Patterns of Evolution

small ground finch
medium ground finch
large ground finch
sharp-beaked ground finch
cactus finch
large cactus finch
small tree finch
large tree finch?
vegetarian finch
woodpecker finch
warbler finch
A tree that represents an estimate (hypothesis) of evolutionary relatedness is a phylogeny.

Classifications can be based on groupings within a phylogeny.

Groupings can be categorized:
- **monophyletic** - a group that includes all of the descendants of a single common ancestor.
- **paraphyletic** - a group that includes some, but not all, of the descendants of a single common ancestor.
- **polyphyletic** - a group that is not based on common ancestry.
Traditional classifications were often based on branching patterns and apparent amounts of evolution. This often creates paraphyletic groupings (e.g. Class Reptilia).

Modern classifications tend to be constructed using monophyletic groups and reflect only the branching pattern of the phylogeny.
Once the phylogeny of a group is known other inferences about evolutionary history can be made:

• Segmentation has evolved twice.

• Sight has evolved multiple times.
Did the ancestor of humans and chimps have opposable toes?

If not, then opposable toes must have evolved again in the chimp lineage.

If so, then opposable toes were lost in the human lineage.

The simpler answer is usually preferred.
Important inferences are made from analysis of phylogenies

**Features of an organism almost always evolve from a pre-existing feature present in their ancestors - complex characters don’t evolve *de novo***.

Wings evolved from forelimbs at least 3 times in vertebrates (birds, bats, pterodactyls)

Wings and forelimbs are **homologous characters** - they arise from the same embryonic structures and their development is controlled by the same genes.

Homology is established by
- correspondence of position
- correspondence of structure
- correspondence in development
- continuity from an inferred ancestor in a phylogeny
**Homoplasy** (multiple origins of the same character state) is **common**.

Independent evolution of similar characteristics in homologous structures is called **parallel evolution** - a type of homoplasy.
Independent evolution of similar characters through different developmental pathways is called **convergent evolution** - another type of homoplasy.
Convergent and parallel evolution are often due to independent adaptation to similar environments.
Evolutionary **reversals** are common. The ancestral state of a character can re-evolve.

The jawless fishes were the first to evolve bone - as protective armor over the outside of their body.

Modern descendants of the early jawless fishes have bodies lacking bone entirely.
Mosaic evolution is common. Species characteristics often evolve independently of each other.

Every organism has a mix of ancestral and derived character states. Slow evolving characters are called conservative characters. They are retained even though other characters change.

In terrestrial vertebrates, walking on four legs is a conservative character. Having 5 digits on the appendages is also conservative. Having incisors in the upper and lower jaws is conservative character.
Change in form is often related to a change in function.
Evolution is usually gradual (gradualism)

Intermediates are often seen in the fossil record.

Living organisms often exhibit gradual variation in form.
Species similarity changes during ontogeny.

**von Baer’s Law:** Development proceeds from the general to the specific. During embryonic development, the characteristics of the broader taxonomic categories are seen in the embryo before the characteristics of the more specific taxonomic category.

**The biogenetic law:** “ontogeny recapitulates phylogeny” is not literally true. Organisms do not develop by progressing through the body types of their ancestors.
Developmental processes underlie some patterns of morphological evolution.

**Individualization** - the taking on of specific forms and functions in a serially repeating character.
**Heterochrony** - an evolutionary change in the timing or rate of developmental events.

**Paedomorphosis** - the retention of larval or juvenile characteristics after the attainment of sexual maturity - due to the relative increase in the rate of maturation of the gonads.

Peromorphosis - the delaying of sexual maturation and prolonging of the juvenile period in a way that results in greater development of some adult features - e.g. an increase in cranium volume.
Allometry - differences in growth rate among different parts or dimensions of an organism.

(A) Flying fish

(B) Halfbeak

(C) Needlefish
Although throughout evolutionary history there has been a trend of increasing complexity, decreases in complexity are also common.

Vertebrate evolution is characterized by many examples of simplification of structures.
Adaptive radiation - the diversification of a genetic lineage into many species with many different adaptations to different aspects of the environment - is common in some groups.

<table>
<thead>
<tr>
<th>Species</th>
<th>Adaptation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Certhidea olivacea</td>
<td>Warbler finch</td>
</tr>
<tr>
<td>Platyspiza crassirostris</td>
<td>Vegetarian finch</td>
</tr>
<tr>
<td>Pinarolaxias inornata</td>
<td>Cocos Island finch</td>
</tr>
<tr>
<td>Cactospiza heliobates</td>
<td>Mangrove finch</td>
</tr>
<tr>
<td>Cactospiza pallida</td>
<td>Woodpecker finch</td>
</tr>
<tr>
<td>Camarhynchus parvulus</td>
<td>Tree finches</td>
</tr>
<tr>
<td>Camarhynchus pauper</td>
<td></td>
</tr>
<tr>
<td>Camarhynchus psittacula</td>
<td></td>
</tr>
<tr>
<td>Geospiza scandens</td>
<td>Cactus finches</td>
</tr>
<tr>
<td>Geospiza conirostris</td>
<td></td>
</tr>
<tr>
<td>Geospiza magnirostris</td>
<td></td>
</tr>
<tr>
<td>Geospiza fortis</td>
<td>Ground finches</td>
</tr>
<tr>
<td>Geospiza fuliginosa</td>
<td></td>
</tr>
<tr>
<td>Geospiza difficilis</td>
<td></td>
</tr>
</tbody>
</table>
One of the most dramatic examples of adaptive radiation is that of the cichlid fishes of the Great Lakes of Africa. In the largest 3 lakes (Victoria, Tanganyika, and Malawi), speciation and adaptation has resulted in “species flocks” that fill different ecological niches. It happened independently in each lake, but has given rise to species with similar habits and a similar range of morphological diversification.