

Biological Evolution

Darwinian Evolution and Natural Selection

Major Concepts

1. Linnaean Classification
2. Fossils
3. Radioactive Dating
4. Fossil Record and Genetic Analysis
5. Theory of Evolution
 - Random, Inheritable Variations
 - Natural Selection

Major Concepts, cont.

6. Examples of Evolution
7. Gradualism and Punctuated Equilibrium
8. Mass Extinctions
9. Sex and Evolution
10. Timescales
11. Estimate of f_i

Diversity of Life

More than 1.8×10^6 species known

Mostly Insects!

More species on land than in sea (~10 times)

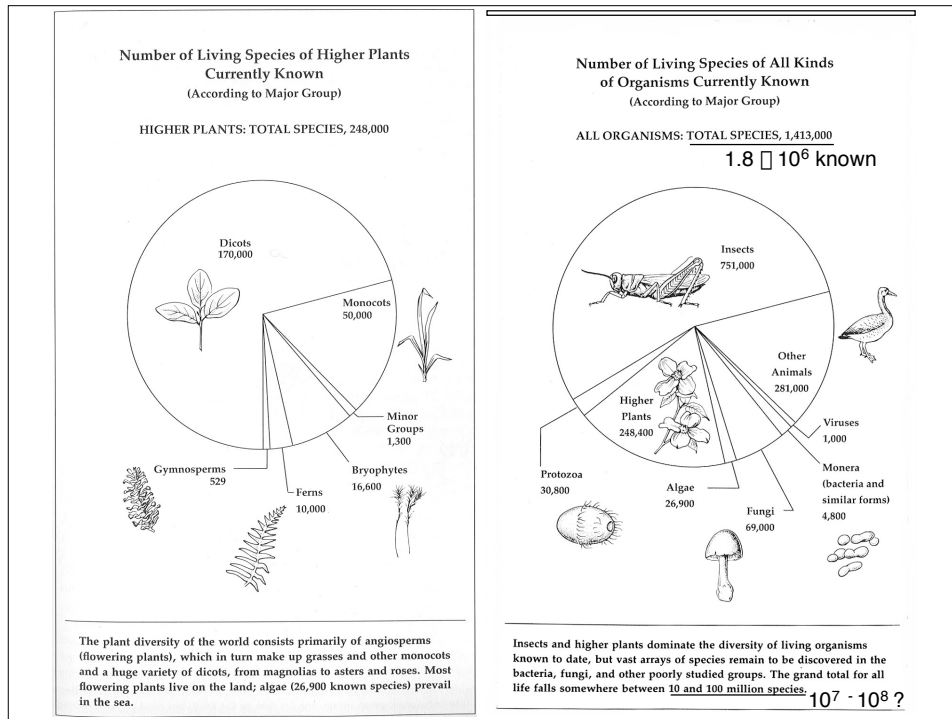
Bacteria & other prokaryotes? (hard to count)

Samples of DNA in nature: > 99% unidentified

Similarity at biochemical level (genetic code)

□ Common ancestor

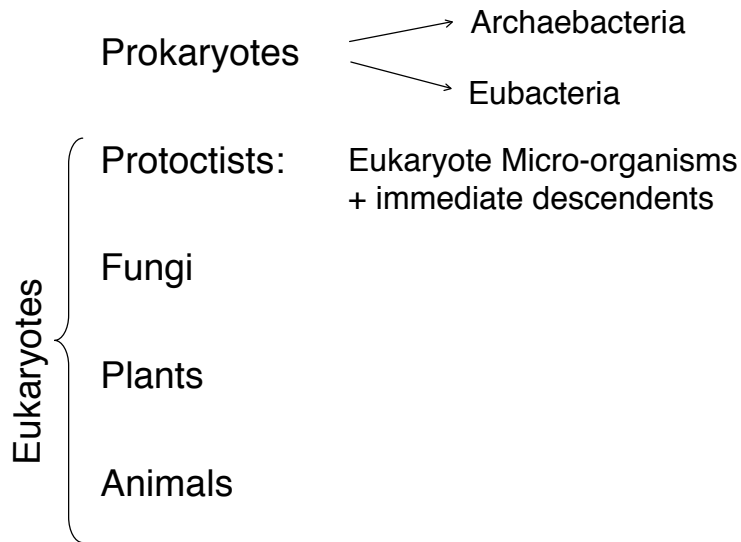
Origin of Diversity?



