IS ARTIFICIAL SYSTEMS RESEARCH FEASIBLE ?

What is ASR and what is its purpose?

How is ASR different from Artificial Life Research?

What is the System of Systems Processes and its Linkage Propositions used in ASR?

How might an ASR be constructed?

How would ASR use LISP to discover new rules?

How would ASR be used to test system structure?

➢ **ASR is Related to Artificial Intelligence and Artificial Life Research**

- ✓ We acknowledge that some AI and most all Artificial Life research involves investigation of how "systems" work
- ✓ But most of this work focuses on modeling real, manifest natural systems, not what is common (isomorphic) to all sys's

➢ **ASR Purpose: To create an artificial environment that allows testing very specific, generic systems structures and processes; remove one, see effects; alter links**

➢ **To test general propositions directly for their efficacy**

- ✓ Use ability of the computer to try out many different configurations of systems structure and process
- ✓ Use ability of computer to compact vast numbers of trials (generations) into tiny, human sized spaces of time, at very little expense

- ➤ **Distinct similarities unquestionable; but also ASR has some unique differences**
  - ✓ All Artif. Life IS Artif. Sys. Research and Artif. Life conclusions should be added to Artif. Sys.
- ➤ **ASR would be based on the Linkage Propositions of a System of Systems Concepts (SSP)**
  - ✓ Artificial Life is bio-mechanism focused; ASR focuses on general systems mechanisms
- ➤ **Artif. Life has "systems behaviors" as outcomes or products; ASR positions "systems behaviors" as integral; in fact, ASR tests "sys behaviors" directly**
- ➤ **Agent *characteristics* not based solely on *biosystems***
- ➤ ***Diversity generation* in ASR agents not based only on *genetic algorithms***
- ➤ **Agent *selection* not based solely on *bioevolution selec.***

- ➢ **That "general" processes can be symbolically represented by computer hardware/software**
  - ✓ **How can you represent a non-manifest system at high specificity?**
  - ✓ **ASR consistent with "unification" theme of ICCS'04**
- ➢ **That "controlled" testing is possible in complex systems, despite their non-linear character**
  - ✓ **Test for successful "minimization" (matter; energy; time)**
  - ✓ **Test for successful "maximization" (negentropy; info)**
- ➢ **That useful data on "sufficing" systems behaviors and patterns can be derived from artificial systems research**

➢ **That most complex systems workers focus on only a small number of systems processes**

  ✓ For example, their work is mostly within the domain of feedback, or self-organization, or networks, or etc.

➢ **That most complex systems workers focus on only one tool or method; and operates on real system data**

  ✓ For example, their life's work is in cellular automata, or simulations using calculus, or etc.

➢ **That ASR is better enabled by including very large numbers of systems processes & their mutual influences**

  ✓ Mutual influences can be represented by language and symbols

  ✓ New "influences" can be derived from previous statements of influence

SYSTEM OF SYSTEM PROCESSES (SSP) I.

- ➢ **Systems mechanisms (processes) are many and axiomatic**
- ➢ **SSP recognizes at least 80 systems processes to-date**
- ➢ **Any one SP is isomorphic across many systems because it is a minimum in use of matter/energy/time**
- ➢ **Clustering of SP's can be used to explain key systems behaviors**
- ➢ **SP's exert "influences" on each other**
- ➢ **Call influences "linkage propositions" because they are defined as a link (by influence) between two SP's**
- ➢ **Systems processes shown as nodes; LP's shown as connecting lines**
- ➢ **Just as SP's are axiomatic minima so are the influences between SP's**
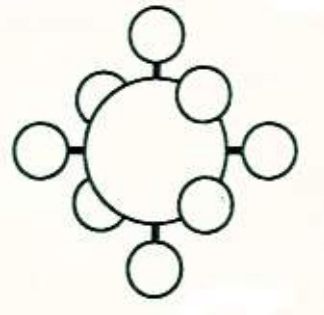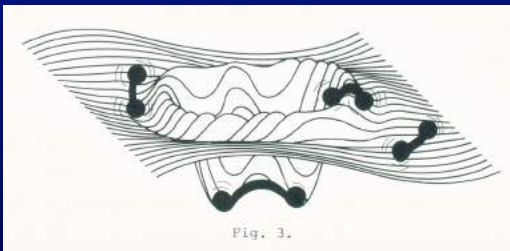
Fig. 1.

Fig. 3.

SMALL NUMBER OF INFLUENCE CATEGORIES

That is, the connecting lines or edges between nodes…..

