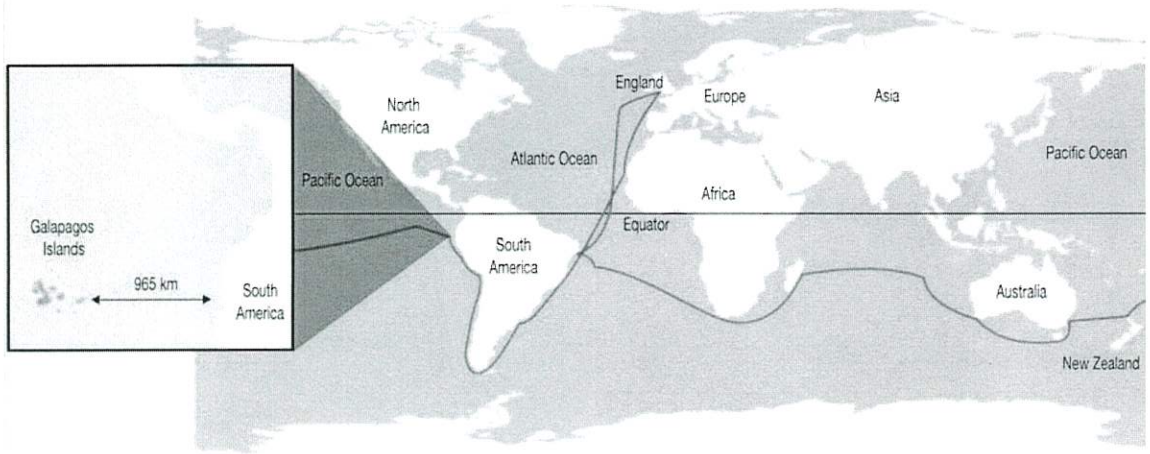
13.2 How Evolution Works

In 1831, the research ship *H.M.S. Beagle* left England for a five-year cruise around the world. On the ship was a young man named Charles Darwin (1809–1882). During the trip, Darwin collected thousands of plant and animal species. He was amazed at the diversity of life he encountered. Darwin wrote down his observations and collected evidence about evolution. That evidence led him to propose a theory about how evolution works called *natural selection*.

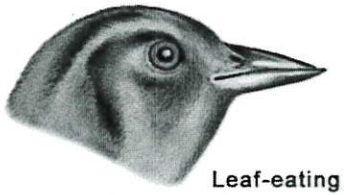
The finches of the Galapagos

The voyage of the *Beagle*

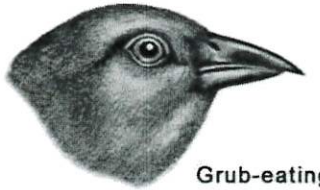
One of the places where the *Beagle* stopped was the Galapagos Islands, located 965 km west of South America. There, Darwin observed that the finches were different than those found on the mainland. He also noted differences in finches from island to island. One difference he found was in the shape of their beaks. The shape of finch beaks appeared to differ with the type of food eaten (Figure 13.8). Darwin concluded that finch beaks were adapted for the type of food they ate. He began to think about why and how the finches became different from each other.



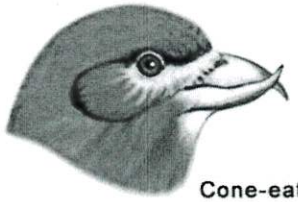
Seed-eating species
Cracks seeds with its beak.



Leaf-eating species
Rips apart leaves with its beak.



Grub-eating species
Probes the bark of trees with its beak.



Cone-eating species
Uses its beak to pull apart cones and lift the seeds out.

Figure 13.8: *The beaks of finches are adapted to obtain food in different ways.*

Darwin's hypothesis about finches

Darwin hypothesized that an ancestral species of finch from the mainland somehow ended up on the Galapagos Islands. The finches of that species scattered to different environments. There, they had to adapt to different conditions. Over many generations, they evolved adaptations that allowed them to get enough food to survive and reproduce. Each group of finches became isolated from the other groups. Eventually, each group became a different species (Figure 13.9). When Darwin returned to England from his voyage, he began to develop a theory about how the adaptations evolved.

