UNIT 4

Mechanisms of Evolution

Chapter 22

Descent with Modification: A Darwinian View of Life

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

Framework

This chapter describes Darwin's formulation of evolution—all of life has descended from a common ancestor, and the mechanism of natural selection has resulted in the evolution of species adapted to their environments. The scientific and philosophical climate of Darwin's day was quite inhospitable to the implications of evolution, although ideas from taxonomy, geology, and paleontology set the stage for Darwin's work. Evidence for evolution is drawn from homologies (anatomical and molecular), biogeography, and the fossil record, as well as examples of natural selection in action.

Chapter Review

Charles Darwin presented the first convincing case for evolution in his book *On the Origin of Species by Means of Natural Selection,* published in 1859. Darwin made two major claims: The species present on Earth today descended from ancestral species, and **natural selection** is the mechanism for evolution. Natural selection leads to **evolutionary adaptation,** as individuals with beneficial heritable traits leave more offspring, and the frequency of such traits in a population increases over generations. **Evolution** may be defined as the changes in a population's genetic composition over time.

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

Resistance to the Idea of Evolution Darwin's book challenged both the prevailing scientific views and the world view that had been held for centuries in Western culture.

The Greek philosopher Plato believed in two worlds, an ideal and eternal real world and the illusory world perceived by the senses. Aristotle proposed that all living forms could be arranged on a "scale of nature" of increasing complexity and that each group of organisms was permanent and perfect.

The Old Testament account of creation supported the idea of perfect and fixed species. One of the goals of biology in the 1700s was to classify the species that God had created. Linnaeus developed both a binomial system for naming organisms according to their genus and species, and a hierarchy of classification groupings. **Taxonomy,** the branch of biology that names and classifies organisms, originated in the work of Linnaeus.

Fossils are remnants or impressions of past organisms, usually found in **sedimentary rocks** formed through the compression of layers of sand and mud into superimposed layers called strata. Fossils from strata of different ages reveal some of the organisms that have existed at different periods of Earth's history.

Cuvier may be considered the father of **paleontology,** the study of fossils. Advocating **catastrophism,** he maintained that the differences he observed in the fossils found in different strata were the result of local catastrophic events such as floods or drought and were not indicative of evolution.

Theories of Gradualism **Gradualism,** the idea that immense change is the cumulative result of slow but continuous processes, was proposed by Hutton in 1795 to explain the geologic state of the Earth. Lyell, a contemporary of Darwin, extended gradualism to a theory of **uniformitarianism,** stating that the rates and effects of geologic processes have remained the same through Earth's history and continue in the present.

Darwin took two ideas from the observations of Hutton and Lyell: The Earth must be very old, and very slow processes can produce substantial change, perhaps even on living species.

Lamarck's Theory of Evolution Lamarck published a theory of evolution in 1809. He explained the mechanism of evolution with two principles: The use or disuse of body parts leads to their development or deterioration, and acquired characteristics can be inherited. Although present genetic knowledge rejects his mechanism, Lamarck proposed several key evolutionary ideas: that evolution is the best explanation for the fossil record and that adaptation to the environment is the main result of evolution.

■ INTERACTIVE QUESTION 22.1

a. Match the theory or philosophy and its proponent(s) with the following descriptions.

A. catastrophism	a. Aristotle
B. inheritance of acquired characteristics	b. Cuvier
C. gradualism	c. Darwin
D. natural selection	d. Hutton
E. taxonomy	e. Lamarck
F. scale of nature	f. Linnaeus
G. uniformitarianism	g. Lyell

Theory	Proponents	
1. _____	_____	Ordering the diversity of God's creations by naming and classifying species
2. _____	_____	History of Earth marked by floods or droughts that resulted in extinctions
3. _____	_____	Early explanation of mechanism of evolution
4. _____	_____	Profound change is the cumulative product of slow but continuous processes
5. _____	_____	Fixed species on a continuum from simple to complex
6. _____	_____	Differential reproductive success leads to adaptation to environment and evolution
7. _____	_____	Geologic processes have constant rates throughout time

b. Now place 1 through 7 in chronological order.

_____ _____ _____ _____ _____ _____ _____

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

Darwin's Research Darwin was 22 years old when he sailed from Great Britain on the HMS *Beagle.* He spent the voyage collecting thousands of specimens of the fauna and flora of South America, observing the various adaptations of organisms living in very diverse habitats, and making special note of the geographic distribution of the distinctly South American species. He was particularly struck by the uniqueness of the fauna of the Galápagos Islands. Darwin also read and was influenced by Lyell's *Principles of Geology.*

Darwin began to link the origin of new species to the process of adaptation to different environments. In 1844 he wrote an essay on the origin of species and natural selection but did not publish it. In 1858 Darwin received Wallace's manuscript describing an identical theory of natural selection. Wallace's paper and extracts of Darwin's unpublished essay were jointly pre-

sented to the Linnaean Society, and Darwin published *The Origin of Species* the next year. Within a decade, Darwin's book and its defenders had convinced the majority of biologists that evolution was the best explanation for the diversity of life.

