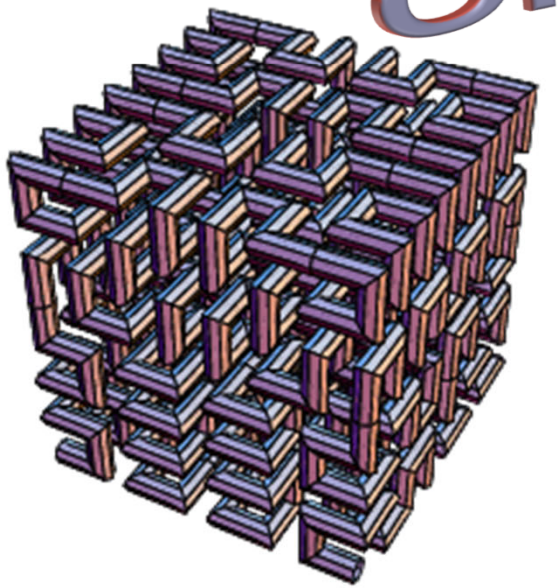
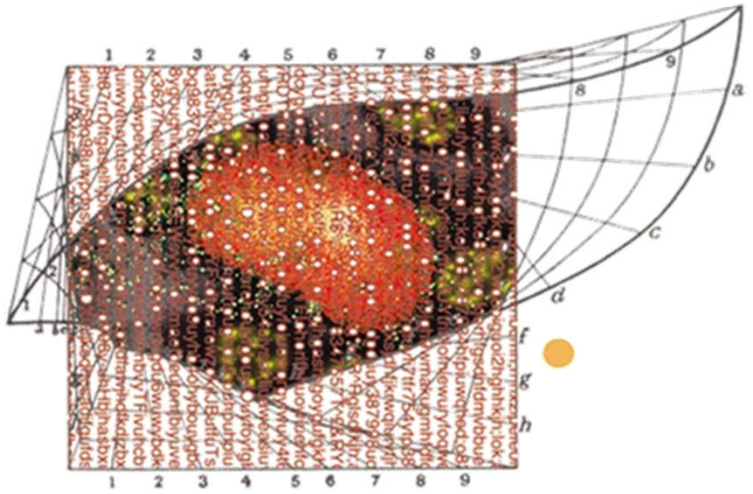
lecture 6: Modeling

Modeling Principles of Organization





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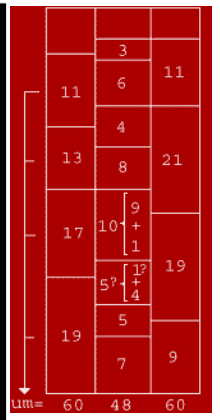
abstracting symbol mappings

Raphael's "*Plato and Aristotle*"

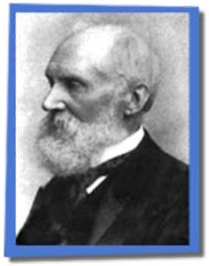
- ***Aristotle*** (384-322 BC)
  - First (??) to relate symbols more explicitly to the external world and to successively clarify the nature of the symbol-world relation.
    - Student of Plato, educated Alexander the Great
    - first to consider specific ***observable*** factors which determine *motion*.
  - 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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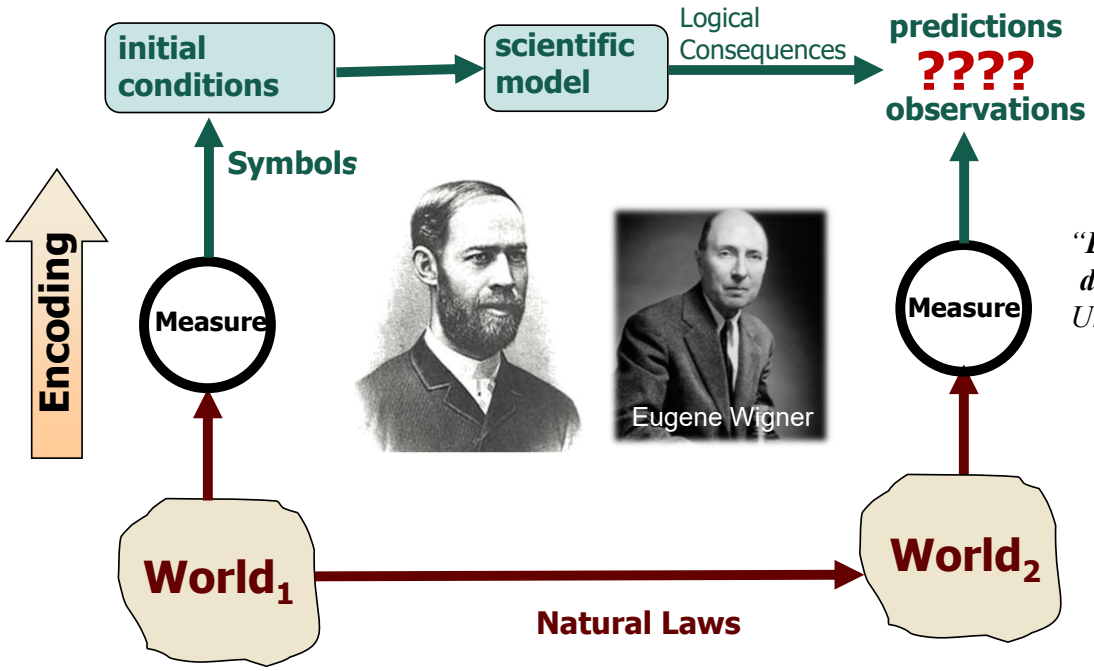
Hertzian scientific modeling paradigm



