Chapter 7

Evolution and the Fossil Record
Guiding Questions

• What lines of evidence convinced Charles Darwin that organic evolution produced the species of the modern world?
• What are the two components of natural selection?
• What is the source of the variability that is the basis of natural selection?
• What role does geography play in speciation?
• What factors lead to evolutionary radiation?
• Why is convergence one of the most convincing kinds of evidence that evolutionary changes are adaptive?
• Why do species become extinct?
• What is mass extinction?
• In what ways can evolutionary trends develop?
**Visual Overview**

**The Evolution of Life**

**EVIDENCE FOR EVOLUTION**

- **Human arm**
- **Bat wing**

Darwin concluded that similar configurations of organs in distantly related animals often reflect a common ancestry; they represent homology.

- **Ear-wiggling muscle**

Darwin concluded that some anatomical features that lack functions are vestigial; they are remnants of features that were functional in evolutionary ancestors.

- **Tortoise**
- **Chick**

Darwin concluded that the similarity of embryos of animals that are quite different as adults must reflect a common ancestry.

- **Genetic changes—mutations in the chemical code of DNA or rearrangements of segments of chromosomes—produce the variability upon which natural selection operates.**

- **Chromosomes**

- **DNA**

- The geographic distributions of organisms, such as the restriction of particular species of giant tortoises to single islands in the Galápagos, suggested to Darwin that species arise from isolated populations.

- **Aardvark**
- **Alligator**
- **Dawn redwood**

Darwin noted that artificial selection by animal breeders serves as a model for natural selection.

Ancient taxa that have survived to the present with little speciation have undergone little evolutionary change and are called living fossils.
**TRENDS AND PATTERNS**

Cichlid fishes have undergone a spectacularly rapid evolutionary radiation in Lake Victoria, a relatively young body of water.

**Mammals**

Mass extinction of the dinosaurs permitted the great evolutionary radiation of the mammals, illustrating how the disappearance of one taxon can trigger the expansion of another.

**Dinosaurs**

The fossil record documents some gradual evolutionary trends, such as the enlargement and flattening of coiled systems.

Like many other large-scale evolutionary trends, increase in the average body size of horses followed a complex pattern with some small species originating long after horses first appeared.

**Early amphibian**

The origin of the legs of early amphibians from the fins of fishes was the adaptive breakthrough that triggered the evolutionary radiation of terrestrial vertebrates.

**Thylacine (marsupial)**

Evolutionary convergence between distantly related taxa—the evolution of similar shaped animals with a similar mode of life—is powerful evidence that evolution is adaptive.
Evolution

• Changes in populations, which consist of groups of individuals that live together and belong to the same species
Evolution

• Adaptations
  – Specialized features of animals and plants that perform one or more useful functions
  – Allow that organism to excel in its environment
Charles Darwin

• 1831
  – Set sail on the *Beagle*
  – Schooled in uniformitarianism
    • Lyell’s *Principles of Geology*
  – Keen observer
Charles Darwin

- **Rhea**
  - Large flightless birds
  - Found only in South America
  - Also found extinct fossil forms
Charles Darwin

- Sloths and extinct armadillos
  - Unique to the Americas
Charles Darwin

- Oceanic islands
  - Many barren
  - Must have originated elsewhere

- Galápagos Islands
  - Tortoises with unique shells on each island
  - Common ancestry
  - Later differentiation
Charles Darwin

- Finches of the Galápagos
  - Different beak types
    - Slender
    - Sturdy
    - Woodpecker-like
  - Differentiation based on lifestyle
Charles Darwin

• Additional observations
  – Anatomical relationships
    • Embryos of many vertebrates quite similar
    • Homology
      – Presence in two different groups of animals or plants of organs that have the same ancestral origin but serve different functions
    • Vestigial organs
      – Organs that serve no apparent purpose but resemble organs that perform functions in other creatures
Theory of Evolution

• Natural Selection
  – Process that operates in nature but parallels the artificial selection by which breeders develop new varieties of plants and animals
  • Success of an individual determined by advantages it has over others
    – Survives to bear offspring with same trait
Theory of Evolution

• Genes
  – Hereditary factors

• Particulate inheritance
  – Gregor Mendel: Organisms retain identities through generations
  – Peas
    • No blending
    • Colors could be masked for generations
Theory of Evolution

