Investigation 4:

Fossils through Geologic Time

Key Question

Before you begin, first think about this key question.

How can we determine the age of a fossil?

Think about what you know about the conditions under which fossils form. If different fossils are found in different layers of rock, could you tell which fossils are the oldest? The youngest?

Share your thinking with others in your class. Keep a record of the discussion in your journal.

Materials Needed

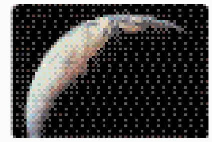
For this investigation your group will need:

- metric measuring tape (as long as possible)
- chalk
- chart paper
- calculator
- "stratigraphic" notebook with "fossils" (this can be made using the detailed instructions provided in the Teacher's Edition)

Investigate

Part A: Geologic Time

1. Geologists know that Earth is about 4.5 billion (4,500,000,000) years old. Primitive life evolved as much as 3.5 billion years ago, or more, but large and complicated life did not develop until much later. In terms of Earth's history, humans are very recent. Find them on the chart.



a) When did modern humans appear?

b) How does this compare to when life began on the planet?

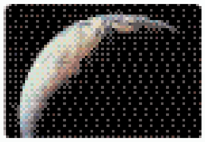
2. To get a better sense of this kind of time scale, your group is going to think of time as if it were distance.

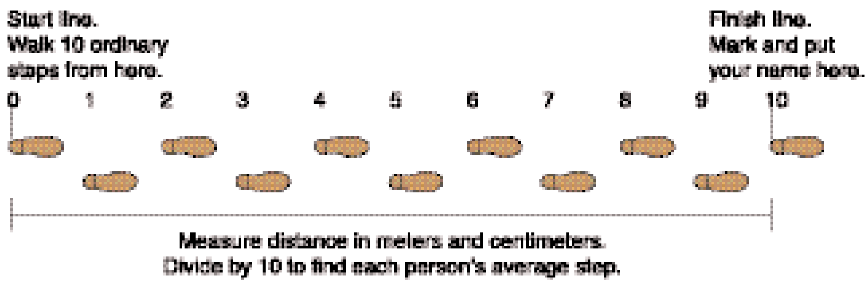
In a suitable place (a corridor or the schoolyard), mark a starting point with chalk. Next, each person should walk 10 normal paces, mark the distance with chalk, and put his or her name beside this point.

Major Divisions of Geologic Time
(boundaries in millions of years before present)

Era	Period	Event	
Cenozoic	Quaternary	modern humans	1.8
	Tertiary	abundant mammals	65
Mesozoic	Cretaceous	flowering plants; dinosaur and ammonoid extinctions	145
	Jurassic	first birds and mammals; abundant dinosaurs	213
	Triassic	abundant coniferous trees	248
Paleozoic	Permian	extinction of trilobites and other marine animals	286
	Pennsylvanian	fern forests; abundant insects; first reptiles	325
	Mississippian	sharks; large primitive trees	360
	Devonian	amphibians and ammonoids	410
	Silurian	early plants and animals on land	440
	Ordovician	first fish	505
	Cambrian	abundant marine invertebrates; trilobites dominant	544
Proterozoic		primitive aquatic plants	2500
Archean		oldest fossils; bacteria and algae	

Check for any hazards before pacing off your steps.





3. When everyone in your group has measured his or her 10-step distance, put the lengths on a chart like the one shown.

Names of Group Members	Distance of Steps (in meters and centimeters)	Average Step (total distance for each person divided by 10)
Total for Your Group (add each person's average)		T =
Average Group Step (divide total by number of persons in your group)		AGS =

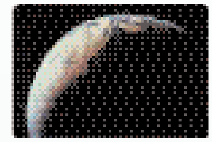
4. Find the Average Class Step (ACS) by taking the Total (T) for each group, adding them all together, and dividing the total figure by the number of students participating. How does this number compare to the Average Group Step (AGS)?

   You may want to round the ACS figure up or down to make it into the nearest convenient number (for example, if it is 78 cm, round it up to 80 cm).

5. You will now apply your average distance to time.

   Think of one average step as representing 100 years of time. On this scale it means:

   - You have lived for about one-eighth of a step.
   - Your parents have probably lived for about one-third of a step.
   - Only someone at least 100 years old would have lived one step or more.



