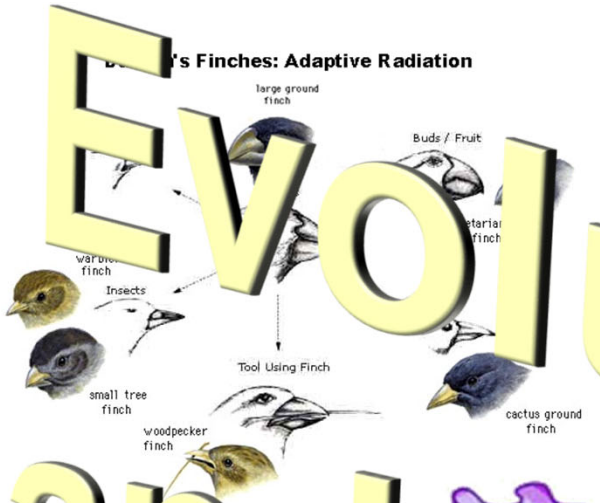
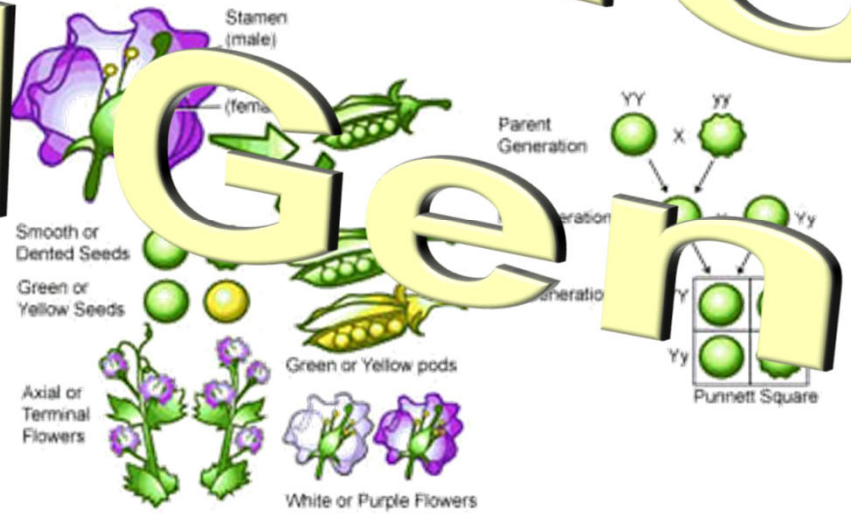
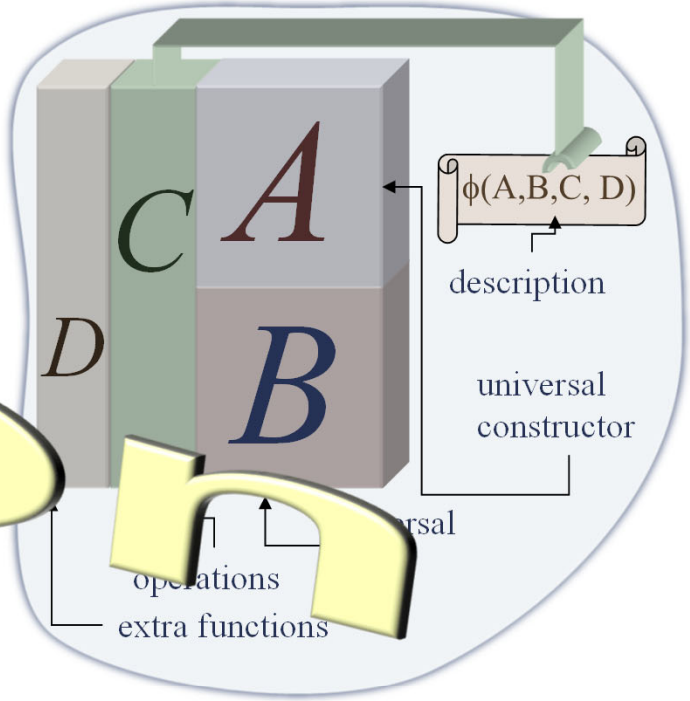
lecture 13: Evolution and Genes

