lecture 8: Modeling

Modeling Principles of Organization

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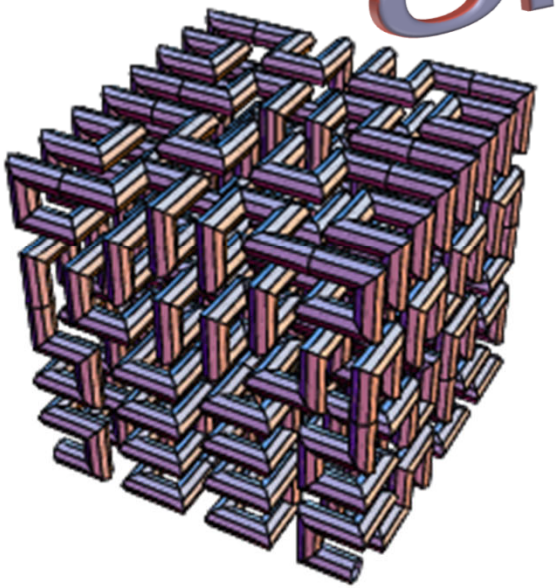

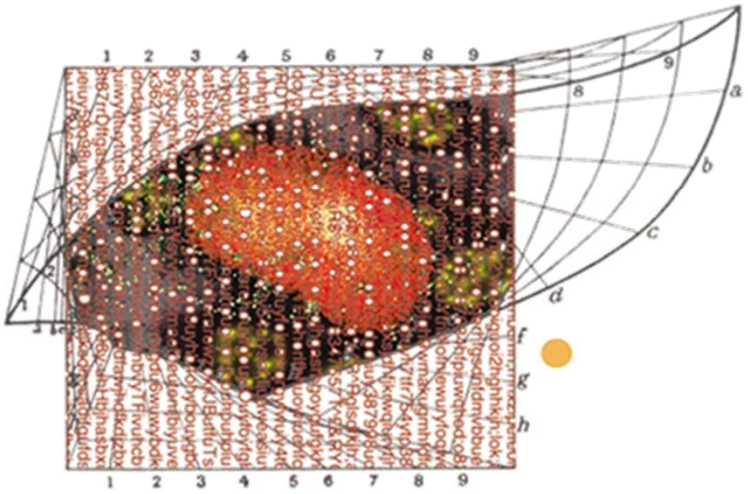

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evaluation

- 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%)

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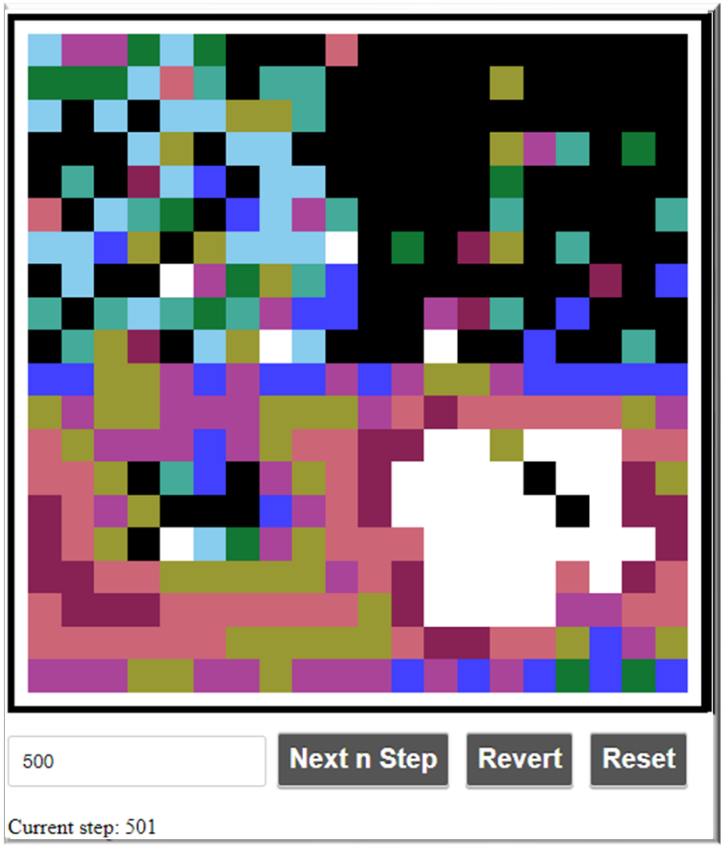
The Black Box: Due: **October 9th, 2024**

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 and 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)

