Developing the Theory of Natural Selection

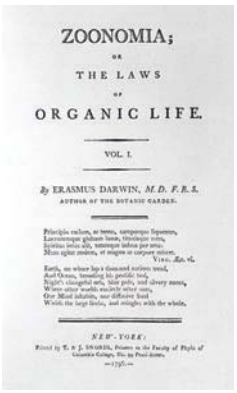
Charles Darwin was one of the most famous people to consider the question of how living things evolve; however, the concept of evolution had been discussed for more than 100 years when Darwin proposed his theory of evolution.

Early Ideas About Evolution

Early scientists observed relationships among organisms and how they seemed to be well adapted for specific environments. Darwin built upon the work of these scientists to develop a theory for how evolution occurs. A theory is an explanation based on evidence that has been repeatedly confirmed through experimentation or observation. Today, we have a wide body of evidence that supports Darwin's theory of evolution.

FIGURE 5: Ideas about evolution have developed over time.

1735 *Systema Naturae* Carolus Linnaeus proposed a new system of organization for plants, animals, and minerals based upon their similarities.



1794-1796 *Zoonomia* Darwin's grandfather, Erasmus Darwin, considered how organisms could evolve through mechanisms such as competition.

1809 *Philosophie Zoologique* Jean-Baptiste Lamarck presented evolution as occurring due to environmental change over long periods of time.

1749 *Histoire Naturelle* Georges-Louis Leclerc, Comte de Buffon, discussed important ideas about relationships among organisms, sources of biological variation, and the possibility of evolution.

1798 An Essay on the Principle of Population Thomas Malthus argued that the increasing human population would challenge the world's ability to supply enough food for everyone.

1830 *Principles of Geology* Charles Lyell proposed the theory of uniformitarianism. This theory states that both gradual and catastrophic geological changes have occurred at a constant rate on Earth and are ongoing.

Analyze How does the information in Figure 5 support the idea that theories change and develop over time as new evidence is discovered?

Darwin's Voyage

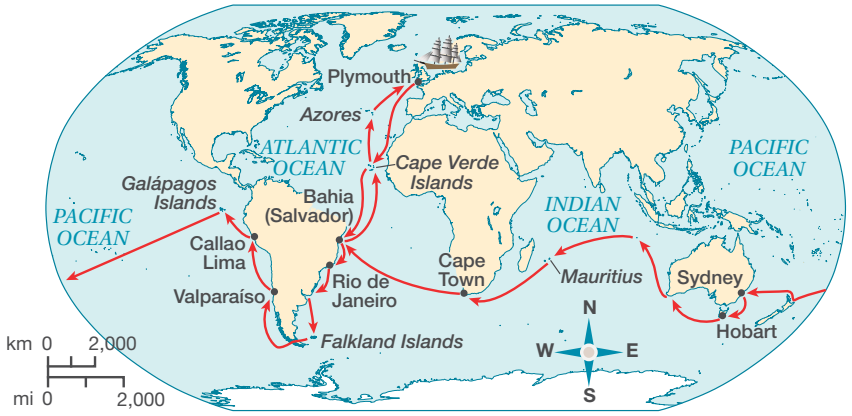
FIGURE 6: Charles Darwin

In 1831, the ship HMS *Beagle* set sail from England on a five-year journey to map the coast of South America and the Pacific islands. The ship captain saw it as an opportunity to collect specimens and study natural history. An invitation was extended to Charles Darwin, a recent graduate from the University of Cambridge. To prepare for the trip, Darwin collected scientific tools, as well as books, one of which was Lyell's *Principles of Geology*, which he read along his travels.

The first stop occurred at the Cape Verde Islands, where Darwin noticed a band of seashells on a cliff high above the shoreline. Darwin was curious about how the shells ended up there. During the following year, the young naturalist explored the rain forest to collect specimens of plants, animals, and rocks. As he worked, Darwin kept a diary, recording each new observation. This approach allowed him to do comparative studies, such as noting the differences between fossils found on a later stop in the Falkland Islands and those found on the coast of South America. Darwin also noted geological phenomena that made him wonder how environments changed.

FIGURE 7: Darwin's Journey on the HMS *Beagle*

Explore Online



Near the end of his journey, the *Beagle* arrived in the Galápagos Islands. At this stop, Darwin would make some of his most widely known observations, which are still studied today. Darwin noted that the species found on one island looked different from those on nearby islands and on the mainland. He was struck by the variation of traits among similar species. Some traits seemed well suited to the animals' environments and diets.

FIGURE 8: Galápagos tortoises (*Geochelone elephantopus*) had variations in their traits that seemed to match their environment.

