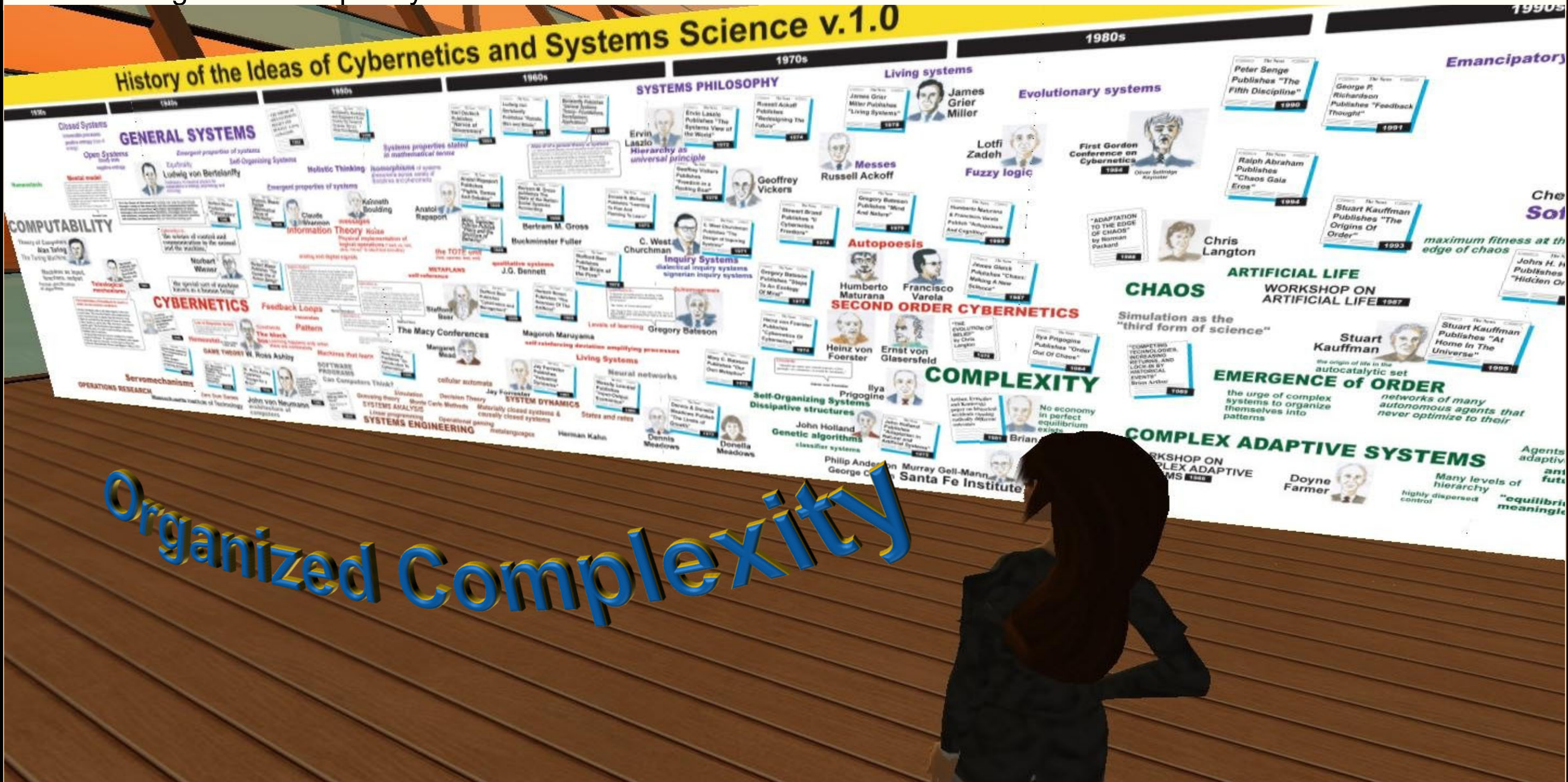
lecture 9: organized complexity



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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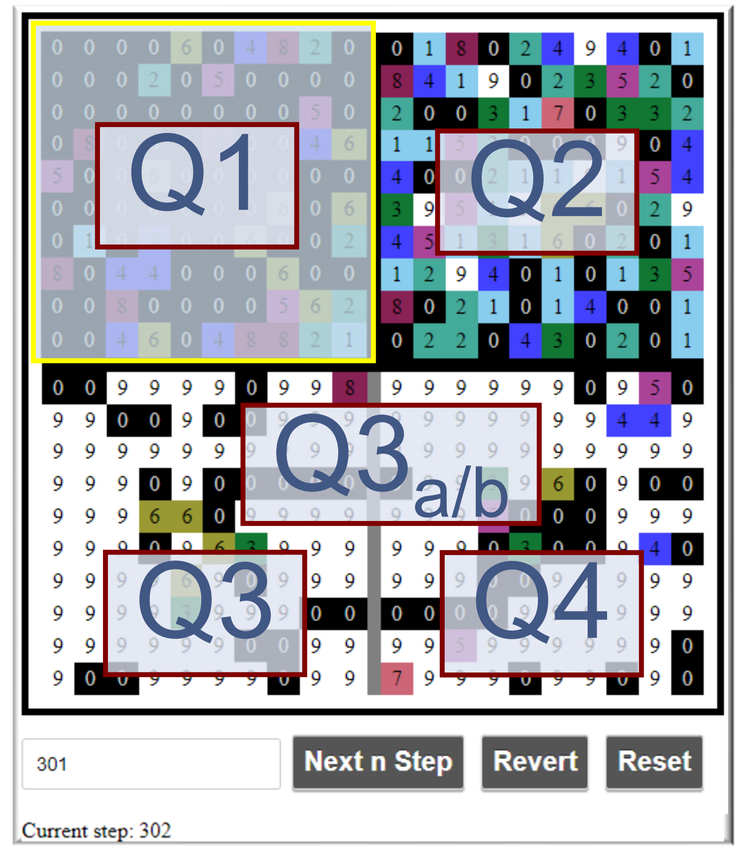
The Black Box: Due: October 14th, 2022

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!!??

