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Join us in being green! The following Educator
Resources are now available exclusively on
the Natural Inquirer website at http://www.
naturalinquirer.org.

These resources can be found with the “Caves and
Karst” journal and on the “For Educators” pages:
• Note to Educators
• Lesson Plan
• Reflection Section Answer Guides
• National Education Standards

Photo courtesy of Pete Pattavina, U.S. Fish and

Photo courtesy of Ernesto Medina, University of
Puerto Rico.

Photo courtesy of stephanjezek, istockphoto.com.

Photo courtesy of Dave Bunnell, Under Earth
Images.
Natural Inquirer editorial review boards hard at work.

Editorial Review Board Comments
Mrs. Anna Moates - 8th Grade English/Language Arts Class, World Language Academy, Georgia

I believe you did a good job, but some of the pictures are a little dark.

The most important thing I learned is what a hydrologist is.

I learned that it is important for a scientist to have safety glasses etc in order for them to be safe.

I learned that karst covers about 20 percent of the earth’s surface.

I loved that you put reflection section but you could have put more fun facts. It makes the reader interested.

The most important thing I learned was WNS and how it affects bats.
Scientists report their research in journals, which are special booklets that enable scientists to share information with one another. This journal, *Natural Inquirer*, was created so that scientists can share their research with you and with other middle school students. This journal presents the research of scientists with USDA Forest Service and other cooperating organizations. The USDA Forest Service is an agency of the U.S. Department of Agriculture. If you want to know more about the USDA Forest Service, you can read about it on the inside back cover of this journal. Information is also available at http://www.fs.fed.us.

All of the research in *Natural Inquirer* concerns nature, such as trees, forests, animals, insects, outdoor activities, and water. First, you will “Meet the Scientists” who conducted the research. Then, you will read something special about science and about the natural environment. You will also read about a specific research project, which is written in the format that scientists use when they publish their research in journals. Then, YOU will become the scientist when you conduct the FACTivity associated with each article. Don’t forget to look at the glossary and the special sections highlighted in each article. At the end of each section of the article, you will find a few questions to help you think about what you have read. Your teacher may use these questions in a class discussion.

Be sure to try the Caves and Karst Crossword and eyeChallenge on pages 59 and 60!

**Who Are Scientists?**

Scientists collect and evaluate information about a wide range of topics. Some scientists study the natural environment. To be a successful scientist, you must:

- **Be curious**—Are you interested in learning?
- **Be enthusiastic**—Are you excited about a particular topic?
- **Be careful**—Are you accurate in everything you do?
- **Be open-minded**—Are you willing to listen to new ideas?
- **Question everything**—Do you think about what you read and observe?

To learn more about your favorite scientists and their work, you can view and order scientist cards and print your own posters online at http://www.naturalinquirer.org.
Welcome to the Natural Inquirer Caves and Karst Edition!

You probably have heard about caves before, but you may not have heard of karst. So what does karst mean? Karst refers to a type of landscape or topography that is formed when rocks are dissolved by a weak acid. Over time, groundwater that is acidic wears away rock and creates tunnels and open spaces. Approximately 20-25 percent of the United States is karst landscapes (figure 1). Karst landscapes usually have sinkholes, caves, streams that seem to disappear or sink, and springs (figures 2-5).

Figure 1. Map of karst features in the United States. Map courtesy of the National Cave and Karst Research Institute.

Figure 2. A sinkhole is a hole or depression in the landscape that is created when layers of dirt and soil are washed down into the cracks and crevices in a karst landscape. Illustration by Stephanie Pfeiffer.
Karst landscapes vary in size from very large to very small areas. Additionally, some karst cannot be seen easily because it is buried beneath other kinds of rocks or deep layers of sediment or covered with vegetation. In the United States, a large amount of drinking water comes from karst aquifers—approximately 40 percent! Aquifers are underground areas that hold water. Karst aquifers are areas of dissolvable rock that are water-bearing and can also absorb water. The largest karst aquifer in the United States is the Floridan aquifer, which extends from Florida into South Carolina (Figure 6).

Caves are found in karst landscapes, but also found in other areas. Generally, caves are defined as naturally occurring cavities or
openings in the earth (figure 7). Scientists who study caves are called speleologists (spē lē ə la jists). Caves are fascinating for multiple reasons. One reason caves are fascinating is because they are home to unique ecosystems. The lack of light and other extreme conditions result in interesting animal adaptations and rock formations. Caves are also fascinating because they often contain fossils.

Some examples of animals that live in caves are Texas blind salamanders, cave fish, crayfish, tooth cave spiders, and bats (figure 9). Some of these animals are endangered species and need extra protection.

