

lecture 4: the information turn in the life sciences

Information Control
General Principles
Computation
networks

Biocomplexity
cybernetics

Computers

Genes

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



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, resources lineraly
 - Charles Lyell (XIX)
 - Gradual change in geological landscape
 - Jean-Baptiste Lamarck (XIX)
 - Mechanism: mutation and (acquired) inheritance
 - Alfred Russel Wallace
 - Reached same conclusion as Darwin (with less evidence)
 - 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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(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 survived, 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.



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 - Al-Jahiz (781 – 869 AD)
 - on the struggle for existence
 - Thomas Hobbes (> 1651)
 - Erasmus Darwin (> 1767)
 - Thomas Malthus (> 1798)
 - Populations grow exponentially
 - Charles Lyell (XIX)
 - Gradual change in geology
 - Jean-Baptiste Lamarck (> 1809)
 - Mechanism: mutation
 - Alfred Russel Wallace (> 1844)
 - Reached same conclusion as Darwin (with less evidence)
 - Charles Darwin (> 1859)
 - Evolution, inevitable

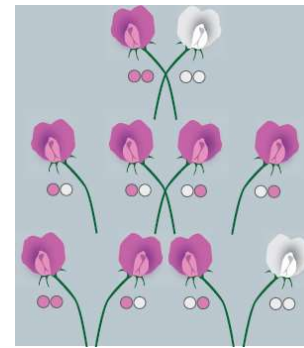


Lucretius and Epicurism (translated by Stephen Greenblatt):
 "... moving randomly through space, like dust motes in a sunbeam, colliding, hooking together, forming complex structures, breaking apart again, in a ceaseless process of creation and destruction. There is no escape from this process. ... There 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 ..."

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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

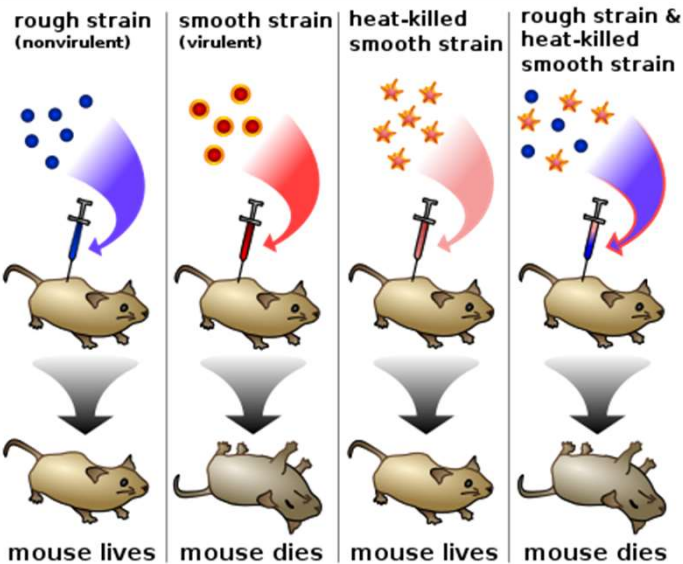
identifying the loci of genetic information

■ 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)