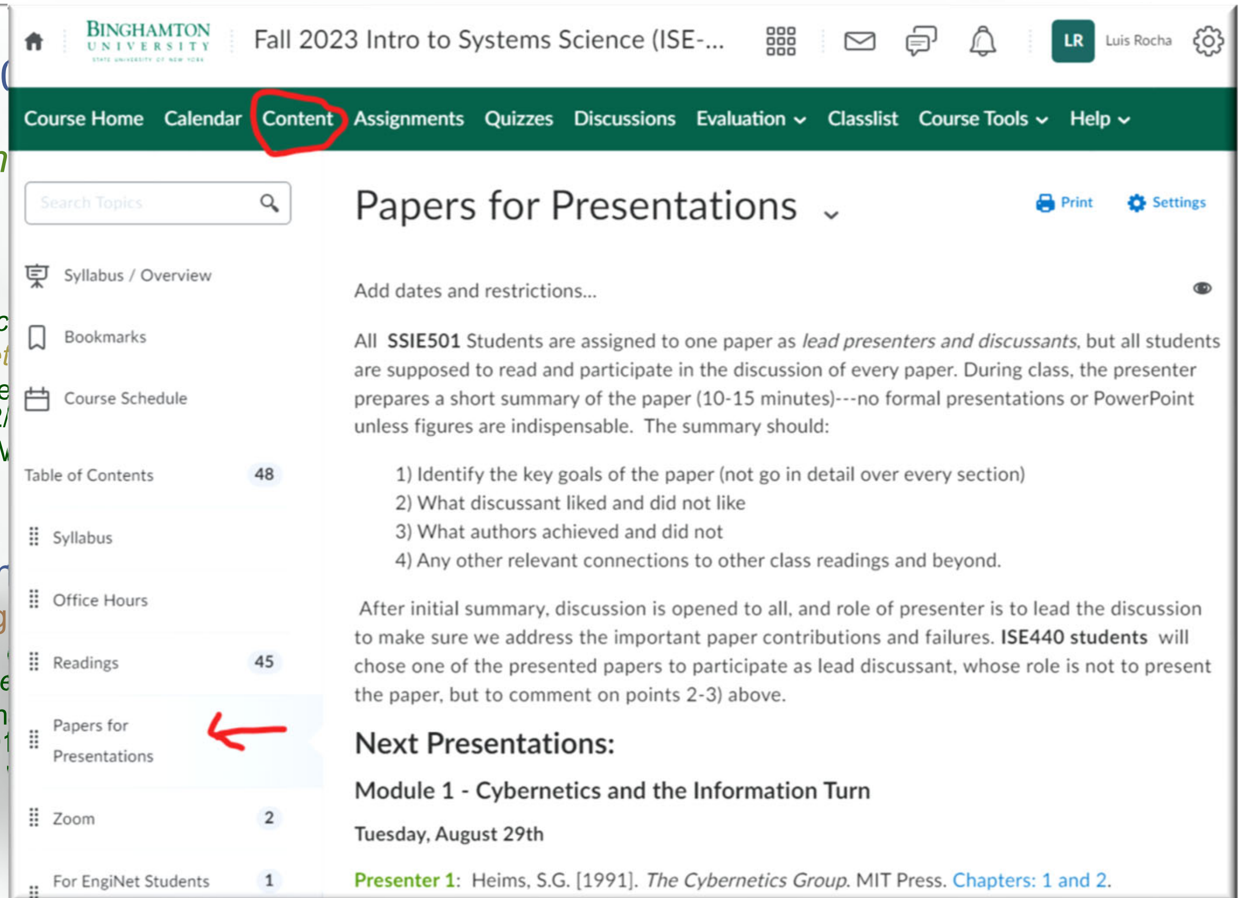


next readings (check brightspace)

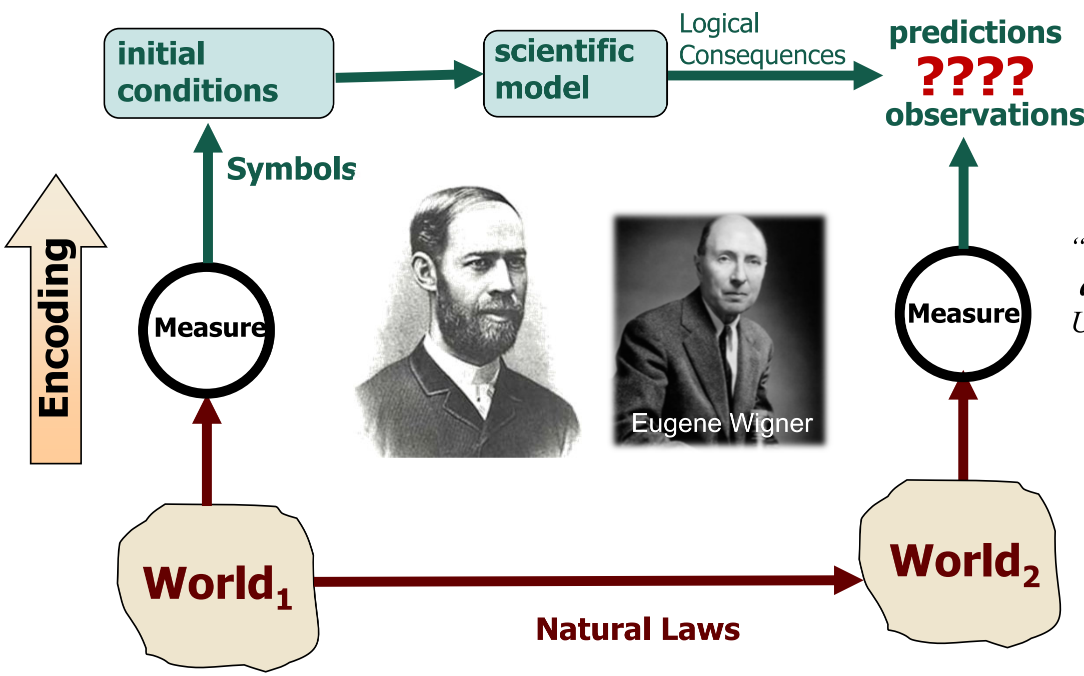
- Paper Presentation: 20%
  - Present (501) and lead (501&440) the discussion of an article related to the class materials
  - *section 01* presents in class, *section 20* (Enginet) posts videos on Brightspace (exceptions possible)
- Thursday September 21st
  - Module 2: Systems Science
    - Reading and Discussion Group 3 (Enginet)
      - Sarah Donovan, Nicole Dates, et al:
        - Klir, G.J. [2001]. *Facets of systems Science*. Springer. Chapter 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&44 materials
  - *section 01* presents in class, *section*
- October 3rd
  - Module 2: Systems Science
    - Reading and Discussion Group 4
      - Klir, G.J. [2001]. *Facets of systems Sc*
        - Optional: Klir, G.J. [2001]. *Facet*
      - Schuster, P. (2016). The end of Moore *Complexity*. **21**(S1): 6-9. DOI 10.1002/
      - Von Foerster, H., P. M. Mora and L. W 5.
- October 10/12th
  - Module 3 - The Organization of Com
    - Reading and Discussion Group 5 (Eng
      - Simon, H.A. [1962]. "The Architecture Also available in Klir, G.J. [2001]. *Face*
      - Golan, Amos, and John Harte. "Inform *of Sciences* **119**.33 (2022): e21190891
      - James, R., and Crutchfield, J. (2017).
- Future Modules
  - See brightspace