The Origin of Species Darwin's book developed two main points: evolution as the explanation of life's unity and diversity, and natural selection as the mechanism of adaptive evolution.

Darwin's concept of **descent with modification** included the notion that all organisms were related through descent from some unknown ancestor and had developed increasing modifications as they adapted to various habitats. The history of life is analogous to a tree with a common ancestor at the fork of each new branch. The taxonomy developed by Linnaeus provided a hierarchical organization of groups that suggested to Darwin this branching tree of life.

Evolutionary biologist Ernst Mayr described Darwin's theory of natural selection as follows:

Observation 1:	Species have the potential for their population size to increase exponentially.
Observation 2:	Most population sizes are stable.
Observation 3:	Resources are limited.
Inference 1:	There is a struggle for limited resources and only a fraction of offspring survive.
Observation 4:	Individuals vary within a population.
Observation 5:	Much of this variation is inherited.
Inference 2:	Individuals whose inherited characteristics fit them best to the environment are likely to leave more offspring.
Inference 3:	Unequal reproduction leads to the gradual accumulation of favorable characteristics in a population over generations.

■ INTERACTIVE QUESTION 22.2

Summarize in your own words Darwin's theory of natural selection as the mechanism of evolution.

Darwin found support for the struggle for existence and the capacity of organisms to overproduce in the essay on human population growth published by Malthus in 1798.

Artificial selection used in the breeding of domesticated plants and animals provided Darwin with evidence that selection among the variations present in a population can lead to substantial changes. He reasoned that natural selection, working over thousands of generations, could gradually create the modifications essential for the present diversity of life.

Natural selection results in the evolution of populations, groups of interbreeding individuals of the same species in a common geographic area. Evolution is measured only as change in the relative proportions of variations in a population over time. Natural selection affects only those traits that are heritable—acquired characteristics cannot evolve. And natural selection depends on the specific environmental factors present in a region at a given time. If the environment changes, different adaptations will be favored.

22.3 Darwin's theory explains a wide range of observations

Natural Section in Action: Differential Predation and Guppy Populations J. Endler and D. Reznick, studying guppy populations in isolated pools in Trinidad over many years, have observed variations in the age and size of sexual maturity that correlate with the type of local predator. They transplanted guppies from pools with pike-cichlids to pools with killifish predators and observed, over 11 years, a change in age and size at maturity in the transplanted population, documenting evolution in a natural setting over a relatively short period of time.

Natural Section in Action: The Evolution of Drug-Resistant HIV The evolution of drug resistance in HIV illustrates two facets of natural selection: It is an editing, not a creative, mechanism that selects for variations already present in a population. And it is regional and temporal, selecting for traits that fit the local environment at that current time.

■ INTERACTIVE QUESTION 22.3

Within a few weeks of treatment with the drug 3TC, a patient's HIV population consists entirely of 3TC-resistant HIV. Explain how this rapid evolution of drug resistance is an example of natural selection.

Homology, Bioeography, and the Fossil Record **Homology** is a similarity resulting from common ancestry. The forelimbs of all mammals are **homologous structures,** containing the same skeletal elements regardless of function or external shape. Comparative anatomy illustrates that evolution is a remodeling

process in which ancestral structures become modified for new functions. Some homologous structures that differ greatly in adult form and function are more evident during embryonic development.

Vestigial organs are rudimentary structures, of little or no value to the organism, that are historical remnants of ancestral structures.

Homologies can be seen on a molecular level. DNA, RNA, and an essentially universal genetic code, which have been passed along through all branches of evolution, are important evidence that all forms of life descended from the earliest organisms and are thus related. Homology is evident on different hierarchical levels, reflecting evolutionary history and the degree of relationship among organisms. Closely related species have a larger proportion of DNA and proteins in common than do more distantly related species.

