can be used to teach or train others in detailed knowledge of how systems work;

Table One lists the starting set of candidate Systems Processes we intended to compact, shorten, justify using these criteria. Clearly applying these criteria to “test” each and every candidate process is an iterative and evolving task. We eliminate all terms that function as human descriptive expressions, all terms that are naming human-based methods, all that designate classes or taxonomies humans use to talk about systems, and such. The terms remaining are supposed to be only those that describe how systems work. Thus many of the purely human terms found in catalogues, dictionaries, and encyclopedia’s are eliminated (e.g. see Francois, 2004). We consider this a very important strategy. Some of the terms below are similar to others but we use them all to ensure rigorous inclusion. One of the persistent problems in systems theory is the lack of a widespread consensus on explicit criteria for even recognizing a systems-level theory much less the elusive general theory of systems. A consensus on requisite processes and only those requisite processes might help form the needed consensus on GST criteria.

TABLE ONE: The original working list of Systems-Level Processes Used for Compaction:

1. Adaptation Processes
2. Allometry, Systems-Level
3. Allopoiesis
4. Amplifiers as a Process
5. Ashby’s Conjecture (Requisite)
6. Asymmetry as a process
7. Attractors
8. Bifurcations
9. Binding Processes
10. Boundary Conditions as a Proc
11. Boundaries as Universal Constants
12. Catastrophe Processes
13. Causality Processes (linear vs. non-)
14. Chaotic Processes
15. Circuits & Network Motifs
16. Closed Systems
17. Competitive Processes
18. Complexity Processes
19. Concrescence P’s
20. Constraint Fields & Analysis
21. Cooperative Processes
22. Counterparity Diagrams & Proc’s
23. Criticality, Self-
24. Cycles and Cycling P’s
25. Decay, Autolytic & Senescent Proc
26. Deterministic/Directive Process
27. Deutsch’s & Dollo’s Conjecture
28. Development Patterns & Laws
29. Dissipative Processes
30. Diversification Processes
31. Duality-Complementarity Mech's
32. Dysergy as a Process
33. Embodiment & Subsumption Proc
34. Emergence Processes
35. Energy Processes
36. Entropy, General
37. Entropy-Dissipation Processes
38. Equifinality as a Process
39. Equilibrium & Steady State Proc’s
40. Ergodic Processes
41. Evolutionary Processes
42. Exaptation, Cooption as Processes
43. Exclusion Principle
44. Feedback, Coupled
45. Feedback, General
46. Feedback, Negative
47. Feedback, Positive
48. Feedforward & Anticipatory Proc
49. Field Processess & Potentials
50. Flow Processes
51. Fractal Structure (as a Processes)
52. Functions, System (Purpose)
53. Growth Patterns & Laws
54. Hierarchies & Clustering as a Process
55. Hypercycles
56. Information-Based Processes
57. Input Processes
58. Instability Mechanisms
59. Integration Processes
60. Interactions, Binding, Linkages
61. Least Action/Energy Principles
62. Limits, Informational
63. Limits, Physical
64. Limits, Wilson-Troncale
65. Maximality Principles
66. Minimization Principles
67. Metacrescence as a P
68. Morphodynamic Processes
69. Motif’s, Circuits, Subgraphs,
70. Network Structure & Processes
71. Neutralization as a Process
72. Non-Equilibrium Thermodyn-Irrever
73. Open Systems Processes
74. Origins Processes
75. Oscillation Processes
76. Output Processes
77. Pathology Processses
78. Periodic Processes
79. Phases, Stages, Transitions
80. Pleioetiology as Process
81. Pleiotrophy as Process
82. Plenitude, Principle of
83. Potential Spaces or Fields
84. Power Laws, Cross-Disciplinary
85. Quantum Processes
86. Recursive Processes
87. Redundancy Processes
88. Replication Processes
89. Scaling & Scaled Processes
90. Self-Organization & Autopoiesis
91. Singularities
92. Soliton Theory (Long Waves)

93. Spin Processes
94. Stability Processes
95. States, Systems
96. Steady State Mechanisms
97. Storage Processes
98. Structure as Process
99. Sub-Specialization Processes
100. Symmetry, Systems-Level as a Proc
101. Synergy as a Processes
102. Synchrony as a Process
103. System Identification, Sub-, Super-
104. Systems of Systems Processes
105. Thermodynamic Processes
106. Tipping Points
107. Transducer Processes
108. Transgressive Equilibrium
109. Variation Processes
110. Zipf's/Pareto's Relation as a Process

Representative Process-by-Process Working Discussion

We do not intend to cover arguments for inclusion, compression or elimination of all 110 candidate Systems Processes in this initial paper of the series. So we have rather arbitrarily selected ~15 to serve as examples of the 55 Systems Processes that have made it to our current working list. Each short summary will attempt to cover the same five items, namely: (1) a basic, overview definition of the process; (2) how it is a process; (3) how it is a systems-level process and isomorphic; (4) why we included or excluded it from the working list; (5) a sample of some of its identifying features or functions or influences on other systems processes. Please note that our purpose here is not to provide a comprehensive presentation of these systems process examples. Rather our purpose is to explain how we reduced the list of processes to consider to half the original number to enable greater manageability and eliminate redundancies.