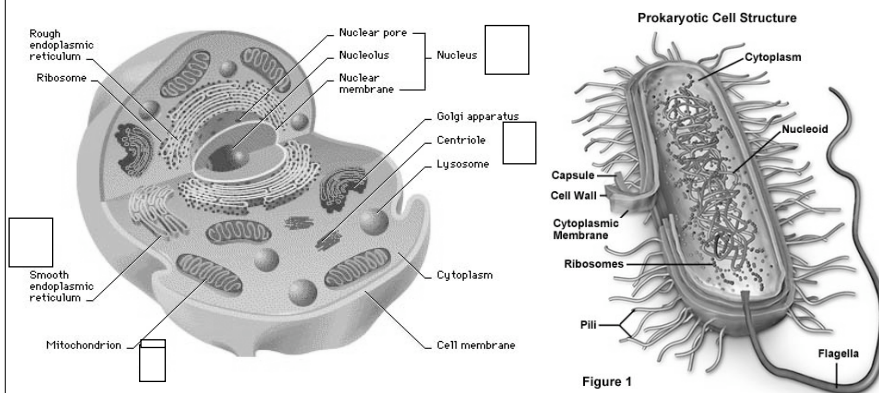
Hierarchical Classification

- Originally by Linnaeus
- Based on outward form
- Now can be checked with genetic analysis
- Lower levels imply closer relationship
- Higher levels are more inclusive
- Until recently, kingdom was highest level
- Traditionally 5 kingdoms

Five Kingdoms



Reminder: Eukaryote and Prokaryotes



First appeared $\sim 1.5 - 2 \times 10^9$ years ago
 complex structure, $\sim 10^4 - 10^5$ genes

First appeared $\sim 3 - 4 \times 10^9$ years ago
 Few thousand genes

Genetic Analysis

Sequencing nucleic acids ———>
New information on genetic distance of species
e.g., chimpanzees and humans share 99% of DNA

Shows that “archaeobacteria” are very different
from other (true) bacteria

————> 3 domains (new highest level)

Archaea	Eubacteria	Eukaryotes (Eukarya)
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Examples of Classification

	Human Beings	Garlic
Domain	Eucarya	Eucarya
Kingdom	Animalia	Plantae
Phylum	Chordata	Angiospermophyta
Class	Mammalia	Monocotyledonheae
Order	Primates	Liliales
Family	Hominidae	Liliaceae
Genus	Homo	Allium
Species	Sapiens	Sativum

The Oldest Life (based on genetic analysis)

More phyla in sea (35) than on land (10)

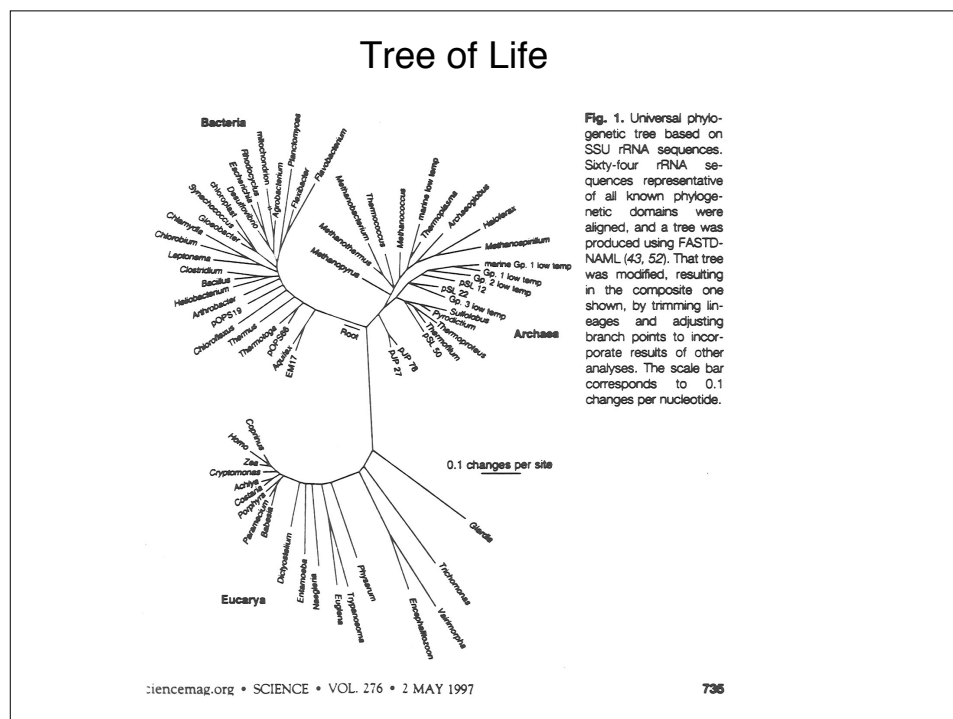
Root of tree of life lies between Archaea & Eubacteria - closer to Archaea