- Paper Presentation: 20%
  - Present (501) and lead (50
    - class materials
      - Enginet students post/send v
- Module 2: Systems Scien
  - Discussion Set 4 (Group
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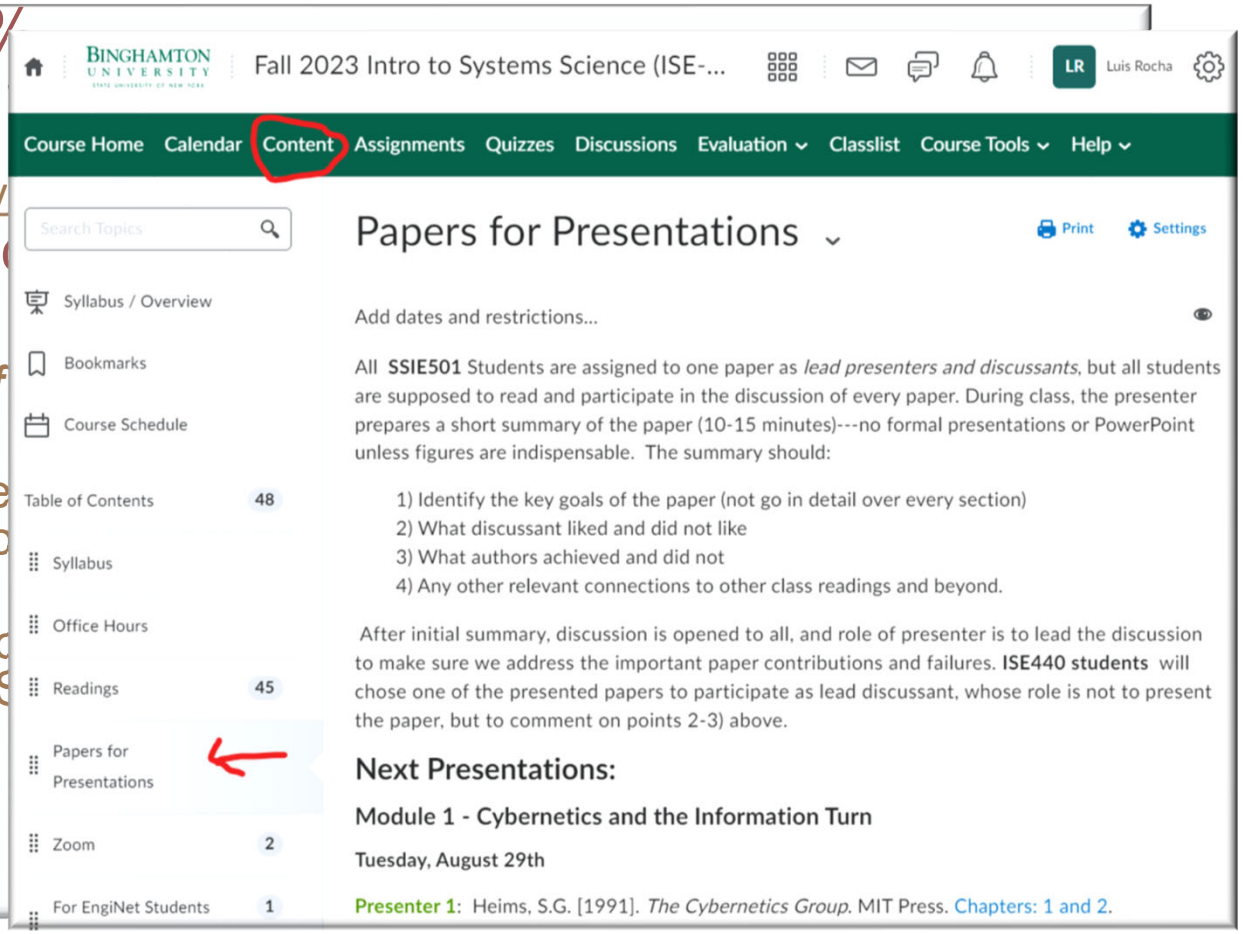

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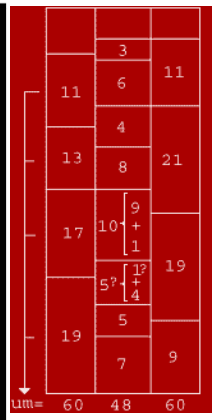
abstracting symbol mappings

Raphael's "*Plato and Aristotle*"

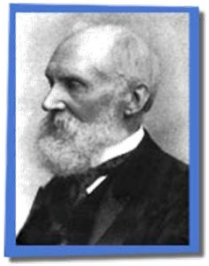
- ***Aristotle*** (384-322 BC)
  - First (??) to relate symbols more explicitly to the external world and to successively clarify the nature of the symbol-world relation.
    - Student of Plato, educated Alexander the Great
    - first to consider specific ***observable*** factors which determine *motion*.
  - In ***Physics***
    - he recognized (mathematical) ***rules*** which could describe the ***relation*** between an object's weight, the medium's density and the consequent rate of motion (fall):
      - (1) for freely falling or freely rising bodies, speed is proportional to the density of the medium.
      - (2) in forced motion, speed is proportional to the force applied and inversely proportional to the mass of the body moved
    - first time that ***observable*** quantities had been expressed in symbolic (numerical) form allowing the results of observations to be used in calculations
      - The nature of ***causation***
      - http://classics.mit.edu/Aristotle/physics.html



Ishango bone

Modeling!

"*When you can measure what you are speaking of and express it in numbers you know that on which you are discoursing. But if you cannot measure it and express it in numbers. your knowledge is of a very meagre and unsatisfactory kind*". Lord Kelvin



Lebombo bone

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symbol-world relation

- Galileo (1564-1642)
  - Progressive dissociation of the symbols from objects
    - The interrelationships among signs themselves studied quite apart from the relations among the objects they represent
      - Previously, symbols were still generally regarded as inherent properties of the referent objects themselves
      - Aristotle's *Physics* postulated certain primary qualities/elements such as "Fire". Galileo regards "primary" properties as only those that can be mathematically quantified, such as size, shape and motion.
- Newton (1643-1727)
  - Extends process of abstraction
    - Distinguishes between symbols
      - Arising from *observation*
        - represent initial conditions
      - Arising from *symbol relations*
        - representing laws which govern the subsequent motion.

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Heinrich Hertz (1857-1894)

- Some facts about Hertz
  - First to broadcast and receive radio waves
  - Established that light is a form of electromagnetic radiation.
  - His name is associated with the SI unit for frequency
- *Principles of Mechanics* (1894)
  - Goal was to purge physics of mystical, undefined, unmeasured entities
    - such as force (which one can infer but not measure)
  - Physical theories to be based only on measurable quantities
    - the results of *measurements* are symbols.
    - Physical theory becomes about building *relationships* among observationally-derived symbols: ***models***
      - what Hertz called "images."

