## AST 205. Lecture 20. November 26, 2003

### The Evolution of Advanced/Multicellular Organisms

- Context
- The Three Domains of Life
- The Tree of Life and Biodiversity on Earth
- Evolution as the origin of diversity
- Variations on Darwin's basic idea
- Landmark developments in the evolution of life
- Multicellular life forms
- The rise of intelligence
- Human culture and domination of the planet

## Assignments for week of Dec 1

- A precept debate/discussion in the same format as last week's
- Bring a one page brief to precept outlining your argument/views & be prepared to discuss them.
- TOPIC: Assume the existence of an extrasolar planet similar to Earth with physical conditions equally hospitable to life and of the same age. Will life exist there, and if so, how closely will it resemble terrestrial life?
- Problem Set 8 due in lecture on Dec 3

$$N = f(p)n(e)f(l)f(i)f(c)R_*L$$

- Radial velocity techniques have provided first direct clues about f(p), ≥ 5 -10%
- No direct information on n(e) yet
- $R_*$ measured by astronomical observations
- f(l) depends on biochemistry & **cell biology**
- Depends on evolution towards complexity
- Detailed knowledge of *one & only one* case
- But/thus no first principles general theory

Convergence or Divergence of Cosmic and Biological Evolution? (How similar to here?)

- Large/coarse scales -> convergence
- But on some small/fine scales -> divergence
- Divergence *might* begin on the scale of planetary systems since known extrasolar systems are unlike the Solar System
- However it *might* not occur until far finer levels of detail <- assumption!

## Cell Types:

**Prokaryotic: simple/primitive genes & structure**

**Eukaryotic: complex/advanced genes & structure**

**but**
**Three Domains of Life:**

| **Bacteria, Archaea,** (procarya) | **Eukarya** |
|---|---|
| No nucleus | Nucleus |

## The Three Domains of Life

| Characteristic | Bacteria | Archaea | Eukarya |
|---|---|---|---|
| Nuclear envelope | no | no | yes |
| peptidoglycan wall | no | yes | yes |
| membrane lipids | unbranched | some branched | unbranched |
| translation start | f-methionine | methionine | methionine |
| chromosomes | single circular | single circular | multiple linear |

The 3 domains have roughly equal genomic separations.

## Metabolic Energy System of Life:

**Common energy storage/transport in all life forms:**
**ATP (adenosine triphosphate)**
**ADP (adenosine diphosphate)**

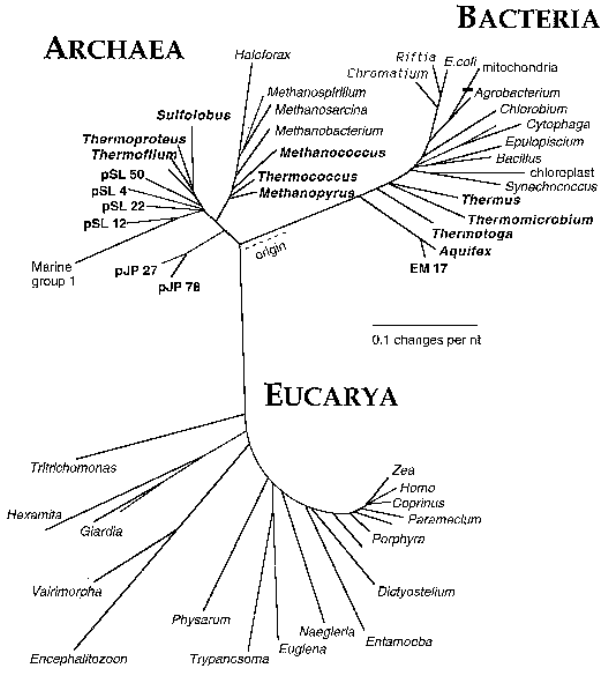
**Diverse ADP -> ATP mechanisms:**

| | | | |
|---|---|---|---|
| **Photoautotroph:** | **CO** | **sunlight** | **plants** |
| **Chemoautotroph:** | **CO** | **inorganics (S, Fe, $NH_3$)** | **extremophiles** |
| **Photoheterotroph:** | **organics** | **sunlight** | **some prokaryotes** |
| **Chemohetertroph:** | **“** | **organics** | **animals, many prokaryotes** |

