Chapter 15 and 16
Darwin and Evolution of Populations

What You'll Learn

You will analyze the theory of evolution.

You will compare and contrast the processes of evolution.

Section Objectives:

- Summarize Darwin's theory of natural selection.
- Explain how the structural and physiological adaptations of organisms relate to natural selection.
- Distinguish among the types of evidence for evolution.

Charles Darwin and Natural Selection

- The modern theory of evolution is the fundamental concept in biology.
- Recall that evolution is the change in populations over time.

Fossils shape ideas about evolution

- When geologists provided evidence indicating that Earth was much older than many people had originally thought, biologists began to suspect that species change over time, or evolve.
- Many explanations about how species evolve have been proposed, but the ideas first published by Charles Darwin are the basis of modern evolutionary theory.

Darwin on HMS *Beagle*

- It took Darwin years to develop his theory of evolution.
- He began in 1831 at age 22 when he took a job as a naturalist on the English ship HMS *Beagle*, which sailed around the world on a five-year scientific journey.

Darwin on HMS *Beagle*

Darwin on HMS *Beagle*

- As the ship’s naturalist, Darwin studied and collected biological and fossil specimens at every port along the route.
- His studies provided the foundation for his theory of evolution by natural selection.

Darwin in the Galápagos

- On the Galápagos Islands, Darwin studied many species of animals and plants that are unique to the islands but similar to species elsewhere.
- These observations led Darwin to consider the possibility that species can change over time.

Darwin continues his studies

- For the next two decades, Darwin worked to refine his explanation for how species change over time.
- English economist Thomas Malthus had proposed an idea that Darwin modified and used in his explanation.
- Malthus's idea was that the human population grows faster than Earth's food supply.

Darwin continues his studies

How did this help Darwin?

- He knew that many species produce large numbers of offspring.
- He also knew that such species had not overrun Earth.

Darwin continues his studies

- He realized that individuals struggle to compete in changing environmental conditions.
- Only some individuals survive the competition and produce offspring.

Darwin continues his studies

- Darwin observed that the traits of individuals vary in populations. Variations are then inherited.
- Breeding organisms with specific traits in order to produce offspring with identical traits is called artificial selection.
- Darwin hypothesized that there was a force in nature that worked like artificial selection.

Darwin explains natural selection

- Natural selection is a mechanism for change in populations.
- It occurs when organisms with favorable variations survive, reproduce, and pass their variations to the next generation.
- Organisms without these variations are less likely to survive and reproduce.

Darwin explains natural selection

- As a result, each generation consists largely of offspring from parents with these variations that aid survival.
- Alfred Russell Wallace, another British naturalist, reached a similar conclusion.

Darwin explains natural selection

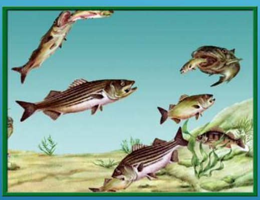
- Darwin proposed the idea of natural selection to explain how species change over time.

- In nature, organisms produce more offspring than can survive.

Darwin explains natural selection

- In any population, individuals have variations. Fishes, for example, may differ in color, size, and speed.

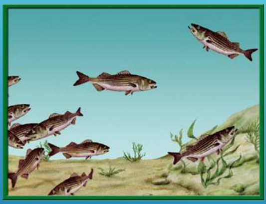
Darwin explains natural selection



- Individuals with certain useful variations, such as speed, survive in their environment, passing those variations to the next generation.

Darwin explains natural selection

- Over time, offspring with certain variations make up most of the population and may look entirely different from their ancestors.



Interpreting evidence after Darwin

- Volumes of scientific data have been gathered as evidence for evolution since Darwin's time.
- Much of this evidence is subject to interpretation by different scientists.
- One of the issues is that evolutionary processes are difficult for humans to observe directly.

Interpreting evidence after Darwin

- The short scale of human life spans makes it difficult to comprehend evolutionary processes that occur over millions of years.
- Almost all of today's biologists accept the theory of evolution by natural selection.

Adaptations: Evidence for Evolution

- Recall that an adaptation is any variation that aids an organism’s chances of survival in its environment.
- Darwin’s theory of evolution explains how adaptations may develop in species.

Structural adaptations arise over time

- According to Darwin’s theory, adaptations in species develop over many generations.
- Learning about adaptations in mole-rats can help you understand how natural selection has affected them.

Structural adaptations arise over time

- The ancestors of today’s common mole-rats probably resembled African rock rats.