Evolution and Genes







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key events coming up

- Labs: 35% (ISE-483)
  - Complete 5 (best 4 graded) assignments based on algorithms presented in class
    - Lab 3: March 11th
      - Cellular Automata and Boolean Networks (Assignment 3)
        - Delivered by SSIE583 Group 3
        - Due: March 25th
    - Lab 4 : April 2nd (Tuesday after Easter break)????
      - Evolutionary Algorithms, (Assignment 4)
        - Delivered by SSIE583 Group 2
        - Due April 8th
- 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
  - Dates TBA
    - Conrad, M. [1990]. "The geometry of evolution." *Biosystems* **24**: 61-81.
      - Mario Franco
    - Stanley, Kenneth O., Jeff Clune, Joel Lehman, and Risto Miikkulainen. "Designing Neural Networks through Neuroevolution." *Nature Machine Intelligence* **1**, no. 1 (January 2019): 24–35.
      - Jessica Lasebikan
    - Lindgren, K. [1991]."Evolutionary Phenomena in Simple Dynamics." In: *Artificial Life II*. Langton et al (Eds). Addison-wesley, pp. 295-312.
      - Akshay Gangadhar
    - Salahshour, Mohammad. "Interaction between Games Give Rise to the Evolution of Moral Norms of Cooperation." *PLOS Computational Biology* **18**, no. 9 (September 29, 2022): e1010429
      - Srikanth Iyer
    - Discussion by all

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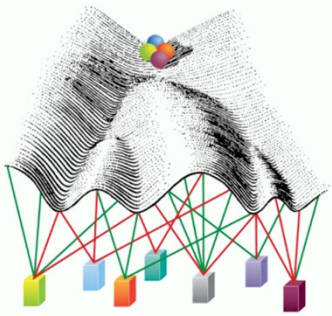
until now

- Class Book
  - Floreano, D. and C. Mattiussi [2008]. *Bio-Inspired Artificial Intelligence: Theories, Methods, and Technologies*. MIT Press. Preface**, Chapters 1 and 4.**
- Lecture notes
  - Chapter 1: What is Life?
  - Chapter 2: The logical Mechanisms of Life
  - Chapter 3: Formalizing and Modeling the World
  - Chapter 4: Self-Organization and Emergent Complex Behavior
  - Chapter 5: Reality is Stranger than Fiction
    - posted online @ http://informatics.indiana.edu/rocha/i-bic
- Papers and other materials
  - Optional
    - Nunes de Castro, Leandro [2006]. *Fundamentals of Natural Computing: Basic Concepts, Algorithms, and Applications*. Chapman & Hall.
      - Chapter 2, 7, 8
      - **Chapter 3, sections 3.1 to 3.5**
    - Flake's [1998], *The Computational Beauty of Life*. MIT Press.
      - Chapters 10, 11, 14 – Dynamics, Attractors and chaos



- Projects
  - Due by May 6th in Brightspace, “Final Project Paper” assignment
    - ALIFE 2023
      - Not to submit to actual conference due date (April 3rd , 2024)
      - https://2024.alife.org/
      - 8 pages, author guidelines:
      - https://2024.alife.org/call_paper.html
      - MS Word and Latex/Overleaf templates
    - Preliminary ideas **by March 15**
      - Submit to “Project Idea” assignment in Brightspace.
  - Individual or group
    - With very definite tasks assigned per member of group

ALIFE 2024

Tackle a real problem using bio-inspired algorithms, such as those used in the labs.

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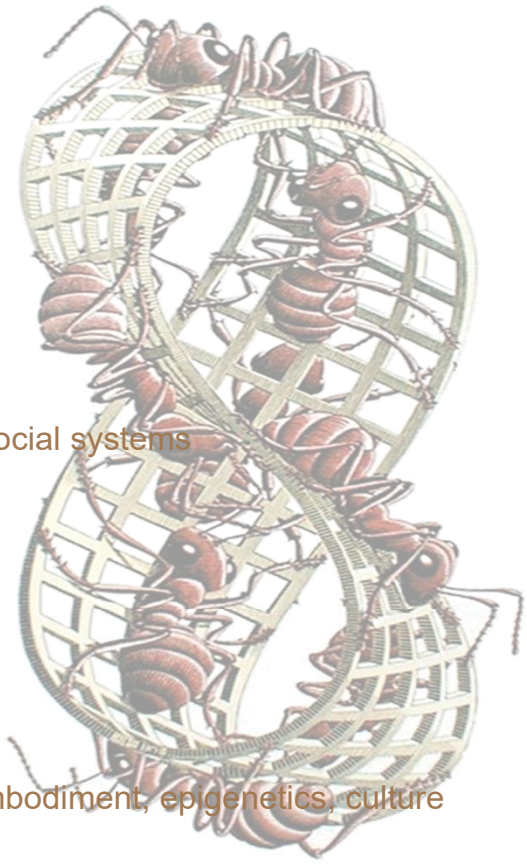
exploring similarities across nature

- 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
- self-organization, collective behavior, emergence
  - Complex behavior from collectives of many simple units or agents
    - cellular automata, dynamical networks, morphogenesis, swarms, brains, social systems
  - Mechanism
    - Parallelism, multiplicity, multi-solutions, redundancy
- evolution
  - Adaptation, learning, social evolution
  - Mechanism
    - Reproduction, transmission, variation, selection, Turing's tape
- Network causality (heterogenous complexity)
  - Behavior derived from many inseparable sources
    - Immune system, anticipatory systems, brain-body-environment-culture, embodiment, epigenetics, culture
  - Mechanism
    - Modularity, control, hierarchy, connectivity, stigmergy, redundancy



