

THE MAKING OF A THEORY—FACT OR FICTION

OVERVIEW

This activity supports the viewing of the film *The Origin of Species: The Making of a Theory*. Before and after watching the film, students discuss and evaluate several statements about Charles Darwin, Alfred Russel Wallace, and the specific evidence that led each of them to the theory of evolution by natural selection. This activity serves as an anticipation guide to focus students on several key concepts covered in the film. It can also be used as a pre- and post-assessment.

KEY CONCEPTS AND LEARNING OBJECTIVES

- Charles Darwin and Alfred Russel Wallace *independently* discovered the natural origin of species and formulated the theory of evolution by natural selection based on distinct sets of observations and facts.
- The natural origin and evolution of species provide scientific explanations for both the diversity and unity of life as well as the sequence of changes found in the fossil record.
- Natural selection acts on variation among individuals within populations. The differential survival and reproductive success of individuals with different traits causes populations to change from one generation to the next.
- By comparing organisms living today with the fossil records of extinct organisms, it is possible to reconstruct an evolutionary history and infer lines of evolutionary descent.
- Observations of the natural world raise questions. Scientific explanations provide answers to such questions, which can then be tested using additional observations and evidence.
- Communication among scientists plays a crucial role in scientific discoveries.

Students will be able to

- evaluate claims based on information and evidence presented in the film; and
- participate in a collaborative discussion of their interpretation of the evidence with their peers.

CURRICULUM CONNECTIONS

Curriculum	Curriculum Topics
AP (2012-13 Standards)	1.A.1, 1.A.2, 1.A.4
IB (2009 Standards)	5.4, D2, D5
NGSS	Middle school: MS-LS2-2, MS-LS2-4, MS-LS4-1, MS-LS4-2, MS-ESS2-3, MS-LS2.A, MS-LS2.C, MS-LS4.A, MS-LS4.B, MS-LS4.C, MS-ETS1.B High school: HS-LS4-1, HS-LS4-5, HS-LS4.B, HS-LS4.C
Common Core	CCSS.ELA-Literacy.SL.8.1, CCSS.ELA-Literacy.L.8.1, CCSS.ELA-Literacy.L.8.2, CCSS.ELA-Literacy.L.8.6, CCSS.ELA-Literacy.RST.6-8.4, CCSS.ELA-Literacy.RST.9-10.4, CCSS.ELA-Literacy.SL.9-10.1, CCSS.ELA-Literacy.L.9-10.1, CCSS.ELA-Literacy.L.9-10.6, CCSS.ELA-Literacy.L.9-10.2, CCSS.ELA-Literacy.RST.11-12.4, CCSS.ELA-Literacy.SL.11-12.1, CCSS.ELA-Literacy.L.11-12.1, CCSS.ELA-Literacy.L.11-12.4, CCSS.ELA-Literacy.L.11-12.6

PROCEDURE

Before Watching the Film

1. Have students work in pairs to complete the table labeled “Before Watching the Film” in the student worksheet. Let them know that they are not supposed to know all the answers; at this point they should just record their best guess for each statement based on what they already know. Ask them to record their reasoning in the space provided after each statement.

During the Film

2. Have students record information and evidence for or against each claim as given in the film in the table labeled “After Watching the Film.”

After Watching the Film

3. Have students work in pairs to discuss the accuracy of the statements based on information presented in the film and complete the “After Watching the Film” table.

4. Depending on available time, have a classroom discussion about each of the statements in the worksheet and ask students which ones are true and which are false. The key is that students support their claims with information and evidence from the film.

KEY TERMS

Darwin, evolution, fossils, natural selection, species, variation, Wallace

TIME REQUIREMENT

This activity can be mostly completed in one 50-minute class period with some homework. See “Teaching Tips” for suggestions on how to implement the activity in the classroom.

SUGGESTED AUDIENCE

This activity is appropriate for middle school life science and all levels of high school biology.