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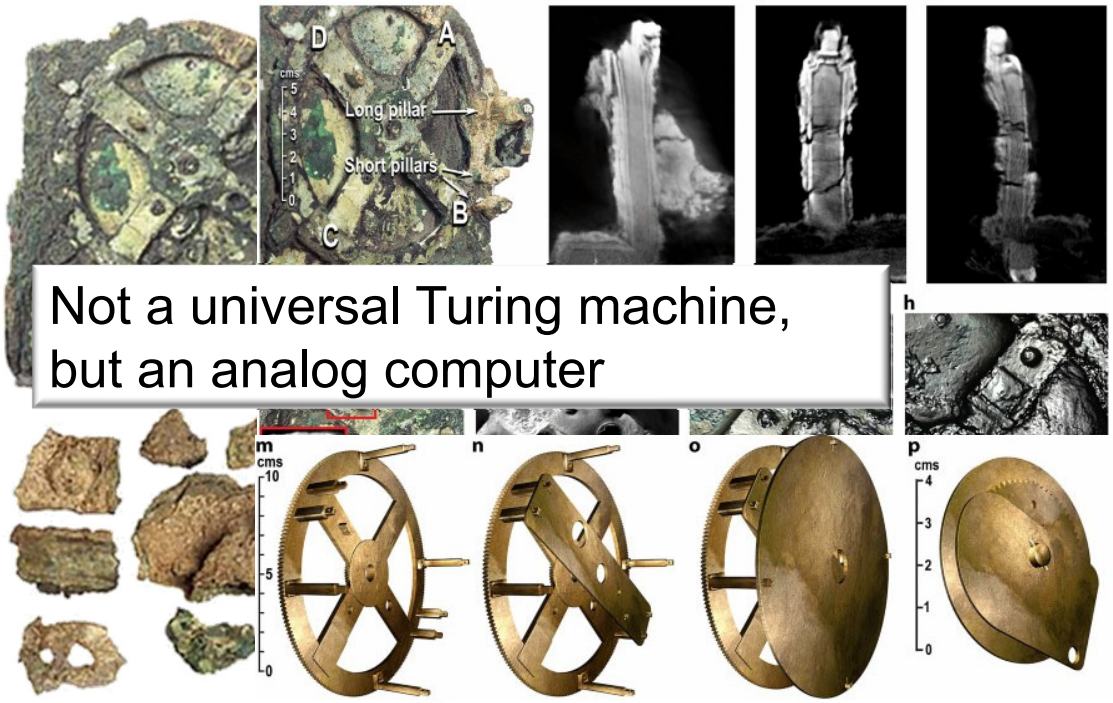
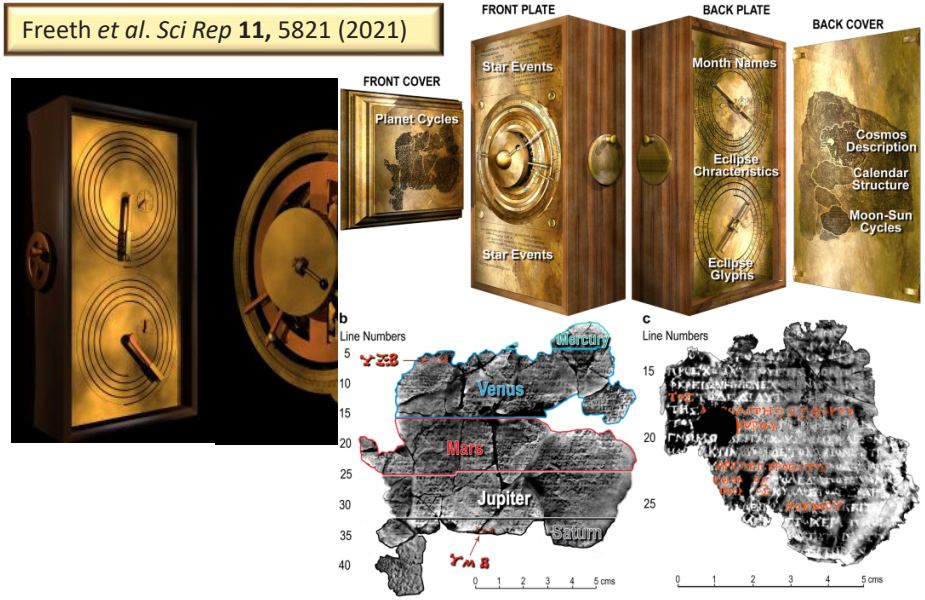
2,000-year-old astronomical calculator

- 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.