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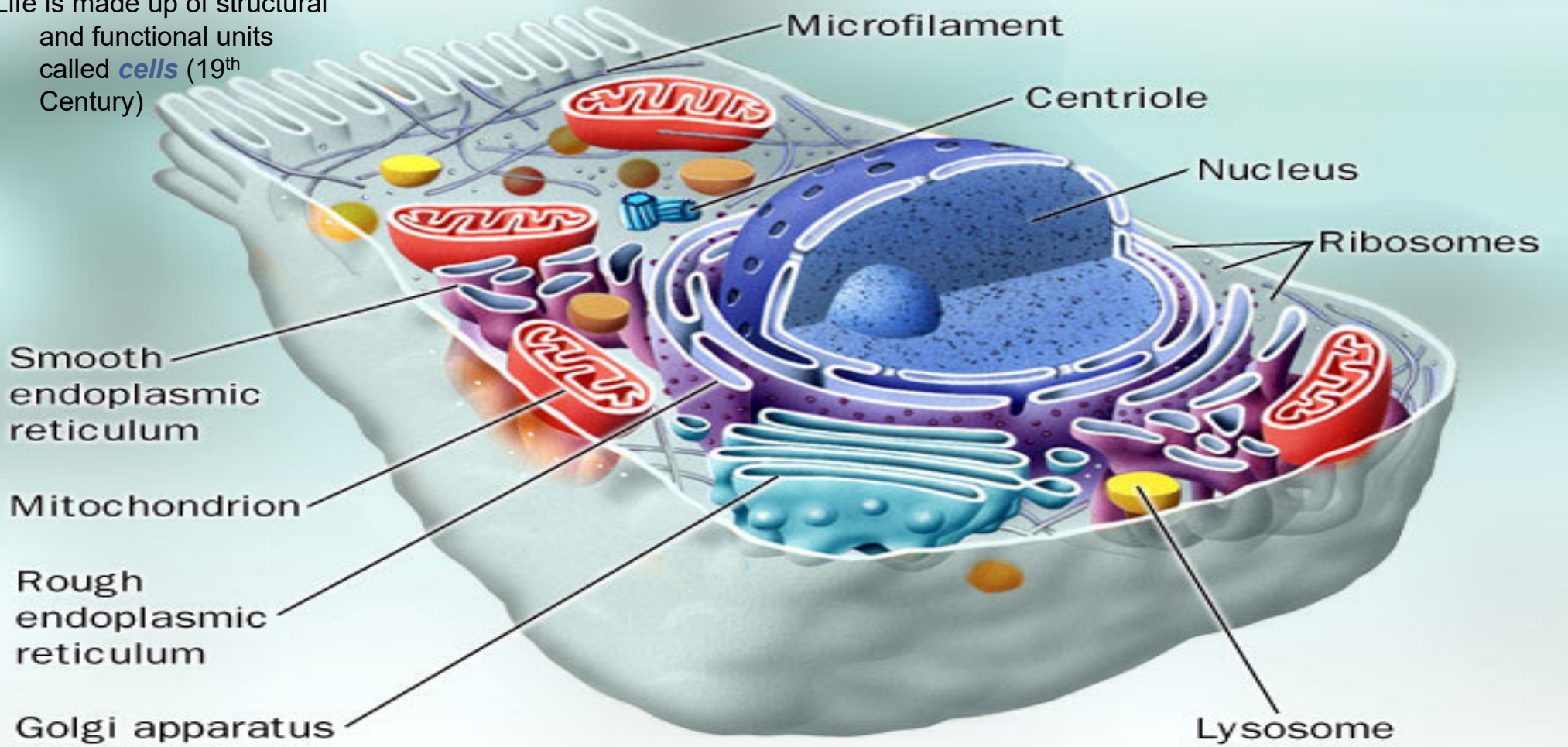
Structure and organelles

Life is made up of structural and functional units called ***cells*** (19th Century)



