

Astronomy 330



This class (Lecture 18):
Biological Evolution
Michael Hutchinson

Next Class:
Origin of Intelligence
Lauren Yang

HW #7 due Thursday.

Music: *Space Oddity* – David Bowie

Paper Rough Draft



Mars is a planet with an overzealous monkey population (Holt et al. 2000; James & Mann 2006; Walker 2007; Wikipedia: Mars).

– *I expect to see a few refs per page!*

- Holt, W., Smith, E., Rowe, T., & Jones, A. B. 2000, The Astronomical Almanac for the Year 1994, Vol. 2 (2nd ed.; Washington, DC: GPO)
- Smith, A. B., Thomas, J. R., Major, W., & Peebles, P. J. E. 2006, Astrophysics Journal, 450, 12
- Wikipedia: Mars, <http://en.wikipedia.org/wiki/Mars>, Accessed: March 25, 2011, Updated: March 24, 2010

Paper Rough Draft



- Worth 1% of your grade, but really worth more.
- Due on or before April 14th! (Hard date!)
 - Beginning of class, else considered late.
- Should pretty much be the final paper.
- Will be looking for scope, ease-of-read, scientific reasoning, proper citation, and general style.
- 6 to 8 pages double-spaced 12-point font, not including references.

HW 2



- Ilana Strauss
<http://science.howstuffworks.com/science-vs-myth/everyday-myths/time-travel.htm>
- Paige Malec
http://www.alien-ufo-pictures.com/ancient_aliens.html

Presentations



- Michael Hutchinson

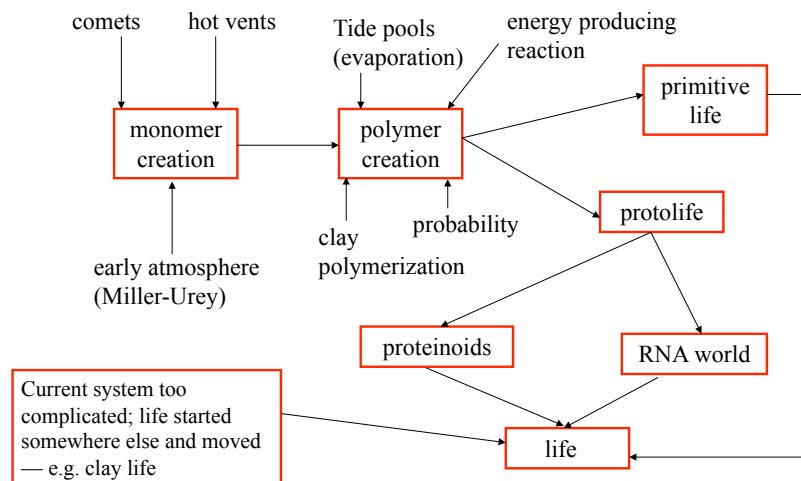
[Space Travel](#)

Outline



- What is f_1 ?
- Two types of cell life: Eukaryotes and Prokaryotes.
- All life can be divided into 3 types:
 - Bacteria
 - Archaea
 - Eukarya
- Genetic diversity of life...

Pathways to Life on Earth



Summing Up



- Existence of organic molecules in space implies that amino acid complexity is common.
- Fact: On Earth polymers arose and evolved to life and did it **quickly**.
- Life it seems evolves naturally through a number of intermediate steps if conditions are right and $f_1 = 1$
- But how often are the conditions right?
- Nonetheless, even with only a vague notion of how life on Earth evolved, it seems that there are possible pathways that take the mysterious polymerization to transition to life steps.
- Still a number of questions:

Summing for f_i



- Is life a natural occurring consequence of the laws of nature?
- Will each planet from n_e outgas and produce water?
- Will it have a reducing atmosphere?
- Will it have the right energy sources to produce life's monomers?
- Monomers from space?
- Will polymerization occur?
- Are tides necessary to wash polymers back into liquid water?
- Will basic life occur? Protolife or life?
- Alternative life?
- Maybe the conditions that produced life on Earth are unusual or maybe common.
- That means f_i can range from small numbers 0.0001 to 1.

