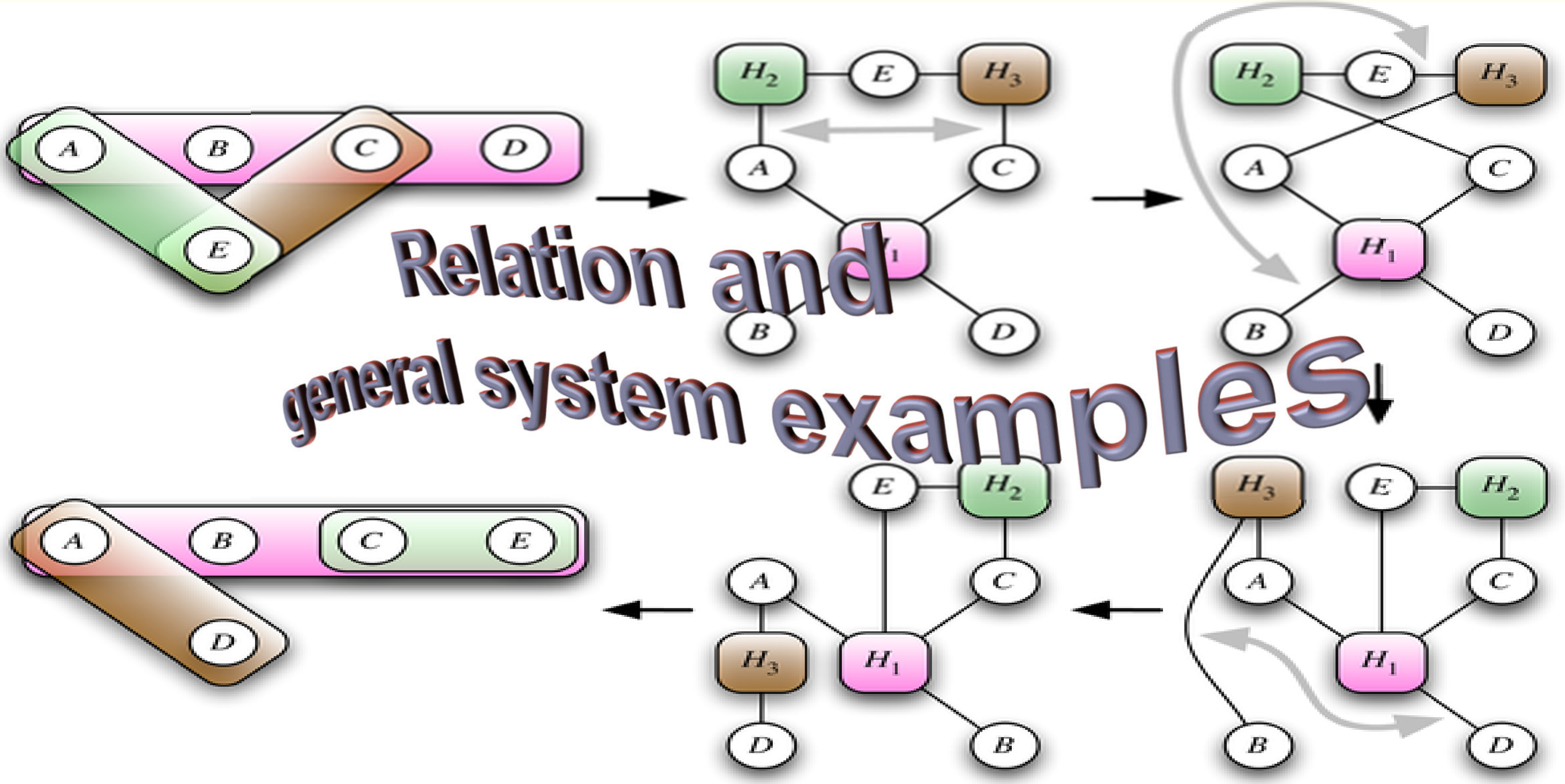
lecture 11: relation and general system examples

Relation and general system examples



evaluation

- Participation: 20%.
  - class discussion, everybody reads and discusses every paper
  - engagement in class, including online
- Paper Presentation and Discussion: 20%
  - All students are assigned to a Reading and Discussion Group
  - **SSIE501** students in group present and discuss papers
    - all students are supposed to read and participate in discussion of every paper.
    - *section 01 groups* present in class, *section 20 groups* present via zoom or send a video
  - Presenter group prepares short summary of assigned paper (15 minutes)
    - no formal presentations or PowerPoint unless figures are indispensable.
  - Summary should:
    - 1) Identify the key goals of the paper (not go in detail over every section)
    - 2) What discussant liked and did not like
    - 3) What authors achieved and did not
    - 4) Any other relevant connections to other class readings and beyond.
  - **ISE440** students in group participate as lead discussants
    - not to present the paper, but to comment on points 2-3) above
  - Class discussion is opened to all
    - lead discussant ensures important paper contributions and failures are addressed
  - Post presentation 1-2 page report uploaded to Brightspace
    - 1-4) plus 5) statement of individual contributions
- Black Box: 60%
  - Group Project (2 parts)
    - Assignment I (25%) and Assignment II (35%)

