DARWIN

EVOLUTION | REVOLUTION

Educator's Guide

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- Gallery inquiries and classroom activities for your students
- California Content Standards for each applicable section

The Darwin Education Title Sponsor is
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Dear Educator,
Welcome to *Darwin: Evolution | Revolution*. This guide includes an exhibition overview, links (in colored text), and curriculum to help make your Museum visit an engaging educational experience.

References to California Content Standards are included where appropriate. Full text of standards is available at **http://www.cde.ca.gov/index.asp**.

If you have questions related to this guide please call the Museum Education Department at 619.255.0311 or email **education@sdnhm.org**.

The Darwin Education Title Sponsor is The Joan and Irwin Jacobs Fund of the Jewish Community Foundation. This exhibition season is sponsored by Jerome's Furniture and Eleanor and Jerry Navarra and Family. *Darwin: Evolution | Revolution* is organized by the American Museum of Natural History, New York (www.amnh.org) in collaboration with the Museum of Science, Boston; The Field Museum, Chicago; the Royal Ontario Museum, Toronto; and the Natural History Museum, London.

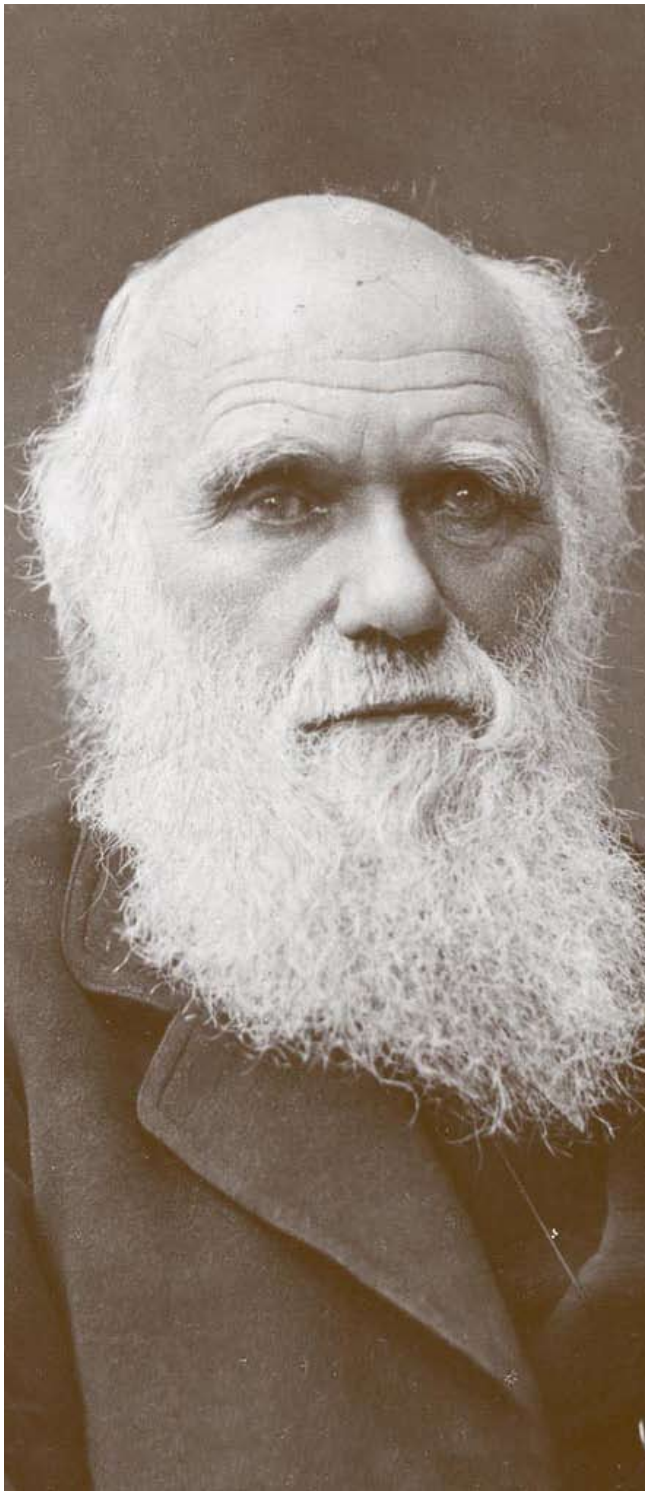
about—Darwin

This exhibition explores the extraordinary life and discoveries of Charles Darwin, whose striking insights in the 19th century forever changed our understanding of the origin of species and launched modern biological science. Visitors of all ages will experience the wonders Darwin witnessed on his journey as a curious and adventurous young man aboard the HMS *Beagle* on its historic five-year voyage (1831–1836) to the Galapagos Islands and beyond.

