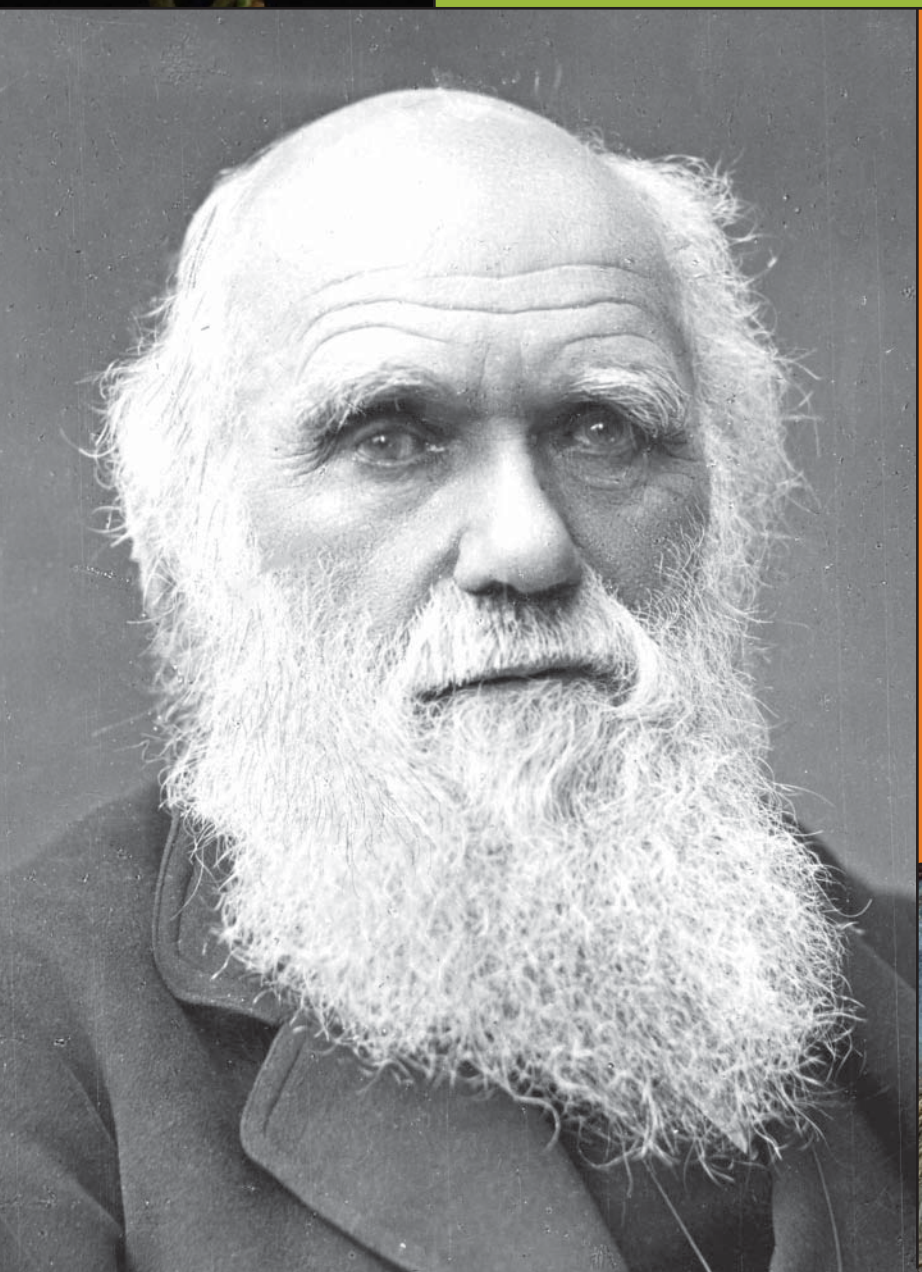
American Museum of Natural History

Darwin

EDUCATOR'S GUIDE

www.amnh.org/education/resources/exhibitions/darwin



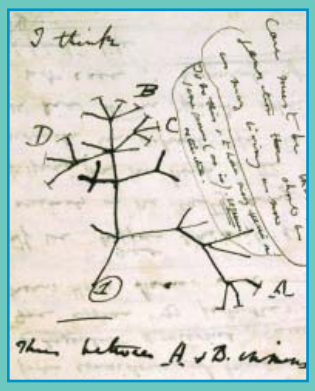
Welcome to *Darwin*! This exhibition tells the story of Charles Darwin, the man and the scientist, and how the evidence he gathered during and after the voyage of the *Beagle* led to the development of the theory of evolution through natural selection. It goes on to explore contemporary evolutionary biology, its applications in medicine and conservation, and how this theory is the foundation for all modern biology.