Hertzian scientific modeling paradigm



*"**Every empirical law has the disquieting quality that one does not know its limitations**." E. Wigner [1957] in "The Unreasonable Effectiveness of Mathematics in the Natural Sciences"*

"The most direct and in a sense the most important problem which our conscious knowledge of nature should enable us to solve is the ***anticipation of future events***, so that we may arrange our present affairs in accordance with such anticipation". (Hertz, 1894)

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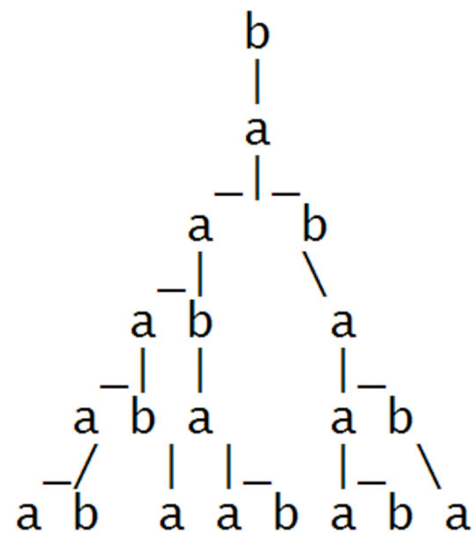
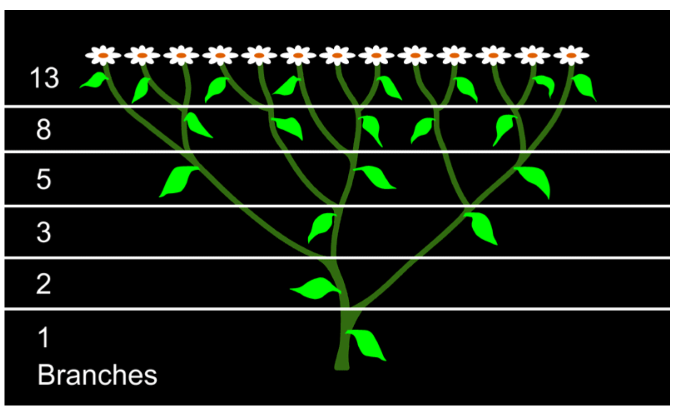
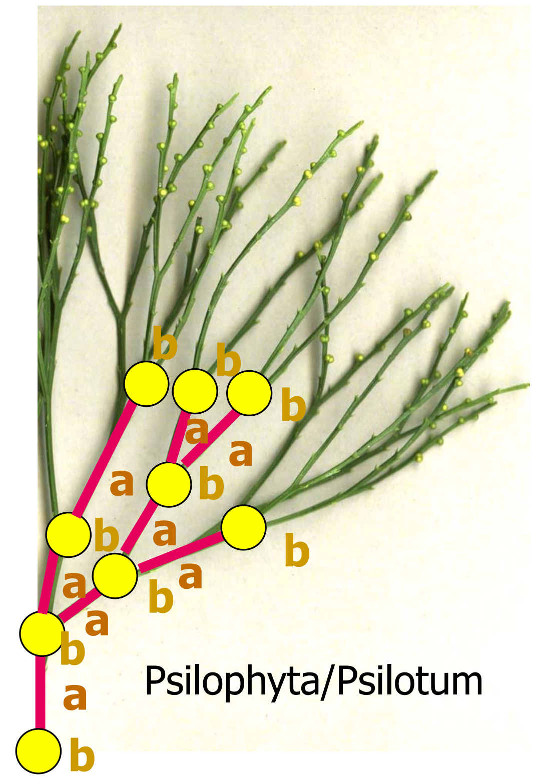
What about our plant?

branching as a model (a general system?)