Earth formed slowly

From geologists, Darwin learned that Earth was formed very slowly over a long period of time. Its surface also changed slowly over time through natural processes like sedimentation and erosion. Darwin reasoned that populations of organisms changed slowly as their environment slowly changed. If the environment changes rapidly from an event like a flood, an earthquake, or a volcanic eruption, a species could become *extinct* (all members die off completely).

Fossil evidence

Darwin used fossils as evidence that different species evolve over a long period of time. He found fossils of species that lived a few million years ago that resembled living species. For example, the *glyptodon*, an extinct mammal, resembled the armadillo, an organism Darwin knew as a living species (Figure 13.10).

Artificial and natural selection

In Darwin's time, animal and plant breeders used selective breeding to produce organisms with the traits they desired. Darwin called selective breeding *artificial selection* because the breeders selected the desired traits to produce changes in a species over a few generations. In wild animals and plants, Darwin believed that traits were selected by the environment. He called this process *natural selection*. He believed that natural selection took longer than artificial selection because it happened by chance.

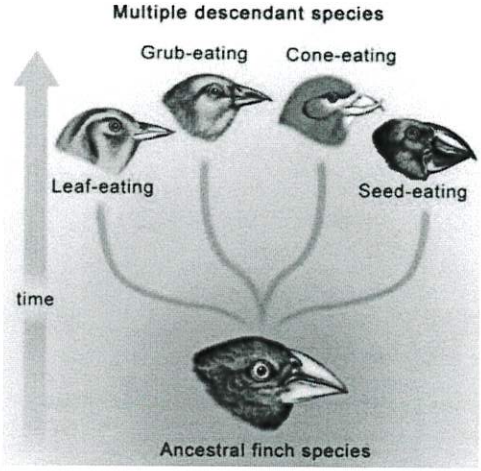
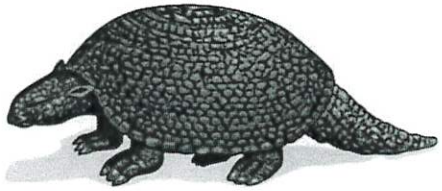
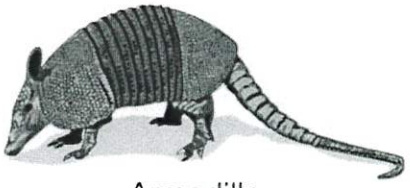


Figure 13.9: *New finch species evolved from a common ancestor.*



Extinct Giant Glyptodon



Armadillo
(Present day)

Figure 13.10: *The ancient glyptodon resembles the modern armadillo.*

Darwin's theory of evolution and natural selection

Darwin publishes his results

In 1859, Darwin published the results of his study in a book called *On the Origin of Species by Means of Natural Selection*. Based on his research and evidence, Darwin concluded that:

1. **Organisms change over time.**
2. **All organisms are descended from common ancestors by a process of branching.**
3. **Evolution is gradual, taking place over a long time.**
4. **The mechanism of evolution is natural selection.**

What is natural selection?

Natural selection is the process by which organisms with favorable adaptations survive and reproduce at a higher rate than organisms with less-favorable adaptations. Darwin based his ideas about natural selection, in part, on the work of British professor Thomas Malthus (1766–1834).

Populations grow faster than their food supply

In 1798, Malthus published his *Essay on Population*. In that essay, he argued that the human population tends to grow faster than the food supply (Figure 13.11). This causes food shortages and a "struggle for existence." Darwin's observations in the Galapagos Islands led him to apply Malthus' ideas to animals and plants.

Darwin's conclusions

Darwin proposed that environmental variables affect the size of a population. Variables include predators, food supply, disease, and climate. He reasoned that if a species produces too many offspring and only a certain number survive, the survivors must be better adapted to their environment than those that die. Darwin concluded that offspring of the survivors would inherit the favorable adaptations. Organisms with unfavorable adaptations die before they can pass them on to offspring.

VOCABULARY

natural selection - the process by which organisms with favorable adaptations survive and reproduce at a higher rate than organisms with less-favorable adaptations.

