

19

Descent with Modification



Endless Forms Most Beautiful



- Lepidopteran insects (moths and butterflies) have many features in common including a juvenile feeding stage called a caterpillar
- Lepidopteran species also have many features that are distinct from each other in both the caterpillar and adult forms

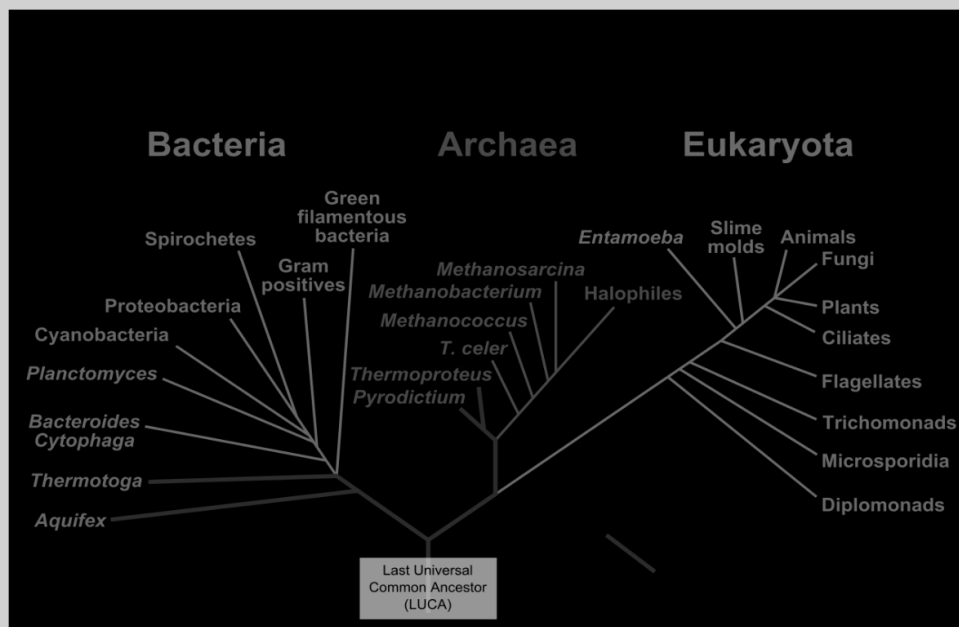


- Lepidopterans illustrate three key observations about life
 - The fit between organisms and their environment
 - The shared characteristics (unity) of life
 - The diversity of life



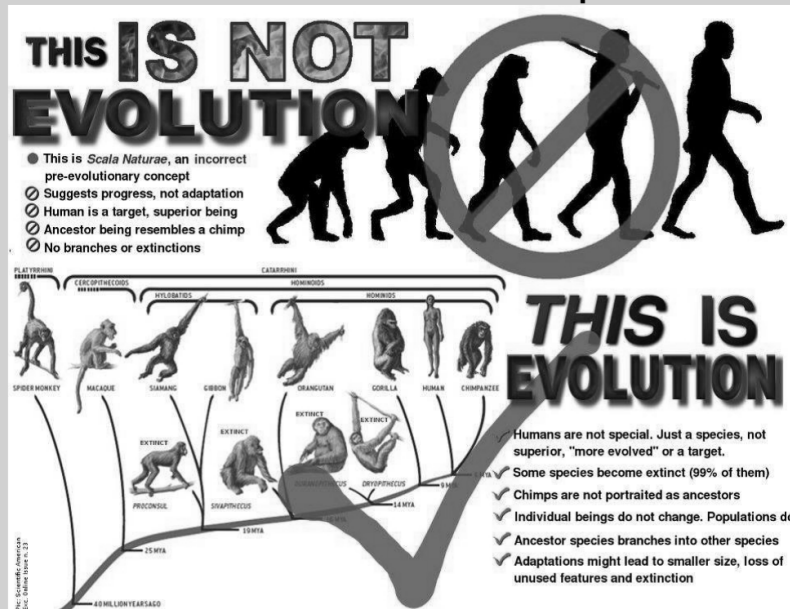
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- A new era of biology began in 1859 when Charles Darwin published *On the Origin of Species*
 - *On the Origin of Species* focused biologists' attention on the great diversity of organisms



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- Darwin noted that current species are descendants of ancestral species
- **Evolution** can be defined by Darwin's phrase *descent with modification*
- Evolution can be viewed as both a pattern and a process




Concept 19.1: The Darwinian revolution challenged traditional views of a young Earth inhabited by unchanging species

- Darwin's revolutionary ideas had deep historical roots

Scientists Who Influenced Darwin




James Hutton (1726-1797)




Jean-Baptiste de Lamarck (1744-1829)

THOMAS MALTHUS



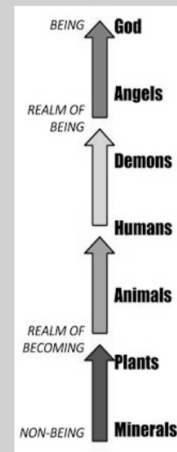
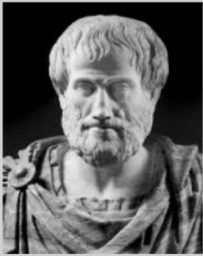
- 230 years ago (1798) Thomas Malthus published *An Essay on the Principle of Population*.
- Stated the human population grows geometrically (2, 4, 8, 16, 32, 64...) while the resources to support it grow arithmetically (1, 2, 3, 4, 5, 6...).



Charles Lyell (1797-1875)

Scala Naturae and Classification of Species

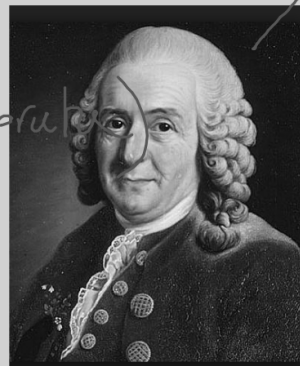
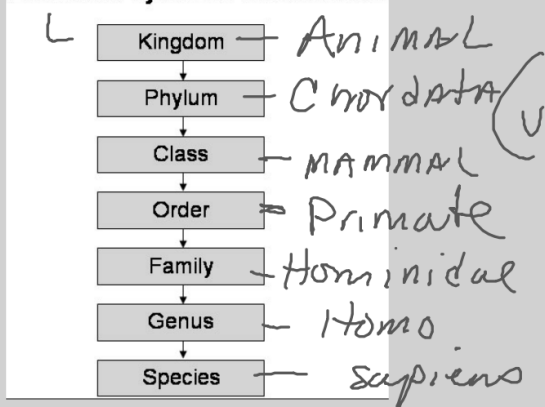
- The Greek philosopher Aristotle viewed species as fixed and arranged them on a *scala naturae*
- This view was consistent with the Old Testament, which holds that species were individually designed by God and therefore perfect



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- Carolus Linnaeus was the founder of taxonomy, the branch of biology that organizes species into a nested classification system of increasingly general categories
- He also developed the binomial format for naming species (for example, *Homo sapiens*)
- Linnaeus ascribed the resemblance among species to the pattern of creation rather than evolution

Linnaeus's System of Classification

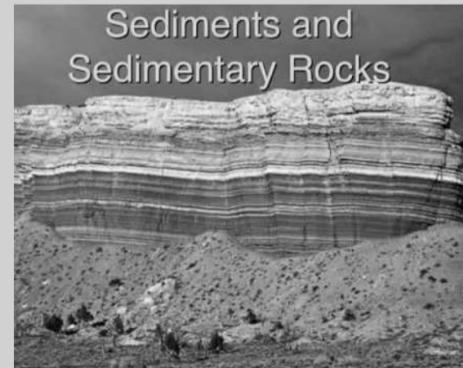
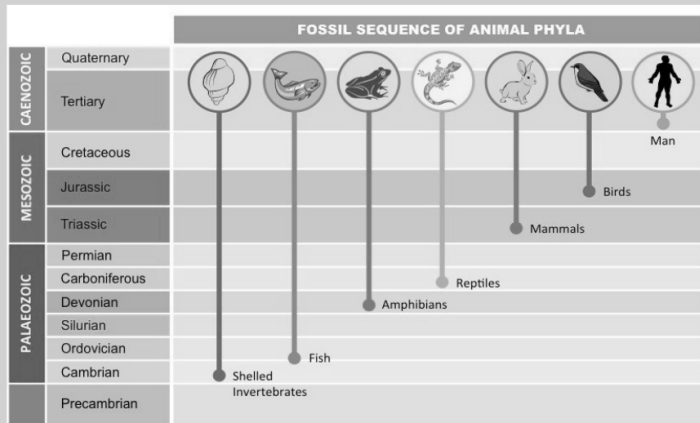