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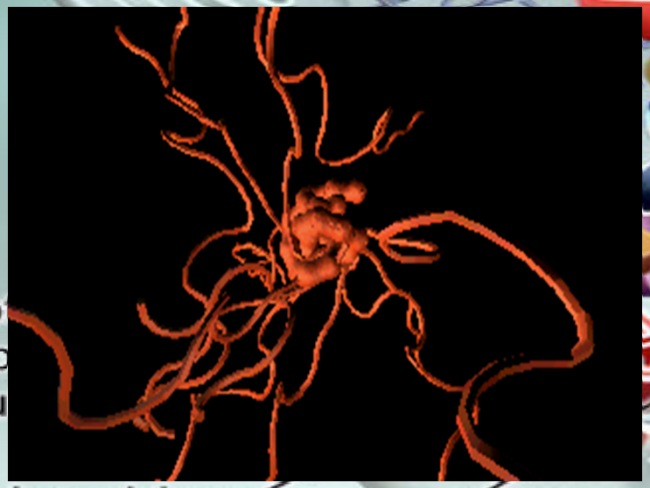
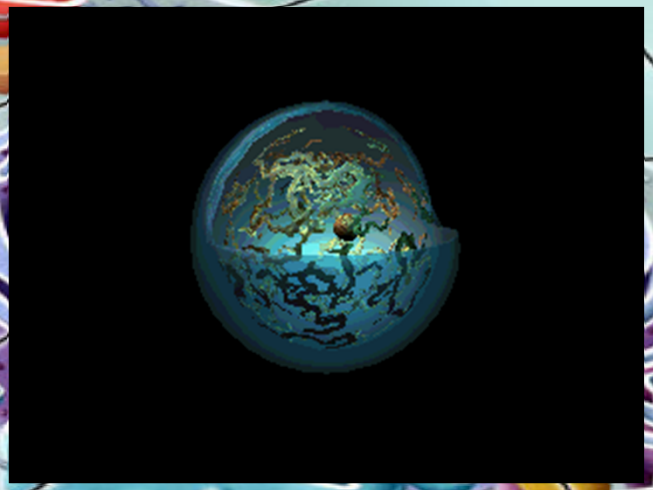
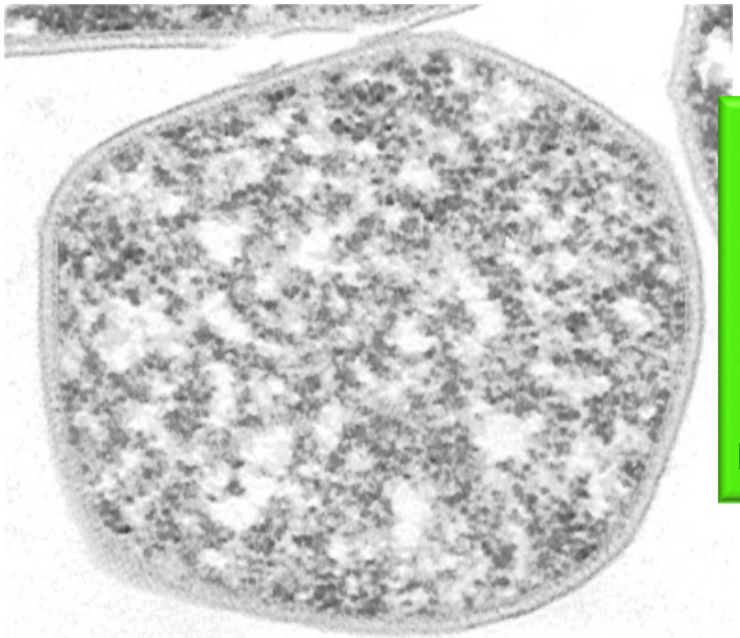
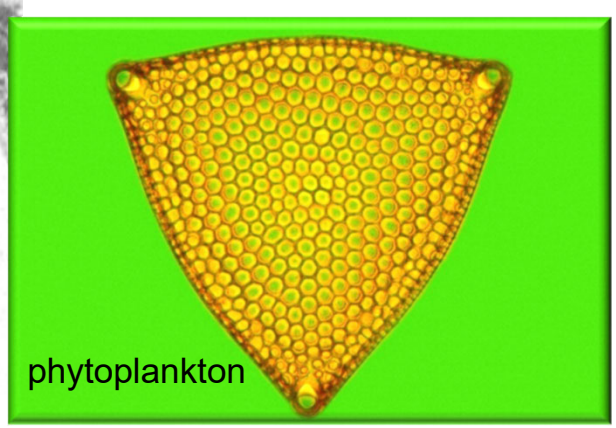
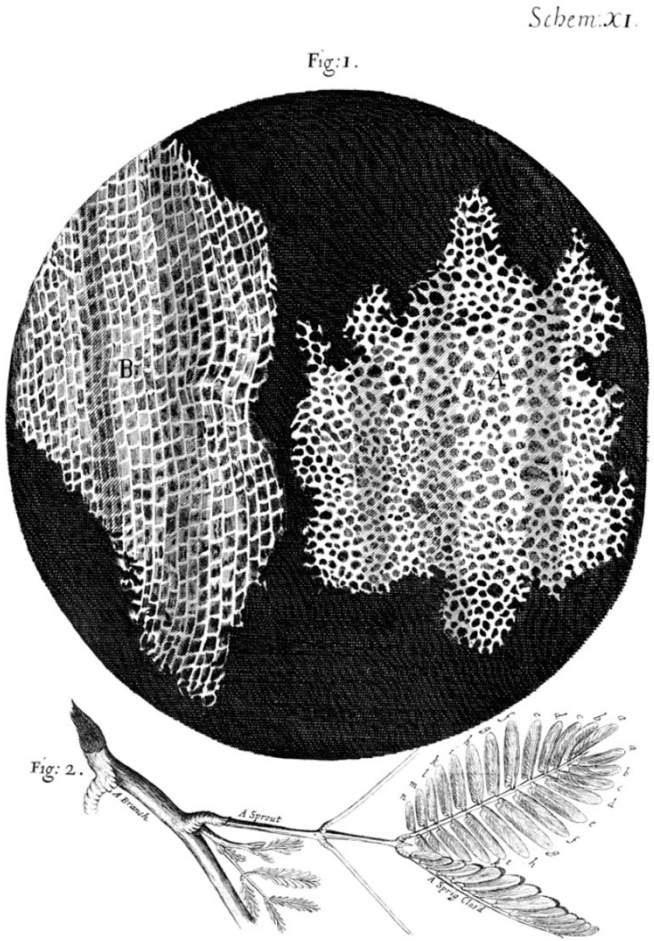




