Chapter 22
Descent with Modification:
A Darwinian View of Life

1. Evolution by Natural Selection
2. Evidence for the Evolutionary Process
1. Evolution by Natural Selection

Chapter Reading – pp. 462-470
Lamarck publishes his hypothesis of evolution.


Hutton proposes his principle of gradualism.

Charles Darwin is born.

Darwin travels around the world on HMS Beagle.

Cuvier publishes his extensive studies of vertebrate fossils.

Lyell publishes Principles of Geology.

While studying species in the Malay Archipelago, Wallace sends Darwin his hypothesis of natural selection.

Darwin writes his essay on descent with modification.

On the Origin of Species is published.

The Galápagos Islands
Evolutionary thought depended on…

1) The discovery of regional variations in related species throughout the world
   • i.e., with unique adaptations for their region

2) Discovery of fossil remains for various extinct species in characteristic sedimentary layers
   • fossils of same species found in layers of same age

3) Evidence for an earth much older than previously thought
   • due to a better understanding of geological processes
   • provides time for evolution to occur (slowly)

***Ultimately led Charles Darwin and Alfred Wallace to propose the Theory of Evolution in the 1850’s***
The Formation of Sedimentary Strata

Sedimentary rock layers (strata)

Younger stratum with more recent fossils

Older stratum with older fossils
Darwin’s Voyage

Darwin in 1840, after his return from the voyage

- his visit to the Galapagos Islands provided his greatest insights into the nature of evolution
Darwin’s Finches

More than any other observation, the finches of the Galapagos islands impressed Darwin with adaptations unique to their environment.

(a) Cactus-eater
(b) Insect-eater
(c) Seed-eater
Darwin’s Key Observations

1) Members of a species vary in phenotype.
   • some phenotypes more “fit” for survival & reproduction

2) Species produce more offspring than can survive.
   • thus the “fittest” phenotypes should be more likely to survive and reproduce, passing on their traits (genes)
Evolution by Natural Selection

The gradual change in the characteristics of a species over time.

- “common descent with modification”
- occurs generation by generation
  - individuals don’t evolve, but populations do

This gradual change is directed by the process of **Natural Selection**.

- external factors select the best adapted individuals for **survival** and reproduction
- only those who survive & reproduce pass on their genetic alleles to the next generation
More on Natural Selection

Natural selection is the process by which external pressures select the best adapted individuals for survival and reproduction:

- evolutionary success = surviving to reproduce fertile offspring
- the genetic alleles of those best able to survive and reproduce will be passed on, increase in the population
- thus natural selection modifies the genetic make up of a population, generation by generation
- the “direction” of evolution is determined by external pressures (aka, selective factors), which will change over time
Examples of Selective Factors

Weather & Climate (temperature, wind, water)
  • those best adapted to current climate survive...

Availability of Food
  • those best at securing, using available food survive...

Predators & Disease
  • those that evade predators, resist disease survive...

Competition for Mates
  • those most successful at mating leave more offspring
2. Evidence for the Evolutionary Process

Chapter Reading – pp. 471-478
A Variety of Evidence Supports Evolution by Natural Selection

a) The Fossil Record
   • consistent with gradual change over long periods

b) Anatomical (Skeletal) Evidence
   • similarities in skeletal structures

c) Embryological Evidence
   • similarities in embryological development

d) Biochemical/Genetic Evidence
   • conservation of DNA sequences, metabolic processes

e) Observable Natural Selection
   • some species visibly evolve in our lifetimes
Fossils include more than just bones
• any evidence of a “once living” creature is a fossil
How is the age of a Fossil Known?

1) radiometric dating (e.g., “carbon dating”)
   • measures the level of radioactive isotopes in material
     • each isotope has a characteristic rate of decay (half-life)
     • dead, “fixed” material no longer exchanges atoms with the environment
     • the amount of radioactive isotope remaining can be used to calculate when the material became “fixed”

2) location in sedimentary layers
   • age of sedimentary layer = age of fossil found in it
   • rocky material is also subject to radiometric dating
Age of Fossil = Age of Sediment

- upper layers are younger, deeper layers are older

**similar fossils are found in the same aged layers throughout the world!**

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b) Anatomical Evidence

- same bone structures modified for different functions
Evolution of Marine Mammals