Homo sapiens

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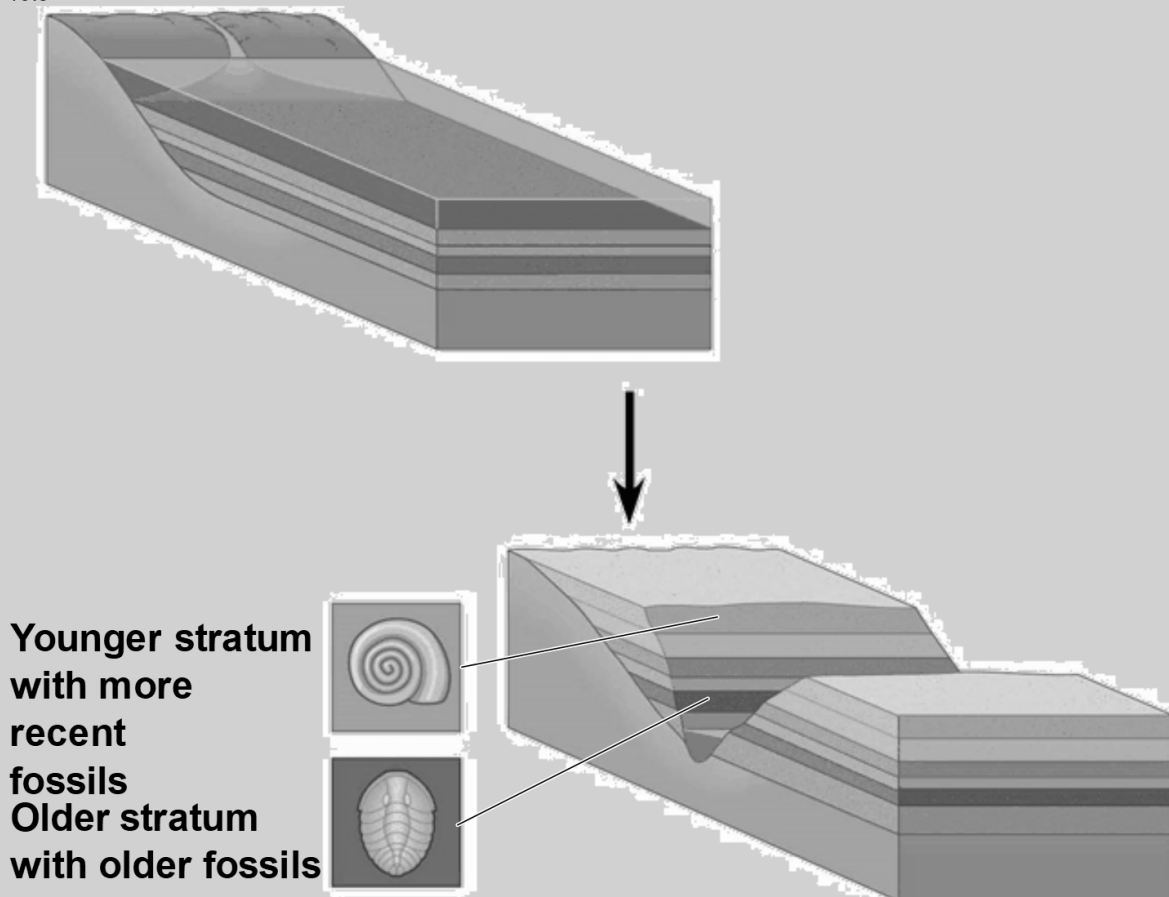
Ideas About Change over Time

- 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**



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Figure 19.3



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- **Paleontology**, the study of fossils, was largely developed by French scientist Georges Cuvier
- Cuvier speculated that each boundary between strata represents a catastrophe that destroyed many species

Theory of Catastrophism

- In the early 19th Century, Georges Cuvier of France supported catastrophism as the way to explain the **patterns of extinction and succession that were observed in the animal fossil record**.
- However, Cuvier felt that there had been **long periods of stability between periods of abrupt changes** in Earth's history, and that the Earth was **millions of years old**.



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- Geologists James Hutton and Charles Lyell perceived that changes in Earth's surface can result from slow, continuous actions still operating today
- Lyell further proposed that the mechanisms of change are constant over time
- This view strongly influenced Darwin's thinking

The Principle of Uniformitarianism

- Scientist James Hutton
 - author of *Theory of the Earth*
 - proposed that geologic processes such as erosion and deposition *do not* change over time.
- **Uniformitarianism**
 - the idea that the same geologic processes shaping the Earth today have been at work throughout Earth's history.



Uniformitarianism According to Charles Lyell

- **Charles Lyell** (1797-1875)
- Espoused extreme form of uniformitarianism by denying catastrophism (*Principles of Geology*)
- **Three aspects hold up today**
- Geological processes of past are the same as today
- Stratigraphy serves to reconstruct history of the earth
- Immense amount of time necessary for geological processes to effect change in the landscape
- Age of earth: The current estimate is 4.5 billion years



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Lamarck's Hypothesis of Evolution

- Lamarck hypothesized that species evolve through use and disuse of body parts and the inheritance of acquired characteristics
- The mechanisms he proposed are unsupported by evidence



Theory of Inheritance of Acquired Characteristics

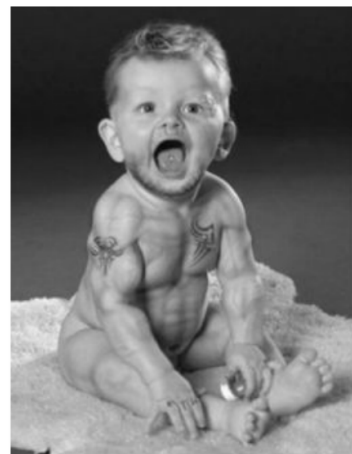
- Altered behavior leads to greater or lesser use of a given structure or organ,
- The use of the structure or organ will cause it to increase in size, whereas disuse cause it to shrink or disappear.
- The acquired traits would be inherited in the next generation.
- Changes in physical anatomy occur to meet the organism's needs.

To receive from an ancestor

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Why was Lamarck Wrong?

1.



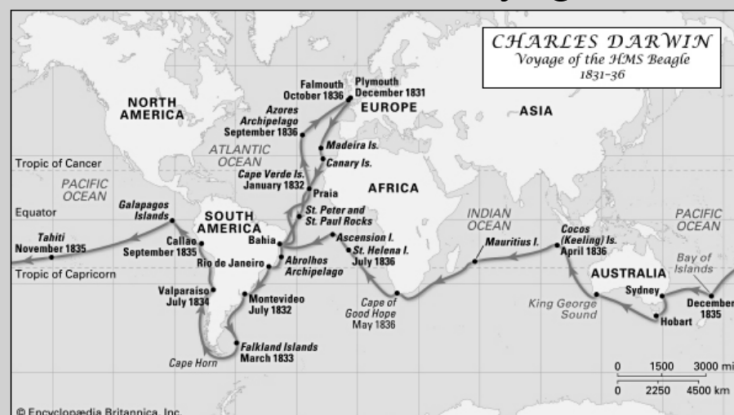
Concept 19.2: Descent with modification by natural selection explains the adaptations of organisms and the unity and diversity of life

- Some doubt about the permanence of species preceded Darwin's ideas

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Darwin's Research

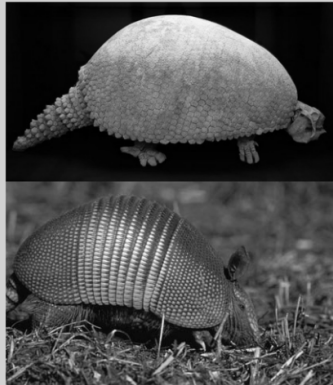
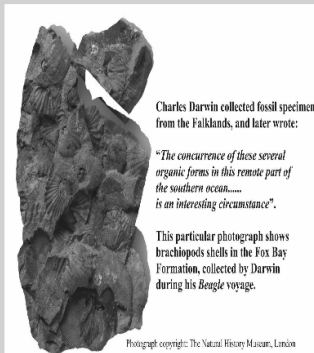
- As a boy and into adulthood, Charles Darwin had a consuming interest in nature
- Darwin first studied medicine (unsuccessfully) and then theology at Cambridge University
- After graduating, he took an unpaid position as naturalist and companion to Captain Robert FitzRoy for a five-year around-the-world voyage on the *Beagle*



