Adventures in Earth Science

For

NYS Library

Summer Reading Programs
For more information, contact NYS Project Coordinator:

Kelly Ann Radzik, Resource Extension Educator
Cornell Cooperative Extension of Columbia and Greene Counties
518.828.3346x201
Kar25@cornell.edu

Note – There are electronic files to accompany these lessons. Contact Kelly or your local Cooperative Extension Office to get copies.

Cornell Cooperative Extension provides equal employment and program opportunity.
Welcome! The following six science activities represent an overview of the basic principles of Earth science, from fossils and rocks, plate tectonics and earthquakes, to geologic time and species classification.

To these resources we at the Paleontological Research Institution and Museum of the Earth have developed several activities to facilitate an understanding of basic Earth science concepts, using an inquiry-based, free-learning pedagogy that allows learners to learn through discovery. Activities have also been included from our colleagues at Indiana University, and the Illinois State Museum of Geology. All content has been developed and reviewed by scientists and education specialists, and provide a basis for understanding the world around us.

Background/Scientific Method:

None of this would make any sense, of course, without a solid understanding of the Process of Science and the Scientific Method. There are few organizations that present the pedagogy for teaching these concepts more explicitly and accurately defined as our friends at the University California Museum of Paleontology (UCMB). This is a wonderful site, presenting often complicated science concepts in a format that is readily transferable to teaching science to a number of demographics.

http://www.ucmp.berkeley.edu/education/teachers.php

Aside from this introduction, you also find a wonderful resource from UCMB called, “How Science Works”. This is not something you need to read through to understand these activities; rather, it is an excellent resource for understanding the scientific method and the process of science, or for referencing specific questions about the scientific process you may have.

1. Xenosmilus Activity approx. 40-60 minutes. Unlike what most of us are taught in school, the Scientific Method is not linear; “I observe, hypothesize, test, analyze data, come to a conclusion, then publish.” This isn’t how science is done at all. There’s a joke among science researchers; “There’s a reason they call it Re-
search – because we do it over, and over, and over, and over....” Science is not a
linear process! It circles around, starts again in the middle, goes back to the
beginning; it bends, morphs, moves forward and back, ideas and understandings
change and evolve.

The resources and activity here will help explain this concept, and help your
audience to grasp that science is a Way of Thinking, not a “start here, end there”
concept. The activity is designed to facilitate learning of this concept through “Being
the Paleontologist” through examining evidence and making educated guesses, then
examining more evidence, furthering their understanding, etc. “Xenosmilus” is an
excellent example of how scientists work from clues to comprise and revise
understandings of past life.

3. The Great Fossil Find: Activity about 40-60 minutes. These resources come
from Indiana University, and can be found online at:

There are two approaches for the “Great Fossil Find” activity; the original produced
by the University of Indiana, and a second that is another interpretation of the
activity from a local teacher. The Great Fossil Find also compliments the Xenosmilus
activity, thus both could certainly be done; just increase the depth of discussion
after the latter.

This activity instills some drama into the mix! The excitement of the chase, the
wonder at finding the first few bones of an ancient animal, and the mystery of what
they might represent! Read this with a theatrical emphasis, and you are sure to
captivate your audience!

4. Ride the Rock Cycle: Activity Time: about 60 minutes. This is a wonderful
activity resource developed by the Illinois State Museum of Geology to facilitate the
understanding of how rock, sand, and magma, are all continuously made and
deposited. This is an active, “get up and go” activity that will have kids running from
station to station to find out what happens next! English and Art is also involved, as
they describe their journey in a diary, and draw a comic strip to show the rock
process. Art and Science Convene!

5. Relative Dating: “Who’s on First??” Activity Time: about 60 minutes. Again,
the folks at UCMB have done a wonderful job of describing Earth science, this time
for discussing how we know the age of rocks and fossils. This activity starts with a
activity of sequencing letters on cards, graduating to fossil pictures printed on “rock
layer” cards. Sequencing these rock layers show participants how paleontologists
use fossils to relatively date rock strata. Dinosaurs are so engaging!

6. Beastie Bios: Activity Time: about 60 minutes. This activity introduces
participants to the vast diversity of life on Earth, and how we gain knowledge of past
life through the fossil record. The concept of geologic time is a tough one to get
across; but by using the rope to demonstrate a relative distance of time, participants start to conceive of the vast expanse of time, and how little humans have occupied that time line.

7. Cretaceous Crime Scene: Activity Time: about 60 minutes. What kid doesn’t love a Crime Scene Investigation? Developed by PRI, this lesson introduces the concepts of observation, inference, hypothesis formation, and hypothesis testing. A veritable “Whodunnit” in the Cretaceous environment!

We are always interested in your opinion and questions regarding the content and implementation of these resources, and welcome your comments and questions. My email is below – please don’t hesitate to contact me! Have Fun!

Carlyn S. Buckler, PhD
Senior Education Associate
Paleontological Research Institution
Museum of the Earth, Cayuga Nature Center
MuseumoftheEarth.org
csb36@cornell.edu
“Adventures in Earth Science”
Overview – 6 One-Hour Lessons to Mix and Match

Lesson 1  “Xenosmilus”
Lesson 2  The Great Fossil Find
Lesson 3  Ride The Rock Cycle
Lesson 4  Relative Dating
Lesson 5  Beastie Bios
Lesson 6  Cretaceous Crime Scene

Sample Schedule for 3 Two-Hour Sessions

“Fossil Day”  Lessons 1 + 4
Lesson 2 as well (for older groups)

“Adventure Day”  Lesson 3
Extra Time for Designing Comic Books

“Ancient Creatures Day”  Lesson 5 + Lesson 6

Other Ideas:

- Invite Fossil Collector to talk (Earth Science Teacher, College Geology Club)
- Invite Local Artist to help with creating Rock Cycle Journey Comic Books
- Supplement with Dinosaur Film Festival (Disney’s Dinosaur, Prehistoric Planet [Discovery Kids], or Land Before Time)

Reference Site for Dinosaur Questions: http://www.bbc.co.uk/nature/14343366
Xenosmilus

Author/Adaptor: Al Janulaw

Overview: In this lesson, students play the roles of paleontologists on a dig. They “unearth” a few fossils at a time and attempt to reconstruct the animal the fossils represent.