Adapted to heat

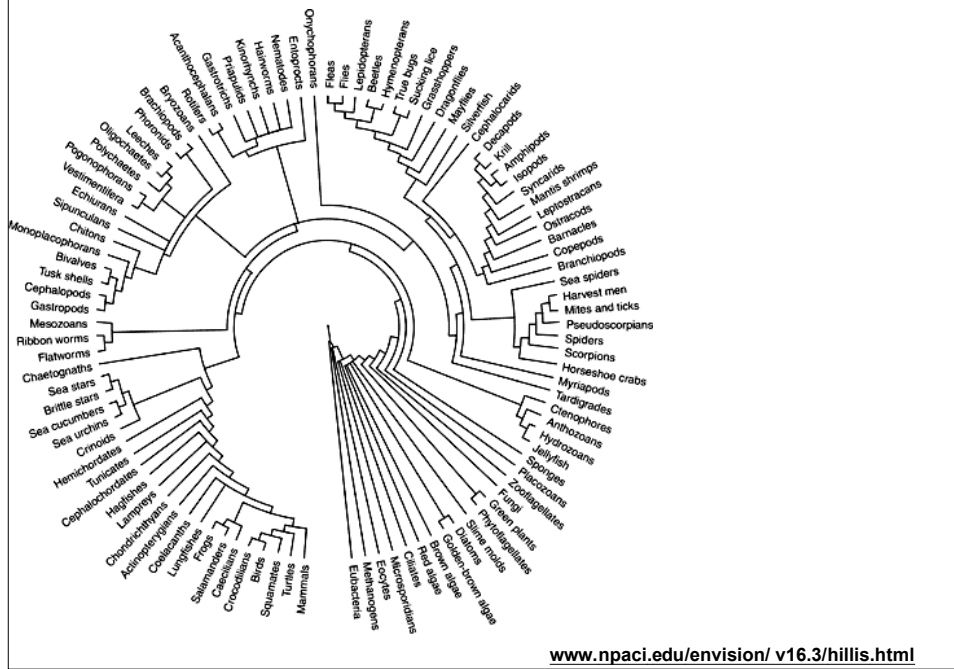
Evidence for life back to 3.8×10^9 yr ago Earth was still being bombarded

Some challenges to oldest fossils; secure to

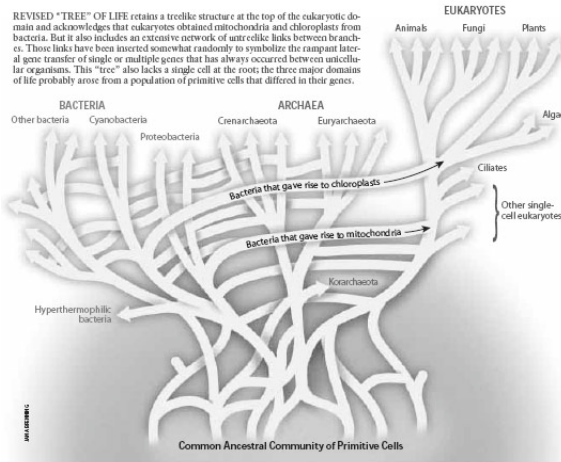
About 2.8×10^9 yr ago



Mandala of Life



Web may be better metaphor than tree



Lateral transfer of genes:
Very common among prokaryotes
Also in eukaryotic cell (organelles)

