The Field Museum
Education Department Presents


Opening March 10, 2006

EXPLORE THE HISTORY OF LIFE

Travel back through time to learn how evolution has created the mosaic of life on Earth.

PART ONE: SECTION 1

Introduction to Evolving Planet
Evolving Planet
Opening March 10

This educator guide is separated into four parts: content, teacher and student resources, fun facts, and a walking map. The content for Evolving Planet consists of 12 sections. Before you visit the exhibition, spend some time viewing the information on the Museum’s Web site at www.fieldmuseum.org/evolving planet to begin planning your visit. We recommend using some of our quick fun facts and pre-activities to introduce your students to the geologic timeline, which is a reference tool that is prominent throughout the exhibition. Each section of this guide has an introduction, guiding questions, pre-activities, field trip activities, post-activities, and answers to guiding questions to help guide your students’ experience.

Acknowledgements:
Teacher contributors: Michael Baker, Bernadette Barnett and Nicholas Guerrero

The Field Museum salutes the people of Chicago for their long-standing, generous support of the Museum through the Chicago Park District. In addition, Museum programs are partially supported by a CityArts Program 4 Grant from the City of Chicago Department of Cultural Affairs and Illinois Arts Council, a state agency.

In accordance with Title IX of the Education Amendments Act of 1972, we do not discriminate on the basis of sex in our programs or activities. Please call 312.665.7271 to contact our Title IX Coordinator should you have questions or concerns.

Citigroup Foundation provides lead corporate support for professional development programs for teachers at The Field Museum.

Evolving Planet is made possible by Kenneth and Anne Griffin. The Elizabeth Morse Genius Charitable Trust is the generous sponsor of Evolving Planet’s Genius Hall of Dinosaurs.
Sections:

Part One:

Introduction to *Evolving Planet*

Section 1
Orientation to *Evolving Planet*

Section 2
The Precambrian: Life Emerges

Section 3
The Cambrian and Ordovician: World of Water

Section 4
The Silurian and Devonian: From Fins to Limbs

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The Carboniferous: Age of Coal Forests

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The Permian: Patchwork of Pangaea

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The Triassic: Dawn of a New Era

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The Jurassic and Cretaceous: Age of the Dinosaurs

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Part Two:

Related Programs, Exhibitions, and Resources

Part Three:

Walking Map
Illinois State Standards

(with adaptations to specific activities and grade levels)

Use of the materials in this educator guide in combination with a field trip to Evolving Planet will help you structure learning experiences that correspond to the following Illinois Learning Standards. Teachers will need to identify specific goals to map to individual lesson plans or larger units of study. This exhibition, while suitable for all students regardless of grade level, maps closely to concepts studied in later elementary, middle school, and high school.

English Language Arts

- State Goal 1: Read with understanding and fluency
- State Goal 3: Write to communicate for a variety of purposes
- State Goal 5: Use the language arts to acquire, assess and communicate information

Mathematics

- State Goal 6: Demonstrate and apply a knowledge and sense of numbers, including numeration and operations, patterns, ratios and proportions.
- State Goal 7: Estimate, make and use measurements of objects, quantities and relationships and determine acceptable levels of accuracy.
- State Goal 8: Use algebraic and analytical methods to identify and describe patterns and relationships in data, solve problems and predict results.
- State Goal 9: Use geometric methods to analyze, categorize and draw conclusions about points, lines, planes and space.
- State Goal 10: Collect, organize and analyze data using statistical methods; predict results; and interpret uncertainty, using concepts of probability.

Science

- State Goal 11: Understand the processes of scientific inquiry and technological design to investigate questions, conduct experiments and solve problems.
- State Goal 12: Understand the fundamental concepts, principles and interconnections of the life, physical and earth/space sciences
- State Goal 13: Understand the relationships among science, technology and society in historical and contemporary contexts.

Social Studies

- State Goal 17: Understand world geography and the effects of geography on society.

Fine Arts

- State Goal 25: Know the language of the arts.
- State Goal 26: Through creating and performing, understand how works of art are produced.
Introduction to the Exhibition

Probably all organic beings which have ever lived on this earth have descended from some one primordial form, into which life was first breathed ... There is grandeur in this view of life ... that, whilst this planet has gone cycling on according to the fixed law of gravity, from so simple a beginning endless forms most beautiful and most wonderful have been, and are being evolved.


Everything that has ever lived on Earth is connected through a single process: evolution. Evolving Planet takes visitors on an awe-inspiring journey through four billion years of life, from single-celled organisms to towering dinosaurs and our extended family. Discover how evolution works, and how we know it works. Explore six mass extinctions that have changed the planet. Walk through a 300 million-year-old forest—examine fossils you won’t find anywhere else—and learn how Field Museum scientists are expanding what we know about the past, present, and future of life on Earth. If you’re looking for dinosaurs, this is the place! Evolving Planet features 27,000 sq. ft. of exploration, including an extended dinosaur hall that includes every major dinosaur group, the worlds they lived in, and what we’ve learned from Sue our very own T. rex.

Orientation to Evolving Planet

Evolving Planet explores the complex, often dramatic, history of life on Earth as revealed through the process of evolution. Scientists estimate there are between 10–100 million species of plants, animals, and microorganisms alive today. This incredible diversity is the result of more than four billion years of cumulative biological change. To explore how life has changed through time, it’s critical that students understand the geologic time scale and its importance. Teachers should note that the geologic time line is displayed as you enter the exhibition and at specific points called “Timeline Moments” on the floor as you proceed through the halls. Each section of this guide contains a time line as well as a summary of the time lines throughout.

If you were to write a history of the Earth, allowing one page per year, your book would contain 4,500,000,000 sheets! That is the equivalent of the distance between Chicago and Madison, Wisconsin (145 miles to the northwest). If you were to read one page every two minutes, you would need 17,503 years to finish.
### Worksheet 1: KWL Chart

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<th>K</th>
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<tbody>
<tr>
<td>What I Know</td>
<td>What I Want to Learn</td>
<td>What I Have Learned</td>
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</table>
### Guiding Questions

1. How old is the Earth?
2. What is the geologic time scale and how are the units of the time scale related (i.e., eon era, period, and epoch)?
3. What is an eon? What are the three eras of the Phanerozoic Eon. In what era did trilobites, dinosaurs, and humans appear? What are the Periods in the Paleozoic Era?
4. How much of Earth’s history is represented by the Precambrian? What major event takes place at the beginning of the Precambrian?
5. Does the duration of certain periods or eras ever change? What happens to the geologic time scale when geologists get more data on the age of fossils and rock layers?

### Answers to Guiding Questions

1. The Earth is approximately 4,500 million years or 4.5 billion years old. The number can be expressed several different ways: 4,000 mya (million years ago), 4,000,000,000 years, 4000000000 years, or 4.0 x 10^9 years. Scientists express geologic age by using the notation “Ma” or mega annum (Latin) and “Ga” or giga annum for billions of years. You may also encounter “mya” for million years ago or “bya” for billion years ago.
Section 1: Pre-Activities and Field Trip Activities

Pre-Activities

1. Download the following from this guide: 24-hour Geological Stopwatch and Worksheet 2 that accompanies the stopwatch. Print one copy of each per student; you may want to print the stopwatch on cardstock (it can also be printed in color). Have students cut out the stopwatch and the arrow and glue them onto pieces of cardboard. Trim the excess cardboard off with scissors. Give each student a pushpin to attach the arrow to the front of the stopwatch—the pushpin will be the handle for turning the arrow. To keep the pin from sticking out too far on the back of the stopwatch, tape a small piece of cardboard over the pin tip on the back. On the stopwatch, Earth’s history is condensed into a single 24-hour day. Note that the Precambrian spans 21 hours of this 24-hour “geologic day!” While in the exhibition, have students keep track of time and fill in the chart on Worksheet 2.

2. Geologic time is a great way to introduce the concept of “big” numbers and to give students a sense of scale. Here are some analogies for dealing with the size of the number one million:
   a. A local charity is trying to raise one million pennies for a worthy cause. How many dollars is this? ($10,000)
   b. You have just won a contest. The prize is that you will get $1 bills from a bank teller at the rate of 1 per second for as long as you can stand there taking them (no bathroom breaks, no napping, etc.). How long will you have to stand there to become a millionaire? (around 12 days)
   c. Write the number one million in at least two different ways. (1,000,000 years or 1000000 years, 1.0 Ma or 1.0 x 106 years in scientific notation)
   d. Print out pages that show one million dots from the Web site at: www.vendian.org/envelope/dir2/lots_of_dots/million_dots.html
   e. Ask students to guess how many salt grains could fit in a:
      Pinch? (one thousand)
      Cup? (one million)
      Bathtub? (one billion)

3. Visit the Web site: www.uky.edu/KGS/education/activities.html#time for classroom activities on geologic time. Note the links to related sites.

Field Trip Activities

1. Using the 24-hour Geologic Stopwatch made in class, have students turn their arrows to the corresponding “time” as they go through the Evolving Planet halls. In each section of the exhibition students will encounter “Timeline Moments” printed on the floor, as well as “Mass Extinction” stations. There are four Timeline Moments in the Precambrian hall that correspond to black triangles on their stopwatches: 1) 4.0 billion years, 2) 3.5 billion years, 3) 2.5 billion years and 4) 600 million years. Have students move their arrows to the points marked on the clock when they reach each stop and write in the major event that occurred at that time. The six red triangles marked on their clocks represent mass extinction events. As students come to each Mass Extinction station, have them write the time of each event in millions of years on their stopwatch, and what percent of life died out. Discuss the cause of extinctions at each stop. Rank the extinction events in terms of their impact when you have finished this exercise.

2. Using Worksheet One: Mass Extinction Chart, have students fill in the information requested on the chart as they proceed through the exhibition. Watch for Mass Extinction stations in bright red that feature diagrams and text describing each event (there are six total in Evolving Planet).

3. Have students look for the “Sixth Extinction” station (Hint: this is at the end of the exhibition). Discuss the causes and importance of this extinction event. Ask students to come up with a list of things that they can do to help slow down this contemporary mass extinction and discuss the ideas as a group.
Section 1: Post Activities

Post-Activities

1. As a creative writing exercise, have students pick an animal from the geologic past and write a “Day in the Life Of...” story. Write the story from the first-person point of view and be sure to describe the environmental conditions at that time, and mode of life of the animal (what it ate, where it slept, how did it moved, etc.). When finished, have each student read and discuss his or her story. Students can be encouraged to illustrate their story.

2. Make a classroom geologic timeline from calculator tape. Instructions can be found at the Web site http://serc.carleton.edu/quantskills/activities/calculatortape.html. Have the students draw, sketch, collage pictures or images online of the typical plants and animals of each time period and tie or tape the images to the timeline. Hang the timeline in the classroom for discussion.


## Section 1: Vocabulary and Resources (geologic or deep time):

<table>
<thead>
<tr>
<th>Vocabulary Words</th>
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<tbody>
<tr>
<td>Geologic time, Eon, Era, Period, Epoch, Paleozoic, Mesozoic, Cenozoic, Precambrian, Achaean, mya (million years ago)</td>
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<table>
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<tr>
<th>Related Museum Exhibitions</th>
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<tr>
<td><strong>Permanent Exhibitions</strong></td>
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<tr>
<td>☐ Earth Sciences</td>
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<tr>
<td>☐ Moving Earth</td>
</tr>
<tr>
<td><strong>Temporary Exhibitions</strong></td>
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| ☐ Dinosaur Dynasty: Discoveries from China  
  (May 27, 2005 – April 23, 2006) |
| ☐ Dinosaurs: Ancient Fossils, New Discoveries  
  (March 30 – September 3, 2007) |
| ☐ Darwin  
  (June 15, 2007 – January 1, 2008) |

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<tr>
<th>Harris Educational Loan Center Material</th>
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<tr>
<td>☐ Mineral Match</td>
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<td>☐ Shake, Rumble and Roll</td>
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<td>☐ Rocks and Minerals</td>
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<tr>
<th>Recommended Multimedia</th>
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| ☐ Explore Deep Time: Geological Time and Beyond CD-ROM  
  (Geological Society of America; www.geosociety.org) |
| ☐ Explore Fossils CD-ROM  
  (Geological Society of America; www.geosociety.org) |
| ☐ Geologic Time Chart Game and related posters  
  (SK Science Kit & Boreal Laboratories; www.sciencekit.com/) |
| ☐ Fossil and Geologic Time Chart  
  (Wards Natural Science; www.wardsci.com/) |

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<th>Recommended Web Sites</th>
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| ☐ www.ucmp.berkeley.edu/help/timeform.html  
  (Univ. of California Museum of Paleontology) |
| ☐ www.geosociety.org/educate/resources.htm  
  (Geological Society of America) |
| ☐ www.enchantedlearning.com/subjects/GeologicTime.html  
  (Zoom Enchanted Learning) |
  (U.S. Geological Survey) |
| ☐ www.sdnhm.org/fieldguide/fossils/timeline.html  
  (San Diego Natural History Museum) |
  (PBS Evolution) |
| ☐ www.cotf.edu/ete/modules/msese/earthsysflr/geo_activity.html  
  (Earth Floor) |
Activity One: The 24-Hour Geological Clock

Directions:
Cut out arrow and clock. Paste pieces onto cardboard backing (or large paper plate) and trim excess with scissors. Place a small amount of glue on the round end of arrow and attach a plastic pushpin - choose a long pin or tack with some height since this will be the handle used for rotating the arrow. Younger students can use a round-headed fastener to attach the arrow to the Stopwatch. When dry, attach arrow to the face of the clock by pushing the pin or fastener into the center. If needed, tape a piece of cardboard over the tip of the pin on the back.
## Worksheet 2: Mass Extinction Chart

<table>
<thead>
<tr>
<th>Extinction Event</th>
<th>Era</th>
<th>Period</th>
<th>Millions of Years Ago</th>
<th>Percent of Life Lost</th>
<th>Main Cause</th>
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<tr>
<td>First Mass Extinction</td>
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<td>Second Mass Extinction</td>
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<td>Third Mass Extinction</td>
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<td>Forth Mass Extinction</td>
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<td>Fifth Mass Extinction</td>
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<td>Sixth Mass Extinction</td>
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Opening March 10, 2006

EXPLORE THE HISTORY OF LIFE

Travel back through time to learn how evolution has created the mosaic of life on Earth.

PART ONE: SECTION 2
The Precambrian: Life Emerges
This educator guide is separated into four parts: content, teacher and student resources, fun facts, and a walking map. The content for *Evolving Planet* consists of 12 sections. Before you visit the exhibition, spend some time viewing the information on the Museum’s Web site at www.fieldmuseum.org/evolvingplanet to begin planning your visit. We recommend using some of our quick fun facts and pre-activities to introduce your students to the geologic timeline, which is a reference tool that is prominent throughout the exhibition. Each section of this guide has an introduction, guiding questions, pre-activities, field trip activities, post-activities, and answers to guiding questions to help guide your students’ experience.
### Sections:

#### Part One:
- Introduction to *Evolving Planet*
  - Section 1: Orientation to *Evolving Planet*
  - Section 2: The Precambrian: Life Emerges
  - Section 3: The Cambrian and Ordovician: World of Water
  - Section 4: The Silurian and Devonian: From Fins to Limbs
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  - Section 7: The Triassic: Dawn of a New Era
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  - Section 9: The Tertiary: Age of the Mammals
  - Section 10: The Hominids: Dawn of Humankind
  - Section 11: The Quaternary: Age of Ice

#### Part Two:
- Related Programs, Exhibitions, and Resources

#### Part Three:
- Walking Map
Introduction: The Precambrian - Life Emerges

This area of the exhibition explores the first four billion years of Earth’s history, known as the Precambrian (4,500-543 million years ago). Spanning approximately 90% of geologic time, this vast and complex interval encompasses many of the most important events in the history of life. Teachers will note that geologic time is shown on the floor for reference in each gallery. For art teachers, note the Charles R. Knight murals throughout the exhibition. Created circa 1920-1930, they are some of the first paintings that show ancient life in natural environments. In this gallery, students will encounter a video that portrays Earth as it might have looked during the early Precambrian.