These introductory comments serve only to open an intended and hoped-for long-term discussion, not to represent the range of arguments for these candidates, many of which have been the subject of book-length treatments. In fact, the electronic database being assembled for SoSPT and its various delivery systems[22], anticipates in-depth coverage of a dozen categories of knowledge on each systems process. Beyond the 5 cited above, these additional categories will include: (6) discinyms for the process (if they exist) and some indication of its isomorphy or limits of its isomorphy; (7) how it influences other systems processes (early indications of the Linkage Propositions between System Processes and that of SoSPT as a meta-level of theory relative to other candidates (8) Comparative Literature Definitions; (9) Examples and Exemplars; (10) History of; (11) Types and Taxonomies of; (12) Evidence of Isomorphy; (13) Experimental Evidence for (in particular science disciplines); (14) Role in Systems Pathology; (15) Formal [math] Development of; (16) Simulation of; (17) Exemplars of Application; (18) Comprehensive Literature Data Base for; (19) Future Research Questions on; (20) Research Workers and Institutions working on. Future papers in this series will systematically elaborate on these while a couple of past papers and presentations have addresses some of these information DBs for some of these.[xx] The candidate Systems Processes are listed in alphabetical order in Table One, which is to say not in ontological order, or by degree of linkage via the Linkage Propositions, or clustering by function (as shown in Troncale, 1978 and subsequent articles).

Boundaries: Boundaries limit the interaction between systems or between a system and it's environment. Boundaries are more like a structure than a process, but in SoSPT, we look to the processes that create the boundaries. Boundaries are found in almost all systems. Examples include cell membranes, atomic structures and corporations. In SoSPT we do not regard boundaries as only "delimiting structures" as we include the farthest extent of intense, local "interactions" or the "limit" of interactions for an entity class also as “boundaries.” In SoSPT the constants and limits found in natural systems are included as “boundaries” as well as the upper limit of size or complexity for each hierarchical scalar level (the Wilson-Troncale Limit). Boundaries serve a variety of functions. They increase stability by “protecting” the system or subsystem from it’s environment. It can also encapsulate complexity so the number of possible interactions between systems or subsystems is limited. (Salthe, 1985, p 156) Questions yet to be answered include, “What are the processes that cause boundaries?” and “Are these processes the same across systems?” During our review of the original SoSPT process list, we decided to group transducer processes with boundaries because they are boundary-based and act across boundaries. Limits and constants were included because they are demonstrated and fundamental final extents of sets of entities or processes.

Chaotic Processes: Chaotic processes are described in Chaos theory in several books, including “Chaos” by James Gleick, where it is labeled “deterministic disorder”. (pg 69). Chaos theory includes the features of attractors, bifurcations and ergodic processes so we included these once independent behaviors under chaos. As a working hypothesis, we are regarding them as consequences or identifying features or functions of chaotic processes rather than processes of their own. Chaos is often associated with fractals.[x-x] But we are studying whether or not chaos leads to fractals or they have their own more immediate mechanism of origin. We have included chaos in the system process list because it is found in many systems in a wide variety of scientific fields. Examples listed in “Chaos” include astronomy, biology, chemistry, climate, earth’s magnetic field, ecology, and economics. Chaotic processes seem to have a creative function within systems. They have the ability to discover and form stable innovative patterns from simple processes. They seem to give systems the ability to form a sort of order out of random-like environments. Bifurcations from chaotic processes seem to allow systems to “choose” between a limited set of options. It is interesting that both ancient mythologies and modern scientific explanations include chaos as an influence (or even source of) emergence and origins. So chaos has a rich set of possible Linkage Propositions with other systems processes already evidenced in its literature.

Competitive processes: Competitive processes are processes where two identities try to obtain the same limited resource. (that resource might be the life of the other in the case of predator-prey relationships.) We considered putting competitive processes under evolutionary processes. However, we decided that it can exist without necessarily being attached to an evolutionary process (eg. economic market competition). As with the other system processes, competitive processes are found in a wide variety of systems, including economic systems, ecosystems and biological systems. Competitive processes often act in a meta-system where different systems are interacting. It can drive complexity and better use of limited resources (Holland, 1995, p89). Sometimes it can serve as a selection mechanism between possible solutions or developmental designs. It is interesting that competition though may be considered a dual opposite force from the “cooperation” or “synergy” systems process (Axelrod, 1997) indicating that it has a number of potential Linkage Propositions or mutual influences with other important systems processes.