- Cell theory
  - Term coined by Robert Hooke (17th century)
  - Matthias Schleiden and Theodor Schwann (19th century)
    - All organisms are composed of one or more cells.
    - All cells come from preexisting cells.
    - All vital functions of an organism occur within cells.
    - Cells contain life's hereditary ***information***







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- Types of Cells
  - Prokaryotic (3.5 billion years ago)
    - in single-celled and colonial organisms
      - Bacteria and Archaea, asexual reproduction,
  - Eukaryotic cells (aprox. 1.6 - 2.1 billion years ago)
    - Contain organelles with their own membranes
      - Single (amoeba) and multicelular, slime mold, colonial (sponge)
- Organisms
  - Unicellular, colonial, and multicellular
- Chromosome structure
  - Haploid: One copy of each chromosome
    - Fungi, male bees, wasps and ants
  - Diploid: Two copies (homologs) of each chromosome
    - One homolg from each parent

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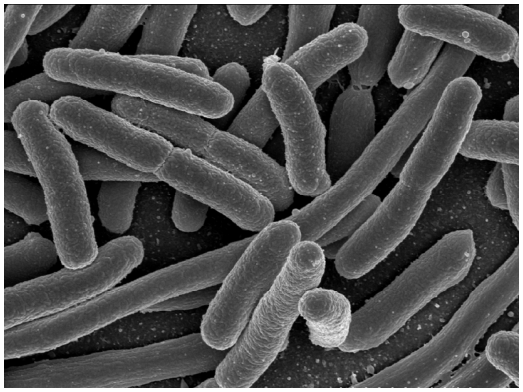