Lesson Concepts:

- Life forms of the past were in some ways very different from living forms of today, but in other ways very similar.
- Fossils provide concrete evidence of past life.
- Form is linked to function.
- Scientists pose, test, and revise hypotheses based on research outcomes.
- Science explains the natural world using evidence from the natural world.
- Science does not prove or conclude; science is always a work in progress.

Grade Span: 4–12

Materials:

- One envelope of fossils, cut from the Fossil Sheet (HTML or pdf), per group
- One Xenosmilus Worksheet (HTML) per student
- One Skeletal Resource Manual (HTML or pdf) per student

Advance Preparation:

- Cut up the Fossil Sheet and place one set of fossils in each envelope. Leave a bit of white paper around each fossil to facilitate cutting.
- Make one copy of the Xenosmilus Worksheet for each student.

Time: One class period

Grouping: Threes or fours

Teacher Background:

The “fossils” are based on Xenosmilus hodsonae, a two-meter-long cat that lived in what is now Florida, between 1.7 and 1.0 million years ago. Xenosmilus looked somewhat similar to the more familiar saber-toothed cat, Smilodon, found in the La Brea tar pits of Southern California. It had long canine teeth, a stout body, and very powerful front legs, which may have been specialized to prey on large animals.

Teacher Resources: A web search for Xenosmilus, Homotherium or Smilodon will yield abundant results.

Teaching Tips:
Student enthusiasm will largely hinge on your showpersonship. Assure them that they are working with replicas of real fossils and functioning the way paleontologists actually work.

If you would like to use this activity again in the future, make sure students put the fossils back in the envelopes after finishing.

The Xenosmilus Worksheet is suitable for 6-12 grade students. Teachers of younger children may want to assemble more appropriate debriefing questions, such as What do you think it was? and How can you tell?

Vocabulary: fossil, skeleton

Procedure:

1. Pass out the envelopes of fossils and the worksheets.
2. Tell the following story (which includes instructions in parentheses) to the class.
3. The script:

   You and your fellow paleontologists are on a fossil dig in Florida, during August of this year. You have had to wade through three miles of swamp carrying shovels, picks, and other digging equipment. Then you needed to go back to the road to lug your tents and other supplies to your campsite. The first evening you plan the dig. One person will shovel mud, another will look through the mud for fossils and the third person will keep watch for alligators.

   The next morning the team arises early and begins digging. After several hours of shoveling mud, swatting mosquitoes, and sweating, you get lucky. Very lucky. Your team discovers four fossils and returns to camp with them.

   Without looking in the envelope, randomly remove four fossils and lay them on the table. These are the cleaned-up fossils. Now that you are back in camp for the evening, arrange the fossils so they make as much sense as possible. Write on your worksheet what you think the animal might be.

   (Allow students time to manipulate the fossils, reflect and record their hypotheses. Request that students not observe the workings of the other groups.)

   The second morning your team arises even earlier, excited about the possibility of finding more interesting fossils. This day, however, your all-terrain vehicle gets stuck in the mud and you have to dig it out during a raging thunderstorm. Your team finally gets to the dig site by noon and, fighting the heat and wet, manages to unearth three more fossils. You return to camp exhausted.

   Again, without looking in the envelope, withdraw three fossils. Use the next few minutes to arrange the new fossils with the ones from yesterday. On your worksheets, record what you think the animals is now.

   (Allow a few minutes for this task.)

   The third morning dawns bright and beautiful with the sort of sunrise that only happens in Florida in the summer. Thrushes singing, cicadas buzzing. The team heads out to what must be its last day of digging this season. At the site, an American crocodile walks past, paying little attention to the strange animals that are grubbing about in the mud. After several hours of digging and mucking, the team discovers three more bones. This makes a total of ten in three days. The team, fills in its hole, carefully marks the location on the map, and returns to camp for the last time. During the final evening in camp the team assembles its ten fossils.
Again, without looking in the envelope, withdraw three more fossils. Put them on the table with the others and see what you have. Record what you think it is now.

Bright the next morning, the team packs up and returns to the Museum of Paleontology. Upon arriving at the Museum you learn that other teams have had successful expeditions this summer and would be glad to share their results.

Walk around the room and see what others have done with their fossils. Discuss your results with them and ask about theirs. (Allow a few minutes for this.) Now, with this additional information, write what you think the fossil is.

After exchanging ideas with other scientists, your team goes to the library and consults a Skeletal Resource Manual, which has drawings of skeletons of living animals.

(Pass out the Skeletal Resource Manuals.)

Look through the Skeletal Resource Manual. Compare your fossils with the skeletons in the book. Record your final idea of what you think your fossil is. Answer all the questions on your worksheet and return the fossils to their envelope.

5. Have each team share with the entire class what they decided the fossil is. Ask for the evidence that led to their final hypothesis.
6. Ask if there is a general consensus on what the animal might have been. If there is no clear, final answer, ask what they would like to do to pursue it.
7. Allow students to search the Internet, use trade books, visit the library, or research the mystery at home.

Extensions:

Use the excellent activity, The Great Fossil Find, found on the ENSI website. The ENSI version of this lesson is somewhat more challenging than the activity above and may leave students a bit unclear on the identity of the fossils—much the way scientists spend a great deal of their time.