Cycles/Cycling/Oscillation/Hypercycles as SysProcesses: Cycle processes include stellar life cycles, sunspot cycles, Milankovitch cycles, limit cycles, oscillating mass on a string, biogeochemical cycles, crustal cycling, software development cycles, periodic processes, waves, synchrony, and many more (see Dewey, 1971 for an exaggerated listing). Cycle processes are described in length in a variety of scientific literature from biology to many fields of human endeavor. They function in systems as a form of dynamic stability. Systems also often use cycles as a form of a clock, to mark the passage of time so that some change can happen after a certain amount of cycles or within a cycle (Winfree, 2001). Cycles can also generate work and store energy, further proof of its nature as a process. We cite a dozen identifying features common to many systems for this systems process in an earlier paper (Troncale, 1985) as well as one in this more recent series designed to show how one might “prove” a systems process using experimental literature (Troncale, 2012). One feature of this systems process is the many names given to phenomena with the same features as evidenced in the title above. SoSPT calls this human historical foible, “discinyms.” Open, future research questions include the following. Are all oscillations cycles? Should resonances be included in cyclic processes? Is the ever present characteristic of “spin” from atomic particles to planets, stars, and galaxies a subset of cycles or a process on its own. We have already found and documented many Linkage Propositions between Cycles and other systems processes.

Duality/Complementarity/Counterparity as SysProcesses: Word pairs naming opposites are everywhere in common languages. But science has also found key opposite pairings of features at some of the most fundamental levels of many natural systems. Opposite charges of subatomic particles, opposite spins, opposite poles of magnetic fields, the opposition of particles and anti-particles, quark-lepton complementarity, pulsars, DNA base pairing, protein stereochemical complementarity, enantiomorphs in crystals, north-south complementary weather patterns, opposite muscle groups, complementary graphs and angles in graph theory and geometry are just a short list of examples. The full list provides evidence that this is an isomorphic pattern and truly transdisciplinary. One of us (LT) has extended the definition of opposites in many case studies like these to show the isomorphic pattern across many different systems and scales of reality (Troncale, 1985). Portrayed in that paper as the result of “equal, but opposite forces” and renamed as “counterparity,” this duality of pairs is described as a generator of dynamics in systems, as a force for change, and as such, a process. Then this dynamic was shown, when joined with other systems processes, to be a participant in the first origins of many systems across many scales of reality and a key step in the SoSPT-based Process of Emergence. Dualities have very profound relationships and interactions with other systems processes such as symmetry and fields – that are vital characteristics of many systems. Identifying Features include dual nature, opposite, equal in energy or form, similarity of “korperplan,” same scale, and generate interaction. There remains considerable work to elucidate how this candidate acts as a process because it is an unusual formulation for the conventional sciences. But for a completely independent, transdisciplinary appreciation of duality see Kelso & Engstrom, 2006.

Emergence/Origin Mechanics as SysProcesses: Once emergence was one of the four forgotten “E’s” of the early general systems movement. Not anymore. There are several popular books on the mystery of emergence purporting to explain how simple rules or a large number of simple interactions can give rise to comparatively complex, unforseen behavior. Such a phenomenon has been observed in physical, biological, computer, and social systems so is a candidate isomorphism. But SoSPT uses a more strict definition of emergence than the new field of complex systems. This is why we have placed emergence together with origins. Most all the entities we recognize in the physical universe have a specific and particular “time” of origin or first appearance. One of the spin-offs of SoSPT is a “theory of emergence” that has an identifiable number of steps, thus mimics the features of a process. It is a systems-level process because each class or scalar level of entity that arises *de novo* is a system. We are essentially talking about origins of systems of all kinds in nature as well as human systems. Since every entity has a different time of origin as well as different “particular” mechanics of origin, we feel emergence and origin processes to be very fundamental and should be included and explained in any general theory if sufficient similarities are present across all the particular origins. If the theory of evolution was the triumph of the 19th Century, then an explicit theory of emergence may become one of the most significant discoveries of the 21st. For Identifying Features and Functions of emergence please see Troncale, 1981.

Feedback: Feedback was probably the first recognized and first widely accepted isomorph by the Founders of the systems movement. Discussions across the disciplines at the NY-ICP Macy Conferences in Mexico resulted in Weiner’s legendary text, “Cybernetics” as early as 1948. In feedback some measure or sensing of the output of a system is compared to a “set point” (established by the environment, context, nature, or humans) prompting interventions sent to the relevant processes of the system to change the output relative to the set point. Feedbacks are characterized as “closed loop” processes with the closure prompting to their “feeding back” action. Initially we listed specific types of feedback, such as positive feedback, negative feedback, coupled feedback, feed-forward, 2nd order feedback, etc, as separate processes. We feel each different type of feedback has significantly different effects on systems.. Negative feedback dampens output to accomplish regulation and control. Positive feedback has the opposite effect and results in increase and growth. Coupled combines both tightly, in a non-trivial manner, by impacting the same or linked system mechanisms to achieve alternating increase and decrease in relevant output resulting further in an oscillation around the set point. In the interest of reducing the number of systems processes, we have recently compressed all into one. Further, aspects of feedbacks are prerequisites to, and/or Identifying Features for another systems process we list as cycles and cycling. One function of feedback is increasing sustainability of the system by near-term response to its systems context or environment. So there are many Linkage Propositions already known for the different types of feedback and in Linkage Propositions we retain their different names. We hope reducing the list by compressing feedback types will not lose useful specificity.