Structural adaptations arise over time

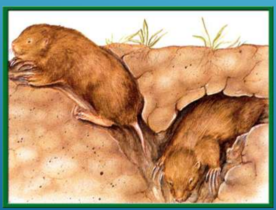
- Some ancestral rats may have avoided predators better than others because of variations such as the size of teeth and claws.

Structural adaptations arise over time

- Ancestral rats that survived passed their variations to offspring.
- After many generations, most of the population's individuals would have these adaptations.

Structural adaptations arise over time

- Over time, natural selection produced modern mole-rats.



- Their blindness may have evolved because vision had no survival advantage for them.

Structural adaptations arise over time

- Some other structural adaptations are subtle.
- Mimicry is a structural adaptation that enables one species to resemble another species.

Structural adaptations arise over time

- In one form of mimicry, a harmless species has adaptations that result in a physical resemblance to a harmful species.
- Predators that avoid the harmful looking species also avoid the similar-looking harmless species.

Structural adaptations arise over time

- In another form of mimicry, two or more harmful species resemble each other.
- For example, yellow jacket hornets, honeybees, and many other species of wasps all have harmful stings and similar coloration and behavior.

Structural adaptations arise over time

- Predators may learn quickly to avoid any organism with their general appearance.

Structural adaptations arise over time

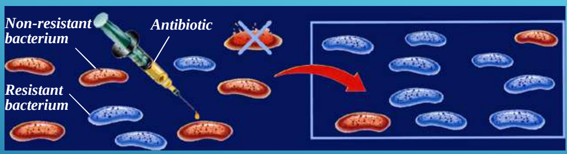
- Another subtle adaptation is camouflage, an adaptation that enables species to blend with their surroundings.

- Because well-camouflaged organisms are not easily found by predators, they survive to reproduce.

Physiological adaptations can develop rapidly

- In general, most structural adaptations develop over millions of years.
- However, there are some adaptations that evolve much more rapidly.
- For example, do you know that some of the medicines developed during the twentieth century to fight bacterial diseases are no longer effective?

Physiological adaptations can develop rapidly

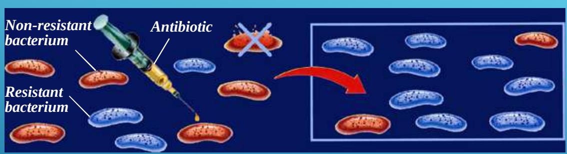


The bacteria in a population vary in their ability to resist antibiotics.

When the population is exposed to an antibiotic, only the resistant bacteria survive.

The resistant bacteria live and produce more resistant bacteria.

Physiological adaptations can develop rapidly



- Today, penicillin no longer affects as many species of bacteria because some species have evolved physiological adaptations to prevent being killed by penicillin.

Physiological adaptations can develop rapidly

- Physiological adaptations are changes in an organism’s metabolic processes.
- In addition to species of bacteria, scientists have observed these adaptations in species of insects and weeds that are pests.

Other Evidence for Evolution

- Physiological resistance in species of bacteria, insects, and plants is direct evidence of evolution.
- However, most of the evidence for evolution is indirect, coming from sources such as fossils and studies of anatomy, embryology, and biochemistry.

Fossils

- Fossils are an important source of evolutionary evidence because they provide a record of early life and evolutionary history.

Fossils

- Although the fossil record provides evidence that evolution occurred, the record is incomplete.
- Although paleontologists do not have fossils for all the changes that have occurred, they can still understand the overall picture of how most groups evolved.

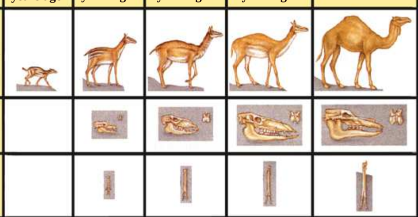
Fossils

- Fossils are found throughout the world.
- As the fossil record becomes more complete, the sequences of evolution become clearer.
- For example, you can see how paleontologists have charted the evolutionary path that led to today’s camel after piecing together fossil skulls, teeth, and limb bones.

Fossils

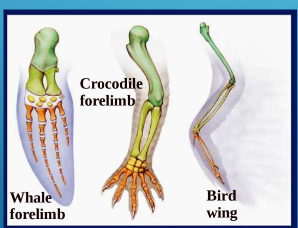
Camel Evolution

Age	Paleocene 65 million years ago	Eocene 54 million years ago	Oligocene 33 million years ago	Miocene 23 million years ago	Present
Organism					
Skull and teeth					
Limb bones					



Anatomy

- Structural features with a common evolutionary origin are called homologous structures.



- Homologous structures can be similar in arrangement, in function, or in both.