Drake Equation

Frank Drake



That's 1.59 life systems/decade



$$N = R_* \times f_p \times n_e \times f_l \times f_i \times f_c \times L$$

of advanced civilizations we can contact in our Galaxy today

Star formation rate

Fraction of stars with planets

of Earthlike planets per system

Fraction on which life arises

Fraction that evolve intelligence

Fraction that communicate

Lifetime of advanced civilizations

15 stars/yr

0.65 systems/star

$1.3 \times 0.1 = 0.13$ planets/system

0.125 life/planet

intel./life

comm./intel.

yrs/comm.



Evolution of Intelligence



- What is intelligence?
- “The ability to model the world, including the organism's own self” is a workable definition.
 - A spectrum of ability
- Crucial development for the full spectrum of intelligence is the diversity of life on Earth.
- Intelligence is not a requirement of life.



<http://www.amanline.net.au/insects/images/site/insect1.jpg>



Evolution of Intelligence



- First, we will examine the diversity of life; the fossil record shows a huge diversity with time.
- Organisms range from bacteria to humans.
- 1.9×10^6 known species
 - Insects account for most (1.0×10^6)
 - Estimated that only 10% are known.
 - Bacteria are hard to classify—only 9000 species so far.



<http://www.amanline.net.au/insects/images/site/insect1.jpg>
http://en.wikipedia.org/wiki/Bacterium#Classification_and_identification



Evolution of Intelligence



- Remember that all of these organisms use nearly identical genetic codes, so life descended from a common ancestor.
- Primary challenge of biology is to explain how life from a single type of organism, diversified so much.
- Evolution is the primary concept.



Life



If we took all the biomass of all the animals, and all the biomass of all the viruses, bacteria, protozoa, and fungi– who weighs more?

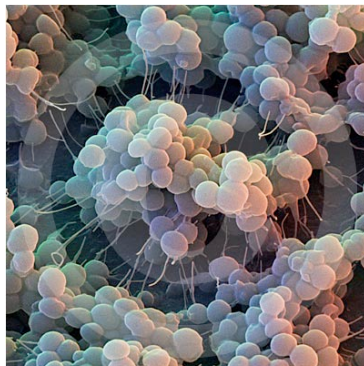
Around 90% of all biomass on the Earth is in the smallest and simplest lifeforms.



Bacteria



- 40 million bacterial cells in a gram of soil
- 1 million bacterial cells in a milliliter of fresh water
- Something like five nonillion (5×10^{30}) bacteria in the world.

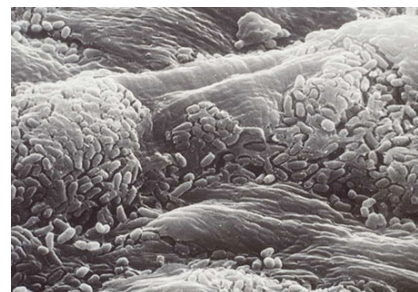


Staph bacteria
http://www.scharfphoto.com/fine_art_prints/archives/000608.php

You or not you?



- This is more non-you cells in your body than you-cells in your body!
 - You are outnumbered 10 to 1!
 - Mostly on your skin and in your digestive track



Bacteria under a toe-nail

<http://news.nationalgeographic.com/news/2007/02/070206-skin-microbes.html>

Question



What is a fair definition of intelligence?