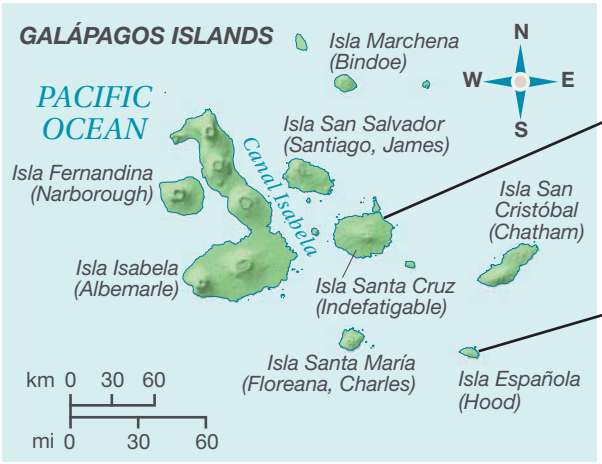
a The high shell edge of saddle-backed tortoises allow them to stretch their long necks.

b Domed tortoises have a short neck and short legs.

Predict Which variety of tortoise (saddle-backed or domed) would most likely live in an environment with mosses and short plants? Which would most likely live in an area with tall plants? Explain your answer.

Among all of Darwin's observations, the most well known are those of the Galápagos finches. These small birds, sometimes known as "Darwin's finches," are closely related, but with significant differences. These observations led Darwin to infer that species must somehow be able to adapt to their surroundings. An adaptation is a feature that allows an organism to survive and reproduce in its environment. It was this analysis that eventually helped shape Darwin's theory about how organisms change over time.

FIGURE 9: Variation in Galapagos Finches



a Large cactus finch *(Geospiza conirostris)*

Species in the genus *Geospiza* have thick beaks and can feed on large, hard seeds that require strength for crushing.

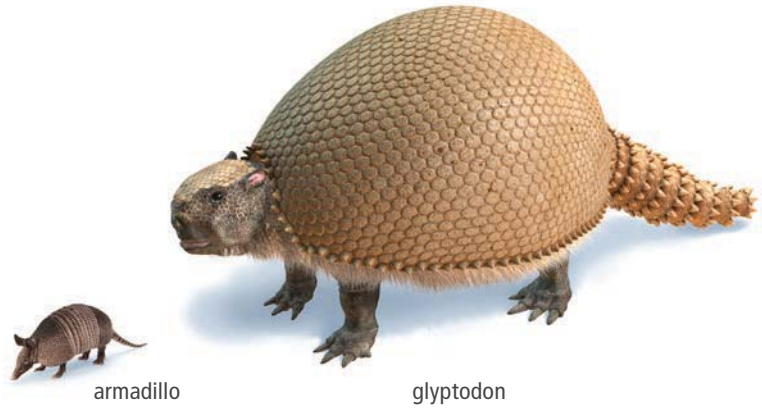
b Small tree finch *(Camarhynchus parvulus)*

Species in the genus *Camarynchus* have biting strength at the tips of their beaks, which is useful for tearing vegetation.

Analyze Use Figure 9 to answer these questions: How do these finches' adaptations help them survive and reproduce in their environment? What type of beak would you expect to see on a finch that eats insects? Explain your answer.

Several years before Darwin landed in the Galápagos, the *Beagle* anchored near Bahia Blanca in Argentina. While there, hunters brought back an armadillo. This was Darwin's introduction to this strange, armored animal. While on a fossil-hunting trip in the area, he found fossils of huge animals, including *Glyptodon*, a giant armadillo. The fact that these fossils looked like the living species suggested that modern animals might have some relationship to fossil forms. These fossils suggested that in order for such changes to occur, Earth must be much older than previously thought.

FIGURE 10: Darwin found fossils of *Glyptodon,* which resembles the modern armadillo.



armadillo glyptodon

Explain How do the *Glyptodon* fossils Darwin found in Argentina show that species have changed over time?

Predict Give three examples of geological processes that could cause fossils of organisms to be found in areas they did not historically inhabit.

During his voyage, Darwin also found fossil shells of marine organisms high up in the Andes Mountains. Darwin later experienced an earthquake during his voyage and observed the effects on the surrounding land. The land that had been underwater was moved above sea level. This experience explained what he saw in the Andes. Darwin's observations on his voyage supported Lyell's theory that daily geologic processes can add up to great change over a long period. Darwin later extended the ideas of an old Earth and slow, gradual change to the evolution of organisms. These observations led to the concept of evolutionary gradualism.

After his voyage, Darwin spent more than 20 years building on his research and knowledge of how evolution occurs. Although he had traveled the world, Darwin also found great insight in his home country of England. One important influence on Darwin's research was the work of farmers and breeders.