➢ **Two-way (mutual) vs. One-way linkage propositions**

- **Congruence or Commonality Influences**
  - ✓ "is isomorphic to"
  - ✓ "is analogous to"
  - ✓ "is identical to"
  - ✓ "is homologous to"
  - ✓ "can substitute for"

- **Causal or Conventional Ordering Influences**
  - ✓ "is a partial cause of"
  - ✓ "is a partial result of"
  - ✓ "contributes to"
  - ✓ "is a necessary but insufficient condition for"

SMALL NUMBER OF INFLUENCE CATEGORIES

A taxonomy of cross-influences becomes possible…..

- **Inversion, Magnitude, or Reciprocity Influences**
  - ✓ **"negates/inhibits"**
  - ✓ **"increases"**
  - ✓ **"decreases"**
  - ✓ **"enhances"**
  - ✓ **"reverses"**
- **Dual Opposite Influences**
  - ✓ **"is a counterparitor to**
- **"Field Influences"**
- **Grouping Influences**
  - ✓ **"is a type of"**
  - ✓ **"clusters with"**
  - ✓ **"sub/super or micro/macro scale relationship to"**

Result is complex net or a "system of systems mech

Both the systems mech's (nodes) & the link prop's (edges) are derived from extensive literature searches of disc-based, refereed journals

