lecture 6: the information turn in the life sciences

evaluation

- Participation: 20%.
  - class discussion, everybody reads and discusses every paper
  - engagement in class
- Paper Presentation and Discussion: 20%
  - **SSIE501** students are assigned to papers individually or as group lead presenters and discussants
    - all students are supposed to read and participate in discussion of every paper.
  - Presenter 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 chose one of the presented papers to participate as lead discussant
    - not to present the paper, but to comment on points 2-3) above
  - Class discussion is opened to all
    - lead discussant ensures we important paper contributions and failures are addressed
- Black Box: 60%
  - Group Project (2 parts)
    - Assignment I (25%) and Assignment II (35%)

bit.ly/atBIC

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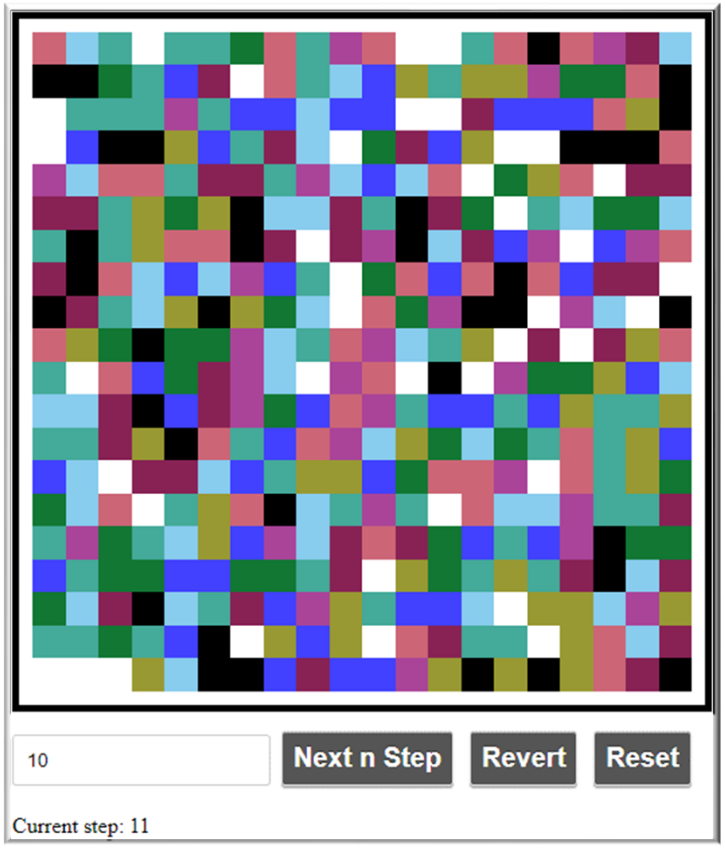
The Black Box: Due: **October 9th, 2024**

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.



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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)
- Module 2: Systems Science
  - Discussion Set 3 (Group 3): September 19th or 24th
    - Klir, G.J. [2001]. *Facets of systems Science*. Springer. Chapters 1 and 2.
      - Optional:
      - Rosen, R. [1986]. "Some comments on systems and system theory". *Int. J. of General Systems*, **13**: 1-3. Available in: Klir, G.J. [2001]. *Facets of systems Science*. Springer. pp: 241-243.
      - Wigner, E.P. [1960], "The unreasonable effectiveness of mathematics in the natural sciences". Richard courant lecture in mathematical sciences delivered at New York University, May 11, 1959. *Comm. Pure Appl. Math*, **13**: 1-14.
    - Klir, G.J. [2001]. *Facets of systems Science*. Springer. Chapter 3.
- Future Modules
  - See brightspace

more upcoming readings (check brightspace)

- Paper Presentation: 20%
  - Present (501) and lead (501&440) the discussion of an article related to the class materials
    - Enginet students post/send video or join by Zoom synchronously
- Module 2: Systems Science
  - Discussion Set 4 (Group 4): October 8th
    - 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

more upcoming readings (check brightspace)

