

Unit 1

Many Planets, One Earth

Background

Introduction

This unit of The Habitable Planet introduces the origin of planet Earth and some of the theories about how it has changed over time to develop a hospitable environment and a fantastic number of different life forms. Although the universe has countless celestial bodies, Earth is the only known planet supporting life as we know it. What has led to the remarkable phenomenon of life on Earth? The history of this process is found in Earth's geologic record, which gives us evidence of both physical and biological evolution. Proceeding through a variety of global phenomena, from the creation of the atmosphere to an apparent ice-ball, the Earth's surface climate has been regulated by the geologic carbon dioxide cycle. As a result of catastrophic occurrences and the resilience of life on Earth, we now live in the balance of the Habitable Planet.

Essential Questions

- How is it that a one-time collection of cosmic dust has gradually changed over time and produced this incredible planet with its tremendous biological diversity?
- What transitions has Earth gone through and why?
- How does evidence of the deep past inform us about today's conditions?
- How does the Earth's geological carbon cycle act as a thermostat?

Content

The Unit 1 video presents two perspectives on the ancient history of planet Earth. First, Professor Andy Knoll, a Harvard University paleontologist, describes how investigations of fossils not only give us clues about the shape, size, and function of ancient animals and plants, but also show the biological responses to geologic changes. He describes how geologic history gives evidence for the rise of living organisms and how physical events influence evolution. These past events have given rise to our present condition. Dr. Ann Pearson then describes how the biological evidence found in fossils can help explain physical phenomena such as the formation of our atmosphere. In particular, she discusses how sterols help explain when free oxygen became available in the atmosphere.

In the second part of the video we are introduced to the Snowball Earth Theory. Professor Paul Hoffman, a Harvard University geologist, explains how Earth's so-called thermostat went haywire and resulted in Earth being entirely covered by glaciers—thus, Snowball Earth. He goes on to explain how the thermostat eventually kicked in and the climate was restored, melting the glaciers and releasing tremendous biological evolutionary potential. Specifically, Dr. Hoffman explains the geologic carbon cycle and how it created our atmosphere and to this day regulates climate on Earth.

Background

Learning Goals

During this session you will have an opportunity to build your understanding of the following:

- a. Knowledge
 - i. Geologic carbon cycling and its relation to maintaining Earth's habitable environments
 - ii. Composition and formation of the atmosphere, especially as it relates to free oxygen
 - iii. Geologic records as evidence of both physical and biological evolution
 - iv. Evolutionary processes throughout Earth's history
 - v. Snowball Earth Theory
 - vi. Cambrian Explosion and its relation to climate change
- b. Skills
 - i. Understand scientific research as a descriptive process
 - ii. How scientists collect evidence of ancient land and life forms
 - iii. How science helps explain current events
- c. Dispositions
 - i. Appreciate the diverse and robust nature of life on Earth
 - ii. Value the fact that evidence from the deep past gives understanding of our present situation

Key Concepts

Albedo	Extremophiles	Prokaryotes
Archaea	Geochemical cycling	Radiometric dating
Bacteria	Heterotrophs	Snowball Earth
Cambrian explosion	Oxidation	Stratigraphic
Cyanobacteria	Phylum	Carbon Cycling
Eukaryotes	Plate tectonics	Diversification

FACILITATOR: These concepts correspond roughly to the sections of the unit. There are a number of other concepts that could be included. It is best to start with the author's major ideas and then ask for input from the study group for other concepts they would include.

Background

Misconceptions about Earth and its History

The most pervasive misconceptions about Earth, its formation, and its history will be primarily derived from creationist arguments about evolution. Although people may disagree about whether these are misconceptions or beliefs, the fact is that they will interfere with new scientific learning, especially as it relates to this unit. The five statements below seem to be the most common misconceptions based on a creationist version of Earth's history and development. You will also find counter-arguments to each point.

Evolution has never been observed.

Evolution is gradual over time; things do not change before our eyes.

Evolution violates the second law of thermodynamics.

This is probably more a misconception about thermodynamics than evolution since it relates directly to physical rather than biological phenomena.

There are no transitional fossils.

Evolution does not claim transitional forms.

Life originated, and evolution proceeds, by random chance.

