CHAPTER 17 DARWIN AND EVOLUTION

Chapter Outline

17.1 History of the Theory of Evolution

A. Darwin's Voyage
   1. In 1831, at the age of 22, Charles Darwin accepted a naturalist position aboard the ship HMS *Beagle* that began a voyage around the world; it provided Darwin with many observations.
   2. The pre-Darwinian world-view was different from the post-Darwinian world-view.
      a. Pre-Darwinian world-view was determined by deep-seated beliefs held to be intractable truths.
         1) The earth is young.
         2) Each species was specially created and did not change over time.
         3) Variations are imperfections varying from a perfectly-adapted creation.
         4) Observations are to substantiate the prevailing worldview.
      b. However, Darwin lived during a time of great change in scientific and social realms.
      c. Darwin's ideas were part of a larger change in thought already underway among biologists.

B. Mid-Eighteenth-Century Contributions
   1. Carolus Linnaeus and Taxonomy
      a. **Taxonomy** is the science of classifying organisms; *taxonomy* had been a main concern of biology.
      b. Carolus Linnaeus (1707–1778) was a Swedish naturalist in the field of taxonomy:
         1) Linnaeus developed a binomial system of nomenclature (two-part names for each species [e.g., *Homo sapiens*]).
         2) He developed a system of classification for all known plants.
         3) Like other taxonomists of his time, Linnaeus believed in the ideas of
            a) *special creation*—each species had an "ideal" structure and function; and
            b) *fixity of species*—each species had a place in the *scala naturae*, a sequential ladder of life.
      c. Linnaeus thought that classification should describe the fixed features of species and reveal God's divine plan.
      d. His ideas reflected the ideas of Plato and Aristotle: the ideal form can be deduced, and organisms can be arranged in order of increasing complexity.
      e. His later work with hybridization suggested species might change with time.
   2. Georges Louis Leclerc
      a. Georges Louis Leclerc, known by his title, Count Buffon (1707–1788), was a French naturalist.
      b. He wrote a 44-volume natural history of all known plants and animals.
      c. He also provided evidence of descent with modification.
      d. His writings speculated on: influences of the environment, migration, geographical isolation, and the struggle for existence.
      e. Buffon vacillated on whether he believed in evolutionary descent and he professed to believe in special creation and the fixity of species.
   3. Erasmus Darwin
      a. Erasmus Darwin (1731–1802) was Charles Darwin's grandfather.
      b. He was a physician and a naturalist whose writings on both botany and zoology contained many comments that suggested the possibility of common descent.
      c. He based his conclusions on
         1) changes undergone by animals during development,
         2) artificial selection by humans, and
         3) the presence of vestigial organs (organs that are believed to have been functional in an ancestor but are reduced and nonfunctional in a descendant).
      d. Erasmus Darwin offered no mechanism by which evolutionary descent might occur.

C. Late Eighteenth-Century Contributions
   1. Cuvier and Catastrophism
      a. George Cuvier (1769–1832), a distinguished French vertebrate zoologist, was the first to use comparative anatomy to develop a system of classifying animals.

b. He founded the science of *paleontology,* the study of fossils, and suggested that a single fossil bone was all he needed to deduce the entire anatomy of an animal.
c. To explain the fossil record, Cuvier proposed that a whole series of catastrophes (extinctions) and re-populations from other regions had occurred.
d. Cuvier was also a staunch advocate of special creation and fixity of species; this presented him with a serious problem when geological evidence of a particular region showed a succession of life forms in the earth's strata.
e. **Catastrophism** is the term applied to Cuvier's explanation of fossil history, the belief held by Cuvier that catastrophic extinctions occurred, after which repopulation of surviving species took place, giving an appearance of change through time.

2. Lamarck's and Acquired Characteristics
   a. Lamarck (1744–1829) was first to state that descent with modification occurs and that organisms become adapted to their environments.
   b. Lamarck was an invertebrate zoologist and held ideas different from Cuvier.
   c. Unfortunately, he saw "a desire for perfection" as inherent in all living things.
   d. **Inheritance of acquired characteristics** was the Lamarckian belief that organisms become adapted to their environment during their lifetime and pass on these adaptations to their offspring.
   e. Experiments fail to uphold Lamarck's inheritance of acquired characters; the molecular mechanism of inheritance shows phenotypic changes do not result in genetic changes that can be passed on to the next generation.

17.2 Darwin's Theory of Evolution

A. Darwin's Background
   1. His nature was too sensitive to pursue medicine; he attended divinity school at Cambridge.
   2. He attended biology and geology lectures and was tutored by the Reverend John Henslow.
   3. Henslow arranged his five-year trip on the HMS *Beagle*; Darwin was an observant student of nature.