Artificial Selection

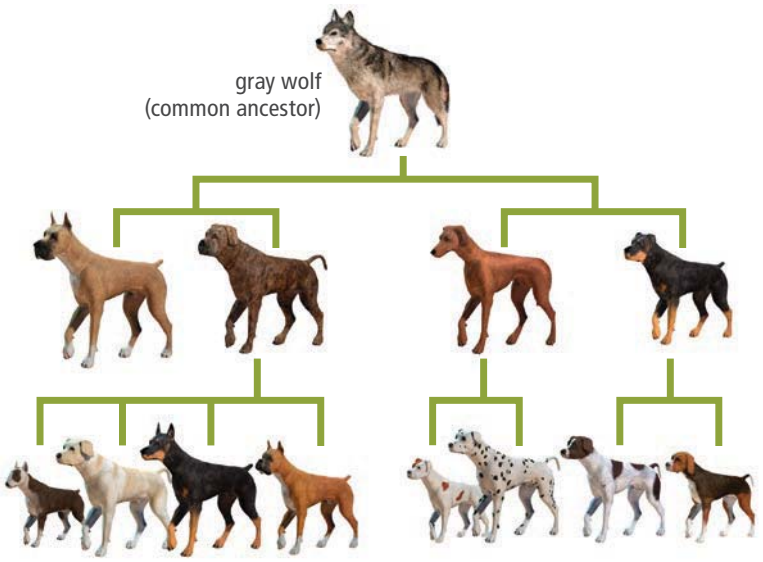
In England, Darwin observed a lot of variation in domesticated plants and animals. Farmers explained to him that, for example, some cows grew big and strong and produced a lot of milk. Others would be smaller and produce far less milk. The farmer would only breed those cows that were larger and that produced more milk. These productive traits were then passed on to the following generations. Through selection of certain traits, breeders could produce a great amount of diversity.

The farmers and breeders were not causing one cow to be more productive than another. Rather, they were controlling which cows would be used to breed offspring. The process of changing a species by breeding it for certain traits is called artificial selection. In this process, humans make use of the genetic variation in plants and animals by acting as the selective agent. Humans determine which traits are favorable and then breed individuals that show those traits.

Humans have been using artificial selection to select for desirable traits in plants and animals for thousands of years. Virtually all of the fruits and vegetables we eat have been greatly altered from their wild forms through the process of artificial selection.

Collaborate Discuss this question with a partner: How is artificial selection different than genetic engineering?

FIGURE 11: Domesticated dogs evolved through artificial selection. The common ancestor for domesticated dogs was the gray wolf.



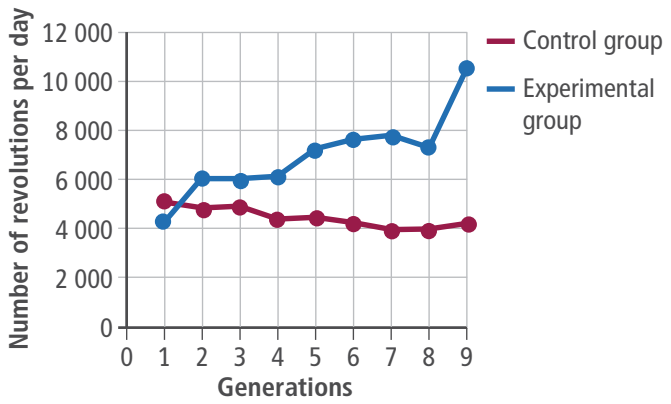
Although Darwin had no knowledge of genetics, he observed that, with human intervention, certain individuals could be selected to produce offspring with desirable traits. When selected and allowed to breed, these individuals would pass their traits onto their offspring. In order for artificial selection to occur, the trait must be heritable. Heritability is the ability of a trait to be passed down from one generation to the next.

Darwin related what he learned about breeding to his ideas on adaptation. In artificial selection, individuals with desired traits are bred over generations, but only if the traits are advantageous to breeders. However, breeders also might select against features that are not desirable or "useful." During artificial selection, humans act as the selective agent. In nature, however, the environment generates the selective pressure that determines if a trait is passed on or not.

Cause and Effect

Selection of Exercise Ability

FIGURE 12: In artificial selection, humans can make use of genetic variation by acting as the selective agent.



Source: Swallow et.al, *Behavior Genetics*, 28:3.

Scientists used mice to study whether exercise ability can improve in animals over several generations. In this experiment, mice were artificially selected for increased wheel-running behavior. The mice that were able to do the most wheel running were selected to breed the next generation. The control group represents generations of mice that were allowed to breed randomly.

Analyze Answer these questions about the data in the graph:

1. What is the difference in results between the mice in the control group and the mice in the experimental group?
2. Use the trend in the data to make a prediction about the number of revolutions on the wheel per day for mice in Generation 10 of the experimental group.

Darwin applied this thinking to develop his theory of evolution by natural selection. In nature, the environment is the selective agent. Similar to artificial selection, in natural selection the characteristics are selected only if they give an advantage to individuals in the environment as it is right now. Furthermore, Darwin realized that desirable traits would only emerge gradually in a population. He knew that it sometimes took many generations for breeders to produce the varieties he had observed.

Explain Make a graphic organizer to summarize Darwin's findings and illustrate how each observation relates to the processes that lead to changes in species.