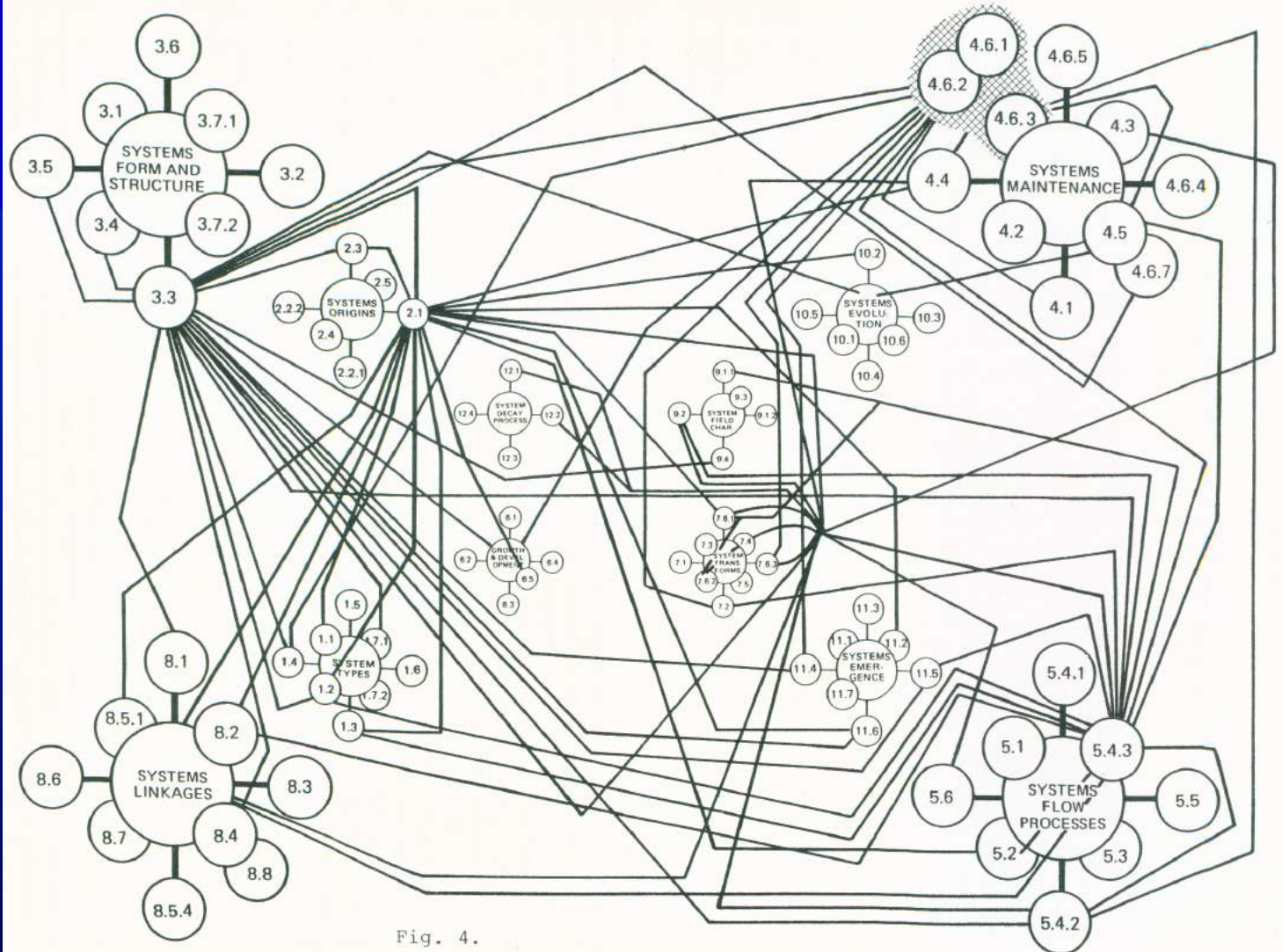**Here 4 SP's across 12 clusters of systems behavior…**
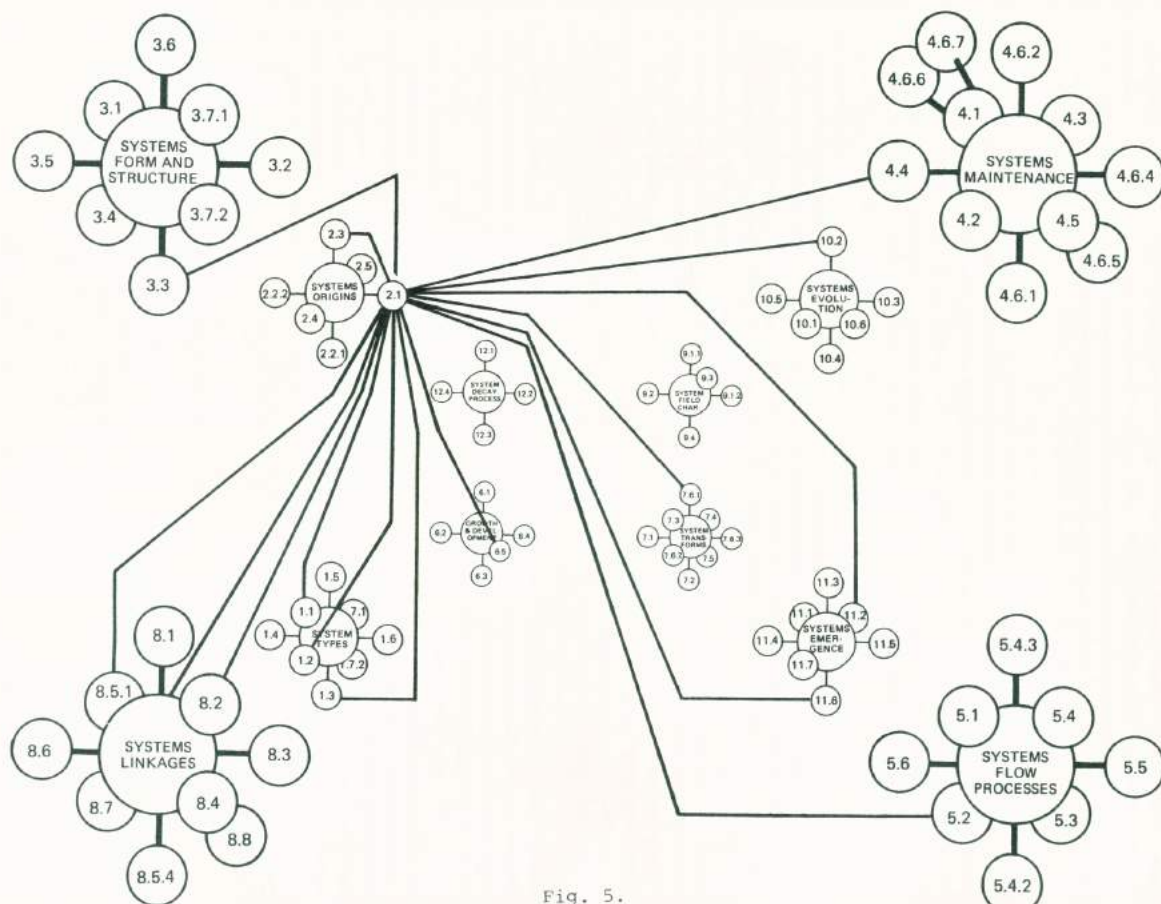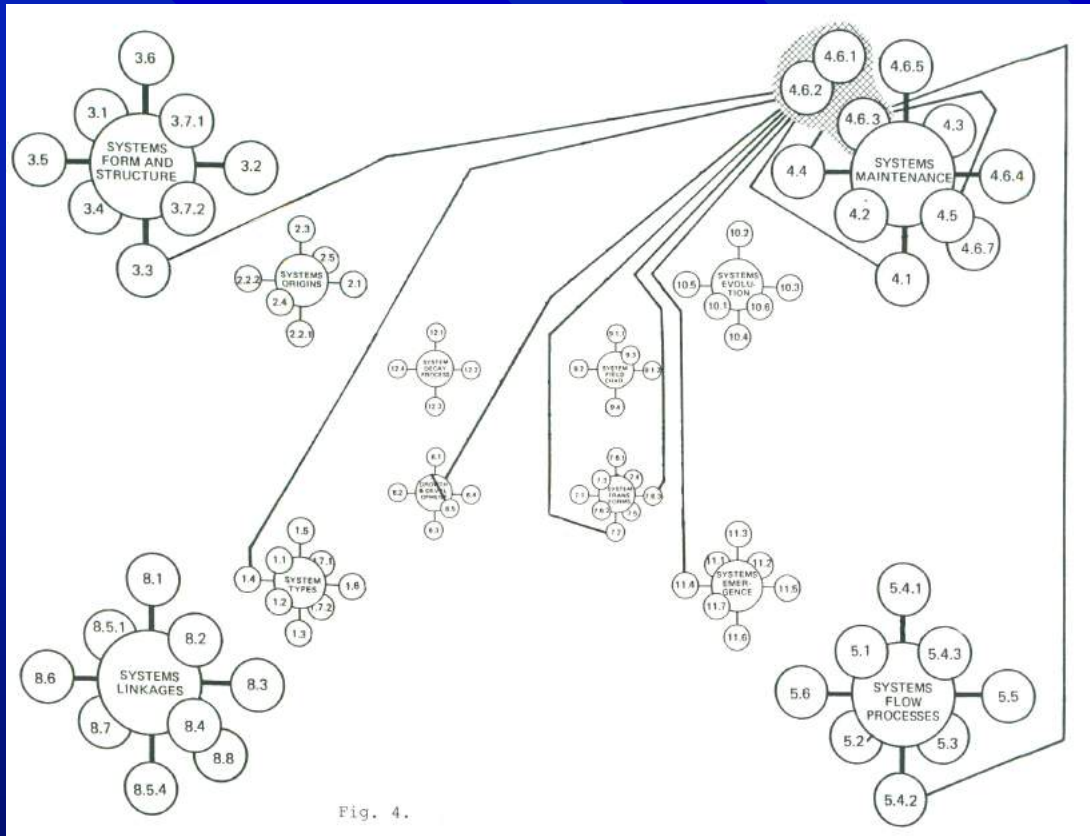