B. Geology and Fossils
   1. His study of geology and fossils caused him to concur with Lyell that the observed massive geological changes were caused by slow, continuous processes.
      a. Darwin took Lyell's book on the voyage of the HMS *Beagle*.
      b. In his book *Principles of Geology*, Charles Lyell presented arguments to support a theory of geological change proposed by James Hutton.
      c. In contrast to catastrophists, Hutton proposed that the earth was subject to slow but continuous geological processes (e.g., erosion and uplifting) that occur at a uniform rate, a theory called **uniformitarianism**.
      d. The Argentina coast had raised beaches; he witnessed earthquakes raising the earth several feet.
      e. Marine shells occurred far inland and at great heights in the Andes.
      f. Fossils of huge sloths and armadillo-like animals suggested modern forms were descended from extinct forms with change over time; therefore species were not fixed.

C. Biogeography
   1. **Biogeography** is the study of the geographic distribution of life forms on earth.
   2. Patagonian hares replaced rabbits in the South American grasslands.
   3. The greater rhea found in the north was replaced by the lesser rhea in the south.
   4. Comparison of the animals of South America and the Galápagos Islands caused Darwin to conclude that adaptation to the environment can cause diversification, including origin of new species.
   5. The Galápagos Islands
      a. These volcanic islands off the South American coast had fewer types of organisms.
      b. Island species varied from the mainland species, and from island-to-island.
      c. Each island had a variation of tortoise; long and short necked tortoises correlated with different vegetation.
      d. Darwin's Finches
         1) Finches on the Galápagos Islands resembled a mainland finch but there were more types.
         2) Galápagos finch species varied by nesting site, beak size, and eating habits.
         3) One unusual finch used a twig or thorn to pry out insects, a job normally done by (missing) woodpeckers (Darwin never witnessed this finch behavior).
         4) The variation in finches posed questions to Darwin: did they descend from one mainland ancestor or did islands allow isolated populations to evolve independently, and could present-

day species have resulted from changes occurring in each isolated population?

D. Natural Selection and Adaptation
    1. Darwin decided that adaptations develop over time; he sought a mechanism by which adaptations might arise.
    2. **Natural selection** was proposed by both Alfred Russel Wallace and Darwin as a driving mechanism of evolution caused by environmental selection of organisms most fit to reproduce, resulting in *adaptation*.
    3. Because the environment is always changing, there is no perfectly-adapted organism.
    4. There are three preconditions for natural selection.
        a. The members of a population have random but heritable variations.
        b. In a population, many more individuals are produced each generation than the environment can support.
        c. Some individuals have adaptive characteristics that enable them to survive and reproduce better.
    5. There are two consequences of natural selection.
        a. An increasing proportion of individuals in succeeding generations will have the adaptive characteristics.
        b. The result of natural selection is a population adapted to its local environment.
    6. Natural selection can only utilize variations that are randomly provided; therefore there is no directedness or anticipation of future needs.
    7. Extinction occurs when previous adaptations are no longer suitable to a changed environment.

E. Organisms Have Variations
    1. In contrast to the previous worldview where imperfections were to be ignored, variations were essential in natural selection.
    2. Darwin suspected, but did not have today's evidence, that the occurrence of variation is completely random.
    3. New variations are as likely to be harmful as helpful.
    4. Variations that make adaptation possible are those that are passed on generation to generation.
    5. Darwin could not state the cause of variations because genetics was not yet established.

F. Organisms Struggle to Exist
    1. Darwin and Wallace both read an essay by Thomas Malthus, a socioeconomist.
    2. Malthus proposed that human populations outgrow food supply and death and famine were inevitable.
    3. Darwin applied this to all organisms; resources were not sufficient for all members to survive.
    4. Therefore, there is a constant struggle for existence; only certain members survive and reproduce.

G. Organisms Differ in Fitness
    1. Organisms whose traits enable them to reproduce to a greater degree have a greater *fitness*.
        a. **Fitness** is a measure of an organism's reproductive success.
        b. Black western diamondback rattlesnakes are more likely to survive on lava flows; lighter-colored rattlesnakes are more likely to survive on desert soil.
    2. Darwin noted that humans carry out **artificial selection.**
        a. Early humans likely selected wolf variants; consequently, desirable traits increase in frequency in subsequent generations and produced the varieties of domestic dogs.
        b. Many crop plant varieties can be traced to a single ancestor.
        c. In nature, interactions with the environment determine which members reproduce more.
        d. Evolution by artificial or natural selection occurs when more fit organisms reproduce and leave more offspring than the less fit.

H. Organisms Become Adapted
    1. An **adaptation** is a trait that helps an organism be more suited to its environment.
    2. Unrelated organisms living in the same environment often display similar characteristics.
    3. Because of differential reproduction, adaptive traits increase in each succeeding generation.

