Introduction

The Field Museum is most notably known for “Sue”, the largest, most complete *Tyrannosaurus rex* fossil ever found. However, the Museum houses hundreds of other dinosaur specimen, many of which are located behind the scenes. Paleontologists from all over the world use these collections to better understand the history of life on earth.

Paleontologist Dr. Peter Makovicky is The Field Museum’s Associate Curator of Dinosaurs. He researches the evolution of dinosaurs and has recently focused on dinosaurs from the southern hemisphere, an area that remains poorly understood. His expeditions to the Antarctic have revealed two dinosaurs new to science and have provided insight to the Antarctic ecosystem of the Triassic and Jurassic periods.

Background

Earth, and the life on it, has changed over time and will continue to change. Geologists use the structure, sequence, and properties of rocks, sediments, and fossils, as well as the locations of current and past ocean basins, lakes, and rivers, to reconstruct events in Earth’s planetary history. For example, rock layers show the sequence of geologic events. The presence and amount of radioactive elements in rocks makes it possible to determine their ages. Understanding how landforms develop, weather, and erode can help infer the history of the current landscape. Local, regional, and global patterns of rock formations reveal changes over time due to Earth forces, such as earthquakes. The presence and location of certain fossil types indicate the order in which rock layers were formed.

Analyses of rock formations and the fossil record are used to establish relative ages. In an undisturbed column of rock, the youngest rocks are at the top, and the oldest are at the bottom. Rock layers have sometimes been rearranged by tectonic forces; rearrangements can be seen or inferred, such as from inverted sequences of fossil types. Core samples obtained from drilling reveal that the continents’ rocks are much older than the rocks on the ocean floor, where tectonic processes continually generate new rocks and destroy old ones. The rock reveals that catastrophic events on Earth can occur quickly, over hours to years, or gradually, over thousands to millions of years. Records of fossils and other rocks also show past periods of massive extinctions and extensive volcanic activity.
Fossils provide evidence about the types of organisms that lived long ago and also about the nature of their environments. Fossils can be compared with one another and to living organisms according to their similarities and differences. Some plants and animals became extinct and are no longer found on Earth, although others now living resemble them in some ways because of biological evolution. Evolution is the process where all living things, which share common ancestors, have changed genetically over time. This process explains both the unity and diversity of all species on Earth. This unity is observed by the similarities between species, which is explained by the inheritance of similar characteristics from related ancestors. The diversity of species is also consistent with common ancestry. It is explained by the branching and diversification of lineages as populations adapted primarily through natural selection, to local circumstances.

Evidence for common ancestry can be found in the fossil record through three methods: 1) by comparative anatomy and embryology, 2) by the similarities of cellular processes and structures, and 3) by comparisons of DNA sequences between species. The understanding of evolutionary relationships has recently been greatly accelerated by using new molecular tools to study developmental biology. Using these tools, scientists can analyze the DNA of living organisms to determine the ancestral relationships between species. These genetic findings are further corroborated by the fossil record to provide evidence of evolution.

Before your Visit be sure to check out the following resources:

- Watch videos and read blogs about Dr. Makovicky’s 2010/11 expedition to the Antarctic: [http://expeditions.fieldmuseum.org/antarctic-dinosaurs](http://expeditions.fieldmuseum.org/antarctic-dinosaurs)
  - Recommended videos:
    - Dinosaurs in Antarctica? (3:15)
    - More about Cryolophosaurus (2:44)
    - More about Glacialisaurus (0:58)
- Emilie Graslie talks to Pete about a new North American meat-eating dinosaur on The Brain Scoop (7:59): [https://www.youtube.com/watch?v=QiSl4inY6ZA](https://www.youtube.com/watch?v=QiSl4inY6ZA)
## NGSS Alignment: Life Science

These lessons align with the following NGSS, among others.

Students who demonstrate understanding can:

**MS-LS4-1.** Analyze and interpret data for patterns in the fossil record that document the existence, diversity, extinction, and change of life forms throughout the history of life on Earth under the assumption that natural laws operate today as in the past.

[Clarification Statement: Emphasis is on finding patterns of changes in the level of complexity of anatomical structures in organisms and the chronological order of fossil appearance in the rock layers.] [Assessment Boundary: Assessment does not include the names of individual species or geological eras in the fossil record.]