PRIOR KNOWLEDGE

For students to be able to answer the questions before watching the film, it may be helpful for them to have heard of Darwin and Wallace and be familiar with the terms “evolution” and “natural selection.” For students who have not been exposed to these concepts, the film can serve as an introduction.

TEACHING TIPS

- One way to structure this activity is for students to complete the “Before” table in class (5-10 min.) and then watch the film (30 min.). They can finish the “After” table the next day in class followed by a class discussion. Alternatively, students can complete the “Before” table in class; watch the film as homework; and complete the “After” table the next day in class, followed by a class discussion.
- Additional information about the events leading up to the formulation of the theory of evolution by natural selection and of Wallace’s and Darwin’s lives is provided in the In-Depth Guide

(<http://www.hhmi.org/biointeractive/film-guides-origin-species-making-theory>). Consider providing students with a copy of the background information in the guide as reading in preparation to watching the film.

- After students have completed their worksheets, have them consider additional questions, such as,
 - What are the key facts and observations presented in the film that led Darwin and Wallace to the *natural origin of species*—in other words, that species descend from other species?
 - What is the evidence for *natural selection* as a mechanism of evolution?
 - How did different observations, from different places, lead to the same conclusions?
 - One point you might want to highlight for students is that the glyptodont/armadillo showed variation over time, whereas the mockingbirds and tortoises showed variation over space. Ask students how each of these types of evidence helped Darwin to reach his conclusion about the origin of species.

ANSWER KEY

1. Most people living around Darwin and Wallace's time, including most scientists, believed in special creation—meaning that God created each species on Earth in its present form.

This statement is true. In Darwin's time, most Europeans, including Darwin, believed that God had created Earth and all of the organisms living on it in their current forms. Although the ancient Greeks, non-Western cultures, and even some naturalists in Europe had put forth ideas about evolution prior to Darwin's and Wallace's work, these notions were not well formulated and were marginalized by the prevailing dogma of special creation.

Darwin and Wallace made observations of the natural world. The evidence they collected did not support the idea that God created species in their present form and unchanging. Their observations and evidence were instead consistent with a natural origin of species.

In his autobiography, Darwin wrote:

The old argument from design in nature, as given by Paley, which formerly seemed to me so conclusive, fails, now that the law of natural selection has been discovered. We can no longer argue that for instance the beautiful hinge of a bivalve shell must have been made by an intelligent being, like the hinge of a door by man. There seems to be no more design in the variability of organic beings, and in the action of natural selection, than in the course which the wind blows.

(Excerpt from *The Autobiography of Charles Darwin: From The Life and Letters of Charles Darwin*, edited by his son Francis Darwin.)

Soon after the publication of *On the Origin of Species*, most scientists accepted the notion that life had evolved, but some remained skeptical about natural selection. Today, the theory of evolution by means of natural selection is a foundational principle of biology.

2. Before he set sail on the HMS *Beagle*, Darwin was training to be a minister. He was asked to join the voyage to be of company to the *Beagle's* captain.

This statement is true. Before embarking on his voyage, Darwin was studying to be a minister at Christ's College at Cambridge. During that time he became an enthusiastic naturalist, collecting beetles and taking classes from botany professor John Stevens Henslow. Henslow was the one who passed on the offer to Darwin to be the naturalist and traveling companion of Commander Robert FitzRoy, captain of the HMS *Beagle*. Darwin's primary job on the voyage was to provide upper-class company for FitzRoy, who wanted a naturalist and a dining companion. Darwin was well suited for the position since he was well educated, an amateur naturalist, and he came from an aristocratic background. For Darwin, the voyage was an extraordinary opportunity to obtain specimens for his collection—but he did not set out to understand the origin of species. The mission of the survey ship HMS *Beagle* was to chart the South American coast.

3. The observation that fossils of extinct organisms are found where similar organisms live today can be explained by the fact that species don't change over time.

This statement is false. In the film we see that Darwin also discovered the fossil remains of large glyptodonts, which are very similar to, though much larger than, present-day armadillos. The living tree sloths and armadillos appeared to have succeeded earlier related species—but they are not the same species. The clustering of similar species in space (that become different over time) suggested that each species had descended with modification from common ancestors.