Bats that live in caves are facing a particularly difficult challenge with a fungus known as white-nose syndrome (WNS). You will learn about WNS in “Cave Conundrum.” In “Tropic Topic,” you will
Did You Know?

Did you know the world’s longest known cave is Mammoth Cave in Kentucky? The cave is over 400 miles of connected passageways!

Figure 8. Visitors walk through the Main Cave, known as Broadway, in Mammoth Cave. Photo courtesy of National Park Service.

learn about karst landscapes in tropical forest areas. Through reading “The Whole Kit and Kaboodle” you will gain an understanding about an Alaska Native Tribe and their unique connection to coastal cave areas. The final article, “A Tale of Two Caves,” will explore how caves develop and how caves near each other can develop differently. These articles represent just a few of the cool science topics that are studied in karst and cave areas.

Figure 9. Cave crayfish live in Mammoth Cave, Kentucky. Photo courtesy of National Park Service.
Cave Conundrum:

Is White-Nose Syndrome Responsible For All Declining Bat Populations?

Photo courtesy of Marvin Moriarty, U.S. Fish and Wildlife Service.
Meet the Scientist

**Sybil Amelon, Wildlife Ecologist:** My most exciting science experience was discovering that even very small bats that weigh only 10 grams (about one third of an ounce) travel long distances every night. We found some species will travel 30 or more miles, one way, in their quest for food. This includes mother bats that have to feed themselves and return to their roost to feed their young periodically through the night.

**Brent Sewall, Biologist:** My favorite science experience is discovering the secret worlds of animals. Many animals, like bats, are hard to find— they often are small, fly fast, move around in the dark, vocalize in frequencies beyond what we can hear, and hide in difficult-to-reach places like caves. With research, though, we can gain new insights into animals’ amazing abilities and how they live their lives. Such insights inevitably lead to a greater understanding and appreciation of the incredible species with which we share the Earth.

What Kinds of Scientists Did This Research?

**Wildlife Ecologist:** This scientist studies the relationship of different kinds of wildlife with each other and with their living and nonliving environment.

**Biologist:** This scientist studies living organisms and living systems.

Thinking About Science

Research questions in science often require a large amount of information to get an accurate answer. Sometimes, scientists discover that there is not enough information to get an accurate answer to a research question. To solve this problem, some scientists begin long-term research studies.

For instance, scientists may want to know how drought affects pine tree growth. First, they would want to know how pine trees grow in both non-drought years and drought years. They would need many years’ worth of data to understand normal
pine tree growth before determining how drought might change that growth.

In 1908, the Forest Service recognized the need for long-term research sites. The Forest Service established a system of Experimental Forests and Ranges (EFRs) (figure 1). At these sites, scientists regularly collect information about the rainfall, soil, plant and animal populations, and other environmental conditions of the area. By recording these data over many years, EFRs provide a broad range of information that can help scientists answer complex, long-term research questions. Similarly, in this research about white nose syndrome, scientists needed to gather research over a longer period of time.

**Thinking About the Environment**

White-nose syndrome (WNS) is a disease affecting hibernating bat populations. The disease is named for the white fungus that collects on the muzzle and other parts of infected bats (figure 2).

The disease was first introduced in New York in winter of 2006. Since the time WNS was first introduced, the disease has spread to caves and
mines across 33 States and 7 Canadian provinces. WNS has killed an estimated 6 million bats in the Eastern United States and Canada (figure 3). At some sites, 90 to 100 percent of bats have died from WNS infection.

Scientists are dedicated to understanding and combating WNS because bats are important to the ecosystems in which they live. In some ecosystems, plants rely on bats to pollinate flowers or spread seeds. Bats, the only free-flying mammal, are also an important indicator species that signal changing conditions in an ecosystem. Some bat species are insectivores, and act as a natural method of pest control in their environment.

**Introduction**

Hibernating bat populations across the Eastern United States have suffered declines since the 2000s. Little brown bat populations have declined 70 percent or more. Populations of the northern long-eared bat and tricolored bat have declined by 30 percent (figures 4, 5, and 6). The scientists studied these three bat species in their research.

The cause of bat population declines is often assumed to be WNS, a deadly disease caused by a fungal pathogen. Evidence suggests WNS is a serious threat to bat populations. However, research has not yet supported WNS as the only cause of bat population

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**Number Crunches**

- How many years has it been since WNS was first introduced in New York?

- Write out 6 million in numeric form.
declines. Therefore, the scientists in this study asked: Is WNS the sole cause of these bat population declines, or is there something else causing bat populations to decline?