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<td><strong>Analyzing and Interpreting Data</strong></td>
<td><strong>LS4.A: Evidence of Common Ancestry and Diversity</strong></td>
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<td>Analyzing data in 6–8 builds on K–5 experiences and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis.</td>
<td>• The collection of fossils and their placement in chronological order (e.g., through the location of the sedimentary layers in which they are found or through radioactive dating) is known as the fossil record. It documents the existence, diversity, extinction, and change of many life forms throughout the history of life on Earth. (MS-LS4-1)</td>
<td>• Patterns can be used to identify cause and effect relationships. (MS-LS4-2)</td>
</tr>
<tr>
<td>• Analyze displays of data to identify linear and nonlinear relationships. (MS-LS4-3)</td>
<td>• Anatomical similarities and differences between various organisms living today and between them and organisms in the fossil record, enable the reconstruction of evolutionary history and the inference of lines of evolutionary descent. (MS-LS4-2)</td>
<td>• Graphs, charts, and images can be used to identify patterns in data. (MS-LS4-1), (MS-LS4-3)</td>
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<tr>
<td>• Analyze and interpret data to determine similarities and differences in findings. (MS-LS4-1)</td>
<td>• Comparison of the embryological development of different species also reveals similarities that show relationships not evident in the fully-formed anatomy. (MS-LS4-3)</td>
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<td><strong>Scientific Knowledge Assumes an Order and Consistency in Natural Systems</strong></td>
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<td>• Science assumes that objects and events in natural systems occur in consistent patterns that are understandable through measurement and observation. (MS-LS4-1),(MS-LS4-2)</td>
<td>• Scientific knowledge can describe the consequences of actions but does not necessarily prescribe the decisions that society takes. (MS-LS4-5)</td>
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**Common Core State Standards Connections:**

**ELA/Literacy —**

**WHST.6-8.2** Write informative/explanatory texts to examine a topic and convey ideas, concepts, and information through the selection, organization, and analysis of relevant content. (MS-LS4-2),(MS-LS4-4)

**WHST.6-8.9** Draw evidence from informational texts to support analysis, reflection, and research. (MS-LS4-2),(MS-LS4-4)

**SL.8.1** Engage effectively in a range of collaborative discussions (one-on-one, in groups, teacher-led) with diverse partners on grade 6 topics, texts, and issues, building on others’ ideas and expressing their own clearly. (MS-LS4-2),(MS-LS4-4)

**SL.8.4** Present claims and findings, emphasizing salient points in a focused, coherent manner with relevant evidence, sound valid reasoning, and well-chosen details; use appropriate eye contact, adequate volume, and clear pronunciation. (MS-LS4-2),(MS-LS4-4)
Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific ideas, principles, and theories.

• Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students’ own experiments) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. (MS-ESS1-4)

ESS1C. The History of Planet Earth
• The geologic time scale interpreted from rock strata provides a way to organize Earth’s history. Analyses of rock strata and the fossil record provide only relative dates, not an absolute scale. (MS-ESS1-4)

Patterns
• Patterns can be used to identify cause-and-effect relationships. (MS-ESS1-1)

Connections to Nature of Science
Scientific Knowledge Assumes an Order and Consistency in Natural Systems
• Science assumes that objects and events in natural systems occur in consistent patterns that are understandable through measurement and observation. (MS-ESS1-1), (MS-ESS1-2)

Common Core State Standards Connections:

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Lesson 1  Recommended as a pre-broadcast activity

RECONSTRUCTING THE PAST

Background Information
200 million years ago the environment of Antarctica was much different than it is today. Antarctica was a temperate environment with rivers that ran through meadows and conifer forests. (For additional information please see the Resources section at the end of this section)

PREREQUISITE KNOWLEDGE

• Familiarity with different ecosystems: Tropical, temperate, tundra.
• Understanding of geologic time periods.
• Extinction is a natural and common process that occurs where there are no living members of a species.
• Species that exist today have arisen from species that existed in the past

MATERIALS

• Handouts S1-S11
• Construction paper
• Markers, colored pencils, or crayons
• Optional: Sticky notes