Earth was a strikingly hostile place. Meteorites bombarded the surface, volcanoes erupted lava and gas, and heavy rains condensed into vast oceans. Two theories of the origin of life are presented: 1) life arose in underwater hydrothermal vents or 2) life’s building blocks were carried to Earth within meteorites. Evidence of extraterrestrial organic compounds (life’s building blocks) are displayed in a rare meteorite from Australia. Note that this meteorite is the same age as the Earth!

Continuing through the gallery, students can explore the evolution of the first form of life—prokaryote cells—through an illuminated model. Prokaryotes are unicellular organisms with a very simple structure. How do we know there was life on Earth at this time? Students can examine fossil carbon (graphite) from Greenland (3,800 mya) and images of what may be the oldest fossilized cells (3,500 mya). Prokaryotes that evolved the ability to photosynthesize transformed the atmosphere of the early Earth by producing oxygen. Touchable specimens in this section include banded iron formation (BIF) and dome-shaped sedimentary features called stromatolites formed by bacterial mats. The process of sexual reproduction and its importance to the evolution of more complex eukaryote cells is discussed in the last section. Students can explore these topics through interactive touch panels and videos on sexual reproduction and natural selection. A diorama of the first multicellular organisms (Ediacarans) is displayed with associated specimens at the end of the gallery.
Section 2: Guiding Questions and Answers

Guiding Questions

1. How much of Earth’s history is represented by the Precambrian?
2. There are two main hypotheses for the origin of life on Earth. Describe these hypotheses and discuss the supporting evidence for both. Are these considered theories or hypotheses and why?
3. What is the difference between prokaryote and eukaryote cells?
4. Fossils of multicellular organisms are found in rocks of late Precambrian age. What types of animals do they represent?
5. What is the difference between asexual and sexual reproduction and what is the relevance of sexual reproduction to the process of evolution?

Answers to Guiding Questions

1. The Precambrian spans four billion years or approximately 90% of Earth’s history.

2. They are considered to be theories since there is evidence supporting both. The first theory states that life (organic compounds) may have formed on Earth in underwater thermal vents (“black smokers”). First discovered in 1977, these chimney-like structures on the ocean floor are formed from the escape of hot, mineral-rich water from deep within the Earth. Communities of bizarre organisms thrive in these deep-sea oases. The second theory states that life came to Earth from outer space in meteorites—fragments of asteroids, planets, or comets that have broken off and collided with Earth. Scientists have discovered that some rare meteorites, called carbonaceous chondrites, contain organic compounds—life’s building blocks. Up to 60 amino acids have been detected in the Murchison meteorite found in Australia! Both of these theories on the origin of life are speculative. Most scientists support the theory that life formed naturally here on Earth and was not transported to Earth in a meteorite.

3. Prokaryotes, such as bacteria, have a simple structure made up of a cell membrane enclosing the cell, cytoplasm or the fluid that makes up the contents of the cell, and DNA (deoxyribonucleic acid) carrying the instructions for cell growth and function. Eukaryotes, such as animal and plant cells, are more complex. These cells have a cell membrane and cytoplasm, but also have unique specialized parts called “organelles” including: mitochondria or the cell’s power-generators, chloroplasts for photosynthesis (only in plants and algae), and a membrane-bound nucleus containing DNA.

4. These fossils represent marine organisms often referred to as the “Vendian or Ediacara fauna.” A fauna is the animal life of a particular region or period. Ediacaran fossils are found in late Precambrian rocks (650 –543 Ma) on all the continents except Antarctica. There are many distinctive forms including a fossil sea pen (Charnia) and other organisms that are considered by some scientists to be relatives of arthropods and echinoderms. For more information on Precambrian life, visit www.ucmp.berkeley.edu/vendian/vendian.html.

5. Asexual reproduction is achieved when a single cell splits in two or “divides,” forming two separate cells with nearly identical DNA. Sexual reproduction involves the exchange of genetic material; that is, two parents pass on half of their DNA to their offspring. The offspring in this case are genetically different from each parent and any other offspring. Only eukaryotes can reproduce sexually.
Section 2: Pre-Activities, Field Trip Activities, and Post-Activities

Pre-Activities

1 Prompt students to form a hypothesis about the first lifeforms by asking the question: “What do you think the first lifeforms looked like and where did they live?” The hypothesis can be in the form of a Hypothesis Chart (Worksheet 2; this section): 1) Form My Hypothesis Statement, 2) Test My Hypothesis (by making observations in the exhibition and recording my observations), and 3) Form My Conclusion.

2 Have students draw a picture of what they think the first lifeforms looked like and where these lifeforms may have lived. Have them bring their drawings with them to the exhibition.

Field Trip Activities

1 Using their hypothesis worksheet, have students gather data about early lifeforms on display in the Precambrian gallery. Encourage students to make sketches to accompany their observations. Be sure to have them include the geologic age of the various lifeforms.

2 Ask students to make a list of the differences between simple bacterial cells called prokaryote cells and more complex animal and plant cells called eukaryote cells. Students should study the illuminated models of each cell type in the exhibition. Which cell type evolved first on Earth?

Post-Activities

1 Have students test their hypothesis on early life by summarizing the data collected in the Precambrian gallery during their field trip. This can be done in a table or chart. Based on their data and observations, ask them to describe whether their hypothesis is valid or whether it needs to be revised.

2 Have students make a 3D “diorama” or reconstruction of Precambrian life similar to displays seen in the exhibition. Be creative by using plaster of Paris to make the seafloor. Use an 8 x 10 inch piece of cardboard as a base and have students spread a thick mixture of plaster on the cardboard to form an irregular seafloor. Popsicle sticks can be used to spread and shape the plaster. For a realistic look, sprinkle sand onto the surface before the plaster is dry and paint with tempera paints. Use mixed media (paints, construction paper, pipe cleaners, noodles, etc.) to make the organisms. Make sure to include a key with a label for each life form. Ask students to describe their creations in class and summarize what they learned.
1 Form My Hypothesis Statement

2 Test My Hypothesis
   (by making observations in the exhibition and recording my observations)

3 Form My Conclusion
## Vocabulary Words

- Precambrian, meteorites, hydrothermal vents, prokaryote cells, eukaryote cells, sexual reproduction, stromatolites, natural selection, multicellular organisms

## Related Museum Exhibitions

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<td>□ Grainger Gallery</td>
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<td>□ Grainger Hall of Gems</td>
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<tr>
<td>□ Moving Earth</td>
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<tr>
<td>□ Traveling the Pacific (see volcano display)</td>
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<td>□ What is an Animal?</td>
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<tr>
<td>□ Gregor Mendel: Planting the Seeds of Genetics (September 15, 2006 – April 1, 2007)</td>
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<tr>
<td>□ Darwin (June 15, 2007 – January 1, 2008)</td>
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## Harris Educational Loan Center Material

(Call 312.665.7555)

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<td>□ Interior of the Earth</td>
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<td>□ Pebbles: How Shaped by Erosion</td>
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<td>□ Igneous Rocks</td>
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<th>Experience Boxes</th>
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<td>□ Shake, Rumble and Roll</td>
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<td>□ Volcanoes</td>
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<td>□ Rocks and Minerals</td>
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<td>□ Geology of Illinois</td>
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<tr>
<td>□ Explore Deep Time: Geological Time and Beyond CD-ROM (Geological Society of America; <a href="http://www.geosociety.org">www.geosociety.org</a>)</td>
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<td>□ Explore Fossils CD-ROM (Geological Society of America; <a href="http://www.geosociety.org">www.geosociety.org</a>)</td>
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<tr>
<td>□ Earth Cycles CD-ROM (Geological Society of America; <a href="http://www.geosociety.org">www.geosociety.org</a>)</td>
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<tr>
<td>□ Geologic Time Chart Game and related posters (SK Science Kit &amp; Boreal Laboratories; <a href="http://www.sciencekit.com/">www.sciencekit.com/</a>)</td>
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<tr>
<td>□ Fossil and Geologic Time Chart (Wards Natural Science; <a href="http://www.wardsci.com/">www.wardsci.com/</a>)</td>
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<td>□ <a href="http://www.geo.msu.edu/geo333/Precambrian.html">www.geo.msu.edu/geo333/Precambrian.html</a> (Michigan State University)</td>
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<td>□ <a href="http://www.enchantedlearning.com/subjects/Geololictime.html">www.enchantedlearning.com/subjects/Geololictime.html</a> (Zoom Enchanted Learning)</td>
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<td>□ <a href="http://www.palaeos.com/Timescale/Precambrian.htm">www.palaeos.com/Timescale/Precambrian.htm</a> (Palaeos Web site)</td>
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<tr>
<td>□ <a href="http://www.emc.maricopa.edu/faculty/farabee/BIOBK/BioBookPaleo2.html">www.emc.maricopa.edu/faculty/farabee/BIOBK/BioBookPaleo2.html</a> (Internet Library)</td>
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<td>□ <a href="http://ares.jsc.nasa.gov/Education/websites/astrobiologyeducation/index.html">http://ares.jsc.nasa.gov/Education/websites/astrobiologyeducation/index.html</a> (NASA Fingerprints of Life)</td>
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The Field Museum
Education Department Presents


Opening March 10, 2006

EXPLORE THE HISTORY OF LIFE

Travel back through time to learn how evolution has created the mosaic of life on Earth.

PART ONE: SECTION 3
The Cambrian and Ordovician: World of Water
Evolving Planet
Opening March 10

This educator guide is separated into four parts: content, teacher and student resources, fun facts, and a walking map. The content for Evolving Planet consists of 12 sections. Before you visit the exhibition, spend some time viewing the information on the Museum’s Web site at www.fieldmuseum.org/evolvingplanet to begin planning your visit. We recommend using some of our quick fun facts and pre-activities to introduce your students to the geologic timeline, which is a reference tool that is prominent throughout the exhibition. Each section of this guide has an introduction, guiding questions, pre-activities, field trip activities, post-activities, and answers to guiding questions to help guide your students’ experience.

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Sections:

Part One:

Introduction to *Evolving Planet*

Section 1
Orientation to *Evolving Planet*

Section 2
The Precambrian: Life Emerges

Section 3
The Cambrian and Ordovician:
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From Fins to Limbs

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Part Two:

Related Programs, Exhibitions, and Resources

Part Three:

Walking Map
This section focuses on the **Cambrian** and **Ordovician** periods, from 543–443 million years ago, of the **Paleozoic Era**. At this time, the continents occupied very different positions than they do today and were covered by extensive shallow seas. It was a world of water. After more than three billion years of evolution, the stage was set for multicellular life to diversify. Sometimes referred to as the **“Cambrian explosion,”** nearly all major animal groups suddenly appeared along with the first animals to possess hard skeletons. In this gallery, students will encounter an amazing digital diorama or “motion mural” of life in a Cambrian ocean 500 million years ago. Based on the famous **Burgess Shale** fossil deposit (British Columbia, Canada), bizarre creatures come to life in this breathtaking animation. **Trilobites**, one of the first organisms to evolve hard skeletons, ruled the Cambrian seas. Some are spiny, lumpy and bumpy, as tiny as a few millimeters or as long as three feet! Teachers will note the “Parade of Trilobites” display showing 33 different trilobite species as well as three unique trilobite 3D interactives: a trilobite eye simulation, rolling trilobite, and a trilobite body match. Students can continue their explorations of this group on the **Evolving Planet** Web site in a unique “Trilobite Dig” interactive (www.fieldmuseum.org/evolvingplanet).

The second part of this gallery focuses on the Ordovician Period, fifty million years later. Life in the oceans has continued to diversify—the number of animal species has tripled! Students will see dozens of fossils on display, including a ten-foot-long giant squid-like **cephalopod** suspended from the ceiling. **Vertebrates** appear as small jaw-less fish. Note the bright red “**Mass Extinction**” display. This biological crisis took place in the Late Ordovician around 450 million years ago, and wiped out 70% of animal species on Earth. It’s the first in a series of six extinction events highlighted throughout the exhibition.
Section 3: Guiding Questions and Answers

Guiding Questions

1. What are the three eras of the Phanerozoic Eon? List the six time periods of the Paleozoic Era and give their time ranges.
2. What are fossils and how do they form? What are body and trace fossils—how are they different?
3. What kinds of organisms were alive in the Cambrian Period? Where would you have to go to find them? Was there any life on land at this time?
4. What are trilobites and what did they look like? Are trilobites living today?
5. Describe the types of vertebrates that existed during the Cambrian and Ordovician periods.
6. What is a mass extinction? What was the probable cause for the mass extinction at the end of the Ordovician Period? What percentage of animal species was wiped out during this crisis?

Answers to Guiding Questions

1. The Phanerozoic is divided into three eras: the Paleozoic, Mesozoic, and Cenozoic. The Paleozoic Era is subdivided into six periods: Cambrian (543–490 million years), Ordovician (490–443 million years), Silurian (443–417 million years), Devonian (417–354 million years), Carboniferous (354–290 million years), and Permian (290–248 million years).
2. Fossils are the remains of ancient life older than 10,000 years. There are two main types of fossils: body fossils and trace fossils. Body fossils are the direct physical remains of ancient plants and animals such as shells, bones, teeth, wood, seeds, and leaves. Trace fossils are the indirect evidence of ancient animal activity (behavior) including tracks, trails, burrows, borings, egg nests, gizzard stones (gastroliths), and dung (coprolites). Fossils should not be confused with artifacts, which are objects that have a human maker. Scientists that study fossils are called paleontologists. Scientists that study artifacts are called archaeologists.
3. Life abounded in the oceans during the Cambrian. However, there is new research that suggests that some of the first organisms to colonize land were bacteria, in the form of mats or “biocrusts” growing in moist sand. The first plants to colonize land were probably similar to modern liverworts and are known from fossil spores found in rocks of latest Ordovician age (420 Ma).
4. Trilobites are arthropods that appeared in the Cambrian Period. They had jointed legs, gills, eyes, antennae, and a hard exoskeleton made of calcite. Their skeletons have three main divisions: head (cephalon), thorax, and tail (pygidium). They lived in ancient oceans for 250 million years, and became extinct at end of the Permian Period.
5. The ancestors of vertebrates evolved in the Cambrian (see Pikaia, Burgess Shale fossil), but it isn’t until the Ordovician, around 470 million years ago, that the first vertebrates, jawless fish, appear in ancient oceans.
6. A mass extinction is a rapid event in which many species die out over a geologically short interval, usually between 10,000 to 100,000 years. During a mass extinction, the organisms that become extinct represent a significant proportion of life on Earth at that time. Current research suggests that the mass extinction at the end of the Ordovician Period resulted from global cooling due to an ice age in the southern hemisphere. Approximately 70% of all species went extinct during this crisis.
Section 3: Pre-Activities and Field Trip Activities

Pre-Activities

1. Dig virtual trilobites on the *Evolving Planet* Web site.
   Have students visit www.fieldmuseum.org/evolvingplanet and explore the “Trilobite Dig” interactive. Students can go on a virtual expedition to several trilobite excavations around the world where they can study the field sites, find different trilobite species, and learn details about each species.
   Divide students into five groups and assign each group to one of the sites.
   Have students step into the shoes of a paleontologist by asking each student to create a field book or journal as if on a real expedition to dig trilobites. Encourage them to make notes about the location and nature of the site (size of area, landscape, time of year), type of rock, tools needed and method of excavation, fossils collected, and what they learned about each species. Have each group present the results of their excavations to the class.

2. Ask students to come up with three to five questions about ancient life or evolution that they hope to have answered during their field trip.

3. Have students visit the *Living Fossils of the Deep: An Expedition to the Bahamian Seafloor* at www.mnh.si.edu/livingfossils/defaulthome.htm and take notes on what they learn about “living fossils.”
   What is a living fossil? Ask students to find at least two examples of animals that can be seen on this Web site that are similar to fossils found in the Cambrian-Ordovician section of the exhibition. (Answers: gastropods, starfish, and crinoids).

Field Trip Activities

1. Have students observe the large motion mural (animation) of a Cambrian sea. Give student copies of Worksheet 3 (this section) from this guide and have them fill out each table. They will need to locate 10 animals from the mural and record the animal type (coral, sponge, arthropod, etc.) and animal name (scientific and common name).
   Examine the real fossils of each animal located in the display associated with the mural. Have students find the fossil of each animal and make a sketch in the appropriate box. When finished, go over the chart and discuss how the animated animals look compared to the real fossils. How do paleontologists reconstruct ancient animals?