- An Accurate Model
  - Requires
    - Varying angles
    - Varying stem lengths
    - randomness
  - The Fibonacci Model is similar
    - Initial State: b
    - b -> a
    - a -> ab
  - *sneezewort*







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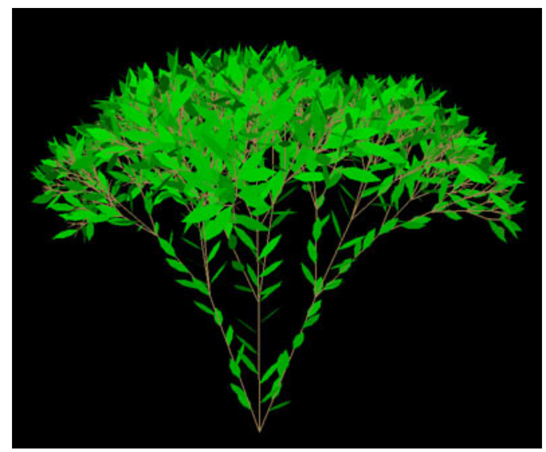
Aristid Lindenmeyer

- Mathematical formalism proposed by the biologist Aristid Lindenmayer in 1968 as a foundation for an axiomatic theory of biological development.
  - applications in computer graphics
    - Generation of fractals and realistic modeling of plants
  - Grammar for rewriting Symbols
    - Production Grammar
    - Defines complex objects by successively replacing parts of a simple object using a set of recursive, rewriting rules or productions.
      - Beyond one-dimensional production (Chomsky) grammars
      - Parallel ***recursion***
      - Access to computers



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example

```
#define CH 900   /* high concentration */
#define CT 0.4   /* concentration threshold */
#define ST 3.9   /* segment size threshold */
#include H       /* heterocyst shape specification */
#ignore f ~ H
```

ω : -(90)F(0,0,CH)F(4,1,CH)F(0,0,CH)

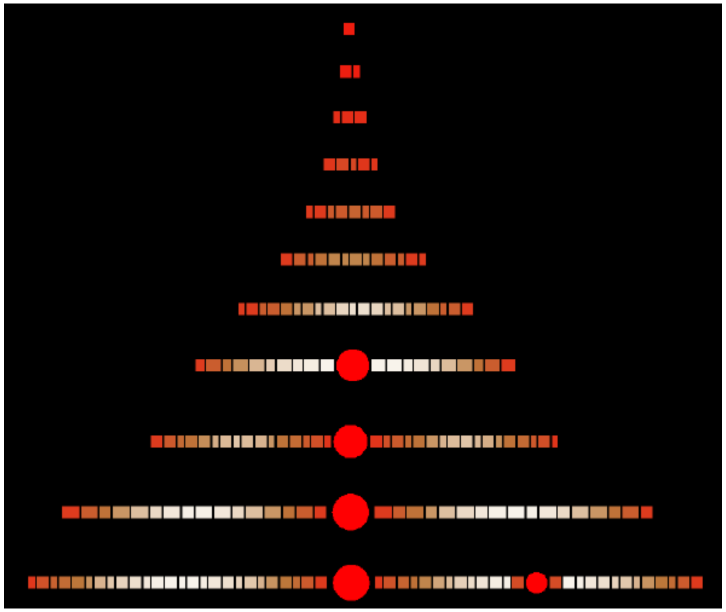
p_1 : F(s,t,c) : t=1 & s>=6 $\rightarrow$ F(s/3*2,2,c)f(1)F(s/3,1,c)

p_2 : F(s,t,c) : t=2 & s>=6 $\rightarrow$ F(s/3,2,c)f(1)F(s/3*2,1,c)

p_3 : F(h,i,k) $<$ F(s,t,c) $>$ F(o,p,r) : s>ST|c>CT $\rightarrow$ F(s+.1,t,c+0.25*(k+r-3*c))