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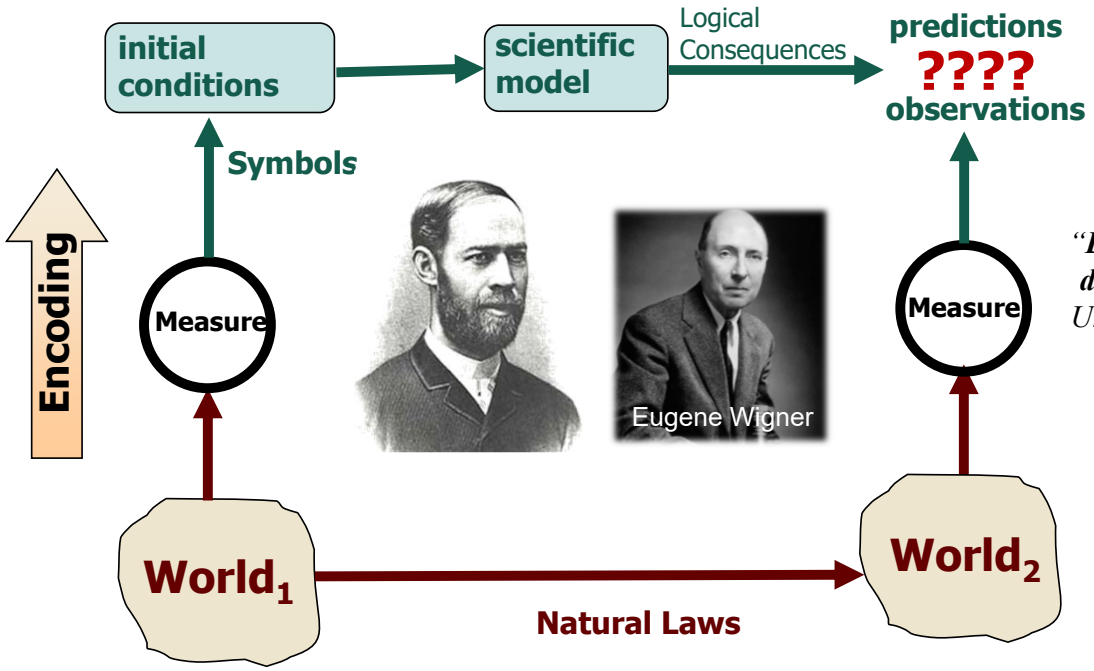
Hertzian scientific modeling paradigm



*"**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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2,000-year-old astronomical calculator

- bronze mechanical **analog** computer
  - discovered more than 100 years ago in a Roman shipwreck, was used by ancient Greeks to display astronomical cycles.
- built around the end of the second century BC to calculate astronomical positions
- With imaging and high-resolution X-ray tomography to study how it worked.
  - complicated arrangement of at least 30 precision, hand-cut bronze gears housed inside a wooden case covered in inscriptions.
  - technically more complex than any known device for at least a millennium afterwards.

Freeth *et al*. *Sci Rep* **11,** 5821 (2021)

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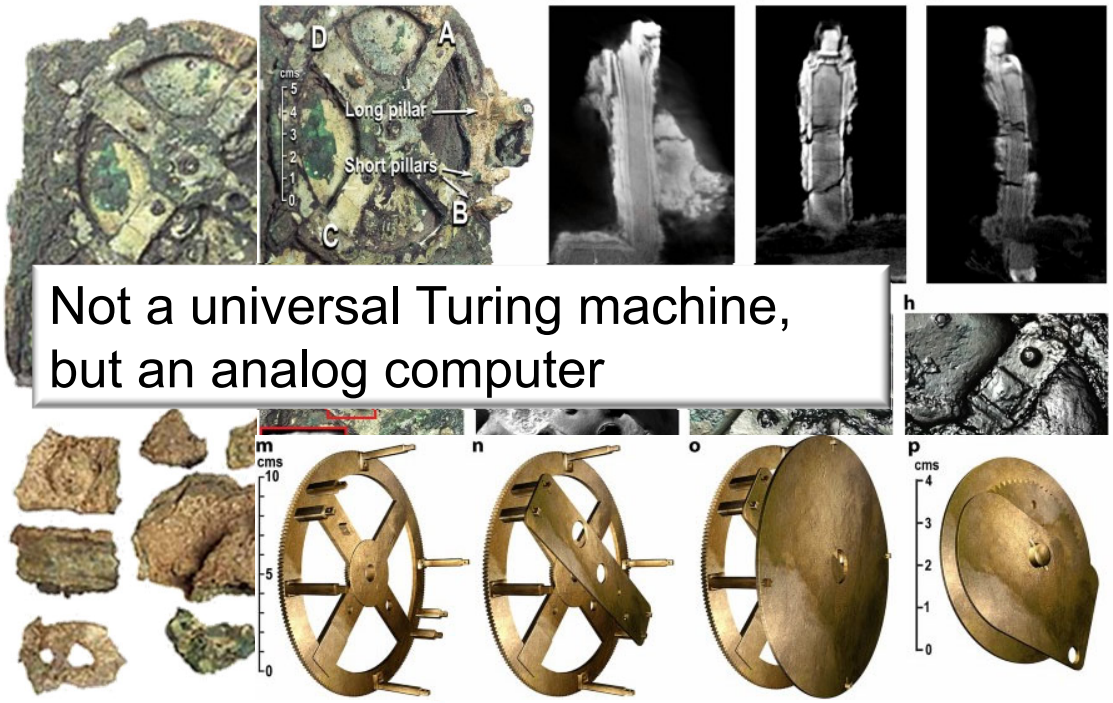
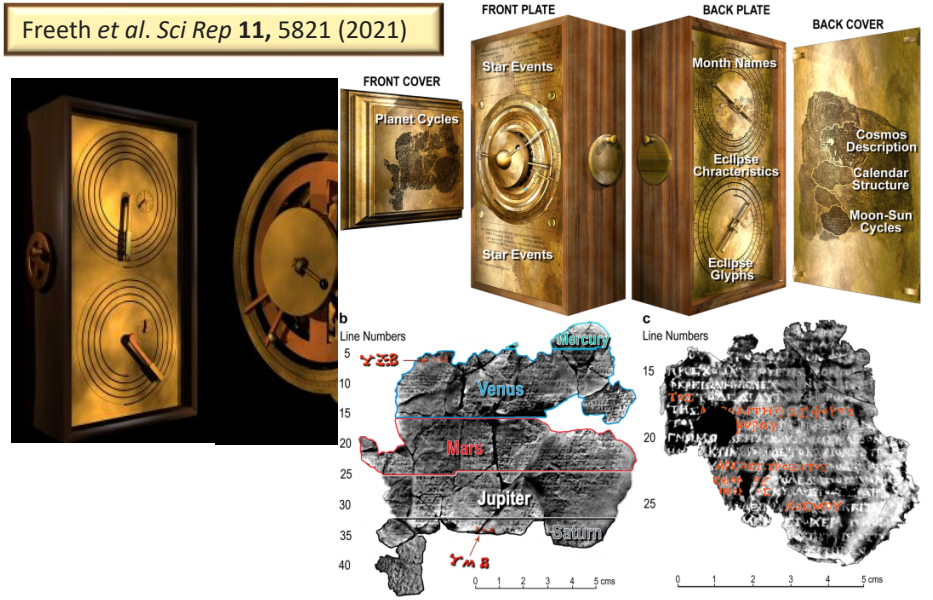


