I. Introduction
   A. Definition of Evolution
      1. simplest definition = change in the genetic composition of a population through time (over generations)
      2. also holds that all living species have arisen from pre-existing species through a natural process of change ("descent with modification")
   B. Microevolution Versus Macroevolution
      1. microevolution
         a. = genetic change in a population over time (this definition differs a bit from your textbook definition)
         b. can lead to speciation, the situation when a species has changed enough to be regarded as a new species
      2. macroevolution = large scale evolutionary changes
      3. note that the distinction between microevolution and macroevolution is blurred
         a. it is really a continuum (but don't confuse this idea of micro-macroevolutionary continuum with Darwinian gradualism)
         b. thus microevolution gives rise to new species and these new species continue to change and can become substantially different
         c. and over long enough periods of time microevolution can become macroevolution
         d. no characteristic of the genetic instruction set, nor any known mechanism for inheritance, nor any fundamental property of the living world, prohibits microevolution from becoming macroevolution
   C. Mechanisms of Evolutionary Change
      1. genetic change (mutation, chromosomal aberration, genetic recombination)
      2. chance events
      3. natural selection
   I. Historical Perspectives (*this information is not presented in your textbook*)
   A. Charles Darwin (1809-1882)
      1. English naturalist
      2. voyage on the HMS Beagle (1831-1836; see below) led him to his theory of evolution by natural selection that revolutionized the science of biology
      3. studied coral reefs and hypothesized on the development of coral atolls
      4. also made many lesser known contributions to the biological and geological sciences
      5. background
         a. from a wealthy family
         b. loved collecting living things
         c. but found schoolwork boring
         d. attempted to study medicine (in his father's footsteps), but gave it up
         e. studied at Christ's College, Cambridge
            1) intended to become a country parson
2) received a degree but was more interested in beetles than Scripture
3) college influences, however, were distinctly creationist
   a) previous Vice-Chancellor of Cambridge embraced Archbishop Ussher's claim that the Creation took place in the year 4004
   b) required reading = William Paley's *Natural Theology*, which argued that the evidence for design in nature was proof of God's hand in the Creation
   c) his two closest teachers believed in the biblical creation story
      1) botanist J.S. Henslow
      2) geologist Adam Sedgwick
   d) most scientists of the time believed in a creator that looked after every detail of the living world
4) Darwin himself claimed to originally believe in the fixity of species as per the Bible

B. Aristotle (384 - 322 B.C.E.; B.C.E. = Before the Common Era)
   1. may have been among the first Greek philosophers to distinguish explanations of nature that involve myth and the supernatural versus those that involve natural causes
   2. also known as the "Father of Marine Biology"
      a. collected and documented many types of marine life from around the Mediterranean
      b. established several marine biology field stations
   2. see in his writings an awareness for the distinction between homology and analogy (Figs. 22.3 & 22.4, p. 5507)
      a. homology refers to those features of related organisms that are modifications of the same basic structure, e.g., the wings of birds, human, arms, forelimbs of dogs, foreflippers of whales
      b. analogy refers to very different structures the exhibit the same function, e.g., bird wings and insect wings
   3. suggested that apes exhibit characteristics that were somewhat intermediate between human beings and other mammals
   4. viewed living things as organized into a continuum from simple organisms to the most complex (*scala naturae*) rather than as discrete, distinct species (although Aristotle's view would later become incorporated into Christian doctrine as a "Chain of Being")
   5. some of his writings suggested an understanding of natural selection
   6. however, Aristotle did not subscribe to the idea that species are transformed into different species over many generations (evolution)

C. William Paley (1743 - 1808)
   1. English clergyman
   2. published *Natural Theology: or, Evidences of the Existence and Attributes of the Deity Collected from the Appearances of Nature* in 1802
   3. argued that the existence of design in nature was proof for God's existence
   4. used the analogy of the watchmaker and the description of the eye to deduce his conclusions
   5. borrowed much of his info from the work of others rather than making his
own observations
6. Paley’s text was undoubtedly required reading throughout the 19th century
7. Darwin spoke with great respect of William Paley

D. Carolus Linneaus (1707 – 1778)
1. Latinized his name from Carl Von Linne
2. developed the basic structure of our present system of classification and nomenclature (Table 22.1, p. 514)
3. important consequence of Linneaus’ system
   a. the living world viewed as being stable and unchanging, able to be organized into clearly defined groups
   b. species regarded as fixed entities since their creation

