I. The Essence of Evolution

Darwin: Evolution is descent with modification

Evolution: Change through time
1. Species accumulate differences
2. Descendants differ from their ancestors
3. New species arise from existing ones

II. Hardy-Weinberg

Gene Pools, Alleles and Allele Frequency

**Gene pool**: All the possible alleles for a particular gene (or all the genes) within a given population

<table>
<thead>
<tr>
<th></th>
<th>Allele B</th>
<th>Allele b</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of alleles</td>
<td>150</td>
<td>50</td>
</tr>
<tr>
<td>Gene Pool</td>
<td>200 alleles</td>
<td></td>
</tr>
<tr>
<td>Allele frequency</td>
<td>0.75</td>
<td>0.25</td>
</tr>
</tbody>
</table>

II. Hardy-Weinberg Principle

**Parental Population**

- \( p = \) dominant allele frequency
- \( q = \) recessive allele frequency
- \( p + q = 1 \)

\[
(p + q)^2 = p^2 + 2pq + q^2
\]

- Genotype frequencies calculated from allele frequencies
- Homozygous Dominant
- Heterozygous
- Homozygous Recessive

**Offspring**

Under certain conditions:
- allele and genotype frequencies in a population will remain constant over time
- No evolution
- equilibrium population

How Many Natural Populations are in Genetic Equilibrium?

So why use Hardy-Weinberg?

- Provides a useful starting point for studying the mechanisms of Evolution by establishing a baseline to compare change
- Helps identify forces of evolution.

II. Hardy-Weinberg Principle

Forces of Evolution

Hardy-Weinberg Equilibrium applies if and only if:
1. no mutation
2. no gene flow
3. no genetic drift
4. random mating
5. no natural selection
Forces of Evolution – Mutation

DNA Mutations
- Point mutations alter a single base.
  - Base substitution, Insertion or Deletion

Chromosome mutations
- Deletions – part of chromosome is lost
- Duplication – part of chromosome is copied
- Inversion – part of chromosome in reverse order
- Translocation – part of chromosome moved to new location

Mutation Frequency
How often?
- 1 in 100,000 cell divisions
- 1 in 50 million base pairs
- 1 in a million gametes

Bacterial genome ≈ 5000 genes
X 200 bacteria = 1,000,000 genes per 200 bacteria
1 mutation in every 1,000,000 genes
1 teaspoon of soil ≈ 1 billion bacteria
1 billion bacterial + 200 bacteria/1 mutation =
5 million mutations in 1 teaspoon of soil

Mutation - Summary
1. Mutation is the most basic force of evolution
   - change in DNA sequence
   - change in Chromosome organization
2. Ultimate source of new alleles
3. Mutation is fairly rare, but…rate of cell division and population size are important factors

Forces of Evolution – Gene Flow

Gene flow = migration between populations
- populations exchange genetic material
- can change allele frequencies by altering the gene pool

Other examples of gene flow
1. Bacterial transformation from plasmid transfer
2. Virus and plasmid vectors in recombinant DNA technology
3. People

Forces of Evolution – Genetic Drift

-> Frequencies of particular alleles change by chance alone.
A. Population bottlenecks
- Populations reduced to small # then recover
- Genetic bottleneck results in loss of genetic variation
- Reduced capacity to evolve

Northern elephant seal
1920 – 20 animals
2007 – 130,000 animals

Founders
original population
event causing bottleneck
resulting population
**Forces of Evolution – Non-Random Mating**

Mating of phenotypically similar individuals
Positive Assortative mating
Inbreeding
Increases proportions of homozygotes
Decreases phenotypic variation

Negative Assortative mating
Increases phenotypic variation

**Forces of Evolution – Natural Selection**

Other elements of natural selection
1. Two measures of fitness
   - survival to reproductive maturity
   - passing alleles on to the next generation
2. Interaction between phenotype and environment
3. Produces adaptive evolutionary change
4. Allele frequencies change over time, not individuals

**Peppered Moths and Industrialized Melanism**

→ The second half of the twentieth century saw widespread implementation of pollution controls, thus trends appear to be reversing and light colored moths may again dominate.