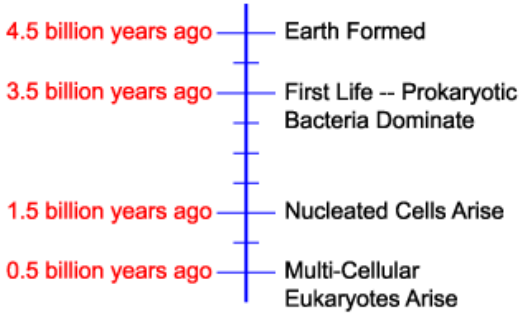

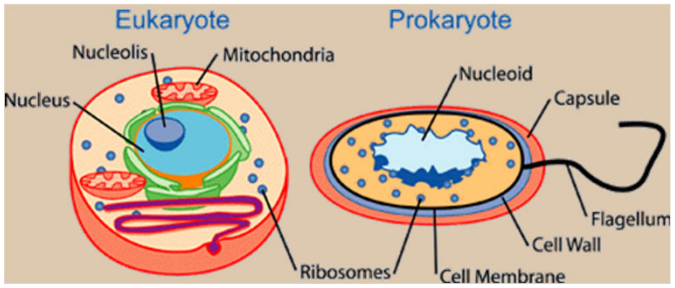

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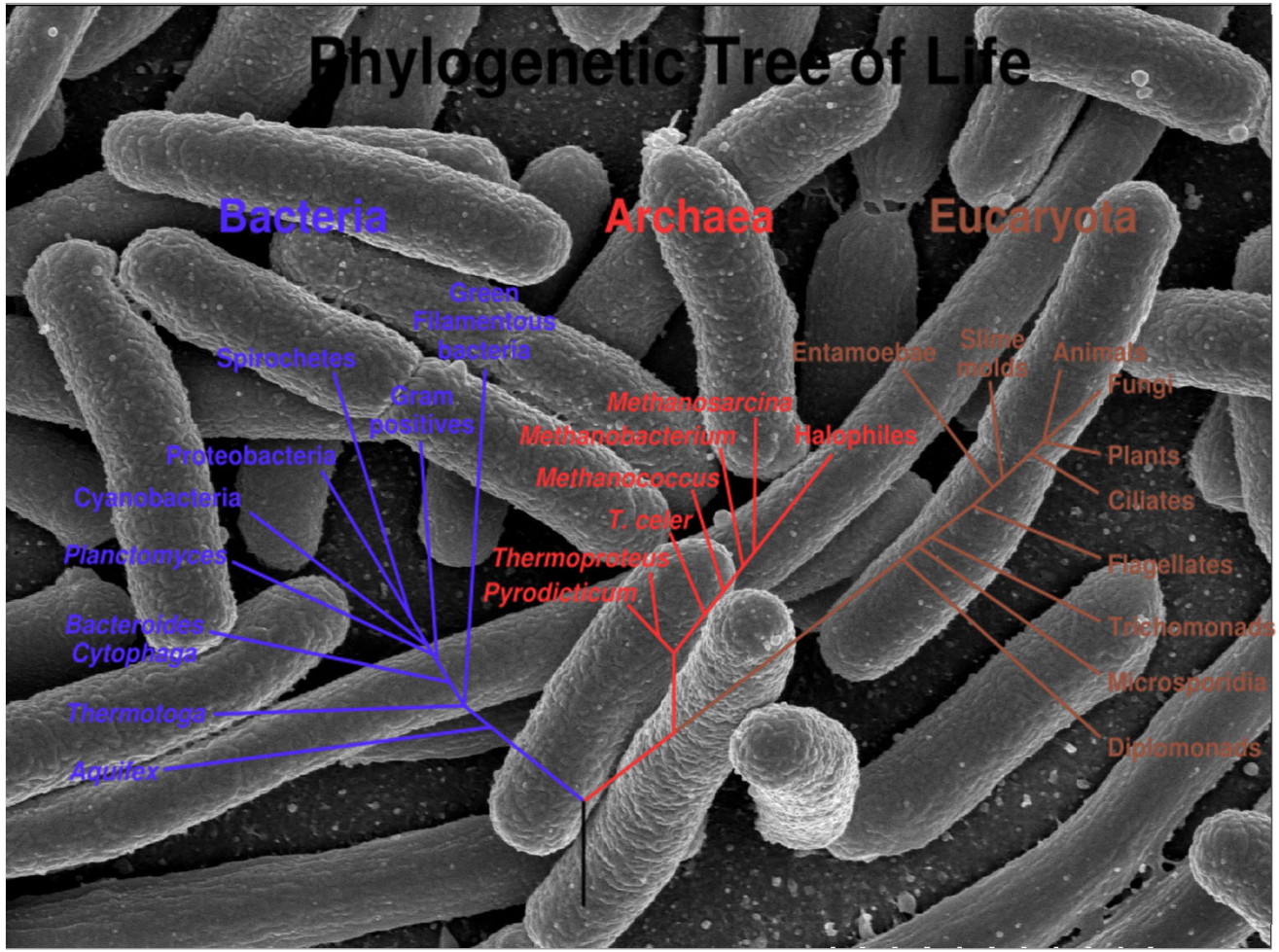

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differences and explanations

- 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 surourvived, 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.

"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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    - Mechanism: mutati
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    - Reached same conclusion as Darwin (with less evidence)
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    - 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 ..."

"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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    - Gradual change in geological landscape
  - Jean-Baptiste Lamarck (XIX)
    - Mechanism: mutation and (acquired) inheritance
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  - 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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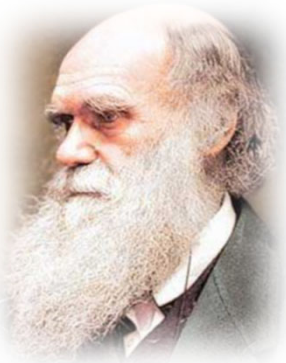
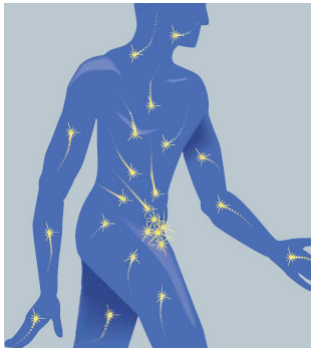
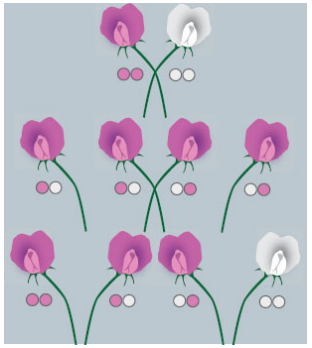
Inheritance mechanism