Darwin's evolutionary theory is the foundation for all of modern biology. Yet, outside of the scientific community, the theory has been the subject of controversy that extends from the time of the publication of *On the Origin of Species* 150 years ago to the present day. The exhibition addresses various controversies that have arisen surrounding the theory since it was first put forward. The exhibition also clarifies the distinction between scientific theories and nonscientific explanations about the origin and diversity of life.

The exhibition is divided into the following sections:

1. Introduction
2. World Before Darwin
3. Young Naturalist
4. A Trip Around the World
5. The Idea Takes Shape
6. A Life's Work
7. Evolution Today
8. Legacy



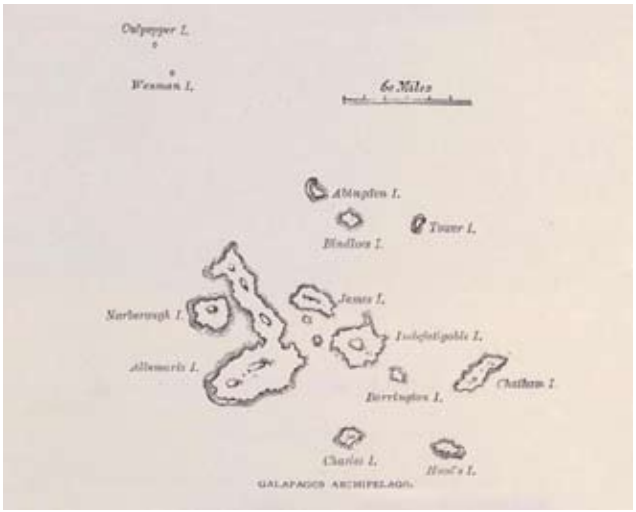
prepare—key concepts

Observations of Order

Many 19th-century naturalists saw order in nature, and a few even recognized that some form of evolution occurs. However, it is Charles Darwin who, with the publication of *On the Origin of Species* 150 years ago, set down the scientific foundation for our understanding of the living world.

Darwin was born into a curious and intellectual family and was always an avid naturalist. He seized opportunities to observe, collect, compare, and analyze throughout his life. For five years he travelled across the southern hemisphere as ship's naturalist aboard the HMS *Beagle*. During the voyage he observed, collected, and dined upon a great variety of living things.

Using the basic scientific tools of a magnifying glass and notebook, Darwin made exciting discoveries, but his most essential resource was his ability to form constructive questions based upon his observations. His intense curiosity about the diversity of species and their range of adaptations to different environments led him to a new understanding of the world around us—and our place in it.



Ask your students to investigate the course of the *Beagle*'s voyage. Print maps at http://commons.wikimedia.org/wiki/File:Voyage_of_the_Beagle-fr.svg.

Give each of your students a copy of the map to take with them to the Museum. While at the exhibition, ask them to label the stops on the map with the name of the country, and the year Darwin arrived there. Have them pick three stops and describe the observations he made at each place.

California State Content Standards

Grade 3 Life Science 3 a–e

Grade 7 Evolution 3 a–e

Grades 9–12 Ecology 6 a, g

Grades 9–12 Historical and Social Science Analysis Skills; Research and Point of View 1

Grades 9–12 Historical and Social Science Analysis Skills; Chronological and Spatial Thinking 3

Building a Theory

The evidence that Darwin collected during the voyage of the *Beagle* led to his theory that species adapt to different environments and change over time. At this point in history most people believed that all plant and animal species on Earth had been created in a fixed form, but natural evidence convinced Darwin otherwise. Among the many species he observed were ostrich-like rheas that differed in form as he made his way up the coast of South America, and Galapagos tortoises that were adapted to life on individual islands. Darwin came to realize that these different species had originated from a

common ancestor and had adapted to their local environments over many generations.