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The Voyage of the Beagle

- During his travels on the *Beagle*, Darwin collected specimens of South American plants and animals
- He observed that fossils resembled living species from the same region, and living species resembled other species from nearby regions



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- Darwin was influenced by Lyell's *Principles of Geology* and thought that Earth was more than 6,000 years old
- He observed the uplift of rocks on the coast of Chile following an earthquake and inferred that similar processes could explain the fossils of ocean organisms he found in the Andes

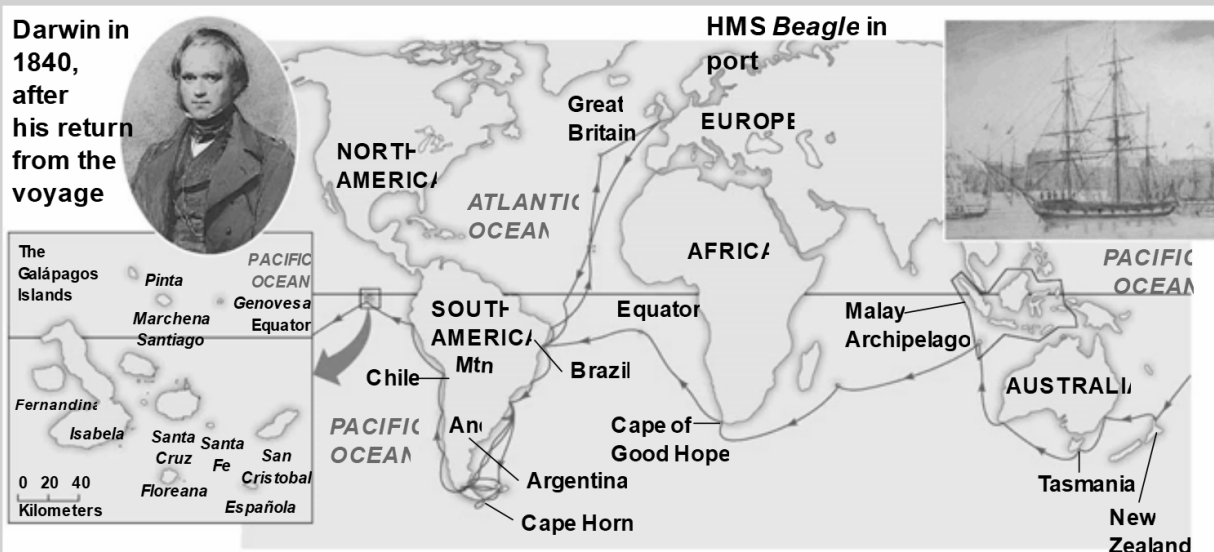
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- His interest in geographic distribution of species was kindled by a stop at the Galápagos Islands west of South America
- He hypothesized that species from South America had colonized the Galápagos and speciated on the islands



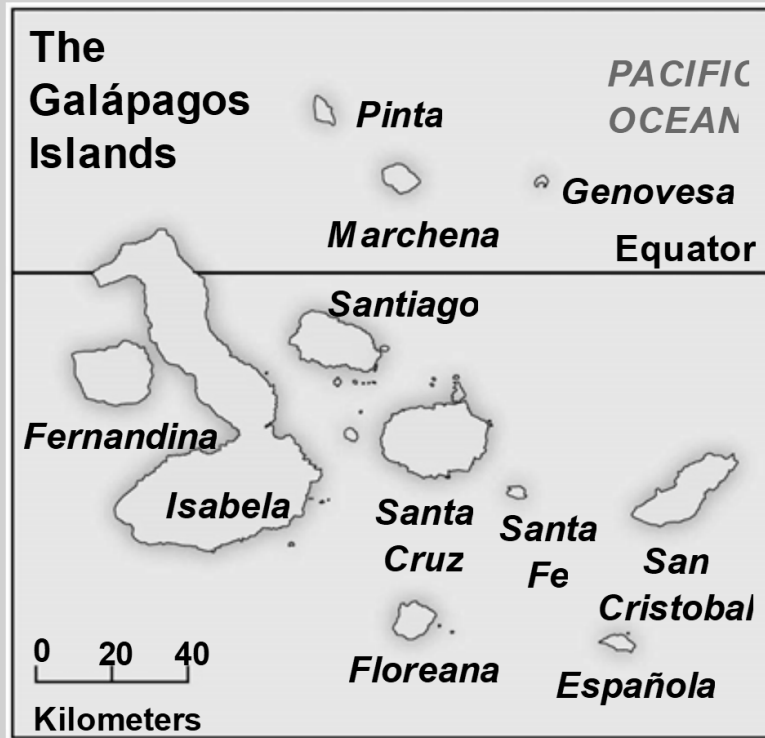
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Figure 19.5



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Figure 19.5-3



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Darwin's Focus on Adaptation

- Darwin perceived **adaptation** to the environment and the origin of new species as closely related processes
- Biologists have since concluded that the diverse group of Galápagos finches arose from an ancestral form by the gradual accumulation of adaptations to different environments

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Figure 19.6



(a) Cactus-eater



(c) Insect-eater



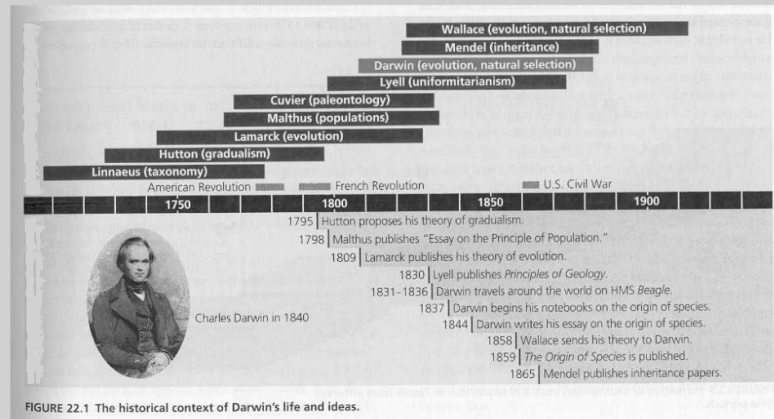
(b) Seed-eater

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- In 1844, Darwin wrote an essay on natural selection as the mechanism of descent with modification but did not introduce his theory publicly
- **Natural selection** is a process in which individuals with favorable inherited traits are more likely to survive and reproduce

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- In June 1858, Darwin received a manuscript from Alfred Russell Wallace, who had developed a theory of natural selection similar to Darwin's
- In July 1958, Lyell presented Wallace and Darwin's work together to the Linnean Society of London
- Darwin quickly finished *On the Origin of Species* and published it the next year



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Ideas from *On the Origin of Species*

- Darwin explained three broad observations about life
 - The unity of life
 - The diversity of life
 - The match between organisms and their environment

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Descent with Modification

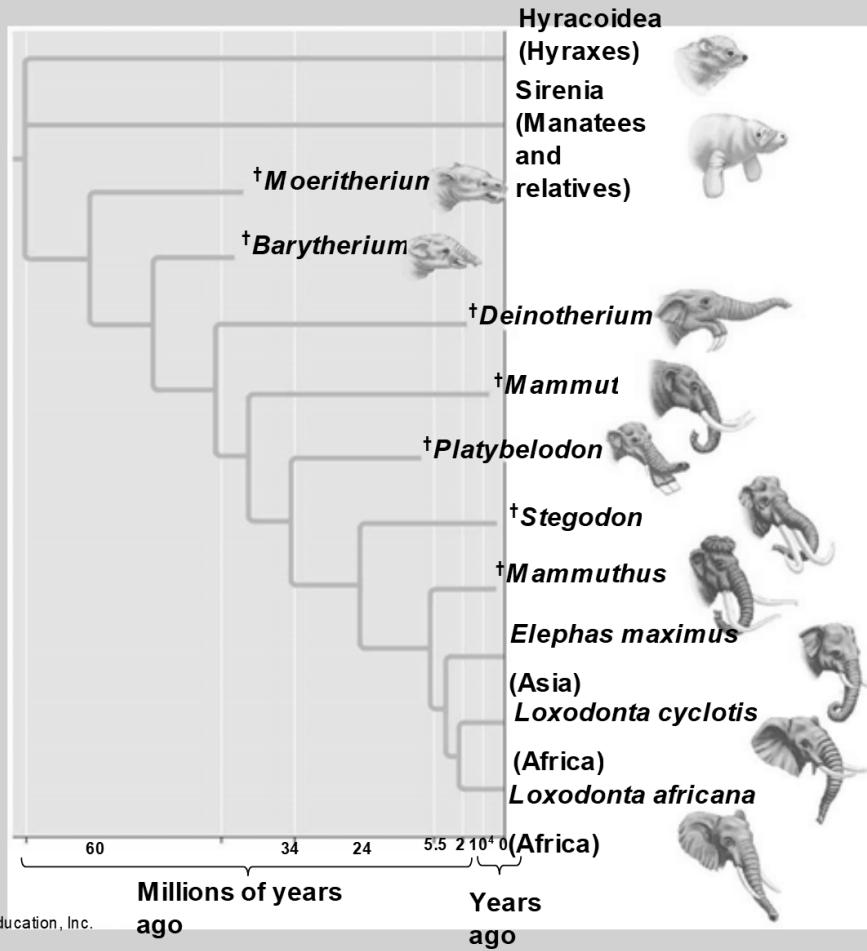
- Darwin never used the word *evolution* in the first edition of *On the Origin of Species*
- The phrase *descent with modification* summarized Darwin's perception of the unity of life
- The phrase refers to the view that all organisms are related through descent from an ancestor that lived in the remote past

