

On the Origin of Species

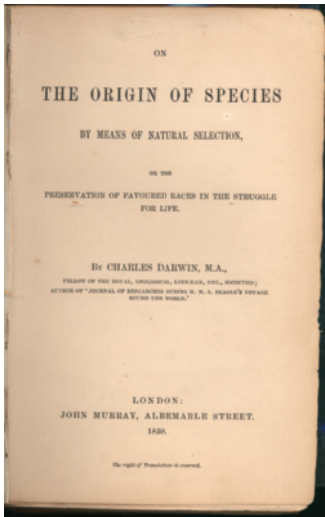


Figure 1 The first edition of Darwin's *On the Origin of Species*

WEB LINK

To learn more about Alfred Russell Wallace and his many contributions,



GO TO NELSON SCIENCE

natural selection the way in which nature favours the reproductive success of some individuals within a population over others

Darwin's *On the Origin of Species* was published in 1859 (**Figure 1**). This book not only described convincing evidence that species *had* evolved, it also proposed a theory of *how* species evolve. Darwin had formulated his theory much earlier. In 1844, Darwin wrote to his friend Sir Joseph Hooker, declaring:

“At last gleams of light have come, and I am almost convinced (quite contrary to opinion I started with) that species are not (it is like confessing a murder) immutable. . . . I think I have found out . . . the simple way by which species become exquisitely adapted to various ends.”

In the same year, Darwin prepared a 231-page outline of his theory and gave it to his wife, with instructions that it be published should he die unexpectedly.

Aware that any theory of evolution would be controversial and rigorously challenged, Darwin continued to gather evidence and look for flaws and weaknesses in his own reasoning. By June 1858, when he had written a quarter of a million words, he received a fateful letter from a brilliant young biologist working in Malaysia. In the letter, Alfred Russell Wallace outlined his own theory of how species evolved. His theory was almost a perfect match to Darwin's. 🌐

The young Wallace, with little evidence, was anxious to publish a theory that he had thought about for only a few days. Darwin, having spent 20 years amassing evidence and developing the same theory, had been unwilling to publish. Charles Lyell and Hooker convinced Darwin to submit a paper along with Wallace's at a meeting of the Linnean Society of London on July 1, 1858. The papers were of interest to scientists of the Linnean Society but went unnoticed by the public. A year and a half later, Darwin published a detailed account of his theory in a 502-page book entitled *On the Origin of Species by Means of Natural Selection or the Preservation of Favoured Races in the Struggle for Life*. The book sold out on the first day.

The Theory of Evolution by Natural Selection

Although Darwin had been hesitant to publish, he was extremely confident in his theory that species had evolved by a process he called natural selection. Darwin described **natural selection** as the way in which the environment, or nature, favours the reproductive success of certain individuals over others. Evolution was simply the result of natural selection occurring over many generations. Darwin's reasoning is illustrated in **Figure 2**.