E. Baron Georges Cuvier (1769 - 1832)
1. vertebrate anatomist and "Father of Paleontology"
2. studied layers of sedimentary rocks of the Paris Basin of Northern France
3. sedimentary rocks are usually the kinds of rocks in which fossils may be found
4. noted lower layers of rock contained fossils of species very different from present life (Fig. 22.2, p. 507)
5. proposed the concept of catastrophism to explain his observations (described below)
   a. layers of sedimentary rocks containing unique assemblages of fossil produced by separate catastrophes (e.g., major floods)
   b. following each catastrophe, the area was repopulated from areas not impacted by the catastrophe
   c. Cuvier suggested there were at least 7 such catastrophes responsible for the layers observed in the Paris basin
   d. later catastrophists hypothesized that there had been 30+ such catastrophes
   e. catastrophism appealed to theologians and young-earth creationists, because it offered a mechanism for rapidly shaping the Earth over the short time scale demanded by a literal interpretation of the Bible
   f. some catastrophists and theologians viewed catastrophism as providing validity for the biblical flood
6. Cuvier also important in the development of the geologic time scale
7. present evidence for the disconcerting view that some species had become extinct
8. vehemently rejected the idea that species could evolve

F. James Hutton (1726 - 1797)
1. developed the rock cycle concept to explain the origin of most geologic features of the Earth
   a. igneous rocks: primary rocks formed as lava or magma cools and solidifies
   b. metamorphic rocks: rocks that have been altered by high pressure & temperature (without re-melting)
   c. sedimentary rocks: rocks formed by the cementing (lithification) together of small grains resulting from the erosion of other rocks
2. suggested that because of destructive erosional processes that "we find no vestige of a beginning and no prospect of an end" to the Earth; thus developed concept of "deep time"

3. proposed the concept that the Earth has been shaped by the same processes that we presently observe, a concept often referred to as uniformitarianism (Hutton did not use this term; it was coined later, then championed by Charles Lyell)

4. Hutton's view led to a gradualistic view (gradualism) of the processes shaping the Earth, in contrast to the catastrophist point of view

G. Charles Lyell (1797 - 1875)
1. used Hutton's rock cycle and principle of uniformitarianism to promote gradualism, the idea that change proceeds so slowly as to be practically imperceptible
2. measured rates of erosion and deposition of sediments along with the thicknesses of sedimentary deposits and rock layers
3. from these measurements he estimated that the Earth was at least millions of years old
4. had a tremendous impact upon Charles Darwin's development of the theory of evolution by natural selection because long time periods were required by Darwin's gradualistic view
5. note: Lyell originally rejected evolution, but later became one of Darwin's supporters
6. note: the use of the term "uniformitarianism" is unfortunate since many assumed it implied all geologic processes operate gradually; rather it may also include the recognition of catastrophic events, such as major volcanic eruptions & collisions with large object from space, which are observable events, as also exerting an influence upon the geologic structure of the Earth's surface

H. Jean-Baptiste Lamarck (1744 - 1829)
1. presented evidence that fossils were the remains of extinct animals
2. occurrence of fossils suggested Lamarck that profound changes had taken place during the history of life on earth
3. proposed the hypothesis of evolution by the inheritance of acquired characteristics
   a. use and disuse
   b. species change through time through transformation (acquired adaptations)
   c. acquired adaptations are passed on to offspring
   d. species strive to achieve perfection
4. Lamarck's evolution was like a "ladder" as opposed to Darwin's "tree"
   a. each species with its own origin and separate lineage
   b. in contrast, Darwin suggested that related species shared a common ancestor

I. Voyage of the HMS Beagle
1. Darwin was given an opportunity (via Henslow, Darwin's botany teacher at Christ's College) to be the Captain's personal gentleman companion
2. Darwin was not hired on as the naturalist, but the original naturalist and Darwin had some disagreements and the original naturalist left the ship early on

3. route of the voyage
   a. left England for South America
   b. passed Canary and Cape Verde Islands in Atlantic
   c. cruised along the coast of South America stopping at various ports
   d. rounded the southern tip of South America and traveled up the Pacific coast of South America
   e. stopped at the Galapagos Islands
   f. traveled across the South Pacific to Australia
   g. rounded the horn of Africa and entered the Atlantic
   h. traveled across Atlantic to South America again
   i. return to Great Britain

3. described and collected many new specimens of living things

4. collected fossils that were clearly related to living species in collection area

5. the turning point, the Galapagos Islands
   a. describes observations at the Galapagos as the "origin of all my views"
   b. these islands = a cluster of small volcanic islands about 580 miles from South American mainland
   c. recent in geologic history (formed approx. 1 million years ago
   d. observations of unique species on these island left a significant impression upon Darwin
   e. compared flora and fauna of Galapagos to those of Cape Verde Islands in the Atlantic
      1) Cape Verde & Galapagos with similar topography and climate
      2) yet flora & fauna were very different
         a) Cape Verde with flora and fauna reminiscent of nearby African flora and fauna
         b) Galapagos with flora and fauna reminiscent of nearby South American flora and fauna
   f. also compared different species on different islands of the Galapagos
      1) each island with its own collection of unique species that were similar yet different from nearby islands
      2) Darwin began to suspect
         a) Galapagos life originated in South America
         b) but once in Galapagos, different populations took different directions, becoming distinct from each other as distinct species
         c) in other words, species did not seem immutable to Darwin anymore
         d) but he could not explain the driving force behind such change in species