The fossil record was a critical piece of evidence for Darwin's formulation of evolutionary theory. But Darwin realized that the fossil record was imperfect. In *On the Origin of Species*, he predicted that the fossil record should contain fossils of creatures with transitional features. Many transitional fossils have been identified today.

Lastly, looking not to any one time, but to all time, if my theory be true, numberless intermediate varieties, linking closely together all the species of the same group, must assuredly have existed; but the very process of natural selection constantly tends, as has been so often remarked, to exterminate the parent-forms and the intermediate links. Consequently evidence of their former existence could be found only amongst fossil remains, which are preserved, as we shall attempt to show in a future chapter, in an extremely imperfect and intermittent record.

(Excerpt from Darwin, *On the Origin of Species*, Chapter Six: On the Absence or Rarity of Transitional Varieties, 1859.)

4. Darwin was eager to share his ideas about evolution with the rest of the world, so he wrote and published his book, *On the Origin of Species*, in just two years after returning from his voyage on the HMS *Beagle*.

This statement is false. Darwin knew that his ideas about evolution would be shocking to most people because they contradicted special creation. So, after returning from his voyage on the HMS *Beagle*, Darwin spent years quietly and methodically amassing scientific evidence in support of his ideas, while sharing his observations and conclusions with only a few close friends. He also published many important papers on his observations of the natural world, including organisms such as barnacles, plants, and pigeons. It wasn't until 20 years after returning from his voyage that Darwin finally felt compelled to publish *On the Origin of Species*. He did so because Alfred Russel Wallace had sent him a summary of his own ideas about evolution, natural selection, and the origin of species.

Wallace had written to Darwin asking him to publish his (Wallace's) theory if he viewed it favorably. Darwin asked two of his friends and colleagues, geologist Charles Lyell and botanist Joseph Hooker, to view the manuscript. Lyell and Hooker decided that the fairest course of action would be to publish Wallace's essay and Darwin's work simultaneously. They announced that both Wallace and Darwin had independently reached the same conclusions.

5. The observation that the more similar two species are, the closer they tend to live geographically is evidence that species descend from other species.

This statement is true. The film shows that between 1854 and 1862, Wallace extensively traveled the Indonesian archipelago, collecting specimens and recording their locales. He noticed a clear divide running through the islands with respect to the distribution of species. The birds on one side were similar to those found in Asia, while the birds on the other side were more similar to those found in Australia. Wallace had effectively discovered the boundary of two converging continental plates that over time had juxtaposed two distinct island systems. In addition, Wallace noted that certain species of butterflies were only found in the Americas, whereas other types were found only in Asia; the same was true for many other animals. Through this research, Wallace surmised that species descend from similar species.

In 1855, while in Sarawak on the Malaysian island of Borneo, Wallace wrote a paper entitled "On the Law Which Has Regulated the Introduction of New Species" on the geographic distribution of species. He proposed that "*Every species has come into existence coincident both in time and space with a pre-existing closely allied species.*" Wallace described that species have evolved over time, with some species becoming extinct and new species evolving from earlier forms. Wallace is often referred to as the father of modern biogeography.

6. The finger bones inside manatee and whale flippers are evidence that these living species are modified forms of older species.

This statement is true. The film shows that Wallace wondered why “imperfections,” such as finger bones in whale flippers, existed. Whales don’t grasp and manipulate objects with their flippers, so why would they need finger bones? Why would seemingly useless structures be present if every species was specially created? Both Wallace and Darwin searched for a scientific explanation for these questions. They concluded that the presence of such structures was consistent with the theory of descent with modification, as the finger bones in whale flippers represented modified forms of structures present in a common ancestor. Often modified forms also have modified functions. For example, the human arm, whale’s flipper, and bat’s wing are adapted for different purposes but share the same basic bone structure, indicating that these organisms descended from a common ancestor.