Not a universal Turing machine, but an analog computer

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



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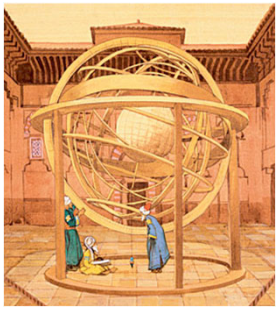
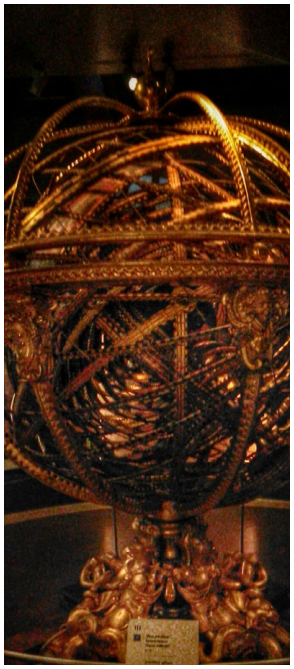
other models

Stonehenge (3000 BC)

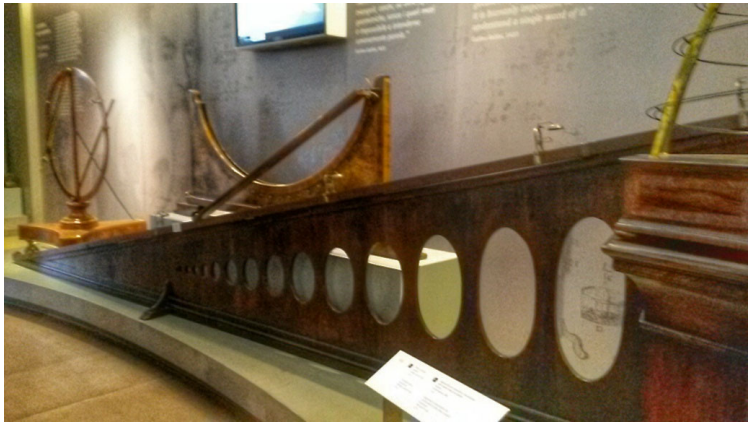


Abbas ibn Firnas (IX)

Mariner's Astrolabe (XV)



Modern Science
(16-17th century)



XVIII to XIX

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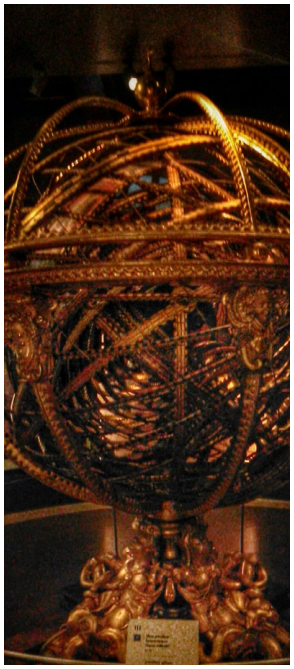
other models



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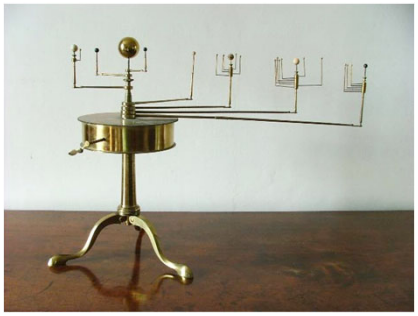
Lopo Homem world map (XVI)

Dieppe Maps (XVI)
XVIII to XIX



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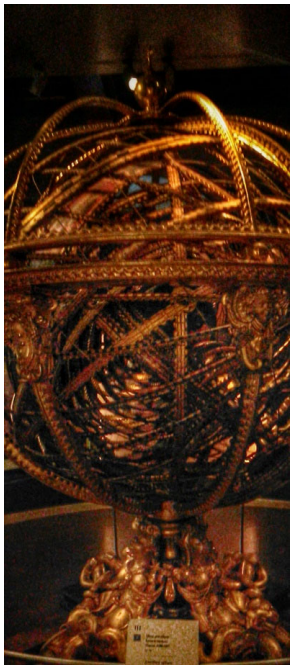