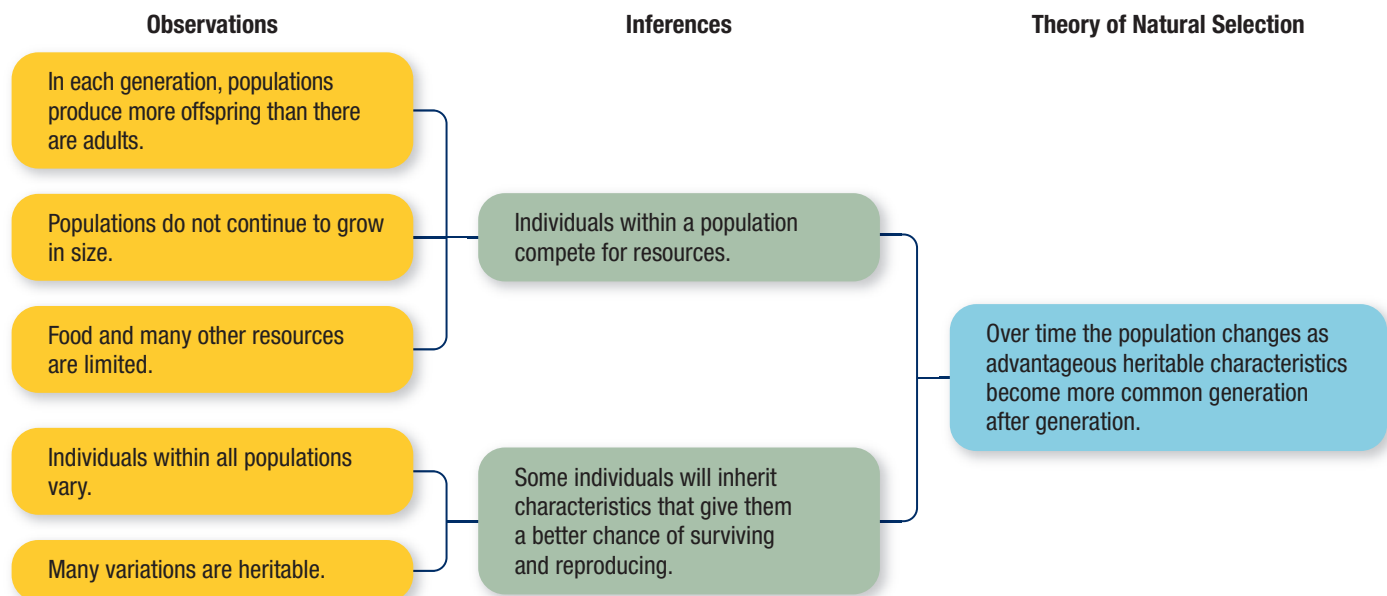


Figure 2 Darwin's theory of evolution by natural selection was powerful because it was based on five key observations that were well established and undeniable. Darwin realized that together, they gave rise to two logical inferences and provided a mechanism for evolution.

Darwin's key observations were undeniable: all healthy populations produced far more offspring than could survive and reproduce, and individuals exhibited heritable variability. Darwin believed that under these conditions, some individuals would have a better chance of success than others. A faster cheetah would surely be more likely to catch prey than a slower cheetah, and a stronger male lion would be more likely to defend and mate with a pride of females. If this were true and these differences were inherited, then the traits of the favoured individuals would become more common in the next generation. Faster cheetahs and stronger lions would have more offspring than slower and weaker individuals of the same species. Indeed, Darwin's theory was so simple and elegant that his friend and eminent zoologist Thomas Huxley exclaimed, "How extremely stupid not to have thought of it myself!"

A contemporary of Darwin's, Herbert Spencer, used the phrase **survival of the fittest** to describe the process of natural selection. Although Darwin himself thought the expression could be a useful synonym, it can be quite misleading. You might consider an individual that lives a long life but is unable to reproduce as physically "fit," but the individual would not pass on genes to the next generation. Such an individual would not be fit with respect to Darwin's theory of natural selection, or Spencer's definition. As you will learn in Chapter 8, the key to natural selection lies in its ability to favour *reproductive* success.

The theory of evolution by natural selection could be extended to virtually every biological characteristic or **adaptation** (Figure 3). Darwin understood that with a diversity of environments, the process of natural selection acting over thousands of generations could produce an unlimited variety of species.

survival of the fittest a phrase that has been used to describe the process of natural selection

adaptation a characteristic or feature of a species that makes it well suited for survival or reproductive success in its environment



Figure 3 All species exhibit adaptations that make them well suited to their particular environment.

Evaluating the Theory

Darwin had proposed a revolutionary theory that challenged not only the established science of the day, but also the currently held beliefs and teachings of a large proportion of society. Darwin knew that all scientific theories must be explanatory, have predictive powers, and be testable.