- **Mutations**
  - Alteration of genes
  - Provides for variability

- **DNA**
  - Deoxyribonucleic acid
  - Transmits chemically coded information
  - Concentrated in chromosomes
    - paired
Theory of Evolution

• Sexual recombination
  – Each parent contributes one-half of its chromosomes to offspring
  – Gamete
    • Special reproductive cell contains one of each type of chromosome
      – Female egg; male sperm
  – Yields new combinations
    • Mutations increase variability

• Gene pool
  – Sum total of genetic components of a population or group of interbreeding individuals
    • Reproductive barriers limit the pool

• Speciation
  – Origin of a new species from two or more individuals of a preexisting species
Inheritance of Brown Hair Color

arrows indicate individuals who married into the family, but whose genetic history is not known
Unaffected "Carrier" Father

Unaffected "Carrier" Mother

Unaffected 1 in 4 chance

Unaffected "Carrier" 2 in 4 chance

Affected 1 in 4 chance
Origination

- **Evolutionary radiations**
  - Pattern of expansion from some ancestral adaptive condition represented by descendant taxa

- **Adaptive breakthrough**
  - Appearance of key features that allow radiation to occur

- **Fossil record documents patterns**
  - Jurassic corals
Origination

- Rates
  - Galápagos Islands
    - Formed millions of years ago
  - Lake Victoria
    - 13,000 years old
    - 497 unique species of cichlid fish
    - Specialized adaptations

- Molecular clock
  - Assume average rate of mutation
  - Determine pace of change
  - Extrapolate timing of change

\[\begin{align*}
\text{Haplochromis chilotes,} & \quad \text{a specialized insect eater (46\% of actual size)} \\
\text{Haplochromis estor,} & \quad \text{a fish eater (16\% of actual size)} \\
\text{Haplochromis sauvagei,} & \quad \text{a mollusk eater (44\% of actual size)}
\end{align*}\]
Evolutionary Convergence

- Evolution of similar forms in two or more different biological groups
- Marsupials and placental mammals
  - Similar form
  - Isolated, adaptive convergent evolution after initial divergence
Extinction

- Caused by extreme impacts of limiting factors
  - Predation
  - Disease
  - Competition
- Pseudoextinction
  - Species evolutionary line of descent continues but members are given a new name
- High rates of extinction make useful index fossil
  - Ammonoids
Extinction

• Rates
  – Average rate has declined through time

• Mass extinctions
  – Many extinctions within a brief interval of time
  – Largest events peak at extinction of > 40% genera
  – Rapid increase follows
Modern Mass Extinctions

• Fossil patterns reflected in modern times
  – Tropical species
  – Large animals
• Loss of habitat
• Direct exploitation
• Likely replacement by opportunistic species
Evolutionary Trends

• Cope’s rule
  – Body size increases during evolution of a group of animals
  – Structural limitations on size

• Specialized adaptations limit evolution
  – Elephants
  – Manatees
Evolutionary Trends

• **Whales**
  – Terrestrial origin
    • 50 M years ago
    • Small (2 m) mammals with feet
  – Marine adaptation
    • 40 M years ago
    • Lost hind limbs
    • No pelvic bones
    • Up to 20 m
Phylogeny

- Complex, large-scale trend within a branching tree of life
- Gradual large-scale change from one species to another is rare
  - Jurassic coiled oysters
Phylogeny

• Axolotl
  – Example of rapid speciation from parent species
    • Parent is amphibious
    • Offspring is aquatic throughout life after one simple genetic change
Phylogeny

- Rates
- Gradualistic Model
  - Very slow rates
- Punctuational Model
  - Rapid evolution with little change between steps
  - Bowfin fish
    - Little change in 60 M years
Phylogeny

• Horses
  – Increase in body size
  – Evolved tall, complex molars, and single-hoofed toe
  – Change driven by climate
    • Expansion of grasslands

• Dollo’s law
  – Evolutionary transition from at least several genetic changes is unlikely to be reversed by subsequent evolution
Visual Overview
The Evolution of Life

Darwin observed that living and fossil members of some animal groups are known only from the Americas and must have originated there by some natural process.

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Axolotl
Salamander

The axolotl, which has the form and aquatic habits of a larval salamander, originated rapidly from a salamander species by way of a single genetic change.

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TRENDS AND PATTERNS

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