This ignores the fundamental roles of natural selection.

Evolution is only a theory; it hasn't been proved.

Evolution is technically the change in allele frequencies over time, which is a fact.

Unfortunately, in addition to these commonly held beliefs, misconceptions about evolution are ever-present. A common misconception is that evolution proceeds in a specific direction leading to the improvement of organisms. This is often stated as "climbing an evolutionary ladder." This is not the case. Organisms either adapt to environments that are always undergoing change or they risk extinction. The very diversity of life allows the struggle for survival to take place. Common misconceptions about fossils include the following claims, which we clarify.

Fossils are pieces of dead animals and plants.

Fossils are not actually pieces of dead animals and plants. They are only the impression or cast of the original living thing. The actual living parts decay away but their shape is permanently recorded in the rock as it hardens.

Fossils of tropical plants cannot be found in deserts.

Fossils record ancient environments present at the time the rocks were deposited.

Getting Ready (45 minutes)

Activity One: Assessing Prior Knowledge, Questions, and Related Experiences

FACILITATOR: Distribute index cards to the study group. On the first card, participants indicate something they know about Earth's formation and history. On the second, they write one question they have about Earth's formation and history. And on the third card, they describe a direct experience that they have had that relates to Earth's formation and history. For example, an individual might write:

- Earth formed from cosmic dust and gradually evolved into the planet today.
- What caused Earth to go through ice ages?
- I found fossils in the sea cliffs on the coast of Oregon.

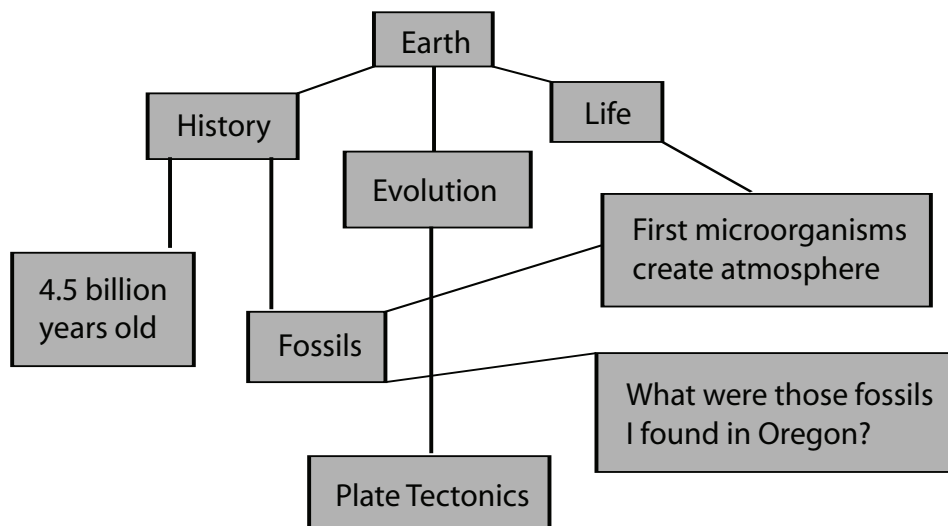


Figure 1.1 An example of a study groups' idea collection, with major subjects identified and the addition of the major focus ideas of the video. This activity links individual pre-existing knowledge with other members of the group and the unit content.

Activity Two: Current Events & Editorial Cartoons

Participants will share an article that they have found related to the week's topic. Everyone in the group will share his or her headline for the articles. The leader should ask a few people to summarize their articles, asking for comments from others with related articles. As the group discusses the articles, a participant should record key concepts and make a list. (Participants may choose to bring in a related cartoon or an editorial instead of an article.)

Getting Ready

Activity Three: Toilet Paper Geologic Time Scale

This activity is a graphic demonstration of the enormous extent of geologic time compared to recent time. You will need: one roll of toilet paper (231 sheets or more), felt-tip marker(s), preferably several colors, and clear tape for repairs. Check the markers to make sure they write without damaging the surface below and test them for clarity and marking the surface.

FACILITATOR: On a flat, protected surface, unroll the first sheet of the roll. Using the perforations between sheets as a ruler (the first is zero), mark the dates and names of items as listed in the table below. The scale of 20 million years per sheet of toilet paper makes the conversion obvious. Re-roll the toilet paper. If it tears, repair with tape.