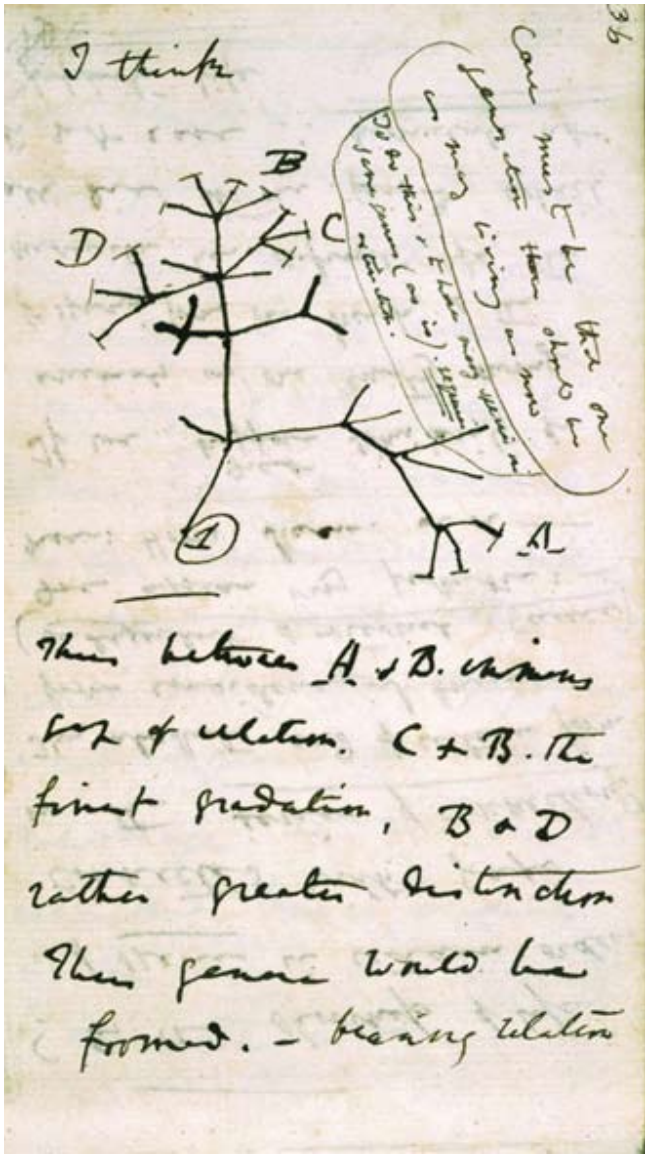
Darwin's breakthrough was his discovery of the underlying mechanism of species generation, which he named natural selection. Aware that his ideas would shake the world, he spent more than two decades rigorously observing, testing, and analyzing data collected both during his travels and in later exhaustive studies. He published four volumes on barnacles, he bred pigeons, dissected orchids, experimented with plants and seeds. He won recognition and acclaim for his work, and 23 years after the *Beagle*'s return he published his great idea on "the preservation of favoured races in the struggle for life."

Scientific knowledge changes over time, as scientists test, refine, and add to what is already understood about the world. Darwin spent his life in study at Down House, his rural retreat outside London. He continued to diligently test and strengthen his work. He fathered a large family and often set his children to investigative tasks including measuring the angles of worm burrows with knitting needles and tracing the paths of bees by dusting them with flour. He used the worm-burrow results in his last scientific work published in 1881, half a century after the *Beagle* set sail. Darwin's life as a scientist is remarkable not only for his discoveries but also for his energy and persistence.

Ask your students to visit the American Museum of Natural History's Spectrum of Life cladogram at http://www.amnh.org/exhibitions/hall_tour/spectrum/flash/ and check on the health of our planet's biodiversity. Investigate each phylum and see how many are threatened.

