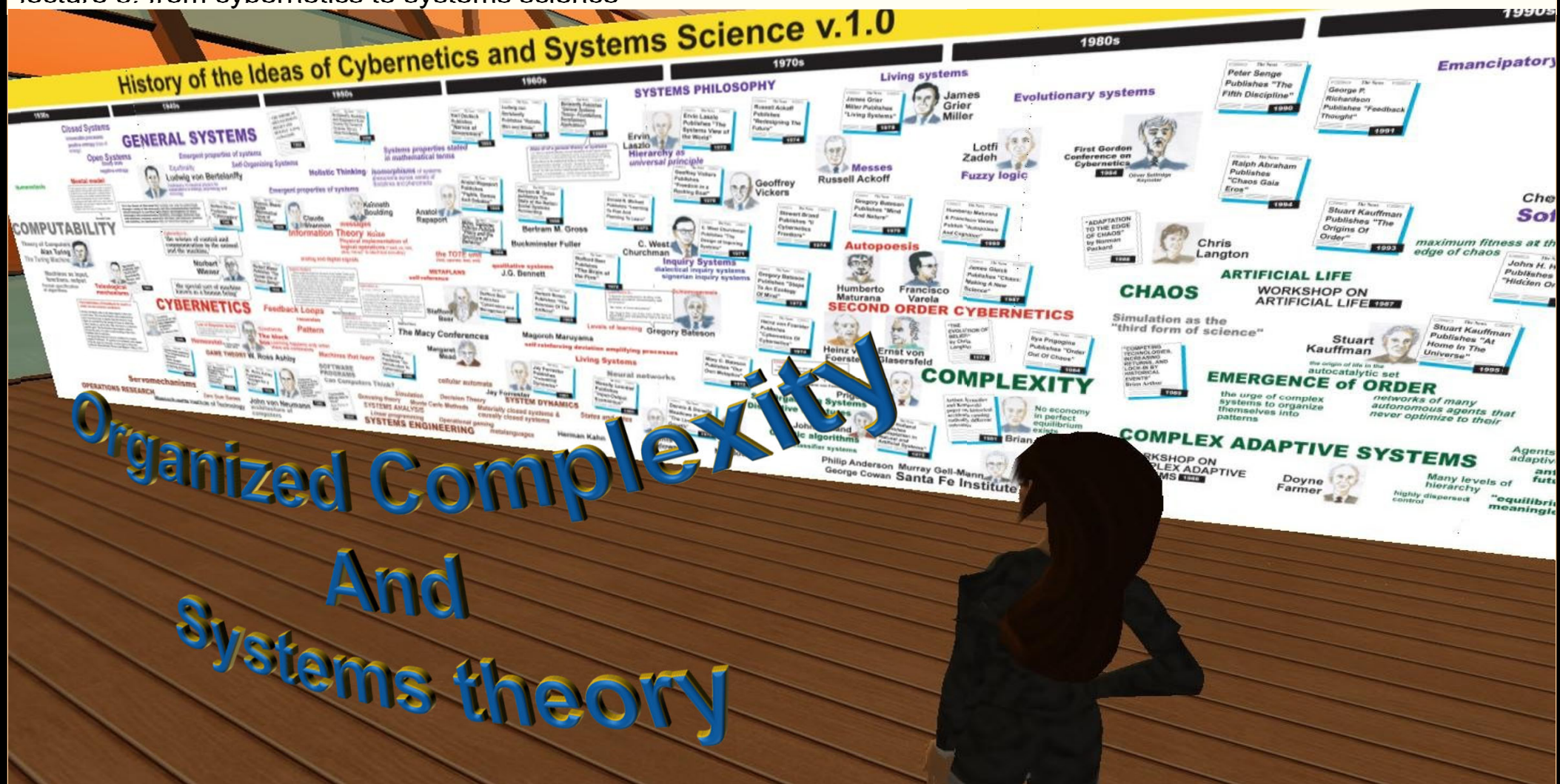


lecture 5: from cybernetics to systems science



Warren Weaver' classes of systems and problems

■ organized simplicity

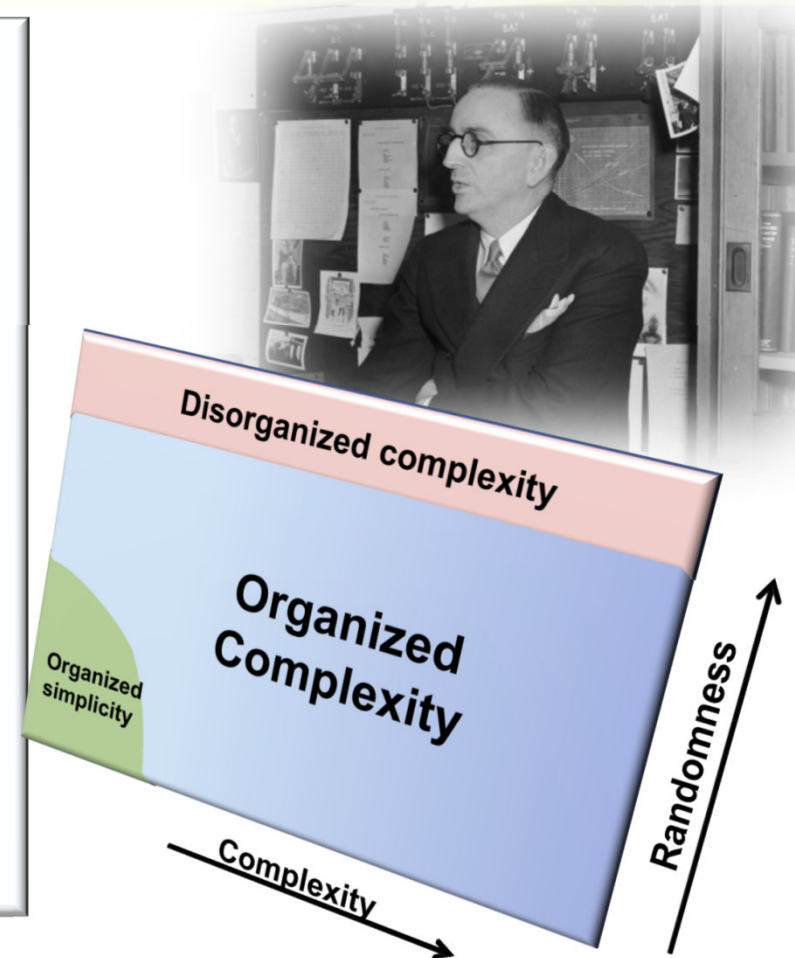
- very small number of variables
 - Deterministic
- classical mathematical tools
 - Calculus

■ disorganized complexity

- very large number of variables
 - Randomness, homogenous
- statistical tools

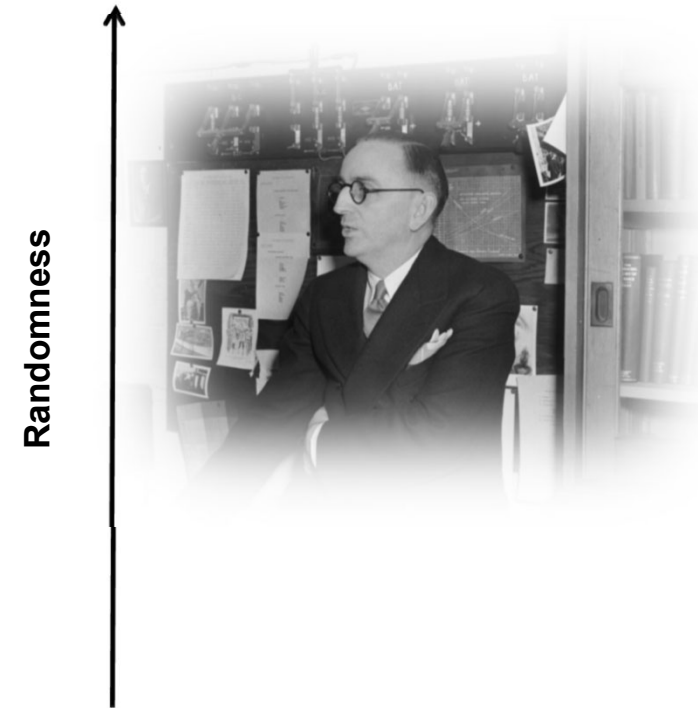
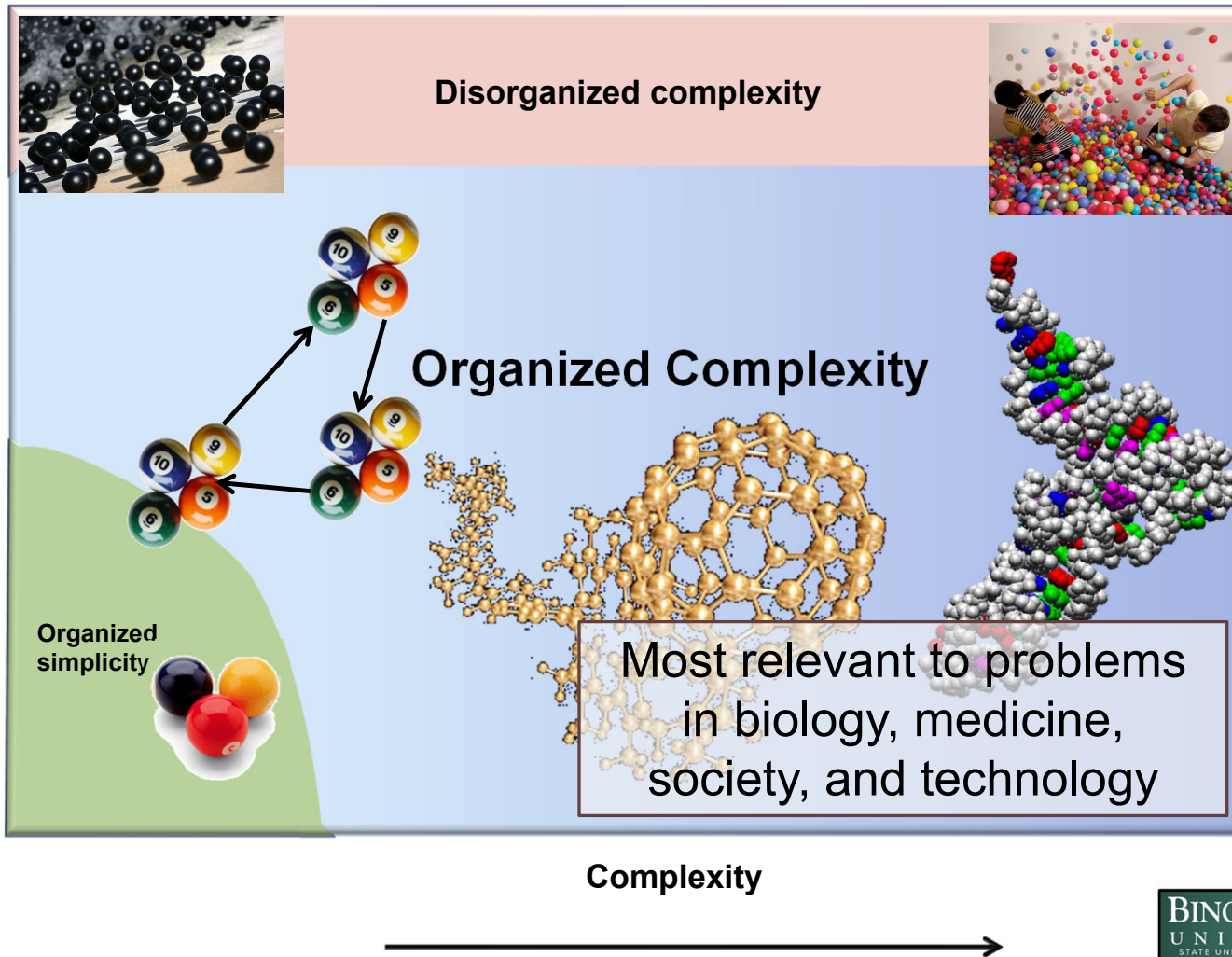
■ organized complexity