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    - class materials
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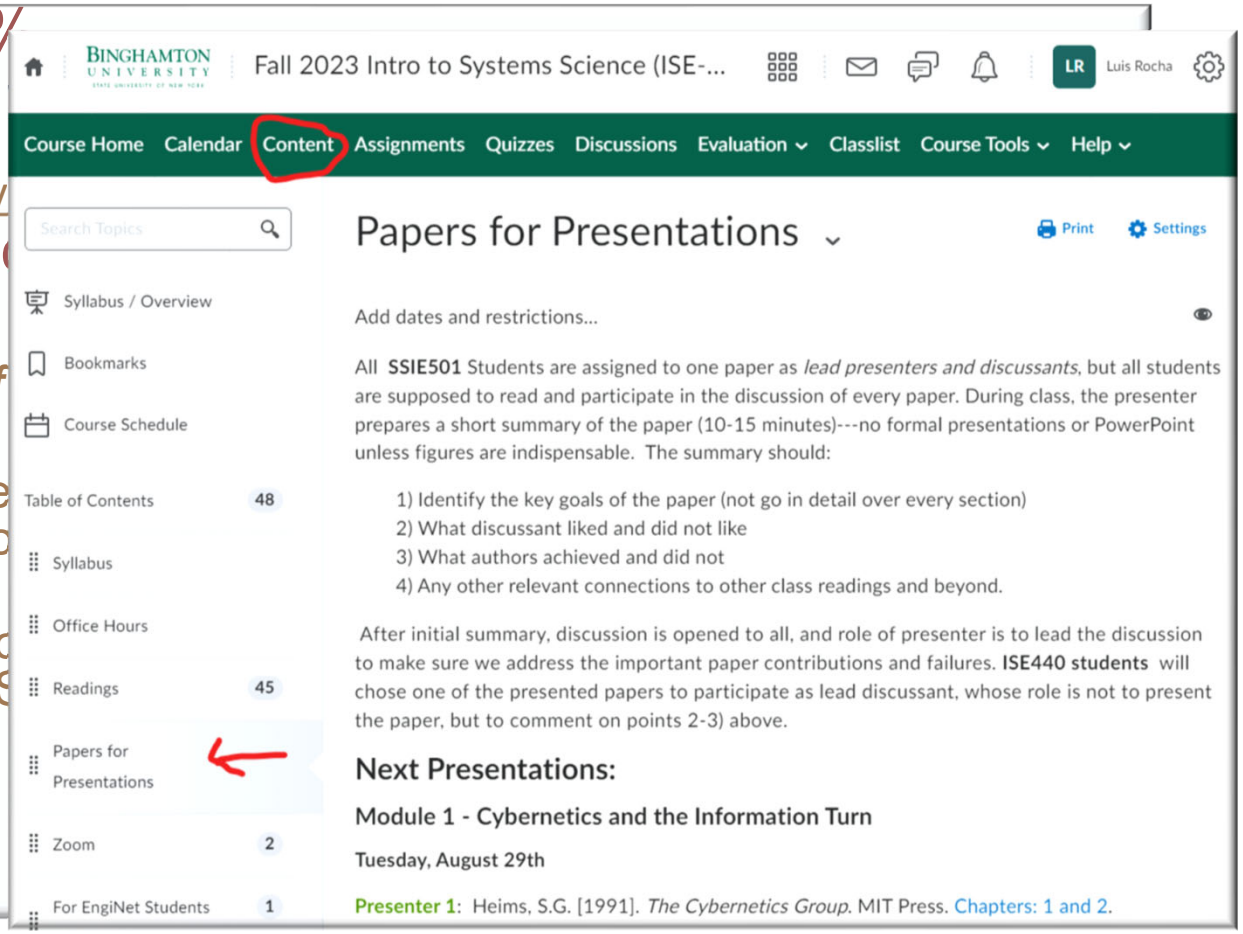

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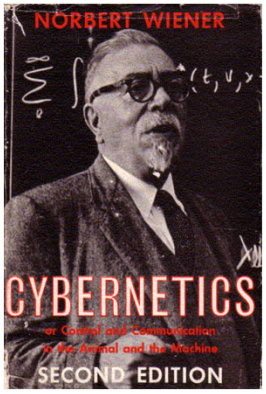
universal computers and general-purpose informatics

- the Josiah Macy Jr. Foundation Meetings
  - post-war science
    - 1946-1953
- Interdisciplinary
  - Since a large class of ordinary phenomena exhibit circular causality, and mathematics is accessible, let's look at them with a war-time team culture
- Participants
  - **John Von Neumann**, Leonard Savage, **Norbert Wiener**, **Arturo Rosenblueth**, Walter Pitts, **Margaret Mead**, Heinz von Foerster, **Warren McCulloch**, **Gregory Bateson**, Claude Shannon, Ross Ashby, etc.
- Key concepts
  - **universal computation** (Turing, Von Neumann), **information** (Shannon, Wiener), **networks** (mcCulloch), homeostasis, **feedback**, complexity, self-organization
  - mind, society, life as general mechanisms



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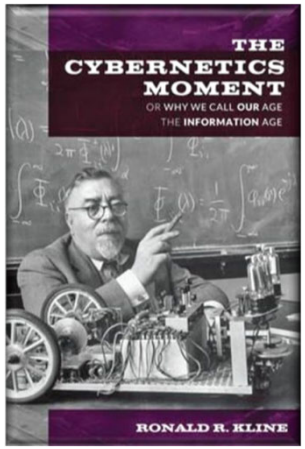
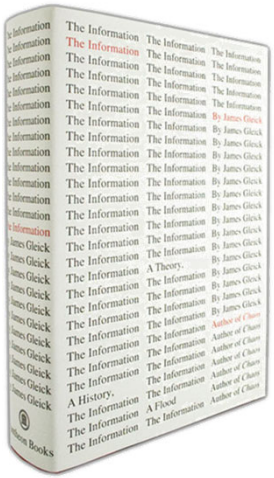
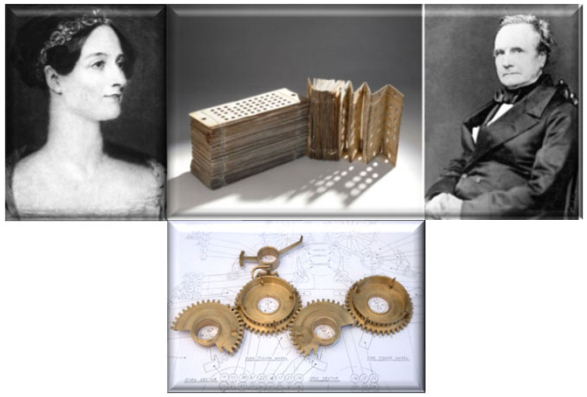
information as its own thing, functional equivalence of mechanisms, and modelling

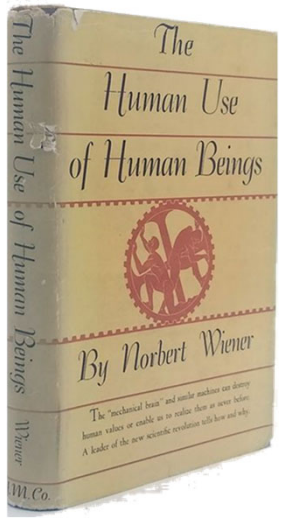
Heims, S.G. [1991]. *The Cybernetics Group*. MIT Press.





