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Introduction to A System of Systems Processes

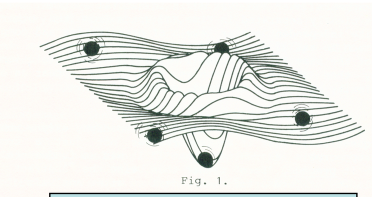
The SSP Model As A Basis for GENSYSML & Student Posters

Needed: A Consensus General Theory of Systems

• Margaret Mead, past President of the ISSS, AAAS, and AAA complained that the ISSS had never applied systems thinking to itself. Ackoff (1971) stated that "the concepts commonly used to talk about systems have not themselves been organized into a system." The knowledge base of systems is itself not systematized resulting in needs.
• There is a need for consensus in the systems sciences and this consensus can emerge only from alternative attempts at comprehensive integration, unification and synthesis.
• Systems science needs a consensus for improved communication among researchers, for better systems education programs, for incremental improvement in theories, for exposing areas needing more work, for a more detailed theory to better inform practical applications. The SSP tries to answer all of these needs, and more, simultaneously.
• The System of Systems Processes (SSP) organizes a comprehensive listing of the mechanisms and processes by which many systems work into a more complete system.
• The SSP is based exclusively on identification and interaction of only the <u>key</u> systems mechanisms (or processes) that purportedly are similar in widely diverse systems, from physical to biological to social to information to technical to business systems.

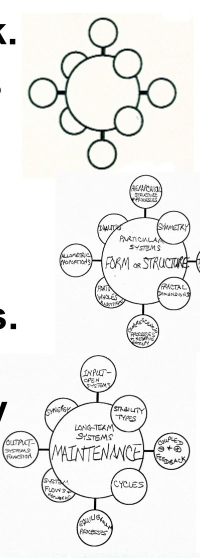
Identification & Selection of Processes/Mechanisms

• The SSP GenSys model begins with a simple insight followed by massive lit surveys.
• The insight involves recognition that many systems workers spend their lives focusing research on one single systems process or structure with the result that other key structures and processes are ignored. Yet it takes <u>all</u> of the processes to make a real system function effectively; so a true general theory of systems must include <u>all</u> such.

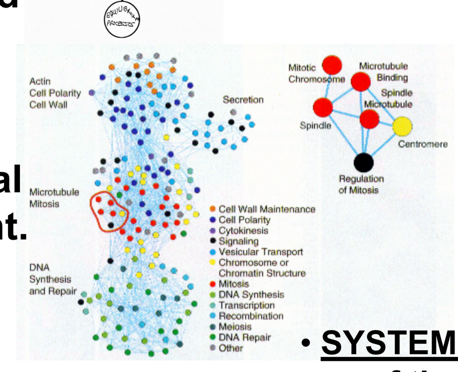

SysProcess as Minimal State

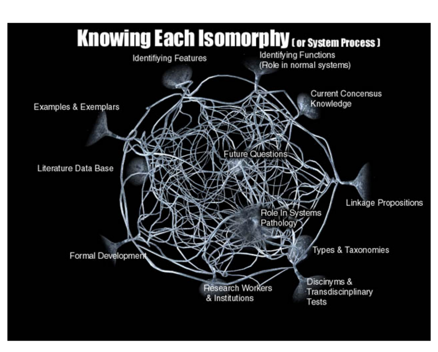
• The SSP posits that each systems process is a minimization of energy, time, material, & space as shown at left. So each process is axiomatic to "systemness." All are self organizing as a group. Each is necessary, but by itself insufficient; all are required. Whatever the start conditions of a new or emerging system, its form and dynamics spontaneously "fall" into the minimum patterns we humans later see as an isomorphy common to many systems. Currently, the SSP recognizes between 80 and 100 key systems processes. They are the nodes of the SSP net.

• Multiple criteria were used to identify & select the candidate systems processes & keep them to the most parsimonious list. Is each truly a process or mechanism as opposed to a human descriptive, taxonomic, or methodological term? Is the process fundamental to the dynamic of systems? Is the process found in phenomena of all natural sciences? Is it common to both physical and social systems? Is it documented in the literature? Is it expressed at an appropriate level of abstraction? Is it rich in necessary interactions with other systems processes? Selection of SSP nodes is an iterative & evolving task.