Fig. 4.

Fig. 5.

➢ **Here see 8 systems processes involved in delivering systems origins**

➢ **Even linkage prop's between one systems process & other result in complex networks**

➢ **This net represents the dynamics true of many systems**

➢ **It is the set of influences to-date (link prop's) for boundary conditions**

➢ **Boundary conditions derive from action of these LP's (its entitation)**
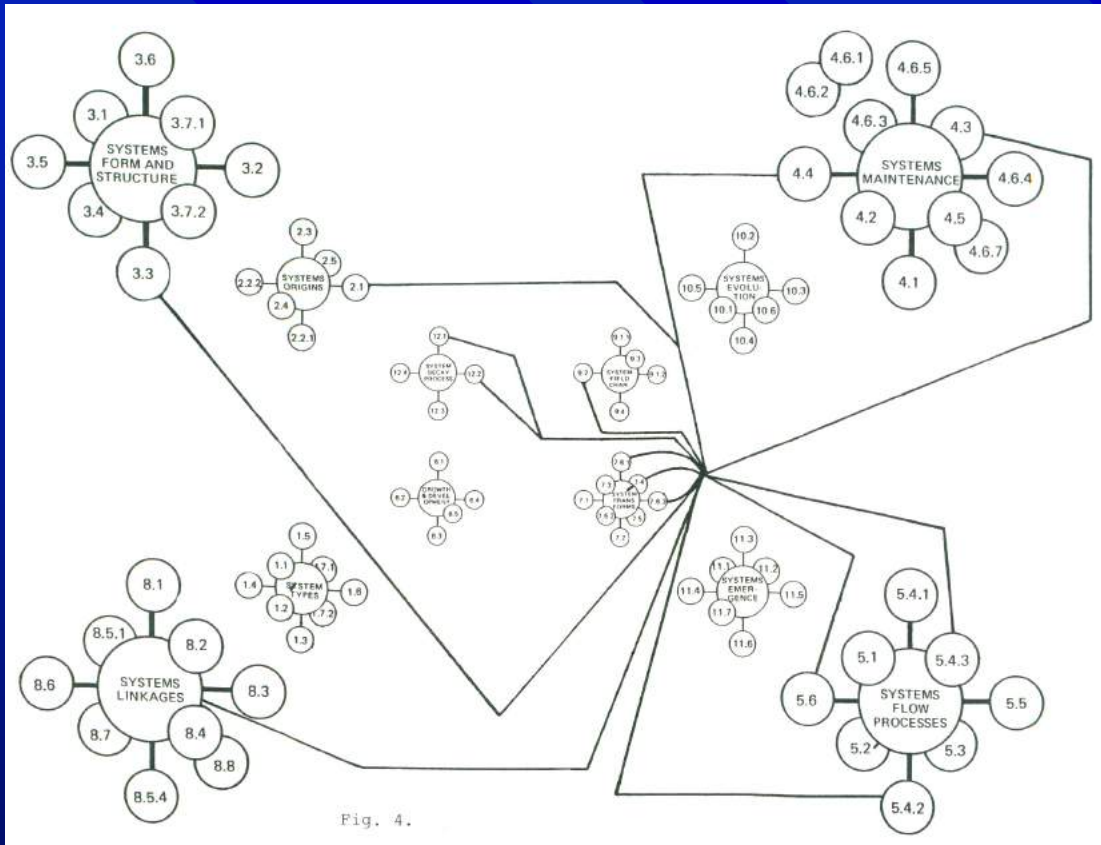
Fig. 4.