Gleick, J. [2011]. *The Information: A History, a Theory, a Flood*. Random House.





"Information is information, not matter or energy. No materialism which does not admit this can survive at the present day." That is, the amount of information was related to a choice among messages (a pattern), not to the material basis or the energy involved in its communication. In discussing the societal implications of cybernetics,

Kline, Ronald R. *The cybernetics moment: Or why we call our age the information age*. JHU Press, 2015.

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differences and explanations

- Evolution
  - adaptation, learning, innovation, social evolution
- Mechanism
  - Reproduction, transmission, variation, selection
- Design causes
  - Natural selection
- explanation?
  - Contingent, historical, context/specific
  - Does not seem lawful

Natural Selection

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path to Darwin

- Evolution by natural selection
  - Organisms vary from one another
  - New variation appears from time to time
  - Variation is passed from parent to offspring
  - “struggle for existence” (limited resources)
- Recognized before Darwin
  - Empedocles (490–430 BC)
    - why animals adapt to environment
  - Lucretius (99 - 55 BC) – Epicurus (341-270 BC)
    - Random evolution, free will
  - Al-Jahiz (781 – 869 AD)
    - on the struggle for existence
  - Thomas Hobbes (XVII)
  - Erasmus Darwin (XVIII)
  - Thomas Malthus (XVIII)
    - Populations grow exponentially, re
  - Charles Lyell (XIX)
    - Gradual change in geological lands
  - Jean-Baptiste Lamarck (XIX)
    - Mechanism: mutation and (acquire
  - Alfred Russel Wallace
    - Reached same conclusion as Darv
  - Charles Darwin
    - Evolution, **inevitable**

(Cosma Shalizi citing Aristotle citing) Empedocles:
A difficulty presents itself: why should not nature work, not for the sake of something, nor because it is better so, but just as the sky rains, not in order to make the corn grow, but of necessity? What is drawn up must cool, and what has been cooled must become water and descend, the result of this being that the corn grows. Similarly if a man's crop is spoiled on the threshing-floor, the rain did not fall for the sake of this--in order that the crop might be spoiled--but that result just followed. Why then should it not be the same with the parts in nature, e.g. that teeth should come up of necessity -- the front teeth sharp, fitted for tearing, the molars broad and useful for grinding down the food -- since they did not arise for this end, but it was merely a coincident result; and so with all other parts in which we suppose that there is purpose? **Wherever then all the parts came about just what they would have been if they had come be for an end, such things survived, being organized spontaneously in a fitting way; whereas those which grew otherwise perished and continue to perish**, as Empedocles says his 'man-faced ox-progeny' did.

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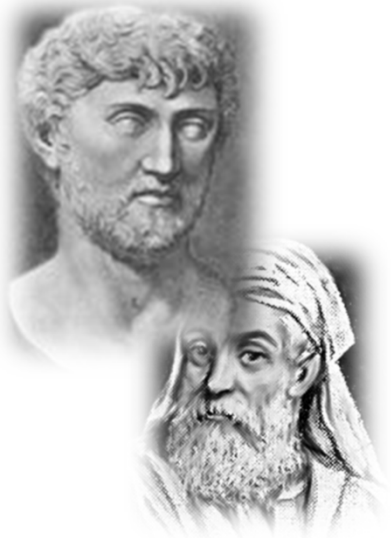
  - Erasmus Da
  - Thomas Ma
    - Populatio
  - Charles Lye
    - Gradual c
  - Jean-Baptis
    - Mechanis
  - Alfred Russ
    - Reached same conclusion as Darwin (with less evidence)
  - Charles Darwin
    - Evolution, **inevitable**

Lucretius and Epicurism (translated by Stephen Greenblatt):
"... moving randomly through space, like dust motes in a sunbeam, colliding, hooking together, forming complex structures, breaking apart again, in a ceaseless process of creation and destruction. There is no escape from this process. ... There is no master plan, no divine architect, no intelligent design. […] All things, including the species to which you belong, have evolved over vast stretches of time. The **evolution is random**, though in the case of living organisms, it involves **a principle of natural selection**. That is, **species that are suited to survive and to reproduce successfully, endure, at least for a time; those that are not so well suited, die off quickly**. But nothing — from our own species, to the planet on which we live, to the sun that lights our day — lasts forever. Only the atoms are immortal ..."



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  - Alfred Russel Wallace
    - Reached same conclusion as Darwin (with less evidence)
  - Charles Darwin
    - Evolution, **inevitable**

"I happened to read for amusement Malthus on population, and being well prepared to appreciate the struggle for existence…it at once struck me that under these circumstances favourable variations would tend to be preserved, and unfavourable ones to be destroyed. The result of this would be the formation of new species." [Charles Darwin]

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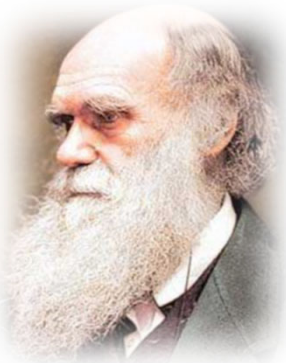
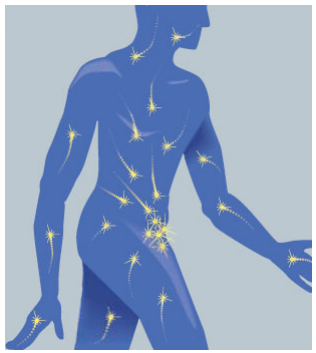
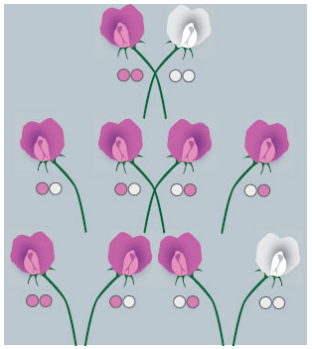
Inheritance mechanism