Not a universal Turing machine, but an analog computer

Freeth *et al*. *Sci Rep* **11,** 5821 (2021)



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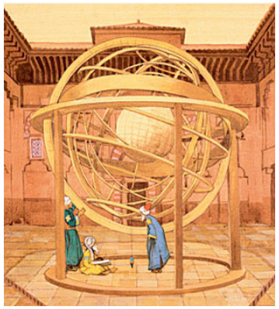
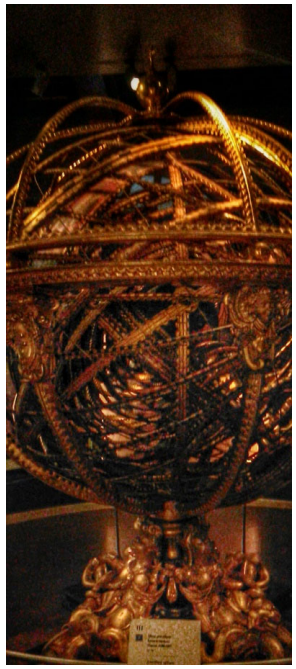
other models

Stonehenge (3000 BC)

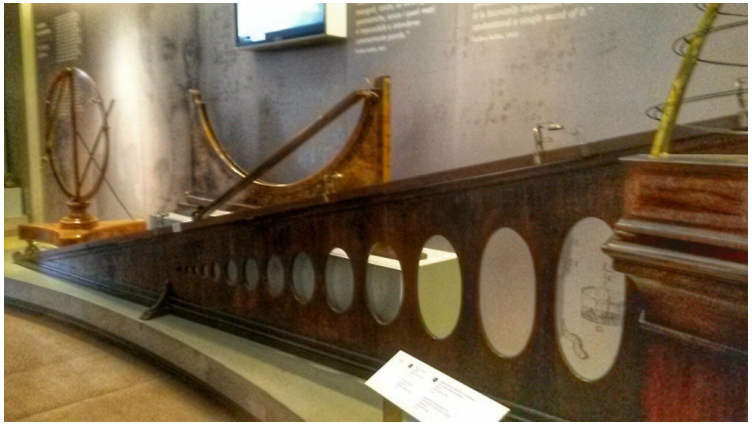


Abbas ibn Firnas (IX)

Mariner's Astrolabe (XV)



Modern Science
(16-17th century)



XVIII to XIX

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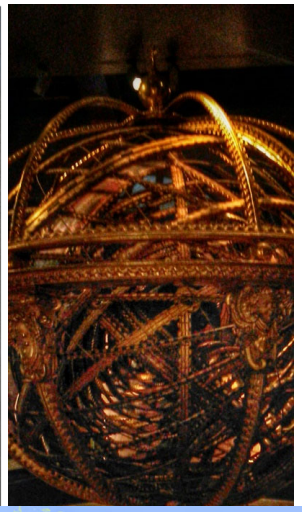

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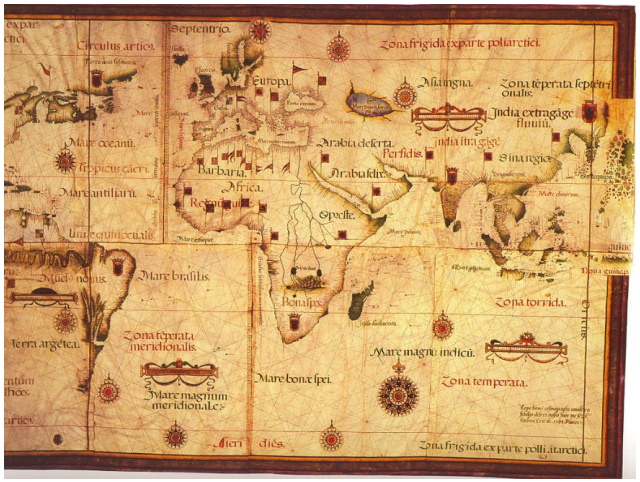
(16



Lopo Homem world map (XVI)

Dieppe Maps (XVI)
XVIII to XIX

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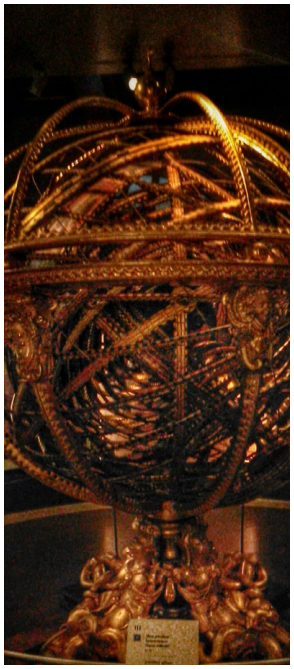
other models



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(16-17th century)