Common ancestor of cetaceans

60 50 40 30 20 0
Millions of years ago

Key
- Purple: Pelvis
- Green: Femur
- Yellow: Tibia
- Blue: Foot

Living cetaceans

†Pakicetus

†Rodhocetus

†Dorudon

Hippopotamuses

Other even-toed ungulates
Vestigial Structures

- Structures with no apparent function or purpose (e.g., whale, snake “hindlimb” bones)
- Consistent with modification of an ancestral structure by evolution
Many diverse species are remarkably similar at early embryonic stages:

- e.g., all vertebrates (including humans) initially develop tails, gills, webbed digits (modified with further development)
- consistent with evolution from a common ancestor
Early human vs chicken embryos

- young embryos of all vertebrate species have the same basic physical structures which become modified in different ways for each species as development progresses...
d) Biochemical Evidence

1) Metabolic processes in all living things are remarkably similar
   • glycolysis, respiration, photosynthesis
   • gene expression (transcription & translation)

2) The genetic code is the same for essentially all forms of life on earth
   • all codons, anti-codons specify the same amino acids in essentially all species

3) Conservation of gene (DNA) & protein sequences, and their function
   • homologous genes between species are remarkably similar in sequence & function
Protein Homology

- the degree of similarity between homologous proteins of different species reflects “evolutionary distance”

### Table 13.4 Comparison of a Protein in Different Species

<table>
<thead>
<tr>
<th>Species</th>
<th>Percent of amino acids that are identical to the amino acids in a human hemoglobin polypeptide</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human</td>
<td>100%</td>
</tr>
<tr>
<td>Rhesus monkey</td>
<td>95%</td>
</tr>
<tr>
<td>Mouse</td>
<td>87%</td>
</tr>
<tr>
<td>Chicken</td>
<td>69%</td>
</tr>
<tr>
<td>Frog</td>
<td>54%</td>
</tr>
<tr>
<td>Lamprey</td>
<td>14%</td>
</tr>
</tbody>
</table>

**e.g. hemoglobin**

***due to similarities in DNA sequences which encode the amino acids of proteins***
An Evolutionary Tree

Branch point

1. Digit-bearing limbs
   - Amnion

2. Homologous characteristic
   - Feathers
   - Crocodiles
   - Ostriches
   - Hawks and other birds

3. Tetrapods
   - Amphibians
   - Mammals
   - Birds

4. Amniotes
   - Lungfishes

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Convergent Evolution

Some species become more similar over time.
e) Observable Natural Selection

Some populations evolve by natural selection on time a time scale that we can observe:

Antibiotic, pesticide resistance

• antibiotic and pesticide use selects for resistant individuals (more likely to survive & reproduce)

Evolution by natural selection can be observed for organisms with a short generation time

• e.g., 30 minutes for bacteria vs. ~20 years for humans

**Populations evolve generation by generation, thus species with short generation times tend to evolve faster!**
Selection for MRSA – Methicillin Resistant Staphylococcus aureus

Key to adaptations:
- Methicillin resistance
- Ability to colonize hosts
- Increased disease severity
- Increased gene exchange (within species) and toxin production

Chromosome map of *S. aureus* clone USA300

Annual hospital admissions with MRSA (thousands)

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Selection for Longer Beak Size with a Different Food Source

Field Study

Soapberry bug with beak inserted in balloon vine fruit

Results

On native species, balloon vine (southern Florida)

On introduced species, goldenrain tree (central Florida)
Artificial Selection

Selective breeding controlled by human beings.

- dramatic differences in form & behavior result from selective breeding over “short” evolutionary time periods
- illustrates the capacity for evolutionary change

Hundreds to thousands of years of breeding (artificial selection)

Ancestral dog (wolf)
...more Artificial Selection

- Brussels sprouts
  - Selection for axillary (side) buds
- Cabbage
  - Selection for apical (tip) bud
- Broccoli
  - Selection for flowers and stems
- Kale
  - Selection for leaves
- Wild mustard
- Kohlrabi
  - Selection for stems
Key Terms for Chapter 22

- evolution, convergent evolution
- natural selection, selective factors
- artificial selection
- vestigial structures
- radiometric dating
- generation time

Relevant Chapter Questions 1-5