Fields as SysProcesses: There are gravitational fields, electric fields, magnetic fields, electromagnetic fields, quantum fields, algebraic fields, scalar/tensor/vector fields and likely other fields yet undiscovered or sensed. In fact, in some quantum field treatments, the fields are thought to be more fundamental and real than the particulars, entities, or things we humans generally regard as real.[x] SoSPT regards fields as one of the most investigated yet least understood of the components of modern systems science as well as of the systems processes. Fields profoundly influence and change entities entering, leaving, or existing in their domains, so we will study them as a process in the hope of uncovering unexpected, but not yet recognized, interactions between fields and our many other systems processes. Identifying features include simultaneously both continuous and discrete aspects, a feature that may help in reconciling our conventional concepts of "things"/"particulars" and the abstracted general aspects of things, processes, typical of a general theory of systems. In terms of interaction with other systems processes fields have influences on waves, symmetry, and origins. One of us in studying quanturm physics was amazed that an abstract of a basic research paper in Nature on a quantum phenomenon cited no less half a dozen of the SoSPT systems processes in the one paragraph, indicating a relationship between the ultimate theory of our universe (quantum chromodynamics) and systems theories.

Flow Processes: Flow processes are generally caused by a field or different potentials across a duality. Systems use flow processes for functions such as energy transfer and storage, messaging and movement. (Holland, 1995 p23) Flows are very common processes in many systems. Examples include water flow in ecosystems, plasma flows in stars, data flows in computer systems and cash flow in economic systems. In fact, after some study it appears that flows are essential for many of the other systems processes. Can you have cycles without flows? Can you have feedback at any of its evident scalar levels without flows? Flows as a systems process motivate us to consider placing some of the SP isomorphies as prerequisite for others. This would be a method or ontology that could be used to cluster the 55 SPs to a smaller number of functional clusters as suggested in the original paper.[x]

Fractal Structure & Processes (Fractal generating processes?) Fractal structure and process is an example of a system "process" where the feature/structure is a result of the actual process. What we want to point to in SoSPT is the process that leads to the fractal structure on all levels and in all domains in which it occurs. All fractal structures in nature are actually approximate because the mathematical concept of fractal is actually infinite. In fractal generating processes, simple recursive iterations can generate complex structures. (Lorenz, 1993, pp176-177) This makes fractal-like structures simple to encode and gives systems the ability to generate interesting/competitive structures without having to store a lot of information. Fractal-like structures also optimally dissipate energy because of the potentially near infinite surface space on the fractal boundaries. Fractal-like structures are found in leaf development on plants, tree branching, clouds, blood vessels and animal coloration patterns. Fractals have strong linkages with minimality rules, chaos, origins, and allometry.

Hierarchy: Many systems are organized into clustered assemblies of subsystems. Often there are several distinct scalar levels of subsystems. Indeed, in SoSPT the entire range of observed natural systems are linked sets of hierarchical levels portrayed in an unbroken series of systems origins. Hierarchies are good examples of SoSPT treatment of what appears to humans as a "structure" found across a wide range of systems (structural isomorphies). SoSPT insists that observers go beyond, behind, (or deeper than) the observed structure to "the process that causes the structure." SoSPT regards the process as the key dynamic that interacts through mutual influences with the other systems processes and produces structure. Just as humans find it easiest to first describe rather static structures (in space, in the cell, etc.) and only afterward with much more study do they address dynamics, so also humans recognize systems structure and only later and with greater difficulty, systems processes that cause the structure. In terms of functions, hierarchies enable higher numbers of components and interactions by organizing them in sets of subsystems enabling more complexity than otherwise possible. Also as H.A. Simon pointed out in his famous parable of Hora and Tempus, hierarchies increase stability of assembly of a much more complex entity from sets of simpler assemblies. We have developed many Linkage Propositions of hierarchy with other systems processes.

Networks & Their Dynamics as SysProcesss: Ecologists and computer scientists were the first to pay explicit attention to networks even though most of us live our daily lives completely immersed in networks -- power networks, informational networks, transportation networks, social networks and more. Graph theory in mathematics has been exploring network architectures for a century. Our very existence is due to biochemical networks in our cells, and we can only think at all because of neural networks. In recent times, explicit study of the architectures and consequences of network structure and function across all systems has let to a plethora of interest, funding, and publications (Newman, Barabasi, & Watts, 2006). So while often presented as a structure, it is the dynamics of networks that lead to key changes in the connected entities. So we consider networks as a systems process. The connectedness of the entities is nearly identical to the canonical definition of system itself, so clearly they represent systems-level processes. In fact, the specific sub-graphs, or pieces of networks can represent many of the other systems processes we cite as specific architectures of connections found to serve a function in the network.