Acknowledgements:

Adapted from The Great Fossil Find on the ENSI website:

Updated May 24, 2004

Home  |  What's new  |  About UCMP  |  History of Life  |  Collections  |  Subway

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The Great Fossil Find

In this activity, you and your partner will play the roles of paleontologists working in the field in Montana, near the town of Ekalaka. One clear crisp afternoon in October, you find four well-preserved and complete fossils.

Open envelope 1 and remove 4 fossils.

Day 1: That night in camp, after dinner, around a Coleman lantern, you and your colleagues begin to assemble the 4 bones you found earlier. Since the bones were all found together in an undisturbed layer, you assume that they are all from the same animal. You spend the rest of the evening trying different arrangements of the bones in hopes of identifying the animal before you get tired.

Take 5 minutes to assemble the bones and make notes in your data chart. What kind of animal do you think this is?

Day 2: You wake up to a beautiful Montana morning and you hurry back out to the dig site. The rock layers that hold your fossils are very hard and only give up three more specimens. As the day ends you make your way back to camp for another try at assembling the mystery animal.

Open envelope 2 and remove 3 fossils. Take 5 minutes to assemble all 7 bones and make notes in your data chart. What kind of animal do you think this is now?

Day 3: The next morning is cold. You can tell that winter is just around the corner and you know that this will be the last day of the digging season, and your last chance to find more fossils of the mystery animal. Just as the day is about to end, one of the members of your team finds 3 final bones.

Open envelope 3 and remove 3 fossils. Take 5 minutes to assemble all 10 bones and make notes in your data chart. What kind of animal do you think this is now?
**Day 4:** Back in the lab, you meet up with some Paleontologist friends. They tell you they have spent the summer working in a different location but with the same geological period. You show them the skeleton you found, and they tell you they have a similar one, but it looks like they have some different bones that you don’t have.

*For 5 minutes, compare your fossils with those of a group near you, looking for clues that will help you assemble your fossils. Apply these clues to your interpretation of your skeleton. What type of animal do you think you have now?*

**Day 5:** In the library at school you find a Skeletal Resource Manual with drawings of the skeletons of some existing animals. You notice some interesting similarities between some of the drawings and your unknown fossil.

*Use the drawings to assist you in your final assembly of the fossil skeleton. Fill in the data table with your final interpretation of the skeleton.*

*When you are finished, pick up the poster instructions at the front and start working on your poster with your partner.*
<table>
<thead>
<tr>
<th>Day 1</th>
<th>Day 2</th>
<th>Day 3</th>
<th>Day 4</th>
<th>Day 5</th>
</tr>
</thead>
</table>

What do your fossils look like? What type of animal do you think it is? What makes you think that?

The Great Fossil Find

Names:
Ride the Rock Cycle

**Purpose:** To teach students that the rock cycle, like the water cycle, has various stages and does not necessarily move linearly through those stages.

**Suggested Goals:** Students will gain an understanding of how a rock can move through the different stages of the rock cycle.

**Targeted Objectives:** As a result of this lesson, students will be able to:
1. Describe the rock cycle
2. Identify the various stages of the rock cycle

**Background:** A useful aid in visualizing the *rock cycle* is shown above. The three major rock types, igneous, metamorphic, and sedimentary, are shown. As you see, each may form at the expense of another if it is forced out of equilibrium with its physical or climatic environment by either internal or surficial forces.

Magma is molten rock. *Igneous* rocks form when magma solidifies. If the magma is brought to the surface by a volcanic eruption, it may solidify into an *extrusive* igneous rock. Magma may also solidify very slowly beneath the surface. The resulting *intrusive* igneous rock may be exposed later after uplift and erosion remove the overlying rock. The igneous rock, being out of equilibrium, may then undergo *weathering* and *erosion,*
and the debris produced is transported and ultimately deposited (usually on a sea floor) as sediment. If the unconsolidated sediment becomes lithified (cemented or otherwise consolidated into rock), it becomes a sedimentary rock. As the rock is buried the additional layers of sediment and sedimentary rock, heat and pressure increase. Tectonic forces may also increase the temperature and pressure. If the temperature and pressure become high enough, usually at depths greater than several kilometers below the surface, the original sedimentary rock is no longer in equilibrium and recrystallizes. The new rock that forms is called a metamorphic rock. If the temperature gets very high the rock melts and becomes magma again, completing the cycle.

The cycle can be repeated, as implied by the arrows. However, there is no reason to expect all rocks to go through each step in the cycle. For instance, sedimentary rocks might be uplifted and exposed to weathering, creating new sediment.

**Materials/Preparation:** Create the dice and posters for the different stations of the rock cycle game. [See attached patterns.]

**Procedure:**
Part I: Play the Rock cycle game. Set up your classroom with 8 areas at which a change in the rock cycle occurs. Each student starts at one area. At each area is a die that the student should role to determine what path they should take. It is possible for the student to remain at the same station for a long time. To make the game more interesting, my rule is that you can only stay at one station for 3 turns. Then you must go to another station. While at each station and while moving to the different stations, students must record what is happening on their journey chart. [See attached log.] After the game is over they will have a record of what happened.

Part II: Cartoons
After their journey is complete, students must create a cartoon of how their adventures in the rock cycle occurred. Points are given for use of correct terms. Each cartoon page should be divided so there are 12 boxes—room for 12 drawings. Students should turn in their adventure log and cartoon together so you can see what has occurred in their adventure.

**Questions:** What happened while you were on the rock cycle?

**Extensions:** Have students create a story or a travel brochure about their time on the rock cycle.

**Assessment:** Evaluate the students' journey logs and cartoons.

**Lesson Specifics:**
Skills: Students will need to use observation, inference, data collection skills to complete the activity.

Duration: 1 day
Journey on the Rock Cycle

This sheet is to help you write about your experiences as a rock during your journey on the rock cycle. You will need to describe your adventures at each spot and tell about what kind of rock you feel that you were.