The Author

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Further Information

THE UNIVERSAL ANCESTOR: Carl Woese in the *Proceedings of the National Academy of Sciences*, Vol. 95, No. 12, pages 6854-6859, June 9, 1998.
YOU ARE WHAT YOU EAT: A GENE TRANSFER RACKET COULD ACCOUNT FOR BACTERIAL GENES IN EUKARYOTIC NUCLEAR GENOMES. W. Ford Doolittle in *Trends in Genetics*, Vol. 14, No. 8, pages 307-311, August 1998.
PHYLOGENETIC CLASSIFICATION AND THE UNIVERSAL TREE. W. Ford Doolittle in *Science*, Vol. 284, pages 2124-2129, June 25, 1999.

Fossils

Hard parts: bones, teeth, ...

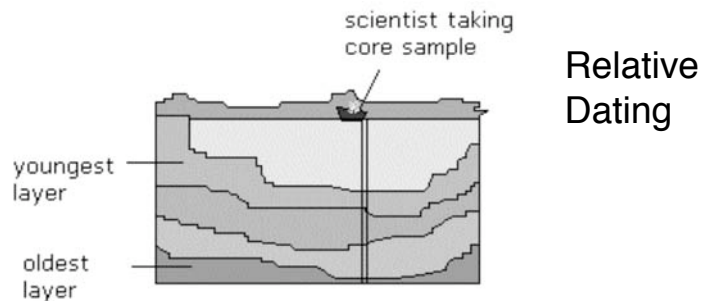
petrification → minerals

Molds → petrification (preserves soft parts)

Bacteria - stromatolites, microfossils

Isotopic ratios - characteristic of life

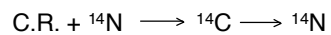
Dating Fossils



Layers increase in age from top to bottom.

Radioactive decay → absolute dates

e.g. ^{14}C produced by cosmic rays



Works to $\lesssim 60,000$ yr

1/2 in 5,730 yr

For older fossils, get date of layers above & below from volcanos -

e.g. $^{40}\text{K} \longrightarrow {}^{40}\text{Ar}$, ...

Decay of Radioactive Atoms

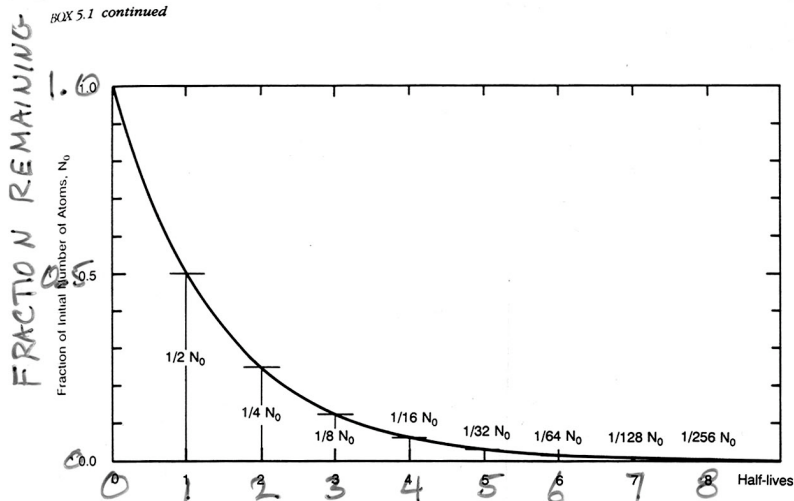


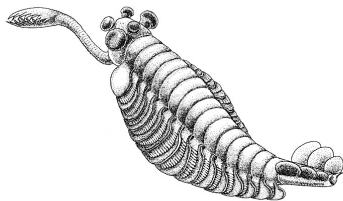
Figure A. Decay of radioactive atoms. At time zero, there is a given number of radioactive atoms, N_0 . The atoms decay into their offspring products at rates such that after one half-life, half the N_0 atoms remain; after two half-lives one-quarter of the N_0 atoms remain; and so forth.

OF HALF-LIVES



Fossils from Burgess Shale ~ 530 Myr Ago

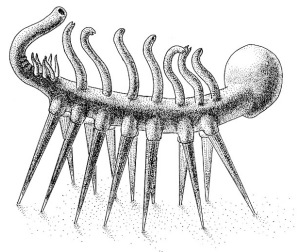
126 | WONDERFUL LIFE (S.J. Gould)



3.21. *Opabinia*, showing the frontal nozzle with terminal claw, five eyes on the head, body sections with gills on top, and the tail piece in three segments. Drawn by Marianne Collins.