- XIX Century
  - Evolution of species quickly accepted
  - Natural selection as most important engine of change, was not
    - What was the mechanism?
- Jean-Baptiste Lamarck (XIX)
  - mutation and (acquired) inheritance
- Charles Darwin
  - "gemules" ejected from each tissue and traveling to sex organs
- Gregor Mendel
  - discrete factors corresponding to traits
  - Each individual would carry two copies (one from each parent), but only one would be "expressed"
- "Synthesis" only in the XX century







Sci. American, Jan 2009

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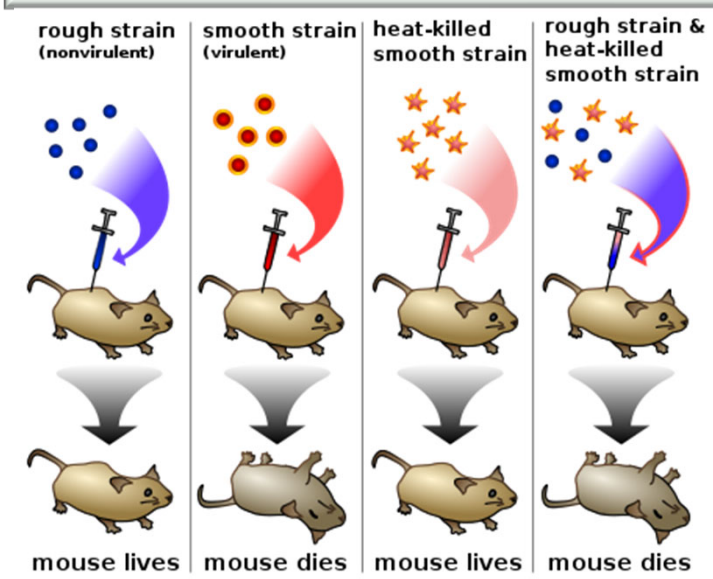
identifying the loci of genetic information

- Frederick Griffith's experiment
  - In 1928: Identified a "transforming principle"
- Avery's experiment
  - Oswald Avery, Colin MacLeod, and Maclyn McCarty
  - 1944: DNA as the loci of "transformation"
    - Chemically knocking off various cellular constituents until trying DNA
    - Considerable resistance in the community accepting this result until the early 1950's (Schrodinger, Delbruck, phage group)



2 different strains of pneumococcus bacteria

initially not well accepted (No auto-catalysis with DNA)

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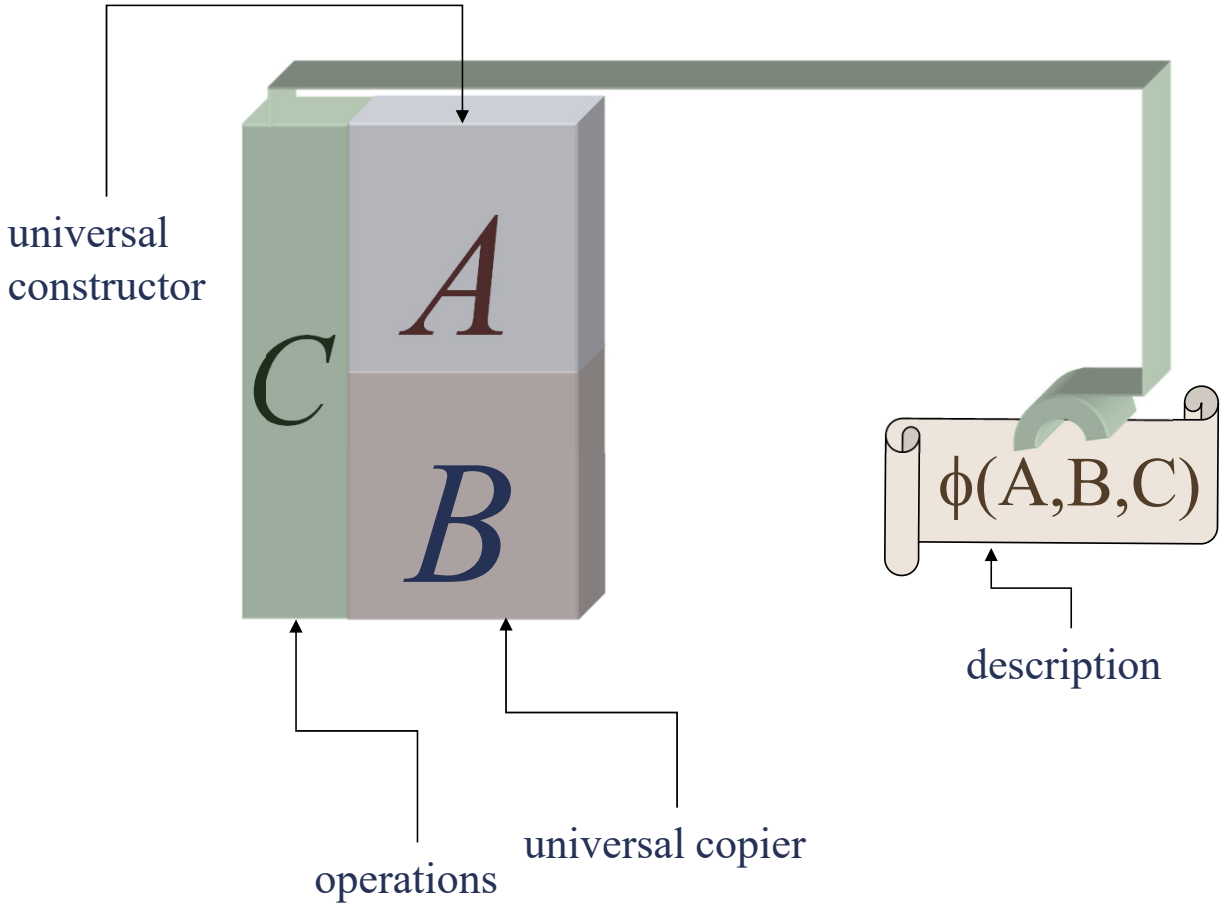
Von Neumann's generalization of Turing's tape

as a general principle (system) of **self-replication**



Description is copied **separately**

Construction: interpreted
(horizontal transmission)