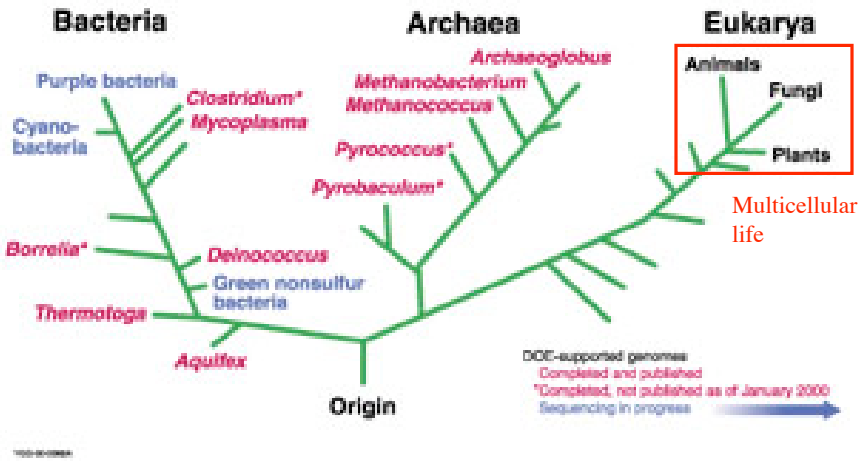
## Tree of Life:

## Map of Genetic Similarities/ differences

Evolution in action!