DIRECTIONS

1. Start class by showing students a picture of Antarctica today (T9).
   a. Ask students to generate a list of words that describes the environment of Antarctica. Write them on the board or chart paper and leave it up for the entire lesson.
   b. Then, ask students what they think Antarctica was like 200 million years ago (MYA). Write their descriptions separate from the previous list.
      i. Do you think the environment of Antarctica 200 million years ago was the same as it is today?
      ii. What do you think Antarctica was like 200 million years ago (MYA)?
   c. Write their descriptions separate from the previous list.
DIRECTIONS (CONT.)

d. Ask students:
   i. What is a paleontologist? What does a paleontologist do?
      (students will most likely state that a paleontologist studies dinosaurs, but the
       goal is for students to understand that the field of paleontology studies aspects
       of all extinct forms of life.)
   ii. What is a fossil?
   iii. How do scientists reconstruct what extinct animals looked like?
   iv. How do scientists understand what extinct animals ate?
   v. How do scientists understand how extinct animals moved?
      (want students to understand that scientists are able to hypothesize reconstructions of
       extinct organisms by comparing them to modern day counterparts)

2. Brief students on the activity. Students will analyze illustrations and photographs of actual fossils
   found on Antarctica. These fossils are plants and animals that existed 200 MYA. They are tasked
   by Dr. Makovicky to reconstruct the Triassic/Jurassic Antarctic environment.

3. After students have determined the environment of ancient Antarctica they will analyze the
   Cryolophosaurus fossils and create hypotheses regarding what this animal looked like, how it
   moved and what it ate. Groups will report their findings in a scientific journal. In the journal they
   must describe:
      i. How the environment has changed over time with:
         1. An illustration of ancient Antarctica
         2. Article describing the environment backed with supporting evidence
         3. An illustration of the Cryolophosaurus
         4. Article describing the appearance and habits of the Cryolophosaurus backed
            with supporting evidence

4. Split students into pairs and provide them with handouts S1-S11.
   a. Optional: All students will play the role of paleontologists, but each group can have their
      own specialists:
      i. Science Communicator – Writes the journal article.
DIRECTIONS (CONT.)

5. Circulate and facilitate discussion amongst groups.

6. This activity may extend over multiple class periods. At the end of the lesson, give students time to present their findings. This can be through oral presentations or “poster sessions”, where students set up their projects at a station with sticky notes; students circulate to each station and leave feedback or identify similarities or differences between their projects on the sticky notes.

Extension
Have students use the National Park Service Official State Fossil site:
https://nature.nps.gov/geology/nationalfossilday/state_fossils.cfm, at home to investigate the fossils found in their state; with this information students should attempt to recreate the ancient environment of their home state.

Resources
The environment of ancient Antarctica:
http://expeditions.fieldmuseum.org/antarctic-dinosaurs/ancient-antarctica
Please use this photo of the Beardmore South Camp to illustrate to your students what modern day Antarctica looks like. A digital version of this photo is also available at: http://bit.ly/modernantarctica
Lesson 2  This is the Broadcast day activity

**BROADCAST ACTIVITY**

**Objectives**
Students will learn...
- What it is like to go on a field expedition in Antarctica.
- How fossils provide clues to past environments and the organisms that lived in those environments.
- How scientists determine the ages of fossils using information from the rock layers.

**MAIN IDEAS**

Pete Makovicky is Associate Curator of Paleontology and Chair of the Department of Geology at The Field Museum. He is interested in issues relating to Mesozoic biogeography and faunal change, and the interplay between phylogeny and the fossil record. Much of his research has been dedicated to fieldwork-driven documentation of dinosaur biodiversity and systematics, and he has hunted for dinosaurs on five continents.

**PREREQUISITE KNOWLEDGE**

Familiarity with different ecosystems: Tropical, temperate, tundra. An understanding that extinction is a natural and common process that occurs where there are no living members of a species.