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- In the Darwinian view, the history of life is like a tree with branches representing life's diversity
- Fossils of extinct species help to "fill in" the morphological gaps between present-day groups

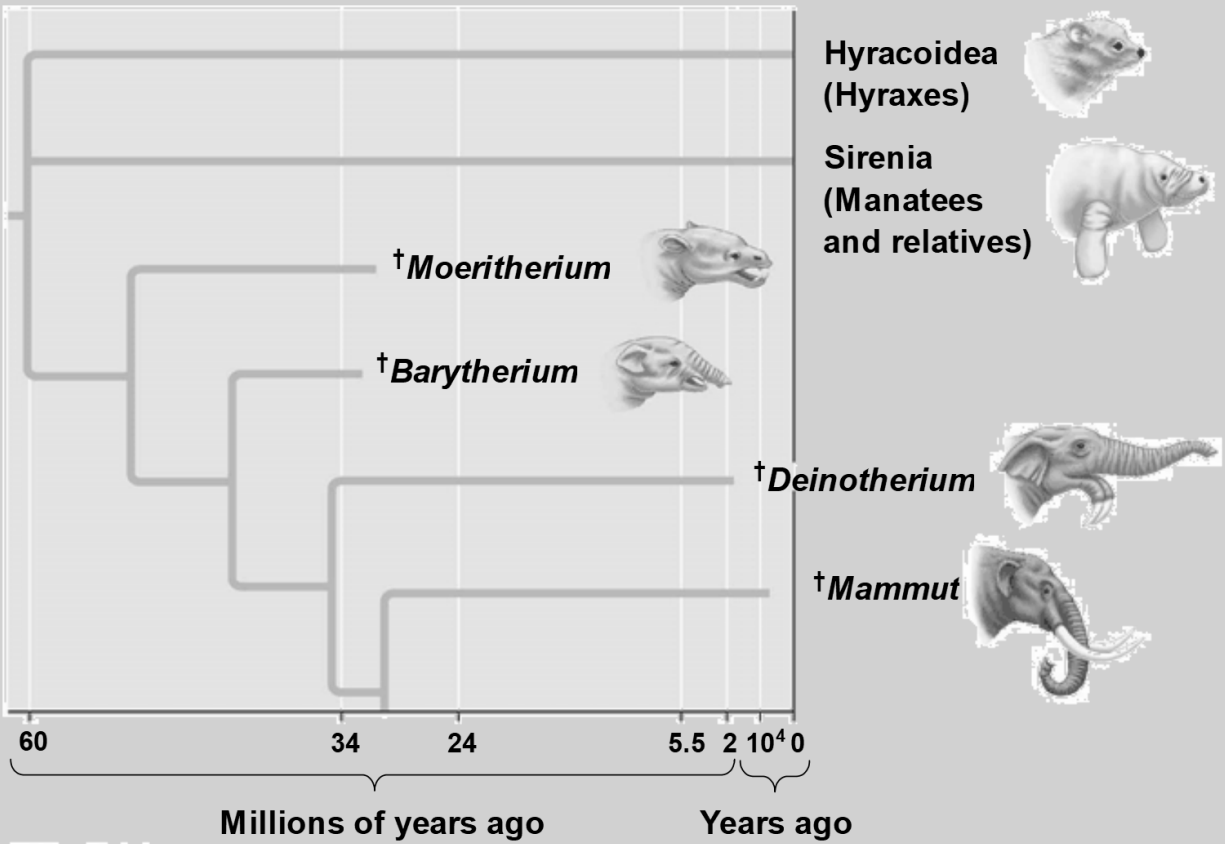
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Figure 19.9



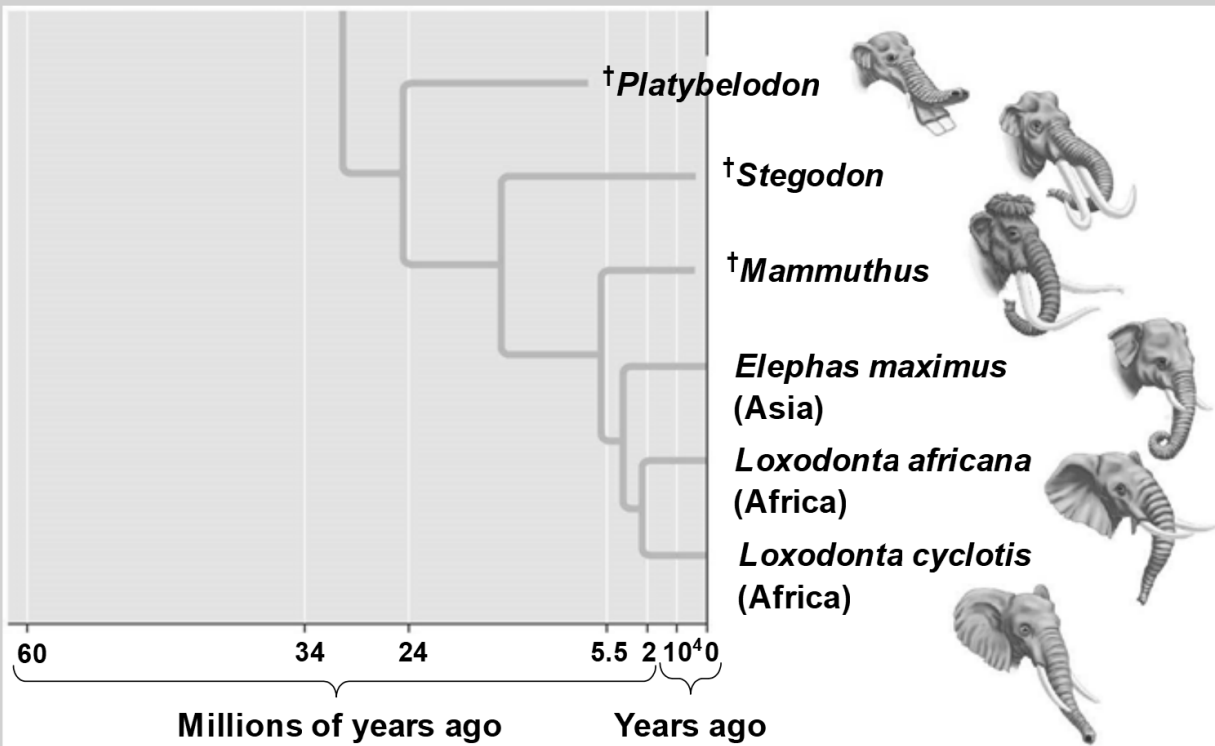
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Figure 19.9-1