7. Darwin and Wallace made observations of the natural world, including that individuals within a species have variations that affect how well they compete for limited resources.

This statement is true. The film shows that Wallace realized that individuals within a species compete for survival. Because individuals within a species vary in traits, in a given environment those individuals with traits that provide them with an advantage are more likely to survive and produce more offspring. Over time, these advantageous traits accrue in the population. Darwin independently made similar observations.

In 1798, Thomas Malthus, an English clergyman and economist, published “An Essay on the Principle of Population.” The central theme of this work was that human population growth would always exceed food supply growth, thus creating ongoing states of hunger, disease, and struggle. He observed that unless kept in check, human populations would double every 25 years.

Malthus wrote:

I think I may fairly make two postulata. First, That food is necessary to the existence of man. Secondly, That the passion between the sexes is necessary and will remain nearly in its present state. These two laws, ever since we have had any knowledge of mankind, appear to have been fixed laws of our nature, and, as we have not hitherto seen any alteration in them, we have no right to conclude that they will ever cease to be what they now are. ... Assuming then my postulata as granted, I say, that the power of population is indefinitely greater than the power in the earth to produce subsistence for man.

(Excerpt from Malthus, T. *An Essay on the Principle of Population*, Chapter 1, 1798.)

Both Darwin and Wallace read Malthus and realized that plant and animal populations have the same potential as human populations to increase rapidly unless kept in check by predators, diseases, and limited resources. On this topic, Darwin wrote:

Can it, then, be thought improbable, seeing that variations useful to man have undoubtedly occurred, that other variations useful in some way to each being in the great and complex battle of life, should sometimes occur in the course of thousands of generations? ... This preservation of favourable individual differences and variations, and the destruction of those which are injurious, I have called Natural Selection, or the Survival of the Fittest.

(Excerpt from Darwin, *On the Origin of Species*, Chapter IV. Natural Selection, 1859.)

8. Darwin and Wallace used DNA evidence to support their ideas about evolution and how species are related.

This statement is false. Darwin and Wallace based their theory of evolution on observations of the natural world—mainly of the variation in physical traits among individuals within species, similarities between animals in the fossil record and existing species, and the geographical distributions of related species. Darwin and Wallace did not know how heredity worked, and genes had not yet been discovered or defined.

At around the same time as Darwin’s and Wallace’s voyages, Gregor Mendel’s experiments with pea plants showed the basic mechanisms of heredity. Mendel provided the famous ratios of variations passed on from one generation to the next



that are the basis for what today we know as Mendel's principles. Darwin never read Mendel. It was not until the next century, around 1900, when new researchers, including Thomas Hunt Morgan, worked with Mendel's discoveries and found that natural selection and heredity could be brought harmoniously together.

REFERENCES

Darwin, C.R. 1958. *The Autobiography of Charles Darwin 1809-1882*. N. Barlow, Ed. New York: W.W. Norton.

Darwin, C.R. 1859. *On the Origin of Species*. London: John Murray.

Wallace, A.R. 1855. On the law which has regulated the introduction of new species. *Annals and Magazine of Natural History* 2nd Ser. 16:184-196.

Wallace, A.R. 1889. *Darwinism*. London: Macmillan.

AUTHORS

Written by Mary Colvard, Cobleskill-Richmondville High School (retired), and Laura Bonetta, PhD, HHMI

Edited by Dennis Liu, PhD, HHMI, and Stephanie Keep, consultant; Copyedited by Linda Felaco

Reviewed by Paul Beardsley, PhD

FIELD TESTERS

Angeliki Aravantinos, John Bowne High School, NY; Kathy Cahn, La Plata High School, NY; Morira Cahdzutko, St. John the Baptist DHS, NY; Linda Ciota, St. John the Baptist DHS, NY; Jerry Citron, Stuyvesant High School, NY; Rosario Cuarteros, Belmont Preparatory High School, NY; Lillieen Ferraro, Linden Academy, NY; Donald Kirkpatrick, Marion High School, SC; Jack Saffer, Central Islip High School, NY.