**MATERIALS**

It is recommended that you do the following prior to this lesson:
- as an introduction to the scientist and what he does.
- Read the Virtual Visits Technical Guide
- Attend the webinar test-run, link and direction will be provided one week prior to your visit
- Check with your IT specialist to make sure you will have available bandwidth on the day of your Visit

You will need the following materials:
- Computer with Ethernet connected Internet
- Projector
- Optional: Scrap paper or note cards
**DIRECTIONS**

1. Follow the Technical Guide provided to set up the Virtual Visits broadcast.
2. While waiting for the broadcast to begin, review information from the Main Ideas section with your class.
3. **OPTIONAL:** Provide students with a sheet of paper or note card to record questions that they come up with during the broadcast.
4. During the broadcast the scientists will interact with classrooms by asking students a question. Please type student responses into the chat box in the broadcast window or use the polling feature.
5. Follow-up the broadcast with a class discussion on what was learned and what students would like to investigate further.
   - a. Ask students how they felt about the experience. What was it like to meet a real scientist? What was their favorite part? Least favorite?
   - b. Ask students to recall the experience. What is the scientist’s job at the Museum? What does he study? How do scientists collect specimens? What types of projects does the scientist work on? What did he show us?
     i. If students have conflicting viewpoints, encourage them to discuss it using evidence from what the scientist said or did.
   - c. Ask students to explain what they learned. What is something you learned about science careers from the broadcast? What is something you learned about science from the broadcast?
   - d. Have students make connections from the broadcast to their life. Has anyone gone to a museum and seen dinosaur fossils?
   - e. Ask students to consider how they can apply this new knowledge in the future.

**TIP:** Before the discussion, project these questions on to the board and have students write down their ideas to increase discussion participation.
Lesson 3  Recommended as a post-broadcast activity

RELATIVE DATING

Standards
MS-ESS1-4: Construct a scientific explanation based on evidence from rock strata for how the geologic time scale is used to organize Earth’s 4.6-billion-year-old history.

Disciplinary Core Ideas
ESS1.C: The History of Planet Earth
• The geologic time scale interpreted from rock strata provides a way to organize Earth’s history. Analyses of rock strata and the fossil record provide only relative dates, not an absolute scale.

PREREQUISITE KNOWLEDGE
• Familiarity with different type of rocks and the rock cycle
• Understanding of geologic time periods.

MATERIALS
• 5 different colored sands
• Clear jar
• Nonsense sequence card handouts S9-S10
• Fossil sequence card handout S11
  • Cut out these cards (laminate if possible) - store each set in separate envelopes
  • Print enough sets for student pairs

DIRECTIONS
Relative Dating Discussion
1. Discuss with students relative dating and how fossils can provide information to relative dates of different rock layers
   a. Set up a classroom demonstration of a jar of different colored sand (this can be done ahead of time or during class)
   b. Each layer of sand represents a rock layer - the goal of the discussion is to have students understand that the sand layer at the bottom will be the oldest layer as it was added earliest and the most time has passed since it was added to the jar. The layer at the very top is the youngest layer as it was added last and the least amount
      i. Make sure to allow enough time between layers to let the sand settle.
DIRECTIONS (CONT.)

i. Ask students if a shovel was found in between two layers of sand, could we estimate the age of the glove?
   1. The shovel would be younger than the layer it was above and older than the layer of sand it was below.
   2. The shovel represents an index fossil found in rock layers.
      a. Define index fossil for students - an index fossil are fossils used to identify geologic time periods in the fossil record. Organisms are identified as index fossils if the organism lived for a short amount of time and scientists know during what time period these organisms lived.

Nonsense Cards
1. Pass out the first envelope containing the nonsense sequence cards.
2. Instruct students to remove the cards and spread them out on their desk so that they can see each card clearly.
3. Point out that one of the cards is labelled “oldest fossil.” This card should begin the sequence.
   TIP: The sequence that students are creating is linear.
4. Allow students 15 minutes to create their card sequence and answer the questions that follow.
   TIP: If students are struggling direct them to look for common shapes among cards.
5. After students have created their own sequence and answered the corresponding questions, create the sequence as a whole group using the class set on a wall in the classroom.
6. As a whole class discuss students responses to the activity’s post-questions.
Fossil Sequence Cards - Whole Class Activity
1. As a whole class you will work together to sequence the fossil sequence cards. (If you have a very large class you could divide your class into groups of 3 or 4 to create their fossil sequence.)