This Educator's Guide is designed to serve as a bridge between the exhibition and the classroom, providing activities and information for use at the Museum as well as before and after your visit. It offers a preview of the exhibition and correlates its content with the national and state standards for science.

KEY CONCEPTS in the Exhibition

1. **Darwin's greatest tool was his ability to observe and analyze.** Darwin made great discoveries using basic scientific tools like a magnifying glass and notebook. But his most powerful tool was his mind. 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.

2. **Scientific knowledge changes over time, as scientists test, refine, and add to what is already understood about the world.** Before Darwin, many 18th century naturalists saw order in nature, and a few even recognized that some form of evolution occurs. Darwin's breakthrough was his discovery of the underlying mechanism, which he named natural selection. New scientific tools and new fields of study, such as molecular biology and genetics, have greatly advanced our understanding of how this process works and have provided significant corroboration for Darwin's theory.



Darwin's first tree of life drawing

3. **The evidence that Darwin collected during the five-year voyage (1831-1836) of the HMS *Beagle* led to his theory that species adapt to different environments and change over time.** At the time most people believed that all plant and animal species on Earth had been created in a fixed form, but 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 adapted to their local environments over time.

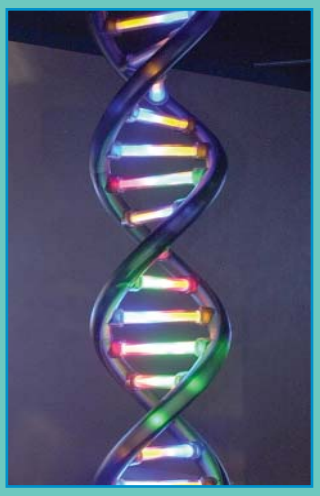
Map of the *Beagle* Voyage

4. **Darwin developed his theory of natural selection after years of rigorous observation, testing, and analysis.** Scientific theories develop as scientists collect evidence about the natural world, form hypotheses that explain what they've observed, use their hypotheses to make predictions, test these predictions with further observations and/or experiments, and generate explanations that survive the testing process. Aware that his ideas would shake the world, Darwin spent four decades at Down House, his rural retreat outside London, testing and strengthening his theory.

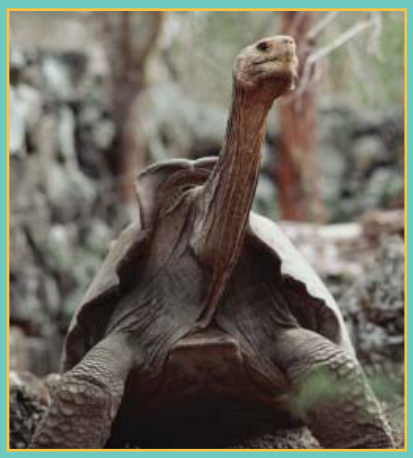
5. **All life, including humans, evolved from a common ancestor through the process of natural selection.** Over the course of biological evolution, populations branch off from one another, stop interbreeding, and become separate species. These species continue to adapt and change over time. Darwin called 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.

6. **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.

7. **Modern biology, and society in general, benefit 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.


The structure of DNA

How Does Natural Selection Work?



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 (pictured above) have longer necks and can reach high food more easily. 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 compared to the short-necked tortoises in this environment. This is an example of how a population or species can evolve.

What is a Theory?

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. Examples of theories that justify great confidence because they work so well to explain nature include gravity, plate tectonics, atomic theory, and evolution.

Teaching Evolution

Evolution is essential to the study of life sciences and key to understanding who we are and the world we live in. Yet, given misunderstandings about the science and the perception among some that it is controversial, teaching evolution can be challenging. The exhibition, this guide, and associated AMNH professional development activities are designed to support you in bringing your students to the exhibition and making this critical science accessible and engaging. In addition, the following online resources offer strategies and information for teaching evolution and for responding to questions and concerns you might encounter from your students and the community.