- sizable number of variables which are interrelated into an organic whole
- study of organization
 - whole more than sum of parts
 - Massive combinatorial searches need for new mathematical and computational tools



Weaver, W. [1948]. "Science and Complexity". *American Scientist*, 36(4): 536-44.

examples



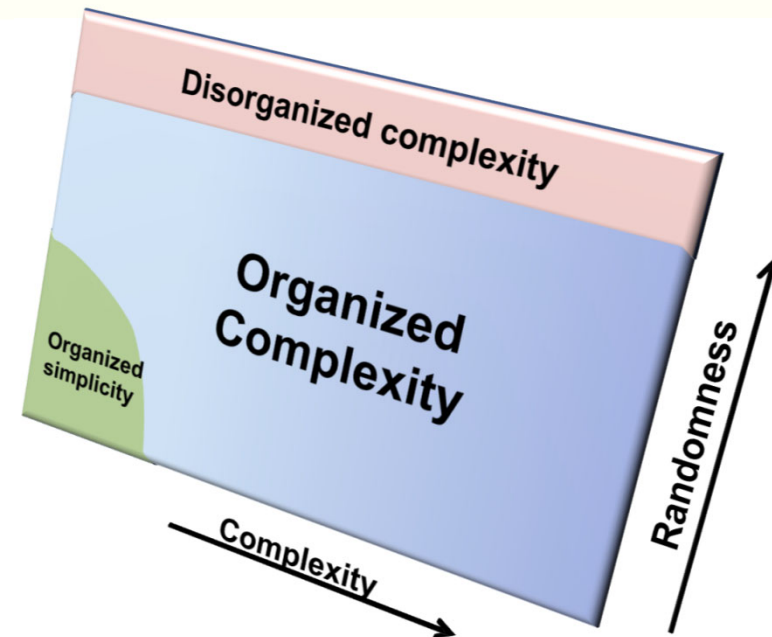
from computational to systems thinking

■ organized complexity

- study of organization
 - whole is more than sum of parts
 - Organizational properties ("systemhood")
- Need for new mathematical and computational tools
 - Massive combinatorial searches
 - Problems that can only be tackled with computers
 - Computer as lab
- Interdisciplinary and collaborative science
 - Thrives in problem-driven environments
 - Los Alamos, Santa Fe, all new computing centers.

■ thinghood and systemhood

- developing general-purpose computing further
 - Computational thinking and cybernetics
 - Some (all?) mechanisms and organizational principles are implementation-independent
 - Hardware vs software
- Integration of empirical science with general systems
 - Interdisciplinarity coupled with computational modeling
- Understanding structure and *function*
 - Of multi-level wholes
 - Systems biology, Evolutionary thinking, Systems thinking
 - **Emergence** (or collective behavior)
 - How do elements combine to form new unities?
 - **Micro- to macro-level behavior**



key roots

- Mathematics
- Computer Technology and Computational Thinking
- Systems Thinking

- Cybernetics

- Looking at mind, life, society with control, computation, information, networks

- Functional equivalence

- General principles and modeling

Organized Complexity

- Study of organization
 - “Whole is more than some of parts”, nonlinearity, interaction, communication

- Interdisciplinary outlook

- Not just math and computing, modeling requires understanding of focus domain
 - Bio-inspired mathematics and computing
 - Computing/Mechanism-inspired biology and social science

Energy Storage System



Kenneth
Boulding



Ludwig
von Bertalanffy



Ralph
Gerard



Anatol
Rapoport

1965: Society for the Advancement
of General Systems Theory

a science of organization across disciplines

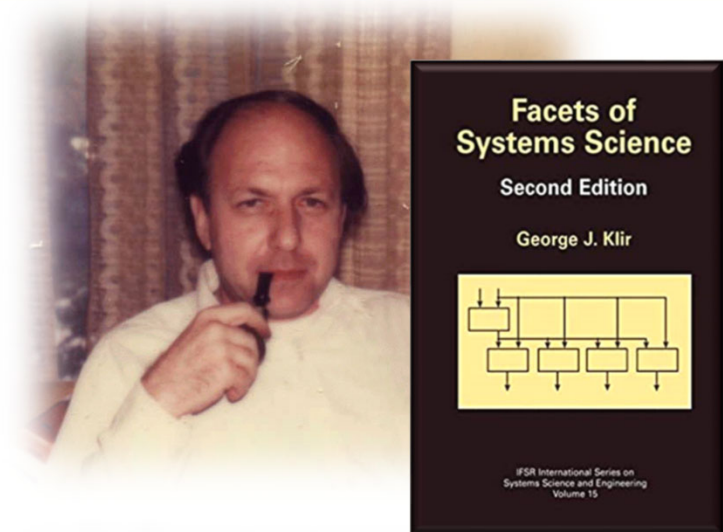
■ Systemhood properties of nature

● Robert Rosen

- Systems depends on a specific adjective: **thinghood**
- **Systemhood**: properties of arrangements of items, independent of the items
 - Similar to “setness” or cardinality

● George Klir

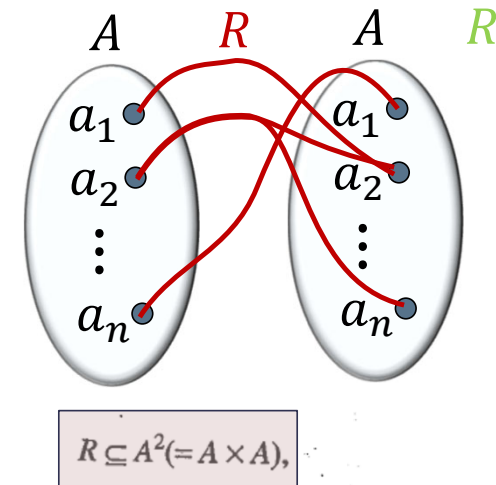
- **Organization** can be studied with the mathematics of **relations**
- $S = (T, R)$
 - S : a System, T : a set of things(thinghood), R : a (or set of) relation(s) (Systemhood)
 - Same relation can be applied to different sets of objects
 - Systems science deals with **organizational properties** of systems independently of the items
- **Examples**
 - Collections of books or music files are sets of things
 - But organization of such sets are systems (alphabetically, chronologically, typologically, etc.)



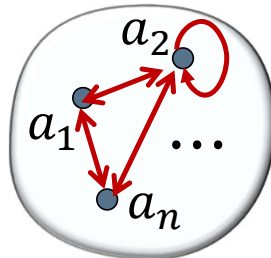
what is a system?

more formally: representation of multivariate of associations/interactions

- $S = (T, R)$
 - a (multivariate) system
- $T = \{A_1, A_2, \dots, A_n\}$
 - A set (of sets) of things
 - *thinghood*
- Cartesian Product
 - Set of all possible associations of elements from each set
 - All n -tuples
 - $\{A_1 \times A_2 \times \dots \times A_n\}$
- R : a relation (systemhood)
 - Subset of cartesian product on T .
 - Many relations R can be defined on the same T



graph A

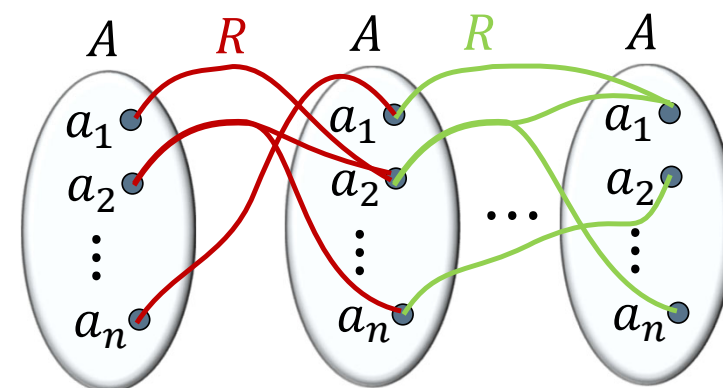


George Klir

what is a system?

more formally: representation of multivariate of associations/interactions

- $S = (T, R)$
 - a (multivariate) system
- $T = \{A_1, A_2, \dots, A_n\}$
 - A set (of sets) of things
 - *thinghood*
- Cartesian Product
 - Set of all possible associations of elements from each set
 - All n -tuples
 - $\{A_1 \times A_2 \times \dots \times A_n\}$
- R : a relation (systemhood)
 - Subset of cartesian product on T .
 - Many relations R can be defined on the same T



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

$$R \subseteq A^3 (= A \times A \times A),$$

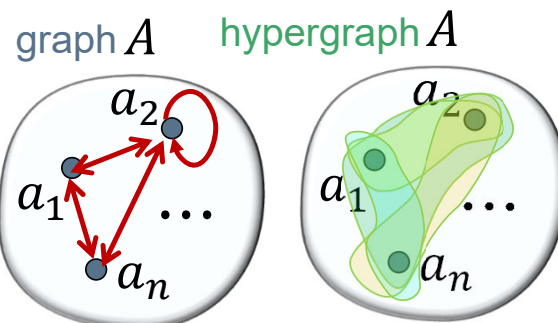
$$R \subseteq A^n (= \underbrace{A \times A \times \dots \times A}_{n\text{-times}}).$$

n -times

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

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

$$R \subseteq (A \times A) \times (A \times A).$$

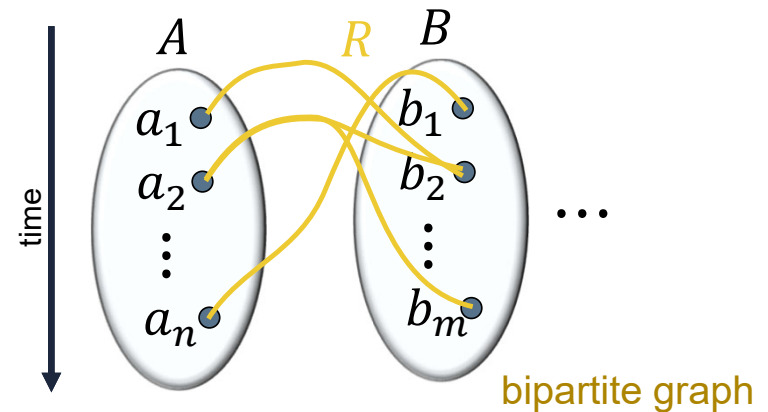


George Klir

what is a system?

more formally: representation of multivariate of associations/interactions

- $S = (T, R)$
 - a (multivariate) system
- $T = \{A_1, A_2, \dots, A_n\}$
 - A set (of sets) of things
 - *thinghood*
- Cartesian Product
 - Set of all possible associations of elements from each set
 - All n -tuples
 - $\{A_1 \times A_2 \times \dots \times A_n\}$
- R : a relation (systemhood)
 - Subset of cartesian product on T .
 - Many relations R can be defined on the same T



bipartite graph

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

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

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

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

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

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

George Klir

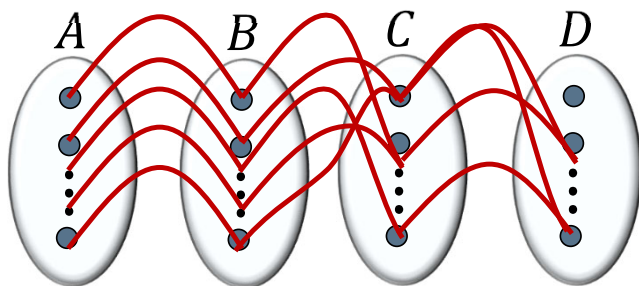
equivalence classes or multilayer network?