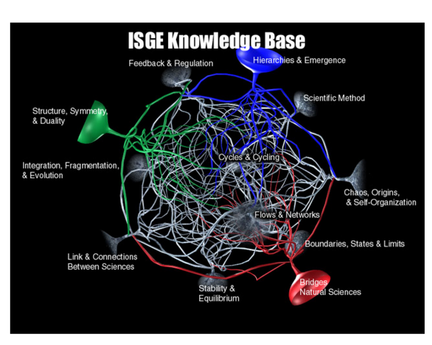


• Several systems processes (isomorphies) are more tightly coupled than others for enabling one of several major systems behaviors. So we cluster the systems processes by the "behavior" or systems attribute that they most enable as shown in the cartoons at right. This simplifies the nodes and nets & creates a "small-world" network where some nodes act as hubs relative to others.
• Note that the systems behaviors are categories & so not processes themselves.
• The graphic at the right below represents a very specific system manifestation. It is a net of interacting proteins in cellular dynamics that are grouped by the key cell function they perform. This graph represents a specific "manifest" system, while the SSP graph represents "systemness" in general; it has been integrated from studies of many such specific systems. Still they have common features, namely, both have massive underlying data sets requiring computers for use, both have extensive refereed literatures to support the interactions, both are inherently "complex networks" enabling application of and discovery of general network theorems of structure and interaction, both need iterative improvement.
• Both can help each other. For example, this one at right from Systems Biology could be tested to suggest new general linkages to the SSP; and the SSP could be mined for new hypotheses for Systems Biology or for explanations of emergent systems-level phenomena.



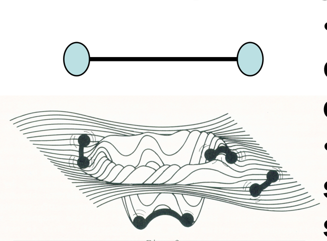


• Extensive literatures exist for each of the systems processes as shown in the nets at left and right.
• Computerized data bases are being assembled at our Institute on the dozens of criteria for "knowing each isomorphy (or systems process)" (see left & the companion student posters on integrating the lit)
• The result will be a comprehensive data set that describes how the isomorphies interact to produce several key systems mechanisms that make a system stable, dynamic, emergent, and enduring. (see right)



What are Linkage Propositions?

• The main goal of the SSP is ID & documentation of the <u>interactions</u> between systems processes in great specificity and quantity, in much greater detail than other GST's.
• We call these interactions "Linkage Propositions" (hereafter LP's) because they tie together (unify, synthesize) the systems processes (linkages) & because they are not proven in the scientific sense in <u>every</u> system yet, so remain as only partially proven "conditionals." They are stronger than conjectures in math because some proof exists.
• To become a candidate LP, strong evidence has to be documented for the interaction in some range of well-studied particular, real systems. But the full range of their transdisciplinarity need not yet be determined. Their specification will help doing this.


LinkProp as Minimal State

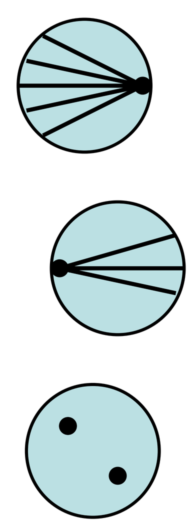
•The basic description of a <u>unit</u> <u>LP</u> is shown above as a basic dyad, a line connecting two nodes. Each node is a systems process (one of the isomorpies); each line is the mutual interaction, influence, or relation between them (one LP).
• These interactions are between minimal energy, time, space, material isomorphs, so they also are minima as shown in the cartoon at left. Given enough time, and sufficient trials, new systems not only "find" the systems processes, they also spontaneously "fall into" the LP's.

• Each Linkage Proposition states how one systems process influences another as in "<u>positive feedback</u> is a partial cause of (necessary condition for) <u>growth and development</u>." Or "<u>coupled feedbacks</u> are a partial cause of <u>oscillations</u>.
• LP's are most easily expressed in language. Our convention at present is to show each systems process as an underlined phrase connected by a standard phrase chosen from our Association Classes that describes the mutual influence.
• Sometimes the LP requires more than two systems processes working together.
• Each systems process has many influences on and is influenced by many other systems processes. This illustrates the "entitation" concept of Gerard, one of the Founders of the ISSS. It also explains the non-linear behavior of many systems.