- 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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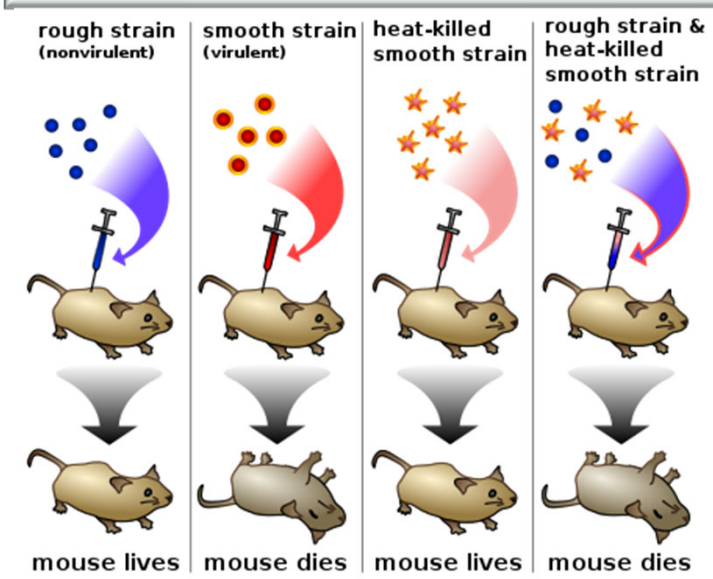
identifying the loci of genetic information

- 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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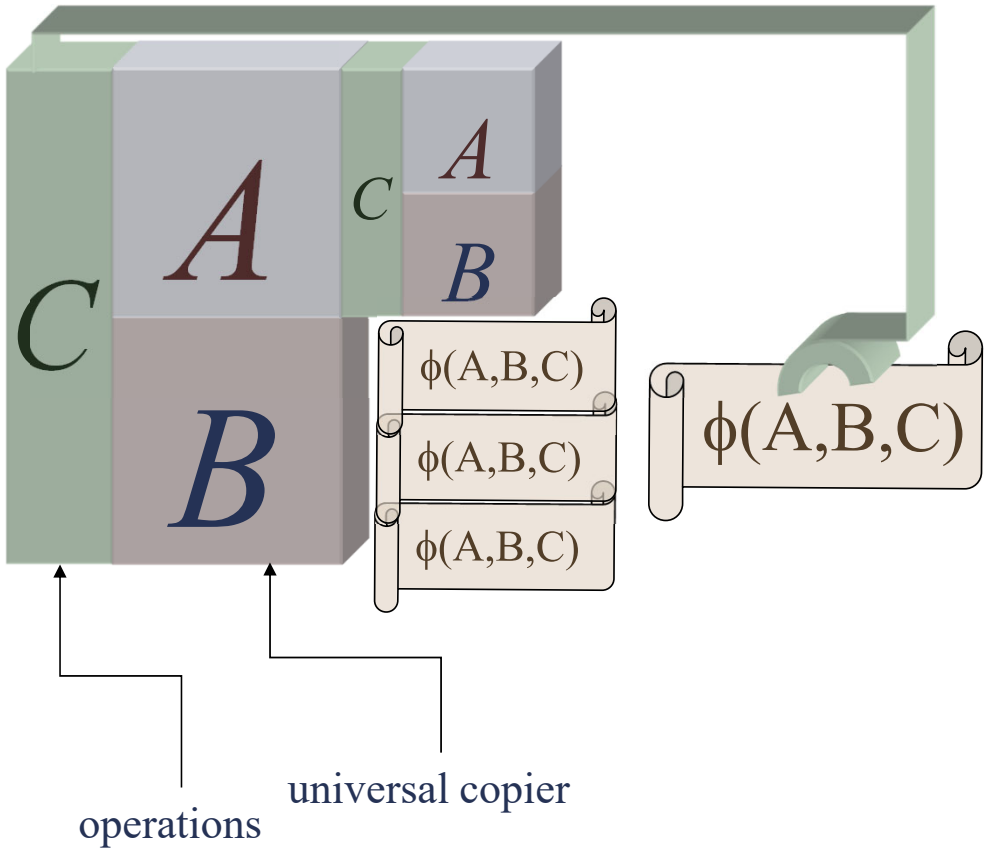
Von Neumann's generalization of Turing's tape

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



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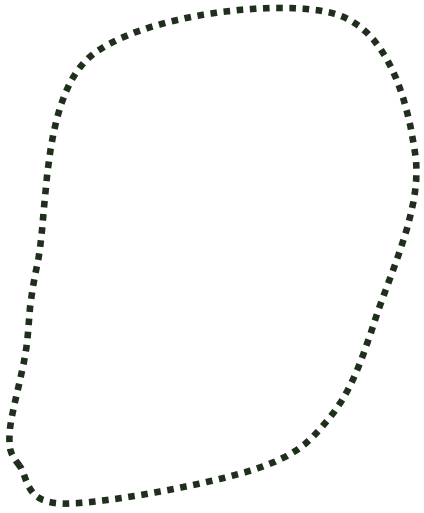
code