> ➤ **The set of linkage propositions to-date for positive, negative, and coupled feedbacks as a sub-cluster and the other systems processes of mutual influence**

> ➤ **This is the entitation of and exclusion principle for feedbacks**

Fig. 4.

> ➤ **The set of linkage propositions to-date between cycles and oscillations as a sub-cluster and the other systems processes of mutual influence**

> ➤ **This is the entitation of and exclusion principle for cycles and cycling**

Bottom Line is that a System of Systems Processes has both generality (since taken from many real systems)

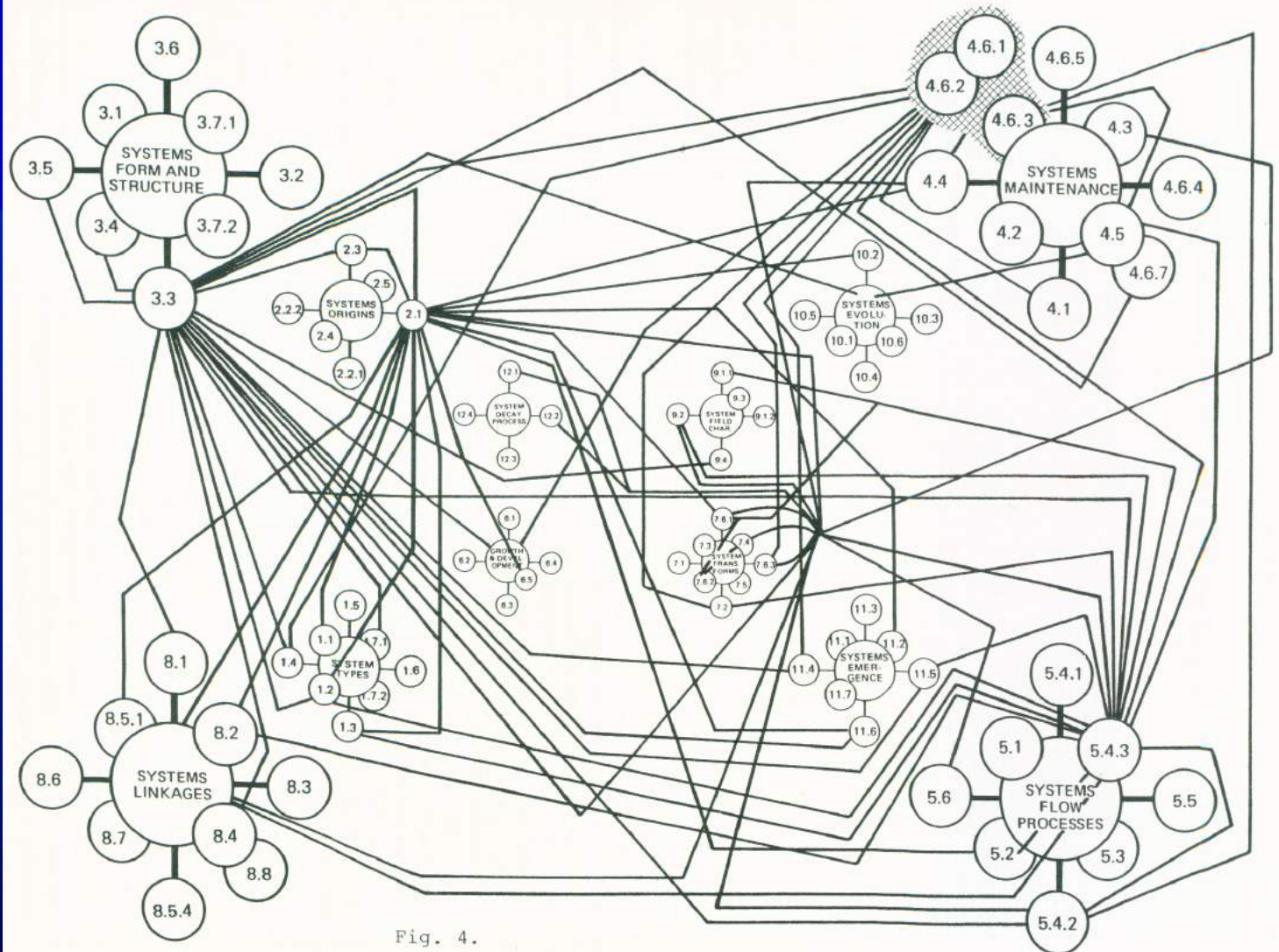**And has high levels of specificity because of the numbers of specific general SP's & LP's**
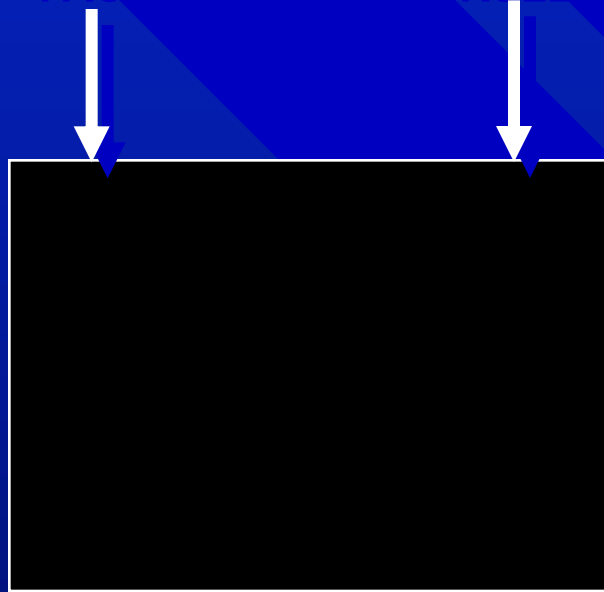