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Figure 19.9-2



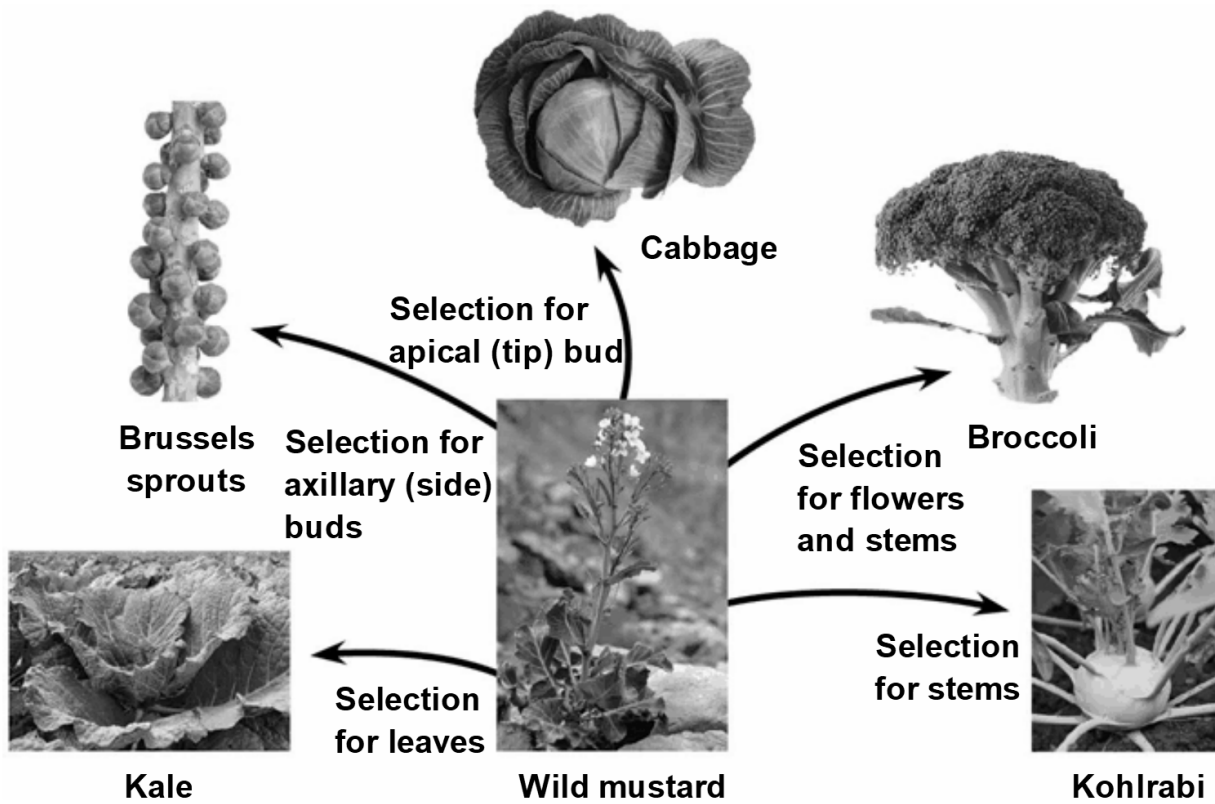
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Artificial Selection, Natural Selection, and Adaptation

- Darwin noted that humans have modified other species by selecting and breeding individuals with desired traits, a process called **artificial selection**
- Darwin argued that a similar process occurs in nature

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Figure 19.10



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- Darwin drew two inferences from two observations
- **Observation #1:** Members of a population often vary in their inherited traits



1. Variation exists within every population

1. Ladybugs have different spots

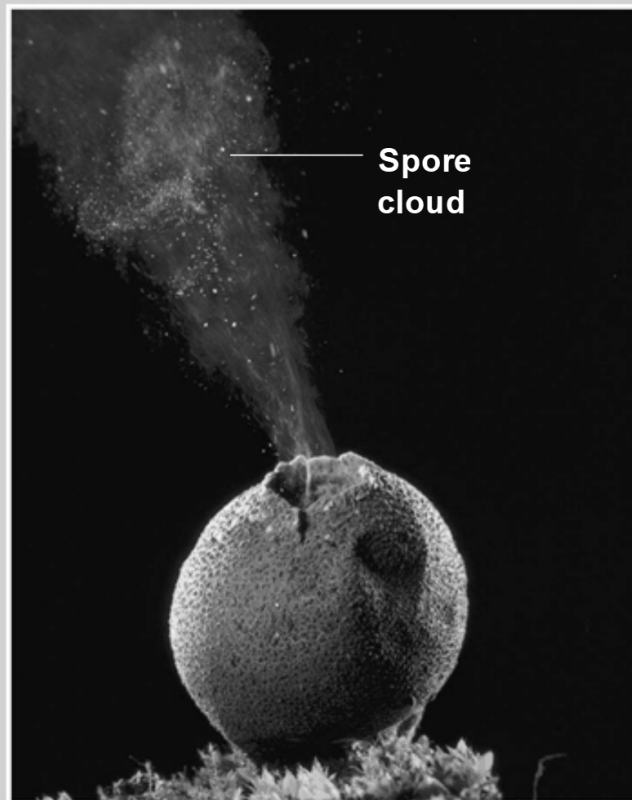
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- **Observation #2:** All species can produce more offspring than the environment can support, and many of these offspring fail to survive and reproduce



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Figure 19.12



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- **Inference #1:** Individuals whose inherited traits give them a higher probability of surviving and reproducing in a given environment tend to leave more offspring than other individuals

- **Inference #2:** This unequal ability of individuals to survive and reproduce will lead to the accumulation of favorable traits in the population over generations

- Darwin was influenced by Thomas Malthus, who noted the potential for human population to increase faster than food supplies and other resources
- If some heritable traits are advantageous, these will accumulate in a population over time, and this will increase the frequency of individuals with these traits
- This process explains the match between organisms and their environment

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Key Features of Natural Selection

- Individuals with certain heritable traits survive and reproduce at a higher rate than other individuals
- Over time, natural selection increases the frequency of adaptations that are favorable in a given environment
- If an environment changes over time, natural selection may result in adaptation to these new conditions and may give rise to new species

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- Note that individuals do not evolve; populations evolve over time
- Natural selection can only increase or decrease heritable traits that vary in a population
- The traits that are adaptive will vary with different environments

N.S. • Heritable traits must be involved in allowing for survival +/or reproductive success

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Concept 19.3: Evolution is supported by an overwhelming amount of scientific evidence

- New discoveries continue to fill the gaps identified by Darwin in *On the Origin of Species*
- There are four types of data that document the pattern of evolution
 - Direct observations
 - Homology
 - The fossil record
 - Biogeography

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Direct Observations of Evolutionary Change

- Two examples provide evidence for natural selection: natural selection in response to introduced species and the evolution of drug-resistant bacteria

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Natural Selection in Response to Introduced Species

- Soapberry bugs use their “beak” to feed on seeds within fruits
 - Soapberry bugs feed most effectively when their beak length is similar to the depth of the seeds within the fruit
 - In southern Florida, soapberry bugs feed on the larger fruit of balloon vines; they have longer beaks
 - In central Florida, they feed on the smaller fruit of introduced goldenrain trees; they have shorter beaks

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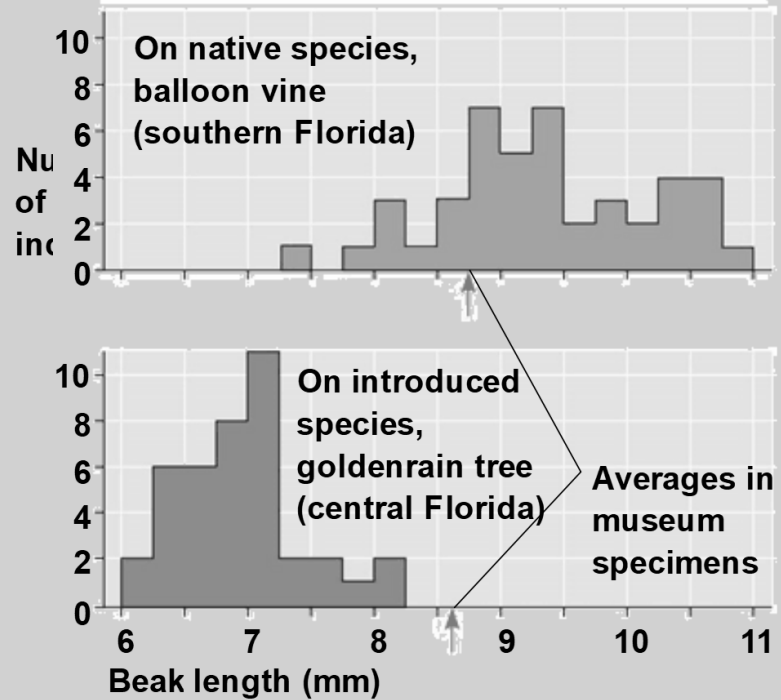
Figure 19.14