Starting at one end of a long hallway, the group should unroll the toilet paper to the end. Note the varying distances. As a group, go through the events and dates described in the text for Unit One. Place markers at the appropriate place on the timeline for each event described in the text.

Sheets	Event	Geological time (Number of years before present)
0.00	Present	0
0.0005	Modern man	10,000
0.01	Neanderthal man	100,000
0.07	Homo erectus	1,300,000
1.15	Beginning of Quaternary Period	23,000,000
0.50	Beginning of Antarctic ice caps	10,000,000
1.15	Beginning of Tertiary/Neocene Period	23,000,000
1.25	First evidence of ice at the poles	25,000,000
2.50	Early horses	50,000,000
3.00	Early primates	60,000,000
3.25	Beginning of Cenozoic Era	65,000,000
3.25	Dinosaurs became extinct	65,000,000
4.00	Rocky Mountains form	80,000,000
7.00	Cretaceous Period begins	140,000,000
7.50	Early flowering plants	150,000,000
9.00	Early birds and mammals	180,000,000
10.40	Jurassic Period begins	208,000,000
12.25	Triassic Period begins	245,000,000
12.25	Beginning of Mesozoic Era	245,000,000
14.00	Final assembly of Pangaea	280,000,000
14.50	Beginning of Permian Period	290,000,000
16.25	First reptiles	325,000,000
16.15	Beginning of Pennsylvanian Period	323,000,000
18.15	Beginning of Mississippian Period	363,000,000
20.45	Beginning of Devonian Period	409,000,000
21.50	Early land plants	430,000,000
21.95	Beginning of Silurian Period	439,000,000
24.50	Early fish	490,000,000
25.50	Beginning of Ordovician Period	510,000,000
28.50	Early shelled organisms	570,000,000
28.50	Beginning of Cambrian Period	570,000,000
28.50	Beginning of Paleozoic Era	570,000,000
28.50	Beginning of Paleozoic Eon	570,000,000
35	Early multicelled organisms	700,000,000
40	Breakup of early supercontinent	800,000,000
70	Formation of early supercontinent	1,400,000,000
60	First known animals	1,200,000,000
125	Beginning of Proterozoic Eon	2,500,000,000
135	Buildup of free oxygen in atmosphere	2,700,000,000
170	Early bacteria and algae	3,400,000,000
190	Oldest known Earth rocks	3,800,000,000
200	Beginning of Archeon Eon	4,000,000,000
230	Precambrian time begins	4,600,000,000
230	Origin of earth	4,600,000,000

Video (45 minutes)

Activity Four: Watch the Video

As you watch the video, think about the following focus questions.

1. Why is it that among all the celestial bodies in the universe, Earth appears to be the only one with a life-sustaining environment?
2. Why are the environments so different in various parts of Earth?
3. How did Earth's atmosphere form and why is it so important?
4. How has climate changed over the history of Earth?
5. What is the evidence for the evolution of life and how do we interpret it?
6. What do fossils tell us?
7. When and how did life form?
8. Why does Earth have a relatively stable climate?
9. How does atmospheric carbon dioxide influence Earth's temperature?
10. What is the relationship of atmospheric carbon dioxide to Earth's surface temperature?
11. Where does carbon dioxide primarily come from?
12. How is carbon dioxide consumed on Earth and where does it go?

Activity Five: Discuss the Video

Discuss the following questions about the video.

1. What does the Snowball Earth Theory claim?
2. What is the evidence in the geologic record for climate change and biological evolution? How do these two relate to each other?
3. What is the Cambrian Explosion and how does it relate to both geologic and biological evolution?

FACILITATOR: Refer back to the misconception section and Activity One: Assessing Prior Knowledge. Has the video contributed to the participants' new understanding of concepts? Are there any changes the participants would make about the arrangement of their cards from Activity One?

Going Further (60 minutes)

Activity Six: Carbon Cycle and Human Influence

FACILITATOR: Conduct this activity with the participants immediately after they see the video. Doing so will help focus attention on the carbon cycle and the path that carbon follows. The activity can be adapted to reflect the effects of various human influences such as deforestation and burning fossil fuels. Be sure to try to model scenarios described in the video.