**Peppered Moths and Industrialized Melanism**

The second half of the twentieth century saw widespread implementation of pollution controls, thus trends appear to be reversing and light colored moths may again dominate.
Forms of Natural Selection

Favors one extreme
Favors average
Favors both extremes

Time
Percentage of population

Before selection

Natural Selection leads to Adaptation

Camouflage – one result of natural selection

Constraints on Evolutionary Perfection

- Evolution requires genetic variation
  - Mutation is random
- Selection can edit only existing variation
  - Evolution tinkers with existing structures
- Adaptations are compromises
  - Seal flippers on land and water
- Chance and selection interact
  - No prediction of future conditions

Chapter 22: Evolution-evidence

I. Artificial Selection

- Evidence of Natural Selection
  - Fossil Record
  - Comparative Anatomy
  - Homologous structures
  - Vestigial structures
  - Embryology
  - Genetic Analysis
  - Biogeographical Evidence
II. Speciation
III. Conclusions

"Nothing in biology makes sense except in the light of evolution"  
- Theodosius Dobzhansky

I. Artificial Selection

- Darwin found evidence for his ideas in artificial selection

Artificial selection:
- organisms may be modified by controlled breeding
- change drastically in short time periods
- examples…
  A) Plants
    - Brassica oleracea

Variations due to artificial selection
- cabbage, cauliflower, broccoli, kale, Brussel sprouts

Genes Within Populations

END
Artificial Selection in animals

Change can happen over a very short geological period if the selection pressure is strong.

II. Evidence of Evolution

Darwin’s Finches: Evidence of Natural Selection

14 species
Beak shape variation
- Seed crackers
- Cactus eaters
- Tool users
- Vampire

Darwin’s: Evidence of Natural Selection

“Seeing this gradation and diversity of structure in one small, intimately related group of birds, one might really fancy that from an original paucity of birds in this archipelago, one species has been taken and modified for different ends.” - Darwin

1. More offspring born than survive
2. Populations accumulate differences
3. Descendants differ from their ancestors
4. New species arise from existing ones

⇒ Evolution is descent with modification

II. Evidence - The Fossil Record - Making Fossils

Fossils: Preserved “remains” of ancient organisms
⇒ Bury in sediment
⇒ Mineralization of organic material
⇒ Hardening of sediment

II. The Fossil Record – Dating Fossils

Dating fossils
Relative dating – old layers under new
Absolute dating – radioactive decay

Half-Life examples

- U-238 ⇒ 4.5 billion years
- C-14 ⇒ 5730 years
- K-40 ⇒ 1.25 billion years
Evolutionary change in body size and toe reduction of horses

II. Evidence - Whale Evolution: A Record of Transition

- *Rodhocetus kasrani* had reduced hind limbs and could not walk; they swam with up-down motion like modern whales.
- *Ambulocetus natans* walked on land like sea lions, swam by flexing & paddling like otters.
- *Pakicetus attocki* lived on land; its skull had whale characteristics.

II. Evidence - Comparative Anatomy

- Organisms can be grouped (classified) by unique anatomical characteristics.
- Similar anatomy is found in organisms with greatly divergent functions.
- Theme = Descent from a common ancestry.
II. Evidence - Vestigial Structures

II. Evidence - Embryology & Comparative Development
Comparative Development Reveals Descent from a Common Ancestor

II. Evidence - Embryology & Comparative Development

Molecular Phylogeny
DNA and the Hemoglobin Gene

II. Evidence - Convergent Evolution

III. The Nature of Species

Biogeography & Convergent Evolution

III. The Nature of Species

Convergent evolution - acquisition of the same biological trait in unrelated lineages.

1. Interbreeding population
2. Potentially interbreeding population
3. Inherent willingness to interbreed
4. Production of viable, fertile offspring

How does a new species appear?
**Biological Species Isolating Mechanisms**

- Geographic
- Behavioral
- Mechanical
- Ecological
- Temporal
- Gamete fusion
- Postzygotic

**Adaptive Radiation and Alpine Buttercup Speciation**

New Zealand buttercups – 14 alpine species.

**Isolation and Speciation**

Lions and tigers are ecologically isolated

**IV. Conclusions**

Support for Evolution comes from
- Fossils, Order of Appearance, Relative and Absolute Dates
- Anatomical Classification
  - Homologous Structures
  - Vestigial Structures
- Embryology/Development
- Genetic Analysis/Molecular Phylogeny
- Convergence
- Speciation → based on isolating mechanisms

**IV. Conclusions**

Evolution – Both a Fact and a Theory

- That evolution has occurred (and is currently occurring) is NOT in scientific debate now; it has been settled.
- FACT – Biodiversity on Earth is a result of evolution from a common ancestor.
- FACT – Evolution continues today.
- THEORY – The intricacies of evolutionary change and mechanisms driving evolution.

**END Evolution**