1. I began my adventure at ____________________.

2. The first thing that happened was ____________________, then I went to ____________________.

3. The next thing that happened was ____________________, then I went to ____________________.

4. The next thing that happened was ____________________, then I went to ____________________.

5. The next thing that happened was ____________________, then I went to ____________________.

6. The next thing that happened was ____________________, then I went to ____________________.

7. The next thing that happened was ____________________, then I went to ____________________.

8. The next thing that happened was ____________________, then I went to ____________________.

9. The next thing that happened was ____________________, then I went to ____________________.

10. The next thing that happened was ____________________, then I went to ____________________.

11. The next thing that happened was ____________________, then I went to ____________________.

12. The next thing that happened was ____________________, then I went to ____________________.

**Challenge**
Create a comic strip story of your experiences from the journey through the rock cycle!
Station: Earth’s Interior

- Magma is forced up
  - Go to volcano
- Pressure occurs
  - More layers
  - Remain here
  - Pressure occurs
  - Remain here
  - Pressure occurs
  - Remain here
- Tectonic plates push upward
  - Go to mountains

Station: Soil

- Pressure occurs
  - Go to earth’s interior
- rocks break down
  - Go to earth’s interior
  - Remain here
- Pressure occurs
  - Go to earth’s interior
  - Remain here
- Sediment being formed
  - Remain here

Journey Through the Rock Cycle

Cut out each die pattern and the signs for each station. Assemble dice by folding along lines and taping the edges together.

As the students travel through the rock cycle, they must roll the die at the station and follow the written directions.

S. Baker 2001
Station: River

- Flood water causes redeposit of silt to flood plain
  - Go to soil

- Sediments form
  - Go to soil

- Water washes away layers
  - Go to mountains

- Silt washed into ocean
  - Go to ocean

- Sediments under pressure
  - Go to earth’s interior

- Ice melts carrying rocks
  - Go to river

Station: Ocean

- Sand washes up onto shore
  - Go to soil

- Ocean floor being subducted
  - Go to earth’s interior

- Ocean floor being subducted
  - Go to earth’s interior

- Dust evaporates with water
  - Go to clouds

- Sand washes up onto shore
  - Go to soil
Volcano erupts spewing forth lava
Go to mountain

Tectonic plates push upwards
Go to mountains

Magma crystallizes
Remain here

Volcanic ash and dust are pushed into atmosphere
Go to clouds

Crystallized magma pushes up to surface
Go to soil

Magma flows into the ocean
Go to ocean
WHO'S ON FIRST?
A RELATIVE DATING ACTIVITY

MARSHA BARBER and DIANA SCHEIDLE BARTOS
From Understanding Science, the University of California Museum of Paleontology

Goal: Participants will gain an understanding of how we know how old a given fossil or rock is.
Time: Depending on discussion time, about an hour

INTRODUCTION
PALEONTOLOGY, AND in particular the study of dinosaurs, is an exciting topic to people of all ages. Although most attention in today’s world focuses on dinosaurs and why they became extinct, the world of paleontology includes many other interesting organisms which tell us about Earth’s past history. The study of fossils and the exploration of what they tell scientists about past climates and environments on Earth can be an interesting study for students of all ages.

Teaching about Earth’s history is a challenge for all teachers. Time factors of millions and billions of years is difficult even for adults to comprehend. However, “relative” dating or time can be an easy concept for students to learn.

In this activity, students begin a sequencing activity with familiar items — letters written on cards. Once they are able to manipulate the cards into the correct sequence, they are asked to do a similar sequencing activity using fossil pictures printed on “rock layer” cards. Sequencing the rock layers will show students how paleontologists use fossils to give relative dates to rock strata.

Once students begin to grasp “relative” dating, they can extend their knowledge of geologic time by exploring radiometric dating and developing a timeline of Earth’s history. These major concepts are part of the Denver Earth Science Project’s “Paleontology and Dinosaurs” module written for students in grades 7-10. The module is an integrated unit which addresses the following National Science Education Standards:

*Science as Inquiry: Students develop the abilities necessary to do scientific inquiry — identify questions, design and conduct scientific investigations, use appropriate tools and technologies to gather, analyze and interpret data, think critically and logically to make the relationships between evidence and explanations, communicate results, and use mathematics in all aspects of scientific inquiry. *Life Science: Fossils indicate that many organisms that lived long ago are extinct. Extinction of species is common; most of the species that have lived on the earth no longer exist. *Earth and Space Science: Fossils provide important evidence of how life and environmental conditions have changed.

The complete “Paleontology and Dinosaurs” module takes approximately four weeks to teach. The “Who’s On First?” activity is a 30-minute introduction to geologic time.
WHO'S ON FIRST? RELATIVE DATING
(Student Activity)

INTRODUCTION
Scientists have good evidence that the earth is very old, approximately four and one-half billion years old. Scientific measurements such as radiometric dating use the natural radioactivity of certain elements found in rocks to help determine their age. Scientists also use direct evidence from observations of the rock layers themselves to help determine the relative age of rock layers. Specific rock formations are indicative of a particular type of environment existing when the rock was being formed. For example, most limestones represent marine environments, whereas, sandstones with ripple marks might indicate a shoreline habitat or a riverbed.

The study and comparison of exposed rock layers or strata in various parts of the earth led scientists in the early 19th century to propose that the rock layers could be correlated from place to place. Locally, physical characteristics of rocks can be compared and correlated. On a larger scale, even between continents, fossil evidence can help in correlating rock layers. The Law of Superposition, which states that in an undisturbed horizontal sequence of rocks, the oldest rock layers will be on the bottom, with successively younger rocks on top of these, helps geologists correlate rock layers around the world. This also means that fossils found in the lowest levels in a sequence of layered rocks represent the oldest record of life there. By matching partial sequences, the truly oldest layers with fossils can be worked out.