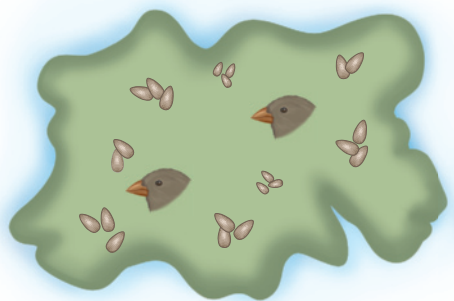
EXPLANATORY POWER

As you learned in previous sections, Darwin had amassed a great deal of evidence from biogeography, the fossil record, the anatomical features of different species, and artificial breeding. Consider how Darwin might have applied his theory of natural selection to explain the evolution of large-billed finches on the Galapagos Islands (Figure 4 and Figure 5, next page).

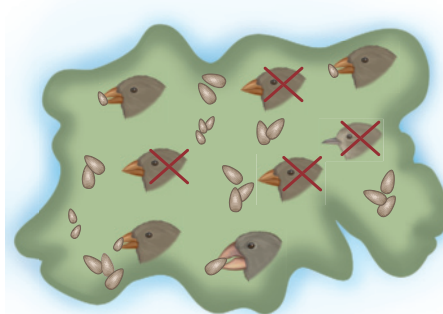
Critics of Darwin questioned the source of variability in characteristics. Although small increases in bill size seemed possible, they wondered how an ancestral giraffe with a short neck could ever evolve into a modern long-necked giraffe. Although Darwin could not have foreseen the discovery of DNA and the role that mutations play in producing variation, he did have evidence from animal breeding that suggested such dramatic changes were possible. Although the source of the variation was a mystery, Darwin argued that if dogs could be so altered in a few hundred years of artificial selection, why could nature not accomplish even greater change in thousands and even millions of years of natural selection.



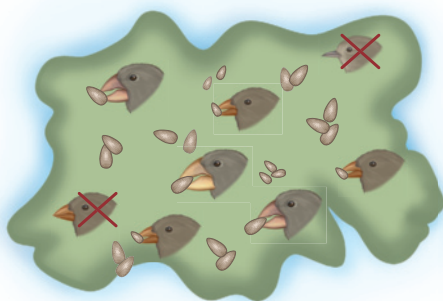
Figure 4 The large-billed ground finch of the Galapagos islands evolved from an ancestral species that possessed a much smaller bill.



(a) An ancestral population of finches with medium-sized bills are the first seed-eating birds to arrive on the Galapagos Islands. They typically eat medium-sized seeds. With no initial competition, the finches establish a growing population on a small island with a variety of plants, some with medium seeds but most with larger seeds.



(b) The finch population grows until it reaches the limit of its food supply. Each year many eggs are laid and hatched, but the island cannot support all the birds. The birds are not all alike—like any species, they exhibit variation. Some birds have slightly larger and some slightly smaller than average bills.



(c) Most of the birds must compete for the same medium-sized seeds, but any bird with an unusually large bill is able to also feed on the larger seeds. These birds have little or no competition and ample food is available to them. Darwin would say that the environment favours, or selects, these larger-billed birds. The larger-billed birds, being healthier, lay more eggs on average. Their young are more likely to be born with larger bills.



(d) As this process is repeated generation after generation, the average bill size of the birds continues to increase. This is evolution by natural selection. Had medium-sized seeds been more common than larger seeds, the advantage of the larger bill might have been offset by the energy needed to grow the bill and/or disadvantages in reaching and manipulating the medium-sized seeds.

Figure 5 Evolution of large-billed finches on the Galapagos Islands

UNIT TASK BOOKMARK

Consider how you can use Darwin's theory of evolution by natural selection to predict outcomes related to your Unit Task topic.

Investigation 7.5.1

Modelling Natural Selection (page 314)

You will design and conduct a controlled experiment to test Darwin's theory in a simulated predator–prey relationship.

PREDICTION

The theory of evolution by natural selection enables scientists to make predictions about how species may change over time. Many of these predictions are associated with changing environments. For example, the theory of evolution predicts that species will evolve in response to climate change because different environmental conditions will favour different traits. Over time, bird species may change the timing of their migration, and plants may adapt to warmer or drier conditions. Such changes are already being documented.