2. Ask students to explore the three trilobite interactive stations:
   1) trilobite eye,
   2) rolling trilobite, and
   3) trilobite body match.
   Based on what they learned from the interactives, have them describe what it must have been like to be a trilobite. What was their vision like?
   Did they have a hard exoskeleton?
   How many parts comprised their body?
   What did they do to protect themselves?
   What would a day in the life of a trilobite be like?

3. Have students fill in the Worksheet 2: Mass Extinction Chart (see Section 1: Orientation to *Evolving Planet*) for the mass extinction that is described in this section.
**Post-Activities**

1. Ask students to write a story about their favorite ancient sea creature, like a trilobite, starfish, cephalopod, or some other animal they saw in the exhibition. Have them describe this animal’s life from its birth, death, and final discovery as a fossil. Read and discuss each story with the class.

2. Have students create their own trilobite using colored pipe cleaners, clay, glass beads, and construction paper. Using the illustration of the trilobite from *Evolving Planet* (below) as a guide, make a clay body and add pipe cleaners for legs and antennae, beads for eyes and other materials for segments etc. Encourage students to refer to sketches and observations they made during their field trip. Be creative—as creative as you noticed in the exhibition. Trilobites were amazingly varied! Display the pieces around the classroom and ask students to discuss their creations.

Illustration of the Ordovician trilobite *Isotelus gigas* showing the shape of its exoskeleton (outer shell) with reconstructed legs and antennae. *Illustration by Karen Carr.*
## Work Sheet 3: Cambrian Sea Animals

<table>
<thead>
<tr>
<th>Picture</th>
<th>Animal Group</th>
<th>Scientific Name</th>
<th>Sketch of the Fossil</th>
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</table>

*No fossil on display*
### Vocabulary Words
Cambrian Period, Ordovician Period, Cambrian explosion, Burgess Shale, trilobites, cephalopods, vertebrates, mass extinction

### Related Museum Exhibitions

#### Permanent Exhibitions
- Earth Sciences
- Grainger Gallery
- Moving Earth
- What is an Animal?

#### Temporary Exhibitions
- Gregor Mendel: Planting the Seeds of Genetics  
  (September 15, 2006 – April 1, 2007)
- Darwin  
  (June 15, 2007 – January 1, 2008)

### Harris Educational Loan Center Material
(Call 312.665.7555)

- Interior of the Earth
- Pebbles: How Shaped by Erosion
- Igneous Rocks

### Experience Boxes
- Geology of Illinois

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- Explore Fossils CD-ROM  
  (Geological Society of America; www.geosociety.org)
- Geologic Time Chart Game and related posters
- SK Science Kit & Boreal Laboratories; www.sciencekit.com/
- Fossil and Geologic Time Chart  
  (Wards Natural Science; www.wardsci.com/)

### Recommended Web Sites
- www.ucmp.berkeley.edu/cambrian/camlife.html  
  (Univ. of California Museum of Paleontology)
- www.geo.ucalgary.ca/~macrae/Burgess_Shale/  
  (Burgess Shale; University of Calgary)
- www.burgess-shale.bc.ca/ (Burgess Shale Geoscience Foundation)
- www.nmnh.si.edu/paleo/shale/index.html  
  (Burgess Shale; National Museum of Natural History)
- www.sdnhm.org/fieldguide/fossils/timeline.html  
  (San Diego Natural History Museum)
- www.palaeos.com/Paleozoic/Cambrian/Chengjiang.html (Chengjiang fossils, China)
- www.blackwellpublishing.com/chengjiang/ (Blackwell Publishing)
The Field Museum
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EXPLORE THE HISTORY OF LIFE
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PART ONE: SECTION 4
The Silurian and Devonian: From Fins to Limbs
Evolving Planet
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Part Three:

Walking Map
Introduction: The Silurian and Devonian - From Fins to Limbs

In this section we explore the Silurian and Devonian periods (443-354 million years ago), encompassing 111 million years of Earth’s history. The continents continued to shift positions, slowly coming together in a cluster stretching from the Equator into the Southern Hemisphere. As continents moved into tropical and subtropical zones, massive reefs appeared in the Silurian Period, hosting a diverse community of corals, trilobites, crinoids, brachiopods, and mollusks. New groups of fish evolved, some with an innovative feature among vertebrates—jaws! Primitive plants colonized the land in moist environments near the water’s edge. These small plants had a simple structure, growing very close to the ground and reproducing with spores. In the Devonian Period, 50 million years later, new leafy trees called lycophytes appeared forming the Earth’s first forests. Lycophytes, growing to heights of over 90 feet, towered over low-growing plants that blanketed the forest floor. Exploiting this new habitat, early insects and their relatives appeared including dragonflies, cockroaches, centipedes, millipedes, and spiders. The big story is the evolution of the tetrapods—four-legged vertebrates. Early amphibians and reptiles evolved and colonized these new terrestrial environments.

Students will encounter a video on plant reproduction as well as an interactive model illustrating the parts of a vascular plant’s stem. Displays of early plants, fish, and invertebrates are featured throughout the gallery. Students will find illuminated models on the evolution of jaws and tetrapod limbs as well as a large display of 27 different types of shark teeth. Note the Charles R. Knight mural Forests of Devonian Time (circa 1926–1930). To illustrate sea life, a diorama based on fossils from the Chicago area gives a snapshot of an ancient reef community. At the end of the gallery, marks the second major mass extinction on Earth. As glaciers developed on southern continents, sea levels dropped and the oceans cooled causing a devastating extinction wiping out 70% of marine organisms. There is also evidence of an extraterrestrial impact at this time.
## Guiding Questions

1. What major terrestrial biome appears by the end of the Devonian Period?
2. Define terrestrial, marine, and transitional types of environments. What evolutionary innovations helped vertebrates colonize land?
3. How has the position of the continents changed through time? Looking at a map of the continents in the Silurian Period, can you locate the approximate position of North America, the United States, and Illinois? What was Illinois’ climate like at this time?
4. Deposits of ancient coral reefs occur in Silurian rocks under the city of Chicago. By looking at these fossilized coral reefs, what can we say about the environmental conditions during the formation of these ancient reefs?
5. What major biotic event happened at the end of the Devonian Period? List some of the proposed causes of this event.

## Answers to Guiding Questions

1. The forest biome. In the Late Silurian and Early Devonian, low-growing plants colonized land but were restricted to the water’s edge. By the end of the Devonian, large trees (Archaeopteris) appeared and expanded into drier environments around the world.

2. Terrestrial environments are those that exist on land, marine environments are aquatic, salt-water areas and transitional environments are characterized by variable conditions occurring at the boundary between terrestrial and aquatic environments. Early vertebrates (tetrapods) evolved limbs, stronger backbones, limb girdles, and lungs to live on land. These early animals had to return to water to reproduce.

3. The continents are attached to a system of rigid crustal plates that move in relation to one another due to forces deep within the Earth’s interior. The position of the continents has changed through geologic time as the plates themselves have moved. During the Silurian, North America was tilted to the east and positioned about 30° south of the Equator. Illinois was located in a subtropical climate zone.

4. Modern coral reefs occur in warm tropical to subtropical waters between 0 to 30° north and south latitude. We can assume that the Silurian reefs formed under similar conditions. This is supported by the position of North America within subtropical zones during the Silurian Period.

5. The second mass extinction event. Scientists have proposed several causes: 1) climatic cooling due to glaciations in the South Pole, 2) reduction in habitats due to sea level drops, and 3) an extraterrestrial impact.
Section 4: Pre-Activities and Field Trip Activities

Pre-Activities

1. Explore the position of the continents at this time in Earth’s history. Ask students to draw and label the location of the major continents during the Silurian and Devonian periods. How are their locations different from their modern positions? Students can make cutouts of the continents in different time periods and glue them onto the outline of a globe.

2. Study the Web site www.mpm.edu/collections/learn/reef/intro.html to learn about ancient reefs from the Silurian Period. Have students use this site to collect data on where these reefs occur, how they form, what types of animals lived in them, and why ancient and modern reefs are important. Use these data to answer the question: How are ancient reefs different from modern reefs?

Field Trip Activities

1. Using the Geological Stopwatch worksheet (see Section 1: Orientation to Evolving Planet), have students find the time on the clock that corresponds with the Silurian and Devonian periods. Have students estimate what times they represent on the Stopwatch.

2. Explore how early plants changed to colonize dry land. Ask students to study the illuminated model of vascular plant tissues and sketch the main structures (stem, cuticle, stomata, and vascular tissue). Find fossil plants in this hall that show one or more of these features. For a list of related exhibitions to visit at the Museum, see the chart at the end of this section.

3. Have students study the display of 27 different ancient shark teeth. As a class, ask them to talk about what we can learn about an animal’s habitat, diet, size, etc. from tooth shape. Why are shark teeth more common than shark bones?

4. Encourage students to view the diorama (model) of an ancient Silurian reef. How do paleontologists use fossils to reconstruct what ancient animals looked like?

5. Study the two illuminated models: 1) evolution of jaws, and 2) fins to limbs. Ask students to come up with one reason why jaws and limbs would each be an evolutionary advantage.

6. Have students fill in the Worksheet 1: Mass Extinction Chart for the mass extinction event that is described in this hall (see Section 1: Orientation to Evolving Planet).
Post-Activities

1. During the Devonian Period, the first forests appeared on Earth. Have students describe the key features that characterize a forest. Were Devonian forests different from modern forests? See www.devonian-times.org for more information on Devonian forests.

2. Have students make a flipbook illustrating how the limbs of early tetrapods (amphibians) evolved from the fins of fish in the Devonian Period. Show how fish fins gradually gave rise to limbs that enabled amphibians to escape predators and find new food sources on land.

3. Ask students to compare the forelimb of a coelacanth fish with any amphibian limb (look online for drawings or x-rays). Have them identify and label the bones in each and discuss any similarities.

4. Start a class terrarium with liverworts, moss, and other low growing, moist plants. Have students compare the life and reproductive cycles of their plants to those outside (e.g., trees, etc.).

5. Start a class aquarium with fish and freshwater frogs. Have students note the differences in the life cycle and general biology of each organism.
Section 4: Vocabulary and Resources

Vocabulary Words

Silurian Period, Devonian Period, corals, crinoids, brachiopods, reefs, lycophytes, jaws, tetrapods, mass extinction, diorama

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- Plants of the World

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- Fossil and Geologic Time Chart, replicas, and Life of the Paleozoic activity set (Wards Natural Science; www.wardsci.com/)

Recommended Web Sites
- www.ucmp.berkeley.edu/silurian/silurian.html (Silurian; Univ. of California Museum of Paleontology)
- www.ucmp.berkeley.edu/devonian/devonian.html (Devonian; Univ. of California Museum of Paleontology)
- www.enchantedlearning.com/subjects/GeologicTime.html (Zoom Enchanted Learning)
- www.palaeos.com/Paleozoic/Silurian/Silurian.htm (Silurian; Palaeos Web site)
- www.palaeos.com/Paleozoic/Devonian/Devonian.htm (Devonian; Palaeos Web site)
- www.devonianetimes.org/ (Devonian Times Web site)
- www.ucmp.berkeley.edu/IB181/VPL/Dir.html (Paleobotany Lab; Univ. of California Berkeley)
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PART ONE: SECTION 5
The Carboniferous: Age of Coal Forests
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Teacher Notes:

Evolving Planet
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Part Three:

Walking Map
The Carboniferous Period, also known as age of the coal forests, lasted from 354–290 million years ago and represents 64 million years of Earth’s history. While glaciers advanced and retreated on the South Pole, marine life diversified in the oceans and vast tropical forests expanded at their margins. The continents extended from pole to pole, with much of Europe, Asia, and North America straddling the Equator. Primitive insects and their relatives, and early tetrapods (four-limbed vertebrates) were among the creatures living in these lush forests. Watch out for giant arthropods! Millipede-like arthropods, reaching lengths of six feet, burrowed their way through the forest while primitive dragonflies, with wingspans of up to two feet, hunted in the treetops. Ferns the size of trees, giant horsetails, and strange scaly trees (lycophytes), filled the primordial forests. Flowering plants wouldn’t evolve for another 160 million years! In the oceans, marine creatures diversify, with some groups becoming so abundant that their skeletons today form extensive rock formations. But it is the coal deposits that give this time period its name. In these forests, dead plant material accumulated and was buried by sediments. Over millions of years, pressure from the sediment and heat beneath the Earth’s surface forced water and other substances out of the plant’s remains, leaving compressed carbon—coal—behind.

In this section, students will encounter dozens of fossils, a life-size Carboniferous forest diorama, seven forest discovery pods, and a fossil mix and match interactive. Teachers should note that this section contains a display on the Tully Monster, Illinois’ State fossil.
Section 5: Guiding Questions and Answers

Guiding Questions

1. What is peat? What is coal and how does it form?

2. The great coal forests of the Carboniferous Period were composed of plants that are very different from trees alive in modern forests. Describe these ancient plants and how they are different from modern plants.

3. Define producers, consumers, and decomposers. Can you give examples of organisms in each one of these groups that lived in Carboniferous forests in Illinois? Visit the Evolving Planet Web site at www.fieldmuseum.org/evolvingplanet and look for information on the Mazon Creek fossil deposit.

4. Toward the end of the Carboniferous Period, the continents continued to drift together, eventually colliding, to form the supercontinent Pangaea. Describe what happened as Africa collided with eastern North America. What prominent features were formed in North America?

5. How does sediment size effect fossil preservation? What type of sediments preserved the fossils of the Mazon Creek deposit? Describe the unique way in which these fossils are preserved.

Answers to Guiding Questions

1. Peat is a type of soil composed of partially decomposed plant material that is waterlogged and low in oxygen. Coal is a member of a group of easily combustible, organic sedimentary rocks composed of mostly plant remains and containing a high proportion of carbon. Most coal deposits were formed from plant remains from Carboniferous forests about 300 million years ago. As plants and trees died, their remains formed peat deposits in swamps that were buried by sediments from rivers and lakes. With deeper and deeper burial, the heat and pressure transformed the peat to coal. There are different “grades” of coal that relate to the amount of alteration that the coal experienced. It takes millions of years for coal to form from peat. Some of the youngest coal deposits are only one million years old—a short amount of time relative to Earth’s history.

2. Carboniferous forests contained a unique assemblage of plants including lycopods (scale trees), seed ferns, true ferns, horsetails, and primitive conifer-like trees. Flowering plants didn’t appear for another 160 million years! Lycopods were the dominant plant in Carboniferous forests. These plants had strap-like leaves with one vein, a bark that had a scaly appearance, cones for reproduction, and they exhibit root systems. Some lycopods and horsetails grew to heights of over 80 feet.

3. Producers are organisms, like green plants, that obtain food or nutrients from inorganic compounds. Consumers obtain nutrients from other organisms and decomposers break down the remains of other organisms. They are the agents of decay.

4. As the western coast of Africa collided with ancient North America toward the end of the Carboniferous, the ensuing collision created the southern Appalachian and Ouachita mountain ranges. This is called the Allegheny orogeny or “mountain-building event.”

5. Fossils preserved in coarse sands and gravels typically don’t preserve fine details. Mazon Creek fossils were buried in fine-grained sediments like mud. Rivers flowing into the bay of an ancient ocean buried plants and animals in fine sediments. Burial was so rapid that the organisms were sealed in sediment and decayed very slowly. The resulting fossils include impressions of soft tissues such as skin, color patterns, eyes, legs, wings, and other delicate structures that normally are not preserved.
Section 5: Pre-Activities, Field Trip Activities, and Post-Activities

Pre-Activities

1. As a class, visit a wooded area to explore the different types of organisms that live in the forest. Explore the leaf litter, areas under logs and on plants. Make a list of the organisms that are found in each area.

2. Listen to recordings of animals in a forest. Have students try to guess the type of animal making each noise. Prompt students with images of animals that lived in the lush Carboniferous forests. Have them try to guess the type of sounds they would make.