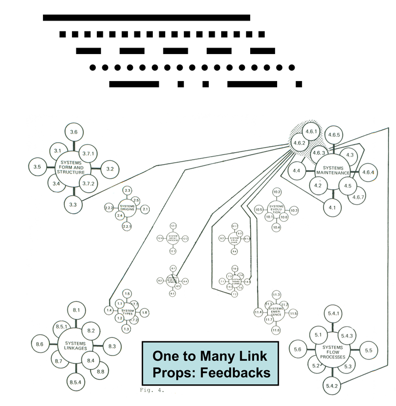
Some Sample Linkage Propositions: Sources

• Here are some general examples of Linkage Propositions we are studying…….
• <u>Transitions/Phases/Modes</u> are in part the result of <u>Symmetry Breaks</u> in <u>Linkages</u>.
• <u>Symmetry Breaking</u> is a partial cause of <u>Scalar Emergence</u>.
• <u>Hierarchical Structure</u> is a partial result of <u>Scalar Emergence</u>.
• <u>Diffusion Limited Aggregation (DLA)</u> is a type of Systems <u>Flow</u>
• <u>Non-Equilibrium Thermodynamics</u> is a necessary condition for <u>DLA</u>.
• <u>Diffusion Limited Aggregation</u> is a partial cause of <u>Fractal Structure</u>.
• <u>Non-Equilibrium Thermodynamics</u> is a necessary condition for <u>Fractal Structure</u>.
• <u>Boundary Conditions</u> are a partial cause of the <u>Exclusion Principle</u>.
• <u>Concrescence Ratio</u> is a partial cause of new <u>Boundary Conditions</u>.
• Notice that several of this small example set are interrelated and so result in paths, or cycles, or subclusters within the complex networks of 100's of LP's in the System of Systems Processes. For example, note the chain from symmetry breaks to emergence to phase states or from DLA to Fractals. Also note that the very existence of these specific interaction sets leads to fascinating new questions.

Association Classes of Linkage Propositions



• Analysis of the many Linkage Propositions reveals that the mutual influences among systems processes fall into ~25 similarity classes; that is, although they are between different processes, the interaction exhibits the same influence or impact.
• So rather than expressing each Linkage Proposition as a unique relation (shown by a unique line of connection), we can express them as members of a limited number of interaction types. Each type can be represented by a different line type.
• This immensely simplifies the otherwise formidable level of detail in the SSP.
• Some of these "association classes" are conventional, and widely recognized.
• Others are new and peculiar to the new complex network type of analysis. For example, at left are our symbols for A "is a partial cause of" B (at top); B "is a partial result of" A (middle); or A "is a counterparitor (paired opposite) of" B.
• We find many repeated such mutual influences in the LP set. It indicates that many of the systems mechanisms require each other and clearly causes a change in the conventional way of thinking about causation.


One to Many Link Props: Feedbacks

• Recognition of these "association classes" has much utility.
• Instead of the multitude of overlapping lines of mutual interaction shown in the modern interactive graphs of systems biology, earth systems science, the Internet, international economics, or ecology, one could ask the computer to show only one association class of linkages, or show each class as a different type of interaction line as shown in the line set at the right. Diagrams summarize and teach.

Tools for Using LP's: Alternative SSP Representations

Understanding of Systems Dynamics as Networks

• The hundreds of Linkage Propositions describing real influences between 80 key systems processes make the SSP difficult to follow so we have explored the use of different clustering strategies, interactive computerized graphics, new mathematical formalisms, and encoding of LP's in Prologue/LISP to simplify use of the SSP.

• <u>GRAPHIC INTERFACE:</u> The network graphic at the right shows a subset of > 90 linkage propositions that describe mutual influences among only 4 systems processes common to many systems. These are only a sample; not even the full set of interactions among these four processes. This SSP "system of systems processes" sample already shows why complex systems behavior and systems dynamics are non-linear. It would be very difficult to "trace" completely stand-alone or independent cause and effects in this network. Many alternative paths are possible. Controlled experiments would leave out many key paths & confound results. That is why Systems Biology and modern science disciplines must turn to systems science for methods and help. Conditions and solutions evident in one may not be as evident in another, and so both can contribute to each other's development.