Copy: uninterpreted
(vertical Transmission)

code

distinction between *numbers that mean things*
and *numbers that do things*.

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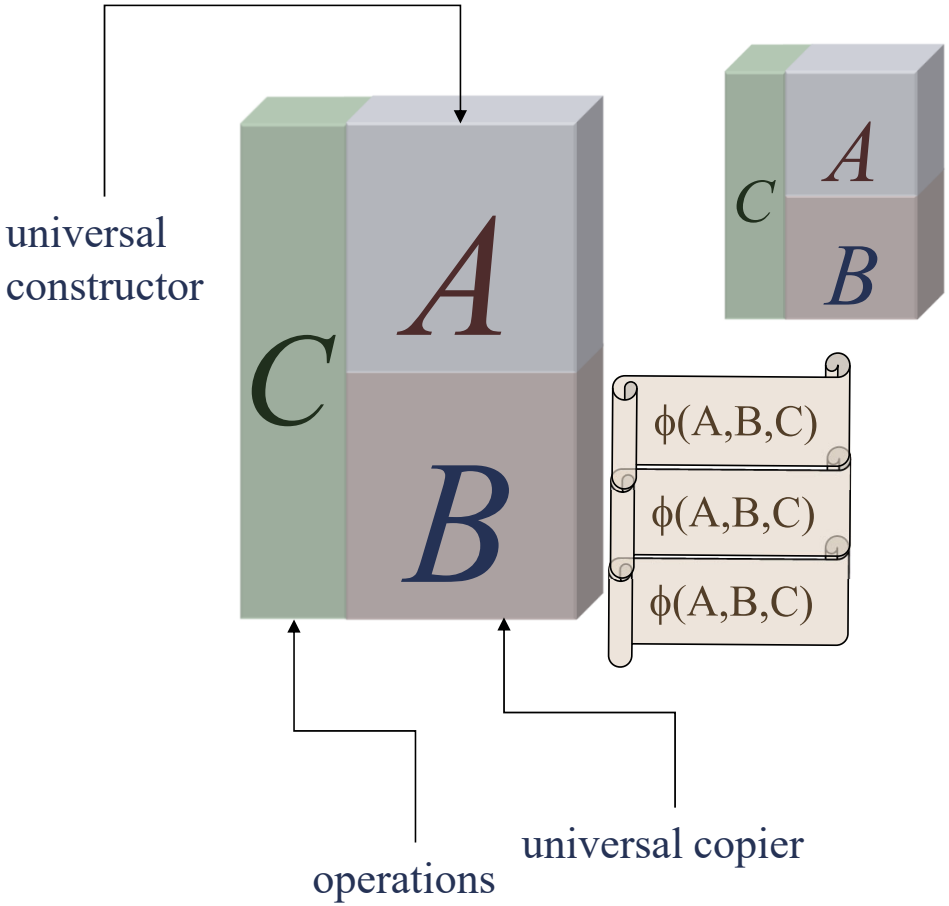

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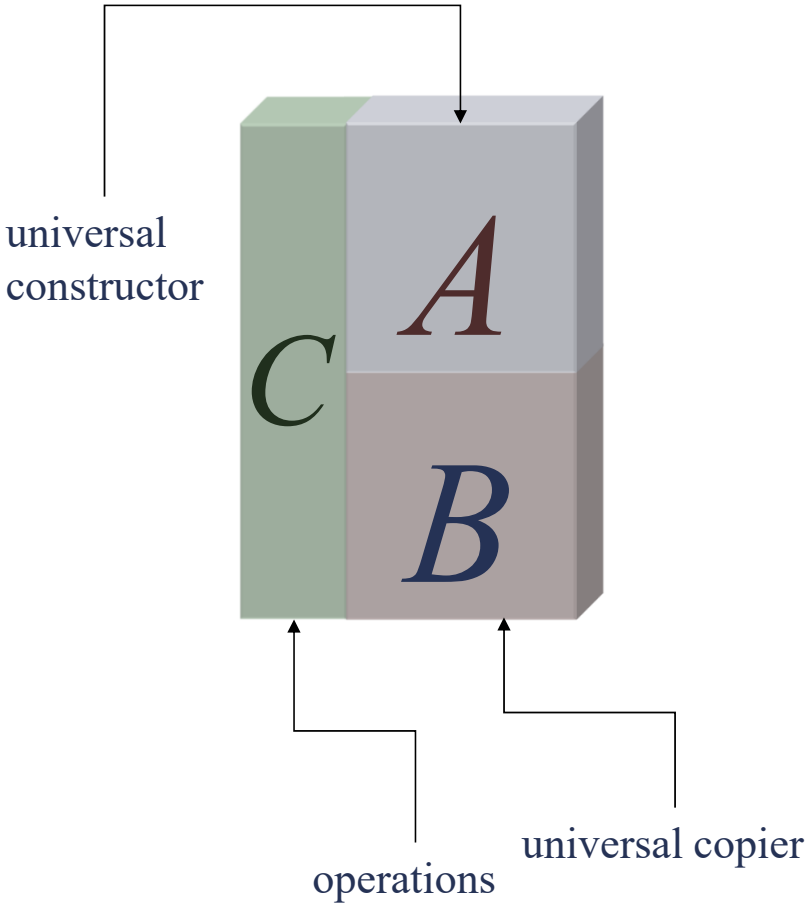