J. After the Voyage
   1. immediately published *The Voyage of the Beagle* which was a literary
success
2. suspicions regarding Galapagos mocking birds representing distinct species confirmed by an ornithologist
3. read an essay by Reverend Thomas Malthus (1766 - 1834) in 1838
   a. essay dealt with population growth
   b. Malthus recognized that natural & human populations tend to increase beyond the capacity of the environment to support them
   c. this essay helped Darwin develop the idea of natural selection as the mechanism of evolutionary change

II. Darwin's Theories of Evolution (the textbook’s presentation differs a bit from what was presented in lecture and here)
   A. Five Theories of Evolution
      1. based upon interpretation of Darwin's writings by biologist Ernst Mayr
      2. Darwin's Origin of Species actually present five independent theories of evolution
      3. these theories compatible and actually complement each other
      4. refutation of one of these would not necessarily refute the others
      5. each theory with its own set of evidence
      6. each theory deals with a different aspect of evolutionary theory
      7. theories
         a. perpetual change
         b. common descent
         c. multiplication of species
         d. gradualism
         e. natural selection
   B. Descriptions and Evidence for These Five Theories
      1. perpetual change
         a. description
            1) the living world is neither constant nor perpetually cycling, but steadily changing
            2) extant species are the results of a natural process of change, never to return to the original starting stages
         b. main evidence = the fossil record
            1) definition of a fossil
               a) evidence for past life
               b) most fossils = the preserved hard parts (e.g., skeletons) of living things (Fig. 22.1, p. 506)
               c) occasionally, but rarely, soft body parts preserved as fossils
               d) thus fossil record biased toward preserving the remains of animals and plants with hard parts
            2) interpreting the fossil record
               a) using the principle of superposition, can infer which fossils are oldest in a series of undisturbed sedimentary rocks (Fig. 22.2, p. 507)
               b) record clearly demonstrates that in the past species existed that no longer exist and that present species are not represented far
back into the past

c) often see progression of fossil forms leading to present day species
   a) evolution of the horse
   b) modern rhinoceroses & tapirs from a common ancestor
   c) birds from dinosaurs
   d) human evolution

d) also see fossil intermediates between major groups
   a) fossils of ancestors to amphibians that are intermediate between fish and amphibians
   b) Archaeopteryx intermediate between birds and dinosaurs
   c) cynodonts (mammal-like reptiles), transitional between ancient stem reptiles and earliest mammals
   d) fossil whales with hind limbs

3) gaps in the fossil record
   a) while many intermediates are represented in the fossil record, many expected intermediates are not represented or have not yet been found
   b) explanations (probably all three involved)
      1) conditions for preservation of remains as fossils are rare
      2) many transitions probably occurred in small isolated populations, thus chances of finding their fossil remains remote
      3) many transitions probably occurred during relative short periods of time, thus chances of finding their fossil remains remote (punctuated equilibrium)
   c) despite the gaps, the transitional sequences that do exist constitute powerful evidence for evolution

2. common descent
   a. description
      1) members of a taxonomic group (e.g., vertebrates) have all descended from a common, more generalized ancestor (e.g., ancestral fish-like vertebrate)
      2) theory extended to include the idea that all extant species have ultimately descended from a common ancestor that lived sometime in the past
      3) consequence: evolutionary relationships may be illustrated as an evolutionary (phylogenetic) tree (Fig. 22.9, p. 511)

   b. evidence
      1) morphological homology
         a) homologous structures are structures in different animals that are constructed of the same basic components (both embryologically as well as structurally) but often modified in some way as an adaptation for an alternative function (variations upon the same body plan)
         b) example of vertebrate forelimbs (Fig. 22.3, p. 507)
c) vestigial structures
   1) =structures that appear to serve no useful functions to their bearers
   2) examples
      a) pelvic elements of modern whales
      b) pelvic elements of snakes
      c) vestigial toe elements in horses
      d) tailbone (coccyx) in humans
      e) appendix in humans

d) contrast homology with analogy (Fig. 22.4, p. 507)

2) comparative development (developmental homology) Fig. 22.5, p. 508
   a) similarities in developmental histories of different animals suggests relatedness
   b) examples
      1) pharyngeal gill pouches and aortic arches in air-breathing mammals
      2) post-anal tail in human development
      3) hind limb buds in whale development
      4) lateral toes in horse development