- **American Association for the Advancement of Science**
  Evolution on the Front Line
  http://www.aaas.org/news/press_room/evolution

- **National Science Teachers Association**
  http://www.nsta.org/evresources

- **National Center for Science Education**
  http://www.ncseweb.org/

- **The Natural History Museum in London**
  http://www.nhm.ac.uk/

- **Educator website associated with PBS Evolution Series**
  http://www.pbs.org/wgbh/evolution/educators/

- **University of California Museum of Paleontology**
  Understanding Evolution
  http://evolution.berkeley.edu/evosite/evohome.html

Come Prepared

Review this guide and online resources (http://www.amnh.org/resources/exhibitions/darwin) and plan your visit ahead of time. Give students directions and supplies before you arrive, since it can be hard to find space or quiet to communicate. Information about school visits is available at http://www.amnh.org/education/schools/. Before you visit, become familiar with the National Science Education Standards listed below that this exhibition can help you teach.

Grades K-4

Standard A: Science as Inquiry
- Understandings about Scientific Inquiry

Standard C: Life Science
- Life Cycles of Organisms
- Organisms and Environments

Standard G: History and Nature of Science
- Science as a Human Endeavor

Grades 5-8

Standard A: Science as Inquiry
- Understandings about Scientific Inquiry

Standard C: Life Science
- Reproduction and Heredity
- Regulation and Behavior
- Diversity and Adaptations of Organisms

Standard G: History and Nature of Science
- Science as a Human Endeavor
- Nature of Science

Grades 9-12

Standard A: Science as Inquiry
- Understandings about Scientific Inquiry

Standard C: Life Science
- Molecular Basis of Heredity
- Biological Evolution
- Interdependence of Organisms

Standard G: History and Nature of Science
- Science as a Human Endeavor
- Nature of Scientific Knowledge
- Historical Perspectives

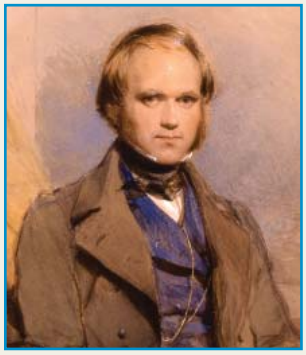
TEACHING IN THE EXHIBITION:

The themes below explore the **Key Concepts** and represent possible tours through the exhibition. Locations are indicated in *italicized* text.

1. Darwin's greatest tools were his skills of observation and analysis.

- **Charles Darwin's magnifying glass (*Introduction*):** Why is this the first object in the exhibit? Ask your students to think about why scientists use tools. Direct them to find a magnified object/specimen in each section of the exhibit. What observations can they make about each one? Can they find other scientific tools in the exhibition? How was each one used?

- **A Trip Around the World section:** Ask your students to observe one or more of the live animals in this section and write down their observations about how the animals look, move, and interact with their environments.



Young Darwin

- **Darwin's Notebooks (*The Idea Takes Shape section*):** Have your students look at Darwin's notebooks. What types of information did he record? Why is it important for scientists to keep detailed notes?

- **Down House and Darwin's Study (*A Life's Work*):** Ask your students what tools Darwin used to conduct his plant and animal experiments at Down House. How did his observations and studies contribute to the development of his theory of natural selection?

2. Scientific knowledge changes over time, as scientists test, refine, and add to what is already understood about the world.

- **"Unconformity" display (*Young Naturalist section*):** Ask your students how geological evidence about the age of the Earth revolutionized science during Darwin's time. How did these discoveries influence Darwin's thinking?

- **World Before Darwin section:** Ask students to consider what 18th century naturalists grasped about how species were related—and what escaped their understanding.

- **Malthus display (*London section*):** Scientists use the research, ideas, and theories of peers and predecessors to advance their own investigations. As your students proceed through the exhibition, ask them what Darwin learned from Malthus. What other scientists mentioned in the exhibit contributed to Darwin's interpretation and analysis of the evidence he collected? How did their different areas of expertise advance Darwin's understanding of the natural world?

- **Evolution Today section:** What evidence can your students find for ways in which Darwin's ideas have influenced evolutionary biologists at work today?