Table 2.1. Set of Students with Four Characteristics

Student	Grade	Major	Age	Full-time/ part-time
Alan	B	Biology	19	Full-time
Bob	C	Physics	19	Full-time
Cliff	C	Mathematics	20	Part-time
Debby	A	Mathematics	19	Full-time
George	A	Mathematics	19	Full-time
Jane	A	Business	21	Part-time
Lisa	B	Chemistry	21	Part-time
Mary	C	Biology	19	Full-time
Nancy	B	Biology	19	Full-time
Paul	B	Business	21	Part-time

Table 2.2. Equivalence Relation R_g Defined on the Set of Students Listed in Table 2.1 with Respect to Their Grades

R_g	A	B	C	D	G	J	L	M	N	P
A	1	0	0	0	0	0	1	0	1	1
B	0	1	1	0	0	0	0	1	0	0
C	0	1	1	0	0	0	0	1	0	0
D	0	0	0	1	1	1	0	0	0	0
G	0	0	0	1	1	1	0	0	0	0
J	0	0	0	1	1	1	0	0	0	0
L	1	0	0	0	0	0	1	0	1	1
M	0	1	1	0	0	0	0	1	0	0
N	1	0	0	0	0	0	1	0	1	1
P	1	0	0	0	0	0	1	0	1	1



$$R \subseteq A \times B \times C \times D$$

Note: same thinghood (set of students), but distinct systemhood or organization projected to a specific set (layer) as equivalence classes.

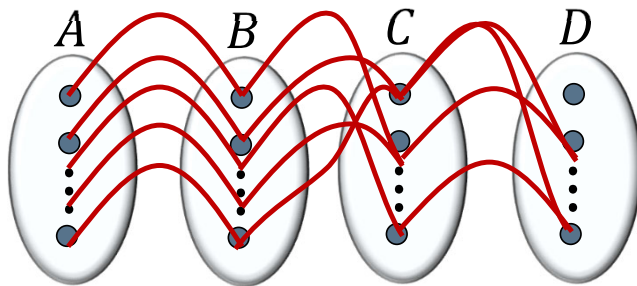
equivalence classes or multilayer network?

Table 2.1. Set of Students with Four Characteristics

Student	Grade	Major	Age	Full-time/ part-time
Alan	B	Biology	19	Full-time
Bob	C	Physics	19	Full-time
Cliff	C	Mathematics	20	Part-time
Debby	A	Mathematics	19	Full-time
George	A	Mathematics	19	Full-time
Jane	A	Business	21	Part-time
Lisa	B	Chemistry	21	Part-time
Mary	C	Biology	19	Full-time
Nancy	B	Biology	19	Full-time
Paul	B	Business	21	Part-time

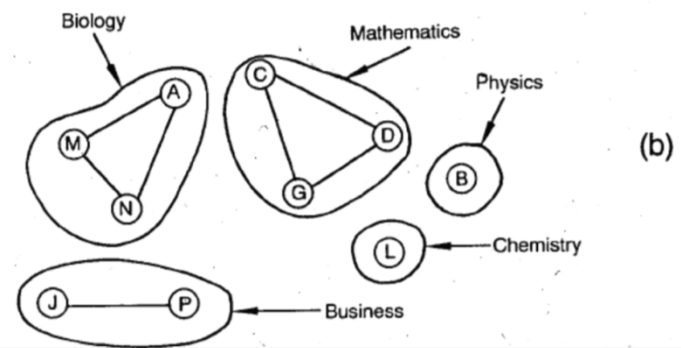
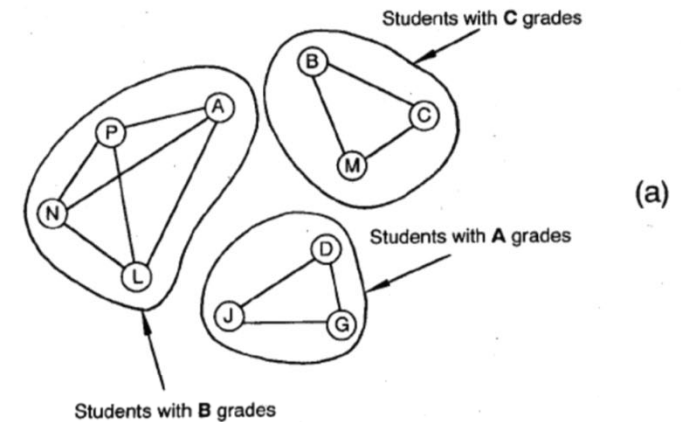
Table 2.2. Equivalence Relation R_g D
Table 2.1 with Res

R_g	A	B	C	D	G
A	1	0	0	0	0
B	0	1	1	0	0
C	0	1	1	0	0
D	0	0	0	1	1
G	0	0	0	1	1
J	0	0	0	1	1
L	1	0	0	0	0
M	0	1	1	0	0
N	1	0	0	0	0
P	1	0	0	0	0



$$R \subseteq A \times B \times C \times D$$

Note: same thinghood (set of students), but distinct systemhood or organization projected to a specific set (layer) as equivalence classes.



study of “systemhood” separated from “thinghood”

- **Study of “systemhood” properties**
 - Classes of isomorphic abstracted systems
 - Search of **general principles of organization**
 - Weaver’s organized complexity (1948)
- **Systemhood properties**
 - preserved under suitable transformation from the set of things of one system into the set of things from the other system
 - Divides the space of possible systems (relations) into equivalent classes
- **Devoid of any interpretation!**
 - General systems
 - Canonical examples of equivalence classes

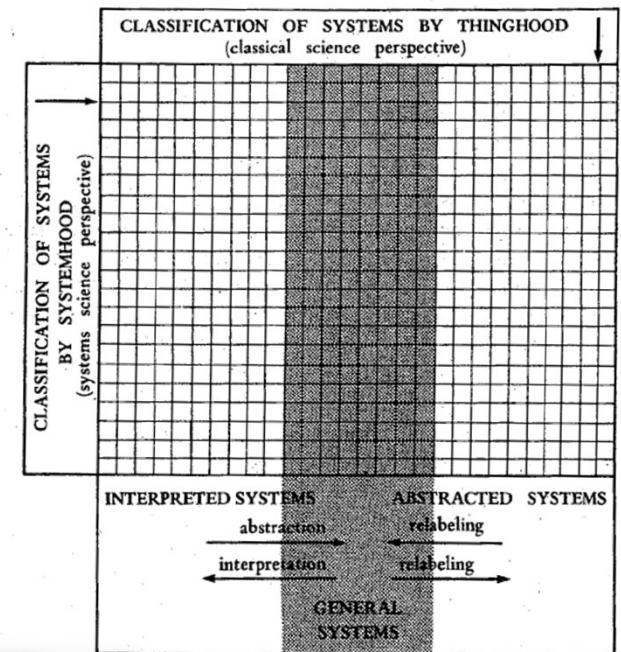


Figure 2.6. Two ways of classifying systems and the role of general systems.

From Klir [2001]

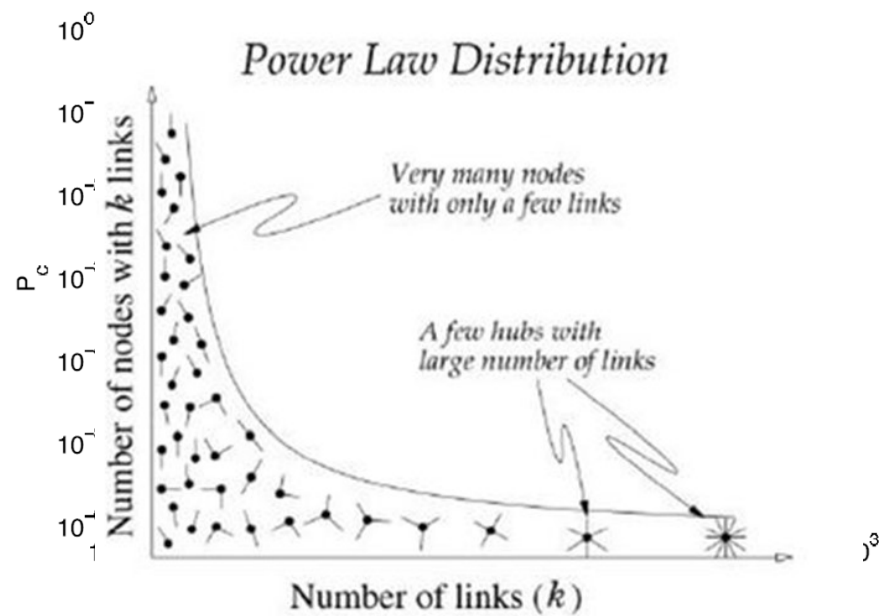


George Klir

example of general principle of organization

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

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

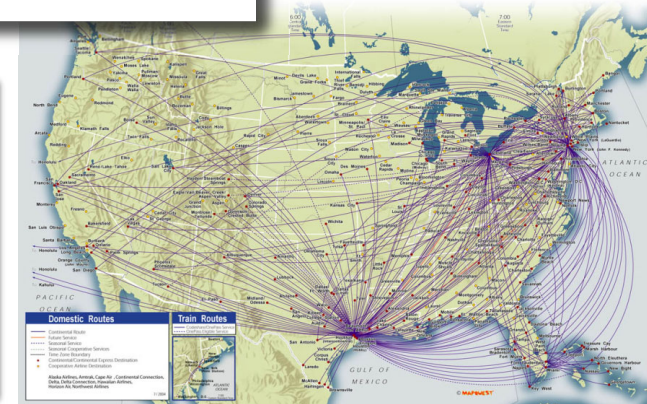
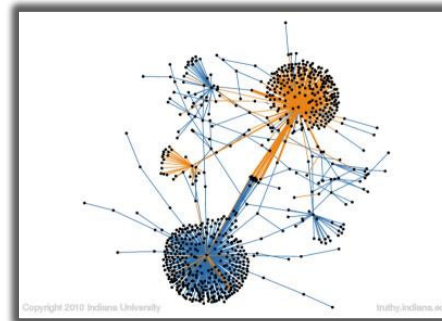
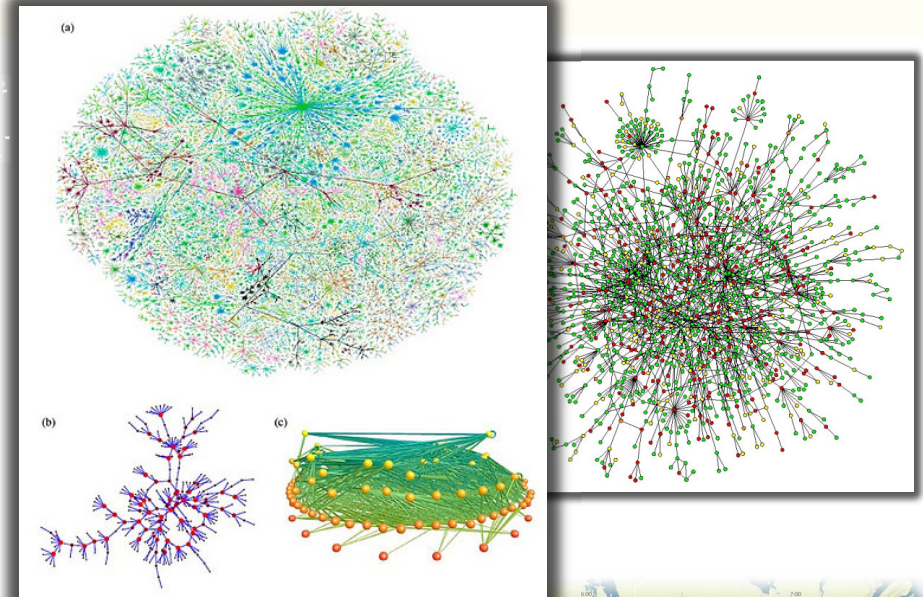
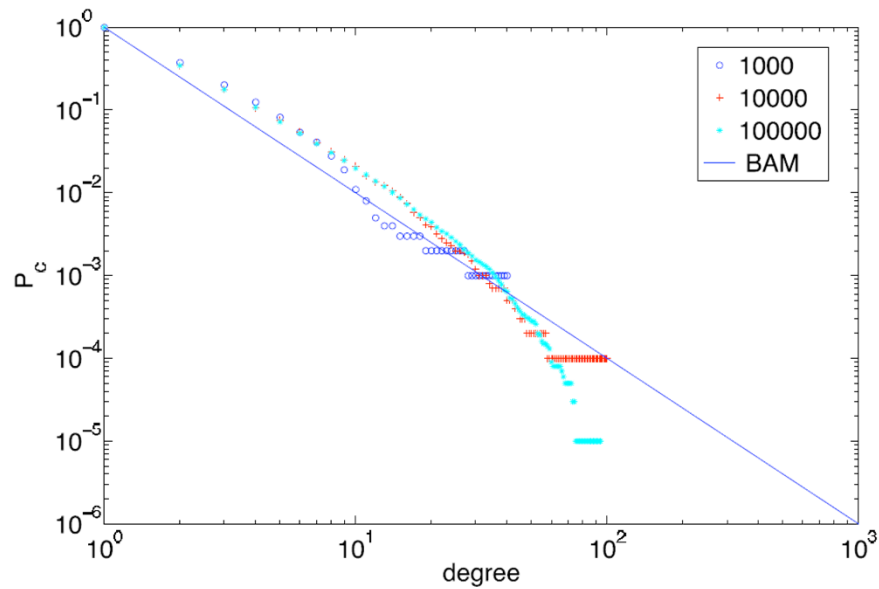