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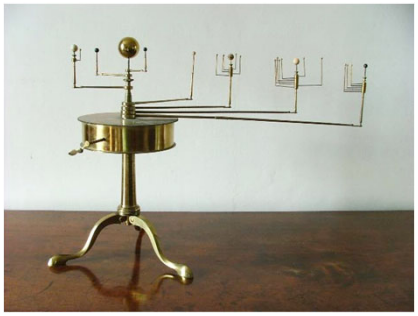

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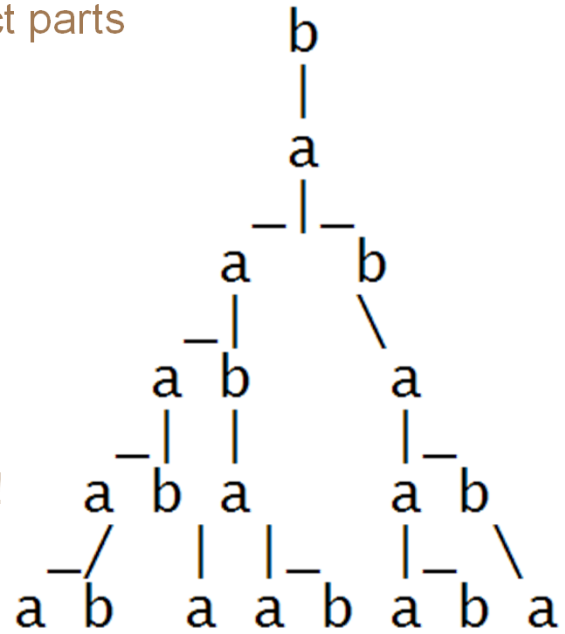
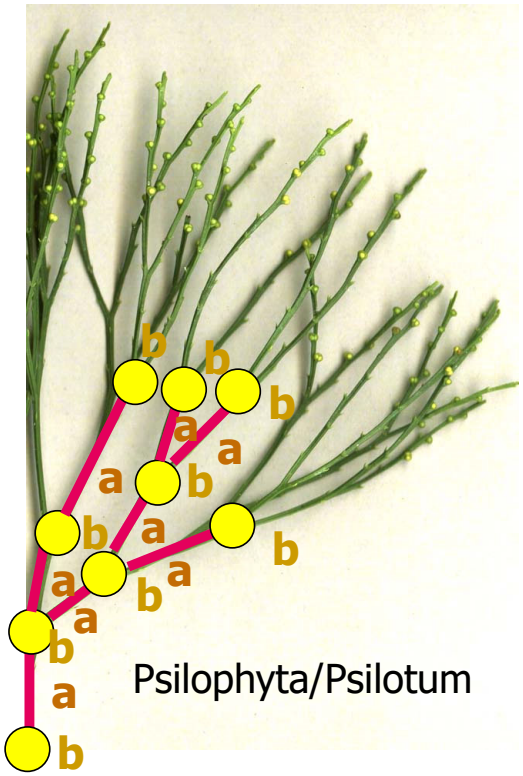
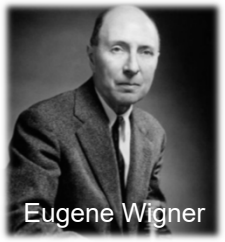
Building models

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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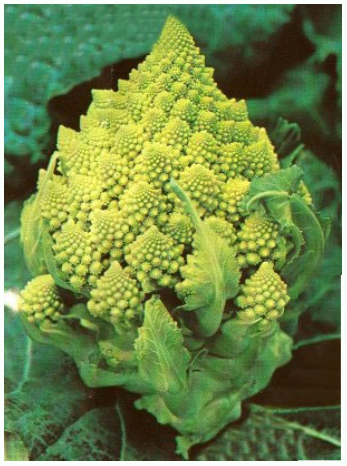
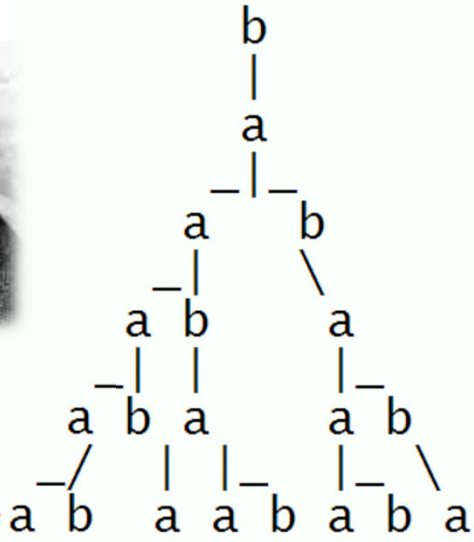
our first model

- ***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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