The scientists hypothesized that if WNS is the sole cause of decline in bat populations, then the following conditions will be true:
- Only bat populations infected with WNS will experience declines;
- Declines in bat populations will happen later at caves farther from where WNS was discovered; and
- Bat populations will begin declining shortly after WNS infects a colony.

**Reflection Section**

- Diseases like WNS are one cause of decline in animal populations. What are some other things that might cause an animal’s population to decline?
- WNS is caused by a fungus. What are some other types of fungi you know of?
- How do you think WNS spreads between bats?
Figure 7. Many species of bats hibernate throughout winter in caves, mines, and other cold, dark places. These sites are called hibernacula (hī bər na kya lə). Photo courtesy of Keith Shannon, U.S. Fish and Wildlife Service, via http://www.flickr.com.

Methods

To test their ideas, the scientists needed to know how bat populations have changed before and after WNS was introduced. They needed a large amount of information about bat populations over a period of many years to understand population trends. They used data collected by State wildlife agencies in New York, Pennsylvania, West Virginia, and Tennessee. These data were gathered during regular surveys of bat hibernacula during winter every 2 years between 1999 and 2011 (figure 7). Biologists visited the same hibernacula to collect data on the location of caves, the number of bats, and presence or absence of WNS (figure 8).

Figure 8. During the surveys, biologists found WNS present in approximately 44-48 percent of the routes they surveyed for all three species. Photo courtesy of Gary Peeples, U.S. Fish and Wildlife Service, via http://www.flickr.com.

Reflection Section

• Biologists collected the same data every 2 years. Why is it important to have routine methods in an experiment?

• Why do you think the scientists used scientific models in this study instead of designing an experiment to do in the field or in a lab?

• If the scientists’ models were different from the real trends in bat populations, what might that tell you about the relationship between bat population declines and WNS?
The scientists graphed the population trends of each bat species in each State using the data. They also graphed the expected scenarios, or models. These models illustrated how the bat populations would change over time if all three of the hypothesized WNS conditions were present. By comparing the results of the models with the graphs of actual population trends, the scientists were able to evaluate whether the hypothesized conditions were true.

### How Do Scientists Detect WNS?

When scientists survey caves, they look for signs of WNS. Visible signs of WNS include skin damage, white fungus on the bats’ noses, and the number of dead bats in the cave. However, these visual methods are not always an accurate way to detect WNS. New research has found a way to detect a WNS infection using a certain range of light. Ultraviolet light, which is invisible to the human eye, makes the skin damage caused by WNS glow an orange-yellow color.

A study showed this method was 98.8 percent effective at positively detecting WNS, and it provides a new, reliable way to identify WNS on bats.


### How Do Scientists Make Models?

You probably have seen toy cars and airplanes that look just like the real thing, only smaller. These toys are actually models, or simplified representations of a larger item. Models are used frequently in our day-to-day lives to help people see and understand large objects, concepts, and processes.

Scientists also use models when a scientific research question is too big or too complicated to answer. In these situations, scientists may use scientific modeling. A scientific model uses data to represent complex scientific concepts in a simpler way. In the case of this study, the scientists used models to better understand how a disease, like WNS, affects bat populations.

Models are useful tools for scientists, but they are only as good as the data that are put into them. The scientists in this study used data taken from four States across 11 years. Using this quantity of data helped the scientists increase the likelihood that their model would give them an accurate representation of the bat populations they were studying. In the table below, the total numbers of surveys conducted, routes traveled, and individual bats counted are shown. The scientists used this information to build their model (Table 1).

#### Table 1. This table shows the set of data the scientists in this study used to make their model.

<table>
<thead>
<tr>
<th></th>
<th>Number of Surveys Conducted</th>
<th>Number of Routes Traveled</th>
<th>Number of Individual Bats</th>
</tr>
</thead>
<tbody>
<tr>
<td>Little brown bat</td>
<td>577</td>
<td>145</td>
<td>982,974</td>
</tr>
<tr>
<td>Northern long-eared bat</td>
<td>460</td>
<td>109</td>
<td>5,206</td>
</tr>
<tr>
<td>Tricolored bat</td>
<td>576</td>
<td>145</td>
<td>68,148</td>
</tr>
</tbody>
</table>
**Findings**

The scientists compared the modeled and real population patterns. The data showed all three of the bat species met at least one of the three hypothesized conditions. However, none of the species met all three conditions (table 2).

Results indicate that certain bat populations were declining before WNS was discovered in those populations. Other bat populations were experiencing a population increase that continued despite WNS infection.