By correlating fossils from various parts of the world, scientists are able to give relative ages to particular strata. This is called relative dating. Relative dating tells scientists if a rock layer is "older" or "younger" than another. This would also mean that fossils found in the deepest layer of rocks in an area would represent the oldest forms of life in that particular rock formation. In reading earth history, these layers would be "read" from bottom to top or oldest to most recent. If certain fossils are typically found only in a particular rock unit and are found in many places worldwide, they may be useful as index or guide fossils in determining the age of undated strata. By using this information from rock formations in various parts of the world and correlating the studies, scientists have been able to establish the geologic time scale. This relative time scale divides the vast amount of earth history into various sections based on geological events (sea encroachments, mountain-building, and depositional events), and notable biological events (appearance, relative abundance, or extinction of certain life forms).

Objectives: When you complete this activity, you will be able to: (1) sequence information using items which overlap specific sets; (2) relate sequencing to the Law of Superposition; and (3) show how fossils can be used to give relative dates to rock layers.

Materials: two sets of sequence cards in random order (set A: nonsense syllables; set B: sketches of fossils), pencil, paper

Procedure Set A:
1) Spread the cards with the nonsense syllables on the table and determine the correct sequence of the eight cards by comparing letters that are common to individual cards and, therefore, overlap. The first card in the sequence has "Card 1. Set A" in the lower left-hand corner and represents the bottom of the sequence. If the letters "T" and "C" represent fossils in the oldest rock layer, they are the oldest fossils, or the first fossils formed in the past for this sequence of rock layers.
2) Now, look for a card that has either a "T" or "C" written on it. Since this card has a common letter with the first card, it must go on top of the "TC" card. The fossils represented by the letters on this card are "younger" than the "T" or "C" fossils on the "TC" card which represents fossils in the oldest rock layer.
Sequence the remaining cards by using the same process. When you finish, you should have a vertical stack of cards with the top card representing the youngest fossils of this rock sequence and the "TC" card at the bottom of the stack representing the oldest fossils.

**Interpretation Questions:**
1) After you have arranged the cards in order, write your sequence of letters (using each letter only once) on a separate piece of paper. Starting with the top card, the letters should be in order from youngest to oldest.
2) How do you know that "X" is older than "M"?
3) Explain why "D" in the rock layer represented by DM is the same age as "M."
4) Explain why "D" in the rock layer represented by OXD is older than "D" in the rock layer represented by DM.

**Procedure Set B:**
1) Carefully examine the second set of cards which have sketches of fossils on them. Each card represents a particular rock layer with a collection of fossils that are found in that particular rock stratum. All of the fossils represented would be found in sedimentary rocks of marine origin. **Figure 2-A** gives some background information on the individual fossils.
2) The oldest rock layer is marked with the letter "M" in the lower left-hand corner. The letters on the other cards have no significance to the sequencing procedure and should be ignored at this time. Find a rock layer that has at least one of the fossils you found in the oldest rock layer. This rock layer would be younger as indicated by the appearance of new fossils in the rock stratum. Keep in mind that extinction is forever. Once an organism disappears from the sequence it cannot reappear later. Use this information to sequence the cards in a vertical stack of fossils in rock strata. Arrange them from oldest to youngest with the oldest layer on the bottom and the youngest on top.

**Interpretation Questions:**
1) Using the letters printed in the lower left-hand corner of each card, write the sequence of letters from the youngest layer to the oldest layer (i.e., from the top of the vertical stack to the bottom). This will enable your teacher to quickly check whether you have the correct sequence.
2) Which fossil organisms could possibly be used as index fossils?
3) Name three organisms represented that probably could not be used as index fossils and explain why.
4) In what kinds of rocks might you find the fossils from this activity?
5) State the Law of Superposition and explain how this activity illustrates this law.
Figure 2-A. Sketches of Marine Fossil Organisms (Not to Scale)

NAME: Brachiopod  
PHYLUM: Brachiopoda  
DESCRIPTION: "Lamp shells"; many living species; exclusively marine; have soft bodies and bivalve shells.

NAME: Ichthyosaur  
PHYLUM: Vertebrata  
DESCRIPTION: Carnivore; air-breathing aquatic animal; extinct

NAME: Trilobite  
PHYLUM: Arthropoda  
DESCRIPTION: Three-lobed body; burrowing, crawling, and swimming forms; extinct

NAME: Eurypterid  
PHYLUM: Arthropoda  
DESCRIPTION: Many were large (a few rare species were 5 feet in length); crawling and swimming forms; extinct

NAME: Graptolite  
PHYLUM: Chordata  
DESCRIPTION: Primitive form of chordate; floating form with branched stalks; extinct

NAME: Ammonite  
PHYLUM: Mollusca  
DESCRIPTION: Squid-like animal with coiled, chambered shell, related to modern-day Nautilus

NAME: Horn coral  
PHYLUM: Coelenterata  
(Cnidaria)  
DESCRIPTION: Jellyfish relative; stony calcareous exoskeleton found in reef environments; extinct

NAME: Crinoid  
PHYLUM: Echinodermata  
DESCRIPTION: Multibranched relative of starfish; lives attached to the ocean bottom; some living species ("sea lilies")

NAME: Placoderm  
PHYLUM: Vertebrata  
DESCRIPTION: Primitive armored fish; extinct

NAME: Shark's tooth  
PHYLUM: Vertebrata  
DESCRIPTION: Cartilage fish; many living species

NAME: Foraminifera  
PHYLUM: Protozoa  
(Sarcodina)  
DESCRIPTION: Shelled, amoeba-like organism

NAME: Gastropod  
PHYLUM: Mollusca  
DESCRIPTION: Snails and relatives; many living species

NAME: Pelecypod  
PHYLUM: Mollusca  
DESCRIPTION: Clams and oysters; many living species
WHO'S ON FIRST? RELATIVE DATING
(Teacher Version)

INTRODUCTION
Scientists have good evidence that the earth is very old, approximately four and one-half billion years old. Scientific measurements such as radiometric dating use the natural radioactivity of certain elements found in rocks to help determine their age. Scientists also use direct evidence from observations of the rock layers themselves to help determine the relative age of rock layers. Specific rock formations are indicative of a particular type of environment existing when the rock was being formed. For example, most limestones represent marine environments, whereas, sandstones with ripple marks might indicate a shoreline habitat or a riverbed.