California State Content Standards

Grade 3 Life Science 3 a–e
Grade 7 Evolution 3 a–e
Grades 9–12 Ecology 6 a, g
Grades 9–12 Evolution 7 a–d, 8 a–f



Evolution: Descent with Modification

Scientific theories develop as scientists collect evidence about the natural world, form hypotheses that explain what they have observed, use their hypotheses to make predictions, test these predictions with further observations and experiments, and generate explanations that survive the testing process. New scientific tools and new fields of study, such as molecular biology and genetics, have greatly advanced our understanding of how natural selection works and have provided significant corroboration for Darwin's theory.

All life, including humans, evolved from a common ancestor through the process of natural selection.

Over the course of biological evolution, populations branch off from one another, stop interbreeding, and become separate species. These species continue to adapt and change over time. Darwin called this process "descent with modification," and grounded it in the evidence that all organisms differ among themselves (variation), pass traits on to their offspring (inheritance), some of which, being better adapted, survive and reproduce (selection), and that periods of time are involved.

Modern evidence supports and expands upon Darwin's theories. Genetic sequences, in combination with morphological studies of organisms, have been used to construct evolutionary family trees that illustrate the relationships between diverse species, and provide very strong support for common ancestry.

Modern biology benefits from our understanding of the process of natural selection. Numerous scientists investigating the natural world today—whether fighting viruses, decoding DNA, or analyzing the fossil record—have found Darwin's theory of natural selection essential to their work. For example, scientists studying flu viruses can anticipate which new varieties might evolve to become most harmful in the near future. They can then create vaccines designed to help the body's immune system ward off most of the upcoming year's varieties, a process that has saved countless lives.

Ask your students to investigate the link between the routine use of antibiotics in farming and the evolution of antibiotic resistant super bugs at http://evolution.berkeley.edu/evolibrary/news/050915_baytril. Is there a more responsible way for industry to produce food? What might your students study if they hope to revolutionize science the way Darwin did in the 19th century?

California State Content Standards

Grades 4–12 Language Arts: Literary Response and Analysis 3

Grade 7 Evolution 3 a–e

Grades 9–12 Ecology 6 a, g

Grades 9–12 Evolution 7 a–d, 8 a–f

Grades 9–12 Historical and Social Science Analysis Skills; Research and Point of View 1

explore—classroom activities

Observations of Order

Darwin described his interest in natural science as steady and ardent. He was more than just a methodical observer and collector of data. His trip on the *Beagle* is famous, but it is important to remember that he did a large part of his work in quiet contemplation of the things that he observed. He was looking for the information behind the data. Ask your students to try the same thing with the following activities.

Furry Pants Will Deliver.

Use safety pins to attach a piece of fake fur to the bottom half of one pant leg on one or more students. Take a walk with your class through an area in which uncultivated plants are growing, like a canyon or empty lot. When you return to the classroom, detach the seeds adhering to the fur. Glue them on to a chart and record the numbers and types. After reviewing the data, ask your students to hypothesize why the seeds stick. What are the advantages conferred through reproductive strategies that employ animal movement?

A Serendipitous Discovery

Sometimes new data is uncovered inadvertently. Read your students this anecdote from Darwin's life.

> One day, on tearing off some old bark, I saw two rare beetles, and seized one in each hand. Then I saw a third and new kind, which I could not bear to lose, so I popped the one which I held in my right hand into my mouth. Alas! it ejected some intensely acrid fluid, which burnt my tongue so that I was forced to spit the beetle out, which was lost, as was the third one.
>
> —Charles Darwin,
> *The Autobiography of Charles Darwin*

What did Darwin accidentally discover in one of his captured beetles? What new information about Charles Darwin's learning style can your students infer from this story?

California State Content Standards

- Grades 4–12 Language Arts: Literary Response and Analysis 3
- Grade 3 Life Science 3 a–e
- Grades 9–12 Historical and Social Science Analysis Skills; Historical Research, Evidence, and Point of View 1–3
- Grades 9–12 Historical and Social Science Analysis Skills; Historical Interpretation 1, 3, 4

Building a Theory

The publication of *On the Origin of Species* changed the world of scientific thought. Species adapt to different environments and change over time. All of biological science is based upon this understanding of life and yet many people still believe that all species on Earth have been the same since the beginning of time. Darwin's theory was controversial at the time and surprisingly remains so to this day. Ask your students to think about how scientific thought is formed and changed through continued acquisition and proofing of evidence.

