Bio 2
Plant and Animal Biology
Evolution

Evolution as the explanation for life’s unity and diversity
Darwinian Revolution

- Two main Points
  - Descent with Modification
  - Natural Selection
Biological Species

- A group of populations whose members have the potential to interbreed in nature and produce viable, fertile offspring
Ring Species

1. The original population started in the north and migrated southward.

2. The population split to the east and west of the Central Valley. Then two populations began to evolve independently.

3. Evolution of eastern population.

4. Evolution of western population.

5. The east and west populations came back together in Southern California, but could no longer interbreed (or produced infertile hybrid offspring).
Allopatric Speciation
Evidence of Allopatric Speciation
Allopatric Speciation

- Mantellinae (Madagascar only): 100 species
- Rhacophorinae (India/Southeast Asia): 310 species
- Other Indian/Southeast Asian frogs

Timeline:
1. 88 mya
2. 65 mya
3. 56 mya

Maps show the migration and speciation process over millions of years ago (mya).
Allopatric Speciation

- 1. Small Population
- 2. Isolation
- 3. Different Environmental Conditions
Sympatric Speciation

- Autopolyploidy
  - Examples:
    - Maidenhair Fern
    - Pseudepidalea pewzowi
Sympatric Speciation

- Allopolyploidy
  - Examples:
    - *Triticum aestivum*
    - Gray Treefrog
Hybrid Zone

Yellow-bellied toad, *Bombina variegata*

Fire-bellied toad, *Bombina bombina*

[Graph showing allele frequency vs. distance from hybrid zone center (km)]

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Hybrid Zone

- Isolated population diverges
- Gene flow
- Population (five individuals are shown)
- Barrier to gene flow
- Hybrid zone
- Hybrid

Possible outcomes:
- Reinforcement
- Fusion
- Stability
Hybrid Zone

- Over time
  - Reinforcement
    - Strengthening of reproductive barriers
  - Fusion
    - Weakening of reproductive barriers
  - Stability
    - Continued production of hybrid individuals
Macroevolution: Evolutionary Change on a Grand Scale

Punctuated Equilibrium

Gradualism

Time
Gradualism

- Also called “Neodarwinism”
- Small changes over time
- Supporter: Ernst Mayr
Punctuated Equilibrium

- Supporters: Niles Eldredge & Stephen J. Gould
- Speciation occurs in episodic events – large periods of time with little change and short periods of time with large changes
Macroevolution through many Speciation Events

(a) Patch of pigmented cells
(b) Eyecup
(c) Pinhole camera-type eye
(d) Eye with primitive lens
(e) Complex camera-type eye
Origin of Evolutionary Novelty

Most novelties are modified versions of older structures

– Exaptation - preadaptation
Macroevolution through Major Changes in the Sequences and Regulation of Developmental Genes

- Effects of Developmental Genes
  - Changes in Rate and Timing
  - Changes in Spatial Patterns
- The Evolution of Development
  - Changes in Genes
  - Changes in Gene Regulation
Evolution of Genes that control Development

- Forms change
- Natural Selection is the force driving change
- How did it occur?

*Endless Forms Most Beautiful* by Sean B. Carroll

*The New Science of Evo Devo*
Effects of Developmental Genes

- “Evo-devo” – Evolutionary Biology and Developmental Biology
Evolution of Genes that control Development

- “Evo-devo” - Tool-kit of master genes
Changes in Rate and Timing

Heterochrony - evolutionary change in the timing or rate of development
Changes in Rate and Timing

Allometric Growth
the variation in the relative rates of growth of various parts of the body
Changes in Rate and Timing

Paedeomorphosis - retention of juvenile features in an adult
Changes in Rate and Timing

Paedeogenesis - sexual maturity in a larval form
Changes in Spatial Pattern

Homeotic Genes (Hox Genes) position information

1. Hypothetical vertebrate ancestor (invertebrate) with a single Hox cluster
2. First Hox duplication
3. Hypothetical early vertebrates (jawless) with two Hox clusters
4. Second Hox duplication
5. Vertebrates (with jaws) with four Hox clusters
Changes in Spatial Pattern

(d) Leech (annelid)
Changes in Spatial Pattern

- Homeobox - DNA, around 180 base pairs long, found within genes that are involved in the regulation of patterns of anatomical development.
Changes in Genes

- Ex. Origin of the insect body plan
  - Hox gene 7
  - Go from multiple legs to only 6
Changes in Gene Regulation

- Ex. Stickleback fish spines
  - Missing in lake fish (no predators, lack of Ca$^+$)
  - Gene not changed, enhancer is
Evolutionary Trends

- Evolutionary trends are not goal oriented
Tree of Life
Systematics

The study of biological diversity in an evolutionary context
Phylogenetic Groupings

- **Monophyletic**
  - ancestor and all its descendants
Phylogenetic Groupings

- **Paraphyletic**
  - ancestor with some but not all its descendants
Phylogenetic Groupings

- Polyphyletic
  - two different ancestors
Phylogenetic Groupings
Similarities

- Homology
  - likeness attributed to shared ancestry
Similarities

- Analogy
  - likeness due to similar ecological roles and natural selection due to convergent evolution
Molecular Homoplasy

- Analogous species that have similar DNA sequences that evolved independently in two species
Ontogeny Recapitulates Phylogeny (Ernst Haeckel)

- Ontogeny – individual development
- Recapitulates – repeats
- Phylogeny – evolutionary descent
Classical Evolutionary Systematics

George Gaylord Simpson
The Science of Phylogenetic Systematics

- Classical Evolutionary Systematics
  - most commonly used up until recently
  - based on shared homologous structures
  - takes into account the amount of adaptive evolutionary change (novelties)
  - Monophyletic and paraphyletic groupings
The Science of Systematics

- Cladistics (Phylogenetic Systematics)
  - based on shared homologous structures
  - only monophyletic groupings

Will Hennig
Cladistics

- **Synapomorphies**: Shared derived characters
- **Plesiomorphies**: Shared Ancestral or Primitive characters
Cladistics

(a) Percentage differences between sequences

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<th></th>
<th>Human</th>
<th>Mushroom</th>
<th>Tulip</th>
</tr>
</thead>
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<td>30%</td>
<td>40%</td>
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<tr>
<td>Mushroom</td>
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</tr>
<tr>
<td>Tulip</td>
<td></td>
<td></td>
<td>0</td>
</tr>
</tbody>
</table>

(b) Comparison of possible trees

Tree 1: More likely
- 15%
- 15%
- 20%

Tree 2: Less likely
- 15%
- 15%
- 10%
Cladistics

Three possible phylogenetic hypotheses

Sites in DNA sequence

1  2  3  4  5  6  7

Species

I  A  G  G  G  G  T
II G  G  G  A  G  G
III G  A  G  A  A  T
IV G  G  A  G  A  A  G

Base-change event
Bases at site 1 for each species
Cladistics

Diagram showing cladistic analysis with labels G, A, and T, indicating evolutionary relationships.
Ichthyolestes (left) and Pakicetus (right)
48 million years old

Ambulocetus
48 - 47 million years old

Rhodocetus
47 million years old

Basilosaurus
38 million years old

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Molecular Clock
Molecular Clock