example of general principle of organization

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

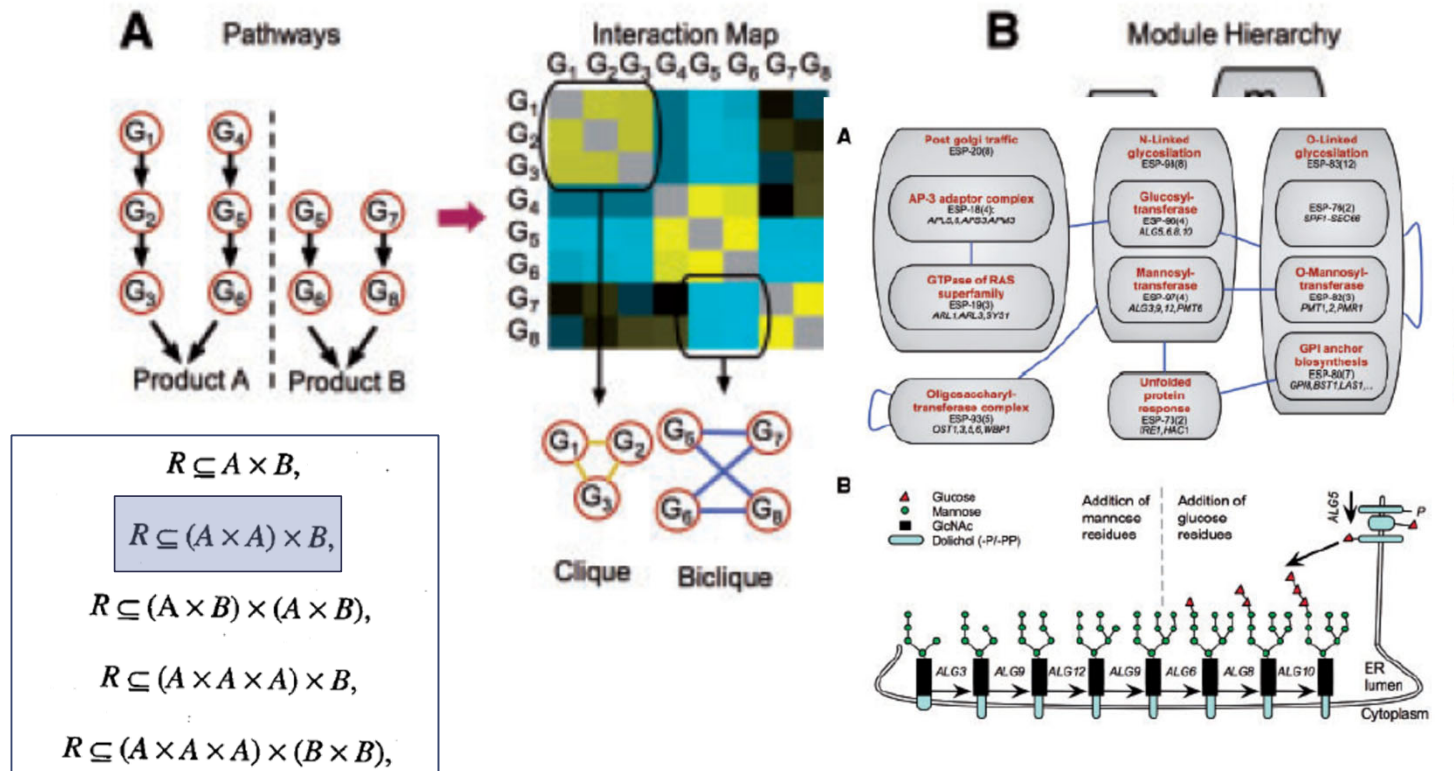
Amaral et al: Most real networks have a cut-off distribution for high degree nodes which can be computationally modeled with vertex aging.

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



Uncovering hierarchical organization

From genetic interaction maps (in yeast)



Jaimovich, A et al. 2010. Modularity and directionality in genetic interaction maps.

Bioinformatics **26**, no. 12 (June): i228-i236.

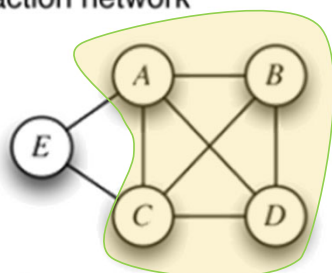
lead to different conclusions about underlying multivariate system

A Protein-protein interaction network

$$C_1 = \{A, B, C, D\}$$

$$C_2 = \{A, E\}$$

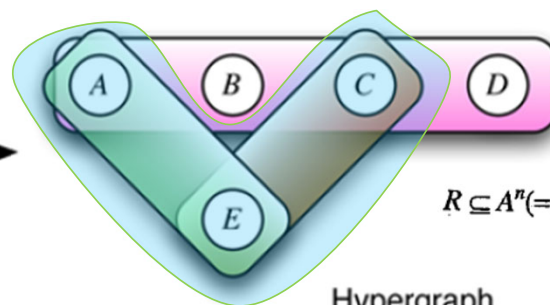
$$C_3 = \{C, E\}$$



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

Max k-core:

$\{A, B, C, D\}, k = 3$



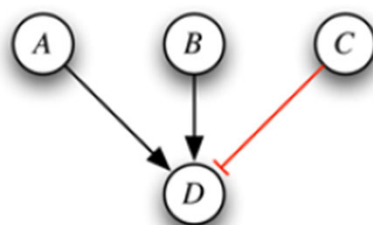
$$R \subseteq A^n (= \underbrace{A \times A \times \dots \times A}_{n\text{-times}}).$$

Hypergraph

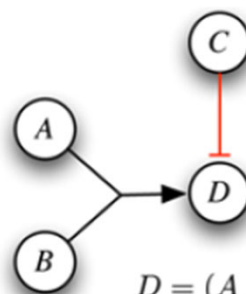
Max k-core:

$\{A, C, E\}, k = 2$

D Logical networks



Interaction graph



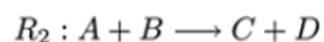
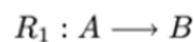
$$D = (A \wedge B) \vee \neg C$$

Hypergraph representation
of boolean relationships

**Separates (linearizes)
contributions**

lead to different conclusions about underlying multivariate system

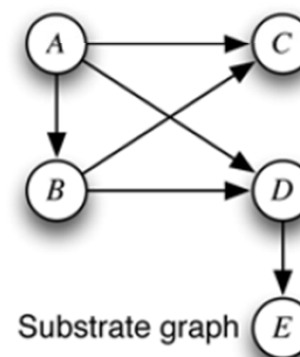
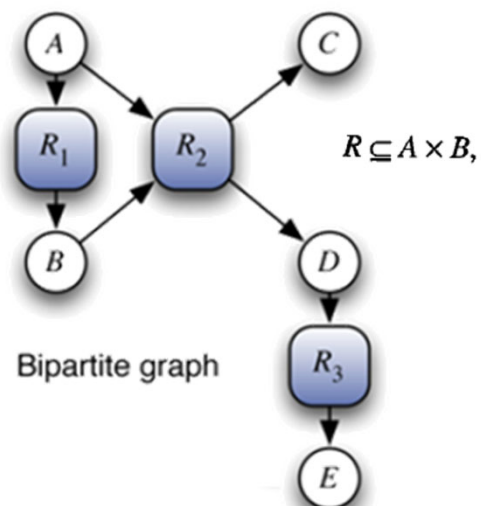
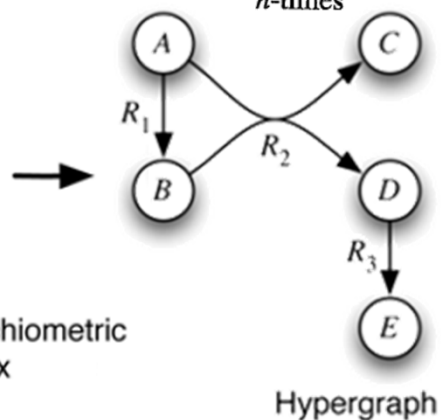
C Reaction networks



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

$$R \subseteq A^n (= A \times A \times \dots \times A).$$

n -times



**Separates (linearizes)
contributions**

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

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

general-purpose study of “systems” properties of nature, technology, and society

complex networks & systems thinking

■ Traditional disciplines

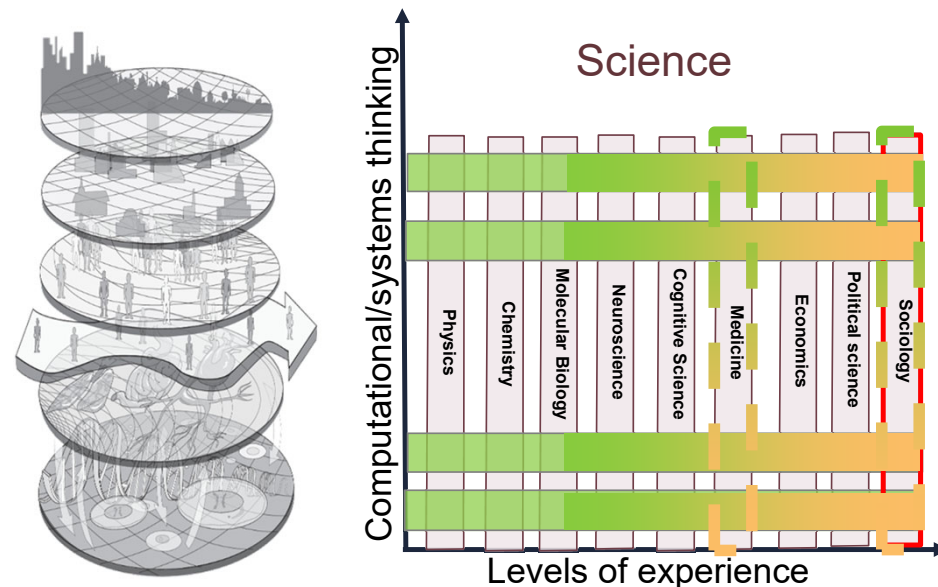
- defined by specific discernable levels of human experience in nature and society
 - Psychology, Sociology, Political Science, Economics, Physics, Chemistry, Biology, etc