Anatomy

- The body parts of organisms that do not have a common evolutionary origin but are similar in function are called analogous structures.
- Although analogous structures don't shed light on evolutionary relationships, they do provide evidence of evolution.

Anatomy

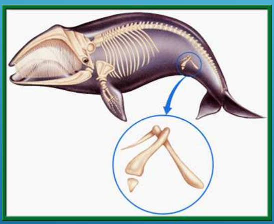
- For example, insect and bird wings probably evolved separately when their different ancestors adapted independently to similar ways of life.

Anatomy

- Another type of body feature that suggests an evolutionary relationship is a vestigial structure—a body structure in a present-day organism that no longer serves its original purpose, but was probably useful to an ancestor.
- A structure becomes vestigial when the species no longer needs the feature for its original function, yet it is still inherited as part of the body plan for the species.

Anatomy

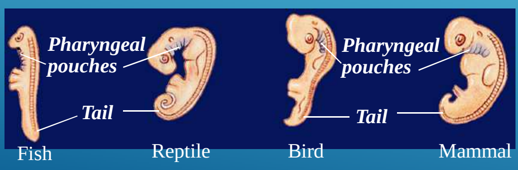
- Many organisms have vestigial structures.



- Vestigial structures, such as pelvic bones in the baleen whale, are evidence of evolution because they show structural change over time.

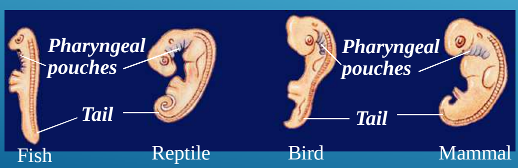
Embryology

- An embryo is the earliest stage of growth and development of both plants and animals.
- The embryos of a fish, a reptile, a bird, and a mammal have a tail and pharyngeal pouches.



Embryology

- It is the shared features in the young embryos that suggest evolution from a distant, common ancestor.



Biochemistry

- Biochemistry also provides strong evidence for evolution.
- Nearly all organisms share DNA, ATP, and many enzymes among their biochemical molecules.

Biochemistry

- One enzyme, cytochrome c, occurs in organisms as diverse as bacteria and bison.
- Biologists compared the differences that exist among species in the amino acid sequence of cytochrome c.

Biochemistry

- The data show the number of amino acid substitutions in the amino acid sequences for the different organisms.

Biochemical Similarities of Organisms

Comparison of Organisms	Percent Substitutions of Amino Acids in Cytochrome c Residues
Two orders of mammals	5 and 10
Birds vs. mammals	8-12
Amphibians vs. birds	14-18
Fish vs. land vertebrates	18-22
Insects vs. vertebrates	27-34
Algae vs. animals	57

Biochemistry

- Organisms that are biochemically similar have fewer differences in their amino acid sequences.

Biochemical Similarities of Organisms	
Comparison of Organisms	Percent Substitutions of Amino Acids in Cytochrome c Residues
Two orders of mammals	5 and 10
Birds vs. mammals	8-12
Amphibians vs. birds	14-18
Fish vs. land vertebrates	18-22
Insects vs. vertebrates	27-34
Algae vs. animals	57

Biochemistry

- Since Darwin's time, scientists have constructed evolutionary diagrams that show levels of relationships among species.
- In the 1970s, some biologists began to use RNA and DNA nucleotide sequences to construct evolutionary diagrams.

Biochemistry

- Today, scientists combine data from fossils, comparative anatomy, embryology, and biochemistry in order to interpret the evolutionary relationships among species.

Section Objectives

- Summarize the effects of the different types of natural selections on gene pools.
- Relate changes in genetic equilibrium to mechanisms of speciation.
- Explain the role of natural selection in convergent and divergent evolution.

Population Genetics and Evolution

- Since Darwin's time, scientists have learned a great deal about genes and modified Darwin's ideas accordingly.
- The principles of today's modern theory of evolution are rooted in population genetics and other related fields of study and are expressed in genetic terms.

Populations, not individuals, evolve

- Genes determine most of an individual's features, such as tooth shape or flower color.
- If an organism has a feature—called a phenotype in genetic terms—that is poorly adapted to its environment, the organism may be unable to survive and reproduce.
- However, within its lifetime, it cannot evolve a new phenotype by natural selection in response to its environment.

Populations, not individuals, evolve

- Natural selection acts on the range of phenotypes in a population.
- Each member has the genes that characterize the traits of the species, and these genes exist as pairs of alleles.
- Evolution occurs as a population's genes and their frequencies change over time.