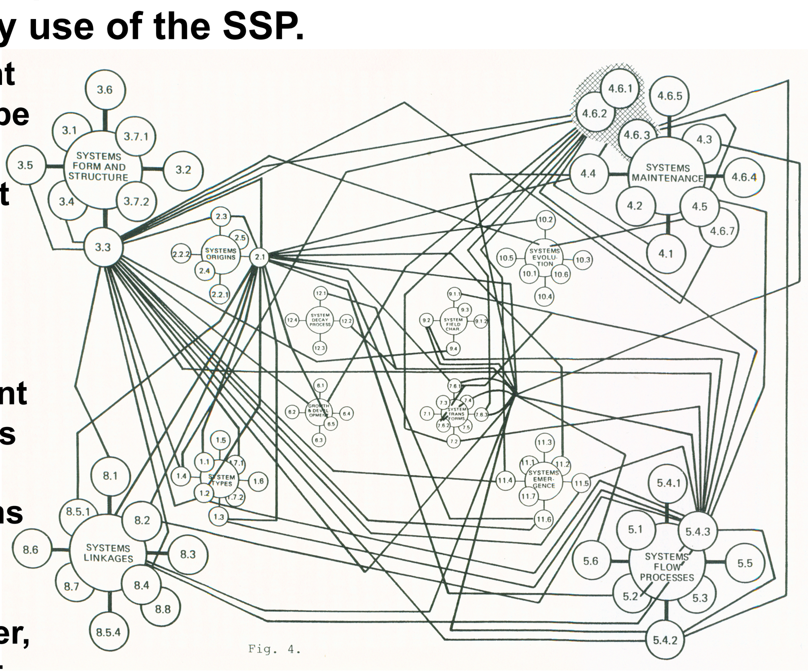
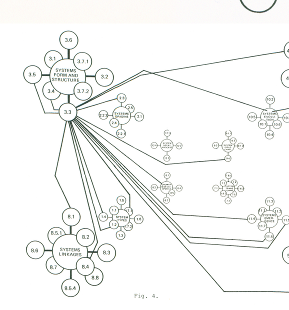
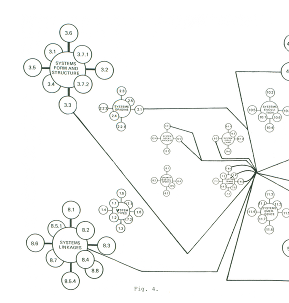


Fig. 4.

• <u>INTERACTIVE GRAPHICS:</u> Putting the above net on the computer in such a way that each of the nodes and each of the LP lines is LIVE would allow users to manipulate the graphic as a tool for exploring, or searching, or understanding the SSP. For example, one could ask the computer to only show all LP's of one type of Association Class for all systems processes. Or any subset of systems processes specified. Or all of the LP's going to and from one systems process as shown at the right. Or students could "fly-thru" the graphic clicking on any node or edge to ask for lit doc'n.

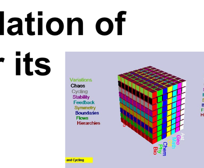

One to Many Link Props: Boundaries

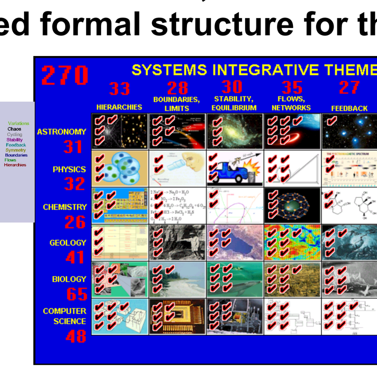
• <u>SYSTEMS DYNAMICS:</u> Each of the graphics at right also shows the reality of one of the early hypotheses of ISSS Founders. These selective graphs manifest "entitation" (global influences and all received impacts) of one isomorphic systems process with all the others currently proposed.
• They also exhibit that even for one systems process, the resulting graph is a network showing all the features expected of a "complex" system; they could be used to study the sciences of complexity.
• The graphic of all LP's above also demonstrates the concept of "equifinality" (Bertalanffy) just now becoming a problem for biomedicine and systems biology investigations. Previous assumptions of linear causality simply do not obtain.