The theory of natural selection also predicted the evolution of antibiotic resistance in bacteria and pesticide resistance in insects. Darwin made predictions regarding the fossil record of humans. Based on the distribution of the living great apes, he predicted that fossils of the most primitive human ancestors would be found on the African continent. Darwin's predictions have been proven correct.

TESTING AND FALSIFICATION

Darwin also knew that to be scientific, a theory must have the potential to be falsified. This means that a scientific theory must be testable—there must at least be the possibility of it being proven wrong. For example, the theory of gravity meets this scientific standard because it could be falsified by observing apples “falling up.” The fact that we never find such evidence adds strength to the theory of gravity. **Table 1** (next page) illustrates a few of the kinds of evidence that could falsify the theory of evolution as well as the evidence that currently exists.

Darwin knew that if evolution had not occurred, if species had not changed over time, it should be easy to find falsifying evidence. His confidence in the theory was greatly strengthened by the complete absence of such evidence.

Table 1 The Potential for Falsification

Hypothetical observations with the potential to falsify Darwin's theory	Actual observations and evidence
amphibians and large land mammals on remote oceanic islands	No native amphibians or large land mammals have ever been discovered on remote oceanic islands.
fossils of complex organisms found in the oldest fossil deposits	Of millions of fossils, none contradict the predicted pattern of increasing complexity over time.
complex organisms with no vestigial features	All organisms that have been studied in detail exhibit many vestigial features.
species thought to be closely related that share no homologous features with each other	All organisms that have been studied in detail exhibit many features that are homologous with other closely related species.

7.5 Summary

- Darwin's theory of evolution by means of natural selection explains how the environment acts to favour the reproductive success of individuals with certain heritable traits over others.
- Darwin's theory of evolution by means of natural selection is able to explain how an adaptation can arise.
- Darwin's theory of evolution by means of natural selection can be used to make predictions about the future evolution of species.
- Darwin's theory of evolution by means of natural selection is a testable scientific theory.

7.5 Questions

- (a) What evidence from Darwin's personal life suggests that he had developed his theory but was very hesitant to make it public?
(b) Why do you think Darwin might not have wanted to publish his ideas? **A**
- (a) How did Wallace influence Darwin's decision to publish?
(b) Do you think Wallace should be given as much credit as Darwin for the theory of evolution by natural selection? Why or why not? **K/U A**
- Use one or two examples to explain what Darwin meant by the term "selection." **K/U**
- A male walrus lives to be 20 years old and mates with 18 females during its life. A second male lives to be 10 years old but mates with 44 females. Which male has natural selection "favoured?" Explain your reasoning. **K/U A**
- Suggest a probable selective advantage for each of the following traits: **A**
 - clear wings of many flying insects
 - long tongue of a chameleon
 - tendrils of climbing plants
 - sweet-tasting and brightly coloured fruits
 - eel's body shape
 - dramatic coloration of the non-venomous false coral snake
- When he published *On the Origin of Species*, Darwin was still planning to write a much more detailed "Big Book" on evolution. He had originally titled his book *An Abstract on the Origin of Species*. His editor convinced him to remove "An Abstract." An abstract is a short summary of a larger scientific document. **T/I A**
 - What does this suggest about Darwin's approach to science?
 - Darwin never completed his "Big Book." Use the Internet and other sources to learn about books that Darwin did write in the years following *On the Origin of Species*.
- Outline the hypothetical steps that might take place as a species of bird evolves a smaller bill after reaching a remote island. **K/U A**
- How did the absence of falsifying evidence increase Darwin's confidence in his theory? **K/U**
- After 1858, Alfred Russell Wallace continued to correspond with Darwin and make contributions to the understanding of evolution. Use the Internet and other sources to research Wallace's thoughts on
 - warning coloration
 - the "Wallace effect" **T/I**