■ 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.

general-purpose study of “systems” properties of nature, technology, and society

complex networks & systems thinking

■ Traditional disciplines

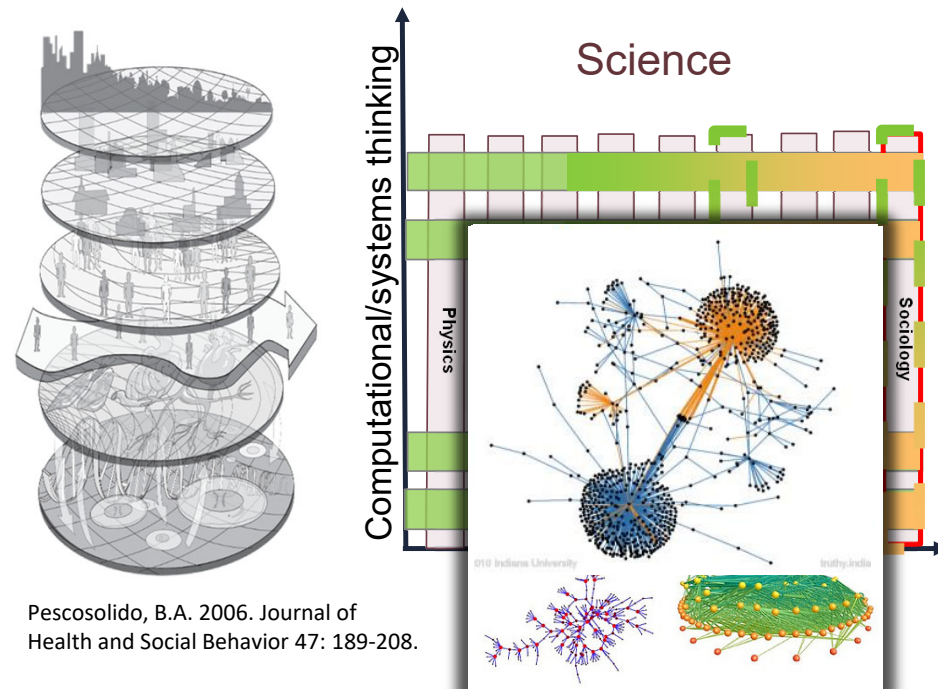
- defined by specific discernable levels of human experience in nature and society
 - Psychology, Sociology, Political Science, Economics, Physics, Chemistry, Biology, etc

■ 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.



general-purpose study of “systems” properties of nature, technology, and society

complex networks & systems thinking

■ Traditional disciplines

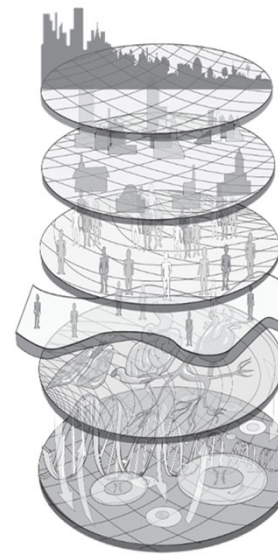
- defined by specific discernable levels of human experience in nature and society
 - Psychology, Sociology, Political Science, Economics, Physics, Chemistry, Biology, etc

■ CNS, systems/computational thinking

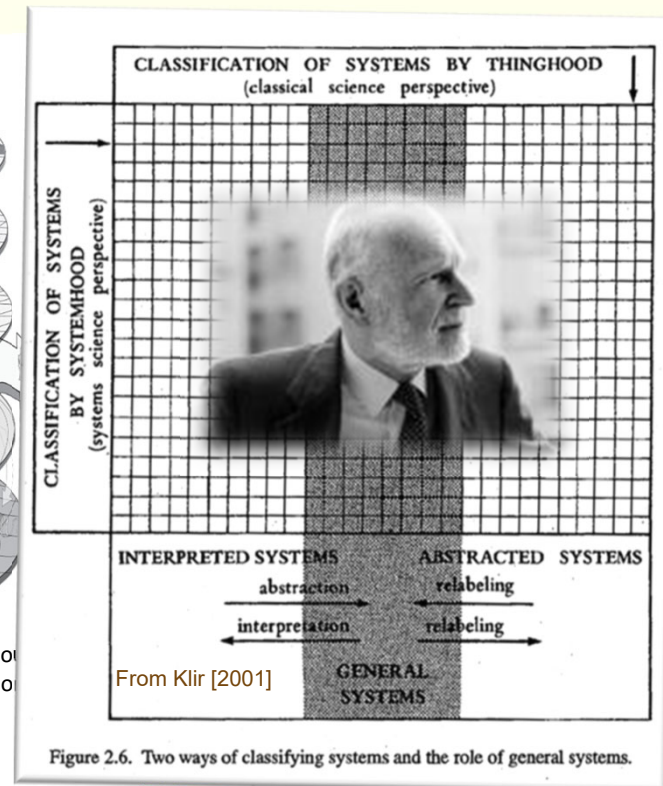
- General-purpose tools and universal laws
 - Search for **general principles of organization**
 - Produce machines and tools for all sciences
- Disciplines are orthogonal to traditional disciplines
 - machine learning, network science, data science & analytics, dynamical systems theory, operations research, 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*



CNS NRT



rocha@binghamton.edu
casci.binghamton.edu/academics/ssie501m

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 and at each level of abstraction, an optimum degree of generality”.

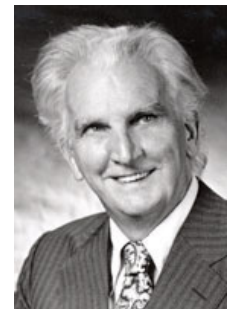
- Empirical and problem-driven

■ 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

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



Howard Pattee



Francisco Varela

general systems theory

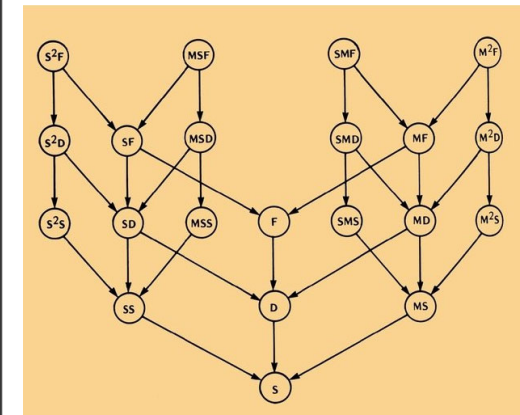
the theoretical biology component



Villa Serbelloni in 1966. Seated, from left to right: Christopher Longuet-Higgins, Ernst Mayr, 'Wad' Waddington, Ruth Sager, Brian Goodwin, Doris Manning and John Maynard Smith. Standing: A. G. Cairns-Smith, Rene' Thom, Sam Devons, John Platt, Howard Pattee, Christopher Zeeman, Dick Lewontin, Karl Kornacker, Paul Lieber, Jack Cowan, Heinrich Kroege, Lewis Wolpert and Donald Michie. *Towards a Theoretical Biology*, Edited by C.H. Waddington, Edinburgh University Press (1968).

The language lives on

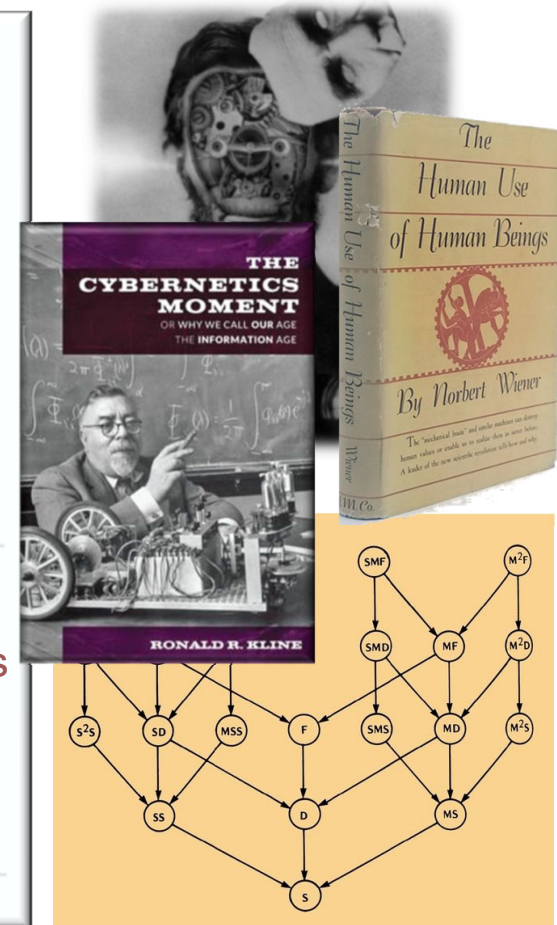
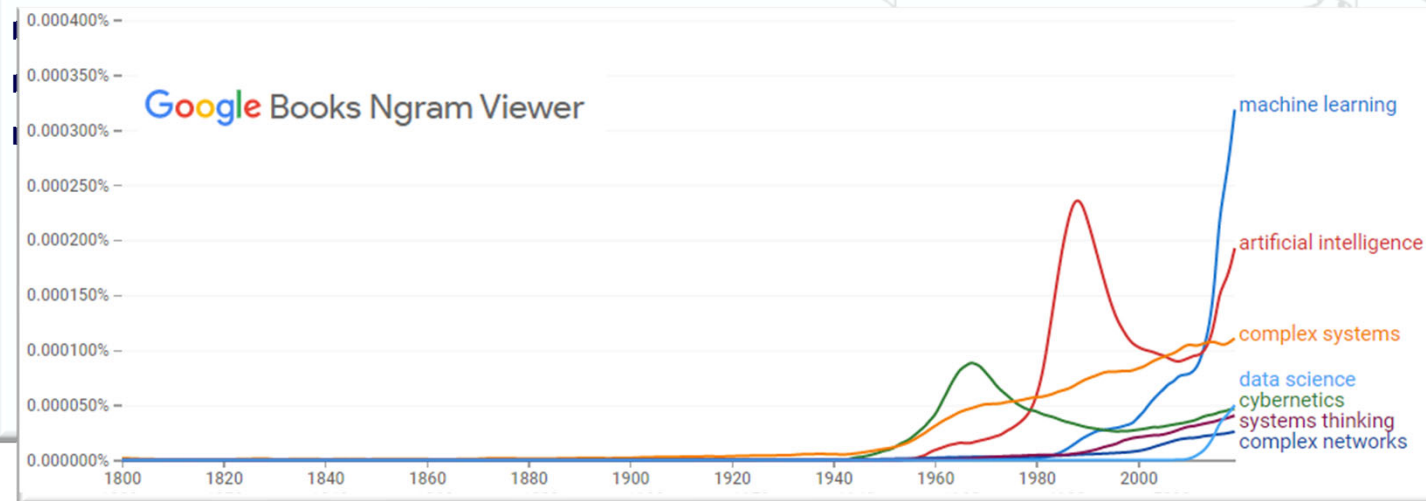
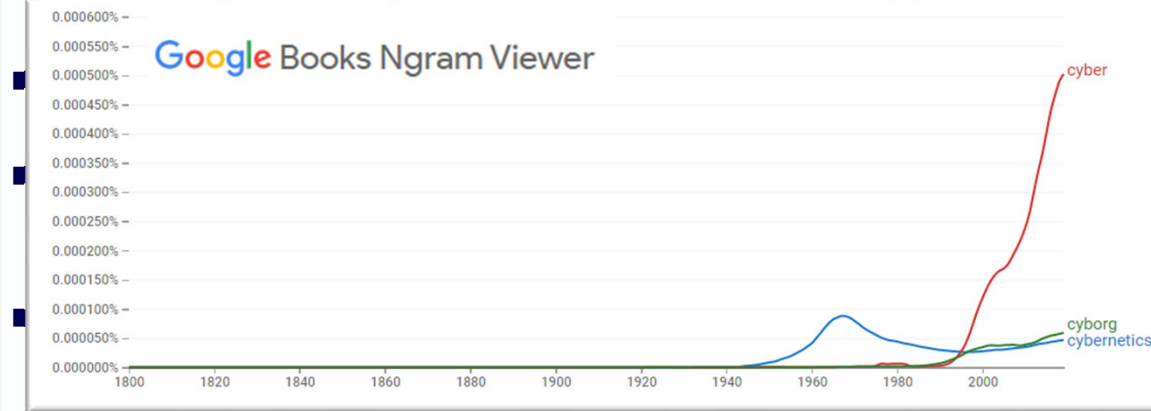
- Learning and cognition as information transmission
 - [Google Books Ngram Viewer](#) [sm](#)
- Conceptual technology/model for understanding life and cognition
- Feedback has come to mean information about the outcome of any process or activity
 - No word existed previously in English to convey that 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