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

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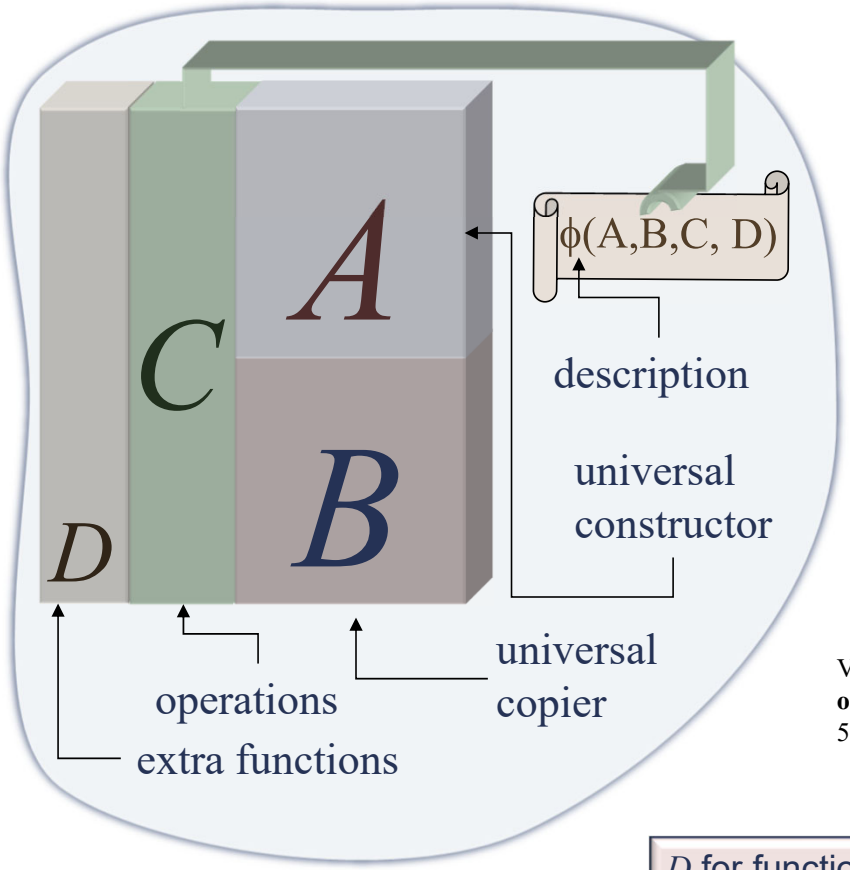
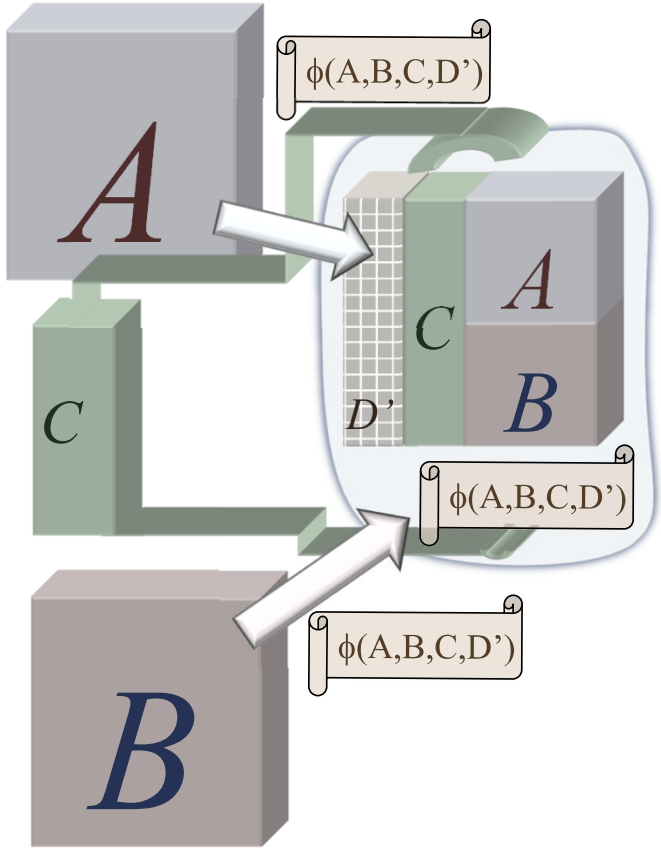
Von Neumann's generalization of Turing's tape

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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readings

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    - **Chapters 1 and 4.**
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  - Chapter 6: Von Neumann and Natural Selection
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