Self-Organization/Autopoiesis/Self-Assembly/Autocatalysis as SysProcesses: As shown in the title, this candidate systems process is a good example of the discinyms cited in SoSPT. Discinyms are "**disci**plinary" syno**nyms**," that is the naming of the same isomorphic pattern or process by different words because they were discovered in different disciplines in different particular phenomena at different times in history. They are a result of the stovepipe metaphor of investigating reality (reductionism) and the lack of communication between the conventional disciplines. So modern biology uses the term self-organization on the organism level, chemists and biochemists use autocatalysis on the molecular level, physicists generally use self-assembly from the nanoparticle to the chemical levels, and on the philosophical-societal level of humans, general systems theorists coined the term autopoiesis. While proponents of each term might argue for needed discrimination, we choose to group these all together into one "nym" in the minimal list of 55. This teaches us a lesson about the need to recognized, document, and widely publicize discinyms to aid in the cross-field communication that is necessary for any eventual consensus to develop on a science of systems. In one of our papers, we cite several other systems processes that contribute to the process of self-organization and apply it to design of security systems (Troncale, 2011b). This continues as we find not only Linkage Propositions between our candidate systems processes but that several SPs are often the Identifying Features of other SPs. That is why SoSPT considers the whole "System of Systems Processes" to be ITSELF a self-organizing network.

Storage Processes: Storage of information and energy happen in many systems. (eg. information in DNA, energy in ATP and fat, energy storage in ecosystems). We are accepting it as a working candidate as we study whether or not this is a system function performed by several processes or a process itself. Is there an underlying set of isomorphic steps that result in a single process for "storage" – no matter what kind of storage? If "storing" is a process, then it's function is to "save" something for some use in the future. It has some form of stability over time and the ability to remove and use whatever is stored later. It can also be used to transport whatever is stored through space. Storage is a large component in Odum's work and in Forrester's System Dynamics. Additional thoughts and questions about storage processes included: do systems “store” space/dimension or force? Is “structure” itself, or any kind of stability a form of storage? Even more radical, can you store time? If time is a flow; is storage a dimension?

Symmetry as a SysProcess: Symmetry has many meanings from natural science to art. In SoSPT we focus on patterned self-similarity in terms of time, space, form, scaling, or transformation. An associated feature is that the self-similar parts are found in harmonious balance. This is another of the SoSPT candidate systems processes that first appears more like a structure than a process. However, in the many instances we are studying, symmetry, especially the special case of “broken” symmetries, as the <u>source of change</u> in entities. It is the context provided by the seeming necessity for symmetry that promotes the change. So SoSPT attempts to perceive the reason why (or as in processes, how) symmetry at so many different scales in nature, manifested by so many different particular mechanisms, causes change. What is the general need or function served for it to reappear in so many different and independent origin times? Galaxies, certain types of stars, crystals (many objects at many scales), inorganic and organic molecules, “fields” of all kinds, chemical reactions, many processes themselves, DNA itself, mathematics (geometry and other specialties), vast numbers of individual organisms all exhibit fundamental symmetries. In SoSPT, even our entire universe or time-space continuum is but one half of a broken symmetry. The presence of symmetry in such a range of domains is one indication of its isomorphy and its critical role (function) in enabling systems to sustain themselves long enough for humans to notice them. Consequently there is a widespread literature on symmetry with several full texts devoted to the subject[x-x], although most of the treatments are strictly restricted to coverage of only one specific discipline, scale or domain, it is the intent of SoSPT to broaden this coverage to comparisons between all manifestations aiming at a general systems formulation through integration and synthesis. While classical treatments of symmetry seem to emphasize it as a “consequence” settled <u>after</u> origins, SoSPT emphasizes symmetry as <u>before</u> origins, as a causative agent or participatory constraint in origins at all scalar levels. That is it’s primary function. Among the tight associations between systems processes documented in the SoSPT, symmetry is often found causing dynamics together with duality, fields, flows, fractals, and origins. Again, this shows that the candidate systems processes are often shown to require or engender each other.