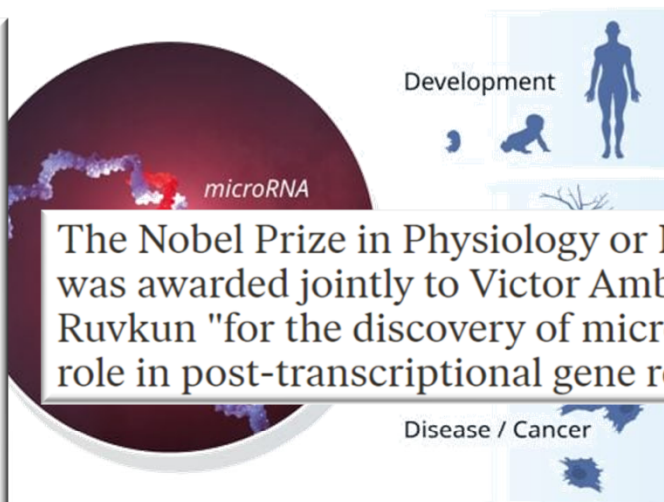
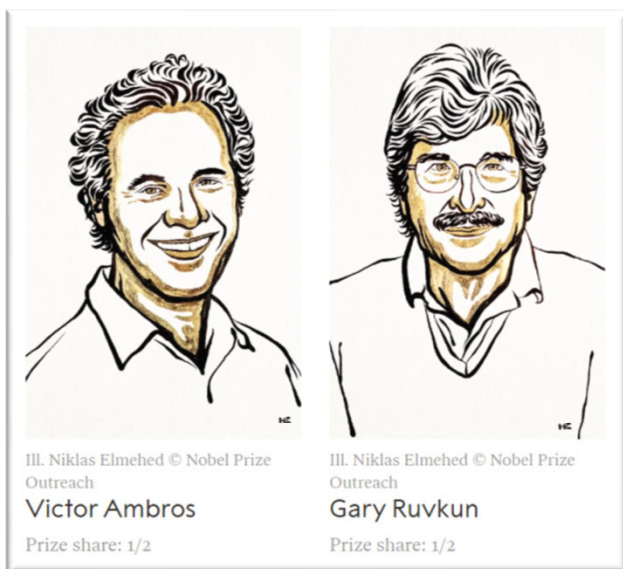
cybernetics and systems science

The language lives on

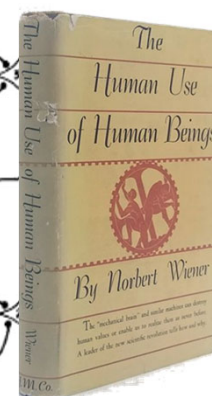
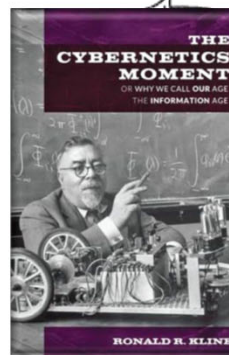
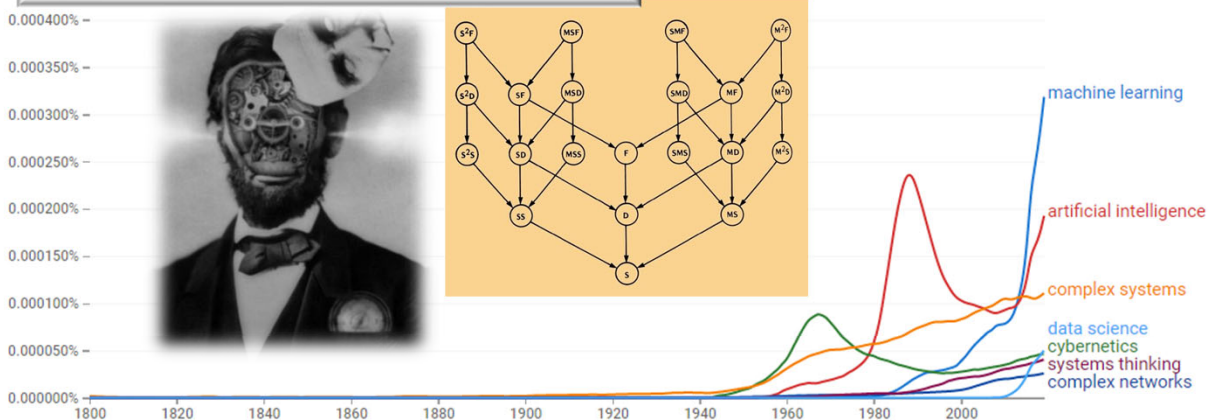
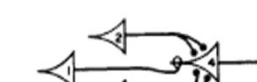
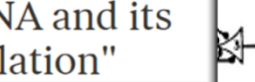
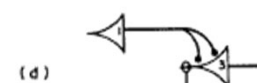
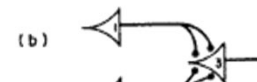
Learning and cognition as information transmission



The concepts, tools, and interdisciplinary praxis lives on



The Nobel Prize in Physiology or Medicine 2024 was awarded jointly to Victor Ambros and Gary Ruvkun "for the discovery of microRNA and its role in post-transcriptional gene regulation"



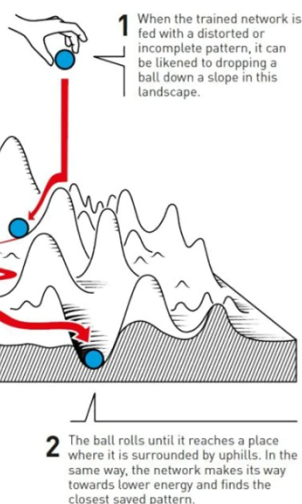
BINGHAMTON UNIVERSITY
STATE UNIVERSITY OF NEW YORK

rocha@binghamton.edu
casci.binghamton.edu/academics/ssie501m

The concepts, tools, and interdisciplinary praxis lives on

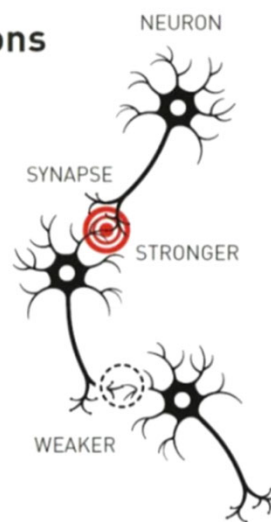
Memories are stored in a landscape

John Hopfield's associative memory stores information in a manner similar to shaping a landscape. When the network is trained, it creates a valley in a virtual energy landscape for every saved pattern.

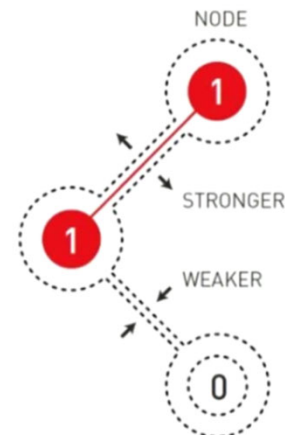


Natural and artificial neurons

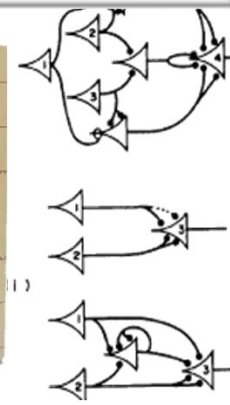
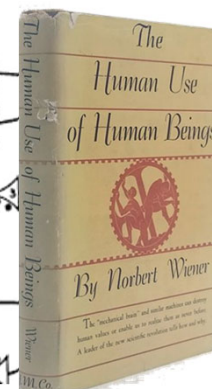
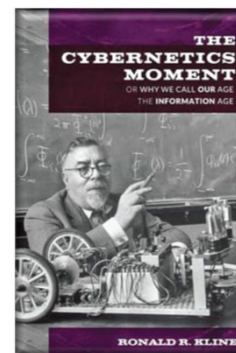
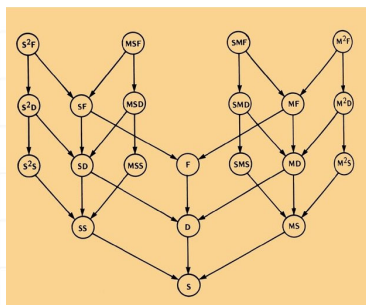
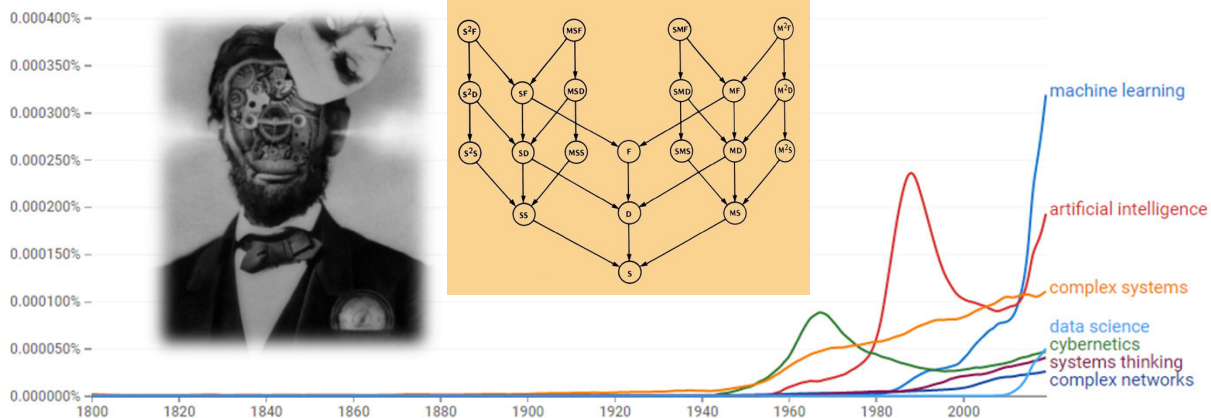
The brain's neural network is built from living cells, neurons, with advanced internal machinery. They can send signals to each other through the synapses. When we learn things, the connections between some neurons get stronger, while others get weaker.



Artificial neural networks are built from nodes that are coded with a value. The nodes are connected to each other and, when the network is trained, the connections between nodes that are active at the same time get stronger, otherwise they get weaker.