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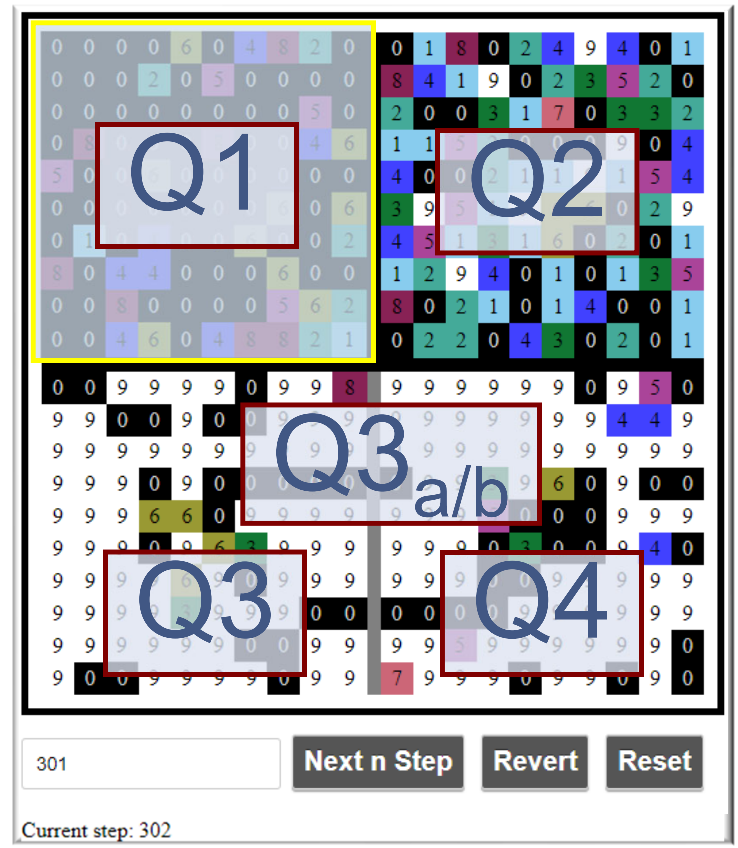
The Black Box: Due: October 6th, 2023

Herbert Simon: Law discovery means only finding **pattern** in the data; whether the pattern will continue to hold for new data that are observed subsequently will be decided in the course of **testing the law**, not discovering it. The **discovery process** runs from particular facts to general laws that are somehow induced from them; the **process of testing** discoveries runs from the laws to predictions of particular facts from them [...] To explain why the patterns we extract from observations frequently lead to correct predictions (when they do) requires us to face again the problem of **induction**, and perhaps to make some hypothesis about the uniformity of nature. But that hypothesis is neither required for, nor relevant to, the theory of discovery processes. […] By separating the question of pattern detection from the question of prediction, we can construct a **true normative theory of discovery**-a logic of discovery.

- Focus on uncovering quadrants
  - using data collection, descriptive patterns & statistics, and induction.
- Propose a formal model or algorithm of what each quadrant is doing.
  - Analyze, using deduction, the behavior of this algorithm.

What is it!!??



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next readings (check brightspace)

- Paper Presentation: 20%
  - Present (501) and lead (501&440) the discussion of an article related to the class materials
  - *section 01* presents in class, *section 20* (Enginet) posts videos on Brightspace (exceptions possible)
- Thursday October 3rd
  - Module 2: Systems Science
    - Reading and Discussion Group 4
      - Klir, G.J. [2001]. *Facets of systems Science*. Springer. Chapter 8.
        - Optional: Klir, G.J. [2001]. *Facets of systems Science*. Springer. Chapter 11
      - Schuster, P. (2016). The end of Moore's law: Living without an exponential increase in the efficiency of computational facilities. *Complexity*. **21**(S1): 6-9. DOI 10.1002/cplx.21824.
      - Von Foerster, H., P. M. Mora and L. W. Amiot [1960]. "Doomsday: Friday, November 13, AD 2026." Science **132**(3436):1291-5.
- Future Modules
  - See brightspace

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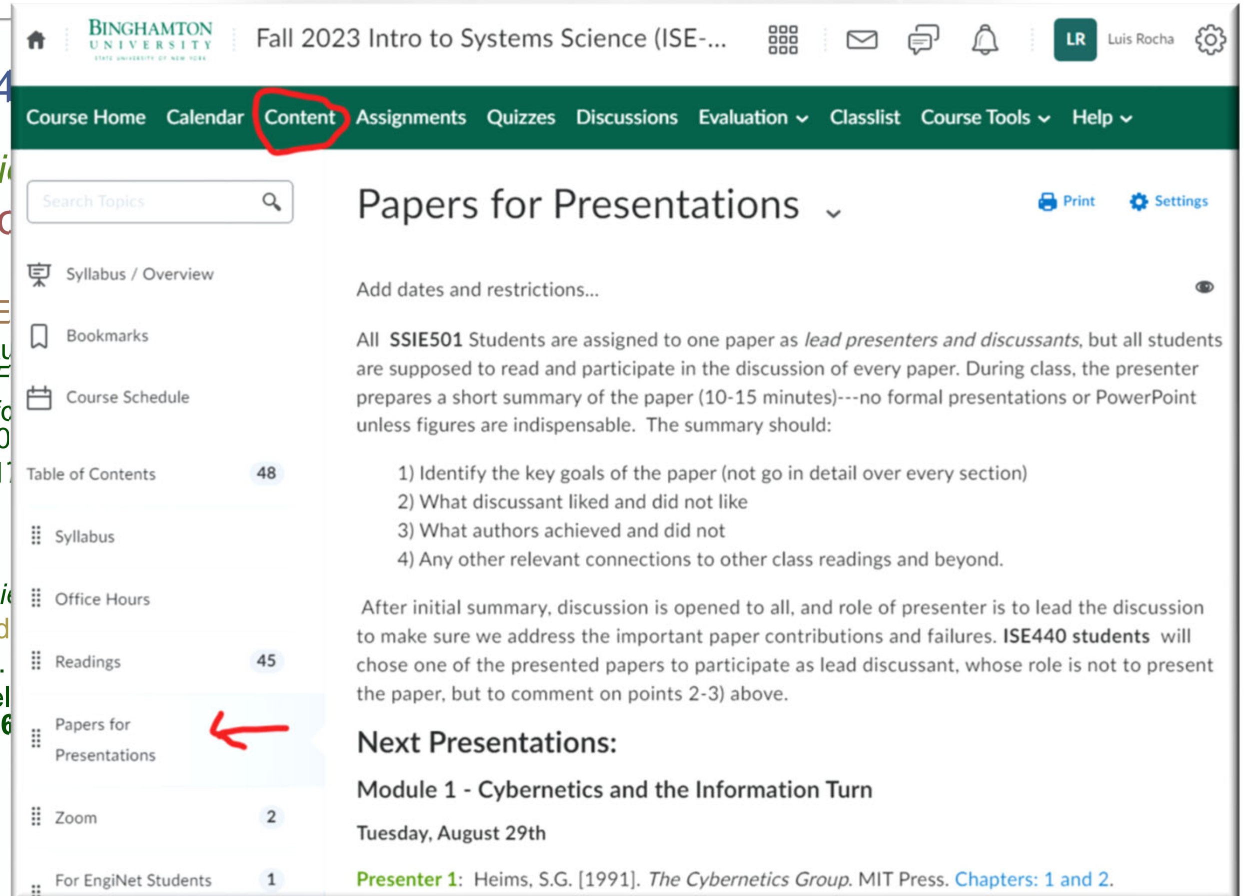
more upcoming readings (check brightspace)

