

SCOPE, SEQUENCE, and COORDINATION

A National Curriculum Project for High School Science Education

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National Science Education Standard—Life Science

Biological Evolution

Natural selection and its evolutionary consequences provide a scientific explanation for the fossil record of ancient life forms, as well as for the striking molecular similarities observed among the diverse species of living organisms.

The millions of different species of plants, animals, and microorganisms that live on Earth today are related by descent from common ancestors.

Teacher Materials

Learning Sequence Item:

907

Fossil Formation

March 1996

Adapted by: Brett Pyle

Natural Selection and its Evolutionary Consequences. Students should study the rock cycle and how fossil rocks form. They should examine common fossils of plants and animals and the process of fossil formation dealing with replacement of remains, fossil traces, and original remains (*Biology, A Framework for High School Science Education*, p. 108).

Contents

Matrix

Suggested Sequence of Events

Lab Activities

1. What a Sap!
2. You've Made Quite an Impression on Me
3. Track 'Em Down
4. Makin' Tracks

Assessments

1. Dinosaur Fossils
2. Fossils in History
3. Fossil Collection
4. Fossilization of Soft Tissue
5. Nuclear Magnetic Resonance Imaging

907

Learning Sequence

Natural Selection and its Evolutionary Consequences. Students should study the rock cycle and how fossil rocks form. They should examine common fossils of plants and animals and the process of fossil formation dealing with replacement of remains, fossil traces, and original remains (*Biology, A Framework for High School Science Education, p. 108*).

Science as Inquiry	Science and Technology	Science in Personal and Social Perspectives	History and Nature of Science
<p>What a Sap! Activity 1</p> <p>You've Made Quite an Impression on Me Activity 2</p> <p>Track 'em Down Activity 3</p> <p>Makin' Tracks Activity 4</p> <p>Fossil Collection Assessment 3</p> <p>Fossilization of Soft Tissue Assessment 4</p> <p>Nuclear Magnetic Resonance Imaging Assessment 5</p> <p>Track Records Reading 1</p> <p>Lessons from Leavings Reading 2</p>			<p>Dinosaur Fossils Assessment 1</p> <p>Fossils in History Assessment 2</p>

Suggested Sequence of Events

Event #1

Lab Activity

1. What a Sap! (1 hour)

Event #2

Lab Activity

2. You've Made Quite an Impression on Me (1½ hours)

Optional Additional Activity

3. Track 'em Down (2 hours)

Event #3

Lab Activity

4. Makin' Tracks (1 hour–half day)

Event #4

Readings from Science as Inquiry, Science and Technology, Science in Personal and Social Perspectives, and History and Nature of Science

The following readings are included in the student version of the unit:

Reading 1 Track Records

Reading 2 Lessons from Leavings

Suggested additional readings:

Hoppe, Kathryn, "Brushing the Dust off Ancient DNA." *Science News*, October 24, 1992, pp. 280-281.

Pendick, D., "Amber-Trapped Creatures Show Timeless Form." *Science News*, January 16, 1993.

Monastersky, R., "The First Monsters." *Science News*, August 27, 1994, pp. 138-139.

Bower, B., "Fossil Hints at Hominids' European Stall." *Science News*, February 11, 1995.

Monastersky, R. "The Lonely Bird." *Science News*, August 17, 1991, pp. 104-105.

Assessment items are at the back of this volume.

Assessment Recommendations

This teacher materials packet contains a few items suggested for classroom assessment. Often, three types of items are included. Some have been tested and reviewed, but not all.

1. Multiple choice questions accompanied by short essays, called justification, that allow teachers to find out if students really understand their selections on the multiple choice.
2. Open-ended questions asking for essay responses.
3. Suggestions for performance tasks, usually including laboratory work, questions to be answered, data to be graphed and processed, and inferences to be made. Some tasks include proposals for student design of such tasks. These may sometimes closely resemble a good laboratory task, since the best types of laboratories are assessing student skills and performance at all times. Special assessment tasks will not be needed if measures such as questions, tabulations, graphs, calculations, etc., are incorporated into regular lab activities.