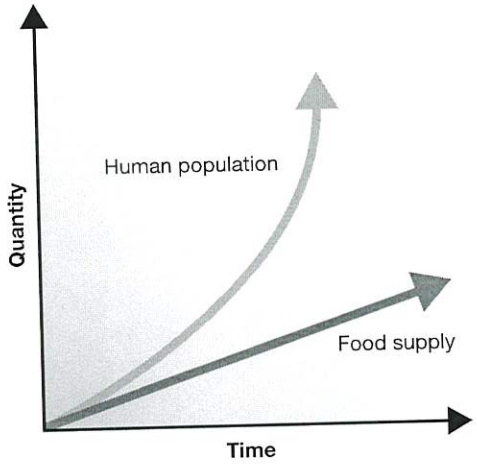


Figure 13.11: *Populations tend to grow faster than their food supply.*

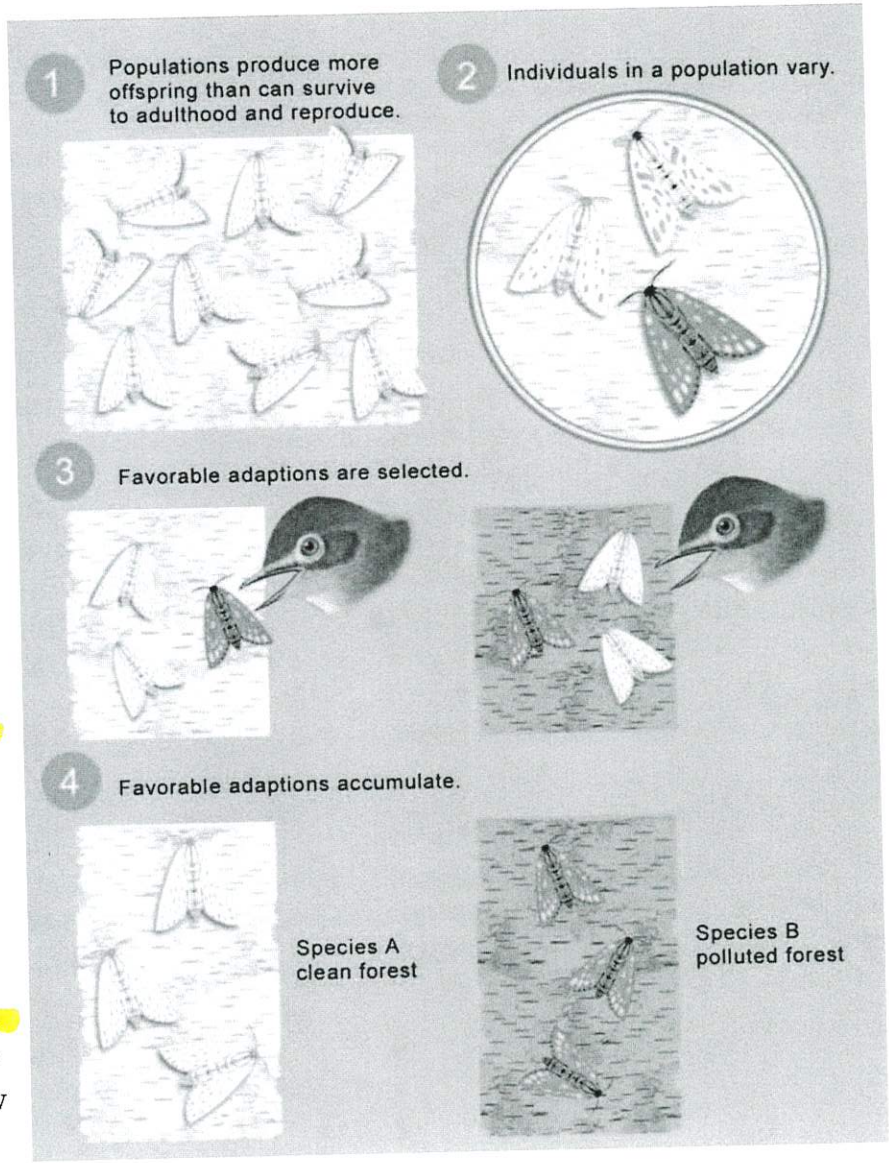
MY JOURNAL

When wolves hunt deer, they are usually able to catch only the weak or sick deer. The stronger and faster deer can escape. Explain how the wolf population may influence the adaptations of the deer population over time.