- Paper Presentation: 20%
  - Present (501) and lead (501&4 materials
  - *section 01* presents in class, *secti*
- Module 3 - The Organization of Co
  - October 10/12th
    - Reading and Discussion Group 5 (E
      - Simon, H.A. [1962]. "The Architectu Also available in Klir, G.J. [2001]. *F*
      - Golan, Amos, and John Harte. "Info *of Sciences* **119**.33 (2022): e21190
      - James, R., and Crutchfield, J. (201
  - October 17th /24th ???
    - Reading and Discussion Group 1
      - Barabasi, A.-L. (2015) *Network Scie*
        - Optional: Barabási, A. L. and
      - Watts, D. J., & Strogatz, S. H.
      - Torres, Leo, Ann S. Blevins, Daniel Complex Systems." *SIAM Review 6*
- Future Modules
  - See brightspace

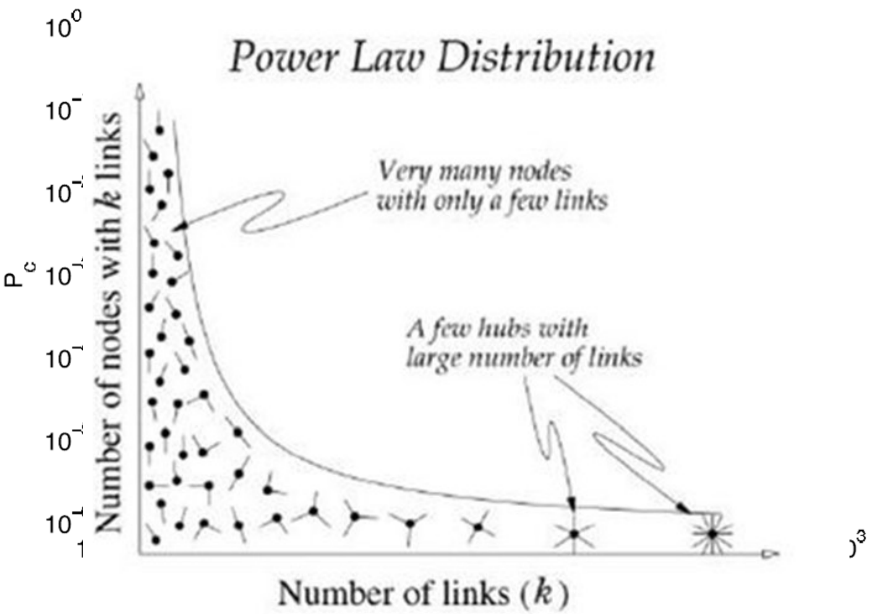


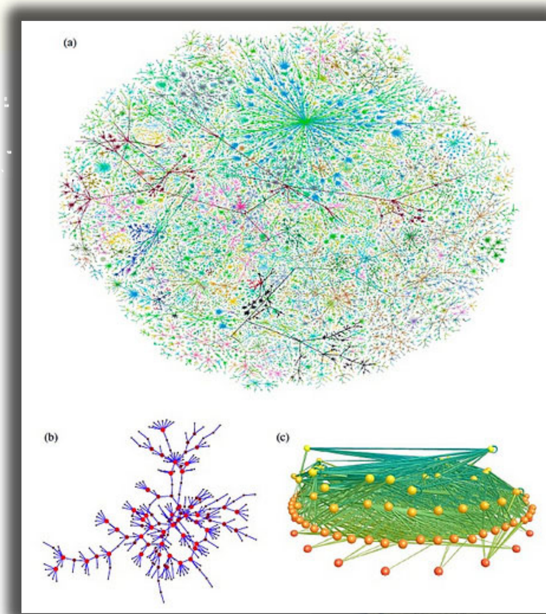
example of general principle of organization

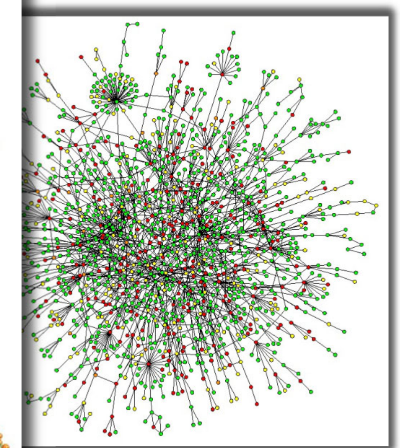
Barabasi-Albert Model: leads to power-law node degree distributions in networks

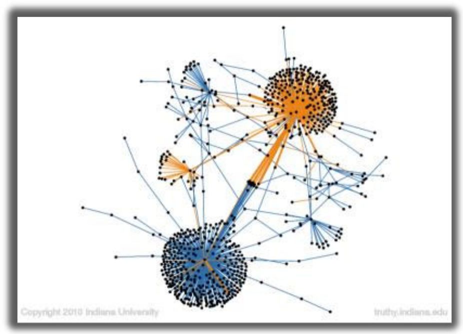
Amaral et al: Most real networks have a cut-off distribution for high degree nodes which can be computationally modeled with vertex aging.