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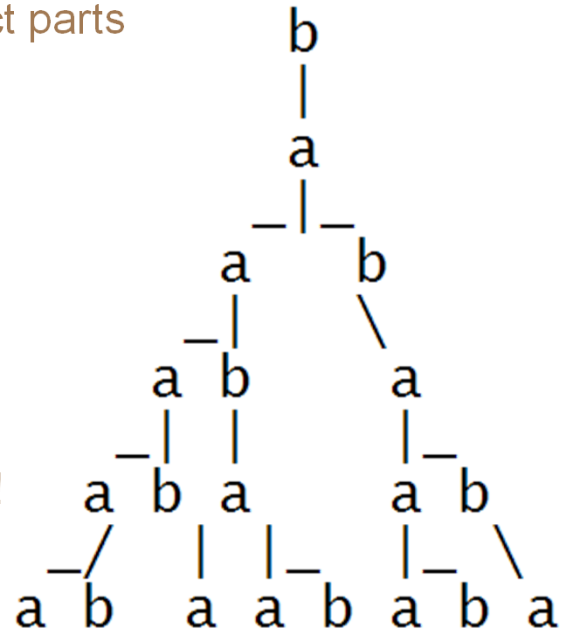
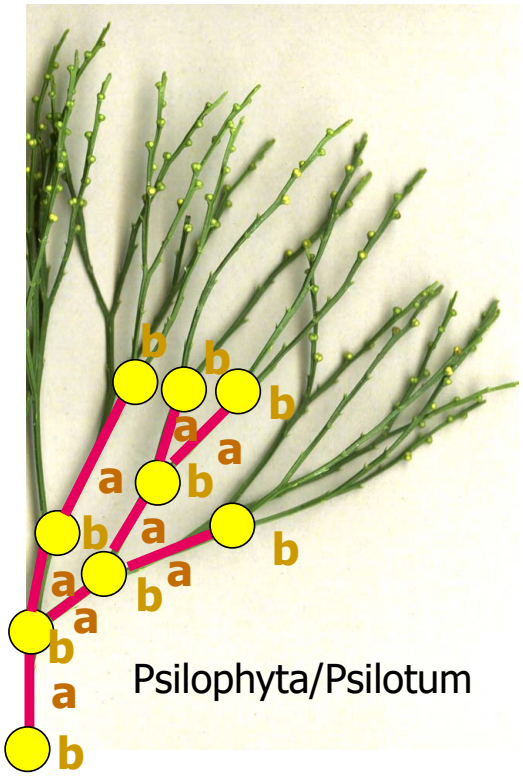
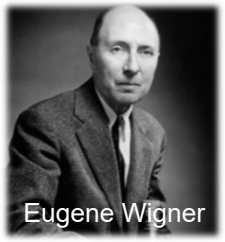
Building models

Lebombo bone

- What do you see?
  - Plants typically ***branch*** out
  - How can we ***model*** that?
    - Observe the distinct parts
      - Color them
      - Assign *symbols*
    - Build Model
      - Initial State: b
      - b -> a
      - a -> b
      - a -> ba
    - Does not model all!







Eugene Wigner

Heinrich Hertz

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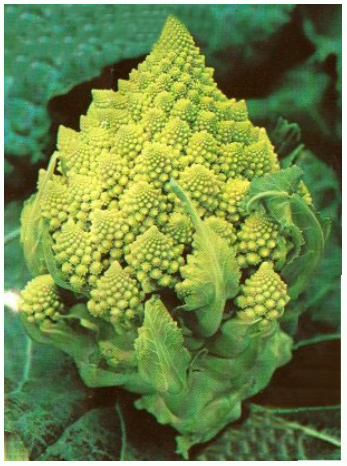
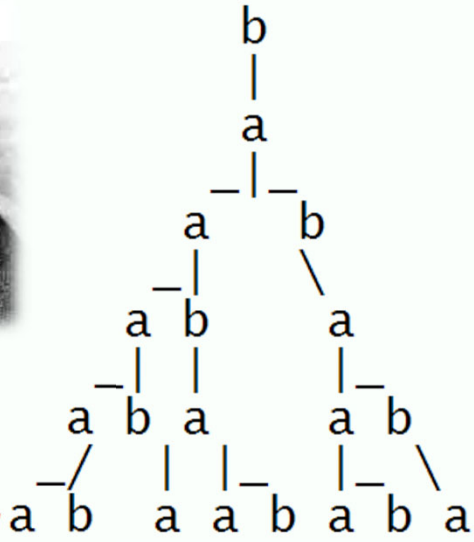
our first model

- ***Rewriting*** production rules
  - Initial State: b
  - b -> a
  - a -> ba
    - n=0 : b
    - n=1 : a
    - n=2 : ba
    - n=3 : aba
    - n=4 : baaba
    - n=5 : aababaab
    - n=6 : babaabaababaa
    - n=7 : abaababaabababaabaababa
  - The length of the string is the Fibonacci Sequence
    - 1 1 2 3 5 8 13 21 34 55 89 ...
  - Fibonacci numbers in Nature
    - https://sciber.blogspot.com/2022/09/modeling-systems.html
    - Romanesco: https://www.wussu.com/fractals/romanesco.htm





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our first model

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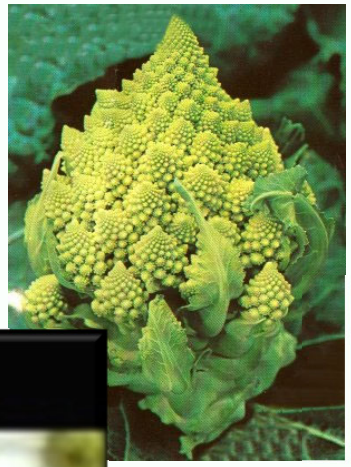