Populations, not individuals, evolve

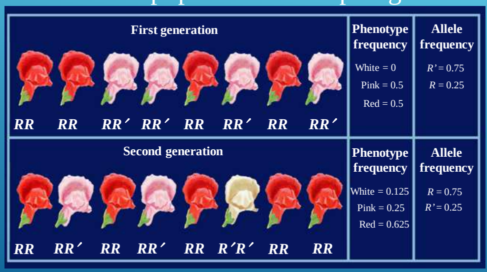
- How can a population's genes change over time?
- Picture all of the alleles of the population's genes as being together in a large pool called a gene pool.
- The percentage of any specific allele in the gene pool is called the allelic frequency.

Populations, not individuals, evolve

- They refer to a population in which the frequency of alleles remains the same over generations as being in genetic equilibrium.

Populations, not individuals, evolve

- Look at the population of snapdragons.



Populations, not individuals, evolve

- A pattern of heredity called incomplete dominance governs flower color in snapdragons.
- The population of snapdragons is in genetic equilibrium when the frequency of its alleles for flower color is the same in all its generations.

Changes in genetic equilibrium

- A population that is in genetic equilibrium is not evolving.
- Any factor that affects the genes in the gene pool can change allelic frequencies, disrupting a population’s genetic equilibrium, which results in the process of evolution.

Changes in genetic equilibrium

- One mechanism for genetic change is mutation.
- Environmental factors, such as radiation or chemicals, cause many mutations, but other mutations occur by chance.

Changes in genetic equilibrium

- Many are lethal.
- However, occasionally, a mutation results in a useful variation, and the new gene becomes part of the population's gene pool by the process of natural selection.

Changes in genetic equilibrium

- Another mechanism that disrupts a population's genetic equilibrium is genetic drift—the alteration of allelic frequencies by chance events.
- Genetic drift can greatly affect small populations that include the descendants of a small number of organisms.

Changes in genetic equilibrium

- Genetic drift has been observed in some small human populations that have become isolated due to reasons such as religious practices and belief systems.
- Genetic equilibrium is also disrupted by the movement of individuals in and out of a population.

Changes in genetic equilibrium

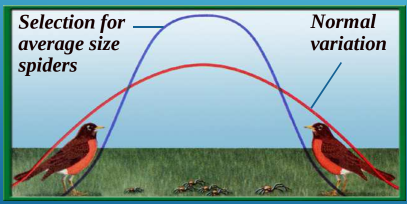
- The transport of genes by migrating individuals is called gene flow.
- When an individual leaves a population, its genes are lost from the gene pool.
- When individuals enter a population, their genes are added to the pool.

Natural selection acts on variations

- Some variations increase or decrease an organism's chance of survival in an environment.
- There are three different types of natural selection that act on variation: stabilizing, directional, and disruptive.

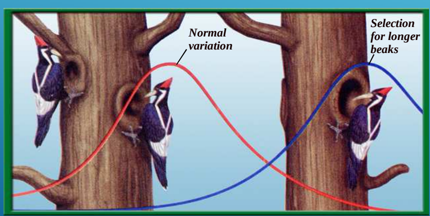
Natural selection acts on variations

- Stabilizing selection is a natural selection that favors average individuals in a population.



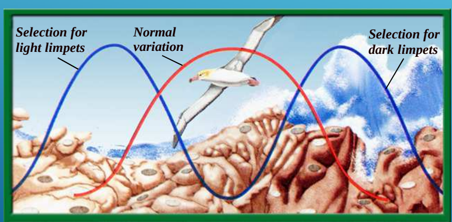
Natural selection acts on variations

- Directional selection occurs when natural selection favors one of the extreme variations of a trait.



Natural selection acts on variations

- In disruptive selection, individuals with either extreme of a trait's variation are selected for.



Natural selection acts on variations

- Natural selection can significantly alter the genetic equilibrium of a population's gene pool over time.
- Significant changes in the gene pool could lead to the evolution of a new species over time.

The Evolution of Species

- Recall that a species is defined as a group of organisms that look alike and can interbreed to produce fertile offspring in nature.
- The evolution of new species, a process called speciation (spee shee AY shun), occurs when members of similar populations no longer interbreed to produce fertile offspring within their natural environment.

Physical barriers can prevent interbreeding

- In nature, physical barriers can break large populations into smaller ones.
- Geographic isolation occurs whenever a physical barrier divides a population.
- A new species can evolve when a population has been geographically isolated.

The Evolution of Species

- When geographic isolation divides a population of tree frogs, the individuals no longer mate across populations.
- Tree frogs are a single population.

The Evolution of Species

- The formation of a river may divide the frogs into two populations.