Look again at the Major Divisions of Geologic Time chart.

In your group, figure out how many steps would represent life through time for the beginning of each of the periods starting with the Cambrian Period, when a great many different kinds of animals become common in the fossil record. How many steps would be required to represent all of the time that life has been on Earth (about 3.5 billion years)?

6. To get another sense of the huge scale of geologic time, use some mathematical calculations. Imagine that you want to make a movie that will include life through time starting from the origin of the Earth to today. Suppose this movie is going to be 24-h long!

   a) How long would humans be on the screen?

   Share your answer, and the calculations you used to get it, with the rest of the class.

Part B: Life through Geologic Time

1. On a long gymnasium floor, a corridor, or a parking lot, measure out a distance of at least 100 ft (about 30 m).

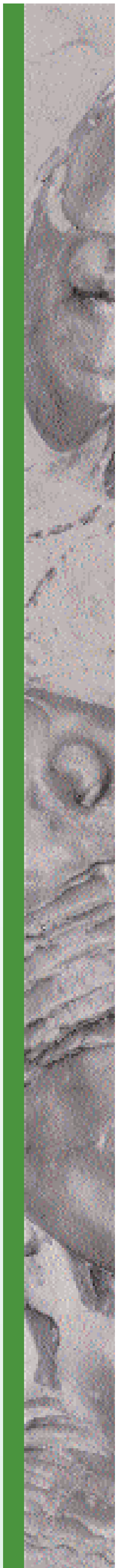
   Use a 100-foot tape measure or lay out a 100-foot piece of rope between the beginning and end of that distance. This will represent all of geologic time.

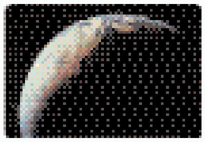
2. Your teacher will give you a chart that shows the dates when various kinds of animals first appeared in the fossil record. Plot these dates along the line. To do that, you will have to form a ratio. For each kind of animal, divide the date of appearance by the total length of geologic time. Use that ratio to figure out where to put the point along your 100-foot line. If you are not sure how to do this, your teacher will help you.

   a) Where would a point be that stands for your age?

   b) Where would a point be that stands for your grandparent's age?

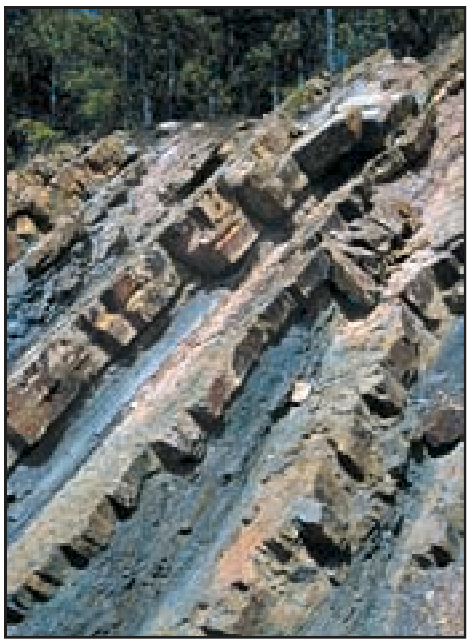
   c) Where would a point be that stands for the beginning of recorded human history (about 4000 years)? How does that compare with the time since the dinosaurs became extinct?





Part C: Figuring out the Fossil Record

1. Your teacher will give each group a special notebook. Think of the notebook as a sequence of sedimentary rock layers. Geologists call this a stratigraphic section. You might see such a section in a highway cut, a river bank, or a sea cliff. Each page stands for a single layer in the sequence.



Each notebook comes from some place around the world. Each one is different. The number of layers is not the same from notebook to notebook, and the layers themselves are different.

Some of the layers contain fossils. Some do not. The names of the different fossils are shown by capital letters on the pages. These letters have nothing to do with the age of the fossils.

You need to keep three important things in mind.

- Sedimentary rock layers are originally deposited one on top of another in horizontal layers. The oldest layer is at the bottom of the stack, and the youngest is at the top.

  The first part of this statement (that sedimentary rock layers are deposited one on top of another) is called the "Law of Superposition."

  The second part of the statement (about originally being in horizontal layers) is called the "Law of Original Horizontality."