© Johan Jarnestad/The Royal Swedish Academy of Sciences



BINGHAMTON
UNIVERSITY
STATE UNIVERSITY OF NEW YORK

rocha@binghamton.edu
casci.binghamton.edu/academics/ssie501m

The concepts, tools, and interdisciplinary praxis lives on

The Nobel Prize in Physics 2024

John Hopfield

"for foundational discoveries and inventions that enable machine learning with artificial neural networks"



John Hopfield. Ill. Niklas Elmehed © Nobel Prize Outreach

Geoffrey Hinton

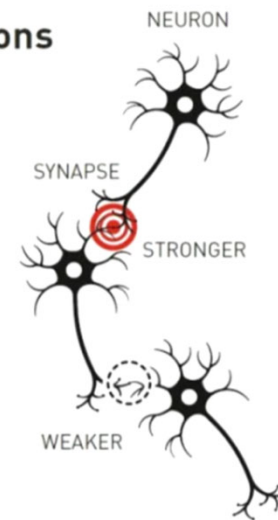
"for foundational discoveries and inventions that enable machine learning with artificial neural networks"



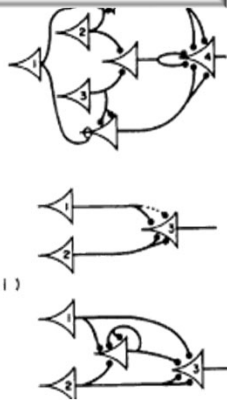
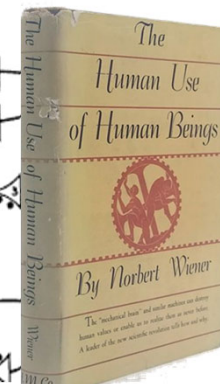
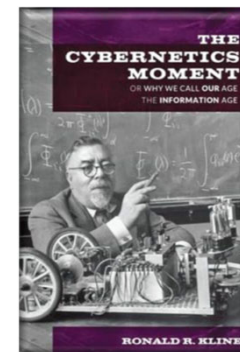
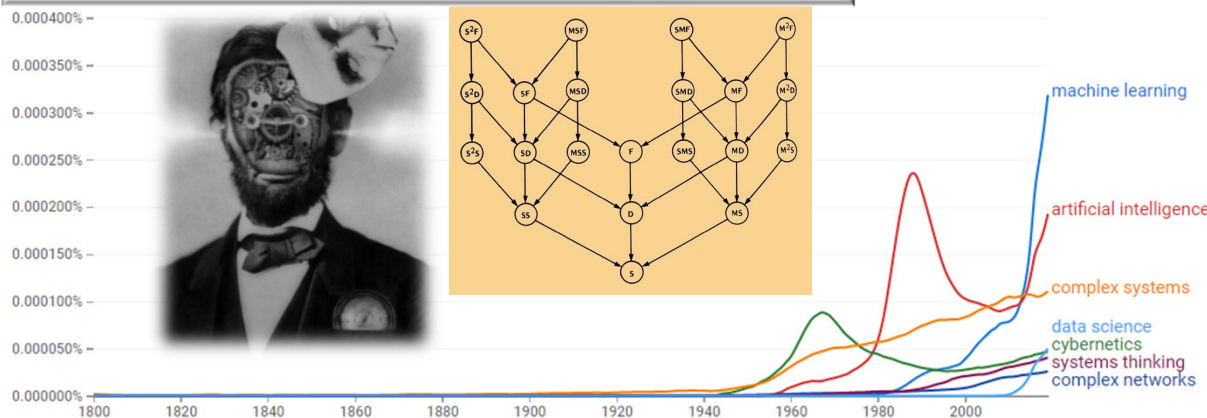
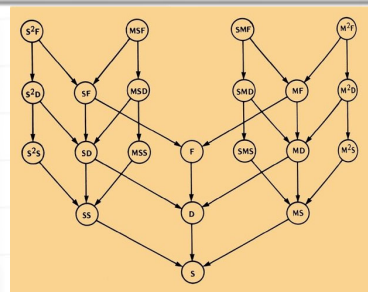
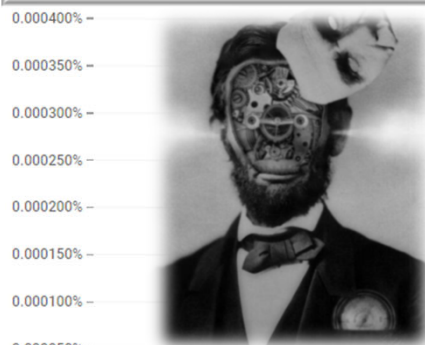
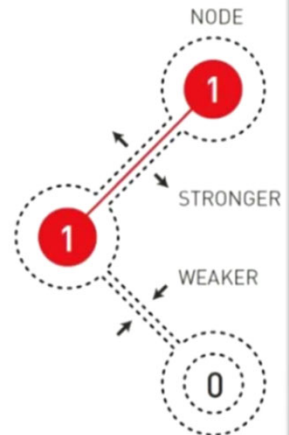
Geoffrey Hinton. Ill. Niklas Elmehed © Nobel Prize Outreach

Natural and artificial neurons

The brain's neural network is built from living cells, neurons, with advanced internal machinery. They can send signals to each other through the synapses. When we learn things, the connections between some neurons get stronger, while others get weaker.



Artificial neural networks are built from nodes that are coded with a value. The nodes are connected to each other and, when the network is trained, the connections between nodes that are active at the same time get stronger, otherwise they get weaker.



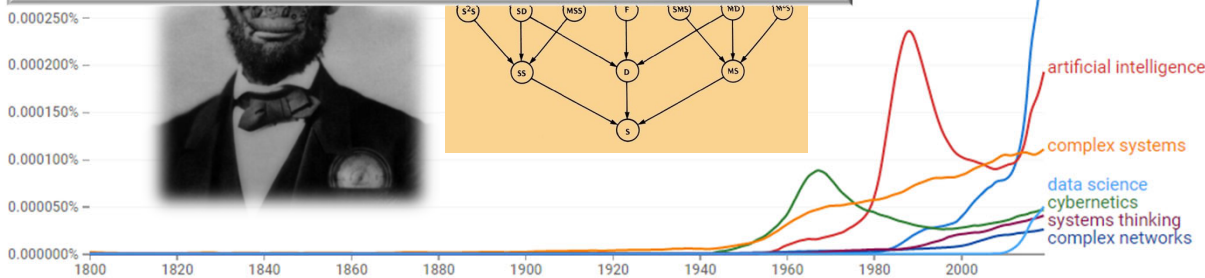
cybernetics and systems science

The concepts, tools, and interdisciplinary praxis lives on



Weston, P. (2007). A walk through the forest. In A. Müller & K. H. Müller (Eds.), *An unfinished revolution? Heinz von Foerster and the Biological Computer Laboratory | BCL 1958 – 1976* (pp. 89-115). Vienna: echoraum.

von Foerster, H. (1962). Perception of form in biological and man-made systems. In E. J. Zagorski (Ed.), Trans. the Industrial Design Education Association (I.D.E.A.) Symposium (pp. 10-37). Urbana: University of Illinois



Natural
artificial

The brain network is a living cell with advanced machinery. It sends signals to other through synapses. It learns through connections. Some neurons are stronger, some are weaker.



Luis M. Rocha @LuisMateusRocha · Oct 8

1/2 Delighted that Physics Nobel went to Hopfield and Hinton! A deserved recognition of their fundamental work and complex systems research in general (including bio-inspired computing)! But weight of the award may lead to being cast as originators of artificial neural nets...

1

2

12

713



Luis M. Rocha @LuisMateusRocha · Oct 8

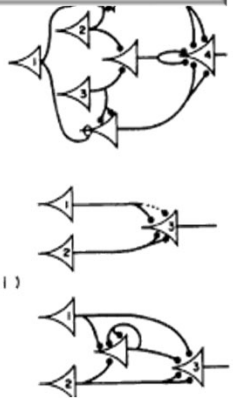
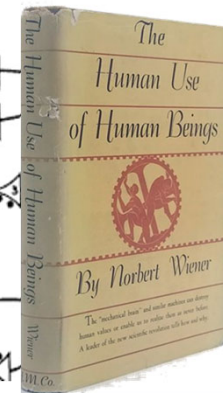
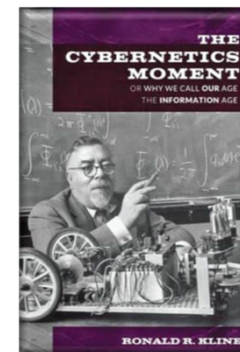
2/2 So here is a shout out to those who came before, most not alive (or physicist enough) to get a Nobel: Warren McCulloch, Walter Pitts, Donald Hebb, John Von Neumann, Frank Rosenblatt, Heinz Von Foerster, Gordon Pask, Teuvo Kohonen, James McClelland, David Rumelhart...

2

2

9

448



BINGHAMTON
UNIVERSITY
STATE UNIVERSITY OF NEW YORK

rocha@binghamton.edu
casci.binghamton.edu/academics/ssie501m

The concepts, tools, and interdisciplinary praxis lives on

How does AlphaFold2 work?

As part of AlphaFold2's development, the AI model has been trained on all the known amino acid sequences and determined protein structures.

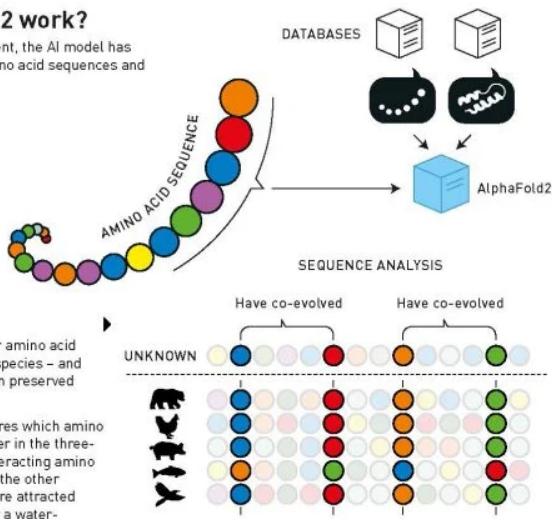
1. DATA ENTRY AND DATABASE SEARCHES

An amino acid sequence with unknown structure is fed into AlphaFold2, which searches databases for similar amino acid sequences and protein structures.

2. SEQUENCE ANALYSIS

The AI model aligns all the similar amino acid sequences – often from different species – and investigates which parts have been preserved during evolution.

In the next step, AlphaFold2 explores which amino acids could interact with each other in the three-dimensional protein structure. Interacting amino acids co-evolve. If one is charged, the other has the opposite charge, so they are attracted to each other. If one is replaced by a water-