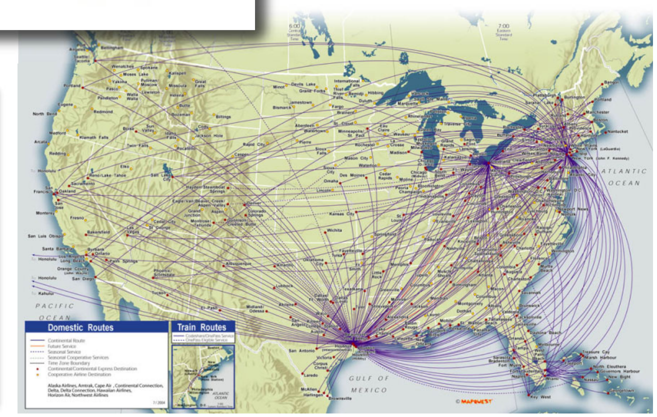
$$R \subseteq A^2 (= A \times A),$$











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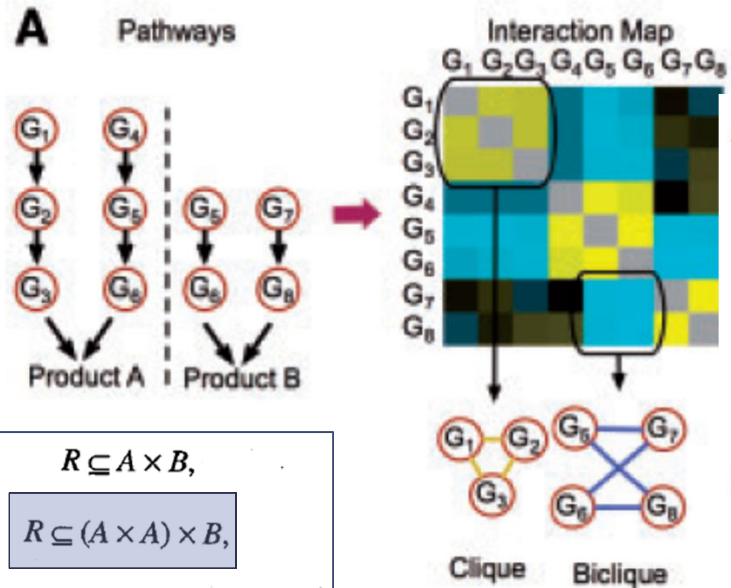
From genetic interaction maps (in yeast)



$$R \subseteq A \times B,$$

$$R \subseteq (A \times A) \times B,$$

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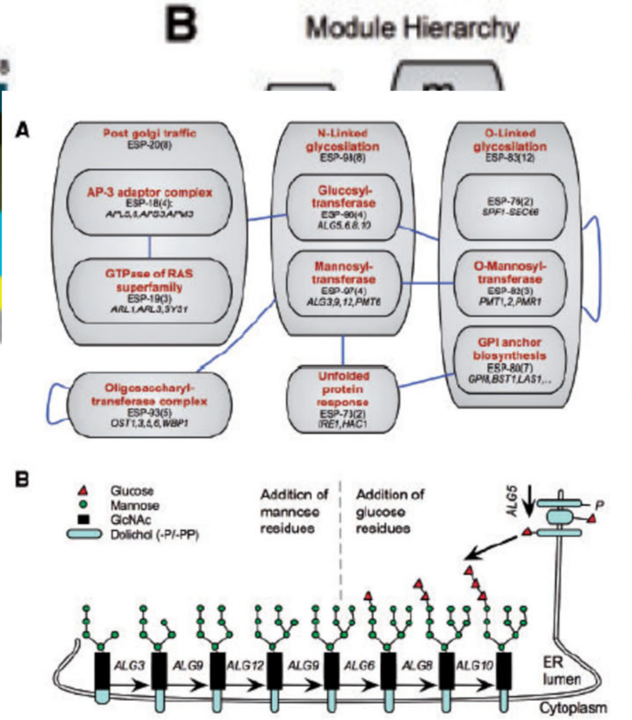
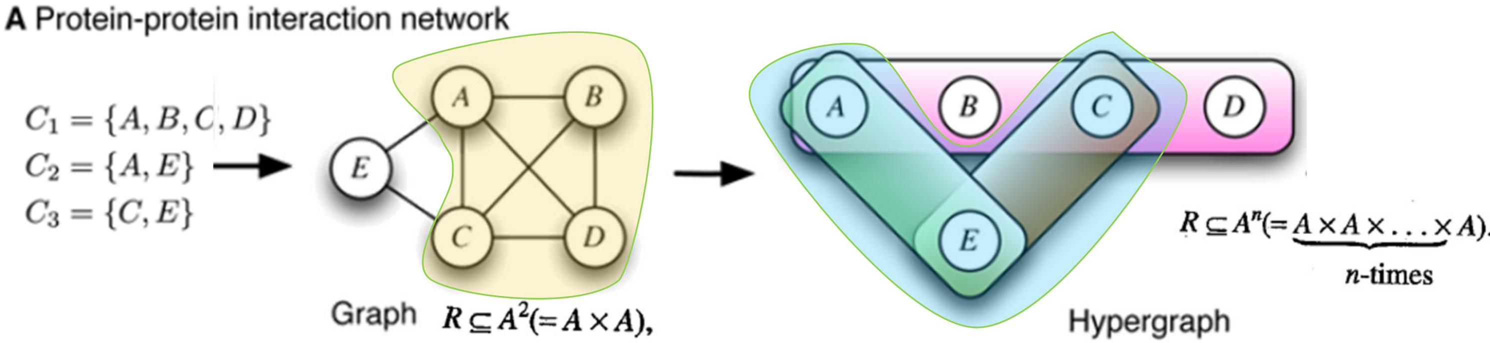