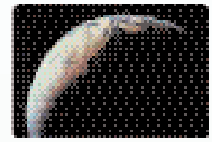
  Combined, these two ideas are very important, because they provide a means to tell which rock layers (and fossils in those rock layers) are older than others.

- Different kinds of plants and animals are called species. A species appears at a certain time and most become extinct at a later time. Once a species becomes extinct, it never appears again.

Inquiry

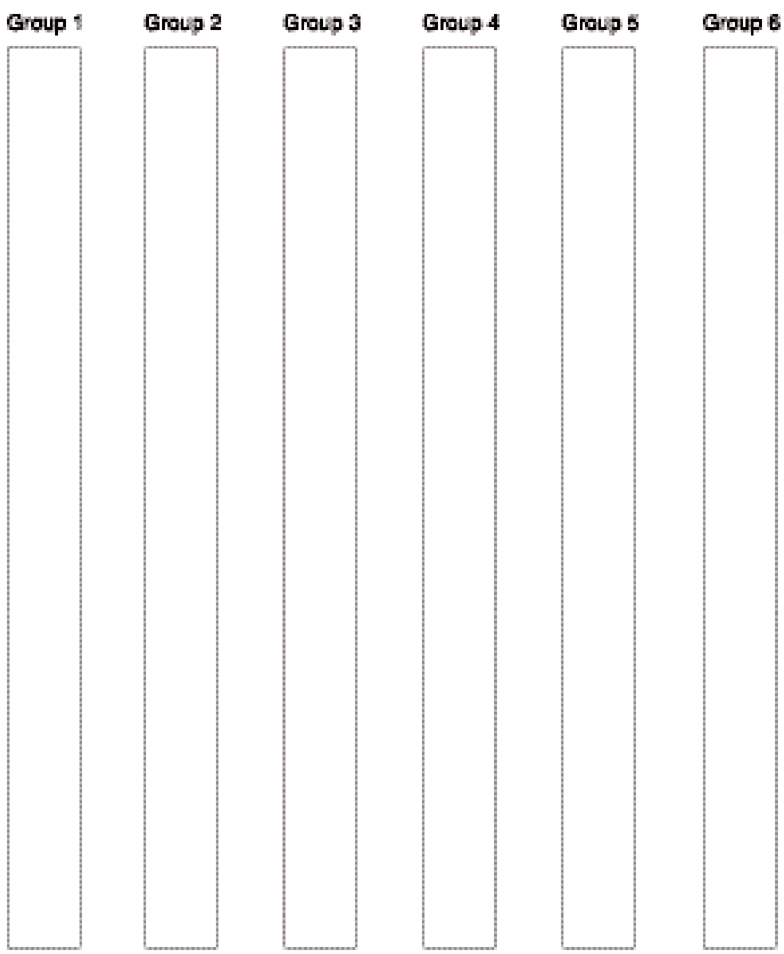
Laws in Science

In science and nature, the word "law" is given a very special status. A scientific law or a law of nature is generally accepted to be true and universal. Laws are accepted at face value because they have been so strongly tested, and yet have always been observed to be true. A law can begin as a hypothesis, but only after years and even decades of testing can a hypothesis become a law. It can become a law only if it has been shown to be true over and over again, without exception. A law can sometimes be expressed in terms of a single mathematical equation, but laws don't always need to have complex mathematical proofs.



- Geologists didn't know beforehand the succession of fossil species through geologic time. They had to figure that out from the succession of fossils in stratigraphic sections all around the world. You're going to do the same thing in this investigation.

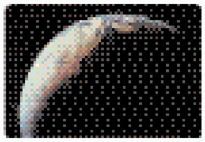
2. You will use the data from each group's notebook to figure out the succession of fossil species. Each group has a sheet of poster board with blank columns (one for each group). On each sheet of poster board, plot your succession of layers in one of the columns. In the column, show the contacts between the layers with horizontal lines. If a layer contains one or more kinds of fossils, label them in the column.



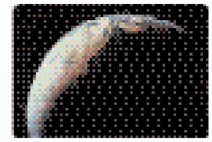
Inquiry

Reporting Findings

In this investigation you are mirroring what paleontologists do. Findings are reported by many different paleontologists and are added to the fossil record.