Field Study



Soapberry bug with beak inserted in balloon vine fruit

Results



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- Correlation between fruit size and beak size has
- also been observed in other locations
- In all cases, beak size has evolved in populations that feed on introduced plants with fruits that are smaller or larger than the native fruits
- These cases are examples of evolution by natural selection

In Florida, this evolution in beak size occurred in less than 35 years

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The Evolution of Drug-Resistant Bacteria

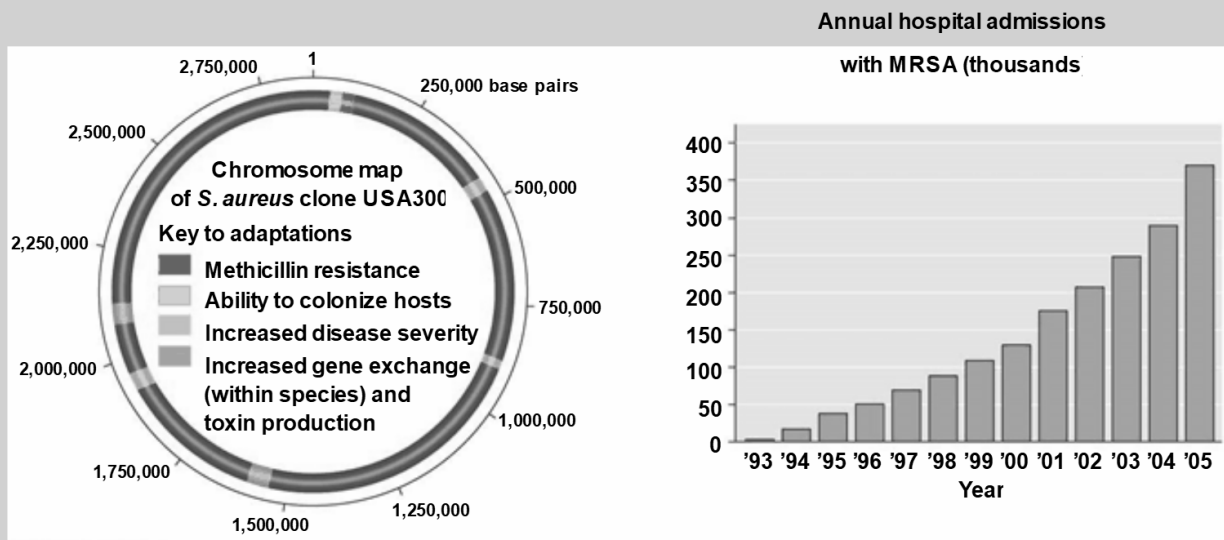
- The bacterium *Staphylococcus aureus* is commonly found on people's skin or in their nasal passages
- Methicillin-resistant *S. aureus* (MRSA) strains are dangerous pathogens
 - *S. aureus* became resistant to penicillin in 1945,
 - two years after it was first widely used
- *S. aureus* became resistant to methicillin in 1961, two years after it was first widely used

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- Methicillin works by inhibiting a protein used by bacteria in their cell walls
- MRSA bacteria use a different protein in their cell walls
- When exposed to methicillin, MRSA strains are more likely to survive and reproduce than nonresistant *S. aureus* strains
- MRSA strains are now resistant to many antibiotics

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Figure 19.15



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- Natural selection does not create new traits, but edits or selects for traits already present in the population
- The local environment determines which traits will be selected for or selected against in any specific population

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Homology

- Evolution is a process of descent with modification
- Related species can have characteristics with underlying similarity that function differently
- **Homology** is similarity resulting from common ancestry

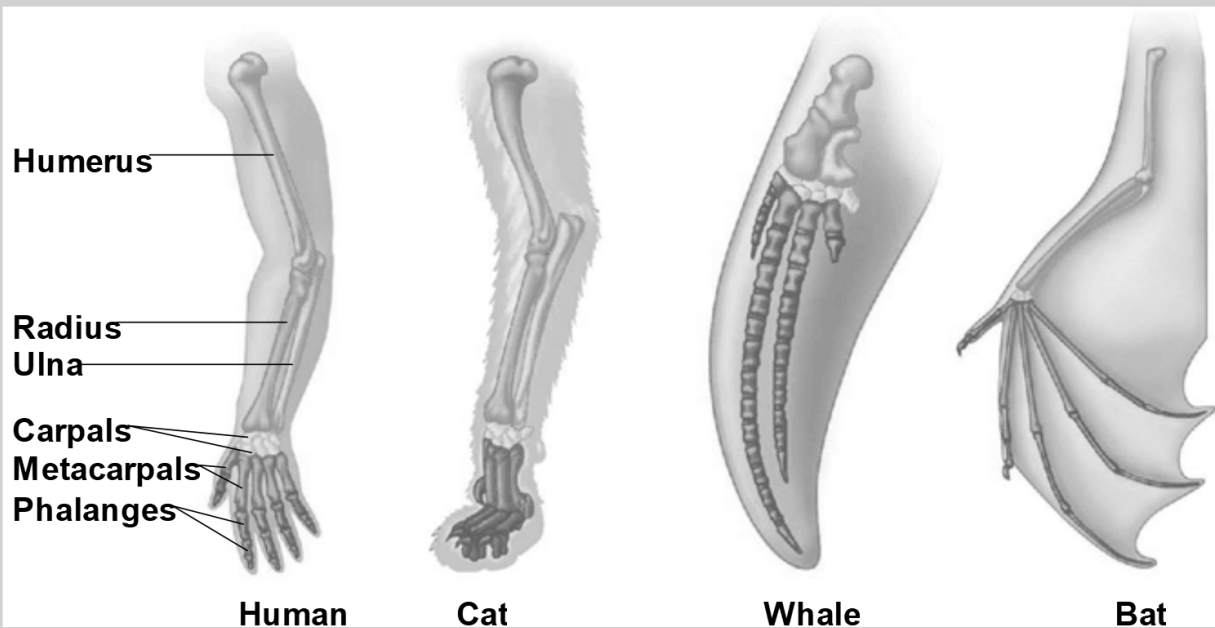
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Anatomical and Molecular Homologies

- **Homologous structures** are anatomical resemblances that represent variations on a structural theme present in a common ancestor

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Figure 19.16

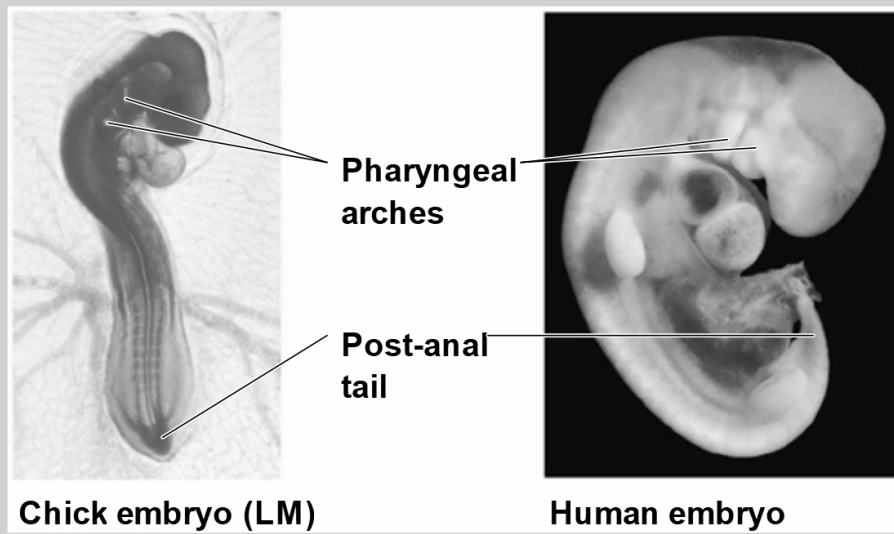


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- Comparative embryology reveals anatomical homologies not visible in adult organisms

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- **Vestigial structures** are remnants of features that served important functions in the organism's ancestors

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- Examples of homologies at the molecular level are genes shared among organisms inherited from a common ancestor
- Homologous genes can be found in organisms as dissimilar as humans and bacteria
- Many organisms have retained genes that, like vestigial structures, have lost their function