3. Visit the Paleontology Portal Web site at www.paleoportal.org and look at the Mazon Creek fossil gallery in the Famous Flora & Fauna section. There are also images of Mazon Creek fossils on the Evolving Planet Web site at www.fieldmuseum.org/evolvingplanet. Discuss how these fossils are preserved in sedimentary concretions. Giving the students some clay, plastic insects and fish, pieces of artificial ferns, and small pieces of tree bark have them recreate fossil-like impressions. Ask students to describe how Mazon Creek fossils formed and why this deposit is so scientifically important.

Field Trip Activities

1. Using the Geological Stopwatch (see Section 1: Orientation to Evolving Planet), have students find the time on the clock that corresponds with the Carboniferous Period. Have students estimate what time it is on the Stopwatch.

2. Have small groups of students positioned at the seven Discovery Pods located inside the Carboniferous forest diorama (walk-in reconstruction). After studying the fossils and images in the pod, have students locate the plant or animal in the forest.

3. Explore how sediment type effects fossil formation. Have students experiment with the Fossil Preservation interactive where they can make an impression in different types of sediment. Discuss which sediment makes a clearer impression and why.

4. Meet Illinois’ State fossil—the Tully Monster. Have students observe the Tully Monster fossils and model on display. After five minutes, ask students and write down their ideas on what kind of animal the Tully Monster is (e.g., worm, fish, mollusk, etc.). Discuss what information is usually NOT preserved in fossils such as soft tissues, color, and behavior.

Post-Activities

1. Explore the stages of coal formation over time and define these terms: peat, lignite, bitumen, and anthracite. Have students create a time-lapse painting that illustrates how ancient forests formed coal beds over millions of years.

2. Have students estimate the amount of coal still in the Earth by printing out a world map and marking the location and approximate size of the major coal reserves. Does Illinois contain coal deposits? If all these reserves were to be mined for energy, how many years will it take to use them up?

3. Have students observe the conditions present in coal formation by doing several activities on the American Coal Foundation Web site at www.teachcoal.org/lessonplans/index.html. Lesson plans are listed by grade and subject. We recommend the K-8 lesson plan on Coal Formation. There are free teacher guides with worksheets and lesson plans that can be downloaded from the Teacher Store.
### Vocabulary Words
- glaciers, coal, coal forest, arthropods, insects, ferns, lycophytes, jaws, tetrapods, mass extinction, diorama, Tully Monster

### Related Museum Exhibitions

**Permanent Exhibitions**
- Earth Sciences
- Grainger Gallery
- Moving Earth
- What is an Animal?
- Plants of the World
- Amphibians and Reptiles

**Temporary Exhibitions**
- Gregor Mendel: Planting the Seeds of Genetics (September 15, 2006 – April 1, 2007)
- Darwin (June 15, 2007 – January 1, 2008)

### Harris Educational Loan Center Material
(Call 312.665.7555)

**Exhibit Cases**
- Interior of the Earth
- Pebbles: How Shaped by Erosion
- Igneous Rocks
- Fossils from Rocks near Chicago

**Experience Boxes**
- Geology of Illinois
- 300 Million Years Ago in Illinois

### Recommended Multimedia

- Explore Deep Time: Geological Time and Beyond CD-ROM (Geological Society of America; www.geosociety.org)
- Explore Fossils CD-ROM (Geological Society of America; www.geosociety.org)
- Plate Tectonics CD-ROM (Geological Society of America; www.geosociety.org)
- Geologic Time Chart Game and related posters (SK Science Kit & Boreal Laboratories; www.sciencekit.com/)
- Fossil and Geologic Time Chart (Wards Natural Science; www.wardsci.com/)

### Recommended Web Sites

- www.ucmp.berkeley.edu/carboniferous/carboniferous.html (Carboniferous; Univ. of California Museum of Paleontology)
- www.museum.state.il.us/exhibits/mazon_creek/about_mazon_creek.html (Mazon Creek; Illinois State Museum)
- www.neiu.edu/~mcproj/frame.html (Mazon Creek Project; Northern Illinois University)
- www.paleoportal.org/famous_finds/assemblage.php?assemblage_id=10 (Mazon Creek; The Paleontology Portal Web site)
- www.enchantedlearning.com/subjects/Geologictime.html (Zoom Enchanted Learning)
- www.palaeos.com/Paleozoic/Carboniferous/Carboniferous.htm (Carboniferous; Palaeos Web site)
- www.geocraft.com/WVFossils/Carboniferous_climate.html (Geocraft Web site)
- www.scotese.com/late.htm (Paleomap Web site)
EXPLORE THE HISTORY OF LIFE

Travel back through time to learn how evolution has created the mosaic of life on Earth.

PART ONE: SECTION 6
The Permian: Patchwork of Pangaea
The Field Museum • Educator Guide: Part 1 • Section 6: The Permian

Evolving Planet

Opening March 10

This educator guide is separated into four parts: content, teacher and student resources, fun facts, and a walking map. The content for Evolving Planet consists of 12 sections. Before you visit the exhibition, spend some time viewing the information on the Museum’s Web site at www.fieldmuseum.org/evolving planet to begin planning your visit. We recommend using some of our quick fun facts and pre-activities to introduce your students to the geologic timeline, which is a reference tool that is prominent throughout the exhibition. Each section of this guide has an introduction, guiding questions, pre-activities, field trip activities, post-activities, and answers to guiding questions to help guide your students’ experience.

Acknowledgements:
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Evolving Planet is made possible by Anne and Kenneth Griffin. The Elizabeth Morse Genius Charitable Trust is the generous sponsor of Evolving Planet's Genius Hall of Dinosaurs.
Sections:

Part One:

Introduction to *Evolving Planet*

Section 1
Orientation to *Evolving Planet*

Section 2
The Precambrian: Life Emerges

Section 3
The Cambrian and Ordovician: World of Water

Section 4
The Silurian and Devonian: From Fins to Limbs

Section 5
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Part Two:

Related Programs, Exhibitions, and Resources

Part Three:

Walking Map
The Permian Period lasted from 290–248 million years ago and represents 62 million years of Earth’s history. It was a time of continental collisions, evolutionary innovation and catastrophic extinctions. By the end of the Permian, most of the major continents had drifted together to form a giant supercontinent called Pangaea. As this vast landmass formed, the amount of coastline shrank along with the tropical swamps it supported. Great mountain ranges were formed as continents collided. In this new world, tetrapods—four-limbed vertebrates—evolved new forms with new ways of living. Among them were early reptiles and synapsids, the group that would one day include the mammals. A new type of egg—the amniote egg—allowed these newcomers to exploit habitats on dry land. Plant fossils from this period indicate that Pangaea was a patchwork of different environments, from arid deserts to lush tropics to cool temperate forests.

In this section, students will encounter mounted skeletons of amphibians, reptiles, and synapsids, an illuminated amniote egg model, a Scientist Stop video, and a Mass Extinction station.
Guiding Questions

1. What is Pangaea? What lines of evidence support the existence of Pangaea?

2. What is a tetrapod? Are humans tetrapods? What groups of tetrapods existed during the Permian Period?

3. How can fossil plants provide clues to the type of climates that existed on Pangaea?

4. Draw and label the parts of the amniote egg (outer shell, embryo, chorion, yolk sac, allantois, and amnion). Why was the evolution of this type of egg so important to the evolutionary success of early tetrapods?

5. How many species died out during the end of the Permian mass extinction? What are the current theories for its cause?

Answers to Guiding Questions

1. Pangaea (“all-Earth”) was a term coined by Alfred Wegener in 1915 to describe the supercontinent that existed from 200 to 300 million years ago that included most of the world’s landmasses. There are many lines of evidence that support continental drift: 1) the physical “fit” of the continental margins, 2) similar rock deposits of the same age occur on different continents, 3) rocks on either side of the Mid-Atlantic Ridge show identical magnetic signatures, 4) ice flow ridges in rock, created by glaciers, align when continents are positioned together, and 5) distributions of terrestrial plants and animals suggest continental connections.

2. A tetrapod is a four-limbed vertebrate. It’s important to note that the evolutionary loss or reduction of limbs has occurred in some groups. Yes, humans are tetrapods. During the Permian, three main groups of tetrapods existed: amphibians, reptiles, and synapsids.

3. Just as plants today are important indicators of climate, fossil plants paint a picture of Pangaea’s diverse environments and climates. Different types of plants living today thrive in different conditions. By comparing fossil plants to their modern relatives, we have an idea of what environmental conditions were like millions of years ago.

4. The evolution of the watertight amniote egg allowed vertebrates called amniotes to colonize dry land. Being less dependent on wet environments, they could live in drier environments off-limits to other tetrapods.

5. It is estimated that approximately 90% of marine animal species died out, as did 80% of land animals. Scientists aren’t sure what triggered this most severe of all mass extinctions on Earth. Some theories hypothesize massive lava flows that covered vast areas in Siberia. Volcanic eruptions of this size would have released enough gases to possibly change the climate. Other theories cite evidence of a devastating asteroid or comet impact at the end of the Permian.
Section 6: Pre-Activities and Field Trip Activities

Pre-Activities

1. Have students play the Gondwana Puzzle contained on Worksheet 5 (this section). Print out the worksheet and have students color the fossil and rock distributions with colored pencils, markers, or crayons. Use a different color for each type of deposit. Have students cut out the continents and assemble them with tape to show how they fit together to form Gondwana (Southern portion of Pangaea). Ask students to present the results of the puzzle and explain the lines of evidence that they used to find the correct continental positions.

2. During the Permian, several important groups of tetrapods evolved including the group that gave rise to mammals. Ask students to define the word “tetrapod” and to make a sketch of a tetrapod. Use books and online resources for reference. Have students research what major groups of tetrapods existed during the Permian Period.

3. Conduct a lesson plan on the different climatic zones on Earth and how they determine the distribution of plants and animals. Describe the differences between arid, tropical everwet, and cool temperate climates. Can we recognize ancient climatic zones? How?

4. Conduct a lesson plan on the nature of the Earth’s crust and interior. Discuss the theory of plate tectonics and why it is important.

5. Give each student a mini-Milky Way bar to use in an experiment on how different materials react differently to physical stresses. Ask the students slowly pull apart or bend the candy bar and record the behavior of the brittle chocolate layer vs. the soft, plastic nougat layer. Have students explain how this is an analogy to the Earth’s crust and mantle.

Field Trip Activities

1. Have students observe the Charles Knight mural in this section called *Reptiles of the Permian Period* (circa 1926–1930). Despite the painting’s title, most of the tetrapods shown are synapsids, not reptiles. Have students study the mural, recording their observations on the time of day, style, mood, movement. What story is being told? These notes will be used to write a narrative on Permian life (see post-activity below).

2. Permian plant fossils indicate that different climatic zones existed on Pangaea. Have students form three groups, one for each climatic zone (arid, tropical everwet, cool temperate) and analyze the types of plants found in each zone. Encourage students to make sketches of plant fossils in the display for their climate zone noting any unique characteristics. As a class, have one person from each group present the results.

3. Using information at the Extinction Station in this section, prompt students to form a hypothesis about the cause of the Permian mass extinction. Their hypothesis can be in the form of K-W-L chart or you can make a worksheet with these three sections: 1) Form My Hypothesis Statement, 2) Test My Hypothesis (by making observations in the exhibition and recording my observations) and 3) Form My Conclusion (see Section 2: Worksheet 2).

4. Have students fill in the Worksheet One: Mass Extinction Chart (see Section 1: Mass Extinction Chart) for the mass extinction that is described in this section.
Post-Activities

1. Using their notes on the Knight mural, have students write a narrative describing what it would be like to be a time-traveler who is visiting the Permian Period. Using a geologic time-line, figure out how old in millions of years you would have to travel back in time to reach the Permian. Prompt them to use descriptive words and observations from their notes to create a detailed, lively story.

2. When continents collide, dramatic features are formed on the Earth’s surface. Have students make a model of continents that have crashed together using paper, clay, bread, and other bendable materials. Encourage students to show how features like mountains and hills are pushed up during collisions.

3. While tetrapods were evolving on land, life abounded in warm tropical oceans during most of the Permian Period. Have students research the fossil deposits from the Glass Mountains of southwestern Texas, which tell the story of life in the tropical oceans during the Permian Period. Detailed information can be found on the following Web sites: www.ucmp.berkeley.edu/permian/glassmts.html and www.palaeos.com/Paleozoic/Permian/Permian.htm. Have students compare and contrast sea life early in the Permian with sea life at the end of the Permian.
Fossils of Mesozoic plants and animals help scientists figure out how continents fit together during the Mesozoic Era. By matching the fossils zones shown in this puzzle, students can reassemble the continents to form a great southern supercontinent - called Gondwana. Give each student a copy of this sheet with the puzzle answer removed. Have students cut out the continents and color the patterned areas with colored pencils, crayons, or markers.

Once colored, have students assemble the continents (Africa, India, Australia, Antarctica, South America, and Madagascar) together with tape and label each continent. The patterned areas (fossil plant and animal occurrences) along with the shape of each landmass will provide clues to how the continents fit together.
## Section 6: Vocabulary and Resources

### Vocabulary Words
- Panaea, amphibians, reptiles, tetrapods, synapsids, amniote egg, mass extinction

### Related Museum Exhibitions

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- Geologic Time Chart Game and related posters (SK Science Kit & Boreal Laboratories; www.sciencekit.com/)
- Discovering the Permian Extinction lab activity (Wards Natural Science; www.wardsci.com/)
Recommended Web Sites

- www.ucmp.berkeley.edu/permian/permian.html (Univ. of California Museum of Paleontology)
- http://palaeo.gly.bris.ac.uk/Essays/wipeout/default.html (Michael Benton’s Web site, University of Bristol)
- www.humboldt.edu/~natmus/lifeThroughTime/Permian.web/ (Humboldt State Museum)
- www.enchantedlearning.com/subjects/dinosaurs/dinotemplates/Permianprintouts.shtml (Zoom Enchanted Learning)
- www.bbc.co.uk/education/darwin/exfiles/permian.htm (BBC Extinction Files Web site)
- http://palaeo.gly.bris.ac.uk/Palaeofiles/Permian/front.html (University of Bristol)
- www.geocities.com/earthhistory/permo.htm (Geocities Web site)
- www.scotese.com/late.htm (Paleomap Web site)
- http://hannover.park.org/Canada/Museum/extinction/tablecont.html (Hooper Virtual Paleontology Museum)
- www.nationalgeographic.com/ngm/0009/feature4/ (National Geographic; When Life Nearly Came to an End)
- www.bbc.co.uk/science/horizon/2002/dayearthdied.shtml (BBC; The Day the Earth Nearly Died)
- www.space.com/scienceastronomy/planetearth/extinction_permian_000907.html (Space.com Web site; Permian asteroid impact)
The Field Museum
Education Department Presents


Opening March 10, 2006

EXPLORE THE HISTORY OF LIFE

Travel back through time to learn how evolution has created the mosaic of life on Earth.

PART ONE: SECTION 7
The Triassic: Dawn of a New Era
Evolving Planet
Opening March 10

This educator guide is separated into four parts: content, teacher and student resources, fun facts, and a walking map. The content for Evolving Planet consists of 12 sections. Before you visit the exhibition, spend some time viewing the information on the Museum’s Web site at www.fieldmuseum.org/evolvingplanet to begin planning your visit. We recommend using some of our quick fun facts and pre-activities to introduce your students to the geologic timeline, which is a reference tool that is prominent throughout the exhibition. Each section of this guide has an introduction, guiding questions, pre-activities, field trip activities, post-activities, and answers to guiding questions to help guide your students’ experience.

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Part Two:

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Part Three:

Walking Map
The Triassic Period (248–206 million years) marks the beginning of the Mesozoic Era. Life rebounded after the greatest mass extinction in Earth’s history. From the few survivors, new life developed. During this time dinosaurs began their 160-million year success story, mammals appeared, flowering plants bloomed, and reptiles diversified on land and in the oceans. Earth’s continents continued to move. Pangaea assembled completely during the Triassic Period before beginning to break apart in the Jurassic Period. Different groups of tetrapods—phytosaurus, rhynchosaurs, and metoposaurs—evolved and disappeared, leaving only fossils and no descendants. The first mammals appeared at this time. Fossil evidence, mostly in the form of teeth, tells us they were small, shrew-like creatures that foraged at night, out of reach of early dinosaurs. Early dinosaurs were small, bipedal (walking on two legs), meat-eaters like Herrerasaurus. At the end of the Triassic, yet another mass extinction event occurred in several phases. Around 50% of marine animal species and around 95% of land plants in northern regions went extinct.