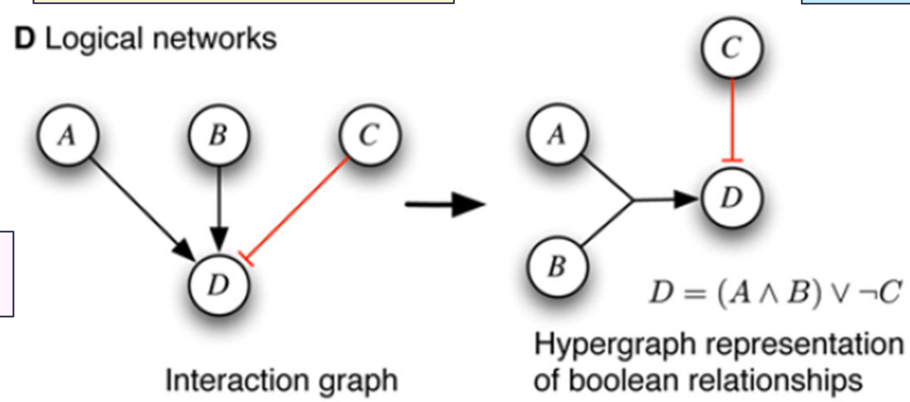
Jaimovich, Aet al. 2010. Modularity and directionality in genetic interaction maps. *Bioinformatics* **26**, no. 12 (June): i228-i236.

lead to different conclusions about underlying multivariate system



Max k-core:
$\{A,B,C,D\}, k = 3$

Max k-core:
$\{A,C,E\}, k = 2$



Separates (linearizes) contributions

Klamt S, Haus U-U, Theis F. [2010]. "Hypergraphs and cellular networks."*PLoS computational biology 5*(5): e1000385.

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lead to different conclusions about underlying multivariate system

C Reaction networks

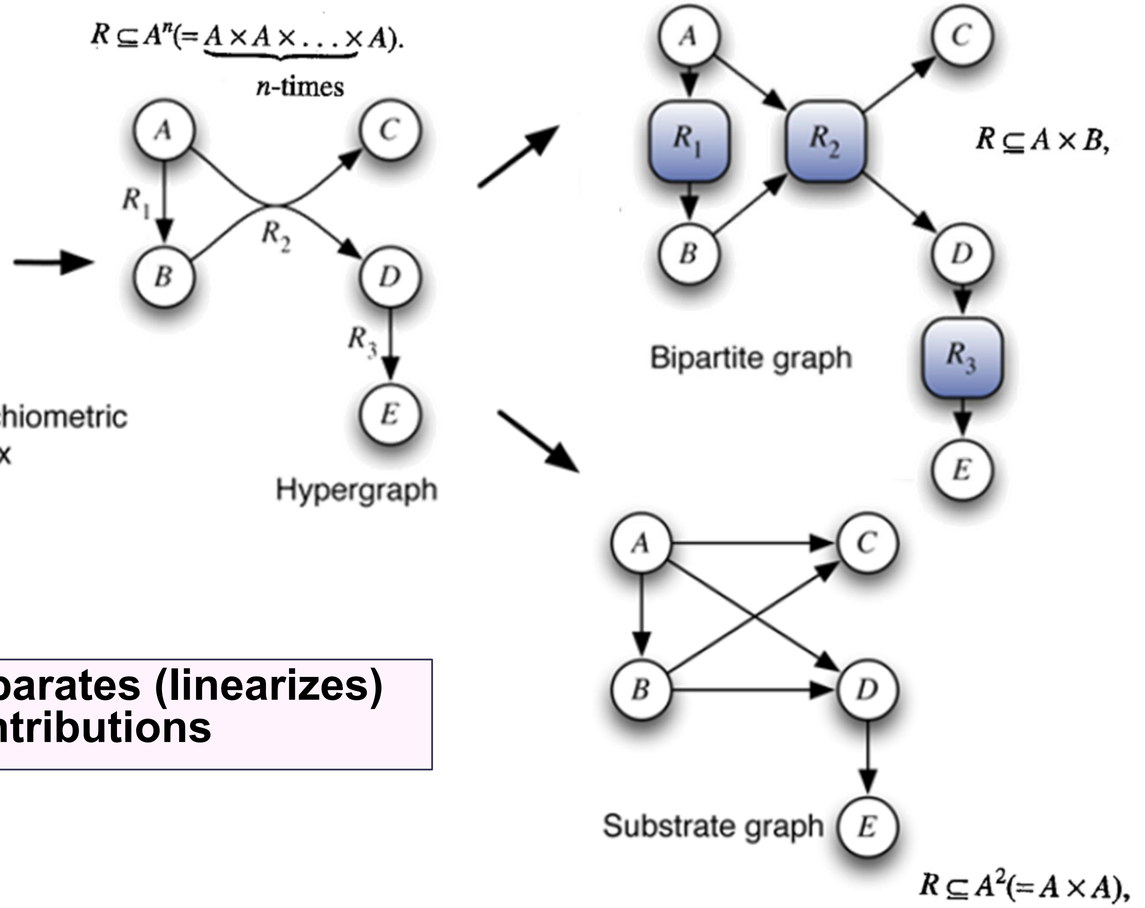
$R_1 : A \longrightarrow B$

$R_2 : A + B \longrightarrow C + D$

$R_3 : D \longrightarrow E$

$$\begin{array}{c} \\ A \\ B \\ C \\ D \\ E \end{array} \begin{array}{c} \begin{array}{ccc} R_1 & R_2 & R_3 \end{array} \\ \begin{pmatrix} -1 & -1 & 0 \\ 1 & -1 & 0 \\ 0 & 1 & 0 \\ 0 & 1 & -1 \\ 0 & 0 & 1 \end{pmatrix} \end{array}$$