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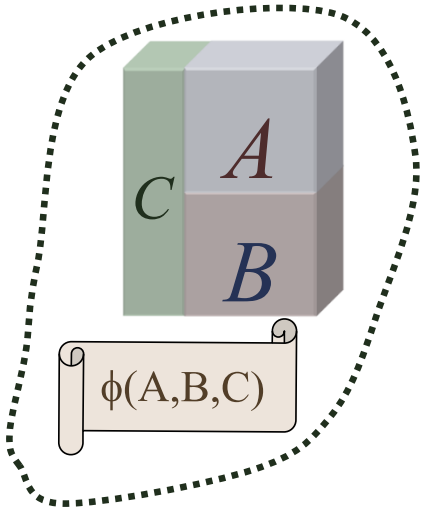

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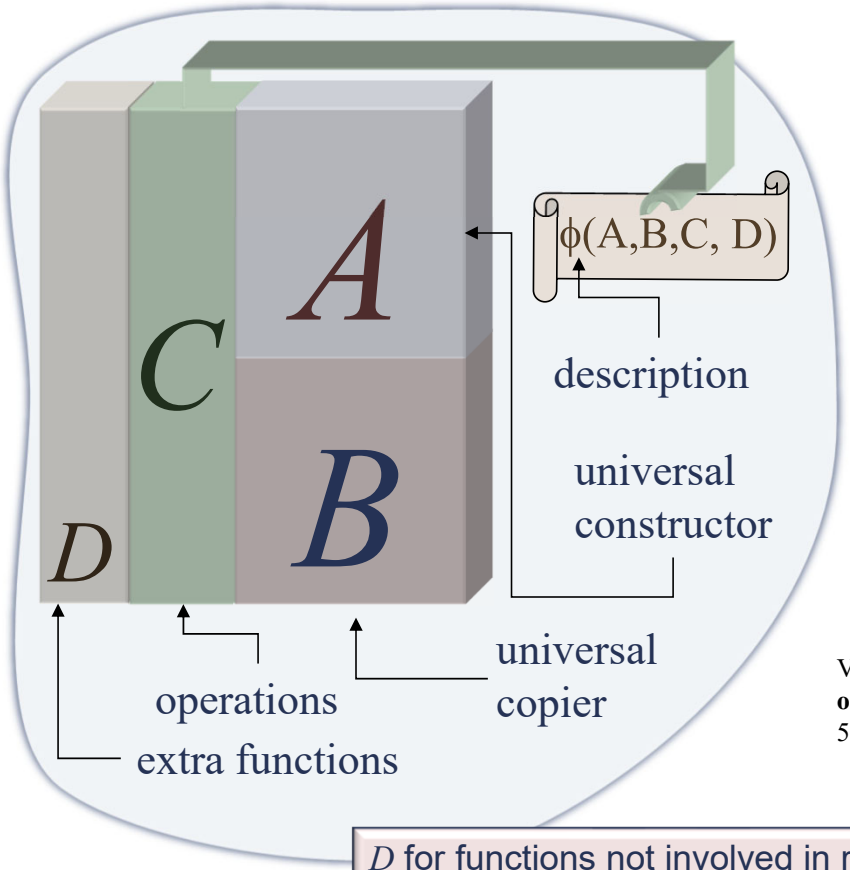
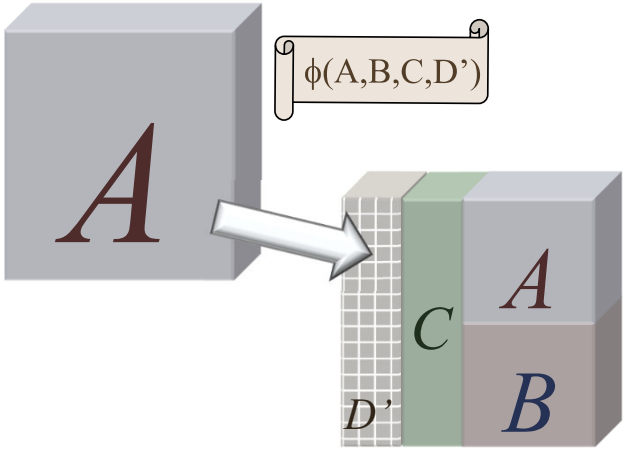
Von Neumann's generalization of Turing's tape

as a general principle (system) of evolution or **open-ended complexity**



Von Neumann, J. [1949]. "**Theory and organization of complicated automata**." 5 lectures at University of Illinois



D for functions not involved in reproduction
Mutations in *D* can be propagated *vertically*
Leads to **open-ended evolution**