In this section, students will encounter the skeleton and flesh model of the early dinosaur Herrerasaurus, a model of an early mammal, an illuminated model of mammalian ear evolution, a phylogeny video, a Scientist Stop on Triassic plants and a Mass Extinction station.
Guiding Questions

1. What are the three main eras of the Phanerozoic Eon? List the time periods that make up the Mesozoic Era and give their time ranges.

2. What are synapsids? What major groups evolved from synapsids? Are humans synapsids?

3. Why are plants usually more resilient than animals during mass extinctions? How do seeds play a role in the resilience of plants?

4. During the Triassic, there were three main plant groups: conifers, bennetites, and ferns. Describe the differences between each group and whether they are extinct or extant.

5. The first dinosaurs evolved in the Triassic. Describe what the earliest dinosaurs looked like. What did they eat? How big were they? Where are their fossils found?

6. What is a mammal? Are humans mammals? During the Mesozoic, there were many different groups of mammals. How do we know this? What type of fossil evidence has been found?

Answers to Guiding Questions

1. The Phanerozoic Eon is divided into the Paleozoic Era, Mesozoic Era, and Cenozoic Era. The Mesozoic Era is subdivided into the Triassic Period (206–248 million years), Jurassic Period (206–144 million years), and Cretaceous Period (144–65 million years).

2. Synapsids are a branch of the amniotes, or egg-laying tetrapods that are characterized by having a single opening in the skull just behind each eye socket. This opening permits muscle attachment to the jaw. Mammals are synapsids alive today—since we are mammals, we are also synapsids.

3. Plants have a simple lifestyle. Even if the environment changes, plants’ basic needs—water, carbon dioxide, and other nutrients—are always available to some degree. The other factor that plays a role involves the seed as a way for plants to lie dormant for long periods until conditions improve.

4. Ferns are low-growing plants that live in moist conditions and reproduce by spores. They are extant or alive today. Conifers are gymnosperms, trees that have needles for leaves and reproduce by seeds. They can live in dry environments and are extant. Bennetites are extinct plants that reproduced by seeds and had unusual palm-like leaves.

5. One of the earliest dinosaurs, *Herrerasaurus*, was discovered in Argentina (South America). *Herrerasaurus* was a meat-eater, or theropod dinosaur that walked on two legs, had serrated teeth, and sharp claws. It is estimated to have reached 13 feet in length and weighed up to 500 pounds. Scientists don’t know for sure, but assume that *Herrerasaurus* may have been colored to blend into the foliage of Mesozoic forests to escape detection by potential prey.

6. A mammal is a type of cynodont that is warm-blooded (produces its own internal heat), has hair on its skin, and has milk-secreting glands. Humans are mammals. In the Triassic, many different mammal groups existed and are known from tiny fossil teeth. Fossil teeth are particularly important because they tell us what species it is, its diet, age, and in some cases its gender. Teeth tend to survive the destructive processes of weathering and fossilization much better than bone does. This is due primarily to the composition of teeth, which are made of very resistant (microscopically dense) enamel.
Section 7: Pre-Activities and Field Trip Activities

Pre-Activities

1. Mammals are unique in that they have a “toolkit” of different-shaped teeth for different tasks. Using a diagram of the dentition or arrangement of human teeth in our skull and lower jaw, have students study the four main types of teeth (incisors, canines, premolars, and molars) and their function. Explain what a dental formula is and have students write their own dental formula by counting their teeth. Visit the Web site http://arbl.cvmbs.colostate.edu/hbooks/pathphys/digestion/pregastric/dentalanat.html for more information and illustrations of dental formulae. What do you notice about the results?

2. Make a timeline for the Mesozoic Era. Have students take a roll of adding machine paper or regular copy paper and figure out a scale where a unit of length is equal to an increment of millions of years. Have them measure off the correct length of paper, noting the three main periods: Triassic, Jurassic, and Cretaceous. On the timeline, have students add images of animals and major events in time. Make sure that the age in millions of years is noted on the timeline.

3. Explore the difference between flowering plants and non-flowering plants by taking students on a field trip to a nearby garden or wooded area. In small groups, have students collect leaves, seeds, and flowers from several plants. Encourage students to collect specimens from a variety of plants and to make sketches of size, color, location, and branching pattern. In class, identify the plants and discuss the differences between flowering and non-flowering plants.

Field Trip Activities

1. Using the Geological Stopwatch worksheet (see Section 1; Orientation to Evolving Planet), have students find the time on the clock that corresponds with the Triassic Period. Have students estimate what time this period represents on the Stopwatch. Note that it is the beginning of a new era — the Mesozoic.

2. Explore the different types of mammals in the What is an Animal? exhibition before visiting Evolving Planet.

3. During the Triassic, many different groups of mammals evolved. In this section, have students study the mammal fossils on display. What do they notice immediately about the size and type of mammal fossils? Ask students to brainstorm about why teeth are the most common fossils that have been found of these mammal groups. Note to teachers: The fossils of Mesozoic mammals were small and shrew-like. Compared with mammals of today, where there are many forms that represent only two main groups, Mesozoic mammals exhibited few forms and represented many groups. What can teeth tell us about animals?

4. In this section, have students watch the video on phylogeny and come up with one feature that humans share with the following animals: worms, fishes, lizards, and rabbits. By looking at features shared by organisms, scientists can tell how closely related the organisms are. Which of the animal groups in this list are humans most closely related to? Which one are humans more distantly related to?

5. The first dinosaurs appeared in the Triassic Period around 230 million years ago. Have students study the display containing the skeleton and flesh model of the dinosaur Herrerasaurus from Argentina. Conduct a poll on whether this dinosaur was a meat-eater or a plant-eater. Ask students to support their opinion with evidence. How do paleontologists know what dinosaurs ate? How do paleontologists know what colors dinosaurs were?

6. Have students fill in the Worksheet One: Mass Extinction Chart for the mass extinction that is described in this section.
Section 7: Post-Activities

Post-Activities

1. Have students choose a modern mammal from one of the Museum’s modern animal halls and have them research its dentition and diet. Encourage students to be creative in their choice. Ask them to write a report on how their animal’s dentition relates to its diet and lifestyle. Students should use sketches, pictures, and other images to illustrate their conclusions. As a class, have students present the results of their study.

2. Explore how animals use color patterns to survive in their environment. Working in small groups, have students create a poster illustrating the different color patterns found on animals. They should mention the following: camouflage, mimicry, cryptic coloration, counter-shading, warning colors, and deceptive coloration. Note to teachers: visit <www.nhptv.org/natureworks/nwep2a.htm>www.nhptv.org/natureworks/nwep2a.htm for information on deceptive coloration. On the poster, have students show an example of each type. Encourage them to use online resources and books as references.

3. In the classroom, have students work in small groups to share their field trip experiences and discuss what they learned. Ask students to write a reflection statement on what they learned about early mammals and the first dinosaurs. Have each student read his or her statement to the class in an oral presentation. Encourage the students to use visual aids.

4. Have students create a Triassic mini-diorama that includes a sculpture of an early mammal and a dinosaur. Provide students with clay or dough, construction paper, pipe cleaners, glue, paints and markers. Encourage students to make their models with the correct scale in relation to one another (i.e., the mammal should be very small compared to the dinosaur) and to use plants of the right type in the diorama.
Section 7: Vocabulary and Resources

Vocabulary Words

- Triassic Period, dinosaurs, flowering plants, mammals, phytosaurs, rhynchosaurs, metoposaurs, bipedal, phylogeny, mass extinction

Related Museum Exhibitions

Permanent Exhibitions

- Earth Sciences
- Grainger Gallery
- Moving Earth
- Animal Biology
- What is an Animal?
- Plants of the World
- Amphibians and Reptiles

Temporary Exhibitions

- Dinosaur Dynasty: Discoveries from China (May 27, 2005 – April 23, 2006)
- Gregor Mendel: Planting the Seeds of Genetics (September 15, 2006 – April 1, 2007)
- Darwin (June 15, 2007 – January 1, 2008)
- Dinosaurs: Ancient Fossils, New Discoveries (March 30 – September 3, 2007)

Harris Educational Loan Center Material

(Call 312.665.7555)

Exhibit Cases

- Interior of the Earth
- Pebbles: How Shaped by Erosion
- Igneous Rocks

Experience Boxes

- Dinosaurs and Other Mesozoic Creatures
- Dinosaur Dinners

Recommended Multimedia

- Explore Deep Time: Geological Time and Beyond CD-ROM (Geological Society of America; www.geosociety.org)
- Explore Fossils CD-ROM (Geological Society of America; www.geosociety.org)
- Plate Tectonics CD-ROM (Geological Society of America; www.geosociety.org)
- Geologic Time Chart Game and related posters (SK Science Kit & Boreal Laboratories; www.sciencekit.com/)
- Fossil and Geologic Time Chart and replicas of Triassic fossils (Wards Natural Science; www.wardsci.com/)
Section 7: Vocabulary and Resources (continued…)

Recommended Web Sites

- www.ucmp.berkeley.edu/mesozoic/triassic/triassic.html (Univ. of California Museum of Paleontology)
- www.paleoportal.org/time_space/time_space.php (The Paleontology Portal)
- www.enchantedlearning.com/subjects/dinosaurs/mesozoic/Triassic.html (Zoom Enchanted Learning)
- www.biologie.uni-hamburg.de/b-online/palbot/triassic/triassic.html (Paleobotany link; University of Hamburg)
- www.bbc.co.uk/sn/prehistoric_life/dinosaurs/chronology/220mya1.shtml (BBC Web site; Walking with Dinosaurs)
- www.sdnhm.org/exhibits/lostworld/teachersguide/background.html (San Diego Museum of Natural History; teacher’s guide to the Mesozoic)
- www.geocities.com/peforanger/triassicdinos.html (Petrified National Forest Web site)
- www.factbites.com/topics/Triassic (Factbites Web site)
The Field Museum
Education Department Presents


Opening March 10, 2006

EXPLORE THE HISTORY OF LIFE

Travel back through time to learn how evolution has created the mosaic of life on Earth.

PART ONE: SECTION 8
The Jurassic and Cretaceous: Age of the Dinosaurs
Evolving Planet
Opening March 10

This educator guide is separated into four parts: content, teacher and student resources, fun facts, and a walking map. The content for Evolving Planet consists of 12 sections. Before you visit the exhibition, spend some time viewing the information on the Museum’s Web site at www.fieldmuseum.org/evolvingplanet to begin planning your visit. We recommend using some of our quick fun facts and pre-activities to introduce your students to the geologic timeline, which is a reference tool that is prominent throughout the exhibition. Each section of this guide has an introduction, guiding questions, pre-activities, field trip activities, post-activities, and answers to guiding questions to help guide your students’ experience.

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Sections:

Part One:

Introduction to *Evolving Planet*

Section 1
Orientation to *Evolving Planet*

Section 2
The Precambrian: Life Emerges

Section 3
The Cambrian and Ordovician: World of Water

Section 4
The Silurian and Devonian: From Fins to Limbs

Section 5
The Carboniferous: Age of Coal Forests

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The Permian: Patchwork of Pangaea

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Section 8
The Jurassic and Cretaceous: Age of the Dinosaurs

Section 9
The Tertiary: Age of the Mammals

Section 10
The Hominids: Dawn of Humankind

Section 11
The Quaternary: Age of Ice

Part Two:

Related Programs, Exhibitions, and Resources

Part Three:

Walking Map
The Jurassic and Cretaceous periods (206–65 million years) represent the remaining 141 million years of the Mesozoic Era. Life had endured a fourth mass extinction at the end of the Triassic Period that decimated plants, marine invertebrates, and certain vertebrates. But survivors diversified in Jurassic and Cretaceous seas, especially mollusks called ammonoids and belemnites, snails, crabs and lobsters, and sea urchins. With them came new reptilian predators—mosasaurs and plesiosaurs. On land, dinosaurs co-existed with lizards and snakes, turtles and crocodilians. In the air, insects evaded early birds and pterosaurs. Plants were part of the picture. Angiosperms—flowering plants—appear and diversify around the world.

In this section, students will encounter dinosaur skeletons and flesh models, videos on coevolution, Apatosaurus and mass extinction, interactives on flower structure, mammal ear, dinosaurs, and seven classic Charles R. Knight murals of ancient life.
Guiding Questions

1. What is a dinosaur? Are dinosaurs alive today? Explain how birds and dinosaurs are related.
2. What are angiosperms? What is coevolution? Name several organisms that coevolved with angiosperms and explain why.
3. How did dinosaurs reproduce? Have baby dinosaurs been discovered?
4. Did humans and dinosaurs live at the same time? When did each live?
5. While dinosaurs ruled the land, what animals lived in the oceans?
6. What catastrophic event wiped out the dinosaurs at the end of the Cretaceous Period?

Answers to Guiding Questions

1. Any diapsid reptile distinguished from other reptiles by specialized features of the hipbones and anklebones. Dinosaurs may be herbivores, carnivores, bipedal, or quadrupedal and range from the Triassic to Cretaceous periods. Yes, dinosaurs are alive today in the form of birds—their direct descendants. When scientists look closely at bird and dinosaur skeletons, they count more than 100 features in common. Current research shows that birds share an ancestor with a group of theropod dinosaurs called dromaeosaurs, also known as “raptors.”

2. Angiosperms (meaning "covered seed") are flowering plants. They produce seeds enclosed in fruit. They are the dominant type of plant today with over 250,000 species. Coevolution is a series of reciprocal steps during which two or more ecologically interacting species respond to one another evolutionarily. A classic example of coevolution involves angiosperms and insects (bees, wasps, flies, ants) that have evolved to pollinate the flower while consuming its nectar.

3. Dinosaurs reproduced by laying eggs like birds do today. Yes, baby dinosaurs have been found preserved inside eggs. Just their bones remain, but in some cases they contain skin impressions. Recent amazing discoveries include a dinosaur preserved sitting on a nest of eggs and a deposit with one adult buried with 34 baby dinosaurs!

4. No! Humans and dinosaurs did not live at the same time. Dinosaurs lived between 228–65 million years ago and the first hominids (humans’ early ancestors) appeared only 4.0 million years ago.

5. During the Mesozoic, the seas teemed with life. All the major invertebrate groups were present, including corals, echinoderms, arthropods, brachiopods, and mollusks. There were many groups of vertebrates in the seas including fishes (sharks and bony fishes), plesiosaurs and their relatives, ichthyosaurs, mosasaurs, and crocodilians. There were also flying reptiles in the air called pterosaurs.

6. A devastating mass extinction occurred at the end of the Cretaceous Period, 65 million years ago. Scientists have found evidence in rocks around the world that an asteroid collided with Earth. This event caused global climate change that killed more than 50% of all life.
Section 8: Pre-Activities and Field Trip Activities

Pre-Activities

1 Pick four to six dinosaurs that are popular with students. Have them vote on their favorite dinosaur. Write the tally and create a graph based on the results. Then develop questions based on the graph for students to answer. Other types of dinosaur votes you can graph include: tallest dinosaur, scariest dinosaur, smallest dinosaur, and heaviest dinosaur.

2 Ask students to break into three groups to make a Mesozoic Mural. Assign one of the Mesozoic Periods (Triassic, Jurassic, and Cretaceous) to each group and have them paint a mural of the dinosaurs that lived only during that time. Encourage students to research the types of plants and animals of each period to make the mural as accurate as possible. You can go to www.zoomdinosaurs.com to get a list of dinosaurs that existed in each time period. When finished, have each group describe their mural in class.

3 Prompt students to form a hypothesis on whether or not birds are related to dinosaurs. Their hypothesis can be in the form of K-W-L chart (Worksheet 1; see Section 1: Orientation to Evolving Planet) or you can design your own worksheet using these three sections: 1) Form My Hypothesis Statement, 2) Test My Hypothesis (by making observations in the exhibition and recording my observations) and 3) Form My Conclusion.