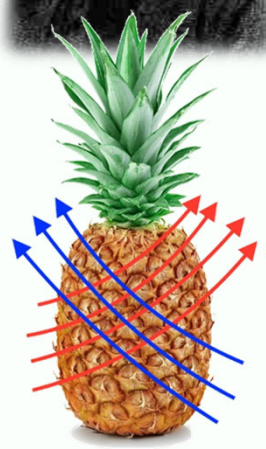

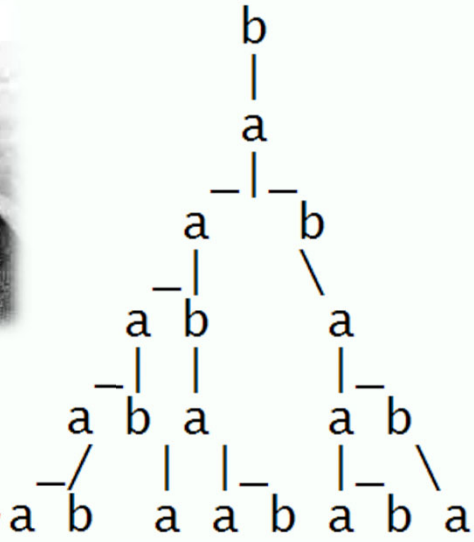

acci Sequence

09/modeling-systems.html
om/fractals/romanesco.htm

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Mathematics

Language

3.

1415926535 8979323846 2643383279
5028841971 6939937510 5820974944
5923078164 0628620899 8628034825
3421170679 8214808651 3282306647
0938446095 5058223172 5359408128
4811174502 8410270193 8521105559
6446229489 5493038196 4428810975
6659334461 2847564823 3786783165
2712019091 4564856692 3460348610
4543266482 1339360726 0249141273
7245870066 0631558817 4881520920
9628292540 9171536436 7892590360
0113305305 4882046652 1384146951
9415116094 3305727036 5759591953
0921861173 8193261179 3105118548
0744623799 6274956735 1885752724
8912279381

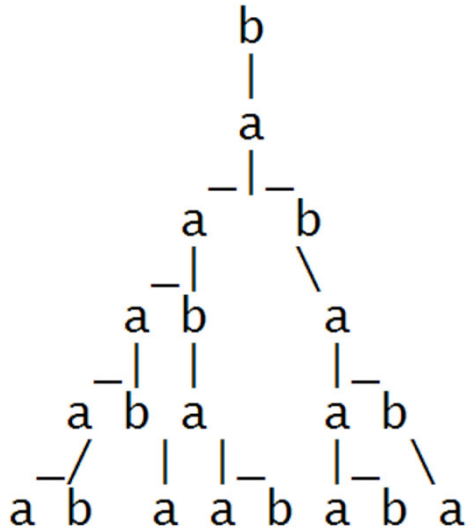
Is The

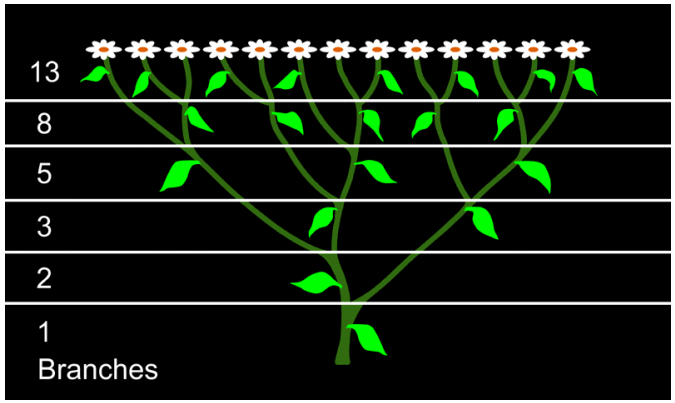
Of Nature

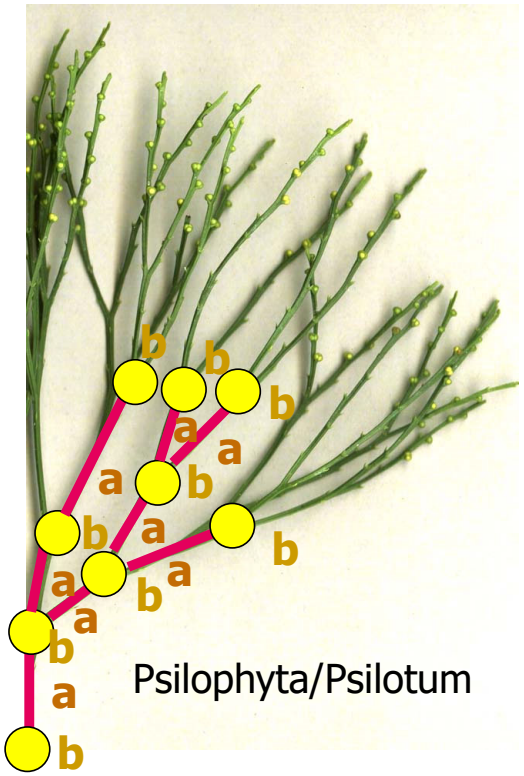
When I was a kid my mother told me
never to stare into the centre of the sun.
So once, when I was 6,
I did

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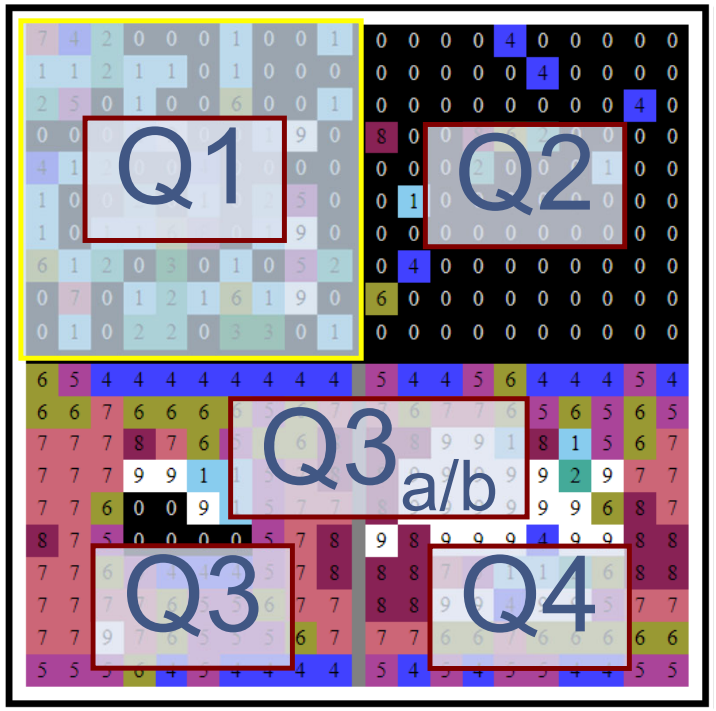
The Black Box: Due: **October 9th, 2024**

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.