3. The evidence that Darwin collected during the five-year voyage of the HMS *Beagle* led to his theory that species adapt to different environments and change over time. (*All in A Trip Around the World section*)

- **Rheas:** How do these animals suggest the geographic replacement of one species by another?

- **Armadillos, tree sloth, Glyptodont and Megatherium fossils:** How are these specimens evidence for the replacement of species through time?

- **Live frogs and iguanas:** Ask students to look closely at these animals' adaptations. What did Darwin learn from examining different closely-related species?

- **Tortoises:** What did the differences between varieties/species on different islands in the Galapagos (micro-geographic replacement) suggest to Darwin?

Galapagos land iguana

Themes to Explore

4. Darwin developed his theory of natural selection after years of rigorous testing and analysis.

- **Darwin's pigeon breeding & plant experiments (*A Life's Work section*):** Ask students to compare what Darwin learned from studying domesticated species versus wild ones. What is the similarity between artificial and natural selection?

- **Darwin's letters (*A Life's Work section*):** It took Darwin over twenty years to publish *The Origin of Species*. Ask your students to locate letters he wrote to colleagues during this time, and to think about why this communication was important to him.

Darwin's microscope

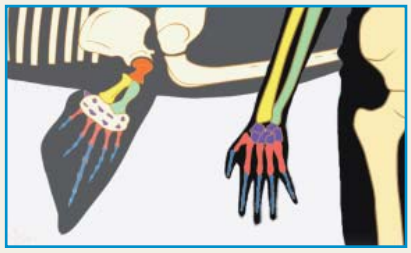
- **"What is a Theory?" display (*Evolution Today section*):** Suggest that students compare the way scientists use the word "theory" to its general usage.

- **The orchid and the moth (*Legacy section*):** How does this story illustrate the predictive power of Darwin's theory? Why is making accurate predictions important in developing scientific theories?

5. All life, including humans, evolved from a common ancestor through the process of natural selection. (*All in Evolution Today section*)

- **How do we know that living things are related? How long does evolution take? How do new species evolve? And what about us?** Ask your students to explore the evidence that scientists use to answer these four questions. Ask students to choose a question and summarize the evidence that answers it.

- **Homology or Embryology display:** Ask students to choose one of the displays. How does the evidence it presents support the concept of common ancestry?



Whale flipper next to human hand

- **Natural Selection Interactive:** Ask students to describe how the processes that take place during the interactive occur in nature.

6. Modern evidence supports and expands upon Darwin's theories. (*All in Evolution Today section*)

- **Tree of life:** Ask your students to describe how scientists determine relatedness among species.

- **Watch the *Natural Selection* video.** What has the new science of genetics contributed to our understanding of evolution?

7. Modern biology, and society in general, benefits from our understanding of the process of natural selection.

- **Viruses/Bacteria:** Ask your students to examine how scientists use the theory of natural selection when they design antibiotics and vaccines?

Bacteria

- **Ammonites display:** What have scientists learned by studying mass extinctions and their survivors?

Evolution of Horses

Back in the CLASSROOM

Here are questions and activities for your students to explore and to extend their understanding of the exhibtion.

Grades K-4

- Visit the Tree of Life Cladogram on the Museum's OLogy website (http://ology.amnh.org/biodiversity/treeoflife/). Have students explore the activity. Ask them to reflect on how scientists sort animals into different groups.
- Ask your students to research a particular animal that lives in its natural environment. What physical characteristics help it survive?
- What did the exhibition explain about what scientists do?
- Ask your students how parents and children are alike and different? What similarities are inherited? Which are learned?

Darwin's magnifying glass

Grades 5-8

- Visit the website Science Explorations: Zoom In on Insects (http://teacher.scholastic.com/activities/explorations/bug/). Have students explore the interactive. Ask them to reflect on how scientists classify organisms into different groups.
- Based on what you saw at the exhibition, what were Darwin's greatest contributions to natural science? What questions remain?
- Ask students to consider why there is such an amazing diversity of species on Earth. How do species acquire many of their unique characteristics?
- Artificial selection occurs when humans breed certain species to enhance or diminish specific traits. Can your students think of some examples? How does this process mimic or differ from natural selection?
- What are the big unknowns in science today? What might your students study if they hope to revolutionize science the way Darwin did in the 19th century?
- Visit the website Science Explorations: Animals, Adaptation & the Galapagos (http://teacher.scholastic.com/activities/explorations/adaptation/). Have students complete the interactives. Ask them to describe some of the ways that animals adapt to their environments.