3. The time interval when one or more species existed is called a zone. Your job is to figure out the “standard” succession of zones, worldwide. To help you do this, draw light pencil lines between the columns, to match up times when fossils A to Z lived. Erase lines and change them as needed.
4. When you are satisfied that you have figured out the succession, write it down in a vertical column on a blank sheet of paper, with the oldest at the bottom and the youngest at the top.
5. As a class, compare the succession of fossil zones from all of the groups.
   a) Are each group’s results the same? If not, discuss the reasons why. Then agree on the single acceptable succession.
   b) Why do some layers contain fossils but other layers have no fossils?
   c) There are two basic reasons why a particular fossil zone might be missing from one or more of the columns. What are these reasons?
   d) How would you use the results of this investigation to tell the ages of the rock layers in a new stratigraphic section?
   e) Imagine that you are studying a newly discovered stratigraphic section somewhere in the world. You find an entirely new fossil species in one of the layers. Would that change your thinking about the standard succession of fossil zones? If not, why not? If so, how?



Digging Deeper

TELLING GEOLOGIC TIME

Species

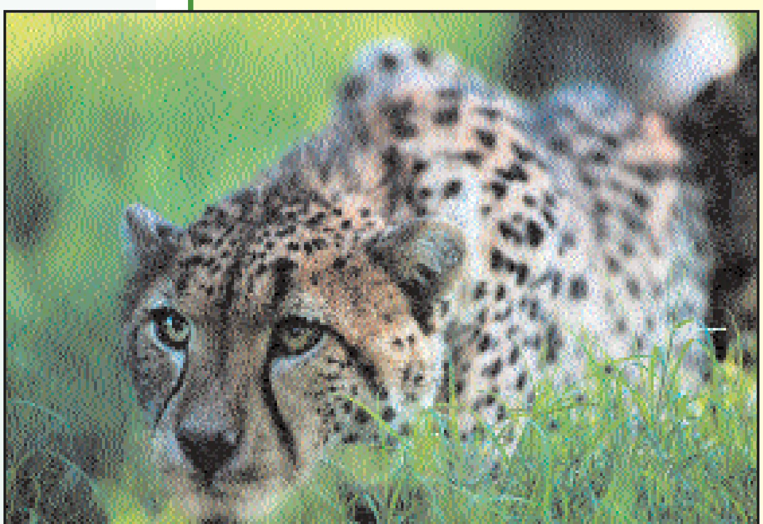
Every plant or animal belongs to a species. A species is a population of plants or animals that can breed to produce offspring that can then produce offspring themselves.

Biologists believe that new species evolve from existing species by a process called natural selection. Here's how it works. Genes are chemical structures in the cells of the organism. The nature of the organism is determined by its genes. The organism inherits the genes from its parents. Occasionally, a gene changes accidentally. That's called a mutation. The changed gene is passed on to the next generation. Most mutations are bad, some are neutral but some mutations make the organism more successful in its life. Organisms that inherit that favorable new gene are likely to become more abundant than others of the species.

Sometimes the population of a species becomes separated into two areas, by geography or by climate. Then the two groups no longer breed with each other. The two groups then slowly change by natural selection. Each group changes in different ways. Eventually, the two groups are so different that they can't breed to produce offspring any more. They have become two different species.

As You Read…
Think about:
1. ***What is a species?***
2. ***How do species change through time?***
3. ***What are index fossils? How are they used in stratigraphic correlations?***
4. ***How has radioactivity been used to refine the geologic time scale?***

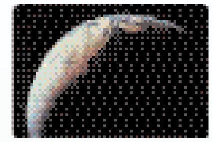
Species eventually become extinct. That means that the population gets smaller and smaller, until no more organisms of that species are left alive. Species become extinct for various reasons. If the environment changes too fast, the species might not be able to adapt fast enough. Also, a new species might evolve to compete with an existing species. Biologists are sure that once a species becomes extinct it never appears again.



In the modern world, biologists can identify species by seeing whether the organisms can breed with one another. Paleontologists have much more trouble with fossil species, because the organisms are no longer around to breed! All that can be done is to match up shells or imprints that look almost identical and then assume that they represent a species. The features of an organism are controlled by its genetics. Thus, similar-looking fossil organisms had similar genetic composition.