Variation Production as a SysProcess: As for many of the systems processes, there are many uses (and ironically “variants) of this term. It usually refers to how compact or distributed a range of data is for any measure for a particular entity. But for most things in the universe, the range is quite wide. In terms of the entities we often call systems, it refers to the “variants” between manifest entities in a class, or its diversity. So in disciplinary terms we talk of diversity of asteroids, diversity of star sizes and types, exoplanet diversity, climate diversity, diversity of individual organisms, diversity of ecologies and beyond into many aspects of humans and human systems including their phenotpes, languages, customs, and religions. In SoSPT, as in other cases, we focus on what is the mechanism that causes the diversity on any particular level. In our studies, variation is a natural feature of all systems, and this variation becomes a primary reservoir for change and interaction. As such it is a process. When compared across many entities, physical to informational to societal, the process that gives rise to the diversity may be generalized from the particulars for each scale to a general process that is a potent cause or condition for change. It was his inability to describe the natural sources of variation in populations of natural organisms that caused Darwin to hesitate to publish his findings on evolutionary mechanisms. He recognized that the generation of variation was the essential first step in the process. But ever since, it is the explication of variation in modern genetics from organisms to populations to later cell and molecular levels that we most associate with explanations of evolution. However, variation if found at all scales of natural systems. And so can be studied and explained from the experiments of many disciplines. Physical systems exhibit wide ranges of variation in aggregation and behaviors. The wide applicability of the normal distribution itself, when applied to natural objects is a sign of variation acting on all scales. One of our teams most recent publications documents the critical role of variation (innovation) in designing man-made systems and extends that to citing particular cases of “pathologies” of systems (one of the several spin-off fields of SoSPT).

Closing Remarks-This Section

We here covered a sample of only 15 of our current list of 55 candidate systems processes for a general theory of systems that purports to describe how systems work. Table Two lists the list of SPs that survived our application of the criteria cited above. Specific fates of those deselected or condensed into others is shown at the end of Table Two.

The difficulties described in the commentary indicate the challenges that face an attempt to include ALL relevant systems processes and yet limit the list to the minimal necessary. Originally we cited 110 candidate processes to bring “shock and awe” to those who normally only examine one or a few favorite processes. One of us showed an early version of this listing to Kenneth Boulding, one of the founders of SGSR-ISSS. His main reaction was surprise and consternation because he had no idea there were so many possible candidate isomorphies of relevance. A true general theory would require detailed analysis of them all and how they affect each other. This latter phrase highlights the key advance enabled by SoSPT, that is, through identifying the minimal, yet complete fundamental systems processes, to enable explicit description and documentation of their mutual influences on each other (Linkage Propositions covered in the second paper of this series). That is what we are attempting in SoSPT. By integrating as much existing systems and natural science literature as possible into this single framework, we hope to help achieve the much-needed unification into a “science” of systems.

Adherents of SoSPT push for inclusion of all possible processes in describing systems origins, maintenance and dynamics but they also recognize the great contributions of those who work on a particular systems process. Workers such as Prigogine on Thermodynamics, Forester on Feedback, Odum on Energy and Emergy, Miller, Salthe and Simon on Hierarchies, Corning and Haken on Synergy, Beihoff and Schindler on Systems-level Variation Processes, and so many more. They all contribute to increased knowledge on how systems work and enrich the detail and usability of the SoSPT knowledge base.

TABLE TWO: The following items were retained from the original list:

1. Adaptation Processes
2. Allometry, Systems-Level
3. Allopoiesis
4. Binding Processes
5. Boundary Conditions as a Proc
6. Causality Processes (linear vs. non-)
7. Chaotic Processes
8. Competitive Processes
9. Constraint Fields & Analysis
10. Cycles/Oscillations/Hypercycles as Processes
11. Decay, Autolytic & Senescent Processes
12. Development Patterns & Laws
13. Duality/Complementarity/Counterparity Mech's
14. Dysergy as a Process
15. Emergence Processes
16. Entropy, General (as a process)
17. Equilibrium & Steady State Proc’s
18. Evolutionary Processes
19. Exaptation, Cooption Processes
20. Feedback, General
21. Field Processess & Potentials
22. Flow Processes
23. Fractal Structure (as a Processes)
24. Functions, System (Purpose)
25. Growth Patterns & Laws
26. Hierarchies & Clustering as a Process
27. Information-Based Processes
28. Input Processes
29. Limits, Physical & General
30. Integration Processes
31. Metacrescence as a Process
32. Network Structure & Processes
33. Neutralization Processes
34. Non-Equilibrium Thermodyn-Irrever
35. Origins Processes
36. Output Processes
37. Phases, Stages, Transitions
38. Power Laws, Cross-Disciplinary as a P
39. Quantum Processes
40. Recursive Processes
41. Redundancy Processes
42. Replication Processes
43. Self-Criticality/Tipping Pts/Catastrophes as a P
44. Self-Organization/Autopoiesis/Autocatalysis
45. Spin Processes
46. Storage Processes

47. Structure as Process
48. Symmetry, Systems-Level (as a process)
49. Synergy/Synchrony/Cooperation as Processes
50. Thermodynamic Processes
51. Variation Processes

The following items are on the new list (added or different form):

52.	Maximality Principles	**[retained with Min as one]**
53.	Minimization Principles	**[retained with Max as one]**
54.	Amplifiers as a Process	**[added from Odum's systems processes]**

The following items were removed or placed under other items in the list:

55.	Ashby's Conjecture (Requisite Variety)	**[not a sysprocess; a consequence]**
56.	Asymmetry as a process	**[dropped -> put under symm as a consequence]**
57.	Attractors	**[dropped; placed under chaos as Identifying Feature]**
58.	Bifurcations	**[dropped; placed under chaos as Identifying Feature]**
59.	Boundaries as Universal Constants	**[subset of Boundaries]**
60.	Catastrophe Processes	**[subset of Self-Criticality]**
61.	Circuits & Network Motifs	**[a subset of Networks]**
62.	Closed Systems	**[eliminated because a taxonomic term]**
63.	Complexity Processes	**[eliminated because a taxonomic term]**
64.	Concrescence Processes	**[subset of Metacrescence and Synergy]**
65.	Cooperative Processes	**[subset Synergy]**
66.	Counterparity Diagrams & Proc's	**[subset of Duality]**
67.	Deterministic/Directive Process	**[not a systems-level process]**
68.	Deutsch's & Dollo's Conjecture	**[not universal to physical systems]**
69.	Dissipative Processes	**[subset of Entropy]**
70.	Diversification Processes	**[subset of Variation Processes]**
71.	Embodiment & Subsumption Proc	**[subset of Hierarchies]**
72.	Energy Processes	**[problematic under min/max universals]**
73.	Entropy-Dissipation Processes	**[subset of Entropy]**
74.	Equifinality as a Process	**[subset under Network Processes]**
75.	Ergodic Processes	**[subset under Chaotic Processes]**
76.	Exclusion Principle	**[a subset of Hierarchy Process]**
77.	Feedback, Coupled	**[a subset of General Feedback Processes]**
78.	Feedback, Negative	**[a subset of General Feedback Processes]**
79.	Feedback, Positive	**[a subset of General Feedback Processes]**
80.	Feedforward & Anticipatory Proc	**[a subset of General Feedback Processes]**
81.	Hypercycles	**[a subset of Cycles Processes or Autopoiesis]**
82.	Instability Mechanisms	**[a subset of Decay Processes or Variation]**
83.	Interactions, Binding, Linkages	**[put under Binding Processes]**
84.	Least Action/Energy Principles	**[subset of Min/Max Processes**]
85.	Limits, Informational	**[subset of Phys & Gen'l Limits]**
86.	Limits, Wilson-Troncale	**[subset of Phys & Gen'l Limits]**
87.	Morphodynamic Processes	**[subset of Structure as a Process]**
88.	Motif's, Circuits, Subgraphs	**[a subset of Network Structure]**
89.	Open Systems	**[eliminated because a taxonomic term]**
90.	Oscillation Processes	**[a subset of Cycles Processes]**
91.	Pathology Processses	**[eliminated because a taxonomic term]**
92.	Periodic Processes	**[a subset of Cycles Processes]**
93.	Pleioetiology as Process	**[a subset of Causality Process]**
94.	Pleiotropy as Process	**[a subset of Network Processes]**
95.	Plenitude, Principle of	**[a subset of Variation Processes]**
96.	Potential Spaces or Fields	**[a subset of Field Processes]**
97.	Scaling & Scaled Processes	**[a subset of Power Law Processes]**
98.	Self-Organization	**[a subset of Autopoiesis Processes]**
99.	Singularities	**[a subset of Chaotic Processes]**
100.	Soliton Theory (Long Waves)	**[a subset of Cycle Processes]**
101.	Stability Processes	**[eliminate because a taxonomic term]**
102.	States, Systems	**[a subset of Phase Processes]**
103.	Steady State Mechanisms	**[a subset of Equilibrium Processes]**
104.	Sub-Specialization Processes	**[a subset Hierarchy processes]**

105.	Synchrony as a Process	**[a subset of Synergy Processes]**
106.	System Identification, Sub-, Super-	**[eliminate because a taxonomic term]**
107.	Systems of Systems Processes	**[the same as SoSPT as a whole; redundant]**
108.	Tipping Points	**[a subset of Self-Criticality Processes]**
109.	Transducer Processes	**[a subset of Boundary Conditions]**
110.	Transgressive Equilibrium	**[a subset of Equilibrium Processes]**
111.	Zipf's/Pareto's Patterns (as a Process)	**[a subset of Power Law Process]**

A Systems Process List as a "Framework" for Unifying the Systems Literature

It should be clear that this paper essentially presents a future research "framework" for unifying systems theories and integrating the vast findings of the natural sciences with those theories. It is an elaborate, but systematic, ontologically-based protocol or plan for forging a future "science"of systems. The basic lesson is that systems theory will become a reliable guide for better systems design and repair when it focuses on investigation and verification of systems-level processes just as the natural sciences became a basis for engineering when it focused on the investigation and gradual elucidation of the natural processes of distinct phenomena. Further such new and exploding fields as "biomimicry" suggest that there is great potential in attempting "systems mimicry," that is, building our human systems through knowledge of how systems formed in nature and imitating their systems processes and linkages between systems processes. Plans and practical actions about who will organize and implement this framework as well as harvest this potential will be addressed In associated papers and presentations.[x]

What does "Science" of Systems Mean and How Would SoSPT Then Qualify as Systems Science?