Grades 9-12

- Visit the Spectrum of Life interactive on the Museum's website (http://www.amnh.org/exhibitions/hall_tour/spectrum/flash/). Have students explore the activity and reflect on how scientists classify organisms into different groups.
- What do your students identify as the most compelling evidence of the predictive power of the theory of natural selection?
- Ask students to name some practical applications of the theory of natural selection. What effect have they had on our lives?
- New evolutionary discoveries are being made every day. Have your students read and summarize an article on a recent discovery in evolutionary biology (e.g. a fossil find, medical development, conservation issue, or genetic research).

For more specific activities to use in your classroom, visit:

http://www.amnh.org/education/resources/exhibitions/darwin/educators

Credits

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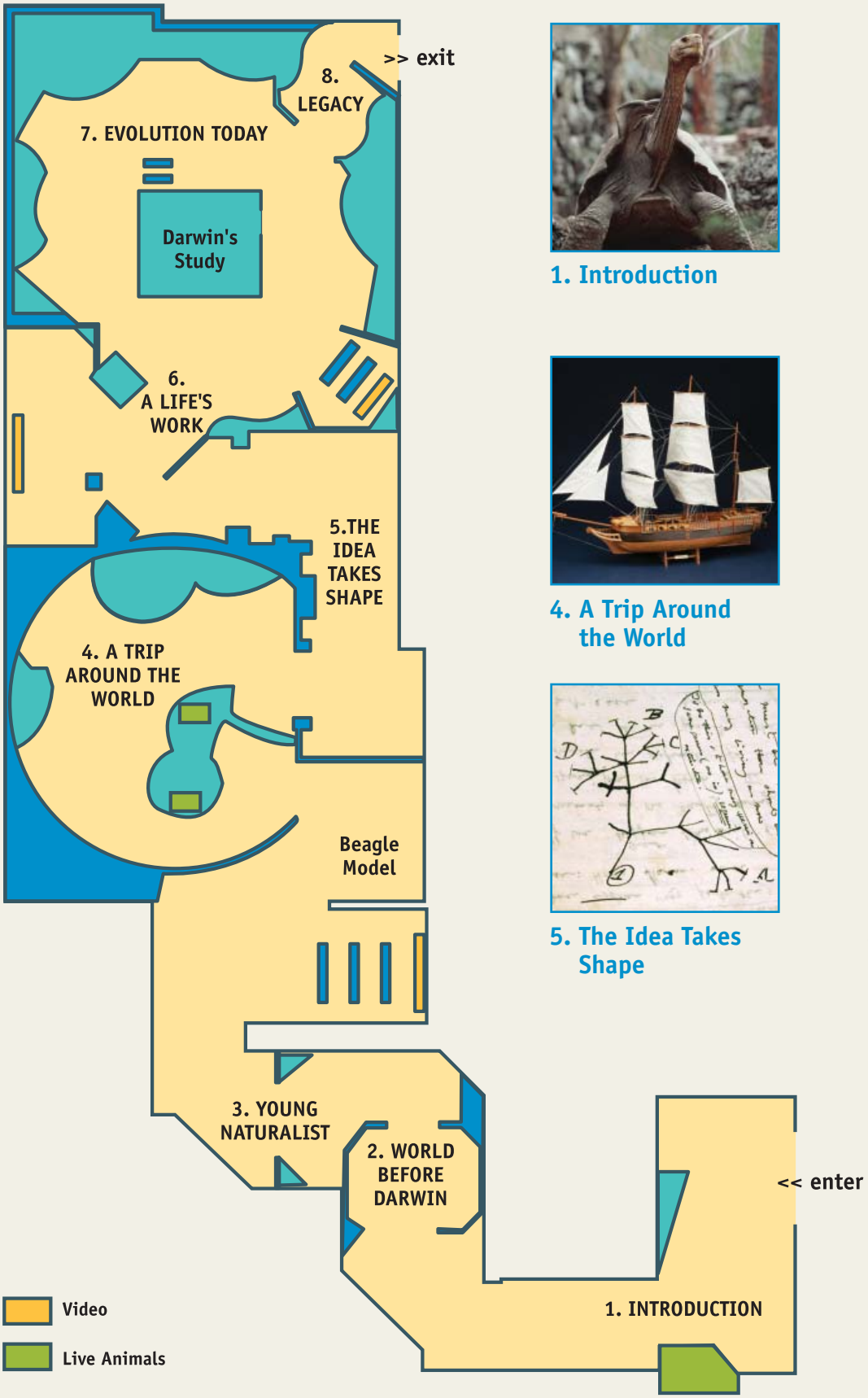
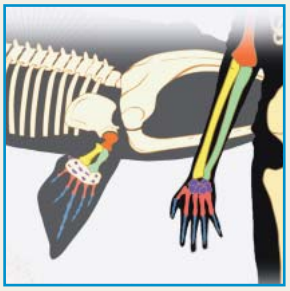
Darwin
MAP of the Hall