The study and comparison of exposed rock layers or strata in various parts of the earth led scientists in the early 19th century to propose that the rock layers could be correlated from place to place. Locally, physical characteristics of rocks can be compared and correlated. On a larger scale, even between continents, fossil evidence can help in correlating rock layers. The Law of Superposition, which states that in an undisturbed horizontal sequence of rocks, the oldest rock layers will be on the bottom, with successively younger rocks on top of these, helps geologists correlate rock layers around the world. This also means that fossils found in the lowest levels in a sequence of layered rocks represent the oldest record of life there. By matching partial sequences, the truly oldest layers with fossils can be worked out.

By correlating fossils from various parts of the world, scientists are able to give relative ages to particular strata. This is called relative dating. Relative dating tells scientists if a rock layer is "older" or "younger" than another. This would also mean that fossils found in the deepest layer of rocks in an area would represent the oldest forms of life in that particular rock formation. In reading earth history, these layers would be "read" from bottom to top or oldest to most recent. If certain fossils are typically found only in a particular rock unit and are found in many places worldwide, they may be useful as index or guide fossils in determining the age of undated strata. By using this information from rock formations in various parts of the world and correlating the studies, scientists have been able to establish the geologic time scale. This relative time scale divides the vast amount of earth history into various sections based on geological events (sea encroachments, mountain-building, and depositional events), and notable biological events (appearance, relative abundance, or extinction of certain life forms).

Objectives: When you complete this activity, you will be able to: (1) sequence information using items which overlap specific sets; (2) relate sequencing to the Law of Superposition; and (3) show how fossils can be used to give relative dates to rock layers.

Explore this link for additional information on the topics covered in this lesson:

- Geologic Time

Materials: Two sets of sequence cards in random order (set A: nonsense syllables; set B: sketches of fossils); pencil, paper

TEACHER SUGGESTIONS
The cards in set A are composed of nonsense syllables. The nonsense syllables or letters sometimes overlap other cards and are being used to introduce the students to the concept of sequencing. The cards should be duplicated, laminated, and cut into sets and randomly mixed when given to the students. It is recommended that students complete Procedure set A and answer the associated Interpretation Questions correctly before proceeding to set B.

The cards in set B represent rock layers containing various fossils. For set B, you may want to color code
each organism type (i.e., color the trilobites blue) before you laminate and cut the cards apart. Sequencing
the rock layers will show the students how paleontologists use fossils to give relative dates to rock strata.
Return to top

To enhance this activity, have students match the fossil sketches to real fossils. You may use fossils from
the John Hanley Fossil Teaching Set. To request a Fossil Teaching Set, call the Geology Museum at the
Colorado School of Mines (303) 273-3815. The following is a list of fossils in the John Hanley Fossil
Teaching Set that may be useful in this activity. Brachiopod V Gastropod VI-2 Trilobite VIII Pelecypod VI-
1 Graptolite X Ammonite VI-3b Corals IIIa, IIIb Shark’s Tooth XI-1a Crinoids IXa, IXb Foraminifera I

Figure 2-A illustrates a hypothetical stratigraphic section of rocks which include fossil assemblages
represented in Set B. It may be useful to share with students after they have completed Set B and answered
the Interpretation Questions.

Procedure Set A:
1) Spread the cards with the nonsense syllables on the table and determine the correct sequence of the eight
cards by comparing letters that are common to individual cards and, therefore, overlap. The first card in the
sequence has "Card 1, Set A" in the lower left-hand corner and represents the bottom of the sequence. If the
letters "T" and "C" represent fossils in the oldest rock layer, they are the oldest fossils, or the first fossils
formed in the past for this sequence of rock layers.
2) Now, look for a card that has either a "T" or "C" written on it. Since this card has a common letter with
the first card, it must go on top of the "TC" card. The fossils represented by the letters on this card are
"younger" than the "T" or "C" fossils on the "TC" card which represents fossils in the oldest rock layer.
Sequence the remaining cards by using the same process. When you finish, you should have a vertical stack
of cards with the top card representing the youngest fossils of this rock sequence and the "TC" card at the
bottom of the stack representing the oldest fossils.

Interpretation Questions:
1) After you have arranged the cards in order, write your sequence of letters (using each letter only once)
on a separate piece of paper. Starting with the top card, the letters should be in order from youngest to
oldest. The correct sequence of letters for the cards in Set A from youngest to oldest rock strata is
MDXONBUAGCT. Please note that none of the letters in this sequence may be reversed and still be
correct. The sequence must be exactly in the order as written. It is not uncommon to have students reverse
the M and D for example and begin the sequence with DM because that is the way they are printed on the
card. It is good at this time to remind them that these letters represent fossils in a rock layer and that one
fossil next to another within a rock layer implies no particular sequencing; they both are approximately the
same age as that particular rock layer. The following question may help clarify this point.
2) How do you know that "X" is older than "M"? "X" is older than "M" because it appears in an older rock
strata (i.e., the card beneath the "DM" card). "M" is not present in the card below it in the stack and is,
therefore, younger.
3) Explain why "D" in the rock layer represented by DM is the same age as "M." Since fossils D and M
died and were deposited in the same rock layer, they both are the same age as the rock layer.
4) Explain why "D" in the rock layer represented by OXD is older than "D" in the rock layer represented by
DM. Using the Law of Superposition, the rock layer OXD is beneath rock layer DM and, therefore, is
older. The fossils within rock layer OXD (i.e., fossils O, X, and D) are older than the fossils in the layer
above it (i.e., D and M in rock layer DM). Therefore, D in the rock layer OXD is older than D in the rock
layer DM.

