Modeling Principles of Organization
Lab Assignments: 35% (ISE-483), 25% (SSIE-583)
- Complete 5 (best 4 graded) assignments based on algorithms presented in class
  - Lab 1: February 6th
    - Measuring Information (Assignment 1)
  - Lab 2: February 20th
    - L-Systems (Assignment 2)

SSIE – 583 - Presentation and Discussion: 25%
- Present and lead the discussion of an article related to the class materials
  - Enginet students post/send video or join by Zoom
- Next Presentation February 13th
    - Presented by Grant Aguinaldo
- Additional Presentations February 20th
  - ???
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)

“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”
Let's Observe Nature!

- **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!

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Psilophyta/Psilotum

Heinrich Hertz

Eugene Wigner
Fibonacci Numbers!

our first model of life

- **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 : babaabaababaabababa
    - n=7 : abaababaababaababaababaababa
  - 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](https://sciber.blogspot.com/2022/09/modeling-systems.html)
    - Romanesco: [https://www.wussu.com/fractals/romanesco.htm](https://www.wussu.com/fractals/romanesco.htm)
**Fibonacci Numbers!**

Our first model of life

- **Rewriting** production rules
  - Initial State: b
  - b -> a
  - a -> ba
    - n=0 : b
    - n=1 : a
    - n=2 : ba

- The length of the string is the Fibonacci Sequence
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- Fibonacci numbers in Nature
  - [https://sciber.blogspot.com/2022/09/modeling-systems.html](https://sciber.blogspot.com/2022/09/modeling-systems.html)
  - Romanesco: [https://www.wussu.com/fractals/romanesco.htm](https://www.wussu.com/fractals/romanesco.htm)
Mathematics Is The Language Of Nature
Monday, February 07, 2022

Companion links for "Modeling Principles of Organization" lecture

Pi the Movie

Fibonacci Sequence

- Fibonacci numbers in Nature. The Romanesco Vegetable.
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
Peter Hilton (1923-2010) discusses intriguing number tricks that can be explained by analysing the properties of Fibonacci numbers and the related Lucas numbers. The explanations themselves benefit from further explanations which, in their turn, lead to further discoveries. Recorded at Imperial College London during the 1996 London Mathematical Society Popular Lecture series.

D'Arcy Thompson

- In retrospect: On Growth and Form by Phillip Ball.
- D'Arcy Thompson's Affine Fish Transformations @ Wolfram
- Geometry of Growth and Form: Commentary on D'Arcy Thompson
- Java applet for shell sketching

Patterns of Life - D'Arcy Thompson, Structuralism and the Shape of Life

Treasures of the Library 5. D'Arcy Thom...
Natural design principles

exploring similarities across nature

- **self-similar structures**
  - Trees, plants, clouds, mountains
    - morphogenesis
  - Mechanism
    - Iteration, recursion, feedback

- **Dynamical Systems and Unpredictability**
  - From limited knowledge or inherent in nature?
  - Mechanism
    - Chaos, measurement

- **Collective behavior, emergence, and self-organization**
  - Complex behavior from collectives of many simple units or agents
    - cellular automata, ant colonies, development, morphogenesis, brains, immune systems, economic markets
  - Mechanism
    - Parallelism, multiplicity, multi-solutions, redundancy

- **Adaptation**
  - Evolution, learning, social evolution
  - Mechanism
    - Reproduction, transmission, variation, selection, Turing’s tape

- **Network causality (complexity)**
  - Behavior derived from many inseparable sources
    - Environment, embodiment, epigenetics, culture
  - Mechanism
    - Modularity, connectivity, stigmergy
readings

- **Class Book**

- **Lecture notes**
  - Chapter 1: What is Life?
  - Chapter 2: The logical Mechanisms of Life
  - Chapter 3: Formalizing and Modeling the World
    - posted online @ casci.binghamton.edu/academics/i-bic

- **Papers and other materials**
  - Logical mechanisms of life
  - Optional
      - Chapter 1 – Introduction
      - Chapters 5, 6 (7-9) – Self-similarity, fractals, L-Systems