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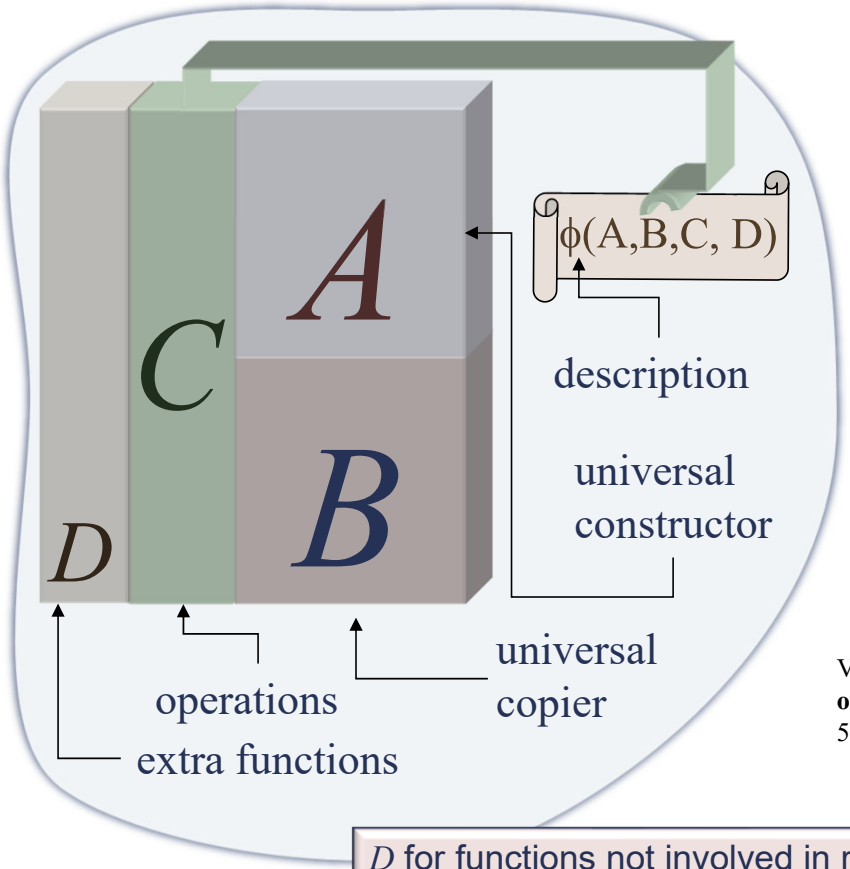

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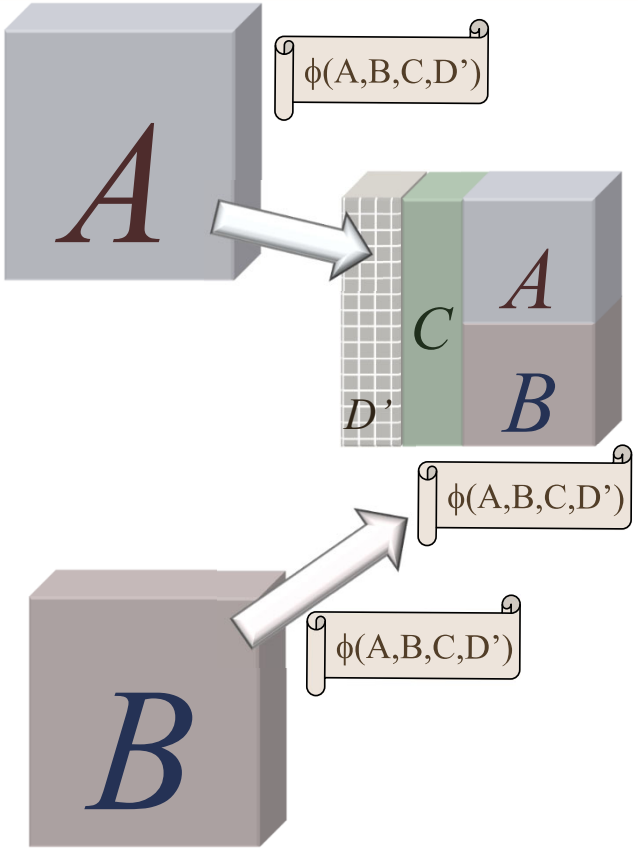

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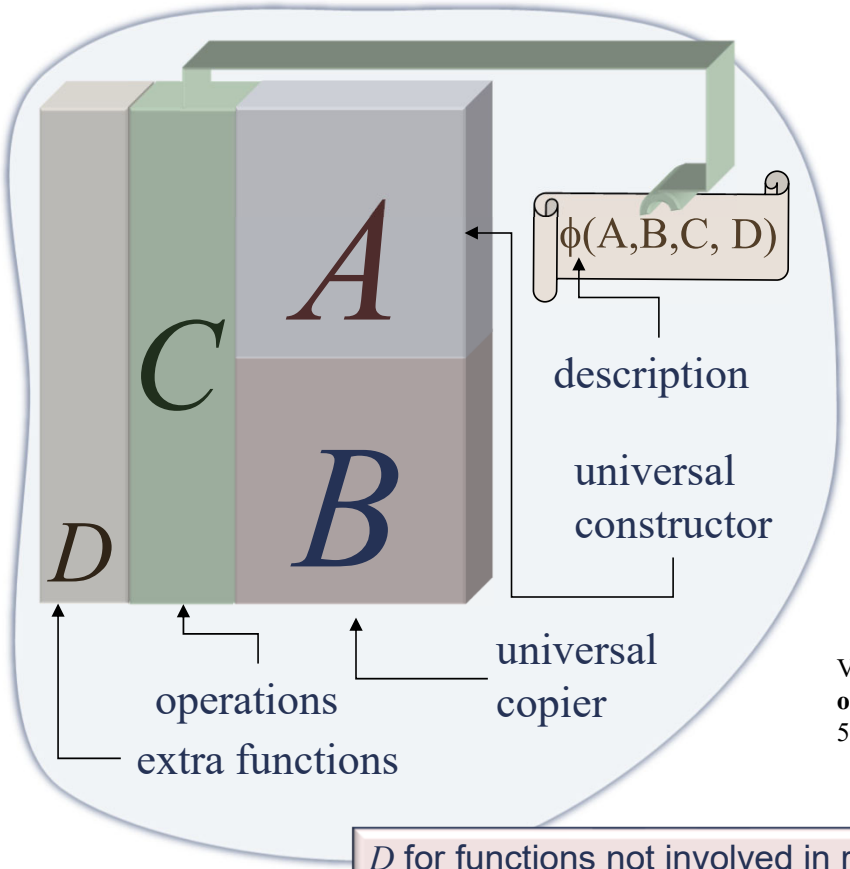