4 Because of the lack of precision of “common names,” scientists have formalized the process of naming animals by using “scientific names.” This system uses words from the Latin and Greek languages that describe how an animal or plant looks, where it is found, or who discovered it. Scientific names can sound intimidating, but learning what they mean and how they are created is fun. Using the chart of descriptor words, below, have students find the meaning of the following dinosaur names from the Evolving Planet exhibition. For example, Ornithomimus translates as “bird mimic.” a. Tyrannosaurus; b. Triceratops; c. Apatosaurus; d. Brachiosaurus; e. Parasaurolophus; f. Deinonychus; g. Stegosaurus

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Section 8: Pre-Activities and Field Trip Activities

Pre-Activities

5 Have students learn geography by making a collage of pictures showing where dinosaur fossils have been found around the world. Create a large map and label the continents. Give students small pictures of different dinosaurs to color and cut-out or download color images from the Web at a dinosaur Web site. Glue the dinosaurs on the continents on which their fossils have been found. What continents contain the most dinosaur groups? Why are some dinosaurs only present on certain continents? What processes affected the distribution of dinosaurs (hint: moving continents)? Did all dinosaurs exist at the same time?

6 We know dinosaurs reproduced by laying eggs. Scientists have discovered many types of dinosaur eggs, some with embryos or babies inside. Have students create their own dinosaur egg using balloons and papier maché. Once the eggs dry, have students paint them to look like a real egg. Create a nest out of hay or straw (found at arts and crafts stores) and place dried eggs inside. Were all dinosaur eggs shaped like spheres? Have students do some research on different dinosaur egg shapes.

Field Trip Activities

1 Using the hypothesis worksheet, have students gather data on the relationship of birds and dinosaurs in this section. Encourage students to visit the Museum’s modern bird halls to make additional observations and sketches.

2 Have students watch the audio-visual Mesozoic Hall Summary in this section and practice their note-taking skills by writing down information on what wiped out the dinosaurs at the end of the Cretaceous Period.

3 Split students into five groups and assign each to a specific group of dinosaurs highlighted in this section. The focus groups are: thyreophorans, sauropods, theropods, ornithopods, and marginocephalians. Have students capture as much data as possible on their group such as, the name, geologic age, characteristics, associated plants and animals, and size. Encourage students to include sketches. Gather back together as a class in the center of this section of the exhibition to share findings.

4 Give students 10-minutes to find and list the different types of animals that lived in the oceans during the Mesozoic Era. There were many different kinds of invertebrates, animals without backbones and other reptile groups. Ask students to share their findings.

5 Have students view and take notes on the coevolution video featured in this section. After watching the video, ask students to think of two examples of modern animals and plants that have coevolved. For example, flowers and their pollinators (e.g., bees, bats, moths, birds), birds and poisonous butterflies, or tropical plants and fruit-eating birds, to name just a few. Ask students to explain the advantages of one of these types of coevolution for their example.

6 Have students fill in the Worksheet One: Mass Extinction Chart for the mass extinction that is described in this section.
Section 8: Post-Activities

Post-Activities

1. Have students test their hypothesis on early life by summarizing the data collected in the Jurassic and Cretaceous gallery on the relationship between birds and dinosaurs. Based on their data and observations, ask them to describe whether their hypothesis is valid or whether it needs to be revised.

2. Have students create a dinosaur skeleton using noodles and glue. Provide them with different kinds of noodles to represent the various bone types. For example, macaroni makes great vertebrae; fettuccine works for limbs and spaghetti can be ribs.

3. Have students draw the skeleton of their favorite dinosaur and label its parts. Students should write an essay about this dinosaur describing why they find it interesting.


5. Visit the Web site www.bbc.co.uk/sn/prehistoric_life/games and have students play The Baryonyx Mystery, Who Dung It?, and Big Al Game.

6. Study the insides of bones by cracking open dried animal bones and examining them with a magnifying glass. To explore what happens to bones during the process of fossilization, compare the modern bones to a dinosaur bone. The fossil bone should be much heavier than the modern bone due to the presence of minerals that were deposited during fossilization. Look up online information on how heavy fossilized dinosaur skeletons weigh.
### Vocabulary Words

- Jurassic Period
- Cretaceous Period
- dinosaurs
- mollusks
- belemnites
- ammonoids
- angiosperms
- birds
- pterosaurs
- mosasaurs
- plesiosaurs
- coevolution
- mass extinction

### Related Museum Exhibitions

#### Permanent Exhibitions
- Earth Sciences
- Grainger Gallery
- Moving Earth
- Animal Biology
- What is an Animal?
- Amphibians and Reptiles
- World of Birds
- World of Mammals
- Plants of the World
- McDonald’s Fossil Preparation Laboratory

#### Temporary Exhibitions
- Dinosaur Dynasty: Discoveries from China
  (May 27, 2005 – April 23, 2006)
- Gregor Mendel: Planting the Seeds of Genetics
  (September 15, 2006 – April 1, 2007)
- Darwin
  (June 15, 2007 – January 1, 2008)
- Dinosaurs: Ancient Fossils, New Discoveries
  (March 30 – September 3, 2007)

#### Audio/Visual
- The Sue Files: Dino Dinning

#### Exhibit Cases
- Interior of the Earth
- Pebbles: How Shaped by Erosion
- Igneous Rocks
- Dinosaur Eggs
- Great Horned Dinosaur, Triceratops
- SUE Skull and Stand (traveling exhibit skull)

#### Experience Boxes
- Dinosaurs and Other Mesozoic Creatures
- Dinosaurs and Their Times: Jurassic
- Dinosaurs and Their Times: Cretaceous
- The T. rex Named Sue
- Dinosaur Dinners
Section 8: Vocabulary and Resources (continued…)

Recommended Multimedia

- Explore Deep Time: Geological Time and Beyond CD-ROM
  (Geological Society of America; www.geosociety.org)
- Explore Fossils CD-ROM
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- Plate Tectonics CD-ROM (Geological Society of America; www.geosociety.org)
- Geologic Time Chart Game and related posters (SK Science Kit & Boreal Laboratories; www.sciencekit.com/)
- Fossil and Geologic Time Chart and Life of the Mesozoic Era activity set
  (Wards Natural Science; www.wardsci.com/)
- Dinosaur materials (The Nature Store; http://thenaturestore.com/dinosaurtoys.htm)
- Large source for dinosaur toys and books (www.dinosaurfarm.com/)

Recommended Web Sites

- www.ucmp.berkeley.edu/mesozoic/mesozoic.html
  (Mesozoic; Univ. of California Museum of Paleontology)
- www.ucmp.berkeley.edu/mesozoic/jurassic/jurassintro.html
  (Jurassic; Univ. of California Museum of Paleontology)
- www.ucmp.berkeley.edu/mesozoic/cretaceous/cretaceous.html
  (Cretaceous; Univ. of California Museum of Paleontology)
- www.ucmp.berkeley.edu/diapsids/dinobuzz.html
  (DinoBuzz; Univ. of California Museum of Paleontology)
- www.paleoportal.org/time_space/time_space.php (The Paleontology Portal)
- www.enchantedlearning.com/subjects/dinosaurs/mesozoic/
  (Zoom Enchanted Learning)
- www.enchantedlearning.com/subjects/dinosaurs/classroom/Quizzes.shtml
  (Zoom Enchanted Learning; dinosaur activities)
  (Kids Connect; dinosaur information, activities and links)
- www.cotf.edu/ete/modules/msese/earthsysflr/mesozoic.html (The Earth Floor)
- www2.biology.ualberta.ca/wilson.hp/mesofish/
  (Mesozoic Fishes Page; Univ. of Alberta)
- www.es-designs.com/geol105/Topics/mesozoic.html
  (Mesozoic overview and study guides)
- www.bbc.co.uk/sn/prehistoric_life/
  (BBC Prehistoric Life; lots of activities and information)
- www.dinosaurgardenplants.com/
  (Mesozoic plants; information, illustrations and links)
EXPLORING THE HISTORY OF LIFE

Travel back through time to learn how evolution has created the mosaic of life on Earth.

PART ONE: SECTION 9
The Tertiary: Age of the Mammals
Evolving Planet
Opening March 10

This educator guide is separated into four parts: content, teacher and student resources, fun facts, and a walking map. The content for Evolving Planet consists of 12 sections. Before you visit the exhibition, spend some time viewing the information on the Museum's Web site at www.fieldmuseum.org/evolvingplanet to begin planning your visit. We recommend using some of our quick fun facts and pre-activities to introduce your students to the geologic timeline, which is a reference tool that is prominent throughout the exhibition. Each section of this guide has an introduction, guiding questions, pre-activities, field trip activities, post-activities, and answers to guiding questions to help guide your students’ experience.

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The Tertiary: Age of the Mammals

Section 10
The Hominids: Dawn of Humankind

Section 11
The Quaternary: Age of Ice

Part Two:

Related Programs, Exhibitions, and Resources

Part Three:

Walking Map
Dinosaurs went extinct at the end of the Mesozoic Era. Out of this biologic crisis came a burst of evolution—new mammals, fishes, insects, birds, and flowering plants appeared. This radiation of plants and animals marks the beginning of the Cenozoic Era. This era is subdivided into two periods: the Tertiary Period (65–1.8 million years) and Quaternary Period (1.8 million years–present). The great supercontinent, Pangaea had split apart by the early Tertiary, forming new ocean basins and mountain ranges. Warm and wet conditions were widespread, but this was to change. As the continents continued to diverge, new waterways formed and allowed cold polar waters to flow south toward the equator. In addition, rising mountain ranges blocked the flow of moist air from the oceans, creating semi-arid environments further inland. Plants and animals adapted to these climatic changes. By the middle of the Tertiary, new flowering plants that favored cooler, drier conditions—the grasses—appeared and quickly spread around the globe. Lush tropical forests gave way to cool, temperate forests dominated by maple, willow, oak, birch, and alder trees. Mammals adapted to live in the advancing grasslands and temperate forests. Some terrestrial mammals evolved to take advantage of aquatic habitats—the whales! Around 20–25 million years ago the primates, the group that contains humans, apes, monkeys and prosimians, evolved in the forests of Africa and South America. The apes gave rise to our family—the hominids.

In this section, students will encounter extraordinary fossils from Green River, Wyoming, that preserve a snapshot of life during the early Tertiary Period. There is a Scientist Stop and a series of murals that accompany the Green River fossils. Special displays on horse and whale evolution are major elements for students to study. Watch for an illuminated model of grass and a section describing convergent evolution. Hominid fossils are included in the next section.
Section 9: Guiding Questions and Answers

Guiding Questions

1. Define browsing and grazing. Give examples of browsing mammals and grazing mammals. How are their teeth different and why do these differences exist?

2. List the main groups of primates and sketch a family tree. Which group gave rise to our species? What are hominids?

3. How does the position of a continent influence its climate?

4. What features do plants have that are clues to climate? Describe how fossil plants can be used to study climate.

5. Describe the two main whale groups that are alive today. What is baleen made of and how has it been used in the past (i.e., women’s corsets, hairbrushes)? How is it used today?

6. What type of plant are the grasses? Describe the different biomes on Earth. Where do grasses occur today and how is their distribution related to climate?

7. What is convergent evolution? Give several examples.

Answers to Guiding Questions

1. Browsers eat leaves, bark, and green stems from plants at levels usually above the ground, while grazers eat vegetation such as grasses at or near the ground level. Examples of modern browsers include deer, camels, and giraffes. Examples of modern grazers include horses, sheep, and cattle. To cope with eating coarse grasses, grazers evolved taller teeth with more enamel for strength.

2. The main primate groups alive today include: humans, apes, old world monkeys, new world monkeys and prosimians (lorises and lemurs). Humankind evolved from the apes. The word "hominid" refers to members of the family of humans, Hominidae, which consists of all species on our side of the last common ancestor of humans and living apes. Some scientists use the term “hominin” to include the human family including the great apes.

3. Climate is the characteristic of the atmosphere near the Earth’s surface at a particular location. It could be thought of as the weather “averaged” over a time period of one year or greater. Climate zones are oriented parallel to the lines of latitude and are affected by temperature and precipitation. Through time, continents move as part of tectonic plates and can move from one climatic zone into another. For example, during much of the Paleozoic Era, Illinois was positioned close to the Equator and had a tropical to sub-tropical climate.

4. Plants have many features that are indicators of climate. These include density of stomata (pores in leaves), thickness of cuticle (outer covering), structure of leaves, pollen type and distribution, and characteristics of wood. Paleobotanists study all of these factors, but pay special attention to pollen analysis and leaf structure. Leaves with entire or non-toothed margins, pointed drip tips, and feather-like venation are good indicators of tropical environments.

5. The two main whale groups alive today are the toothed and baleen whales. Baleen is a tough, horny material made of the protein keratin that grows in comb-like fringes from the upper jaws of some species of whales. It is used to catch small food organisms such as plankton by filtering seawater. People have used baleen to make hairbrushes, clock springs, fans, buggy whips, parasol (umbrella) ribs, and as support pieces in women’s corsets. Native peoples have been using baleen for thousands of years to make containers and bowls, fishing line, nets, toboggans, baskets, animal snares, and art objects. Today plastic has largely replaced the use of baleen.
Grasses are a type of angiosperm or flowering plant that appeared in the Tertiary Period and now dominate the world’s vegetation. There are roughly 10,000 species of grasses and the grassland biome covers 20% of the Earth’s surface. It is the most important plant to worldwide human economies. Grasses flourish in wet or dry environments and can tolerate temperatures as low as –40°F in the winter. Humans devote more than 70% of the Earth’s farmland to the production of specific grasses—the cereal grains. These grasses provide at least half of the world’s caloric intake! Important grasses include wheat, oats, barley, millet, quinoa, rye, sorghum, corn, and rice.

Convergent evolution involves the evolution of a similar structure by organisms that are not closely related. An example of convergent evolution would be the development of a streamlined body for fast swimming in dolphins (mammals) and ichthyosaurus (extinct marine reptiles). Another example is the independent evolution of saber-toothed carnivores in both North and South America during the Tertiary. Saber-tooth carnivores of North America were mammals but in South America, saber-tooth carnivores were marsupials. Organisms can evolve similar traits to exploit new resources or meet environmental challenges.
Section 9: Pre-Activities and Field Trip Activities

Pre-Activities

1. Visit the Fossil Horse Cybermuseum at www.flmnh.ufl.edu/natsci/vertpaleo/fhc/FirstCM.htm. Divide students into four groups and ask them to visit the Gallery of Horses and Amazing Feets: Tales Told by Toes. Have each group study one of the following four animals: Hyracotherium, Miohippus, Meryhippus, and Equus. Each group should make a painting and fact sheet that includes basic information on their horse's number of toes, overall size, and time period. When finished, have students construct a classroom family tree that illustrates how horses evolved through time.

2. Have students make a mini herbarium. Introduce the anatomy of grass plants mentioning the main structures of the spikelet such as glumes, lemmas, and awns. Take students on a field trip to a meadow or prairie to collect grass plants. Note to teachers: make sure that you secure permission in advance for the collection of specimens from the property owner or manager, since many natural areas have rules limiting collection. Each student should collect at least two grass plants including the roots. In class, have students carefully spread out each plant and place between two sheets of newspaper (two on top and two on bottom) with cardboard sheets on the top and bottom to strengthen. Use rubber bands to secure (stack many together) and let dry for 48 hours. When dry, have students mount their plants on paper with rubber cement (you can use 11” x 17” paper to fold and make a protective cover) and label the specimens with date, location, common name, and scientific name. Students also can create their own press book out of the cardboard sheets.

3. Identify, describe, and compare biomes of the world through mapping based on Internet clues. Have students create a color-coded map of the major world biomes. They can work as a class in teams to create one map. The idea of biodiversity and the importance of biodiversity can be introduced here.

4. Ask students to research the Tertiary Period. What major geologic events happened during this period? What species evolved? How did the climate change? Have students write a paragraph outlining their research on this period.

5. Explore the evolution of whales. Go to the Web site www.indiana.edu/%7Eensiweb/lessons/whale.ev.html and do the lesson on “Becoming Whales.” This lesson should require no more than 45 minutes. All images and lesson instructions are provide on the Web site.