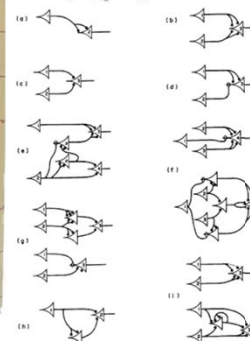
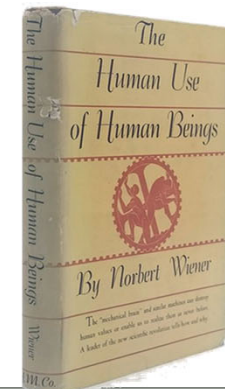
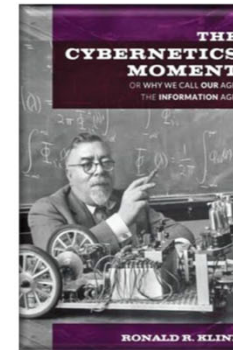
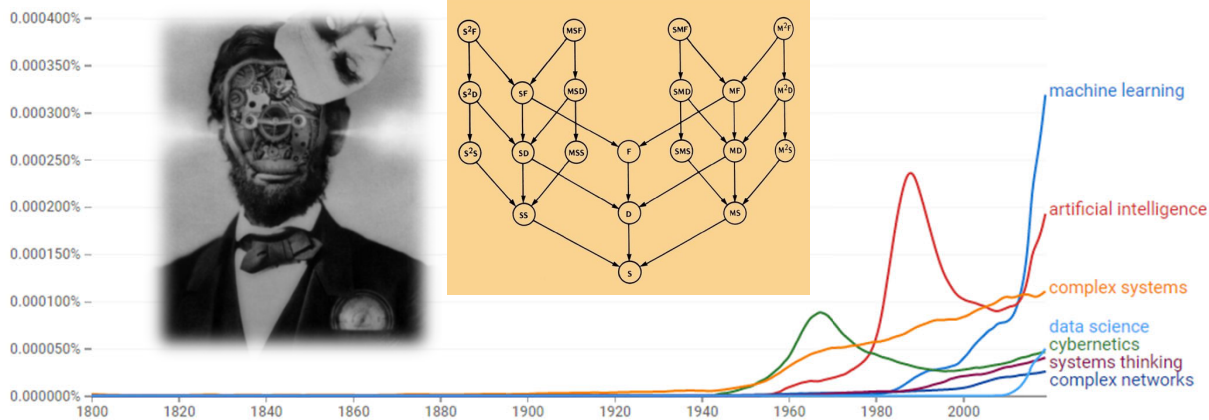
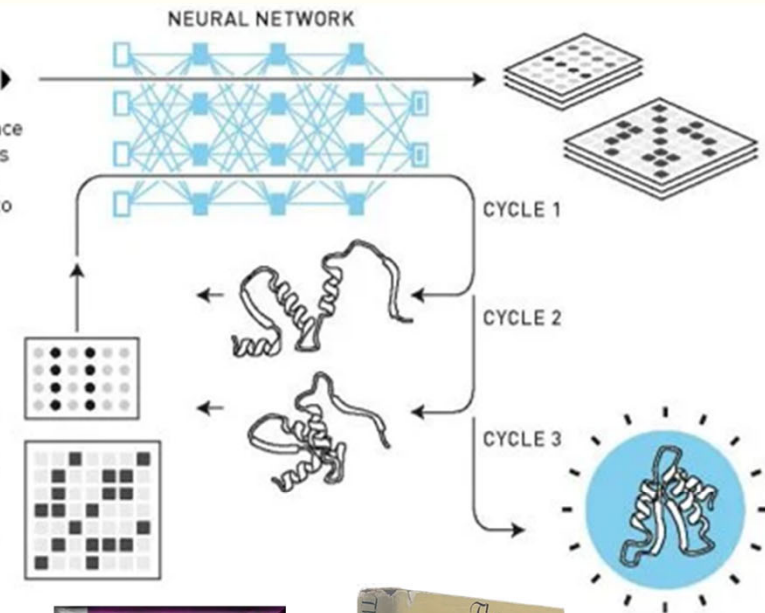


3. AI ANALYSIS

Using an iterative process, AlphaFold2 refines the sequence analysis and distance map. The AI model uses neural networks called transformers, which have a great capacity to identify important elements to focus on. Data about other protein structures – if they were found in step 1 – is also utilised.

4. HYPOTHETICAL STRUCTURE

AlphaFold2 puts together a puzzle of all the amino acids and tests pathways to produce a hypothetical protein structure. This is re-run through step 3. After three cycles, AlphaFold2 arrives at a particular structure. The AI model calculates the probability that different parts of this structure correspond to reality.



The concepts, tools, and interdisciplinary praxis lives on

How does AlphaFold2 work?

As part of AlphaFold2's development, the AI model has

DATABASES  

The Nobel Prize in Chemistry 2024



III. Niklas Elmejd © Nobel Prize Outreach
David Baker



III. Niklas Elmejd © Nobel Prize Outreach
Demis Hassabis



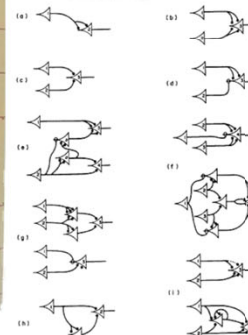
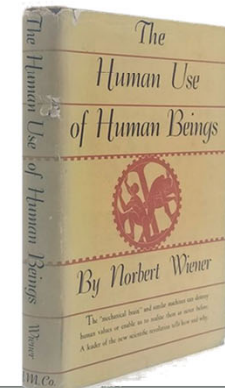
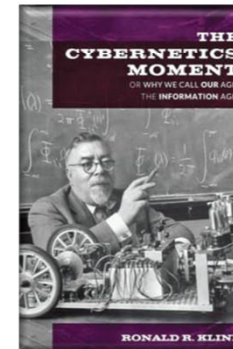
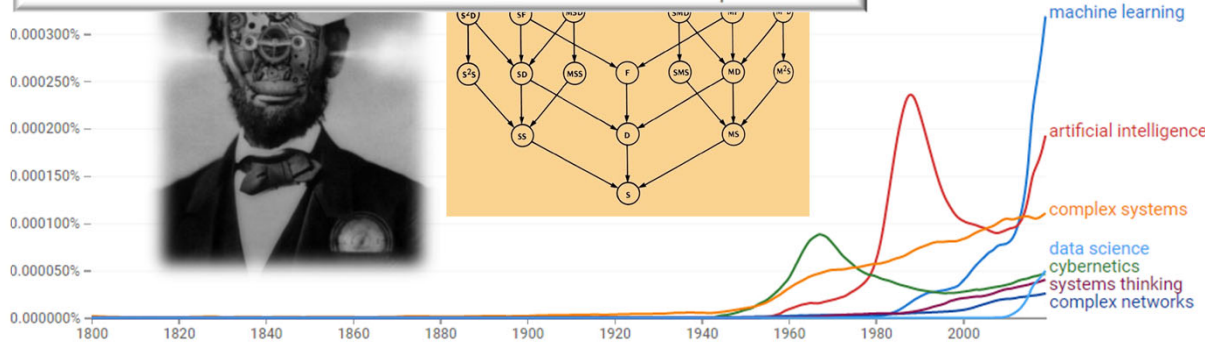
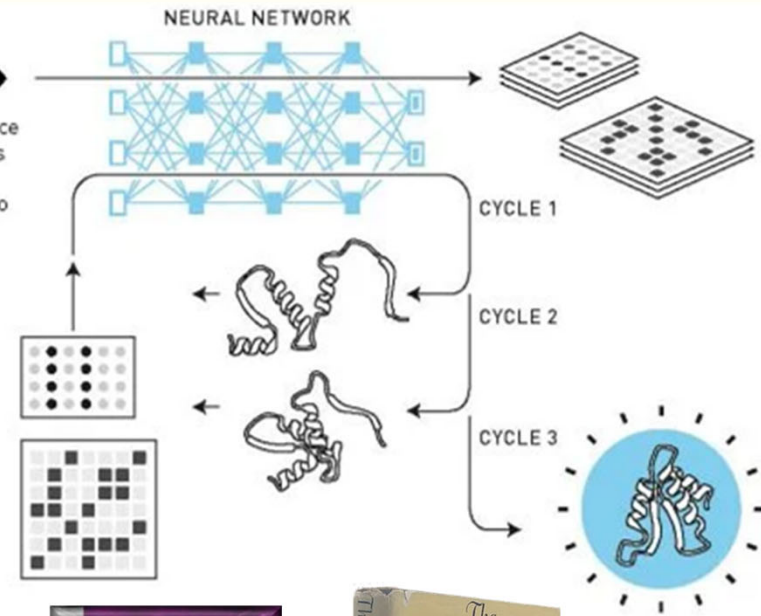
III. Niklas Elmejd © Nobel Prize Outreach
John M. Jumper

3. AI ANALYSIS

Using an iterative process, AlphaFold2 refines the sequence analysis and distance map. The AI model uses neural networks called transformers, which have a great capacity to identify important elements to focus on. Data about other protein structures – if they were found in step 1 – is also utilised.

4. HYPOTHETICAL STRUCTURE

AlphaFold2 puts together a puzzle of all the amino acids and tests pathways to produce a hypothetical protein structure. This is re-run through step 3. After three cycles, AlphaFold2 arrives at a particular structure. The AI model calculates the probability that different parts of this structure correspond to reality.



BINGHAMTON UNIVERSITY
STATE UNIVERSITY OF NEW YORK

rocha@binghamton.edu
casci.binghamton.edu/academics/ssie501m

The concepts, tools, and interdisciplinary praxis lives on

How does AlphaFold2 work?

As part of AlphaFold2's development, the AI model has

DATABASES  

The Nobel Prize in Chemistry 2024



III. Niklas Elmehed © Nobel Prize Outreach
David Baker



III. Niklas Elmehed © Nobel Prize Outreach
Demis Hassabis



III. Niklas Elmehed © Nobel Prize Outreach
John M. Jumper

3. AI ANALYSIS

Using an iterative process, AlphaFold2 refines the sequence analysis and distance map. The AI model uses neural networks



Luis M. Rocha

@LuisMateusRocha

#NobelPrize in

4.

Alp
all
to p
str
Aft
at a
cal
par
to r

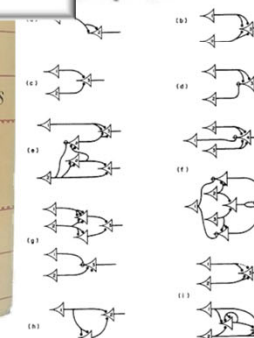
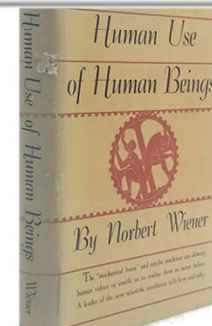
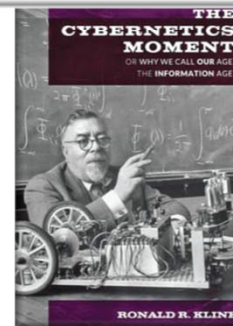
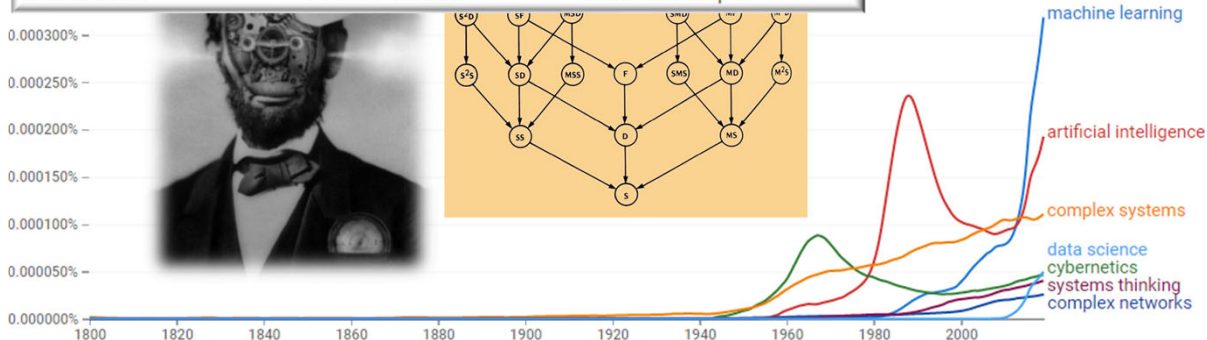
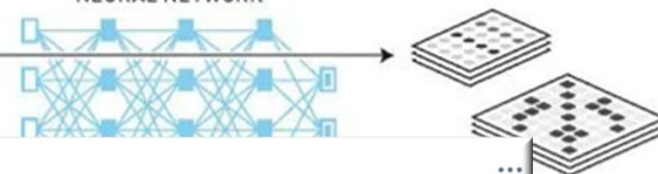
Physiology or Medicine: #Cybernetics (RNA silencing is biochemical information control)

Chemistry: #Cybernetics

Physics: #Cybernetics

Wiener, Von Neumann, Turing, McCulloch, Pitts, Mead, Shannon, Von Foerster, Rosembueth & co charted the interdisciplinary future

NEURAL NETWORK



BINGHAMTON
UNIVERSITY
STATE UNIVERSITY OF NEW YORK

rocha@binghamton.edu
casci.binghamton.edu/academics/ssie501m