The Fossil Record

Paleontologists want to know the history of evolution and extinction of fossil species through geologic time. To do that, they try to study all of the fossils that have been preserved in sedimentary rocks. That's called the fossil record. Paleontologists have been collecting fossils from sedimentary rock layers around the world for



over 200 years. Their goal is to figure out the succession of species through all of geologic time. Once that succession is known, it serves as a scale of geologic time. Then, if you find a particular fossil in a rock, you know where that rock fits into the geologic time scale.

Cambrian trilobites

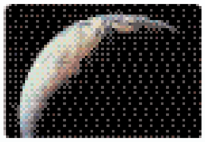
Ordovician trilobites

Devonian trilobites

There's a big problem in figuring out the succession of species through geologic time. You ran into this problem in the investigation. You don't know beforehand what the succession of species is! All you have are many stacks of sedimentary rocks (called stratigraphic sections) around the world to look at. No single stack spans all of geologic time, and no single stack has nearly all of the species that ever lived. You have to compare all of the stacks against one another to get the best approximation to the real succession. That's what you did in **Part C** of this investigation. You compared all of the stacks to one another and matched them up to figure out the succession of fossils. Paleontologists are still refining their ideas about the succession, as new fossils are found.

Stratigraphic Correlation

As you probably figured out already, matching up stratigraphic sections from around the world can be very difficult. If there were no fossils and you could only use the characteristics of the rock layers it would be even harder! This is because at any given time, very

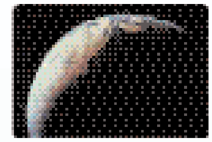


different types of sediments can be deposited in different places. It is these sediments that will eventually become the sedimentary rock layers making up the stratigraphic sections. At any given time, mud may be slowly collecting in some places while in other places sand is piling up rapidly. In other places, maybe there is nothing collecting at all! So you see, very different looking rock layers may mark the same time interval in different stratigraphic sections. The process of matching up equivalent "time layers" of rocks in different places is called stratigraphic correlation. One of the best (and oldest) tools for correlating strata around the world is the use of special fossils called index fossils.

Index fossils have two important characteristics. First, they must have been widely distributed around the world. Second, they must have existed for only relatively short periods of geologic time before becoming extinct. Consider a fossil of an organism that lived only in one place, or that existed for very long periods of geologic time. It would be of little use in matching up layers of rock that were deposited far from one another over the same limited span of time.

Dating Rocks

Knowing the fossil record lets a geoscientist place a particular fossiliferous rock layer into the scale of geologic time. But the time scale given by fossils is only a relative scale, because it does not give the age of the rock in years, only its age relative to other layers. Long after the relative time scale was worked out from fossils, geologists developed methods for finding the absolute ages of rocks, in years before the present. These methods involve radioactivity. Here's how one of the important ones works.



Some minerals contain atoms of the radioactive chemical element uranium. Now and then, an atom of uranium self-destructs to form an atom of lead. Scientists know the rate of self-destruction. They grind up a rock to collect tiny grains of minerals that started out containing some uranium but no lead. Then they use a very sensitive instrument, called a mass spectrometer, to measure how much of the uranium has been changed to lead. Using some simple mathematics, they can figure out how long ago the mineral first formed. Rocks as old as four billion years can be dated this way.

Absolute dating of rocks has provided many "tie points" for the relative time scale developed from fossils. The result is an absolute time scale. When you collect a fossil from a rock, you can place it in the relative time scale. Then you also know about how old it is in years (or usually millions, or tens of millions, or hundreds of millions of years). Even though modern technology makes it possible to date some rocks, the relative time scale is still very important. This is because it takes a lot of time and money to obtain an absolute date, and most rocks cannot be dated using radioactivity.

Review and Reflect

Review

1. According to the chart in this investigation, how long have modern humans (*Homo sapiens*) been on Earth?
2. How are fossils used to match or correlate rock layers deposited in different places at the same time?
3. Why do geologists not use the characteristics of the rocks themselves to identify different rock layers that were deposited at the same time?

Reflect

4. In your own words, explain why you think that geologists still find the relative time scale to be a very useful tool.
5. Why is it that a scientist must look in many places to determine the succession of fossil species through geologic time?

Thinking about the Earth System

6. On your *Earth System Connection* sheet, note how the things you learned in this investigation connect to the geosphere, hydrosphere, atmosphere and biosphere.

Thinking about Scientific Inquiry

7. How did you model the fossil record?