Mechanisms of Evolution
Descent with Modification

• Darwinian evolution = descent with modification by means of natural selection

• On the Origin of Species by Means of Natural Selection, published November 24, 1859.
  – All life has descended from a common ancestor
  – The mechanism of modification is natural selection

Evolution by Natural Selection

• Unifies all of biology

• Explains why we have so many different forms of life on earth today, where they came from, how they are related, why they live where they live, and how each became adapted to their particular environment.

Background of a Theory

• The idea of evolution was NOT new.

• The social and political climate of Darwin’s time was inhospitable to the implications of evolution.

• Many had published ideas on evolution, but Darwin proposed the first plausible mechanism by which it could occur.
• Darwin drew from the ideas of many scientists and authors, both his contemporaries and their predecessors.

• Previous works in natural history, taxonomy, geology, paleontology, and sociology contributed to the formation of Darwin’s theory of natural selection.

• Physical evidence from the disciplines of anatomy, embryology, biogeography, paleontology, molecular biology, and agriculture supports evolutionary theory.

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**Darwinism in a Nutshell**

• Species on Earth today descended from ancestral species.

• Natural selection is the mechanism for evolution.

• Natural selection leads to evolutionary adaptation, as individuals with advantageous heritable traits leave more offspring, and the frequency of those traits in a population increases over generations.

• Evolution may be defined as changes in a population’s genetic makeup over time.

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**Darwinian Evolution Explains**

• How all life is related

• The processes that have transformed life on earth from the earliest forms to the tremendous diversity of life today
Key Concepts

• **22.1** The Darwinian revolution challenged traditional views of a young Earth inhabited by unchanging species

• **22.2** In *The Origin of Species*, Darwin proposed that species change through natural selection

• **22.3** Darwin’s theory explains a wide range of observations

Concept 22.1: The Darwinian revolution challenged traditional views of a young Earth inhabited by unchanging species

In order to understand why Darwin’s ideas were revolutionary

– We need to examine his views in the context of other Western ideas about Earth and its life

The historical context of Darwin’s life and ideas

![Timeline of key events in Darwin's life and the historical context](image-url)

**Figure 22.2**
Resistance to the Idea of Evolution

- *The Origin of Species*
  - Shook the deepest roots of Western culture
  - Challenged a worldview that had been prevalent for centuries

The Scale of Nature and Natural Theology

- Greek philosopher Plato (427-347 BC)
  - Saw the "real" world as perfect and unchanging

- Greek philosopher Aristotle (384 -322 BC)
  - Viewed species as fixed and unchanging, each species occupying a rung on the "ladder of life"
  - Prevailed for over 2000 years

- The Old Testament of the Bible
  - Holds that species were individually designed by God and therefore perfect

Natural Theology

- Philosophy that the Creator’s plan is revealed by studying nature

- Dominated European and American biology even as Darwin emerged.

- Carolus Linnaeus (1707-1778) - The Father of Taxonomy
  - Interpreted organismal adaptations as evidence that the Creator had designed each species for a specific purpose
  - He classified life’s diversity "for the greater glory of God"
Fossils, Cuvier, and Catastrophism

- The study of fossils - Helped to lay the groundwork for Darwin’s ideas

- Fossils are remains or traces of organisms from the past - Usually found in sedimentary rock, which appears in layers or strata

Paleontology, the study of fossils
- Was largely developed by French scientist Georges Cuvier (1769 – 1832, Father of Paleontology)

- Cuvier noted each stratum had a unique set of fossils and that the older the stratum the more dissimilar the fossils were to modern life forms.

- But, he opposed the idea of gradual evolutionary change - And instead advocated catastrophism, speculating that each boundary between strata represents a catastrophe

Cuvier saw boundaries between fossil strata as corresponding to catastrophic events

- He explained the appearance of new species in younger rock by proposing:
  - Periodic localized catastrophes resulted in mass extinctions
  - After the local species became extinct, the area would be repopulated by foreign species immigrating from other areas
THEORIES OF GRADUALISM

• Gradualism
  – Principle that profound change can take place through the cumulative effect of slow but continuous processes
  – Competed with Cuvier’s theory of catastrophism

• Geologists James Hutton (1726 - 1797, Father of Modern Geology) and Charles Lyell (1797-1875)
  – Perceived that changes in Earth’s surface can result from slow continuous actions still operating today
  – If geological change results from slow gradual processes, then the Earth must be ancient.
  – Exerted a strong influence on Darwin’s thinking
    • Small gradual changes accumulating over very long periods of time can cause major changes

Lamarck’s Theory of Evolution

• Jean-Baptiste Lamarck (1744-1829) hypothesized that species evolve
  – Compared modern species to fossils and identified several lines of descent in chronological series of older fossils to younger fossils to modern species
  – Envisioned many ladders of life which organisms could climb
  – Developed and published (1809) a comprehensive model which attempted to explain how life evolves
    • Concluded evolution is best explanation for fossil record and extant diversity
    • Concluded the Earth is ancient
    • Concluded that adaptation is a product of evolution
Lamarck’s Theory of Evolution

- Lamarck believed evolution was driven by an innate tendency toward increasing complexity (equated with perfection).
- He hypothesized that species evolve through use and disuse and the inheritance of acquired traits.
  - The mechanisms he proposed are unsupported by evidence.