Stoichiometric matrix



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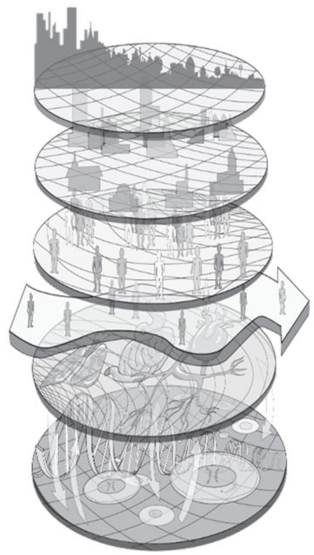
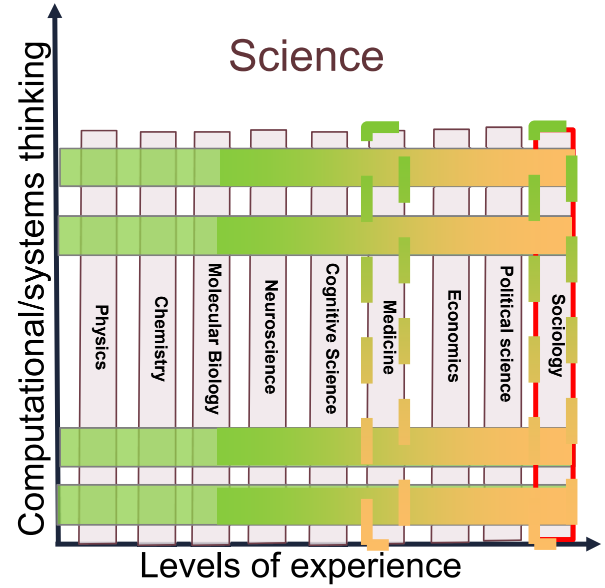
- **Traditional disciplines**
  - defined by specific discernable levels of human experience in nature and society
    - Psychology, Sociology, Political Science, Economics, Physics, Chemistry, Biology, etc
- **CNS, systems/computational thinking**
  - General-purpose tools and universal laws
    - Search for **general principles** of **organization**
    - Produce machines and tools for all sciences
  - Disciplines are orthogonal to traditional disciplines
    - machine learning, network science, data science & analytics, dynamical systems theory, operations research, etc.
- **2-dimensional science**
  - traditional disciplines focus on experimental and observational methods for specific subject matter
  - disciplines of CNS focus on generality of their own methods to any type of data
  - Neither parallel disciplines nor general-purpose methods are sufficient to achieve ***interdisciplinarity***
    - Team culture is necessary
    - E.g. Systems biology, computational biology, computational social science, etc.



Pescosolido, B.A. 2006. Journal of Health and Social Behavior 47: 189-208.



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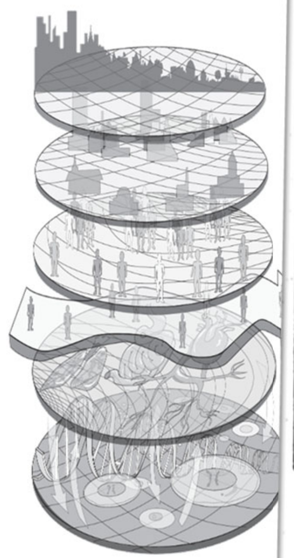

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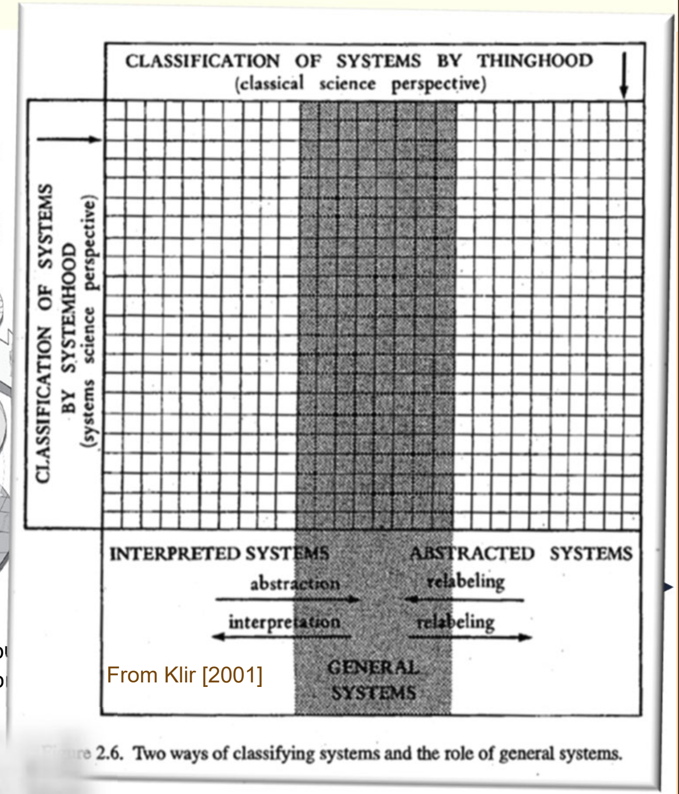

From Klir [2001]

re 2.6. Two ways of classifying systems and the role of general systems.