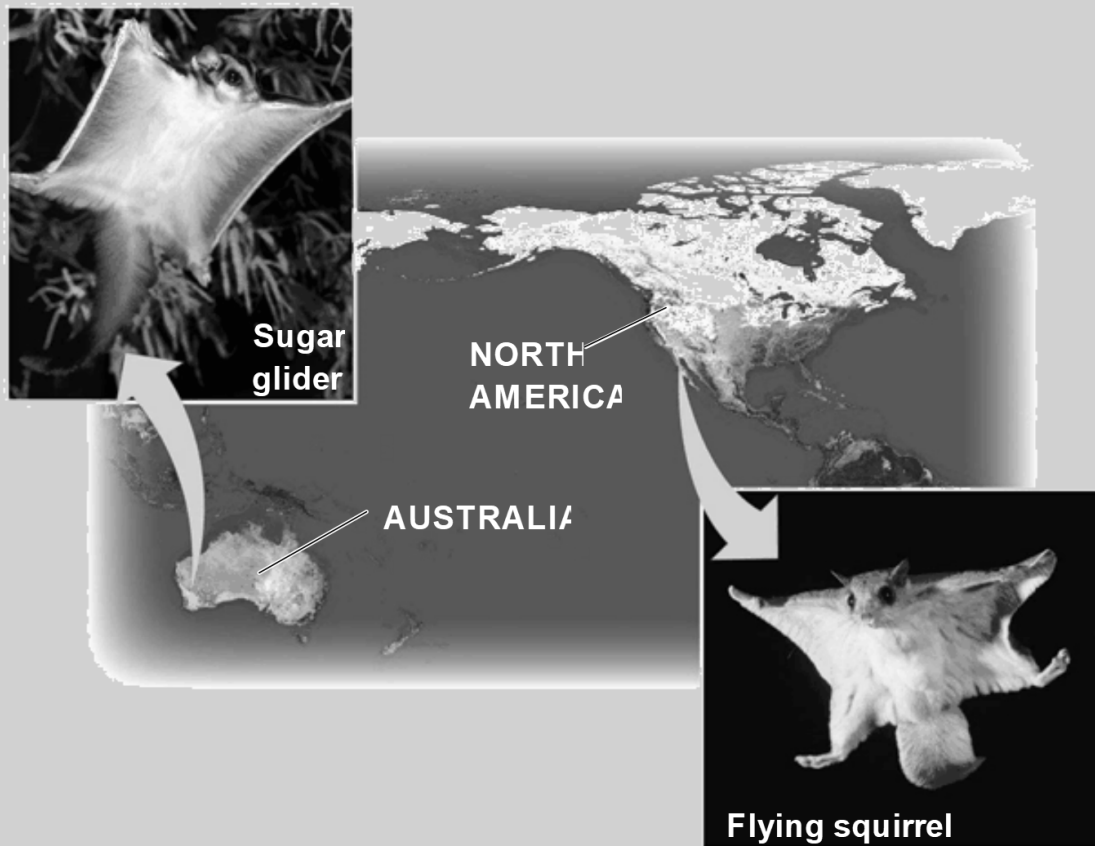
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A Different Cause of Resemblance: Convergent Evolution

- **Convergent evolution** is the evolution of similar, or **analogous**, features in distantly related groups
- Analogous traits arise when groups independently adapt to similar environments in similar ways
- Convergent evolution does not provide information about ancestry

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Figure 19.18



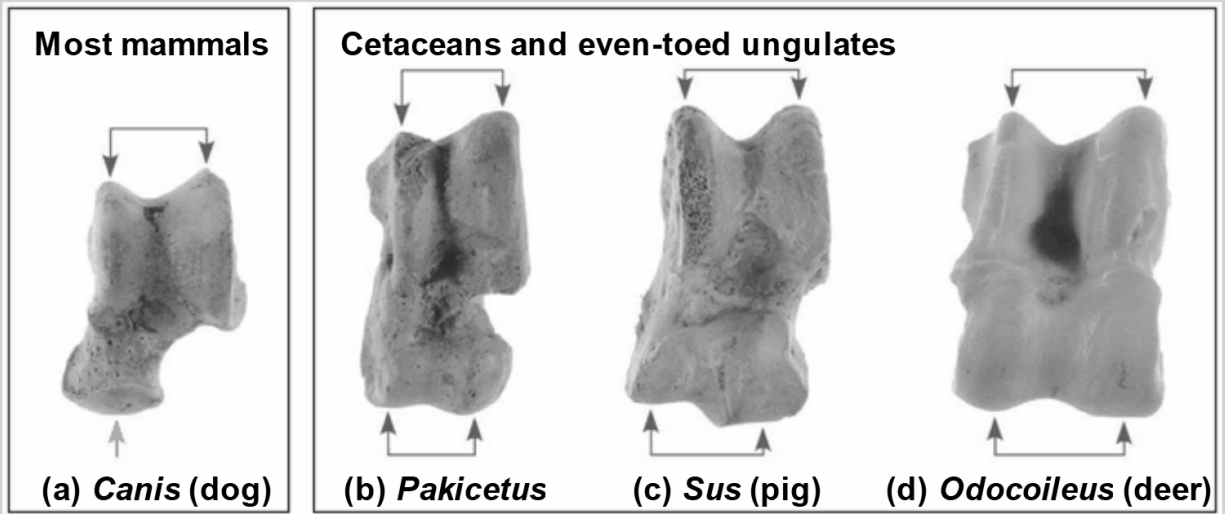
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The Fossil Record

- The fossil record provides evidence of
 - The extinction of species
 - The origin of new groups
 - Changes within groups over time

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Figure 19.19

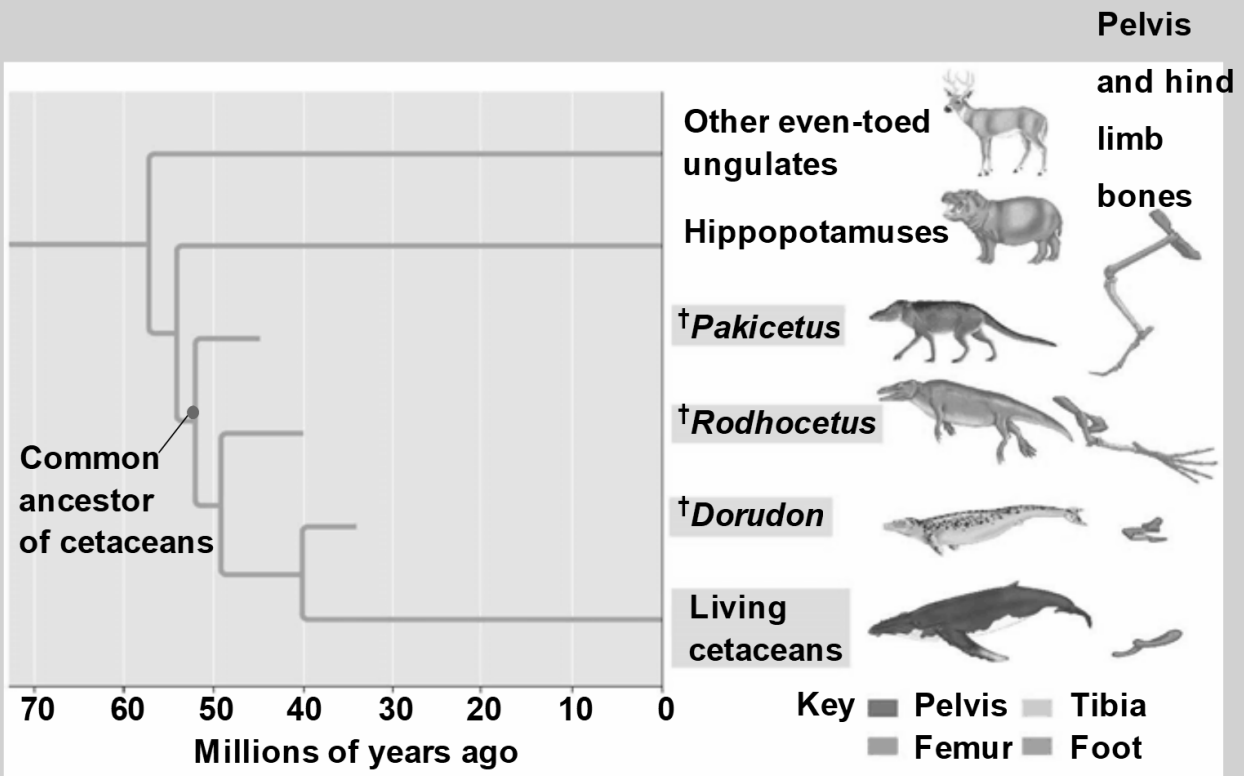


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- Fossils can document important transitions
 - For example, the transition from land to sea in the ancestors of cetaceans