1. Introduction

6. Darwin's Study

4. A Trip Around the World



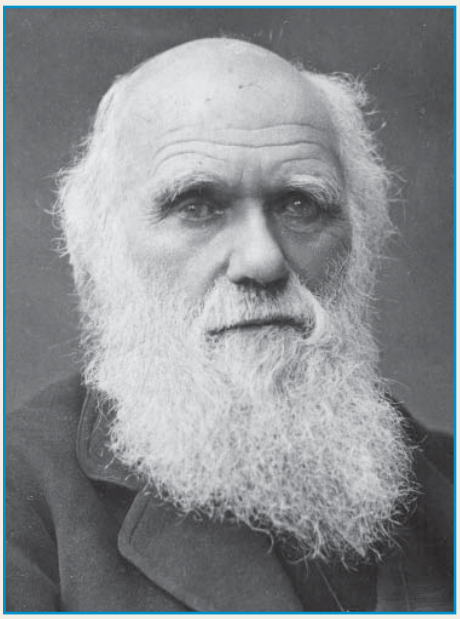
7. Evolution Today

5. The Idea Takes Shape

8. Legacy

SYNOPSIS of the Exhibition

This exhibition explores the extraordinary life and discoveries of Charles Darwin, whose striking insights in the 19th century forever changed the perception of the origin of our own species as well as the myriad other species on this planet 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.



The exhibition features live Galapagos tortoises and an iguana and horned frogs from South America, along with actual fossil specimens collected by Darwin and the magnifying glass he used to examine them. *Darwin* will feature an elaborate reconstruction of the naturalist's study at Down House, where, as a revolutionary observer and experimenter, he proposed the scientific theory that all life evolves according to the mechanism called natural selection. The objects on display, coupled with illuminating text, will provide a clear understanding of the patterns he observed among species, which led to his life's work and publication of the astonishing and brilliant *Origin of Species*, wherein he assembled the massive evidence of life's diversity, animal and plant domestication, and the geologic and fossil record for his theory of evolution.

Charles Darwin's evolutionary theory is central to science and 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 *The Origin of Species* nearly 150 years ago to the present day. The exhibition will address various controversies that have arisen surrounding the theory since it was first put forward. The exhibition will also clarify 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

Darwin
CONNECTIONS to Other Museum Halls

Evolution

Explore the story of vertebrate evolution in the Museum's famed fourth floor fossil halls. Darwin's theory underlies our understanding of the relatedness of species demonstrated in these halls.

- **Miriam and Ira D. Wallach Orientation Center:** Watch the video presentation on The Evolution of Vertebrates.
- **Halls of Saurischian Dinosaurs and Ornithischian Dinosaurs:** Observe the way specimens are displayed according to their evolutionary relationships—which are determined by their shared physical characteristics—rather than chronologically.
- **The Lila Acheson Wallace Wing of Mammals and Their Extinct Relatives (which includes the Hall of Primitive Mammals and the Paul and Irma Milstein Hall of Advanced Mammals):** Follow these halls' dramatic tale of great diversification, sudden extinctions, and the forces behind these phenomena.
- **The Hall of Vertebrate Origins:** Journey 500 million years back in time to see how vertebrates moved through the oceans and onto land.

Diversity of Species

Displays and dioramas throughout the Museum illuminate the extraordinary variety of life on Earth.