Scientific theories explain facts and laws, have predictive power, and so can be tested. Most people would rate facts and laws as more important than theories, thinking of theories as "guesses" or "hypotheses." But for scientists, theories are the highest level of understanding. They are not just stepping stones to more knowledge, but the goal of science. The theory of gravity is a good example of a scientific theory. It is immutable and true. It guides our further understanding of plate tectonics, and even atomic theory.

The Nature of Science

What is the difference between the way most people use the word "theory" and the way scientists use it? What makes an idea testable? What's the difference between a theory and a belief? Watch the short video **Evolution, Education and the Integrity of Science** at http://www.aaas.org/news/press_room/evolution/.

Have a classroom discussion about what you see.

California State Content Standards

Grade 7 Evolution 3 a–e

Grade 7 Earth and Life History 4 a–g

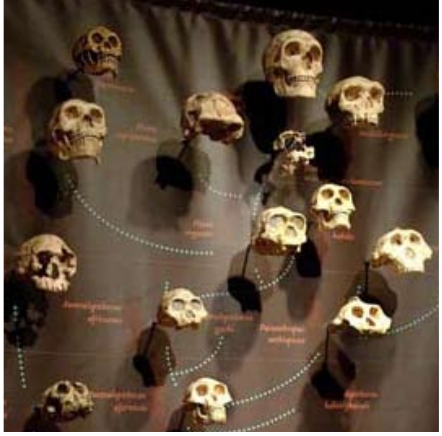
Grades 9–12 Ecology 6 a, g

Grades 9–12 Evolution 7 a–d, 8 a–f

Grades 9–12 Historical and Social Science Analysis Skills; Chronological and Spatial Thinking 1, 2

Grades 9–12 Historical and Social Science Analysis Skills; Historical Research, Evidence, and Point of View 1–3

Grades 9–12 Historical and Social Science Analysis Skills; Historical Interpretation 1, 3, 4



In Favor or Opposed

Read your students the following passage from a letter written by Darwin.

> About thirty years ago there was much talk that geologists ought only to observe and not theorize; and I well remember someone saying that at this rate a man might as well go into a gravel-pit and count the pebbles and describe the colours. How odd it is that anyone should not see that all observation must be for or against some view if it is to be of any service!
> —*Charles Darwin, letter to Henry Fawcett, 1861*

Ask your students why they think that Darwin considered observation without inference odd? Is counting and describing a useful scientific endeavor? Why or why not? What can you learn from this? What are the limitations? What does this quote say about the state of science in Darwin's time? How do you think it has changed? Is the argument for Intelligent Design guilty of observation without theory? Or is it weakened by a deficit of observation?

California State Content Standards

Grades 4–12 Language Arts: Literary Response and Analysis 3

Grade 7 Evolution 3 a–e

Grade 7 Earth and Life History 4 a–g

Grades 9–12 Ecology 6 a, g

Grades 9–12 Evolution 7 a–d, 8 a–f

Grades 9–12 Historical and Social Science Analysis Skills; Chronological and Spatial Thinking 1, 2

Grades 9–12 Historical and Social Science Analysis Skills; Historical Research, Evidence, and Point of View 1–3

Grades 9–12 Historical and Social Science Analysis Skills; Historical Interpretation 1, 3, 4

Evolution: Descent with Modification

Natural selection is the process by which species evolve over time. Individuals inherit traits, or features, from their parents. No two organisms (except identical twins) are exactly alike. This is called individual variation. Inherited variation comes from the mixture of genetic information from parents, and very occasionally from new mutations (copying errors of DNA).

There is a limit to the number of individuals that can survive in any particular environment. Those individuals that have traits that allow them to survive better will tend to pass more of these characteristics to the next generation.

For example, saddleback tortoises have longer necks and can reach high food more easily than other species of tortoises. On islands that lack food close to the ground, animals with this trait have a better chance of surviving and reproducing compared to their short-necked cousins. So over time, the long-necked tortoises are naturally selected in this environment. This is an example of how a population or species can evolve.