2. Ask students to find the card with the letter “R” in the lower left-hand corner. This is the oldest rock layer, and will be the beginning of the sequence that students are creating. Tell students to ignore the letters on the other fossil cards for the time being. They will not provide any clues to help the students build their sequence.
   a. Remind students that extinction is permanent, and once an organism is removed from the sequence it cannot appear later on.

3. Students are to arrange the fossils in order from oldest to youngest. (The correct order will spell out “REPUSWAL”)

4. After students have been given time to create the sequence and answer the corresponding questions. When the sequence is complete compare it to a stratigraphic section of the rocks representative of the fossils on the sequence cards.

5. As a whole class discuss students’ responses to the activity’s post-questions.

Extension - Use real fossils from the N.W. Harris Learning Collection ex. Fossils from Rocks Near Chicago kit

Have students manipulate an online simulation of rock layers using the following site:
http://www.amnh.org/ology/features/layersoftime/game.php

Sources: Adapted from University of California Museum of Paleontology “Who’s On First? A Relative Dating Activity”
Oldest Fossil
NONSENSE CARDS

![Image of nonsense card 1](image1)
![Image of nonsense card 2](image2)
![Image of nonsense card 3](image3)
![Image of nonsense card 4](image4)
NONSENSE CARDS

OLDEST FOSSIL
ANSWER KEY

1

2

3

4

5

6

7

8
Trilobite
Eurypterid
Graptolite
Brachiopod
A

Ammonite

Foraminifera

Pelecypod
Trilobite

Horn Coral

Eurypterid
Brachiopod

Trilobite
FOSSIL CARDS

L

Ichthyosaur
Pelecypod
Shark's Tooth

E

Trilobite
Eurypterid
Graptolite
Brachiopod

A

Ammonite
Foraminifera
Pelecypod

P

Trilobite
Eurypterid
Horn Coral
FOSSIL CARDS

R: Brachiopod, Trilobite
W: Gastropod, Pelecypod, Foraminifera
S: Gastropod, Foraminifera, Crinoid
U: Eurypterid, Placoderm, Horn Coral, Crinoid
### Key to Rock Units

<table>
<thead>
<tr>
<th>Unit</th>
<th>Rock Type</th>
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</thead>
<tbody>
<tr>
<td>A</td>
<td>Sandstone</td>
</tr>
<tr>
<td>B</td>
<td>Shale</td>
</tr>
<tr>
<td>C</td>
<td>Limestone</td>
</tr>
<tr>
<td>D</td>
<td>Dolomite</td>
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<td>E</td>
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### Fossils

- **Shark’s tooth**
- **Placoderm**
- **Foraminifera**
- **Ammonite**
- **Brachiopod**
- **Crinoid**
- **Eurypterid**
- **Gastropod**
- **Graptolite**
- **Pelecypod**
- **Rugosa**
- **Trilobite**
- **Ichthyosaur**
What did Antarctica look like 200 million years ago? We can find out by studying fossils. A **fossil** is the preserved remains of a prehistoric plant or animal. If a plant or animal dies and gets covered in mud, silt, or sand, its bone and tissue can be replaced with minerals over thousands or millions of years to form a fossil. These fossils are like clues to the past. Paleontologists can study them to find out what plants and animals lived in ancient ecosystems. Pictured on the next page are some fossils from The Field Museum's Antarctic fossil collection from the Jurassic Period (about 200 million years ago). Then answer the question on the next page.
Observe the fossils. Based on the fossils on the next page, what do you Antarctica was like 200 million years ago?

What do you think *Cryolophosaurus* looked like? What do you think the *Cryolophosaurus* ate? How do you think the *Cryolophosaurus* moved (walked on two legs, or four legs or flew, etc)?

**Your assignment:** Dr. Makovicky would like you to analyze the illustrations and photographs found in the Antarctic Fossil Catalogue. Your assignment is to reconstruct the Triassic/Jurassic Antarctic environment with your partner. After you have determined the environment of ancient Antarctica you will analyze the *Cryolophosaurus* fossils and create hypotheses regarding what this animal looked like and how it acted (what did it eat, how did it move?).