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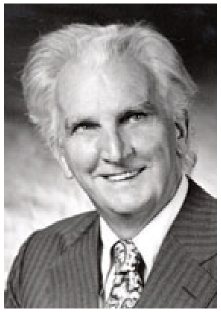
Models of organized complexity

- Systemhood properties
  - Search for a language of *generalized circuits*
  - Isomorphisms of concepts, laws and models across fields
  - Minimize duplication of efforts across fields
  - Unity of science
- Not mathematics
  - Kenneth Boulding
    - "in a sense, because mathematics contains all theories it contains none; it is the language of theory, but it does not give us the content"
    - "body of systematic theoretical construction which will discuss general relationships of the empirical World".
    - "somewhere between the specific that has no meaning and the general that has no content there must be, for each purpose an at each level of abstraction, an optimum degree of generality".
  - Empirical and problem-driven
- Other relevant areas
  - Mathematical theories of control and generalized circuits
  - Information theory
  - Optimal scheduling and resource allocation (operations research, ISE)
  - dynamical systems, chaos, AI, Alife, machine learning, network science, etc.

Ludwig
von Bertalanffy



Kenneth
Boulding

general systems theory

the theoretical biology component

- Systemhood properties of life
  - Search for a language of *generalized circuits*
  - Isomorphy of concepts, laws and models
  - Minimize duplication of efforts across fields
  - Unity of science
- Self-maintaining organization
  - **Dynamics** of regulation and development
    - **Networks** of simple interacting components
  - Dynamics of self-maintenance
    - Autopoiesis, auto-catalytic behavior, autonomy
- Evolutionary systems
  - Encoded production
  - Open-ended evolution
  - “leaky” systems


Stuart Kauffman


Ludwig
von Bertalanffy


Francisco Varela


Howard Pattee

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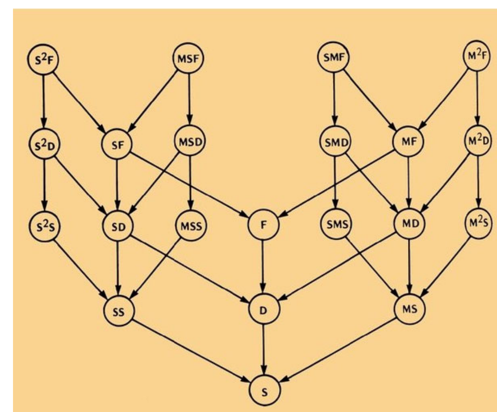
The language lives on

- Learning and cognition as information transmission
  - Brain and mind as mechanism
- Computer as prevalent analogy/model for understanding life and cognition
- Feedback has come to mean information about the outcome of any process or activity
  - No word existed previously in English to convey that concept
- Interaction and organization everywhere
  - Attention shifted from individualism and cause & effect, to circular causation and social interaction
- “Programmed” behavior
- Society and organisms as (general) systems
- Wiener’s prediction of a second industrial revolution centered on communication, control, computation, information, and organization was correct
  - Abundance of technology and mass production of communication devices
    - Grew out of the ideas first reported by the cyberneticians
  - Many disciplines are an offspring of cybernetics