Fig. 4.

ARTIFICIAL SYSTEMS RESEARCH: POTENTIAL USE OF LISP I.

NSF

PRE-EXISTING FACTS

PRE-EXISTING RULES

NEW FACTS

- **Can express linkage propositions in LISP AI language**

- **Facts: program in hundreds of Linkage Propositions as pre-existing facts**

- **Rules: program in allowed interactions and minimization**

- **Use computer space/time to generate new Facts**

ARTIFICIAL LIFE PRECEDENT FOR USING LISP

Good precedent exists in AL for use of LISP in ASR…..

- **Koza (Stanford) used LISP to get programs to write new programs**

- **He used crossover of symbolic expressions (S-expressions in LISP format) which were actually sub-routines**

- **He organized them as "tree" structures and the action of crossover resulted in "swapping" unit branches; very fast discovery of new routines**

- **Using LISP in this way, he was able to**
  - ✓**Discover mathematical theorems; manipulate robots**
  - ✓**Find best strategies in game-playing problems, etc**

IAS

NSF

Other precedents for use of LISP in ASR…..

➢ **Sims (MIT) used LISP statements to generate alternative plants for his Panspermia project**

➢ **Jefferson (UCLA) used LISP for his "programmables:" computer agents that simulated evolution and ecosystem populations**

➢ **LISP also has been used as the driver for a series of robot projects**

➢ **So, how would it be used to implement the Systems Processes and Linkage Propositions of this ASR prototype of a System of Systems Processes (SSP)?**

- **Recall that Linkage Propositions generally have the form SysProcess-Influence-SysProcess**
- **So statement in LISP would have form:**
  - **(influence-as-hyphenated-string SysProcess SysProcess)**
- **e.g. LP "positive feedback is a partial cause of growth/development" would become**
  - **(is-a-partial-cause-of positivefeedback growthdevelopment)**
- **Other examples would be:**
  - **(is-a-partial-cause-of coupledfeedback oscillations)**
  - **(is-a-partial-cause-of positivefeedback selforganization)**
  - **(is-a-partial-cause-of positivefeedback synchrony)**

- **These would be the "symbolic logic" alternative**
  - **Standard expressions; either/or;**
- **To capture the multiple linkage nature of the LP network, it might be better to use the "fuzzy logic" alternative**
  - ✓ **Preface expression with percentage likelihood, SO**
  - ✓ **(0.9 causes A B) (0.3 causes B C)**
  - ✓ **What probability A causes C?**
- ✓ **Could then make fuzzy influences part of Linkage Propositions conditional on actual operation of SSP network**
  - ✓ **Could use multiple rules (causes (and ____ ____ ____) _____)**
  - ✓ **Or could try (causes _____ (and _____ ____))**

➢ **Exclusion Principle and Networks**

   ✓ **If all entities interact in a net, how far beyond the immediate interactions do you go before influence is no longer relevant**

   ✓ **Important to understanding any network**

   ✓ **Especially important to emerging genome and proteome interactome networks**

   ✓ **Key to explaining pleiotrophy in disease and pleiotropic mutations**

   ✓ **E.g. multiple organ disease effects of sickle cell anemia due to change of just one codon to one amino acid in 6th position**