Field Trip Activities

1. Explore the ecosystems and habitats of ancient Wyoming. Review the differences between ecosystems and habitats. Using the Fossil Lake Habitats Worksheet 6 (two pages) in this guide, have students identify and describe the habitat and mode of life for the fossils listed on the worksheet. The specimens shown in the worksheet may differ slightly from those on display. When finished, go over the results as a group. How did the plants and animals get preserved? What can the animals and plants tell you about the type of environment? Are there some organisms that were not preserved?

2. Locate the interactive illuminated model of a grass plant. Have students explore the different structures of the plant and observe the fossils grass specimens on display. What do they notice about the fossils?

3. Compare and contrast predators in North America with those in South America during the Late Tertiary. Have students look for evidence on the types of predators present on each continent and compare the results as a group. What main geological factor influenced the type of predators present on each continent during this time?
Divide students up into six groups. Assign each group to one of the following sections in the Fossil Lake gallery: plants, mammals, reptiles (aquatic and terrestrial), fishes, arthropods, and birds. Have students record key elements of each section including the number of specimens, what they tell us about the environment, and other observations. Have each group present their results and describe the important functions of each animal/plant group. What do the animals and plants tell us about the environment?

Have students look for fossils that show ecological interactions or associations between different species in the Fossil Lake, Wyoming gallery of the exhibition. For example, ask students to look for animals and plants preserved together and animals in predator/prey interactions (hint: fish eating other fish). What conditions were necessary for these extraordinary fossils to form?

Plants are very sensitive to changes in climate and can be important tools in the study of climates of the past. Botanists have determined that plants growing in tropical climates have features such as 1) drip tips or pointed tips to help shed water, 2) entire (smooth) leaf margins, and 3) pinnate (feather-like) leaf venation. Have students look for evidence of these features in the Fossil Lake (Early Tertiary) and the Late Tertiary sections of the exhibition. As a group, go over the differences between leaf types that are observed. What does this tell us about how the climate in the Early and Late Tertiary differed?

Explore other famous Tertiary fossil deposits located in the United States. Recommended sites include: Ashfall Fossil Beds (www.ashfall.unl.edu) in Nebraska, Florissant Fossil Beds (www.nps.gov/flfo) in Colorado, and the John Day Fossil Beds (www.nps.gov/joda) in Oregon. Ask students to write a short report on one of these deposits as it compares to Fossil Lake fossil deposits from *Evolving Planet*. Encourage them to use images, maps, charts, and other materials in their report.

Design a role-playing game or play that focuses on the Mesozoic to Cenozoic transition. The main actors in the play are the last of the dinosaurs and the early mammals of the Tertiary Period. Have students assume the role of a dinosaur or mammal (or plant). The major events include the extinction of the dinosaurs, evolution of new mammals, climate change, and the appearance of flowering plants, especially the grasses. Put on a play that portrays this exciting time in Earth’s history.

Visit the Web site www.bbc.co.uk/sn/prehistoric_life/games and have students play the *Skeleton Jigsaw* and *Evolution Game*.

Prepare fossil fish from the Fossil Lake or the Green River Formation in Wyoming. Small kits of unprepared fish in rock can be purchased on the Internet through various companies. Visit these Web sites for more information: www.ulrichsfossilgallery.com/products/prepkits.html and www.paleotools.com/paleokits.html. Have 3-4 students work on the same fish as a group or individually at different times; preparation takes time and this activity is best done at small increments over several weeks. Students will experience what it is like to step into the shoes of a paleontologist and prepare a fossil for study. Ask students to keep a journal of their work on the specimen and to identify the specimen when finished.

## Worksheet 6: Fossil Lake Habitats

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<tr>
<th>Image of Fossil</th>
<th>Animal Group</th>
<th>Scientific Name</th>
<th>Habitat and Mode of Life</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Dragonfly, species not identified</td>
<td>Freshwater wetlands; predator of insects</td>
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<tr>
<td>2</td>
<td>Example: Insect, dragonfly</td>
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<tr>
<td>Image of Fossil</td>
<td>Animal Group</td>
<td>Scientific Name</td>
<td>Habitat and Mode of Life</td>
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</tbody>
</table>
Section 9: Vocabulary and Resources

Vocabulary Words

- Tertiary Period, Cenozoic Era, radiation, grasses, primates, hominids, humans, monkeys, apes, prosimians, whales, convergent evolution, Green River fossils

Related Museum Exhibitions

### Permanent Exhibitions

- Earth Sciences
- Grainger Gallery
- Moving Earth
- Animal Biology
- What is an Animal?
- Amphibians and Reptiles
- World of Birds
- World of Mammals
- Bushman
- Africa
- Lions of Tsavo
- Mammals of Africa
- Mammals of Asia
- Man-eater of Mfuwe
- Sea Mammals
- Plants of the World
- McDonald’s Fossil Preparation Laboratory

### Temporary Exhibitions

- Dinosaur Dynasty: Discoveries from China  
  (May 27, 2005 – April 23, 2006)
- Gregor Mendel: Planting the Seeds of Genetics  
  (September 15, 2006 – April 1, 2007)
- Darwin  
  (June 15, 2007 – January 1, 2008)
- Dinosaurs: Ancient Fossils, New Discoveries  
  (March 30 – September 3, 2007)

### Audio/Visual

- Fossil Lake
- Wild Mammals of Illinois

### Exhibit Cases

- Interior of the Earth
- Pebbles: How Shaped by Erosion
- Igneous Rocks
- Mammal, Grey Fox
- Great Horned Owl

### Experience Boxes

- Africa: The Land
- Fossils from Fossil Lake
- Dinosaurs and Other Mesozoic Creatures
- People and Animals from Illinois’ Past Trunk

Harris Educational Loan Center Material  
(Call 312.665.7555)
### Recommended Multimedia
- Explore Deep Time: Geological Time and Beyond CD-ROM  
  (Geological Society of America; www.geosociety.org)
- Explore Fossils CD-ROM  
  (Geological Society of America; www.geosociety.org)
- Plate Tectonics CD-ROM  
  (Geological Society of America; www.geosociety.org)
- Geologic Time Chart Game and related posters  
  (SK Science Kit & Boreal Laboratories; www.sciencekit.com/)
- Fossil and Geologic Time Chart, Cenozoic Mammal Chart, and Life of the Cenozoic Era activity set  
  (Wards Natural Science; www.wardsci.com/)
- Walking with Prehistoric Beasts Channel Store;  
  http://shopping.discovery.com/?jzid=4060404-2-0)
- Large source for dinosaur toys and books  
  (www.dinosaurfarm.com/)

### Recommended Web Sites
- www.ucmp.berkeley.edu/zenozoic/zenolife.html  
  (Cenozoic; Univ. of California Museum of Paleontology)
- www.ucmp.berkeley.edu/miomap/  
  (MIOMAP; Univ. of California Museum of Paleontology)
- www.paleoportal.org/time_space/time_space.php  
  (The Paleontology Portal)
  (Wikipedia summary)
- www.factmonster.com/ce6/sci/A0848255.html  
  (Tertiary; Fact Monster)
  (BBC Walking with Prehistoric Beasts)
The Field Museum
Education Department Presents


Opening March 10, 2006

EXPLORE THE HISTORY OF LIFE

Travel back through time to learn how evolution has created the mosaic of life on Earth.

PART ONE: SECTION 10
The Hominids: Dawn of Humankind
Evolving Planet
Opening March 10

This educator guide is separated into four parts: content, teacher and student resources, fun facts, and a walking map. The content for Evolving Planet consists of 12 sections. Before you visit the exhibition, spend some time viewing the information on the Museum’s Web site at www.fieldmuseum.org/evolvingplanet to begin planning your visit. We recommend using some of our quick fun facts and pre-activities to introduce your students to the geologic timeline, which is a reference tool that is prominent throughout the exhibition. Each section of this guide has an introduction, guiding questions, pre-activities, field trip activities, post-activities, and answers to guiding questions to help guide your students’ experience.

Acknowledgements:
Teacher contributors: Michael Baker, Bernadette Barnett and Nicholas Guerrero

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In accordance with Title IX of the Education Amendments Act of 1972, we do not discriminate on the basis of sex in our programs or activities. Please call 312.665.7271 to contact our Title IX Coordinator should you have questions or concerns.

Citigroup Foundation provides lead corporate support for professional development programs for teachers at The Field Museum.

Evolving Planet is made possible by Kenneth and Anne Griffin. The Elizabeth Morse Genius Charitable Trust is the generous sponsor of Evolving Planet’s Genius Hall of Dinosaurs.
Sections:

Part One:

Introduction to Evolving Planet

Section 1
Orientation to Evolving Planet

Section 2
The Precambrian: Life Emerges

Section 3
The Cambrian and Ordovician: World of Water

Section 4
The Silurian and Devonian: From Fins to Limbs

Section 5
The Carboniferous: Age of Coal Forests

Section 6
The Permian: Patchwork of Pangaea

Section 7
The Triassic: Dawn of a New Era

Section 8
The Jurassic and Cretaceous: Age of the Dinosaurs

Section 9
The Tertiary: Age of the Mammals

Section 10
The Hominids: Dawn of Humankind

Part Two:

Related Programs, Exhibitions, and Resources

Part Three:

Walking Map
This section tells the story of the hominids—the group that contains not only modern humans, but many other related groups that once lived on Earth. Though the picture is at present incomplete, scientists agree on two key points: humans evolved from an ape ancestor, and they evolved through the same unpredictable process as every other living thing. This is the story of the human family from its beginnings in Africa over four million years ago to the global rise of modern Homo sapiens. As hominids evolved, so did their technologies—they developed increasingly sophisticated tools, elaborate burial practices and art. The hominid story is still being written, but each new discovery brings us closer to a clearer picture of human evolution.

Students will encounter hominid fossils, stone tools, and a life-sized reconstruction of an early hominid named “Lucy.” In this section there are touchable specimens and a cast of footprints from the famous 3.6 million year old Laetoli hominid trackway from Tanzania. There is an excellent display of stone tools from 2.0 million to 10,000 years old and a Scientist Stop where students can learn about the research of Field Museum curator, Dr. Robert Martin, who studies human evolution.
Guiding Questions

1. What group gave rise to the hominids?  How do we know?
2. Who is “Lucy” and where was she found?  How is she related to us?
3. What two other hominid species lived at the same time as our species *Homo sapiens*?  What happened to them?
4. How and why are stone tools made?  Be sure to mention the terms core, hammer stone, and flakes.  How have stone tools changed through time?
5. How can we use teeth to infer the diets of extinct hominids?  What were the main trends in tooth size and shape over time in the hominid family tree (including us)?
6. How did *Homo neanderthalensis* (“Neanderthals”) differ from modern humans?  Compare and contrast such features as body size, bone structure, facial features, cultural development, and tool use.  What factor was an important influence on the evolution of the Neanderthals?
7. Why did hominids evolve from apes walking on four legs (quadrupedal) to walking on two legs (bipedal)?  Explain potential advantages.

Answers to Guiding Questions

1. Fossil evidence, comparative anatomy, and genetic studies show that the hominids evolved from an ape ancestor around eight million years ago.  Fossils of early hominids are similar to apes differing only in the tooth size and gait—hominids are bipedal, apes are not.  As hominids evolved, fossil show that they developed a unique suite of features including smaller teeth, a downward skull opening, a wider pelvis, big toe parallel with other toes, an arch in the foot, an inward angled femur, and a larger brain.

2. The fossil hominid known as “Lucy” was discovered in 1974 by a team of paleoanthropologists, under the direction of Donald Johanson, in the Afar region of northern Ethiopia.  The fossils are of a small female hominid of the species *Australopithecus afarensis*.  Lucy’s skeleton was small, just over three feet tall and estimated to weigh 60 pounds.  She lived 3.2 million years ago.  Her skeleton indicates that she was a bipedal, early hominid.

3. There is fossil evidence that shows that at least two other species lived at the same time as *Homo sapiens*, including:  *Homo neanderthalensis* (“neanderthals”) and *Homo heidelbergensis*.  Today, only one hominid species survives—modern *Homo sapiens*.

4. Stone tools were made by striking a stone core with a hammer stone to produce sharp flakes that can be used for cutting, chopping, and scraping.  The best types of stone are those that have a conchoidal or glass-like fracture (volcanic glass, flint or chert, and quartzite).  Stone tools increase in sophistication through time from small chipped pebbles to large hand axes to expertly shaped spear points and knives.

5. Dental morphology or the shape and structure of teeth and tooth-wear patterns can provide information on diet.  It’s important to note that hominid diet changed through time from a dominantly herbivorous diet to a dominantly omnivorous (mixed) diet.  Early hominids have dental morphologies with large molars and strong skulls to process a diet of plants including grasses, nuts, and fruits.  Later hominids have teeth adapted for a diet of both plants and meat.  Teeth become smaller and the skull changes to accommodate a larger brain and smaller jaw muscles.
6 Neanderthals were adapted for living in cold climates. They had shorter, stocky bodies with heavier bones, broader shoulders, wider ribcages, wide noses, a receding chin, a low forehead, and heavy brow ridges. They buried their dead and used a moderately advanced toolkit. Neanderthals evolved in Europe 400,000 years ago during the Pleistocene ice age and shared the planet with *Homo sapiens* for 150,000 years. The climate was the most significant factor that shaped the evolution of the Neanderthals.

7 Scientists speculate that hominids became bipedal to conserve energy (less energy is needed to move on two legs), to keep cooler, to provide a better view above tall grasses, and to allow the use of the arms to carry food items or other possessions. Bipedalism was simply more energy-efficient than walking on all fours.
Pre-Activities

1. Introduce human evolution in class with the goal of making a classroom human family tree. Have students use diagrams, sketches, and maps relating to each species to illustrate the tree. Make sure to put a time scale on the tree, since human evolution spans a period of six million years. See the Web sites listed below for more resources.

2. In 1976, a team lead by Mary Leakey discovered the fossilized footprints of human ancestors in Laetoli, Tanzania, Africa. Dated at 3.6 million years, these tracks provide a direct record of early hominid locomotion. Have students visit the Web site www.pbs.org/wgbh/evolution/library/07/1/l_071_03.html and watch the video on the Laetoli Footprints (QuickTime or RealPlayer software is needed for viewing). In class, have students make a plaster footprint of one of their feet. This can be done by mixing plaster, pouring it into a shallow container, and having the student step into it when partially hardened. Ask students to label the different parts of their footprint (toes, heel, arch) and to write a short essay comparing their footprint to one of the Laetoli footprints. Note: you can also have the students walk across newsprint sheets with diluted paint on their feet to make footprints.

3. Inspire students to visit online interactives on human evolution to learn more:
   b. Visit www.pbs.org/wgbh/evolution/humans/humankind/index.html and do the interactives on Origin of Humankind, Hominid Family Tree, Species Gallery, and Interactive Timeline. Students can also explore the interactive on the hominin “Lucy” in the Riddle of the Bones. Teachers should note that Evolving Planet features a life-size reconstruction of “Lucy” as well as a cast of her bones.
   c. There is an extensive library of Web sites on human evolution at: www.pbs.org/wgbh/evolution/library/07/index.html.

4. Have students make a classroom chart that compares brain size, arm length, size of teeth, shape of skull, type of gait (four- or two-legged), geographic location, and tool use of four hominids. We suggest you try comparing these four: Pan troglodytes (chimpanzee), Australopithecus afarensis (“Lucy”), Homo erectus, and Homo neanderthalensis (“Neanderthals”). Using this chart, have students write a short essay discussing which species is more closely and more distantly related to modern humans.

Field Trip Activities

1. Ask each student to locate the life-size reconstruction of the hominid ancestor called “Lucy” and make a sketch of her. Along with their sketch, have students comment on how similar or dissimilar she is to modern humans. What evidence did scientists use to reconstruct her walking on two legs as a biped? Hint: look for Lucy’s skeleton for clues.