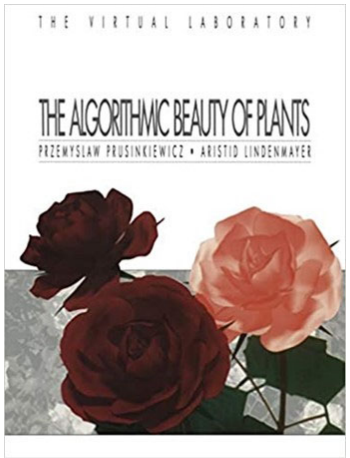
p_4 : F(h,i,k) $<$ F(s,t,c) $>$ F(o,p,r) : !(s>ST|c>CT) $\rightarrow$ F(0,0,CH) ~ H(1)

p_5 : H(s) : s<3 $\rightarrow$ H(s*1.1)



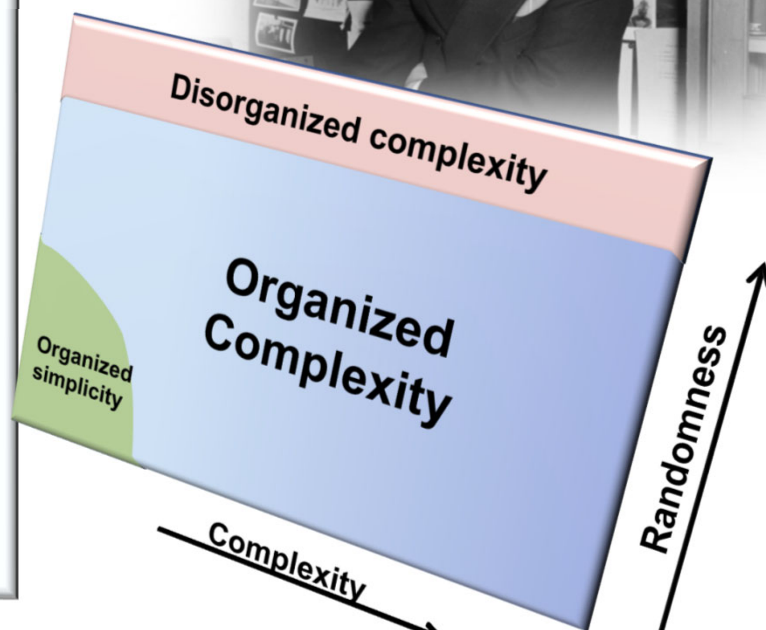
convenient tool for expressing developmental models with ***diffusion of substances***.
pattern of cells in *Anabaena catenula* and other blue-green bacteria

From: P. Prusinkiewicz and A. Lindenmayer [1991]. *The Algorithmic Beauty of Plants*.