➢ **"Entitation" and Networks**

   ✓ **(Gerard) cannot define any specific node of net unless include all mutual influences; now specifiable with System of Systems Processes and its particular set of linkage propositions**

- ➢ **Are any measures of standard use in Artificial Life of relevance to A.S.R.? Yes, namely…….**
  - ✓ **Tracing Pathways**
  - ✓ **Analysis of Geneologies of Survivors, etc.**
- ➢ **Any relevance of ASR to Network Research**
  - ✓ **Measures of net robustness, clustering, modularity, structure, path lengths, etc.**
  - ✓ **Emphasize universality of the SSP as a meta-network of particular/manifest nets both natural and social system based**
- ➢ **Quantifying Trends and Patterns**
  - ✓ **SSP has built in parameter sets and power law results**
  - ✓ **It also traces "evolution" within scale & "emergence" of new scales**
  - ✓ **It offers a "general systems lifecycle" of SP's & LP's and the potential for an empirical study of "emergence" as opposed to pure theory**
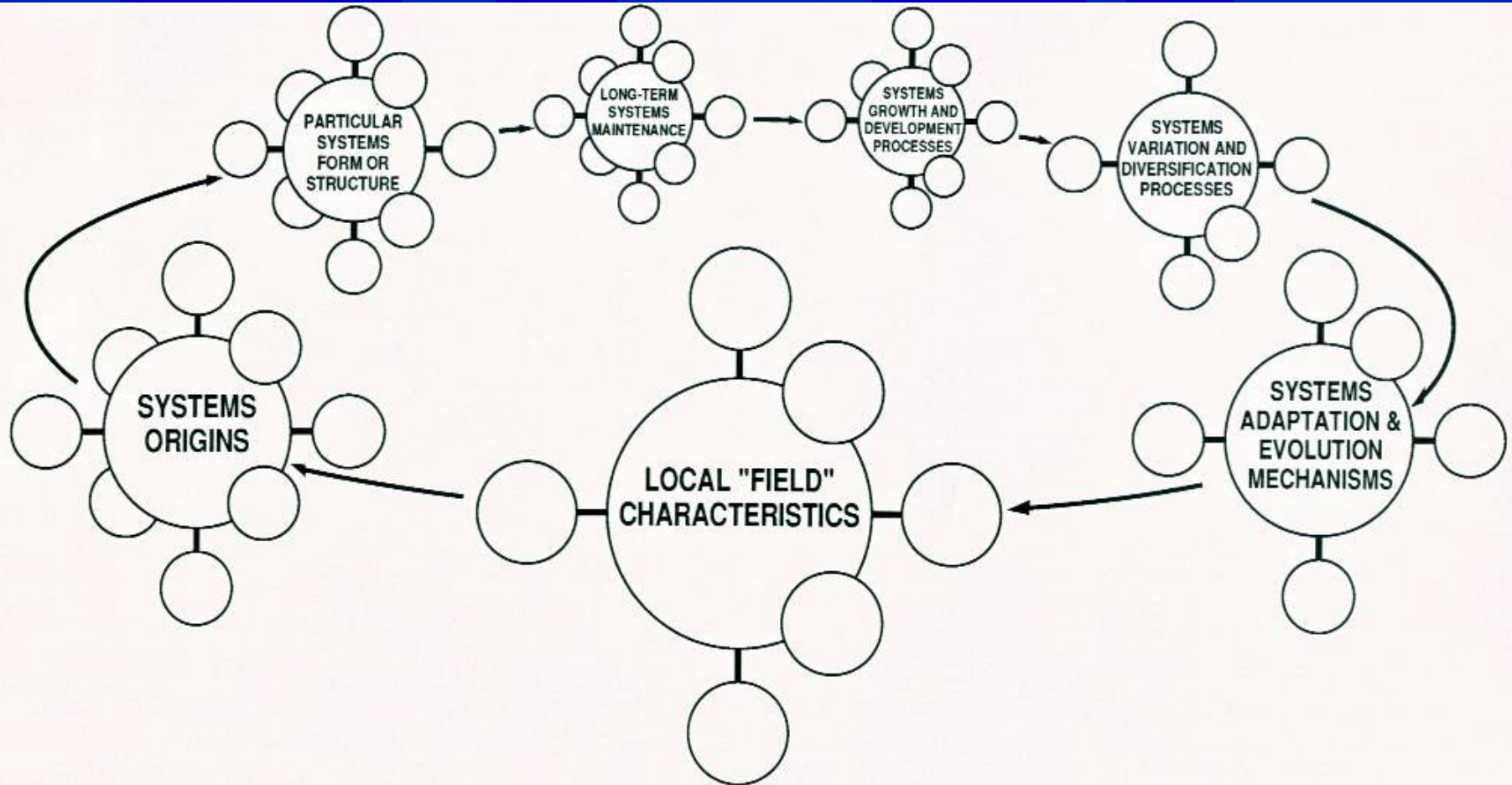
ARTIFICIAL SYSTEMS RESEARCH: POTENTIAL CONTRIBUTIONS