Teachers are encouraged to make changes in these items to suit their own classroom situations and to develop further items of their own, hopefully finding inspiration in the models we have provided. We hope you may consider adding your best items to our pool. We also will be very pleased to hear of proposed revisions to our items when you think they are needed.

Science as Inquiry

What a Sap!**How can insects be fossilized?****Overview:**

Using mucilage or hardening resin students examine how fossils can be trapped in amber and what information can be gained from these fossils. This activity precedes the study of other forms of fossilization.

Materials:**Per lab group:**

mucilage or hardening resin
dead insects (one per student)
small condiment cup, 4–6 oz

Procedure:

Have students collect a dead insect. This can be assigned as homework a few days in advance of this activity.

Students place a layer (~1 cm) of mucilage in the cup, carefully place the insect on top, and set it aside to dry for 2–3 days. They then add a second layer (~1 cm) on top of the insects and again allow it to dry for 2–3 days. They should now be able to remove the fossil.

If using hardening resin, the time for this process probably can be greatly reduced using the same procedure. Pour 1 cm of resin (with hardener) into the cup, place insect inside, and cover with another 1 cm of resin. Allow to dry and harden according to the instructions of the particular resin.

Have students examine their samples and read the suggested reading "Brushing the Dust off Ancient DNA" before answering the questions on the student sheet.

Background:

Amber is hardened tree sap. Insects are attracted to the sweet sap and become stuck. As more sap flows out, some insects become completely encased. This type of fossilization preserves the entire insect including soft parts and fluids. The encased insects do not decompose because no air or microbes can get to them. This has allowed scientists to do detailed studies on the DNA of these insects and has even led to speculation about the recovery of dinosaur DNA from blood in Mesozoic-era mosquitoes (see suggested reading "Amber-Trapped Creatures Show Timeless Form").

Hardening resin is used in making costume jewelry and can be found at hobby shops and some craft stores.

Variations:

If hardening resin is used, students can drill a small hole in one corner so that the “fossil” can be kept and used as a key chain, etc. The mucilage is probably not sturdy enough for this purpose and is much more susceptible to cracking.

Adapted from:

Dixon, D., *Be a Fossil Detective*. New York, N.Y.: Derrydale Books, 1989.

Hoehn, R.G., *Earth Science Curriculum Activities Kit*. West Nyack, N.Y.: The Center for Applied Research in Education, 1991.

Science as Inquiry

You've Made Quite an Impression on Me

**How are molds and casts formed?
What can they tell us about organisms?**

Overview:

Students simulate another common process of fossil formation and consider what characteristics of the organism can be accurately determined from fossil molds and casts.

Materials:**Per lab group:**

plaster of paris (dry powdered supply), 2 lbs per class
paper cups or plastic condiment cups, 6–8 oz, 1 per student
nonstick cooking spray, 12–16 oz
petroleum jelly (alternate—instead of cooking spray)
assorted fossil shells or seashells, 30–40
clay (alternate—instead of second layer of plaster)
water, to mix with plaster—2 parts powdered plaster to 1 part water
(2 lbs plaster to 1 pint water)

Procedure:

Have students select a shell or fossil from which to make a mold. If possible, have them bring in one of their own. Prepare the plaster of paris and pour about 2 cm into each student's cup. Students should put a light coating of nonstick cooking spray on the shell or fossil and press it into the plaster. The plaster may need to sit for a minute or two before placement of the fossil. The plaster must be firm enough so that the fossils do not sink completely in. They should be pressed in only halfway or they will be extremely difficult to get out without breaking the mold.

Allow the plaster to begin to dry. It will be easiest to remove the fossils when the plaster is still slightly wet but is firm enough so that the imprint remains intact. Once the mold is completely dry (~30 minutes), coat the inside of the mold with cooking spray and pour in enough plaster to completely fill the mold. Remove the cast when dry. Have the students compare both the cast and the mold to the original shell or fossil.

Background:

It is best to prepare the plaster immediately before it is to be used. It will begin to dry quickly and once it starts to stiffen it will become increasingly difficult to pour into the cups. You may wish to prepare several small batches one after another so that this will not become a problem. Some

variations of this activity recommend using petroleum jelly as a coating material. This will be slightly messier but may provide a better nonstick surface. It is best to experiment before you do the activity with your class to find a combination that works best. Clay may be used to produce the cast instead of a second layer of plaster.