*Hint:* Dr. Makovicky and his colleagues follow the principle of uniformitarianism. This principle assumes that natural laws and processes that occur on Earth today operate in the same way as millions of years ago. Following this idea archeologists are able to make inferences about past environments and animals by comparing them to modern day environments and animals.

a. Groups will report their findings in a scientific journal. In the journal you must describe:
   - How the environment has changed over time with:
     - An illustration of ancient Antarctica
     - Article describing the environment with supporting evidence
     - An illustration of the *Cryolophosaurus*
     - Article describing the appearance and habits of the *Cryolophosaurus* with supporting evidence
Antarctic Fossil Catalog

(left) Trunk of conifer tree fossil (size of fossil compared to known size of paleontologist glove) from Triassic Fremouw Formation

(right) Present day: Temperate coniferous forest - found in coastal and mountain areas that have mild winters, warm summers and plenty of rainfall.

(left) Horsetail (Neocalamites) fossil - these plants were much bigger than modern ones (6-9 feet) but are structurally the same

(right) Present day horsetail - prefer to grown in wet, sandy soils, grows in temperate environments, average height 2-3 feet tall
Antarctic lobster fossil

Southern rock lobster
Teeth Comparison

*Cryolophosaurus elliotti*

Labeled *Cryolophosaurus* skull

*Cryolophosaurus* reconstructed skull

Komodo dragon skull

Komodo dragon, diet carnivore, meat eater, teeth are serrated

*(left)* *Tritylodont* tooth
Diet of *Tritylodont* - herbivore, teeth worked in a grinding motion
Femur Comparison

Cryolophosaurus femur

© The Field Museum, GN90031d.
Mounted composite cast of *Pteranodon longiceps* (=P. ingens) at the American Museum of Natural History, New York. Photo credit Matt Martyniuk

© The Field Museum, GEO83965, Photographer Ron Testa
### Ancient Environment of Antarctica:

<table>
<thead>
<tr>
<th>Claim</th>
<th>Supporting Evidence</th>
<th>Reasoning</th>
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### Description of *Cryolophosaurus*:

<table>
<thead>
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How Old Is It? (Relatively)

**Background Information:** Earth, and the life on it, has changed over time and will continue to change. Geologists use the structure, sequence, and properties of rocks, sediments, and fossils, as well as the locations of current and past ocean basins, lakes, and rivers, to reconstruct events in Earth’s planetary history. For example, rock layers show the sequence of geologic events. The presence and amount of radioactive elements in rocks makes it possible to determine their ages. The presence and location of certain fossil types indicate the order in which rock layers were formed. Analyses of rock formations and the fossil record are used to establish *relative ages*. Relative age is the age of a rock compared to the ages of other rocks. The Law of Superposition states that in an undisturbed column of rock, the youngest rocks are at the top, and the oldest are at the bottom. Rock layers are sometimes rearranged by tectonic forces; rearrangements can be seen or inferred, such as from inverted sequences of fossil types.

**Nonsense Sequence Cards Instructions:**

1. Remove the cards from the envelope.
2. Spread the cards out on your desk facing up.
3. Find the card that is labeled “oldest fossil” - this is the first card in your sequence.
4. Order the cards knowing that the oldest fossil card is first in the sequence. This will be a timeline of the fossils in different rock layers. Each card represents a new rock layer.
5. After you have answered the questions on the next page, return your cards to the envelope.
Questions
Nonsense Sequence Cards:

1. How do you know that ▲ is older than ▶?

2. How do you know that ▽ is older than □?

3. Explain why ▽ in the rock layer represented by ▲ is the same age as △.

4. Explain why ▽ in the rock layer represented by ▲ is older than ▽ in the rock layer represented by ▲.
**Fossil Sequence Cards Instructions:**

1. Remove cards from the envelope
2. Spread the cards out on your desk facing up
3. Find the card that is labeled “R” - this is the first card in your sequence
4. Order the cards knowing that “R” is first in the sequence order
5. After you have created your sequence, write down the order of letters that appear in the left hand corner of each card (Question 1 below)
6. After you have answered the questions below return your cards to the envelope.

**Questions:**

1. Write the sequence of letters (that appear in the lower left hand corner), from oldest fossil to youngest.

2. Which fossil may be index fossils?

3. Which fossils would not be useful as index fossils?

4. What rock type would these fossils be found in?