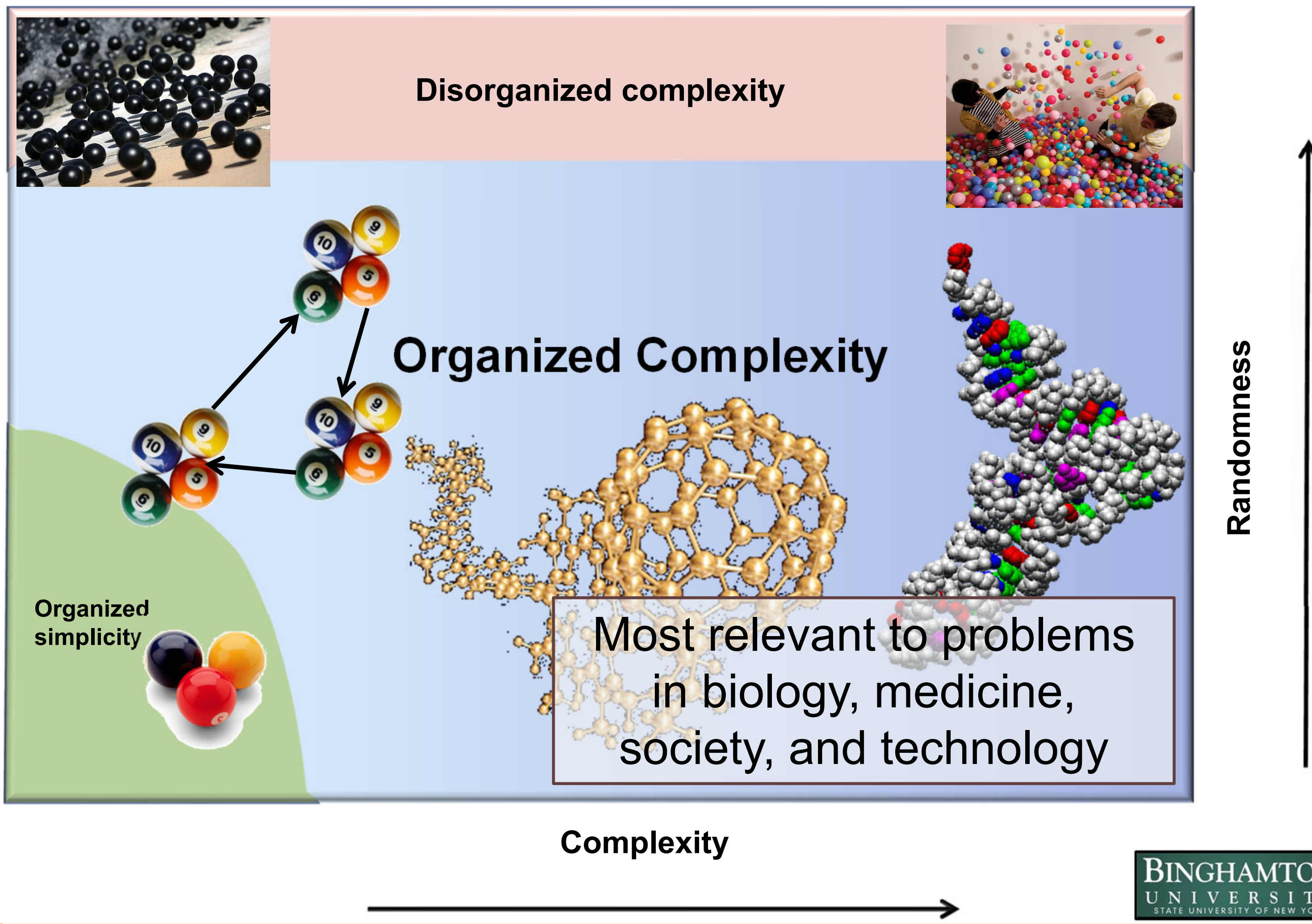
Warren Weaver’ classes of systems and problems

- 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



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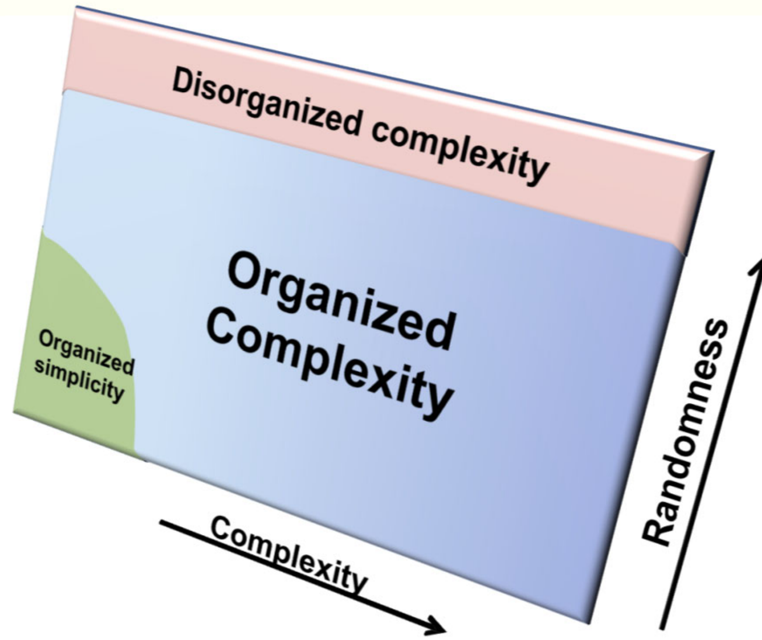
from computational to systems thinking

- 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**



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readings

- Class Book
  - Klir, G.J. [2001]. *Facets of systems science*. Springer.
- Papers and other materials
  - 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.