A mold is formed when an organism is buried in sediment. If the sediment hardens before the soft parts of the animal decay, a hollow space is left after decomposition. This is the mold. If the mold is later filled by other minerals it is referred to as a cast. Molds and casts preserve the shape of the dead organism but not the internal detail that other fossils may retain.

There are many kinds of fossils. The majority represent the hard parts of organisms. Most have been petrified, a process in which the organism's organic substances are slowly replaced by minerals carried in water. These minerals may be different from the substances they replace, but the shape of the organism remains.

Variations:

Have students make molds of various types of objects, including some soft and/or flexible objects. Have them compare the accuracy of the molds to the real objects and how this varies depending upon the composition of the original.

Adapted from:

Crow, L., "Time." *SS&C Project Trial Materials*. National Science Teachers Association, 1994.

Hayes, N.L., *Biological Science, An Ecological Approach*. Boston: Houghton Mifflin Company, 1982.

Hoehn, R.G. *Earth Science Curriculum Activities Kit*. West Nyack, N.Y.: The Center for Applied Research in Education, 1991.

optional/additional activity for Event 2

Teacher Sheet

Science as Inquiry

Track ‘Em Down**What can you determine about dinosaurs from fossil tracks?****Overview:**

This is an optional activity that addresses the question: what can we learn about dinosaurs from their fossil tracks? It can be done either before or after Activity 4. Students use data collected on themselves to infer similar information about dinosaurs.

Materials:**Per lab group:**

paper dinosaur tracks, 9–10

meter stick

stopwatch

calculator

illustrations of dinosaurs and tracks (included in Student Materials)

Procedure:

Working in groups of four, students first measure their tracks as they walk or run in order to produce a graph that will be used to estimate dinosaur speeds. Choose an area where lab groups can lay out 10-meter-long tracks to measure speed and stride length. They can choose to walk, run, or jog. Two lab group members should mark the spot where the toe of the right foot hits on successive landings to determine stride length. Students should be timed over the 10-meter course and actual speed determined for each. Stride length and actual speed for each member of the group is recorded in a data table. Using the following formula students should calculate dimensionless speed for each individual and add this to the data table. For an explanation of dimensionless speed see the background information below.

$$\text{dimensionless speed} = \frac{\text{actual speed (meters/second)}}{\sqrt{\text{leg length (meters)} \div \text{gravitational acceleration (meters/s}^2\text{)}}$$

Once students have completed the calculations they share their information so that each group has a list of the data for each student in the class. They should make a graph of stride length vs. dimensionless speed and plot a best-fit line. They then measure the stride length and the footprint length of the dinosaur tracks that have been placed on the floor of the classroom.

Footprint length is used to determine leg length when direct measurement is not possible (fossil bones are absent). Leg length of a dinosaur = footprint length \times 5. If the tracks are from a quadrupedal dinosaur, make sure students use the footprint length of a rear foot. They should use stride length to determine the dimensionless speed of the dinosaur from the graph (find stride length on

the Y-axis and follow this line until it intersects the best-fit line, drop straight down to the X-axis, and record the dimensionless speed). Record this information in a second data table and use it to calculate actual speed of the dinosaurs using the following formula:

$$\text{actual speed} = \text{dimensionless speed} \times \sqrt{\text{leg length (meters)} \div \text{gravitational acceleration (meters/s}^2\text{)}}$$

Using their diagrams of dinosaurs and tracks, students should determine what types of dinosaurs made the tracks they measured.

Background:

In this lab students use data collected on themselves to infer similar information about dinosaurs. The fundamental equation used relates the speed of an animal to leg length, stride length, and a value called dimensionless speed. The reason that data collected on humans can be used to determine speeds of dinosaurs is based on the value called dimensionless speed. This value is based on the fact that upright tetrapods (humans are classified as bipedal tetrapods), regardless of size, move in approximately the same manner. This has been demonstrated in studies of a wide variety of modern animals.