2. Ask students to explore the touchable hominid skulls in this section. What do they notice about the skull of these specimens? What features are not found in modern humans? How do these features affect the appearance of the face?
Section 10: Field Trip Activities and Post-Activities

3 Pose the question: How did ancient humans make tools? Ask students to describe the general method for making stone tools. Teachers, note that this section in the exhibition contains a large display of stone tools for reference. Give students time to study this section and discuss what they've observed. Name some tools that we make today and describe how they are different from the early tools in the display.

4 In the section “What makes a hominid?,” split students up into eight groups and assign each group to one of the following categories: 1) tooth size, 2) bipedalism, 3) brain size, 4) skull opening, 5) pelvis shape, 6) toes, 7) foot arch, and 8) femur. Have each group find the section on their topic and gather data. When finished, have each group summarize what they learned about their topic.

5 Are there some anatomical structures in our bodies that aren’t useful anymore? Yes. Some features are merely remnants and no longer serve a purpose. Have students guess what some of these structures are before going into this section. Examples of now-useless structures include: wisdom teeth, third eye-lid, ear muscles, palmaris muscles, goose bumps, and our fifth toe. After going through the section, ask them to describe what they have learned in the exhibition. Are humans evolving today?

6 Using Worksheet 7 in this guide, have students explore the display cases on stone tools in this section and answer the questions listed on the worksheet for each tool type. Why did ancient people create stone tools? Who made these stone tools? Ask students to describe the trends they observe in tool development over time.

7 The last area of the hominid section features objects made by ancient humans that had a symbolic purpose. Ask students to examine these objects and make sketches of some of them. Can students locate objects that classmates are wearing that have a similar function? Can they think of other examples of modern symbols that correspond to what they see in the display? (Hint: painted rocks vs. modern graffiti or murals).

Post-Activities

1 Ask a local flint knapper to visit your class and do a demonstration on the making of stone tools. Lead a discussion on the importance of tool-making. Emphasize that tool making was one of many skills that was passed from parents to children and master to apprentice in ancient cultures. Have students think of other skills that might be passed from one generation to another in ancient cultures (e.g., pottery, basket-making, weaving, etc.). Visit these Web sites for more information: http://virtual.parkland.edu/ias/mainmenu.htm (Illinois Archaeological Survey) and http://museum.state.il.us/iaaa (Illinois Association for the Advancement of Archaeology).

2 How does archaeology reveal information about ancient peoples? Have students step into the shoes of an archaeologist and become a forensic detective. Do the lesson plan called Forensic Detectives: Archaeology at Work at: http://school.discovery.com/lessonplans/programs/forensics_archaeology. Students will watch a video, explore two burial sites and write a mystery about the archaeological discovery of a body. There is second lesson plan for grades 6-8 at: http://school.discovery.com/lessonplans/programs/archdetectives.

3 To illustrate some of the difficulties in unearthing an archaeological find, make mini-excavation sites that the students can make in class and exchange. Follow the lesson plan at www.pbs.org/saf/1203/teaching/teaching3.htm; you can create a more challenging sediment for students to excavate by making a sand and wax mixture to cover the artifacts. Experiment to see what works best for your needs.

4 Take a field trip with students to a local zoo to see other primate species and explore similarities and differences between them and humans. Encourage students to think about comparative anatomy, tool making, and language.
Section 10: Post-Activities

Post-Activities (continued…)


6. What does art tell us about ancient peoples? Have students explore cave paintings and create a classroom cave mural. Go to the official Web site for the Lascaux cave in France at www.culture.gouv.fr/culture/arcnat/lascaux/en/index.html. Let students explore the cave and make sketches of the paintings. Have students make a list of the many different animals from the cave. Discuss what the paintings tell us about the life of ancient peoples living in France over 17,000 years ago. Using what they learned, create a classroom cave painting and have the students explain their paintings in terms of life at that time in human history. What other surfaces did ancient peoples use to communicate? What types of methods were used to mix the paint used in these cave paintings and what did they mix the paint with?
<table>
<thead>
<tr>
<th>Stone tools</th>
<th>What was this tool used for?</th>
<th>What is this tool’s age range?</th>
<th>Who made this type of tool?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early stone tool</td>
<td>Simple chipped pebbles with sharp edges used for cutting and chopping.</td>
<td>Early stone tools were made from 2.5–1.5 million years ago.</td>
<td>Australopithecines or Homo habilis</td>
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<tr>
<td>Hand axe</td>
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<td>Stone point</td>
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<tr>
<td>Harpoon Needle</td>
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</table>
Section 10: Vocabulary and Resources

<table>
<thead>
<tr>
<th>Vocabulary Words</th>
<th>Hominids, ancestor, human family, burial practices, art, stone tools, Lucy, Laetoli, <em>Homo sapiens</em>, Neanderthals</th>
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</thead>
<tbody>
<tr>
<td><strong>Related Museum Exhibitions</strong></td>
<td><strong>Permanent Exhibitions</strong></td>
</tr>
<tr>
<td></td>
<td>- Earth Sciences</td>
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<td></td>
<td>- Grainger Gallery</td>
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<td>- Moving Earth</td>
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<td>- Animal Biology</td>
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<td></td>
<td>- What is an Animal?</td>
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<td>- Amphibians and Reptiles</td>
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<td></td>
<td>- World of Birds</td>
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<td>- World of Mammals</td>
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<td>- Bushman</td>
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<td></td>
<td>- Africa</td>
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<td>- Lions of Tsavo</td>
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<td>- Mammals of Africa</td>
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<td>- Mammals of Asia</td>
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<td>- Man-eater of Mfuwe</td>
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<td>- Sea Mammals</td>
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<td>- Plants of the World</td>
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<td>- McDonald’s Fossil Preparation Laboratory</td>
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<td></td>
<td><strong>Temporary Exhibitions</strong></td>
</tr>
<tr>
<td></td>
<td>- Dinosaur Dynasty: Discoveries from China (May 27, 2005 – April 23, 2006)</td>
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<td></td>
<td>- Gregor Mendel: Planting the Seeds of Genetics (September 15, 2006 – April 1, 2007)</td>
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<td>- Darwin (June 15, 2007 – January 1, 2008)</td>
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<td>- Dinosaurs: Ancient Fossils, New Discoveries (March 30 – September 3, 2007)</td>
</tr>
<tr>
<td><strong>Harris Educational Loan Center Material</strong></td>
<td>(Call 312.665.7555)</td>
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<tr>
<td></td>
<td><strong>Audio/Visual</strong></td>
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<tr>
<td></td>
<td>- Archaeology</td>
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<td><strong>Exhibit Cases</strong></td>
<td><strong>Experience Boxes</strong></td>
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<td></td>
<td>- Southwest Archaeology and Daily Life</td>
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<td>- Africa: The Land</td>
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<td>- Hominid Evolution</td>
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<td>- People and Animals from Illinois’ Past Trunk</td>
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</tbody>
</table>
Section 10: Vocabulary and Resources (continued…)

<table>
<thead>
<tr>
<th>Recommended Multimedia</th>
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</thead>
</table>
| □ Explore Deep Time: Geological Time and Beyond CD-ROM  
  (Geological Society of America; www.geosociety.org)  |
| □ Explore Fossils CD-ROM  
  (Geological Society of America; www.geosociety.org)  |
| □ Plate Tectonics CD-ROM (Geological Society of America; www.geosociety.org)  |
| □ Geologic Time Chart Game and related posters (SK Science Kit & Boreal Laboratories; www.sciencekit.com/)  |
| □ Fossil and Geologic Time Chart many replicas and skull sets on human evolution  
  (Wards Natural Science; www.wardsci.com/)  |
| □ Walking with Prehistoric Beasts Channel Store  
  (http://shopping.discovery.com/?jzid=40600404-2-0)  |

<table>
<thead>
<tr>
<th>Recommended Web Sites</th>
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<tbody>
<tr>
<td>□ <a href="http://www.becominghuman.org/">http://www.becominghuman.org/</a> (Becoming Human)</td>
<td></td>
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<tr>
<td>□ <a href="http://www.pbs.org/wgbh/aso/tryit/evolution/">www.pbs.org/wgbh/aso/tryit/evolution/</a> (PBS Human Evolution)</td>
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</tr>
<tr>
<td>□ <a href="http://www.talkorigins.org/faqs/homs/">www.talkorigins.org/faqs/homs/</a> (Talk Origins Archives; Fossil Hominids)</td>
<td></td>
</tr>
</tbody>
</table>
| □ www.anth.ucsb.edu/projects/human/  
  (Human Evolution 3D Gallery; Univ. of California, Santa Barbara)  |
| □ www.indiana.edu/~origins/  
  (Human Origins and Evolution out of Africa; Univ. of Indiana)  |
| □ www.archaeologyinfo.com/ (Archaeology Info; Human Evolution)  |
| □ www.indiana.edu/~ensiweb/lessons/c.bigcla.html  
  (Classroom Cladogram - Human Evolution; Univ. of Indiana)  |
| □ http://evolution.berkeley.edu/evolibrary/article/0_0_0/history_17  
  (Fossil Hominids and Human Evolution; Understanding Evolution)  |
| □ www.ucmp.berkeley.edu/cenozoic/cenolife.html  
  (Cenozoic; Univ. of California Museum of Paleontology)  |
| □ www.paleoportal.org/time_space/time_space.php (The Paleontology Portal)  |
The Field Museum
Education Department Presents


Opening March 10, 2006

EXPLORE THE HISTORY OF LIFE

Travel back through time to learn how evolution has created the mosaic of life on Earth.

PART ONE: SECTION 11
The Quaternary: Age of Ice
Evolving Planet
Opening March 10

This educator guide is separated into four parts: content, teacher and student resources, fun facts, and a walking map. The content for Evolving Planet consists of 12 sections. Before you visit the exhibition, spend some time viewing the information on the Museum’s Web site at www.fieldmuseum.org/evolvingplanet to begin planning your visit. We recommend using some of our quick fun facts and pre-activities to introduce your students to the geologic timeline, which is a reference tool that is prominent throughout the exhibition. Each section of this guide has an introduction, guiding questions, pre-activities, field trip activities, post-activities, and answers to guiding questions to help guide your students’ experience.

Acknowledgements:
Teacher contributors: Michael Baker, Bernadette Barnett and Nicholas Guerrero

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In accordance with Title IX of the Education Amendments Act of 1972, we do not discriminate on the basis of sex in our programs or activities. Please call 312.665.7271 to contact our Title IX Coordinator should you have questions or concerns.

Citigroup Foundation provides lead corporate support for professional development programs for teachers at The Field Museum.

Evolving Planet is made possible by Kenneth and Anne Griffin. The Elizabeth Morse Genius Charitable Trust is the generous sponsor of Evolving Planet’s Genius Hall of Dinosaurs.
Sections:

Part One:

Introduction to *Evolving Planet*

Section 1
Orientation to *Evolving Planet*

Section 2
The Precambrian: Life Emerges

Section 3
The Cambrian and Ordovician: World of Water

Section 4
The Silurian and Devonian: From Fins to Limbs

Section 5
The Carboniferous: Age of Coal Forests

Section 6
The Permian: Patchwork of Pangaea

Section 7
The Triassic: Dawn of a New Era

Section 8
The Jurassic and Cretaceous: Age of the Dinosaurs

Section 9
The Tertiary: Age of the Mammals

Section 10
The Hominids: Dawn of Humankind

Section 11
The Quaternary: Age of Ice

Part Two:

Related Programs, Exhibitions, and Resources

Part Three:

Walking Map
Explore the **Quaternary Period** (1.8 – today), one of the Earth’s greatest ice ages. By the end of the Tertiary Period, a new **land bridge** connected North and South America and migrations of plants and animals began. At this time, the Earth entered the most intense ice age in its history, which continues today. **Ice sheets** advanced and retreated as the climate fluctuated between colder intervals (glaciations) and warmer intervals (interglacials). Organisms adapted to the icy conditions by evolving large bodies to cope with the cold. Many mammal groups reached massive proportions as they spread across the globe. This was the age of the **wooly rhinoceros** and **mammoth**, **giant ground sloth**, **Irish elk**, **cave bear**, and **saber-toothed cat**. Humans like other mammals, diversified and colonized new continents—different hominid species lived alongside one another.

Early humans evolved in Africa and spread to Asia, Europe, Australia, and the Americas. At least five hominid species were living when the Quaternary Period began. Over time these species went extinct, and others evolved, including our own. Today, humans are the primary cause of a sixth **mass extinction**. For the past 10,000 years, species have been going extinct at a higher rate than ever before. The destruction of habitat by human activity is the single biggest cause of this extinction.

In this section, students will encounter interactives on the causes of ice ages, video presentations on biogeography and the Quaternary **ice age**, and the sixth Mass Extinction Station. Spectacular mounted skeletons can also be seen of a mastodon, mammoth, cave bear, rhinoceros, Irish elk, giant ground sloth, **glyptodont**, and **giant beaver**. There is a display on the **Rancho La Brea tar pits**, including a tar pit interactive and an impressive mounted skeleton of a saber-toothed cat.
Guiding Questions

1. What are ice ages? How many ice ages have there been on Earth? Was the most recent ice age the most intense?

2. What are land bridges? Why are they important to the story of a changing Earth to the story of new species' evolution?

3. What happened during the great faunal exchange that occurred between North and South America around 3.0 million years ago? Which animals migrated to North America? Which animals migrated to South America?

4. Explain what is meant by biogeography? Why is it important?

5. What happened to the large ice age mammals or “megafauna” during the Pleistocene ice age? Why?

6. What is the extinction rate for the sixth extinction? What is the main cause of this extinction? What can you do to slow it?

Answers to Guiding Questions

1. Ice ages are long periods of colder temperatures that result in an expansion of ice sheets over significant areas on Earth. The climate doesn’t stay cold during the entire period and alternates between episodes of ice sheet growth (glaciations) and episodes of relative warmth (interglacials). Today about 10% of the Earth’s surface is covered by ice. At the height of the last ice age in the Quaternary Period, approximately 30% of the surface was covered by ice. Geologists have discovered evidence of at least four main ice ages in Earth’s history: 1) Precambrian (800–600 mya), 2) Ordovician–Silurian Periods (460–430 mya), 3) Late Carboniferous–Permian Periods (350–250 mya), and 4) Quaternary Period (4 mya–12,000 years). Some scientists believe that the Earth experienced one of the most severe ice ages during the Precambrian between 700–600 million years ago. Today, most scientists believe that we are currently in an interglacial stage, or a warm phase of an ice age, that began around 2.0 million years ago.

2. Land bridges are areas of dry land exposed during periods of low sea level that connect two previously isolated landmasses. These connections form especially during ice ages when water is incorporated into extensive continental ice sheets causing the sea level to drop. Examples include the Isthmus of Panama and the Bering Straight exposed during late Tertiary Period. Land bridges serve as important migration routes for plants and animals.

3. The great faunal exchange marked the migration of species between North and South America during the late Tertiary Period. South America had been an island continent for nearly 80 million years and its mammals evolved in isolation. After the development of the Panama land bridge around 3.5 million years ago, the opossum, armadillo, ground sloth, glyptodonts, and others migrated from South America to North America. Migrations of placental mammals (horses, saber-tooth cats, rodents, camels, elephants, and others) from North America to South America also took place.

4. Biogeography is the study of the geographic distribution of plants and animals on the surface of the Earth. Island biogeography, a subfield of biogeography, studies the distribution of organisms on islands and other isolated areas. The study of biogeography can help us understand how the distributions of organisms, habitats, and ecosystems have changed through time.
35 different kinds of large mammals became extinct in North America at the end of the late Pleistocene, around 10,500 years ago. These groups included mammoth, mastodon, wooly rhinoceros, glyptodon (giant armadillos), giant beaver, camel, horse, giant ground sloth, sabertooth cat, American lion, and shortfaced bear. There are competing theories that suggest that over-hunting by humans wiped out many of these species. However, it is more likely that these extinctions were caused by a combination of factors. Dramatic fluctuations in climate occurred in the late Pleistocene as glaciers retreated, habitats shifted, and the climate warmed. Hunting by humans was one of many stressors that resulted in the extinction of large ice age mammals.

The extinction rate of the current or sixth major mass extinction is 30,000 species per year—that is 82 species every day, four species every hour! For the first time in history, a single species—humans—is the cause of a mass extinction. The biggest threat is habitat destruction.