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 $1.8 \times 10^6$ 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

Prokaryotes
  Archaebacteria
  Eubacteria

Protoctists:
  Eukaryote Micro-organisms
  + immediate descendents

Eukaryotes
  Fungi
  Plants
  Animals

Reminder: Eukaryote and Prokaryotes

First appeared ~ 1.5 - 2 x 10^9 years ago
complex structure, ~ 10^4 - 10^5 genes

First appeared ~ 3 - 4 x 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)

Examples of Classification

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<thead>
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<th>Domain</th>
<th>Human Beings</th>
<th>Garlic</th>
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<tr>
<td>Kingdom</td>
<td>Eucarya</td>
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<td></td>
<td>Sapiens</td>
<td>Sativum</td>
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</table>
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 $3.8 \times 10^9$ yr ago Earth was still being bombarded
Some challenges to oldest fossils; secure to
About $2.8 \times 10^9$ yr ago
Web may be better metaphor than tree

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

Hard parts: bones, teeth, …
  petrification ——> minerals
Molds ——> petrification (preserves soft parts)
Bacteria - stromatolites, microfossils
Isotopic ratios - characteristic of life

Dating Fossils

Relative Dating

Layers increase in age from top to bottom.
Radioactive decay ——> absolute dates
e.g. $^{14}$C produced by cosmic rays
\[ \text{C.R.} + ^{14}\text{N} \rightarrow ^{14}\text{C} \rightarrow ^{14}\text{N} \]
Works to $\leq$ 60,000 yr  
1/2 in 5,730 yr
For older fossils, get date of layers above & below from volcanos -
e.g. $^{40}$K ——> $^{40}$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.
Fossils from Burgess Shale ~ 530 Myr Ago

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

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.
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

**Elephants and relatives**

Gradualist

Punctuated Equilibrium
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