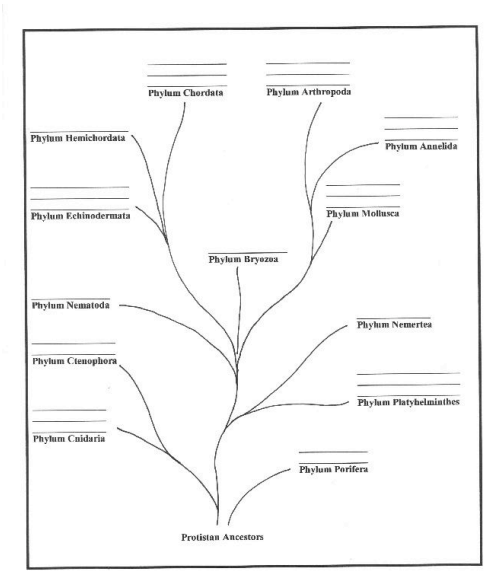


## The Tree of Life from Genomic Sequencing




## Multicellular Life Form Tree

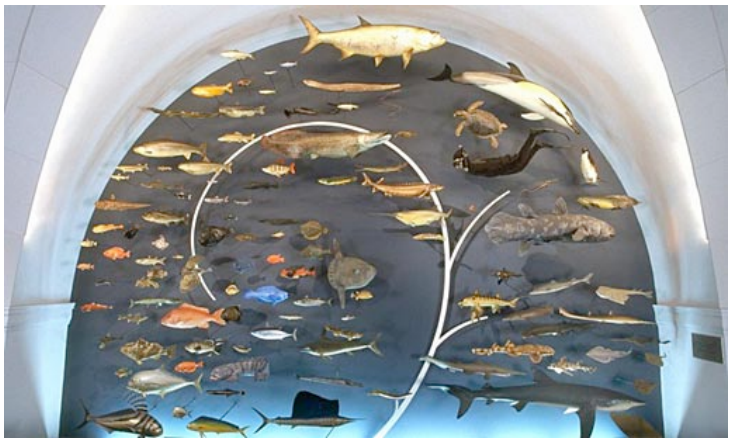
# Metazoa (animal) Tree



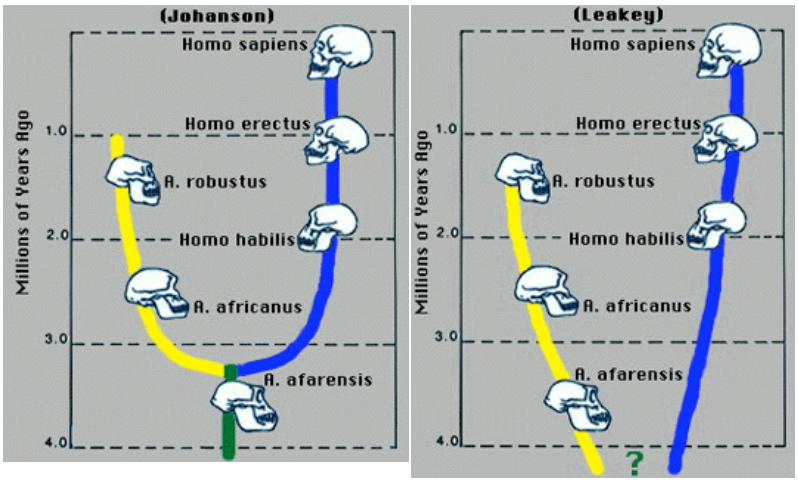

ANIMAL TREE OF LIFE

# Invertebrate Tree

# Marine Vertebrate Tree



# Alternative proposed human evolutionary trees



Darwinian evolution -> bio-diversity/complexity

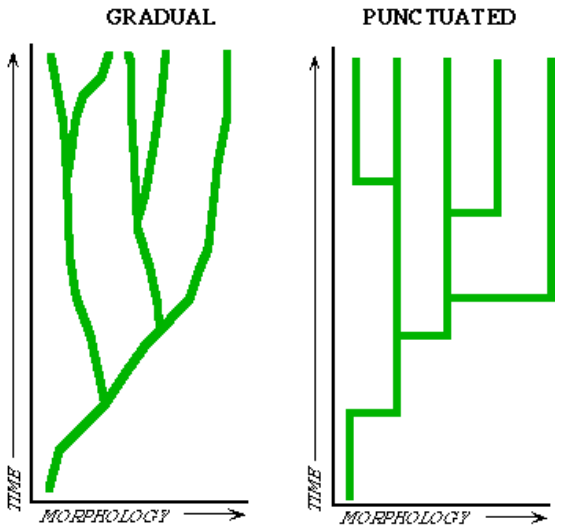
- Random biological variations + reproductive competition -> *gradual* evolution/adaptation
- DNA level: imperfect replication + replication efficiency competition -> genetic evolution
- Logic level: Errors + frequent effective copying -> many copies (almost a tautology)
- Extensive support from evidence in existing life forms and from fossil record

## More on biological evolution

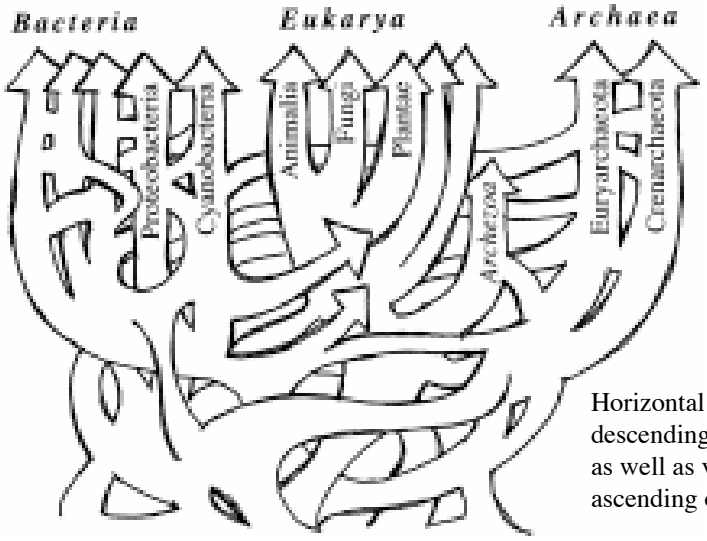
- Not really "survival of the fittest"; more like "survival of the fit enough"
  - Diverse environments -> diverse adaptations
  - Diverse successful strategies -> diverse adaptations in a single environment
- Variations are not purposeful
- Complexity not always better/favored
- Environmental change -> evolutionary pressure -> rapid change

# Darwinian gradual evolution vs punctuated equilibrium model

Evidence shows apparent instances of both types of evolution in the history of life on Earth; both have probably been important.




# Likely complexity of evolution (more like a tangle of vines than a tree!)




Horizontal and descending limbs as well as vertical ascending ones!