- **The Hall of Biodiversity:** Find the beetle collection on the Spectrum of Life wall for clues to Darwin's passion for these creatures. Next to the Galapagos Island iguana, watch a video of its relative, the marine iguana, feeding underwater.
- **The Milstein Hall of Ocean Life's Tree of Life:** Split between vertebrates and invertebrates, this model displays the major groups of animals that inhabit the oceans today.

Geology

Darwin drew on the fossil record to challenge the contemporary view of Earth as a young, unchanging planet.

- **Hall of Planet Earth:** Visit the "How has Earth evolved?" section to see how the geologic record has preserved early life forms. Explore "How do we Read the Rocks?" to learn what geologic formations tell us about Earth's past.

Voyage of the Beagle

The Museum halls contain many of the animals that Darwin encountered during his five-year voyage.

- **Hall of Mammals and Their Extinct Relatives:** Find the toxodonts, an extinct group first described by Darwin, and some of its other prehistoric relatives. Many of the notungulates on display are from the area of Argentina where Darwin unearthed fossils of giant sloths. These finds led to his understanding of descent from a common ancestor.
- **Birds of the World Hall:** The High Andes diorama displays many of the birds that so fascinated Darwin: finches, condors, rheas, and ovenbirds.
- **Hall of Reptiles and Amphibians:** Stop at the entrance to the *Darwin* exhibition to look at the Galapagos Island tortoise, which famously inspired Darwin's thinking on geographic variation.
- **South American Peoples Hall:** Darwin delighted in South America's tropical beauty and its people. This hall displays many of the cultural artifacts that gave Darwin his first and only look at how people lived outside his native England. Look for the bolas used by Patagonian gauchos, models of guanaco and other cameloids, and an early farming exhibit showing the great variety of vegetables that Darwin noted as examples of artificial selection.

Darwin

Correlations to the STANDARDS

New York

Mathematics, Science, and Technology

Standard 1	Scientific Inquiry	S 1,2,3
Standard 4	Application to Physical Setting and Living Environment	S 1,2,3,4,5,6
Standard 6	Common Themes	S 1,3,4,5
Standard 7	Connections	S 1,2

English Language Arts

Standard 1	Communication for Understanding	
Standard 3	Communication for Analysis	

Social Studies

Standard 2	World History	H 2,3
Standard 3	Geography	G 1,2

New Jersey

Science

Scientific Processes	Habits of Mind Inquiry and Problem Solving	5.1
Science and Society	Cultural Contributions Historical Perspectives	5.2
Nature & Process of Technology	Nature of Technology	5.4
Life Science	Diversity and Evolution Reproduction and Heredity	5.5
Earth Science	Processes that Shape Earth	5.8
Environmental Science	Natural Systems and Interactions	5.1

Social Studies

Geography	The World in Spatial Terms Places and Regions	6.6

Language Arts Literacy

Reading	Inquiry and Research	3.1
Writing	Writing as a Product	3.2
Speaking	Discussion Questioning	3.3
Listening	Active Listening Listening Comprehension	3.4
Views and Media	Writing as a Product	3.2
Writing	Constructing Meaning Literacy	3.5

Connecticut

Science

Heredity and Evolution	Organisms and Environment	3.2
Energy in Ecosystems	Organisms and Environment	4.2
Structure and Function	Organisms and Environment	5.2
Energy in Ecosystems	Populations in Environments	6.2
Heredity and Evolution	Reproduction	8.2
Heredity and Evolution	Variability and Inheritance	10.4
Heredity and Evolution	Genetic Change Over Time	10.5
Science and Technology	Populations Limited by Environment	10.6
Genetics	Molecular Basis for Evolution Enrichment	
Evolution	Natural Selection Enrichment	

Language Arts

Standard 1	Reading and Responding
Standard 3	Communicating with Others
Standard 4	English Language Conventions

Social Studies: History

Standard 1	Historical Thinking
Standard 4	Applying History

Social Studies: Geography

Standard 1	Places and Regions

To see the full lists of state education standards, visit the following websites:

New York:
http://www.edinformatics.com/ny/ny_standards.htm

New Jersey:
http://www.state.nj.us/njded/cccs/

Connecticut:
http://www.state.ct.us/sde/dtl/curriculum/