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

- Darwin’s ideas had deep historical roots

Scala Naturae and Classification of Species

- The Greek philosopher Aristotle viewed species as fixed and arranged them on a *scala naturae*
- The Old Testament holds that species were individually designed by God and therefore perfect

Ideas About Change over Time

- Carolum Linnaeus interpreted organismal adaptations as evidence that the Creator had designed each species for a specific purpose
- Linnaeus was the founder of taxonomy, the branch of biology concerned with classifying organisms
- He developed the binomial format for naming species (for example, *Homo sapiens*)
**Figure 22.3**

Sedimentary rock layers (strata)

- Younger stratum with more recent fossils
- Older stratum with older fossils

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**Paleontology**, the study of fossils, was largely developed by French scientist Georges Cuvier.
- Cuvier advocated **catastrophism**, speculating that each boundary between strata represents a catastrophe.

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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.

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**Concept 22.2: 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 5-year around the world voyage on the **Beagle**.
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
- He experienced an earthquake in Chile and observed the uplift of rocks

Darwin was influenced by Lyell’s Principles of Geology and thought that the earth was more than 6000 years old
- 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

Darwin’s Focus on Adaptation

- In reassessing his observations, Darwin perceived adaptation to the environment and the origin of new species as closely related processes
- From studies made years after Darwin’s voyage, biologists have concluded that this is what happened to the Galápagos finches

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
- In June 1858, Darwin received a manuscript from Alfred Russell Wallace, who had developed a theory of natural selection similar to Darwin’s
- Darwin quickly finished The Origin of Species and published it the next year
The Origin of Species

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

Descent with Modification

- Darwin never used the word evolution in the first edition of 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

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

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

• 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

Observations
- Individuals in a population vary in their heritable characteristics.
- Organisms produce more offspring than the environment can support.

Inferences
- Individuals that are well suited to their environment tend to leave more offspring than other individuals.
- Over time, favorable traits accumulate in the population.
### Natural Selection: A Summary

- Individuals with certain heritable characteristics survive and reproduce at a higher rate than other individuals
- Natural selection increases the adaptation of organisms to their environment over time
- If an environment changes over time, natural selection may result in adaptation to these new conditions and may give rise to new species

### Direct Observations of Evolutionary Change

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

### Concept 22.3: Evolution is supported by an overwhelming amount of scientific evidence

- New discoveries continue to fill the gaps identified by Darwin in *The Origin of Species*
Natural Selection in Response to Introduced Plant Species

- Soapberry bugs use their “beak” to feed on seeds within fruits
- In southern Florida soapberry bugs feed on balloon vine with larger fruit; they have longer beaks
- In central Florida they feed on goldenrain tree with smaller fruit; they have shorter beaks
- Correlation between fruit size and beak size has also been observed in Louisiana, Oklahoma, and Australia

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

The Evolution of Drug-Resistant Bacteria

- The bacterium *Staphylococcus aureus* is commonly found on people
- One strain, methicillin-resistant *S. aureus* (MRSA) is a dangerous pathogen
- *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

- 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
• 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.

Homology

- **Homology** is similarity resulting from common ancestry.
- Anatomical
- Molecular
  - Examples of homologies at the molecular level are genes shared among organisms inherited from a common ancestor.

Anatomical Homologies

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

• Comparative embryology reveals anatomical homologies not visible in adult organisms.

• Vestigial structures are remnants of features that served important functions in the organism’s ancestors.
Homologies and “Tree Thinking”

- **Evolutionary trees** are hypotheses about the relationships among different groups
- Homologies form nested patterns in evolutionary trees
- Evolutionary trees can be made using different types of data, for example, anatomical and DNA sequence data

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

The Fossil Record

- The fossil record provides evidence of the extinction of species, the origin of new groups, and changes within groups over time

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

- **Biogeography**, 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

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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 data and attempts to explain and integrate a great variety of phenomena
- 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