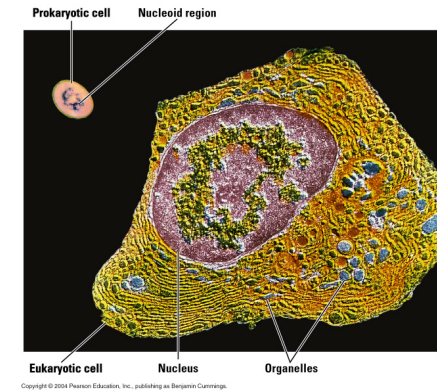
- Able to get an A on the midterm.
- Able to develop a new iphone application
- Leslie
- The ability to model the world, including the organism's own self
- The ability to model the world into food or threat

Classification of Life



1. Prokaryotes

- No cell nucleus– DNA floating around
- Always single-cell creatures like bacterium
- Came first
- Outnumber and outweigh the second class (eukaryotes)

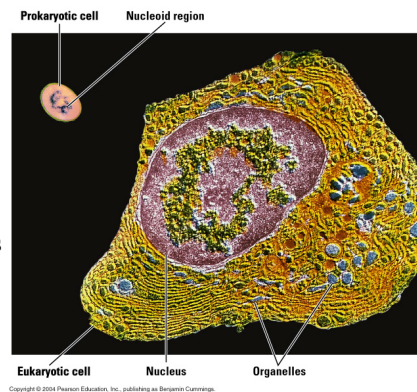


Classification of Life



2. Eukaryotes

- Have a cell nucleus, a membrane to protect the DNA
- Basis of all multi-cell creatures
- Also some single-cell creatures like amoebas.
- DNA arranged into chromosomes in nucleus– 23 pairs for humans.

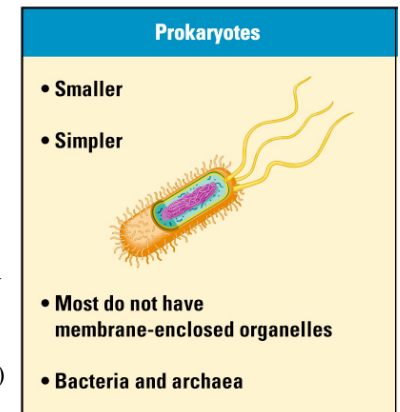


Prokaryotes



Divided into 2 domains:

- Eubacteria or “true” bacteria
- Archaea
 - 20% of the world's biomass.
 - Thought to be the oldest surviving organisms.
 - Often found in harsh environments: hot springs, undersea vents, salty seashores, etc, which were probably more common on the early Earth.
 - Some evidence that ancient organisms were heat-lovers (maybe)

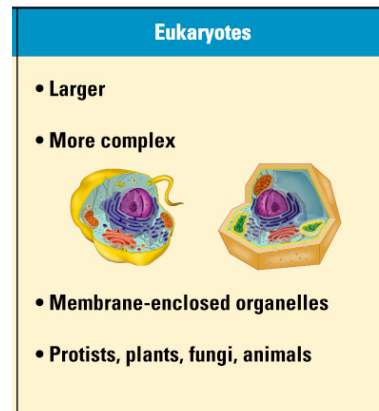


Carl Woese here at UIUC, discovered Archaea scheme.

Eukaryotes

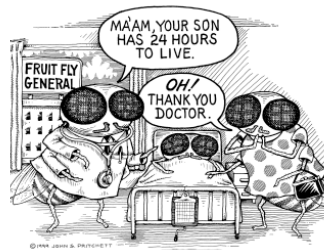


- All animals, plants, and fungi.



Genetic Relations

- This is a major change from the old methods of assigning groups based on outward form and anatomy.
- Instead based on studies of the genetic code.
- Surprise: Human and chimpanzees share about 99% of the same DNA, and about 97% with mice.
- Surprise: 2 species of fruit fly look very much alike, but only share about 25%. Some of this differences is due to “junk” DNA.