The dinosaur tracks on the following pages can be used as models for the footprints to be placed on the floor. You can also draw track outlines from illustrations from other sources. You should use prints from at least one carnivorous dinosaur (for question 3 on the student worksheet). It is also advisable to use at least one bipedal and one quadrupedal set of tracks. A figure is included showing the placement of tracks for a carnivorous (bipedal) and an herbivorous (quadrupedal) dinosaur. The spacing between footprints will determine if the dinosaur was running or walking. It would be best to have at least one set of carnivorous dinosaur tracks placed to indicate a running dinosaur.

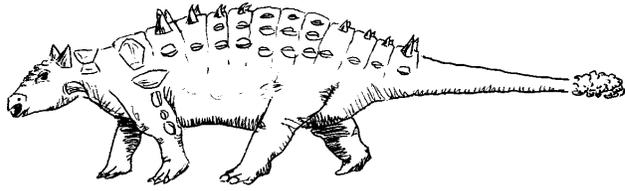
Variations:

If you are adventurous you can cut a piece of wood into the shape of a dinosaur footprint and make your own tracks outside in a muddy area and let them dry and harden. The students can then do their measurements of these instead of paper footprints in the classroom.

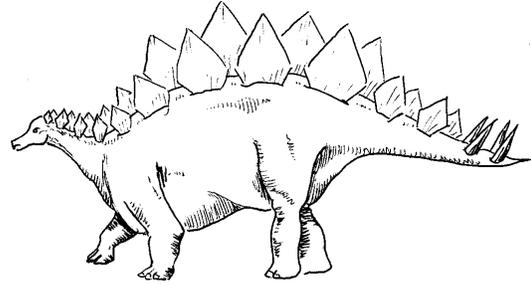
Adapted from:

Lucas, S.G., *Dinosaurs: The Textbook*. Dubuque, Iowa: Wm. C. Brown Publishers, 1994.
Over, D.J., "Determining Dinosaur Speed." *Journal of Geological Education*, Vol. 43, 1995.

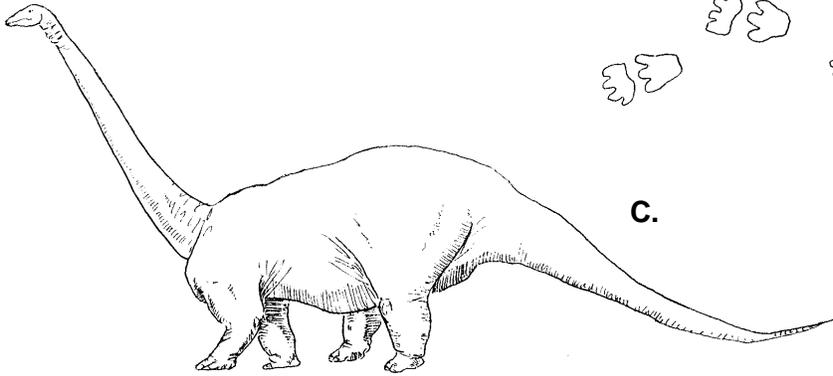
A.



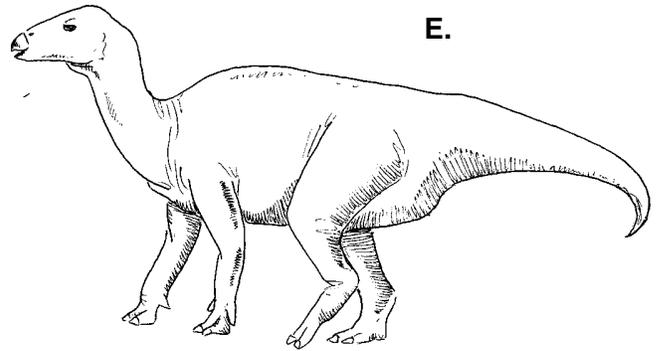
B.