The Evolution of Species

- Over time, the divided populations may become two species that may no longer interbreed, even if reunited.

Reproductive isolation can result in speciation

- As populations become increasingly distinct, reproductive isolation can arise.
- Reproductive isolation occurs when formerly interbreeding organisms can no longer mate and produce fertile offspring.

Reproductive isolation can result in speciation

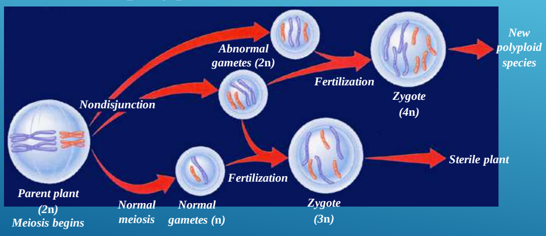
- There are different types of reproductive isolation.
- One type occurs when the genetic material of the populations becomes so different that fertilization cannot occur.
- Another type of reproductive isolation is behavioral.

A change in chromosome numbers and speciation

- Chromosomes can also play a role in speciation.
- Many new species of plants and some species of animals have evolved in the same geographic area as a result of polyploidy.
- Any individual or species with a multiple of the normal set of chromosomes is known as a polyploid.

A change in chromosome numbers and speciation

- Mistakes during mitosis or meiosis can result in polyploid individuals.



A change in chromosome numbers and speciation

- Polyploidy may result in immediate reproductive isolation.
- When a polyploid mates with an individual of the normal species, the resulting zygotes may not develop normally because of the difference in chromosome numbers.

A change in chromosome numbers and speciation

- However, polyploids within a population may interbreed and form a separate species.
- Polyploids can arise from within a species or from hybridization between species.
- Many flowering plant species and many important crop plants, such as wheat, cotton, and apples, originated by polyploidy.

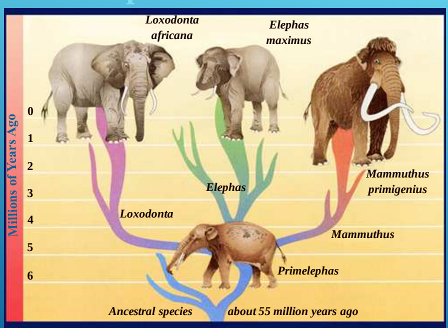
Speciation rates

- Scientists once argued that evolution occurs at a slow, steady rate, with small, adaptive changes gradually accumulating over time in populations.
- Gradualism is the idea that species originate through a gradual change of adaptations.
- Some evidence from the fossil record supports gradualism.

Speciation rates

- In 1972, Niles Eldredge and Stephen J. Gould proposed a different hypothesis known as punctuated equilibrium.
- This hypothesis argues that speciation occurs relatively quickly, in rapid bursts, with long periods of genetic equilibrium in between.

Speciation rates



Speciation rates

- According to this hypothesis, environmental changes, such as higher temperatures or the introduction of a competitive species, lead to rapid changes in a small population’s gene pool that is reproductively isolated from the main population.
- Speciation happens quickly—in about 10,000 years or less.

Speciation rates

- Biologists generally agree that both gradualism and punctuated equilibrium can result in speciation, depending on the circumstances.

Patterns of Evolution

- Biologists have observed different patterns of evolution that occur throughout the world in different natural environments.
- These patterns support the idea that natural selection is an important agent for evolution.

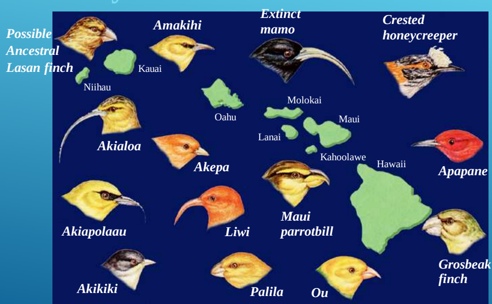
Diversity in new environments

- When an ancestral species evolves into an array of species to fit a number of diverse habitats, the result is called adaptive radiation.

Diversity in new environments

- Adaptive radiation in both plants and animals has occurred and continues to occur throughout the world and is common on islands.
- Adaptive radiation is a type of divergent evolution, the pattern of evolution in which species that were once similar to an ancestral species diverge, or become increasingly distinct.

Diversity in new environments



Diversity in new environments

- Divergent evolution occurs when populations change as they adapt to different environmental conditions, eventually resulting in new species.

Different species can look alike

- A pattern of evolution in which distantly related organisms evolve similar traits is called convergent evolution.
- Convergent evolution occurs when unrelated species occupy similar environments in different parts of the world.