Science is a promiscuous term in current misusage. Many seem to adopt the term for their area of specialty to garner the prestige and funding that being a science seems to engender. However, most of these claims do not stand up to critical appraisal.

A wide range of types of "science " has emerged over the last three centuries. There is "descriptive" science, "discovery" science, "hypothesis-&-experiment" driven science, "formal" science, and even "theoretical" aspects of science when coupled sufficiently with the experimental validation required by advocates of science. By formal we mean verification of what really happens in nature using mathematics or computer modeling and simulation. Both theoretical and formal are still dependent on eventual verification through experiment. For systems theory to become truly a science of systems, it would need to approximate the central feature of verification and validation typical of the conventional sciences. SoSPT does this by proving isomorphy using the experimental data of the natural sciences directly in the proof.

We recognize that there is a large contingent of humans who state emphatically that there is no such thing as objectivity and so no intrinsic value to experimental methods. They are a very high percentage of those attracted to systems studies. Still, our airplanes, electronics, health systems, water systems, transport systems, communication systems, computer systems, etc. etc. all operate on objective principles that are sufficiently reliable for us to use all of these modern "extended phenotypes" for better quality of life and survival. So how is it that anti-science proponents continue to deny any aspect of objectivity for science or the artefacts they use and rely on daily?

Many of those areas now indisputably called "sciences" began at the descriptive stage, progressed through the discovery phase, and then the experimental to the formal/theoretical. Biology and geology, and aspects of astronomy and cosmology are still going through these early phases. The ultimate test though is experimentation involving alternative hypotheses, prediction, and very sophisticated tools and correspondence principles to determine which of the alternatives mechanisms or processes is consistent with the measures obtained when testing nature. We judge the SoSPT attempts to be midway between initial discovery and naming phases and direct experiment.

So what type of "science" might systems science be? Anything that has "science" in its title is usually NOT science (social science; design science; management science, etc.) while if it does not, it is (physics, chemistry, biology, geology, etc.) Until recently, most of systems thinking could be best characterized as faith-based, anti-reductionist approaches, so was more on the theoretical level without any real representation of testing and experiment. With the advent of serious testing of hypotheses in network theory, in the physics and mathematical approaches of the large and growing complex systems community, and "proving isomorphy" approaches using the literature of the natural sciences[x] n SoSPT, we argue that we are on the cusp of appearance of a more testable "science" of systems. The knowledge base being assembled by the SoSPT comes directly from the experimental literature of the recognized natural sciences. The more the systems processes and their Linkage Propositions can be verified by this broad experimental literature from many disciplines, domains, use of tools, experiments, and scales of reality, the close we come to a true "science" of systems as judged by the criteria of the indisputable sciences themselves.

Insights and Future Work: Reconciling SoSPT and the Natural Sciences Literature

We recognize that the systems processes listed above are not completely orthogonal with some of the most established ways of presenting the knowledge base of the natural sciences. Astronomy, physics, chemistry, mathematics, computer science, and to some extent even geology and biology document and make sense of their findings through established theories, laws, formal equations, and key physical concepts such as space, time, dimension, mass, force, energy, interaction, and information. In fact, the processes of phenomena on the various scalar levels of the various sciences are at present defined in terms of these concepts. For a more adequate synthesis, future versions of this systems process list have to either deduce how to include these important parameters or figure out the relation of the systems-level processes to these. One avenue of approach is recognizing that as formalisms for the above have matured, more and more "dimensionless" relations have been discovered. Perhaps dimensionless patterns and so-called "field" explanations are the source of both systems processes and these key traditional parameters on the generalized level of a theory of systemness.

Another avenue of future work is reconciling the SoSPT with other major integrations in the systems literature by renowned past workers. We are thinking of how the comprehensive SP lists might relate to Millers massive work on Living Systems,[x] Odum's impressive work on Systems Ecology, [x] Forrester's extensive exploration of Systems Dynamics. [x] Each of these workers have devised elaborate "symbol" systems to represent and use their theory of systems. How would these symbols relate to the upcoming symbol systems of SoSPT?

Another area of future concern is how to apply the SoSPT given its complexity. Tools will be needed to increase its usability [x] and teachability. [x] In addition, correspondences with the body of work in Soft Systems Methodology and various forms of Systems Engineering must be found.

But the most fundamental work for the future will be increasing the detailed body of knowledge for each of the systems processes and their linkage propositions – the heart of SoSPT. This will take a devoted community of natural scientists as well as systems scientists. We are organizing teams for this task through INCOSE (the International Council on Systems Engineering: three ongoing official projects of their Systems Science Working Group) and ISSS (the International Society for the Systems Sciences: three ongoing SIGs – Special Integration Groups). Both societies have signed cooperative agreements with each other for these and other tasks relevant to both. In addition, we are organizing new groups for SoSPT spin-offs in the area of Systems Pathology (the new International Society for Systems Pathology, ISSP) and for Systems Law and Legislation. Please contact LT about these opportunities.

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