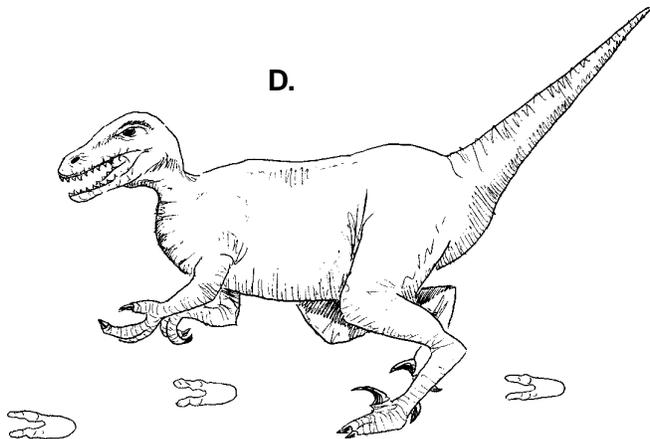
C.

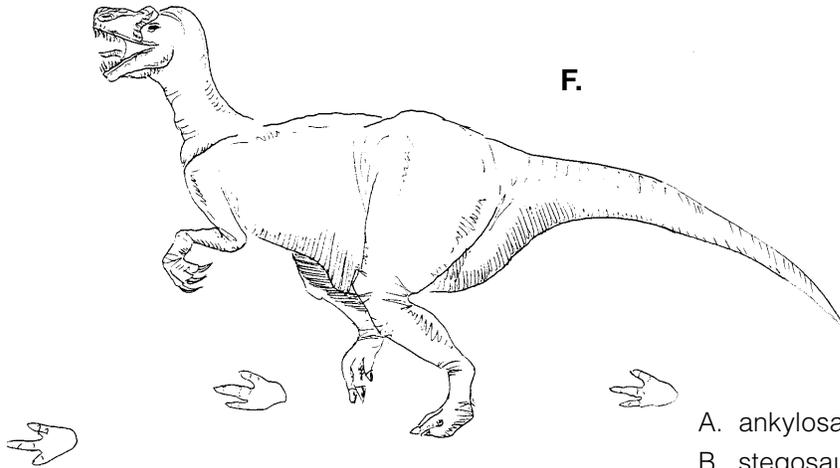


E.



D.





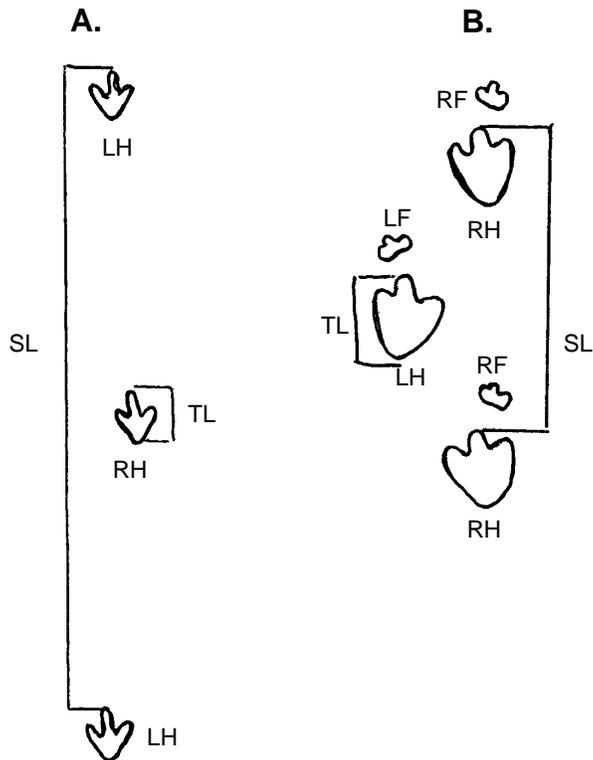
- A. ankylosaur *Euoplocephalus*
- B. stegosauran *Stegosaurus*
- C. sauropod *Brontopodus*
- D. raptor *Velociraptor*
- E. iguanodont *Iguanodon*
- F. carnosaur *Carnosaurus*

- A. carnivorous dinosaur trackway
- B. quadrupedal herbivorous trackway

SL = stride length

TL = track length

The tracks are labeled right (R), left (L), front (F), and hind (H).



Science as Inquiry

Makin' Tracks**How do you study animals you can't see from
evidence they leave behind?****Overview:**

Students use animal tracks as a tool for identification and a source of information about the animal. This activity gives students experience in working with animal tracks as if they were paleontologists working with fossil tracks.