Materials

Three easily procured, inexpensive, and uniform objects for each participant—e.g., small rocks, pencils, pens, shells, etc.—and poster board or large pieces of paper labeled as carbon pools, atmosphere, biomass, soil, ocean, fossil fuel deposits, and underground rocks.

1. Based on the video, review the carbon cycle and the major reservoirs. Participants should draw what they think the cycle looks like and then compare diagrams as a formative mid-lesson assessment.
2. Give all participants their objects and tell them that each object represents one carbon unit.
3. Form groups of six and give each person a reservoir pool sign.
4. Form a circle of six.
5. Act out the natural carbon cycle by having each person pass one carbon unit to the next person. Be sure to order the pools so that atmosphere goes to biomass to soil to ocean to atmosphere. Discuss the parts, processes, and outcomes of the natural cycle as it progresses. (Everyone still has three carbon units.)
6. Mimic trades between aspects of the cycle. For example, sometimes atmosphere trades with biomass, as in respiration and photosynthesis, or atmosphere trades with soil as in nitrogen fixing bacteria, plants, and photosynthesis. Discuss how trades are made. Everyone still has three carbon units and the cycle remains in equilibrium.
7. Model what happens when things are not in equilibrium. A familiar and understandable example might be to mimic deforestation. In this case, biomass (trees) releases a carbon unit to the atmosphere. Atmospheric carbon dioxide increases. Discuss what happens to climate. Another example might be burning fossil fuels. Carbon is released into the atmosphere. Discuss potential climate change.
8. Model the examples from the video. What happened when all the land masses were together? How did the carbon change pools and what were the effects? Discuss how Earth's thermostat then helped to moderate the Snowball Earth.

Activity Seven: Return to Essential Questions

The facilitator should draw the attention of the participants back to the essential questions posed in the Background Section of this unit guide. Discuss how the participants' ideas may have changed in regard to the questions. Discuss the most logical and complete answers to the questions.

Activity Eight: Discuss Classroom Supplementary Activities

Following the Between Sessions section of each unit are Classroom Supplementary Activities. These activities are related to the unit topic and are suitable for middle and secondary school science classrooms. If the participants in this study group are teachers, the facilitator should take the time to review these lessons. If participants are familiar with the lessons, they should describe how they have used them. Discuss how the classroom activities might be used in relation to a specific science topic and how the activities can help relate the unit topic to classroom lessons.

Between Sessions

Next Week's Topic Overview

Read Unit 2 before the next session. In Unit 2, the emphasis is on the Earth's atmosphere. Sub-topics will examine the structure of the atmosphere, the greenhouse effect, atmospheric feedback mechanisms, and the global carbon cycle and circulation patterns. Some of the sub-topics are linked to projections into the future, and the uncertainties with predicting future global climate change will be a key part of the discussion.

On-Line Computer Simulation

Carbon Cycle Lab

Read the introduction to the simulation.

Run the simulator to the year 2100 while maintaining the current parameters.

- What happens to the coal, oil, and gas reserves?
- What happens to the oceanic carbon dioxide concentration? Why?
- What happens to atmospheric carbon dioxide?
- Predict what will happen to global temperatures.

Continue the simulation past the year 2100.

What happens to atmospheric carbon dioxide? Why?

Notice that the goal (in green) is set at 550 parts per million (ppm) of carbon dioxide.

Determine where you have to set the parameters to make this goal.

Why is deforestation one of the parameters?

What kind of changes will people have to make to meet this goal?

Research and diagram the carbon cycle. Include the following terms in your diagram: carbon dioxide, fossil fuels, ocean, decomposition, photosynthesis, and cellular respiration. In your diagram, draw pictures and use arrows to show the path of the carbon dioxide.

Read for Next Session

Read the Unit 2 Professional Development Guide background section. Consider the essential questions as you read the text. The misconceptions section will give you some insight into what misunderstandings people may have about Earth's atmosphere. Consider discussing the topic with your friends or students and discussing common misconceptions.

Current Events

Bring in a current event article, cartoon, or editorial related to Earth's atmosphere.

Supplementary Classroom Activity 1

Explaining Fossil Footprints

In this activity, students observe and interpret fossil evidence. From the evidence, students propose hypotheses or explanations for events that took place in the ancient past.