- **Applications to Human Genetics**
  - ✓ **Actualizes, or allows testing of older genetic network manifestations; e.g. "penetrance"; e.g. variable expressivity (e.g. cleft palate); ecology of genes**
- **Applications to Systems Biology and Networks**
  - ✓ **Provides a generic system gleaned from all natural science literatures to develop new hypotheses for wetlab investigation**
- **Applications to Systems Pathology; Interdisc**
  - ✓ **For systems education implications, see poster # 7**
  - ✓ **For systems pathology implications, see poster # 6**
  - ✓ **For origin of life implications, see poster # 68**

➢ **Need list of criteria defining relation of testing using computers and testing in manifest, particular systems**

➢ **Caveat: Testing in computer space IS STILL NOT testing in real space**

  ✓ **What are the criteria for comparison between agents?**

  ✓ **Proven need for wetlab follow-up and confirmation in networks of gene and protein interactions in Systems Biology**

ARTIFICIAL SYSTEMS RESEARCH: OBSTACLES TO OVERCOME

- ➢ **What is the Selection Mechanism?**
- ➢ **What Resource do the Agents Compete/ Coop to Gain or Optimize?**
  - ✓ **Minima of matter/energy/time and maximization of information or complexity principles; better at dissipation? How actualize?**
- ➢ **What Denotes Survival or Success for Agents?**
  - ✓ **What are the criteria for comparison 'tween agents?**
- ➢ **What generates variation in the population?**
  - ✓ **What is the reproductive mechanism?**
  - ✓ **Variation mechanisms are usually peripheral instabilities on the reproductive or stability mechanism**

ARTIFICIAL SYSTEMS RESEARCH: PRACTICAL RES REQUIREMENTS

- ➢ **Many student programmers at upper division UG or graduate level**
- ➢ **Enabling Software; considering use of SWARM**
- ➢ **Parallel processors in IAS computer lab**
- ➢ **Collaboratory of systems researchers**
  - ✓ **Interacting via NGI-Internet 2**
  - ✓ **Use collaboratory medium such as LabView(tm)**

POTENTIAL BENEFITS OF ASR

➢ **Could lead to better understanding of interactions only vaguely described in systems today**

➢ **Could allow for direct exploration of the new taxonomy of systems pathologies**

➢ **As new field, could catalyze increase interest in syssci due to excitement & attention surrounding new area**

➢ **Could lead to new discoveries and understanding of phenomena of key importance to the natural sciences**

  ✓ **For example, could lead to new mechanisms for variety creation unknown in current largely biological mechanisms**

SUSTAINABILITY OF PROPOSED ARTIFICIAL SYSTEMS RESEARCH

- Prospects for a ISSS-SIG on Artificial Sys. Research
  - One dozen ISSS Members Declare Interest in writing
  - Sub-task identification; Grad & Honors UG Theses
  - Year-around Internet communications
  - Reports and work at annual meetings
- Multi-year, Multi-institutional Plan
- Software for "Collaboratory" Effort
- Prospects for Funding
  - NSF - Multi-Section Complexity Inititiative
  - ONR - Tradition of funding advanced comp. Applic's

NEED FOR THE NEW FIELD OF ARTIFICIAL SYSTEMS RESEARCH

➢ **RIGOR: Marked absence of sysmodel testing: Need for more and more testing of comprehensive systems models**

➢ **TIME: Cannot wait billions of years for outcomes of tests between alternative systems structurprocess config's**

➢ **MORALITY: Cannot run tests on existing systems without brutal interventions**

ARTIFICIAL SYSTEMS RESEARCH: METHODOLOGIES

- **NATURAL: Altho described as artificial, will actually use the same selection mechanisms as natural physical and biological systems**

- **"Controlled" testing in complex systems... by removing only one of a full set of connections and searching for pathologies; microbial mutants**
  - ✓ **Big role of microbial mutant research as analogy**

- **Pre-Run User Construction of Configuration of Isomorphy-Linkage Proposition (LIP) set**
  - ✓ **Find the relative efficacy of human postulates on the full set**

- **Post-Run Emergence of Configuration of LIP set**
  - ✓ **Let it run and find the best set; or set of interactions**

CORRESPONDENCE PRINCIPLES BETWEEN ASR & REAL WORLD

- ➢ **What is a correspondence principle?**
  - ✓ **Example of analyzing starlight; or ultracentrifuging macromolecules**
  - ✓ **Role of correspondence principle in science praxis**
  - ✓ **Why correspondence principles are so important to systems science**
- ➢ **What would a correspondence principle in systems science look like relative to natural sci**