The process of natural selection

Darwin proposed that natural selection is the process for evolution. Today, it is still the most thorough explanation of how evolution occurs. The process of natural selection may be summarized in the steps below.

1. **Populations over-reproduce.** All organisms produce more offspring than can survive to adulthood and reproduce. This means that many of those offspring will die without reproducing. Survivors that are able to reproduce pass their traits on to their offspring.
2. **Individuals in a population vary.** There is random variation in traits among individuals in a population of a species. The variations each individual possesses happen by chance. Those variations are inherited.
3. **Favorable adaptations are selected.** The changing environment causes a selection of favorable traits (adaptations). Adaptations that fit well with the environment are passed on to offspring in greater numbers than adaptations that do not fit well.
4. **Favorable adaptations accumulate.** Favorable adaptations accumulate over many generations. This may lead to new species.



13.3 Natural Selection

Natural selection explains how a population changes in response to its environment. Those changes are called *adaptations*. Adaptations are inherited, therefore they must be carried on genes. Since Darwin developed his theory before Gregor Mendel's experiments, he knew nothing about genes. In this section, you will learn about the connection between natural selection and heredity.

Mutations

What causes genetic variation?

Since Darwin's time, there has been a growing body of knowledge about heredity. That knowledge explains many of Darwin's observations and supports the theory of evolution. For example, Darwin observed that individuals in a population show variation in their traits. Today, scientists know that variations in the population of a species are caused by random mutations in genes.

Random mutations in genes produce variations of traits in a population.

Mutations lead to alleles

Recall that alleles are different forms of a gene. A gene mutation leads to different alleles of that gene which in turn, leads to variations of a trait. Mutated alleles may cause favorable and unfavorable adaptations.

Favorable alleles are selected

Imagine a population of brown squirrels that has a single gene that determines fur color. A mutated allele causes white fur instead of brown fur. The squirrels with brown fur can hide from predators better than squirrels with white fur (Figure 13.12). Most of the squirrels that survive to reproduce are brown. Since brown fur is a favorable adaptation, the allele for brown fur is selected over the allele for white fur. What would happen to the frequency of the brown fur allele if the climate changed and the ground became covered in snow for most of each year?

STUDY SKILLS

Reviewing past topics will help you understand the concepts in this chapter. Below are topics and the page number in the text where you will find them. For each topic, go back and reread the page. Then, write down how that topic relates to what you are currently learning.

Species (definition) - page 47
Populations - page 95
Bacteria and evolution - page 181
Alleles - page 218
Mutations - page 242

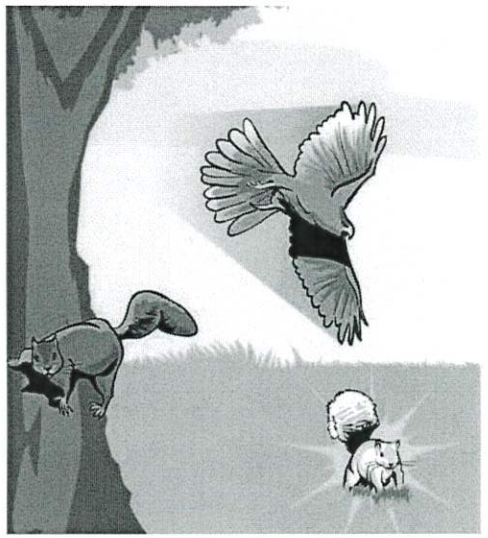


Figure 13.12: *Squirrels with brown fur are better adapted than squirrels with white fur.*

The importance of genetic variation

Helpful mutations

You have learned that some mutations are harmful because they cause genetic disorders. Mutations may also be helpful because they contribute to genetic variation. **Genetic variation** refers to the variety of alleles in a population. **Genetic variation is necessary for natural selection and ensures that a population has a better chance of survival should the environment change.**

Changing environment

Because our fictional squirrel population carries an allele for white fur, it may have a better chance of surviving a change to a colder climate. The allele for white fur may be selected over the brown if the ground is covered in snow for most of each year. Over many generations, the frequency of the white fur allele may increase in the population while brown decreases.