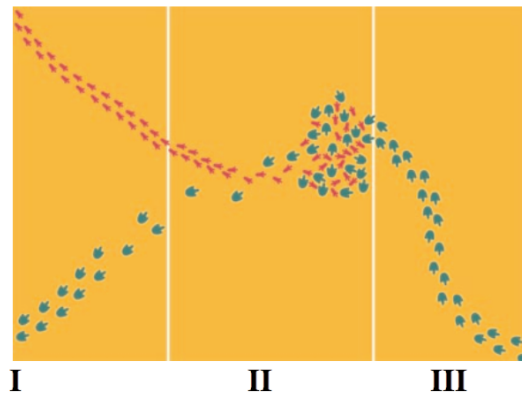


Figure 1.2 Use this diagram to observe, predict, hypothesize, and infer about the animals' activities from secondary evidence.

Students will:

- Propose explanations and make predictions based on evidence.
- Recognize and analyze alternative explanations and predictions.
- Understand that scientific explanations are subject to change as new evidence becomes available.
- Understand that scientific explanations must meet certain criteria. They must be consistent with experimental and observational evidence about nature, and they must make accurate predictions, when appropriate, about systems being studied. They should also be logical, respect the rules of evidence, be open to criticism, report methods and procedures, and make knowledge public.

Procedure

Hand out a copy of the figure above to each student or use an overhead transparency. Separate each of the three sections of the figure.

- Reveal Section I of the figure and ask students to explain what is happening. Be sure to differentiate between observations and inferences.
- Reveal Section II of the figure and again have students make observations and inferences about what happened.
- Reveal Section III of the figure and ask students to describe what they think happened and hypothesize about the entire sequence.
- Discuss how the students' observation, inferences, and hypotheses change based on the evidence.

Supplementary Classroom Activity 2

Cupcake Geology

Students' understanding of their environment must include some knowledge of the section of Earth on which they live. Knowing about differences in the Earth's structure and understanding the processes of scientific investigations are essential for knowledgeable citizens. Among these processes are hypotheses about unknown conditions and plans to investigate these unknowns. Sampling is a critical concept in these investigations.

This lesson is fun for students and actively engages them in scientific investigations.

Purpose

- The students will learn that the earth and soil are made up of various substances in different arrangements.
- Students will learn how to hypothesize an outcome of an investigation, plan a sampling strategy, and test their hypothesis.
- Students will understand the value of systematic sampling.
- Students will become familiar with soil and be encouraged to ask questions about things they might not understand.

Materials

- Cake mix or recipe, frosting
- Food colorings
- Straws

Prepare a white cake mix recipe and divide into several batches. Add various food colorings to each batch of cake mix. Add small amounts of each colored batch to a cupcake pan. Bake. Top cupcake with frosting.



Inside cupcake

Samples

Outside cupcake

Figure 1.3 Cupcakes at various stages of the investigation

Supplementary Classroom Activity 2

Procedure

1. Pass out napkins, straws, and a cupcake to each student.
2. Ask the students to predict what the inside of their cupcake looks like and to draw a picture.
3. Explain to the students that geologists don't know what the inside of Earth looks like; they must somehow predict or guess what it looks like.
4. Demonstrate how to sample the cupcake with a straw and explain that this is similar to a core sample of Earth. Insert the straw into the cupcake, remove, and gently squeeze out the sample.
5. Have the students take one core sample of their cupcake.
6. Have the students draw a picture of what they think the inside of the cupcake looks like based on their one core sample.
7. Direct the students to take four more core samples in any way they want. Encourage them to record how they take the samples.
8. Have the students draw another picture of what they think the inside of the cupcake looks like based on their five samples.
9. Discuss how their predictions have changed based on their samples.
10. Have the students cut their cupcake in half and record the actual cross section of their cupcake.
11. Discuss with the students the results of their investigation and the importance of sampling in understanding unknown situations.

Action

Have students dig a hole in the soil near school and near their home. They should then draw or diagram the layers of soil they find and compare the differences.

Evaluation Strategies

Collect the students' diagrams of the investigation and have them explain how sampling is essential to scientific investigations.

Notes