## Landmark developments in the evolution of life on Earth

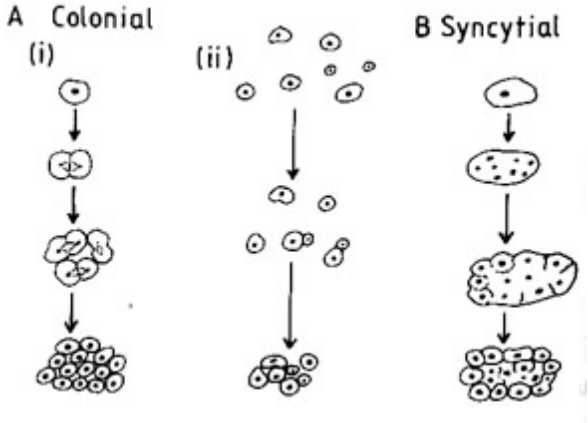
- Chemical building blocks of proteins & nucleic acids
- Self-replicating metabolic biochemical molecules
- Membrane enclosed prokaryotic cells/origin of "life"
- Branching of bacteria and archaea domains
- Oxygenation of the atmosphere and oceans
- Branching of eukarya domain/complex cells
- Multicellular organisms (metazoans & metaphyta)
- Genetic/hormonal control of cell specialization
- Sexual reproduction
- Aging and genetically programmed death

## Landmark developments in the evolution of life on Earth

- Sudden/explosive radiation of plant & animal species
- Development of chorda (central fiber) leads to spine/vertbrates, complex nervous systems & brains
- Land dwelling plant & animal species + flying animals
- Extreme diversification & specialization of life forms
- Mass extinctions -> new cycles of diversification & specialization
- Internal temperature regulation ("warm blooded animals)
- Tool use, abstract language, intelligence, culture
- Global spread/colonization
- Manipulation of environment and biology

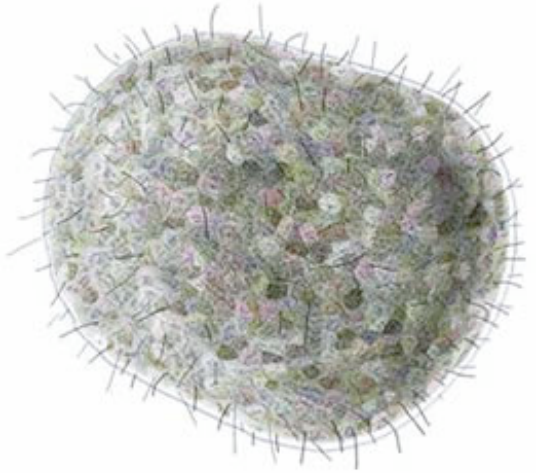
# Development of multicellularity

Bacteria form cooperative groups or colonies & use chemical signals called autoinducers to coordinate their activities, possibly a model for the development of multicellular life forms.




All living metazoans appear to share a single common ancestor!

# Simplest living multicellular metazoan: Placozoan - Trichoplax adhaerens

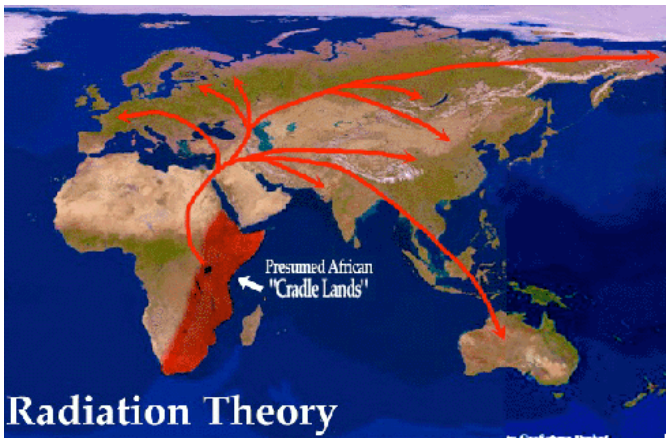


Only 4 types of cells; 1 internal, 2 on top; 1 on bottom

Early animal fossil with backbone & central nervous system

Gradual increase in skull/brain size with time

# Human global radiation




Appears to be confirmed by recent humen genome data.

# Humans “take over” the Earth

- Tools and fire, language
- Art, religion, warfare, global migration
- Hunter-gatherer & herding cultures
- Agricultural cultures -> cities, politics
- Nations/empires
- Technology
- Science
- Global culture
- …

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