- 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.



1 Next n Step Revert Reset

Current step: 501

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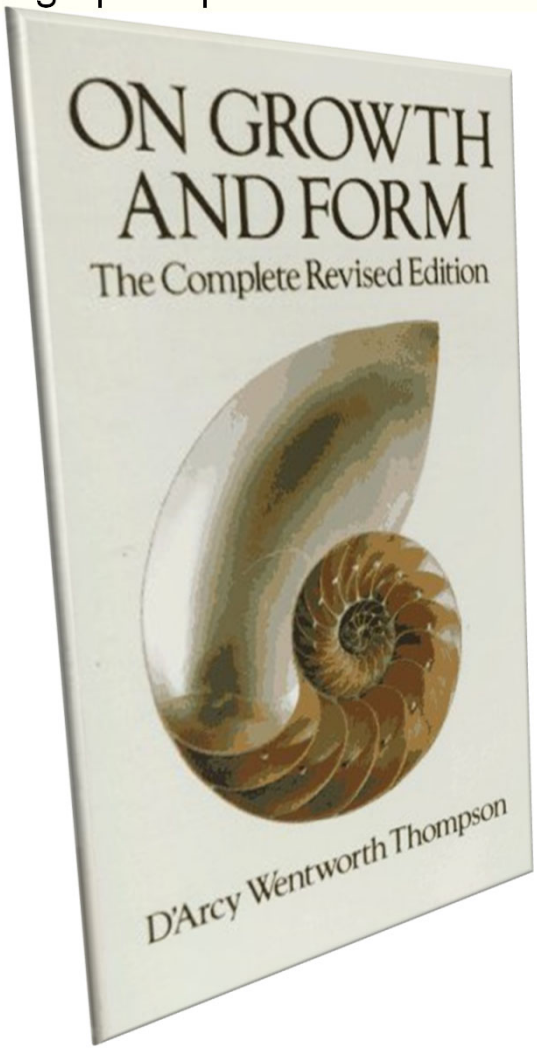
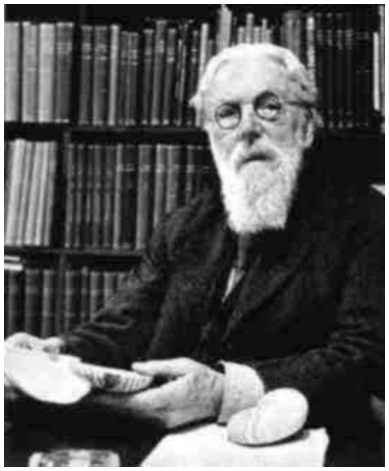
design principles



- D'Arcy Wentworth Thompson (1860 - 1948)
  - *On Growth and Form* (1917), laid the foundations of bio-mathematics
    - Equations to describe static patterns of living organisms
      - Shells, cauliflower head, etc.
    - Transformations of form changing a few parameters



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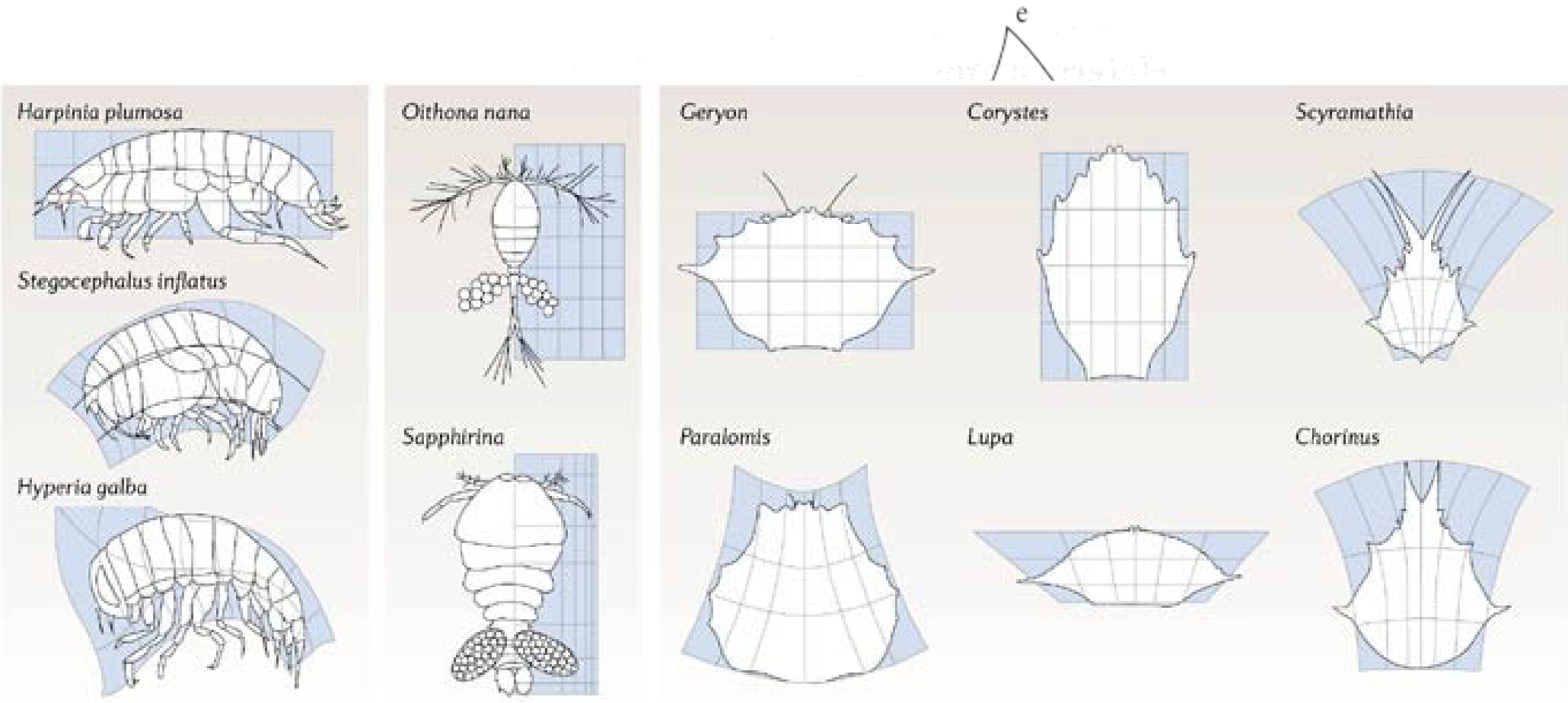