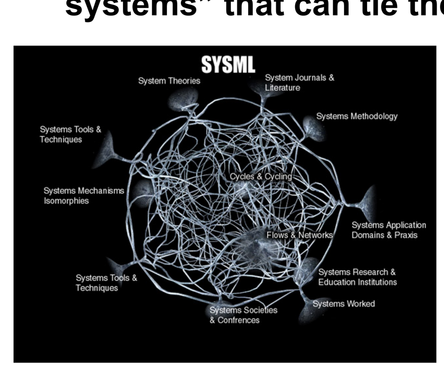

One to Many Link Props: Cycles

• <u>ENCODED IN COMPUTER LANGUAGES:</u> The language nature of the Linkage Propositions enables their translation into Prolog or LISP statements. For example, one could encode the LP Association Classes as:
• (is-a-type-of _____ _____) /or/ (inhibits _____ _____) /or/ (is-a-partial-cause-of _____ _____) where the underlines are the two systems processes involved. As such these statements could be put into computer space to work on each other and used to simulate real systems in a new way or to discover new network theorems, or LP's, or suggest hypotheses for experiments in the natural sciences. Prolog statements have been used in Artificial Life research to act as agents evolving still newer agents across relatively vast time periods while taking only days of CPU computer time and resources.
• <u>ENCODED AS A NEW FORMAL MATH:</u> These are inherently "complex networks" enabling application of and discovery of general network theorems of structure and interaction. In previous work, we have suggested how to formalize the association classes to arrive at an abbreviated formal structure for the SSP.

• You may recognize that the entire SSP project requires a firm foundation of massive data sets and literature connections to provide evidence for its formulations. We use seven natural sciences as the first source.
• Our Institute is attempting to organize a open source project called GENSYSML which would document and interconnect, in one place, case studies from several key natural science disciplines (shown at right) as a significant resource for those interested in developing a better "science of systems" that can tie the natural to the social sciences and human crises.

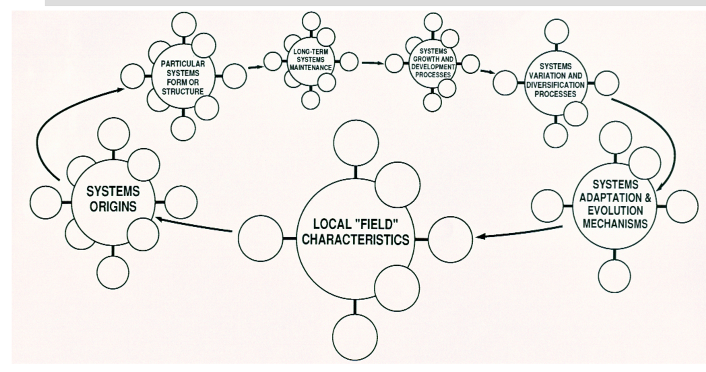






• Extensive refereed literatures exist that support the interactions that are codified in the LP's. These literatures extend from the physical sciences, thru the biological sciences, to the social and applied sciences as indicated in the accompanying student posters for selected systems processes and their Linkage Propositions.
• One of our Institute projects is to have students study and harvest this vast literature from both the hard and soft sciences to build a computer tool that allows a user to click on any node (systems process) or linkage and automatically retrieve the refereed sources that support its inclusion in the SSP. We would call this tool GENSYSML using XML protocols and open its use to all interested parties.

Some Uses & Applications of the SSP



• Beyond basic systems behaviors, the SSP could also be used to detail interactions that lead to a General Systems Life Cycle as shown at left. This is a prototype. It is a rearrangement of the systems behaviors clusters in a time sequence that suggests the stages thru which many different kinds of systems progress during their existence. Some interactions via LP's are prerequisite to others although we have found that the mutuality and self-organizing, near axiomatic nature of the systems processes complicate some stages. The accompanying student posters indicate the place of their systems process in the proposed GS Life Cycle Stages.

• The SSP and GENSYSML would have multiple other uses. It could be used…..
• As a comprehensive knowledge base for more detailed and improved <u>systems education programs</u>.
• As a source of novel information & insight for rapidly expanding, well-funded new research specialties such as Systems Biology, Earth Systems Sciences, & the Sciences of Complexity,
• To provide practical design alternatives for a wide range of <u>Systems Design Applications</u> of all types.
• To improve <u>systems models and systems simulations</u> of real and artificial systems.
• To <u>improve communications</u> among the wide range of systems workers from many different disciplines by providing <u>standards</u> and translations among the different systems studied.
• To <u>enrich the meaning</u> & understanding of each isomorphic systems mechanism or process.
• To <u>assess</u> the <u>rigor and completeness</u> of alternative general theories of systems & the completeness & rigor of alternative real systems models and simulations.
• To improve our <u>understanding</u> of the sources <u>of complex behavior</u> in complex systems.