Procedure Set B:
1) Carefully examine the second set of cards which have sketches of fossils on them. Each card represents a
particular rock layer with a collection of fossils that are found in that particular rock stratum. All of the
fossils represented would be found in sedimentary rocks of marine origin. Figure 2-A gives some
background information on the individual fossils.
2) The oldest rock layer is marked with the letter "M" in the lower left-hand corner. The letters on the other

Adventures in Earth Science

Lesson Four - Page 6
cards have no significance to the sequencing procedure and should be ignored at this time. Find a rock layer that has at least one of the fossils you found in the oldest rock layer. This rock layer would be younger as indicated by the appearance of new fossils in the rock stratum. Keep in mind that extinction is forever. Once an organism disappears from the sequence it cannot reappear later. Use this information to sequence the cards in a vertical stack of fossils in rock strata. Arrange them from oldest to youngest with the oldest layer on the bottom and the youngest on top.

**Interpretation Questions:**
1) Using the letters printed in the lower left-hand corner of each card, write the sequence of letters from the youngest layer to the oldest layer (i.e., from the top of the vertical stack to the bottom). This will enable your teacher to quickly check whether you have the correct sequence.
2) Which fossil organisms could possibly be used as index fossils? The graptolite, placoderm, ammonite, ichthyosaur, and shark's tooth could possibly be used as index fossils since they are found in only one layer. Technically, however, given only this set of strata, one cannot say that the shark's tooth and ichthyosaur could be used as index fossils because we do not know if they continue in younger rock layers above this set of strata.
3) Name three organisms represented that probably could not be used as index fossils and explain why. The brachiopod, crinoid, eurypterid, foraminifera, gastropod, horn coral, pelecypod, and trilobite could probably not be used as index fossils since they overlap more than one stratum.
4) In what kinds of rocks might you find the fossils from this activity? Marine sedimentary rocks such as limestone, shale, and sandstone might contain fossils similar to those depicted in this activity.
5) State the Law of Superposition and explain how this activity illustrates this law. In a "normal" horizontal sequence of rocks, the oldest rock layers will be on the bottom with successively younger rocks on top. This activity illustrates this law because when the cards are placed in the correct order, the vertical stack shows the oldest fossils in a rock layer in the bottom of the stack and the youngest fossils in rock stratum on the top.
Figure 2-B. Stratigraphic Section for Set B
Set A

TC  CGA
AU  UBN
BN  NO
OXD  DM
Set B

Trilobite
Brachiopod

Eurypterid
Trilobite

Brachiopod
Graptolite

Horn Coral
Trilobite

Eurypterid

Horn Coral
Cenozoic

Eurypterid
Placoderm
**Objectives:** This lesson is designed to introduce students to vast history and diversity of Earth’s life.

**Time:** Approximately 1 hour, depending on discussion time

**Age Level:** Grades 4-12

**Materials:**
- Beastie Bio organism images
- Rope (cut to 4.5 meter length, with one end labeled “Today” and the other end labeled “4.5 Billion Years Ago”)
- Paperclips
- Rulers

**Time:** Allow for 10 minutes for an introduction to the topic (see below), and 30 to 45 minutes to complete the project.

**Background**

For centuries, humans have been uncovering the remains of animals and plants from bygone eras. These ancient remains are called fossils. Fossils can include anything from dinosaur bones and seashells to footprints and leaf impressions. Together, fossils tell us about life’s grand history on Earth.

Our planet is approximately 4.5 billion years old. It’s generally thought that life first originated around 3.8 to 4.0 billion years ago. First life was small and single celled (think of bacteria), and it stayed single-celled for billions of years. Around 600 million years ago, the first animals had evolved. Shortly after that time, animals with skeletons—hard parts such as shell and bone—evolved. These hard parts make these animals’ preservation as fossils more likely, so we have a good fossil record from this time and later. In this activity, students will explore the history of life on Earth during the past 600 million years, placing it on a time line to see where different animal (and plants) lived during Earth’s history.
Procedure

Part I – Discussion
1. Introduce the concept of fossils and how they tell us about the history of life on Earth.

2. Explain that students will examine different animals and plants from different ages, and explore their place in Earth’s history.

Part II – The Project
1. Provide each student with at least one animal or plant image from the Beastie Bio images. After giving them a moment to explore their organism, ask them to show and generally discuss what they think about their creature. Did it swim, walk, or crawl? Did it eat meat, plants, or both?

2. Stretch out the rope and explain that it represents Earth’s 4.5-billion-year history. Have students, one by one, paperclip their creature to the rope where they think it lived in time.

3. After all creatures have been placed on the rope, have students take back their creature, and now hand out info cards telling the creatures name and age.

4. Have a group of students measure along the rope, making a mark every 5 cm. The distance between marks equals 50 million years (1 cm = 10 million years).

5. With the rope marked and labeled, have each student again place their animal on the rope, but placing correctly on the rope/timeline based on the now-known age of the creature.