Arthur, Wallace. "D'Arcy Thompson and the theory of transformations." *Nature Reviews Genetics* 7.5 (2006): 401-406.

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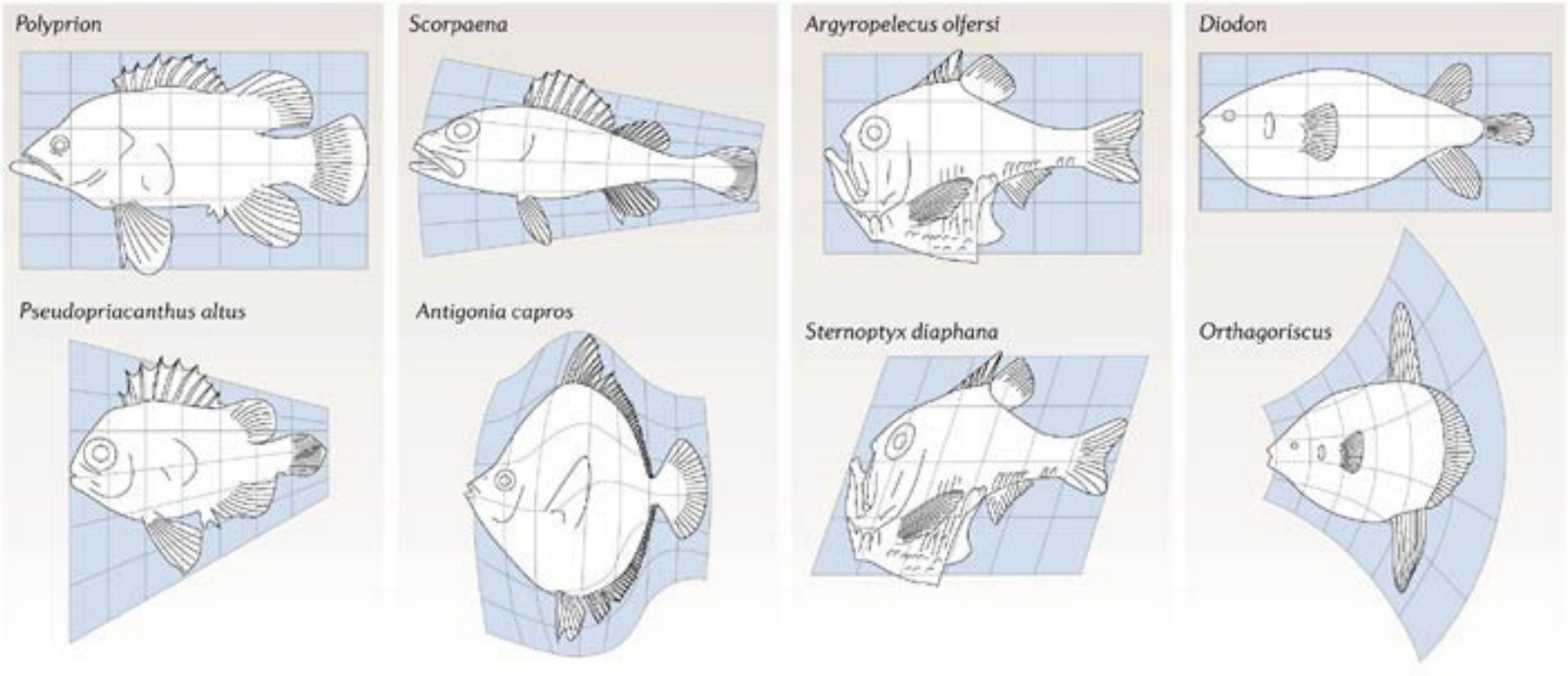

Arthur, Wallace. "D'Arcy Thompson and the theory of transformations." *Nature Reviews Genetics* 7.5 (2006): 401-406.

Fig. 517. *Argyropelecus Olfersi.* Fig. 518. *Sternoptyx diaphana.*

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D’Arcy Thompson

Polyprion

Scorpaena

Argyropelecus olfersi

Diodon

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NEWS | 20 September 2024

Mathematicians discover new class of shape seen throughout nature

‘Soft cells’ – shapes with rounded corners and pointed tips that fit together on a plane – feature in onions, molluscs and more.

By Philip Ball

Arthur, Wallace. "D'Arcy Thompson and the theory of transformations." *Nature Reviews Genetics* 7.5 (2006): 401-406.

Fig. 517. *Argyropelecus Olfersi.* Fig. 518. *Sternoptyx diaphana.*

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readings

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