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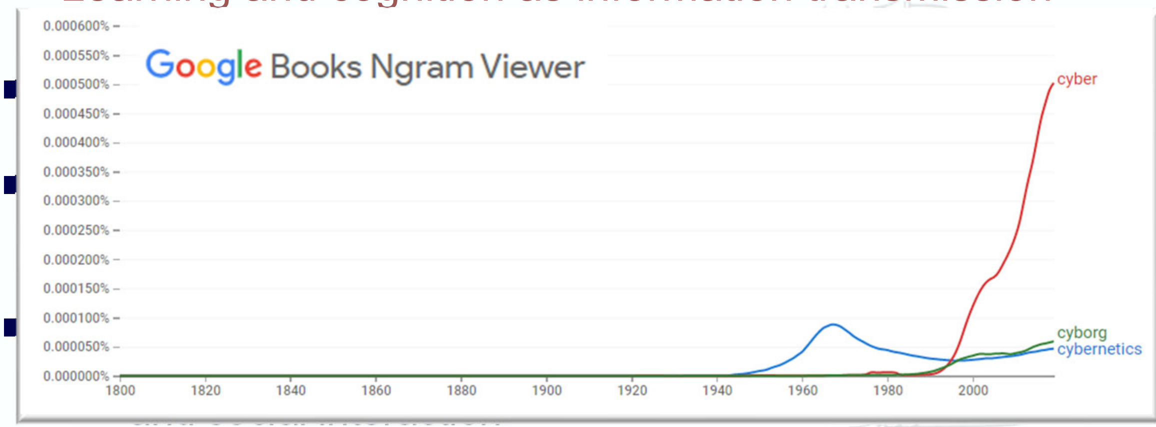
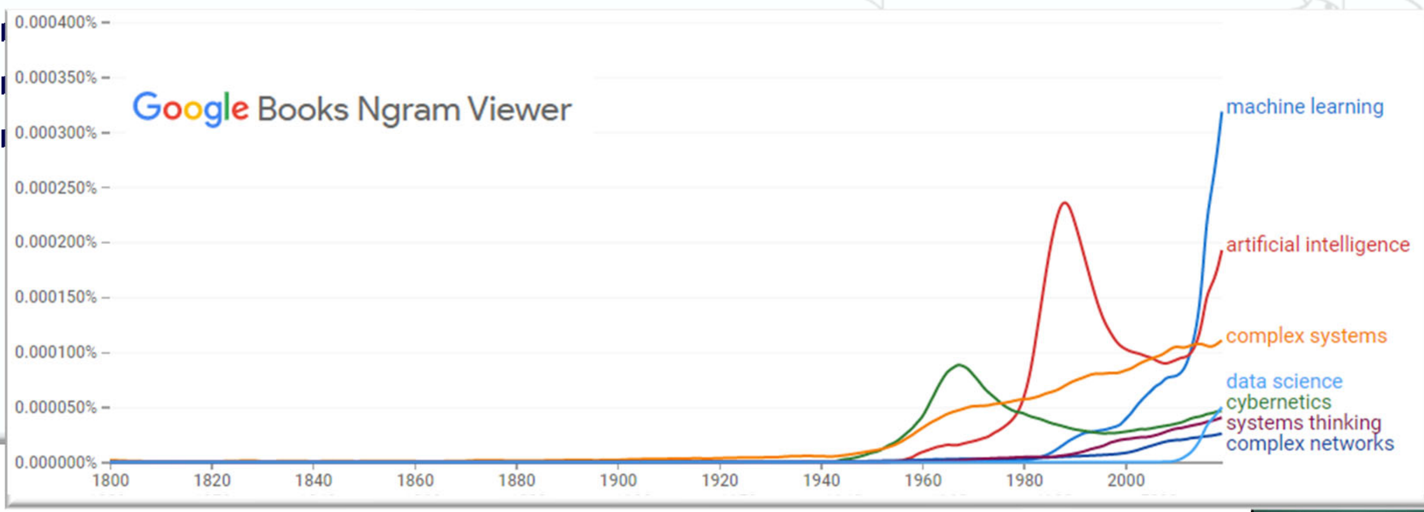
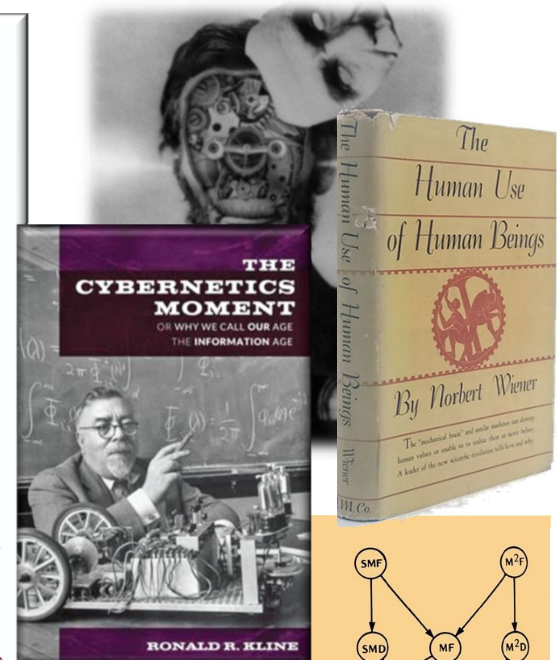
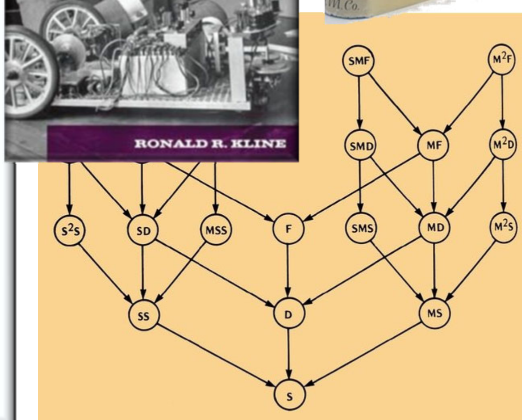
The language lives on

- Learning and cognition as information transmission
- life and
- ome of any
- pt
- ircular causation
- as









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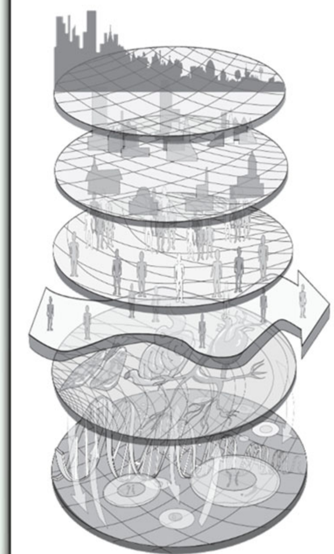
systemhood of health

- A system possesses ***systemhood*** and ***thinghood*** properties
  - *Thinghood* refers to the specific material that makes up the system
  - *Systemhood* are the abstracted properties
    - E.g. a clock can be made of different things, but there are implementation-independent properties of "clockness"
  - Systems science deals with the implementation-independent aspects of systems
    - Allows the conceptualization of unobserved organizations across domains, cultures,…
- Reductionism in Biology (analysis)
  - search and characterization of the *function* of building blocks (genes and molecules)
- Post-genome informatics or systems Biology
  - Synthesis of biological knowledge from genomic **information**
    - The genome contains information about building blocks but it is naive to assume that it also contains the information on how the building blocks relate, develop, and evolve.
- Biomedical complexity pursued as systems modeling
  - Towards an interdisciplinary understanding of ***principles*** of life and health via the search and characterization of networks of building blocks (genes and molecules)
    - Systems biology embraces the view that most interesting human organism traits such as immunity, development and even diseases such as cancer arise from the *operation of complex biological systems or networks*.
    - Multilevel regulation and signaling networks in health and disease
      - E.g. social determinants of health, epidemiology
    - Systems concepts
      - control, modularity, networks, information and hierarchies



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- Papers and other materials
  - Module 2: Systems Science
    - Reading and Discussion Group 4
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- Class Book
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  - Module 3 - The Organization of Complex Systems
    - Reading and Discussion Group 5 (Enginet)
      - Simon, H.A. [1962]. "The Architecture of Complexity". *Proceedings of the American Philosophical Society*, **106**: pp. 467-482. Also available in Klir, G.J. [2001]. *Facets of systems Science*. Springer, pp: 541-559.
      - Golan, Amos, and John Harte. "Information theory: A foundation for complexity science." *Proceedings of the National Academy of Sciences* **119**.33 (2022): e2119089119.
      - James, R., and Crutchfield, J. (2017). "Multivariate Dependence beyond Shannon Information". *Entropy*, **19**(10), 531.