Materials:**Per lab group:**

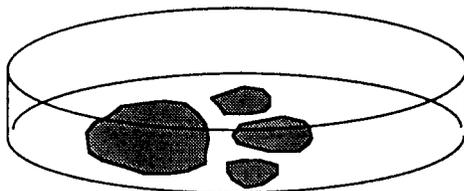
plaster of paris (dry powdered supply)
thin cardboard strips (~2–3 cm wide of varying lengths, 20–50 cm)
scissors
tape
field guide to local animal tracks
water (to mix with plaster)

Procedure:

This activity can be done in two ways. The first involves a field trip to an area where wild animal tracks would be observable (a local nature preserve or park). If this option is not available another version can be done at school.

As a field trip, students are given a field guide to tracks made by animals in the area. They can then break into groups and try to locate as many different sets of tracks as possible and identify, using the field guide, what animal made the tracks. When they locate a good print they should make a plaster cast.

To make a cast, students first clean any leaves, sticks, etc., from the track. They then place a cardboard ring around the print (cut to appropriate size), tape it in place, and pour plaster over the print, partially filling up the ring (see figure below).



Placement of cardboard ring
around print to hold plaster.

After allowing the plaster to dry, students remove the cast, brush away any excess dirt, and label. If enough plaster is available they should make casts of three to four consecutive footprints in order to study stride length and movement.

If this activity is done at school you may have to make some prints. If you can locate a muddy area (or create one with a hose) you can use a pet dog or cat to make prints. While students do not have the opportunity to identify wild animals as in the first version, they can still make casts of the prints and study stride length, etc., of the animal.

Background:

Check local state parks or nature preserves for brochures showing animal tracks. Another source would be a state wildlife or state parks agency. If these sources fail you could construct your own guide to local tracks from guidebooks such as Peterson's or Audubon's. Local park guides or rangers can also be helpful in helping students identify various tracks.

Variations:

You can also have the students look for other evidence of animals, such as burrows, diggings, or feces (some are distinctive, such as rabbit "pellets"). Again, local field guides may be helpful in providing students with information on what to look for.

Adapted from:

"Ecology Investigation." *Making Casts of Animal Tracks*, Prentice Hall.

History and Nature of Science

Dinosaur Fossils**Item:**

People enjoy learning about dinosaurs. Most of what we know about dinosaurs comes from fossils. Which parts of a dinosaur were more likely to have been preserved as fossils?

- A. DNA
- B. muscles
- C. eyes
- D. bones

Justification:

Explain why this is true.

Answer:

The correct choice is D. Possible ideas to be found in student answers:

- Bones are more durable and most likely to be around long enough to be fossilized; soft body parts such as muscles and eyes are rapidly removed by decomposers and so are unlikely to become fossilized.

Possible misconceptions to be found in student answers:

- People know what dinosaurs looked like, so muscles must have been preserved.
- People know what dinosaurs looked like, so eyes must have been preserved.

History and Nature of Science

Fossils in History**Item:**

Hundreds of years ago, people believed that fossils were the “seeds” of past life forms that were simply “planted” in the wrong place. When they were planted in stone, they began growing and became stone. Leonardo da Vinci argued against this idea. What are some of the arguments he might have made, or how might you have explained to those people what fossils really are?

Answer:

Several observational facts are not explained by this "seeds" theory. Why do some of the animals evidenced not exist today and yet some others do? Some of these past life forms seem almost, but not quite, identical to present life forms. How did these creatures undergo these changes?

Science and Inquiry

Fossil Collection

Item:

A slip causes a major mess at a museum. A senior scientist at the City Museum had an unfortunate accident. As the scientist carried the evolutionary sequence tray for the butterfly and crab collection, the scientist's arm was bumped by a teenager running to get to the science book section to do a science report on evolution. You have been asked to reassemble the collection. As you know, a fossil is any preserved part or trace of an organism that once lived, and there are several possible types and processes of fossil formation. Organize the collection based on type of fossil.

Facilities:

Per pair of students: one set of precut fossils in a numbered envelope, one fossil record sheet, and glue or tape. A variety of fossil types should be represented.