Natural selection in action

Scientists have observed natural selection in species that produce new generations quickly. An example is pesticide resistance in the potato beetle. Farmers routinely spray pesticides to prevent this pest from destroying their crops. Each time they spray, a few of the beetles survive. The survivors carry a mutated allele that resists the pesticide. The survivors pass the resistant allele to their offspring. Because generations multiply quickly, it does not take long for a population of pesticide-resistant beetles to evolve (Figure 13.13).

VOCABULARY

genetic variation - the variety of alleles in a population.

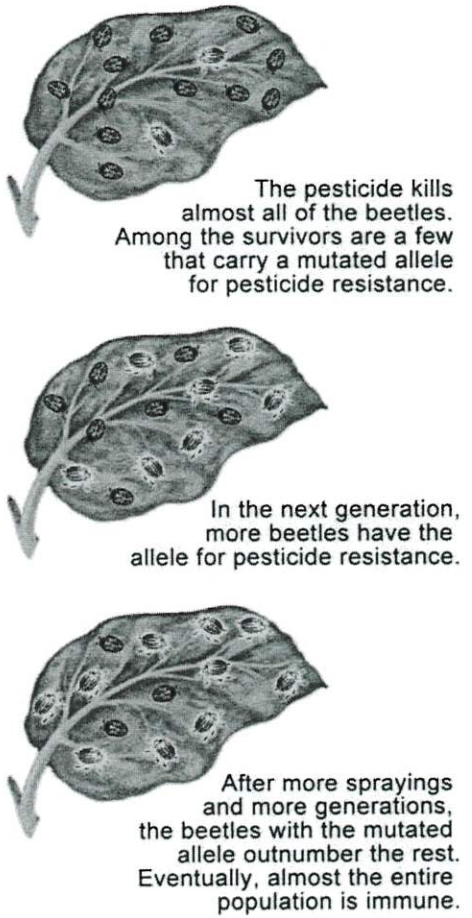
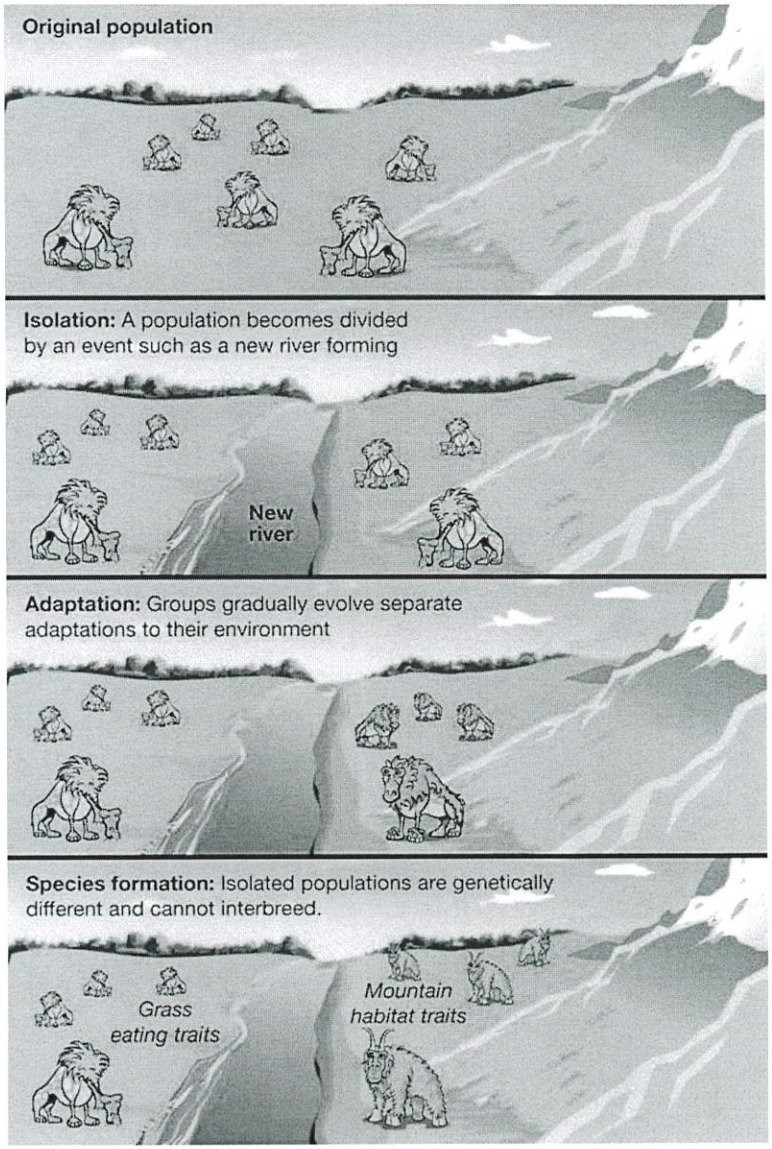