Erasmus Darwin (1731-1802)

Organic life beneath the shoreless waves
Was born and nurs’d in ocean’s pearly caves;
First forms minute, unseen by spheric glass,
Move on the mud, or pierce the watery mass;
These, as successive generations bloom,
New powers acquire and larger limbs assume;
Whence countless groups of vegetation spring,
And breathing realms of fin and feet and wing.
Erasmus Darwin. The Temple of Nature. 1802.

Erasmus did not propose natural selection, but he had ideas that Charles expanded upon in The Origin of Species, such as how life evolved from a single common ancestor, forming "one living filament".

Addressed how one species could evolve into another. Some of his mechanisms are close Lamarckism (as were some of Charles'). He also talked about competition and sexual selection causing changes in species. "The final course of this contest among males seems to be, that the strongest and most active animal should propagate the species which should thus be improved".

Like his grandson, Erasmus reached conclusions through an "integrative" approach: he used his observations of artificial selection in domesticated animals, the behavior of wildlife, and integrated his knowledge of many different subjects, including paleontology, biogeography, systematics, embryology, and comparative anatomy.
**James Hutton**

- Suggested natural selection as a possible mechanism affecting animals:
  
  "...if an organised body is not in the situation and circumstances best adapted to its sustenance and propagation, then, in conceiving an indefinite variety among the individuals of that species, we must be assured, that, on the one hand, those which depart most from the best adapted constitution, will be the most liable to perish, while, on the other hand, those organised bodies, which most approach to the best constitution for the present circumstances, will be best adapted to continue, in preserving themselves and multiplying the individuals of their race." – *Investigation of the Principles of Knowledge*, 1794

**Concept 22.2: In The Origin of Species, Darwin proposed that species change through natural selection**

- In the early 19th century natural theology still dominated Europe and America.
  
  - It was generally believed that species had remained unchanged since their creation, but a major change would challenge this thinking

**Darwin’s Research Background**

- Born in 1809 into a family of physicians and naturalists.
- As a child, and into adulthood, he had a consuming interest in nature.
- Sent to the University of Edinburgh to study medicine.
- Left Edinburgh and enrolled at Cambridge to study for the clergy.
- Studied under Reverend John Henslow, a botanist and graduated in 1831.
- Henslow introduced him to Captain Robert FitzRoy, and he was accepted on board the HMS Beagle, to embark on a voyage around the world in December 1831.
Voyage of the Beagle: Field Research

• While the ship’s crew surveyed the coast of S. America:
  – Darwin observed and collected many thousands of specimens of South American plants and animals, and fossils
  – He observed various adaptations of plants and animals that inhabited many diverse environments

– He noted that the species of South America are distinct from those in Europe.

– Temperate species in S. America were taxonomically closer to tropical species in S. American than to temperate species of Europe

– S. American fossils were distinctly S. American

• Darwin’s interest in the geographic distribution of species was sparked by the Beagle’s stop at the Galápagos Islands near the equator west of South America
- Geographic distribution of species was confusing on the Galapagos.
- Most animal species were unique yet resembled those from S. America
- Darwin collected many species of finches there, some unique to individual islands

- Fourteen species of Galápagos finches have beak shapes adapted to suit their environments.

**By the time the Beagle left the Galapagos**

- Darwin had read Lyell’s Principles of Geology.
- He began to doubt the church’s position that the Earth was static and created only a few thousand years before
- In recognizing that the Earth is ancient and constantly changing he began to recognize that life on earth also changes.
Darwin’s Focus on Adaptation

- As Darwin reassessed all that he had observed during the voyage of the Beagle and began his first notebook on the origin of species in 1837
  - He started to perceive adaptation to the environment and the origin of new species as closely related processes

Example of Adaptation and Speciation

- Two populations of the same species become isolated in different environments and diverge as each adapts to local conditions.

- Over many generations, the two populations could become dissimilar enough to become named as different species.

- In subsequent studies of the Galapagos finches:
  - Biologists have concluded that this is what happened: all are descendant of the S. Amer. warbler finch. Each diverged as it adapted to the local environment.
  - Their different beaks are adaptations to the food available on their home islands.
  - Speciation is closely tied to adaptation.

![Figure 22.6a–c](image)

- (a) Cactus eater. The long, sharp beak of the cactus ground finch (Geospiza scandens) helps it tear and eat cactus flowers and pulp.
- (b) Insect eater. The green warbler finch (Certhidea olivacea) uses its narrow, pointed beak to grasp insects.
- (c) Seed eater. The large ground finch (Geospiza magnirostris) has a large beak adapted for cracking seeds that fall from plants to the ground.