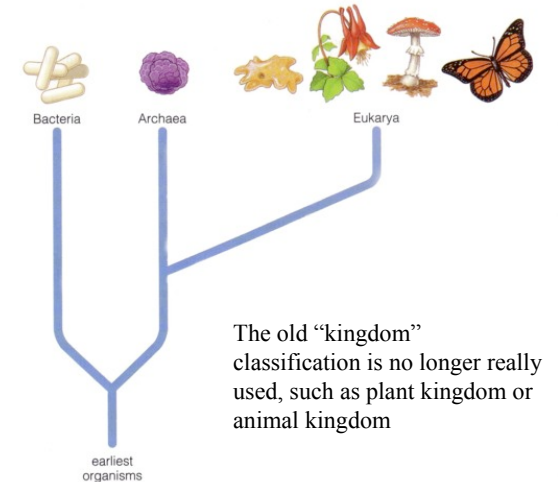
<http://www.uglybug.org/index00.shtml>

<http://www.pritchettcartoons.com/fruitfly.htm>

3 Domains of Life



- Genetically speaking, Archaea and Eukarya are more similar to one another than are Bacteria and Archaea
- Implies that Archaea and Bacteria split and then all Eukarya split from Archaea
- A major implication for the evolution of life on Earth



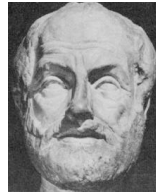
Question



What type of life is more closely related to us?

- Archaea
- Eubacteria
- True Bacteria

Changes in Bio-Systems

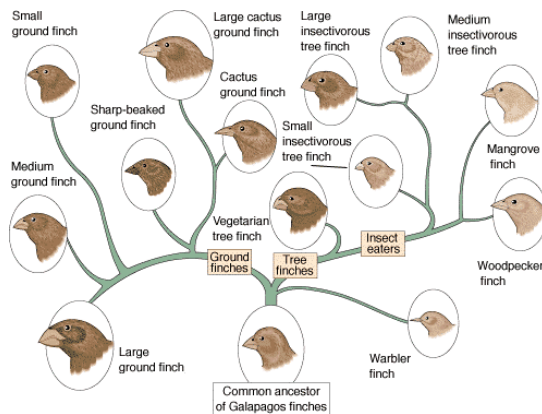


- Today's view: evolution is the most important and unifying property of life.
- Anaximander (c. 610-547 BC): life arose in water and gradually became more complex
- Empedocles (c. 492-432 BC): survival of the fittest (but, *"a good idea stated within an insufficient theoretical frame loses its explanatory power and is forgotten"* by Hans Reichenbach)
- Aristotle (384-322 BC): species are fixed and independent of each other → evolution discarded for 2000 years
- Fossil record: slowly broke down the Aristotelian theory

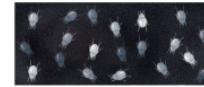
Filling the Niche with Finch



- Other Evidence:
 - Adapted species in the Galápagos Islands, in particular finches
 - Artificial breeding of house/farm animals and vegetables
- DNA is really the mechanism of natural selection, but evolution requires both heredity and environment



For the Species Survival



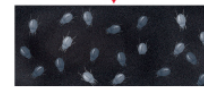
1 Population with varied inherited traits



2 Elimination of individuals with certain traits



3 Reproduction of survivors



4 Increasing frequency of traits that enhance survival and reproductive success

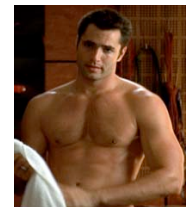
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- Darwin (1809-1882) & Malthus (1766-1834):
 - Populations can grow faster than food sources can support them.
 - Creates a struggle for survival that can wipe out competitors.
 - Individual variations has advantages or disadvantages in the struggle for survival
 - Natural selection can create unequal reproductive success

Mutant Sex



- Mutations from changes in the bases of DNA.
- Usually copying errors, but also radiation–radioactivity, cosmic rays, chemical agents, or UV light.
- About 3 mutations per person per generation.
- Most mutations are neutral, changes in the *junk* DNA.
- Why is sex important to this class?



http://www.mutantx.net/features/press_vw_sexxy.html



Mutant Sex



- Sexual reproduction leads to greater genetic diversity– a difference between prokaryotes and eukaryotes?
- Asexual reproduction does not allow 2 new and beneficial mutations to combine.
- Blackberries have not changed much in 10 millions years, but sexual plants have produced: raspberries, thimbleberries, cloudberries, dewberries, etc.
- Sex is useful in the process, but the mutations are still key.

<http://www.alcasoft.com/arkansas/blackberry.html>