6. After the creatures have been properly placed on the timeline, have a discussion regarding the placement of beasts. Are there any surprises?
<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
</table>
| 1 | Belemnitella  
(Squid Relative)  
Jurassic  
150 Ma | 6 | Dire wolves  
(Mammals)  
Quaternary  
20,000 Ya | 11 | Elrathia  
(Trilobite)  
Cambrian  
500 Ma |
| 2 | Diplacanthus  
(Spiny Fish)  
Devonian  
380 Ma | 7 | Coccosteus  
(Armored Fish)  
Devonian  
380 Ma | 12 | Dunkleosteus  
(Armored Fish)  
Devonian  
380 Ma |
| 3 | Majungasaurus  
(Dinosaur)  
Cretaceous  
70 Ma | 8 | Phorusrhacus  
(Bird)  
Tertiary  
10 Ma | 13 | Equus  
(Mammal)  
Quaternary  
20,000 Ya |
| 4 | Dimetrodon  
(Mammal Relative)  
Permian  
300 Ma | 9 | Thallassomedon  
(Swimming Reptile)  
Cretaceous  
95 Ma | 14 | Mesohippus  
(Mammal)  
Tertiary  
30 Ma |
| 5 | Bison  
(Mammal)  
Quaternary  
20,000 Ya | 10 | Rhamphorhynchus  
(Flying Reptile)  
Jurassic  
150 Ma | 15 | Neuropteris  
(Seed Fern)  
Carboniferous  
310 Ma |
16 Lepidodendron (Club Moss Tree) Carboniferous 310 Ma

17 Archaeopteryx (Bird) Jurassic 150 Ma

18 Ichthyosaurus (Swimming Reptile) Jurassic 195 Ma

19 Redwood (Flowing Plant) Today

20 Daspletosaurus (Dinosaur) Cretaceous 75 Ma

21 Metoposaurus (Amphibian) Triassic 215 Ma

22 Acanthostega (Amphibian) Devonian 365 Ma

23 Mastodon (Mammal) Quaternary 20,000 Ya

24 Mammoth (Mammal) Quaternary 20,000 Ya

25 Smilodon (Mammal) Quaternary 20,000 Ya

26 Herrerasaurus (Dinosaur) Triassic 230 Ma

27 Mosasaurus (Swimming Reptile) Cretaceous 75 Ma

28 Mortoniceras (Squid Relative) Cretaceous 75 Ma

29 Thrinaxodon (Mammal Relative) Triassic 250 Ma

30 Coelophysis (Dinosaur) Triassic 215 Ma
31
Alligator
(Reptile)
Today

32
Opossum
(Mammal)
Today
Cretaceous Crime Scene: an Adventure in Scientific Investigation

Objectives: This lesson is designed to introduce students to observation, inference, hypothesis formation, and hypothesis testing.
Age Level: Grades 4-7
Time: About an hour
Materials:
- Cretaceous Crime Scene presentation (PowerPoint or pdf)
- Cretaceous Crime Scene suspect profiles and footprint identification sheet, printed
- Paper footprints & victim
- Tape for applying footprints & victim to floor

Time: One hour: Allow for 15 minutes+ for an introduction to the topic (see below) and 30-40 minutes to complete the project, with another 10 minutes or so for discussion.

Background

All science starts with a question. In humankind’s attempt to understand and explain natural phenomena, we ask questions and then begin trying to answer those questions. The process of finding an answer—an evidence-based answer—is science.

“What’s a Fossil?”

A fossil is any evidence of past life — a leaf, pollen, bone, skin, tooth, or a footprint, dung, or the impression of a tail dragging in the sand — greater than approximately 10,000 years old. Now, scientists use that age with reservation, because the real age depends on how long it takes for the organic matter to disappear or mineralize. Hard parts of bodies fossilize much more readily than soft parts, such as organs, skin and hair. This is why we know the structure of many dinosaurs and past life, but not much about their flesh, hair or feathers. See the accompanying pdf from the Children’s Museum of “How a Dinosaur Fossil Forms”. If you have online capability in your room, a good video on what a fossil is and how they are formed is at:
Talk with the kids about fossils – what do you think the fossils of 10,000 years from now look like? How do we know how old fossils are?

For the Cretaceous Crime Scene activity, students will explore answers to the question: Who killed our poor, innocent Thescelosaurus (THES-IL-3-sor-3s) dinosaur? On the floor is a “chalk outline” of the victim’s body. Surrounding it are the clues to its killer: footprints of other dinosaurs. By examining the diets of the other dinosaurs, coupled with the relationship of the footprints (which ones are on top of others, therefore telling the sequence of the dinosaurs’ appearance at the crime scene), students can formulate an evidenced-based, scientific opinion of who killed Thescelosaurus.

Procedure:
Part I – Discussion
1. Introduce the concept of fossils and how footprints, in addition to shells and bones, can be fossilized.

2. Explain that students will examine a crime scene: A plant-eating Thescelosaurus has been killed, and it’s their job to find the killer.

Part II – The Project
1. Discuss the crime scene and the known suspects using the provided materials.

2. Based on the suspect profiles, ask students to hypothesize on the identity of the killer.

3. Allow students to explore the crime scene, and ask them to make observations about the scene. Based on the footprints, for example, were all of the suspects at the crime scene?
4. If students don’t recognize that certain footprints overlap, ask the question of them. Explain that overlap can tell us the relative timing of each dinosaur’s passing through the crime scene. What is the sequence of dinosaurs walking through the scene?

Now, with this information, students can reconstruct the sequence of activity at the site. Those dinosaurs that passed through before the *Thescelosaurus* can be released from the suspect list.

Based on the provided map, the sequence of dinosaurs walking through the scene is:

- *Triceratops*
- *Alamosaurus*
- *Tyrannosaurus*
- *Parasaurolophus*
- *Thescelosaurus* (VICTIM)
- *Velociraptor/Dromaeosaurus*

*Triceratops* definitely passed through before *Parasaurolophus*, but its timing relative to *Alamosaurus* cannot be determined.

5. Thus, the killer must either be *Velociraptor* or *Dromaeosaurus*. The key is geography! The murder happened in Montana; *Dromaeosaurus* is from North America, but *Velociraptor* is from Asia, so...

THE KILLER IS *Dromaeosaurus*!