3) genetic relatedness (molecular homology)
   a) if related species are indeed descendants of a common ancestral species then their genetic codes should be similar
   b) more distantly related species have greater differences in their DNA or corresponding proteins
   c) differences in the DNA result from the accumulation of mutations after divergence from common ancestor
   d) example of chimpanzees and human being
      1) genetic relatedness between humans and chimpanzees is greater than 98%
      2) chimpanzees are genetically more similar to humans than they are to other apes such as orangutans
      3) many proteins (e.g., hemoglobin) of both humans and chimps have identical amino acid sequences

3. multiplication of species
   a. description: species arise from pre-existing species through a splitting and alteration process; "splitting" leads to reproductively isolated populations that become distinct from one another, ultimately becoming distinct species (adaptive radiation)
   b. mechanisms for reproductive isolation
   c. evidence: island biogeography
      1) many island groups with their own unique assemblage of species
      2) most reasonable explanation for patterns observed: present species derived from relatively few colonizers that exhibited adaptive radiation
      3) examples
a) Galapagos finches, tortoises, & mockingbirds  
b) Hawaiian honeycreepers, silverswords, cave crickets & fruit flies  
4) biogeography often supported by morphological, biochemical, and fossil evidence

4. gradualism
   a. description: evolutionary change involves the accumulation of many small incremental changes over very long periods of time
   b. contrast gradualism with punctuated equilibrium
      1) gradualism: evolutionary change is a continuous, almost imperceptible process from one generation to the next
      2) punctuated equilibrium: evolutionary change takes place in spurts followed by long periods of little change
   c. evidence for gradualism
      1) direct observations of rapid change in species during human life spans extremely rare (but not completely lacking) - Darwin concluded from this observation that evolution must proceed exceptionally slowly
      2) careful examination has demonstrated numerous examples of gradualism
      3) but fossil record also illustrates punctuated equilibrium as well

5. natural selection
   a. Darwin's mechanism for how evolutionary change takes place
   b. Darwin developed the theory using inductive reasoning starting with observations and drawing conclusions
   c. form of the theory
      1) observation 1: living things generally produce more offspring than is necessary merely to replace the parents
      2) observation 2: natural populations tend to remain constant in size
      3) conclusion 1: not all individuals survive; or they fail to reproduce
      4) observation 3: within a population, individuals exhibit variation in their characteristics, that is no two individuals are exactly alike
      5) observation 4: at least some of this variation is heritable
      6) conclusion 2: some organisms exhibit heritable characteristics that make them more likely to survive and produce offspring
      7) conclusion 3: those individuals with the most favorable (adaptive) characteristics will contribute greater numbers of offspring with the same favorable characteristics to the succeeding generation
      8) conclusion 4: thus, over time, the population changes in its genetic composition
      9) conclusion 5: through the accumulation of genetic change over many generations, a species may change substantially, perhaps being transformed eventually into a new species
   d. evidence for natural selection
      1) artificial selection of domesticated animals
2) beak depth in Galapagos finches
3) peppered moths in England during the Industrial Revolution
4) pesticide resistance in insects
5) antibiotic resistance in pathogenic bacteria
6) sickle cell anemia in humans
e. important things to note
1) theory deals with change within a population over time, not within individuals
2) theory does not specify that a new species will definitely occur
3) theory does not explain source of new genetic traits upon which natural selection would act
4) theory does provide an experimentally testable mechanism for change in a population
5) natural selection acts as a sorting mechanism, selecting for individuals with most adaptive characteristics
6) natural selection is not a random process

TEXT PAGES COVERED
503-512; 514

VOCABULARY

- evolution
- microevolution
- macroevolution
- speciation
- fossil
- gradualism
- perpetual change
- common descent
- multiplication of species
- natural selection
- homologous structure
- vestigial structure
- uniformitarianism
- homology
- analogy
- scala naturae
- catastrophism
- rock cycle
- fossil
- superposition

STUDY QUESTIONS

1. Be able to describe the influence of the following individuals on the development of evolutionary theory: Aristotle, Linnaeus, Paley, Cuvier, Hutton, Lyell, Lamarck, and Malthus.

2. What kinds of observations led Darwin to the conclusion that species changed through time?

3. According to Ernst Mayr, Darwin's theory of evolution really consisted of five distinct theories: perpetual change, common descent, multiplication of species, natural selection, and gradualism. Define each of these theories. What evidence supports each of these theories?

4. Explain natural selection in terms of observations and the conclusions drawn from these observations.

5. Discuss the lines of evidence supporting evolution and natural selection: the fossil record, morphological homology, comparative development, genetics, island
biogeography of species, and actual observations of change.

6. What is the significance of gaps in the fossil record? What possible explanations, consistent with evolutionary theory, are there for these gaps? Are there any examples of intermediate fossil forms?

7. In spite of the tremendous success and acceptance of evolutionary theory, what aspects of evolutionary theory could not be addressed adequately by Darwin?