Wild Bean Savannah

Play a natural-selection game with your students. Spread out a patterned cloth. This is the savannah. Populate your savannah with 20 dried beans, red and white, ten of each. One set of the beans should contrast with the fabric and the other should blend in. Explain that the vegetation of the savannah has changed so that one type of bean no longer has the adaptive advantage of camouflage. They are in peril from predators. Now you are ready to play:

- Roll a die. The number on the die tells you how many of the imperiled beans could not escape predators. If the roll of the die is odd round up to the next even number.
- Take those beans off the savannah.
- The savannah population will replenish itself so put back the same total number of beans you took away EXCEPT the new generation must consist of half the imperiled color and half the protected color. (Example: if white is your imperiled color and you removed four white beans put back two red and two white.)
- Count all the red beans and all the white beans now on the savannah and graph the results.
- Continue to roll the die, remove imperiled beans, repopulate with half of each color and graph the results until natural selection has resulted in a complete revision of the original savannah population.
- Read this great story of descent with modification resulting in the evolution of a SUPER-SONIC defense adaptation. http://www.eurekalert.org/features/kids/2009-07/aaft-mus071009.php

Complete the activities below as you walk through the exhibition. You will need a pen or pencil and a hard surface to write on.

For the Love of Beetles:

As a child, Darwin loved to collect beetles. He was amazed by how many different kinds there were. Pick any two beetles from the *Young Naturalist* or *A Trip Around the World* sections, and draw them in the boxes on the right. Then, answer the questions below the boxes. Don't forget to write the correct name of your beetle specimens!

Name:	Name:

How are these two beetles different?

_____

How are these two beetles similar?

_____

Treasure Hunt for Tools When you walk in, you'll see a magnifying glass that Darwin used. How many other tools can you find in the exhibitition? Describe three of them and what you think Darwin used them for.

1. _____

2. _____

3. _____

It's Alive! Choose a live animal and draw it on the other side of this page. Pick two features of the animal (such as eyes or claws) and write about how you think they help the animal survive.

Save the Insects! Explore the "Nowhere to Hide" interactive in the last room of the exhibition.

- Which insects survive when the leaves are green? _____
- What happens to these insects when you change the color of the leaves? Why?

_____

Complete the activities below as you walk through the exhibition. You will need a pen or pencil and a hard surface to write on.

Voyage of the *Beagle*

Pick three things that Darwin collected during his five-year voyage around the world. In a few sentences, describe what you think he learned from each one.

1. _____

2. _____

3. _____

Animals and Adaptation

Choose an animal, either alive or a mounted specimen, and draw a picture of it on the other side of this page. List four of its features, and describe how you think each helps make the animal well-suited for its environment.

1. _____

2. _____

3. _____

4. _____

Why are Living Things so Diverse?

Watch the Natural Selection video in the last room of the exhibition. Fill in the words below that represent the underlying mechanism of natural selection.

V_____ I_____ S_____ T_____ A_____

Pick an example from the exhibition that illustrates natural selection at work. Use the five terms above to explain how these organisms evolved.

_____

_____

_____

_____

Complete the activities below as you walk through the exhibition. You will need a pen or pencil and a hard surface to write on.

A Trip Around the World

Pick a specimen that Darwin collected during his five-year voyage aboard the *Beagle*. Draw it on the back of this page and label the features that make it well-suited to live in its environment. Write a paragraph explaining how this piece of evidence contributed to Darwin's understanding of the mechanics of evolution. Make sure you refer to the features that you have labeled in your drawing.

Who Influenced Darwin's Thinking?

As you go through the exhibition: or, consider the important contributions of other scientists of the day. Pick three whose work was fundamental to Darwin's theory. How did their thinking influence his?

1.

2.

3.

VISTA

VISTA is an acronym for the underlying mechanism of natural selection first conceived by Darwin. Pick an example from the exhibition that illustrates natural selection at work. Using this example, explain each step of the process: Variation, Inheritance, Selection, Time, and Adaptation.

What is the Evidence for Natural Selection?

The last room in the exhibition contains four types of evidence that support the theory of natural selection: Homologies, Embryology, Vestigial Organs, and the Tree of Life. Choose two and describe in your own words how each supports the theory of natural selection.

1.

2.

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