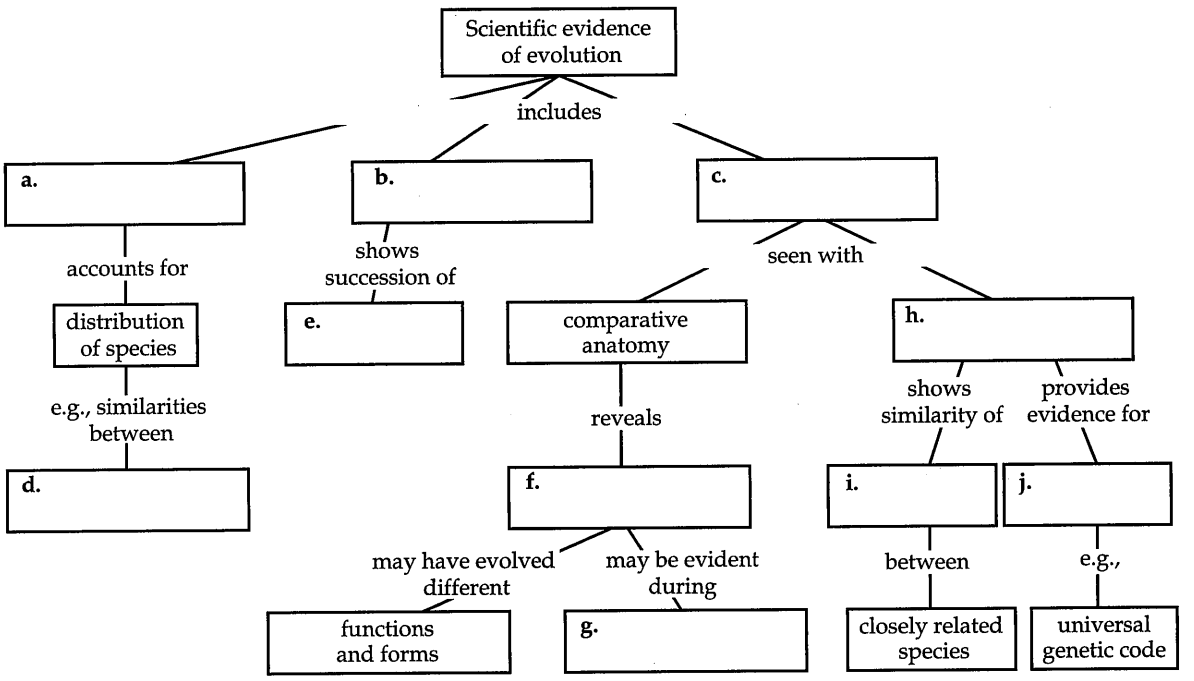
The geographic distribution of species, or **biogeography,** provides evidence for evolution. Islands often have **endemic** species, found nowhere else and usually closely related to species on the nearest island or mainland. Widely separated areas having similar environments are not likely to be populated by closely related species. Rather, each area is more likely to have species that are taxonomically related to those of their region, regardless of environment. Biogeographic distribution patterns are explained by evolution; modern species are found where they are because they evolved from ancestors that inhabited those regions.

The major branches of evolutionary descent established with evidence from homologies and molecular biology are also supported by the sequence of fossil forms found in the fossil record. Paleontologists continue to discover transitional fossils linking modern species to their ancestral forms.

What Is Theoretical about the Darwinian View of Life? A scientific "theory" is a unifying concept with broad explanatory power and predictions that have been and continue to be tested by experiments and observations. Scientists continue to explore whether natural selection is the main mechanism of evolution or whether other factors have contributed to the evolutionary history of life.

■ INTERACTIVE QUESTION 22.4

Complete the following concept map that summarizes the main sources of evidence for evolution.



Word Roots

bio- = life; **geo-** = the Earth (*biogeography:* the study of the past and present distribution of species)
end- = within (*endemic:* a type of species that is found only in one region and nowhere else in the world)
homo- = like, resembling (*homology:* similarity in characteristics resulting from a shared ancestry)
paleo- = ancient (*paleontology:* the scientific study of fossils)
taxo- = arrange (*taxonomy:* the branch of biology concerned with naming and classifying the diverse forms of life)
vestigi- = trace (*vestigial organs:* structures of marginal, if any, importance to an organism, historical remnants of structures that had important functions in ancestors)