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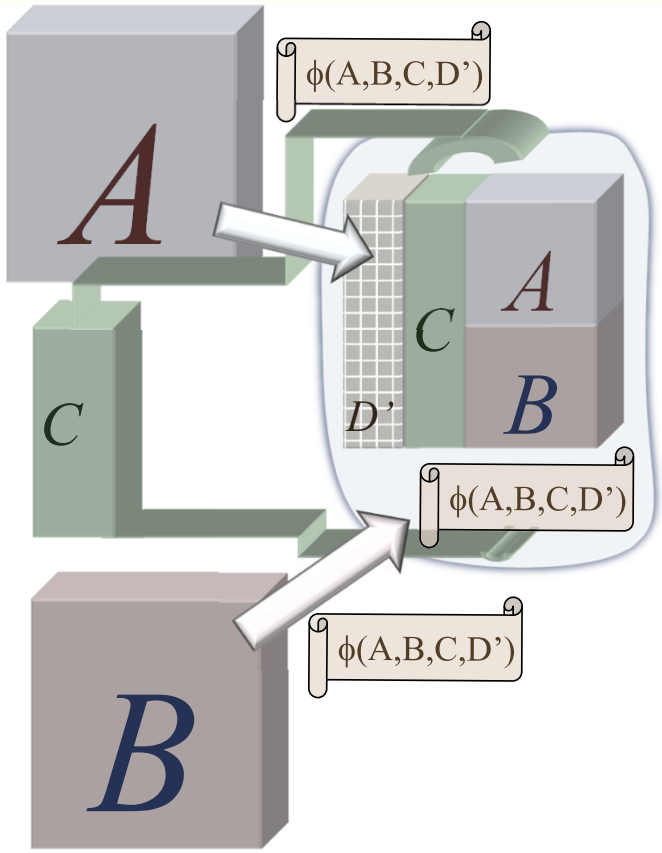

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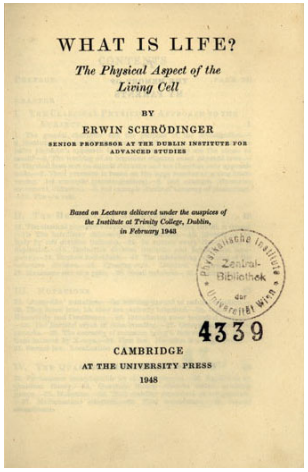
Erwin Schrödinger(1943-1944)



- puzzled by the persistence of living structures
  - Call to understand how life stores and perpetuates order
  - "[…] **chromosomes**[…] contain in some kind of **code-script** the entire pattern of the individual's future development."
    - "complete (double) copy of the code-script."
- **aperiodic crystals as structures that can replicate themselves**
  - "We believe a gene—or perhaps the whole chromosome **fiber**—to be an aperiodic solid."
    - "structure without predictable repetition"
  - DNA is entirely regular
    - Instead of "aperiodicity" we have **encoded information**: separated description/construction

"Turing invented the stored-program computer, and von Neumann showed that the description is separate from the universal constructor. This is not trivial. Physicist Erwin Schrödinger confused the program and the constructor in his 1944 book *What is Life?,* in which he saw chromosomes as "*architect's plan and builder's craft in one*". This is wrong. The code script contains only a description of the executive function, not the function itself." (Sydney Brenner)

Brenner, Sydney. [2012]. "Life's code script." *Nature* **482** (7386): 461-461.

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Schrodinger vs. Von Neumann

self-replication vs. decoupled, encoded information

Von Neumann, J. [1949]. "**Theory and organization of complicated automata**." 5 lectures at University of Illinois

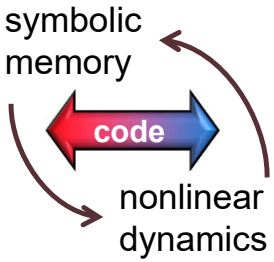
Brenner, Sydney. [2012]. "Life's code script." *Nature* **482** (7386): 461-461.

"Turing invented the stored-program computer, and von Neumann showed that the description is separate from the universal constructor. This is not trivial. Physicist Erwin Schrödinger confused the program and the constructor in his 1944 book *What is Life?,* in which he saw chromosomes as "*architect's plan and builder's craft in one*". This is wrong. The code script contains only a description of the executive function, not the function itself." (Sydney Brenner)

two roles of information
data/program (Turing)
passive/active (Von Neumann)
description/construction-function (Pattee)
genotype/phenotype (Biology)

semiotic closure (semiotic coupling)

fundamental principle of *organized complexity*
Leads to **open-ended evolution**
General principle that includes *Natural Selection*
Von Neumann described this scheme **before** structure of DNA molecule was identified in 1953 by Watson & Crick



Howard Pattee

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readings

- Class Book
  - Klir, G.J. [2001]. *Facets of systems science*. Springer.
- Papers and other materials
  - Discussion Set 3 (Group 3): September 19th
    - Klir, G.J. [2001]. *Facets of systems Science*. Springer. Chapters 1 and 2.
      - Optional:
      - Rosen, R. [1986]. "Some comments on systems and system theory". *Int. J. of General Systems*, **13**: 1-3. Available in: Klir, G.J. [2001]. *Facets of systems Science*. Springer. pp: 241-243.
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