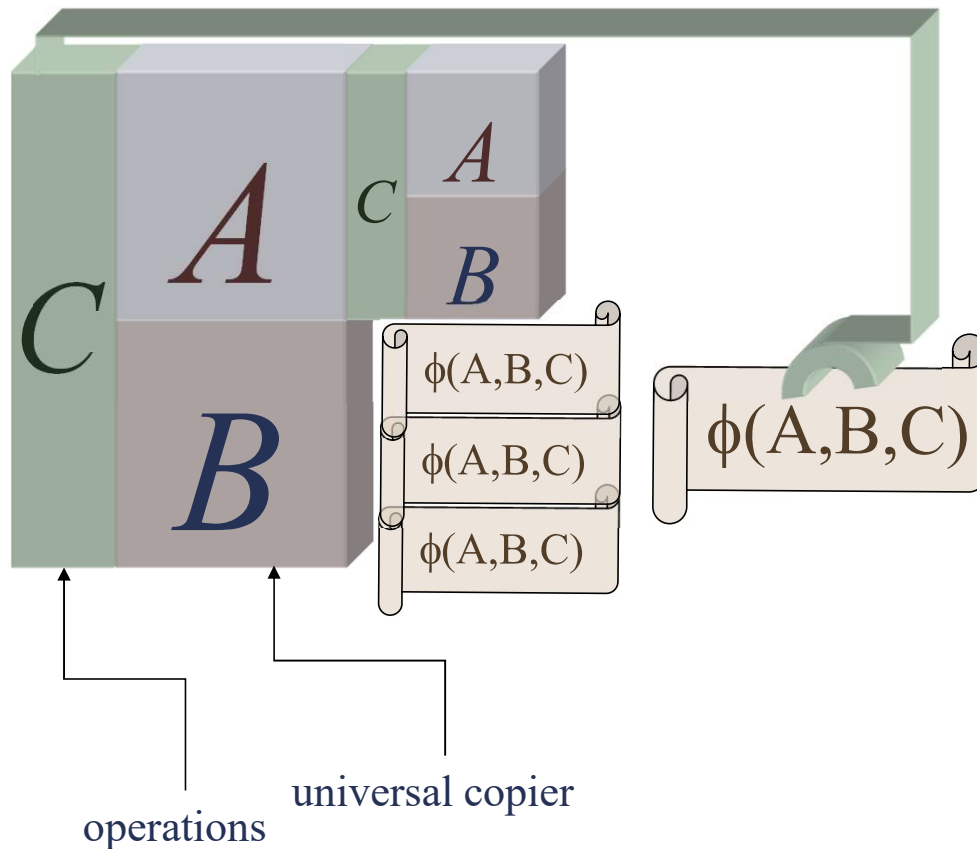
initially not well accepted (No auto-catalysis with DNA)

2 different strains of pneumococcus bacteria



Von Neumann's generalization of Turing's tape

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



Description is copied **separately**

Construction: **interpreted**
(horizontal transmission)

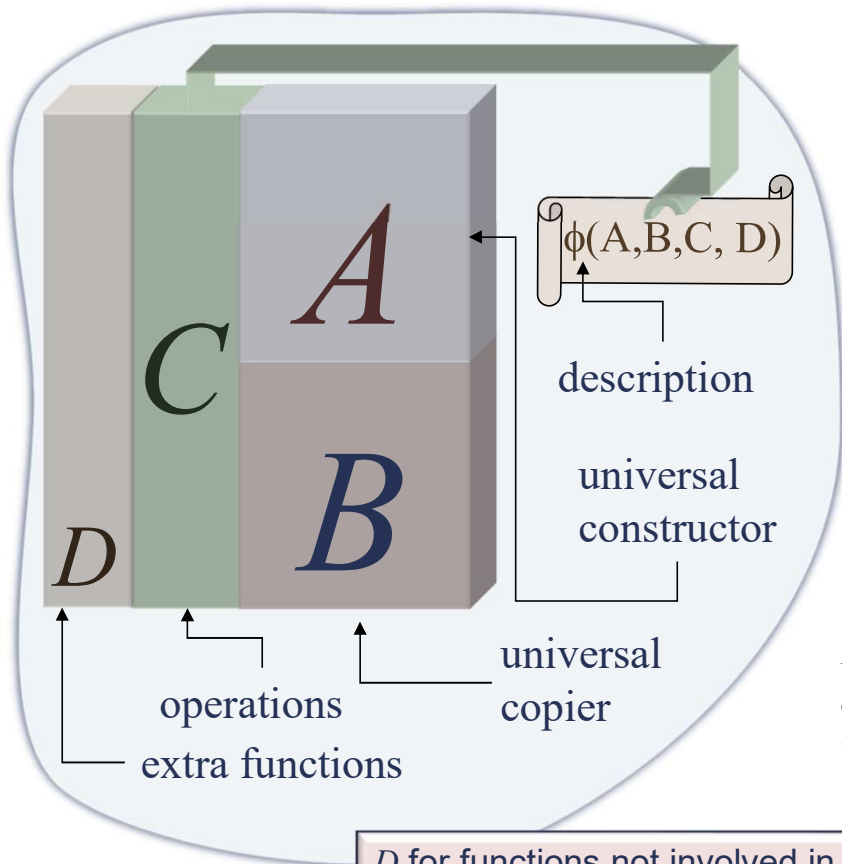
Copy: **uninterpreted**
(vertical Transmission)



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

Von Neumann's generalization of Turing's tape

as a general principle (system) of evolution or **open-ended complexity**



D for functions not involved in reproduction
 Mutations in D can be propagated *vertically*
 Leads to **open-ended evolution**



Von Neumann, J. [1949]. "Theory and organization of complicated automata."
 5 lectures at University of Illinois