Structure Your Knowledge

1. Briefly state the main components of Darwin's theory of evolution.

Test Your Knowledge

MULTIPLE CHOICE: *Choose the one best answer.*

1. The classification of organisms into hierarchical groups is called
   a. the scale of nature.
   b. taxonomy.
   c. evolution.
   d. biogeography.
   e. natural selection.
2. The study of fossils is called
   a. homology.
   b. gradualism.
   c. paleontology.
   d. anthropology.
   e. biogeography.
3. To Cuvier, the differences in fossils from different strata were evidence for
   a. changes occurring as a result of cumulative but gradual processes.
   b. divine creation.
   c. evolution by natural selection.
   d. continental drift.
   e. local catastrophic events such as droughts or floods.
4. Darwin proposed that new species evolve from ancestral forms by
   a. the gradual accumulation of adaptations to changing or different environments.
   b. the inheritance of acquired adaptations to the environment.
   c. the struggle for limited resources.
   d. the accumulation of mutations.
   e. the exponential growth of populations.
5. The best description of natural selection is
   a. the survival of the fittest.
   b. the struggle for existence.
   c. the reproductive success of the members of a population best adapted to the environment.
   d. the overproduction of offspring in environments with limited natural resources.
   e. a change in the proportion of inheritable variations within a population.
6. The remnants of pelvic and leg bones in a snake
   a. are vestigial structures.
   b. show that lizards evolved from snakes.
   c. are homologous structures.
   d. provide evidence for inheritance of acquired characteristics.
   e. resulted from artificial selection.
7. The hypothesis that whales evolved from land-dwelling ancestors is supported by
   a. evidence from the biogeographic distribution of whales.
   b. molecular comparisons of whales, fish, and reptiles.
   c. historical accounts of walking whales.
   d. the ability of captive whales to be trained to walk.
   e. fossils of extinct whales found in Egypt and Pakistan that had small hind limbs.
8. Darwin's claim that all of life descended from a common ancestor may best be supported with evidence from
   a. the fossil record.
   b. comparative embryology.
   c. taxonomy.
   d. molecular biology.
   e. comparative anatomy.
9. The smallest unit that can evolve is
   a. a genome.
   b. an individual.
   c. a species.
   d. a population.
   e. a community.

10. Which of the following would *not* be considered part of the process of natural selection?
    a. Many of the variations among individuals in a population are heritable.
    b. More offspring are produced than are able to survive and reproduce.
    c. Individuals with traits best adapted to the environment are likely to leave more offspring.
    d. Many adaptive traits may be acquired during an individual's lifetime, helping that individual to evolve.
    e. Differential reproductive success leads to gradual change in a population.

11. When cytochrome *c* molecules are compared, yeasts and molds are found to differ by approximately 46 amino acids per 100 residues (amino acids making up a protein), whereas insects and vertebrates are found to differ by approximately 29 amino acids per 100 residues. What can one conclude from these data?
    a. Very little can be concluded unless the DNA sequence for the cytochrome *c* genes are compared.
    b. Yeasts evolved from molds, but vertebrates did not evolve from insects.
    c. Insects and vertebrates diverged from a common ancestor more recently than did yeasts and molds.
    d. Yeasts and molds diverged from a common ancestor more recently than did insects and vertebrates.
    e. The evolution of cytochrome *c* occurred more rapidly in yeasts and molds than in insects and vertebrates.

12. All of the following influenced Darwin as he synthesized the theory of evolution by natural selection *except*
    a. the biogeographic distribution of species such as the finches on the Galápagos Islands.
    b. Lyell's book, *Principles of Geology*, on the gradualness of geologic changes.
    c. Linnaeus's hierarchical classification of species, which could be interpreted as evidence of evolutionary relationships.
    d. examples of artificial selection that produce rapid changes in domesticated species.
    e. Mendel's paper in which he described his "laws of inheritance."

13. What might you conclude from the observation that the bones in your arm and hand are similar to the bones that make up a bat's wing?
    a. The bones in the bat's wing may be vestigial structures, no longer useful as "arm" bones.
    b. The bones in a bat's wing may be homologous to your arm and hand bones.
    c. Bats and humans evolved in the same geographic area.
    d. Bats lost their opposable digits during the course of evolution.
    e. Our ancestors could fly.

14. The best description of endemic species are species that are
    a. found only on islands.
    b. found in the same geographic area.
    c. found only on mainlands.
    d. found only in that location and nowhere else on Earth.
    e. disease causing and pesticide resistant.

15. Which of the following is an example of convergent evolution?
    a. the increase in size and age of sexual maturity of guppies transplanted to pools with killifish, predators that prey mainly on small guppies
    b. two very different plants that are found in different habitats, but evolved from a fairly recent common ancestor
    c. similarities between the marsupial sugar glider and the eutherian flying squirrel
    d. the remodeling of a vertebrate forelimb in the evolution of a bird wing
    e. the many different bill sizes and shapes of finches on the Galápagos Islands

16. Chimpanzees and humans share many of the same genes, indicating that most likely
    a. the two groups belong to the same species.
    b. the two groups belong to the same phylum.
    c. the two groups share a relatively recent common ancestor.
    d. humans evolved from chimpanzees.
    e. chimpanzees evolved from humans.