Answer:

Students should demonstrate understanding of the various processes of fossil formation, including imprints, molds, petrified fossils due to mineral replacement of hard parts, casts, actual parts like teeth and bones, frozen or otherwise preserved fossils (e.g., amber-encased insects), and footprints or tracks. Furthermore, students should demonstrate some knowledge of which types of fossils are likely to be formed depending on the type of organism. For example, leaves and feathers are often fossilized as thin films of carbon or imprints, and organisms with hard parts (e.g., teeth, shells, and bones) may form molds.

Science and Inquiry

Fossilization of Soft Tissue**Item:**

A dinosaur egg was recently found that contained the fossilized remains of the dinosaur's embryonic skin and muscle tissue. This made it an incredibly rare and valuable find. Why is this type of fossil so rare?

Answer:

Soft tissues readily decay and are therefore difficult to preserve. Since such an object would also be susceptible to being eaten by predators and/or scavengers, such a find would be extremely rare.

Science and Inquiry

Nuclear Magnetic Resonance Imaging**Item:**

Nuclear magnetic resonance imaging is a technique that allows scientists to see images of different types of material, even within solid rock. How could this technique be used by paleontologists to find fossils? Explain in terms of what you know about the composition of fossils and where they are found. Why would this technique be better than the traditional approaches to finding fossils? Give several reasons.

Answer:

Fossils are often found buried within layers of sedimentary rock. Traditional paleontological methods must rely on the exposure of such fossils that result from normal geological events such as uplifting, faulting, and erosion. There is no guarantee that such events will coincidentally occur precisely where fossils are located, so their discovery is to some degree a matter of chance. Nuclear magnetic resonance imaging would provide an efficient method for actively searching for fossils, especially in areas known to be rich in previous fossil finds. Having knowledge of the location of a buried fossil would also help in the safe uncovering of the fossil, lessening the chances of damaging the find while digging it up. It would also help in the event that several specimens were buried together in that you could make a preliminary identification of the fossils before excavation actually begins. Nuclear magnetic resonance imaging could be used to check a construction site before digging to avoid possible accidental destruction of potentially important fossil finds.

Consumables		
Item	Quantity per lab group	Activity
cardboard strips, 2–3 cm wide, 20–50 cm long	—	4
clay (alternate)	—	2
condiment cup, 4–6 oz	1	1
dinosaur tracks (paper)	9–10	3*
fossil shells, assorted	30–40	2
insects (dead)	1 per student	1
illustrations of dinosaurs and tracks	(included with Student Materials)	3*
mucilage or hardening resin	—	1
nonstick cooking spray, 12–16 oz can	1	2
paper cups or plastic condiment cups, 6–8 oz	1 per student	2
plaster of paris (dry powder)	2 lbs per class	2
plaster of paris (dry powder)	—	4
tape	—	4
petroleum jelly (alternate)	—	2
water (to mix with plaster)	—	2, 4

Nonconsumables		
Item	Quantity per lab group	Activity
calculator	1	3*
field guide to local animal tracks	1	4
meter stick	1	3*
scissors	1	4
stopwatch	1	3*

* optional or additional activity

Key to activities:

1. What a Sap!
2. You've Made Quite an Impression on Me
3. Track 'em Down
4. Makin' Tracks

Activity Sources

- Crow, L. "Time," *SS&C Project Materials*. National Science Teachers Association, 1994.
- "Ecology Investigation." *Making Casts of Animal Tracks*, Prentice Hall. (year not known)
- Hayes, N.L., *Biological Science: An Ecological Approach*. Boston: Houghton Mifflin Company, 1982.
- Hoehn, R.G., *Earth Science Curriculum Activities Kit*. West Nyack, N.Y.: The Center for Applied Research in Education, 1991.
- Lucas, S.G., *Dinosaurs: The Textbook*. Dubuque, Iowa: Wm. C. Brown Publishers, 1994
- Over, D.J., "Determining Dinosaur Speed." *Journal of Geological Education*, Vol. 43, 1995.

Student Readings

- Chin, K., "Lessons from Leavings." *Natural History*, June 1995, p. 67.
- Lockley, M., "Track Records." *Natural History*, June 1995, pp. 46–51.