Figure 13.13: *How a population of potato beetles changes over time.*

How a new species evolves

How does a new species evolve? Scientists theorize that natural selection leads to the formation of new species. Recall that a *species* is an isolated population of similar organisms that interbreed and produce fertile offspring. One way for a new species to evolve happens in three steps: *isolation*, *adaptation*, and *species formation*.



Isolation *Isolation* happens when a population becomes divided by an event. Possible events include floods, volcanic eruptions, mountain formation, earthquakes, and storms. The original population becomes divided into smaller populations. Each population is physically and reproductively isolated from the others.

Adaptation *Adaptation* happens through natural selection. The event that causes isolation may also change the environment. As the environment changes, the population that lives there undergoes natural selection. Over time, each separated population may become adapted to their environment. If the environments are different, each population will have different adaptations.

Species formation *Species formation* happens when the isolated populations become so different that they can no longer interbreed, even if they could unite again. Over many generations, the isolated populations become genetically different from each other. Each population may have different allele frequencies. Random mutations in each population may create new alleles and thus new traits. As a result, one or more new species are formed.

Extinction of a species

What is extinction?

Extinction occurs when the environment changes and the adaptations of a species are no longer sufficient for its survival. Changes may include increased competition with other species, newly introduced predators, loss of habitat, and catastrophes. Based on the fossil record, scientists think most of the species that once lived on Earth are now extinct.

An example of extinction

The dodo bird is an example of how human impact may contribute to extinction. The dodo was first sighted around 1600 on Mauritius, an island in the Indian Ocean (Figure 13.14). It was a flightless bird with a stubby body and tiny wings (Figure 13.15). Scientists believe that the dodo evolved from a bird capable of flight. When an ancestor of the dodo landed on Mauritius, it found a habitat with plenty of food and no predators. It had no reason to fly and eventually evolved into a flightless bird.

The cause of the dodo's extinction

The dodo was extinct less than eighty years after its discovery. Some of the birds were eaten by the Dutch sailors who discovered them. Also, domestic pigs and cats destroyed their nests which were built on the ground. But the main cause of their extinction was the human destruction of their habitat.

The importance of genetic variation

One reason the dodo may have become extinct is the lack of genetic variation. As a species' population gets smaller, its genetic variation may decrease. Natural selection requires genetic variation. Therefore, a small population may be more susceptible to extinction than a large population if their environment changes. If genetic variation is not present, the population may not have enough favorable adaptations to survive changes in the environment. Scientists study extinctions like the dodo's in hope of preventing future extinctions.

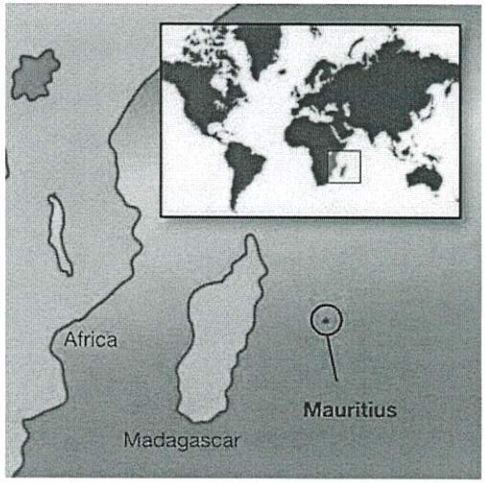


Figure 13.14: *Mauritius is located off the coast of Madagascar.*

Figure 13.15: *The dodo was a flightless bird.*