I. *On the Origin of Species* by Darwin
    1. After the HMS *Beagle* returned to England in 1836, Darwin waited over 20 years to publish.
    2. He used the time to test his hypothesis that life forms arose by descent from a common ancestor and that natural selection is a mechanism by which species can change and new species arise.
    3. Darwin was forced to publish *Origin of Species* after reading a similar hypothesis by Alfred Russel Wallace.

17.3 The Evidence of Evolution

A. Common Descent
    1. The hypothesis of common descent is supported by many lines of evidence.
    2. The more varied the evidence, the more certain it becomes.
    3. Darwin synthesized much of the current data but biochemical research was yet to come.

B. Fossils Evidence
    1. The **fossil record** is the history of life recorded by remains from the past.
    2. Fossils are at least 10,000 years old and include skeletons, shells, seeds, insects trapped in amber, and imprints of leaves.
    3. The fossil record traces history of life and allows us to study history of particular organisms.
    4. Fossil evidence supports the common descent hypothesis; fossils can be linked over time because they reveal a similarity in form, despite observed changes.
    5. Transitional forms reveal links between groups.
        a. *Archeopteryx* is an intermediate between reptiles and birds.
        b. *Eustheopteron* is an amphibious fish.
        c. *Seymouria* is a reptile-like amphibian.
        d. Therapsids were mammal-like reptiles.
    6. The fossil record allows us to trace the history of the modern-day horse *Equus*.
        a. Earliest fossils show an ancestral *Hyracotherium* the size of a dog, with cusped low-crowned molars, four toes on each front foot, three on each hind foot—all adaptations for forest living.
        b. When forests were replaced by grasslands, the intermediates were selected for durable grinding teeth, speed, etc. with an increase in size and decrease in toes.
        c. Living organisms resemble most recent fossils in the line of descent; underlying similarities allow us to trace a line of descent over time.

C. Biogeographical Evidence
    1. **Biogeography** studies the distribution of plants and animals worldwide.
    2. Distribution of organisms is explained by related forms evolving in one locale and spreading to other accessible areas.
        a. Darwin observed South America had no rabbits; he concluded rabbits originated elsewhere.
        b. Biogeography explains the abundance of finch species on the Galápagos Islands lacking on the mainland.
    3. Physical factors, such as the location of continents, determine where a population can spread.
        a. Cacti are restricted to North American deserts and euphorbia grow in African deserts.
        b. Marsupials arose when South America, Antarctica, and Australia were joined; Australia separated before placental mammals arose, so only marsupials diversified in Australia.

D. Anatomical Evidence
    1. Organisms have anatomical similarities when they are closely related because of common descent.
        a. **Homologous structures** in different organisms are inherited from a common ancestor.
        b. **Analogous structures** are inherited from unique ancestors and have come to resemble each other because they serve a similar function.
        c. Vertebrate forelimbs contain the same sets of bones organized in similar ways, despite their dissimilar functions.
    2. **Vestigial structures** are remains of a structure that was functional in some ancestors but is no longer functional in the organism in question.
        a. Most birds have well-developed wings; some bird species have reduced wings and do not fly.
        b. Humans have a tailbone but no tail.
        c. Presence of vestigial structures is explained by the common descent hypothesis; these are traces of an organism's evolutionary history.
    3. Embryological development reveals a unity of plan.
        a. During development, all vertebrates have a post-anal tail and paired pharyngeal pouches.
            1) In fishes and amphibian larvae, the pouches become gills.
            2) In humans, first pair of pouches becomes a cavity of middle ear and auditory tube; second pair becomes tonsils, while third and fourth pairs become thymus and parathyroid glands.
            3) The above features are explained if fishes are ancestral to other vertebrate groups.

E. Biochemical Evidence
    1. Almost all living organisms use the same basic biochemical molecules, e.g., DNA, ATP, and many identical or nearly identical enzymes.

2. Organisms utilize the same DNA triplet code and the same 20 amino acids in their proteins.
3. Many organisms share same introns and types of repeats, which is remarkable since there is no obvious functional reason why these components need to be so similar.
4. This is substantiated by the analysis of the degree of similarity in amino acids for cytochrome *c* among organisms.
5. These similarities can be explained by descent from a common ancestor.
6. Life's vast diversity has come about by only a slight difference in the same genes.

F. Because it is supported by so many lines of evidence, evolution is no longer considered a hypothesis.
1. Evolution is one of the great unifying theories of biology, similar in status to the germ theory of disease in medicine.
2. In science, **theory** is reserved for those conceptual schemes that are supported by a large number of observations or a large amount of experimental evidence and have not been found lacking.