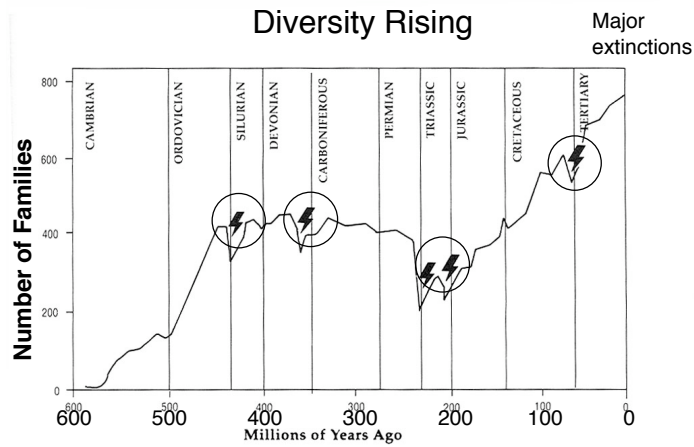
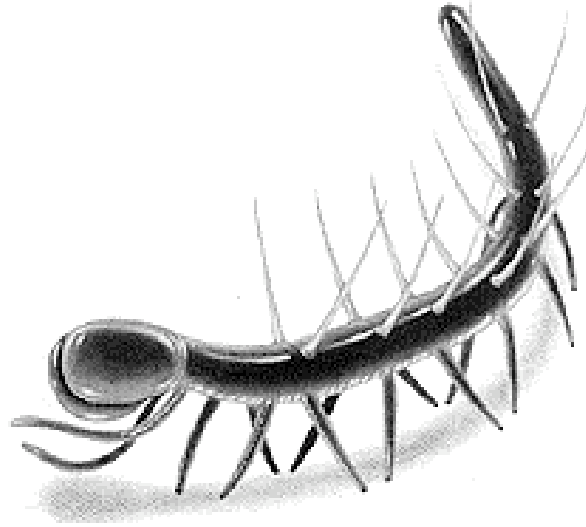
Many basic body plans (phyla) tried out in Cambrian; some did not survive; never attempted again.

154 | WONDERFUL LIFE

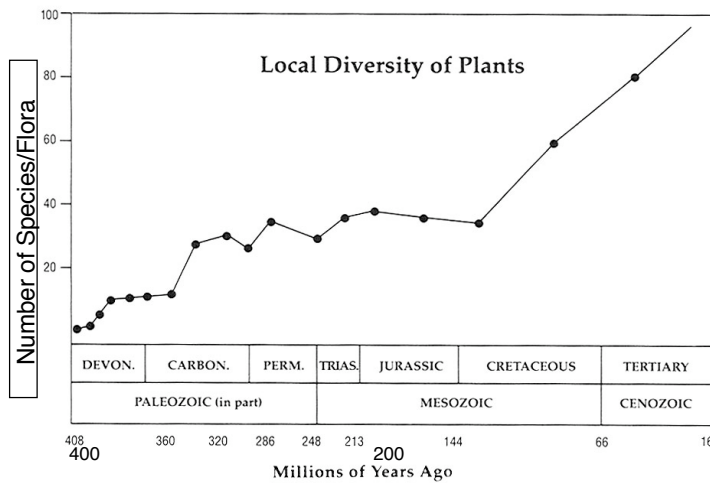


3.34. *Hallucigenia*, supported by its seven pairs of struts, stands on the sea floor. Drawn by Marianne Collins.

Correct Version of Hallucigenia



Biological diversity has increased slowly over geological time, with occasional setbacks through mass global extinctions. There have been five such extinctions so far, indicated here by lightning flashes. The data given are for families (groups of related species) of marine organisms. A sixth major decline is now underway as a result of human activity.



The average number of plant species found in local floras has risen steadily since the invasion of the land by plants 400 million years ago. The increase reflects a growing complexity in terrestrial ecosystems around the world.