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- Fossil evidence shows that living cetaceans and their close relatives, the even-toed ungulates, are more different from each other today than were early cetaceans and even-toed ungulates

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Biogeography

- **Biogeography**, the scientific study of the geographic distribution of species, provides evidence of evolution
 - Earth's continents were formerly united in a single large continent called **Pangaea**, but have since separated by continental drift
 - An understanding of continent movement and modern distribution of species allows us to predict when and where different groups evolved

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- **Endemic** species are species that are not found anywhere else in the world
 - Islands have many endemic species that are often closely related to species on the nearest mainland
 - or island
- Darwin explained that species on islands gave rise to new species as they adapted to new environments

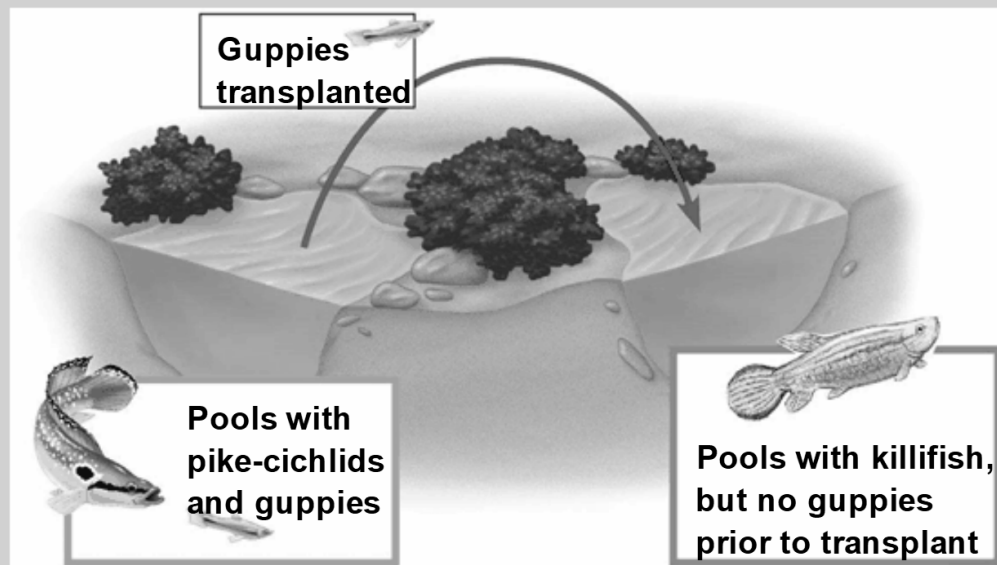
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What Is Theoretical About Darwin's View of Life?

- In science, a theory accounts for many observations and explains and integrates a great variety of phenomena
- The predictions of a scientific theory must stand up to continual testing by experimentation and observation
- Darwin's theory of evolution by natural selection integrates diverse areas of biological study and stimulates many new research questions
- Ongoing research adds to our understanding of evolution

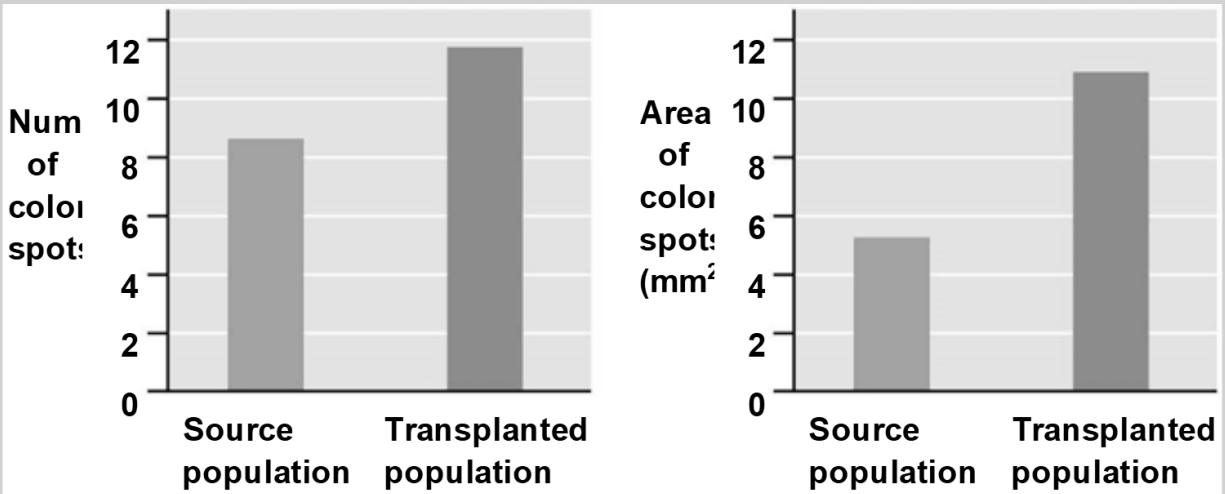
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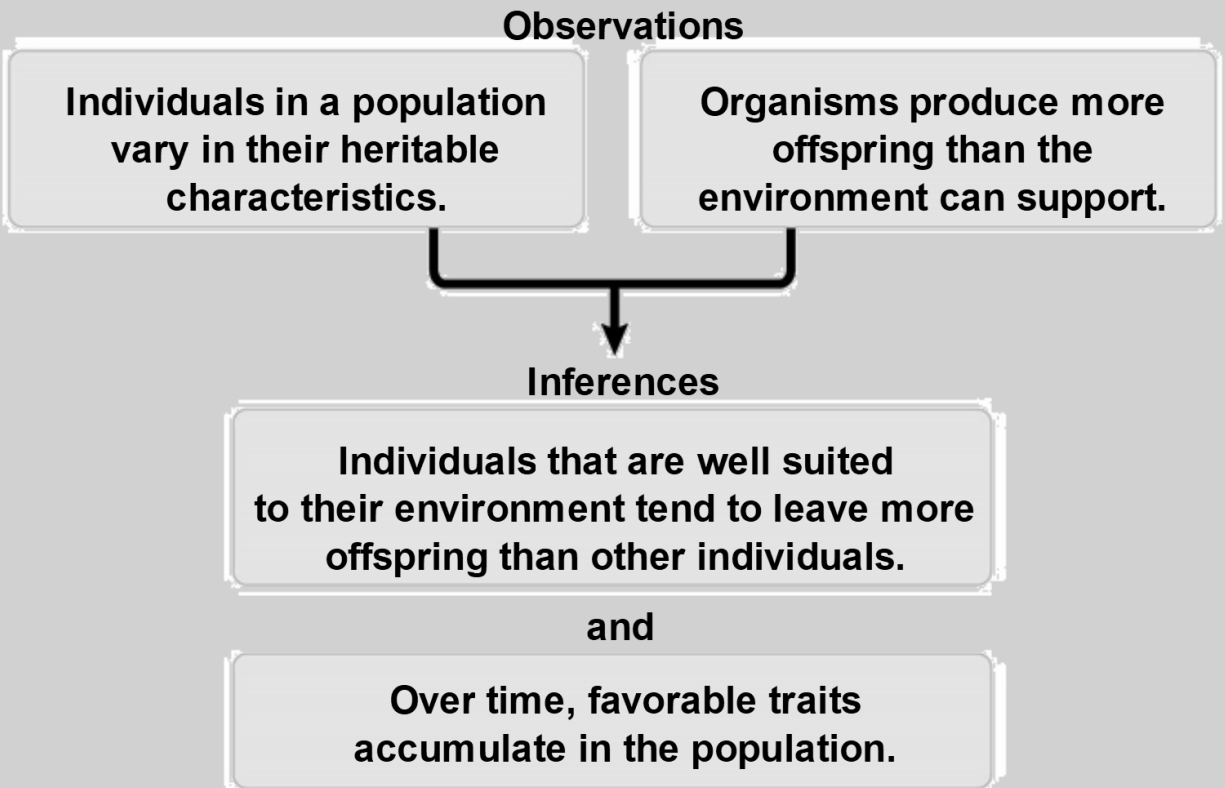
Figure 19.UN01-2



Data from J. A. Endler, Natural selection on color patterns in *Poecilia reticulata*, *Evolution* 34:76–91 (1980).

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Figure 19.UN02



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