Summary of Fossil Record

- Simple organisms first, more complex later
- Prokaryotes, eukaryotes, multi-cellular, ...
- Recent (last 150 Myr) rise in diversity caused by flowering plants and insect hosts
- Not deterministic “progress”
- Some organisms become more complex
- Many stay about the same
- Increase in diversity and a “left wall of minimal complexity”

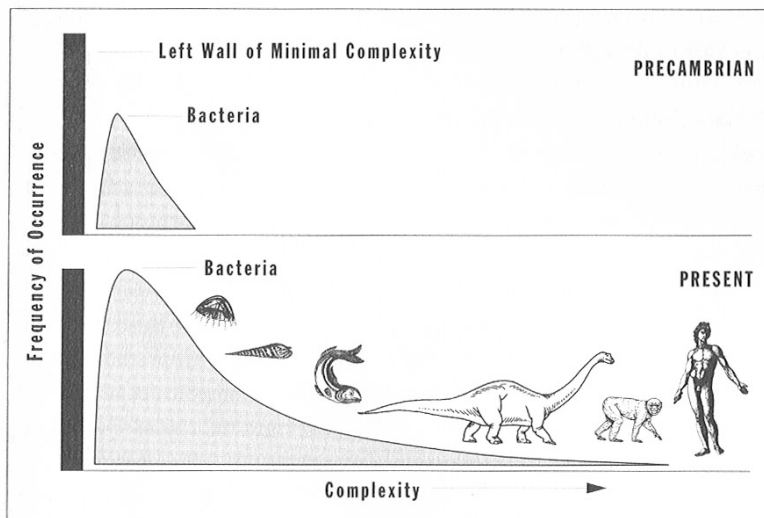


FIGURE 29

The frequency distribution for life's complexity becomes increasingly right skewed through time, but the bacterial mode never alters.

S. J. Gould

Theory of Evolution

Developed independently by Darwin and Wallace
Based on earlier ideas, but key feature was the role
of selection

Two Key ingredients:

1. Random, inheritable variations
2. Natural Selection (competition for scarce resources produces "survival of the fittest")

1. Mutation ultimate source of variation
(but sexual reproduction produces great variation without many mutations)

2. Selection

Organism level → species gradually evolves

Species level → (speciation + extinction)

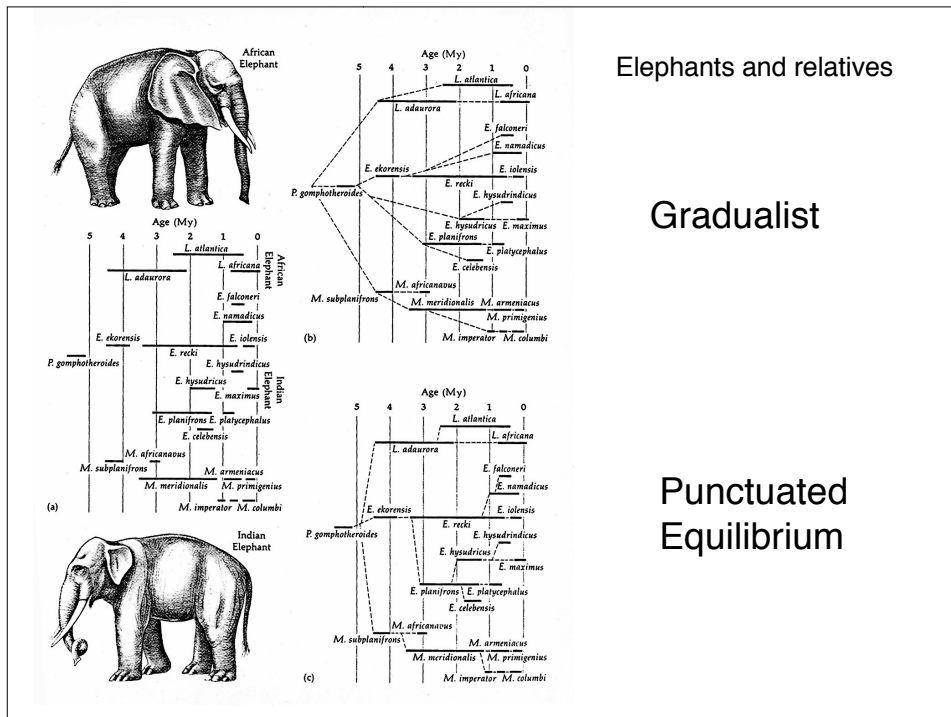
“Life” evolves

Topics:

Gradualism vs. Punctuated Equilibrium

Speciation: the role of geographical isolation

Ecological niches

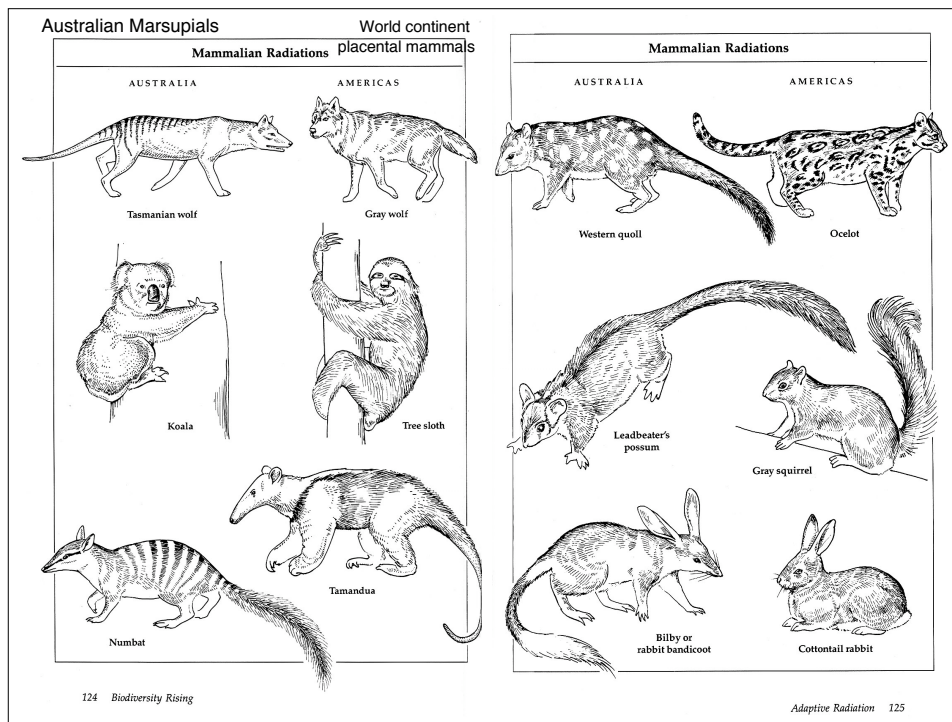


Speciation

- Darwin's "Origin of Species" did not explain
- Modern synthesis – Ernst Mayr
 - Geographic isolation
 - Islands
 - Mountaintops
 - Genetic drift
 - Varieties no longer interfertile: new species
- Adapting to different, but close environments
 - Hybrids are not well adapted

Ecological Niches

- "Niche" (a way of making a living)
 - Different food source
 - Different microclimate
 - Species diversity high when environment is complex
- Convergence
 - With long geographic isolation
 - Find similar types of animals
 - From very different evolutionary sources



Statements about Evolution

True or False (& Why?)

1. People who move to the south and adapt to hot weather are an example of evolution
2. Almost all species that ever lived are now extinct
3. Extinction represents a failure of evolution
4. A natural catastrophe, like an asteroid impact or an ice age, is needed to cause natural selection
5. Evolution always selects more complex, intelligent organisms for survival
6. Major diversification of surviving groups usually follows a mass extinction

Purpose in Evolution?

“That our earth is the only planet in the stellar universe where the development of organized and intelligent life exists, that our sun is in all probability the center of the whole material universe, and that the supreme end and purpose of this vast universe was the production and development on our earth, of the living soul in the perishable body of man, are the conclusions which Dr. Alfred Russel Wallace sets forth in an article in the current number of the ‘Fortnightly Review’.”

- **From the International Herald Tribune, March 5, 1903**

Evolution: Theory or Fact?

- Facts
 - fossils and ages are facts
 - Order of origins of groups are facts
 - Genetic relationships are facts
- Theory (explanation of facts)
 - Variations and selection
 - Theory makes predictions
 - Predictions are checked
 - Theory is refined