**Table 2.** This table shows whether or not the modeled bat populations met the three hypothesized conditions.

<table>
<thead>
<tr>
<th>Hypothesized Condition</th>
<th>Little brown bat</th>
<th>Northern long-eared bat</th>
<th>Tricolored bat</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Only bat populations infected with WNS will experience declines</td>
<td>No; Bat colonies with and without WNS experiences similar population changes</td>
<td>No; Bat colonies with and without WNS experiences similar population changes</td>
<td>Yes; Bat colonies with WNS declined more severely than bat colonies without WNS</td>
</tr>
<tr>
<td>2. Declines in bat populations will happen later at caves farther from where WNS was discovered</td>
<td>No; Patterns varied greatly by region, though most areas experienced declines</td>
<td>Yes; Declines were slower and less severe further from the point of WNS introduction</td>
<td>No; Declines did not vary with distance from the point of WNS introduction</td>
</tr>
<tr>
<td>3. Bat populations will begin declining shortly after WNS infects a colony</td>
<td>Yes; Onset of bat population declines matched local detection of WNS within 1 year</td>
<td>No; Bat population declines began before local detection of WNS by 10+ years</td>
<td>No; Bat population declines began before local detection of WNS by 3-7 years</td>
</tr>
</tbody>
</table>

**Reflection Section**

- The results for two populations of northern long-eared bat showed little or no negative impact since WNS was detected in those areas. What do you think are some potential explanations for these results?

- Think about the methods the scientists used to get these results. What are some potential sources of error that could affect the results?

- What do you think it means that several of the populations were experiencing declines for years before WNS was discovered near them?
Discussion

The results of the study support the idea that WNS is an important cause of decline of bat populations in the Eastern United States. However, the results indicate that WNS is not the only cause of decline. Most efforts to aid bat populations have focused on preventing transmission of WNS by humans (figure 9). However, WNS also is often transmitted through non-human means, like one bat contacting and infecting another bat.

The findings in this research also suggest that there are other important causes of decline that may be overlooked. Other potential sources of mortality include agricultural pesticides and chemicals, climate change, collisions with human-built structures and vehicles, and habitat loss or degradation of habitat. These results suggest that scientists should continue to combat WNS while also addressing other threats to bat populations.


Reflection Section

- How might humans contribute to the spread of WNS?
- How does habitat degradation affect hibernating bats?
- What are some ways scientists could combat the other threats to bat populations?

Glossary

degradation (degraðəʃən): The act of impairing or bringing to a lower level of quality.
hibernacula (hī bər nə kə ˈlə): Shelters occupied during the winter by a hibernating animal.
indicator species (in də kā tə spē shēz): Type of plant or animal that serves as a measure of the environmental health of an area.
insectivore (in ˌsektə vər): An organism that feeds mainly on insects.
mortality (mɔr tə lə tē): Death of an organism or organisms.
pathogen (paθə jan): An organism or other agent that causes disease.
representation (re prə zen tə shən): A likeness, picture, image, etc.
route (raʊt): An established, selected, or assigned course of travel.
transmission (tran(t)ʃən): The process of transferring from one person, animal, or place, to another.

Accented syllables are in bold. Marks and definitions are from http://www.merriam-webster.com.
Definitions are limited to the word’s meaning in the article.

FACTivity

Time Needed
One class period

Materials
(for each student or group of students)
• Cave Conundrum Graphic Organizer
• Writing utensil

In this FACTivity, you will predict and observe how diseases spread in populations. Over one class period, you will simulate the spread of the “flu” in your class over 5 days of school.

Methods
Your teacher will divide the class into small groups of four to five students. Your teacher will select one student to “have the flu,” and designate a “sick” area where students will go if they become “sick.” You will participate in two simulations with five rounds each. In each simulation, you will predict and simulate how the flu will spread throughout your class over the course of 1 “week.” When a classmate becomes “sick,” he or she should move to the designated “sick” area of the room at the beginning of the next round. Cross out each day on the chart as the round ends.

Before you begin, discuss how you think the “flu” will spread throughout the class over the course of 1 week. How many and which students will be left in class by Friday? We can hypothesize what will happen using these three assumptions:

1. Only students who interact with the “sick” student will get the “flu,”
2. The students who sit nearest to the “flu” student will contract the “flu” first, and
3. Students who interact with the “sick” student will have the “flu” the next day.

Write your predictions about how the “flu” will spread in your class in the “Simulation One” section of the graphic organizer before each round. As the activity progresses, remember to write down what did happen in each round.

Simulation 1

1. Monday (Round 1): The student with the “flu” will shake hands with two students nearest them, “infecting” them. The original “sick” student should go to the designated “sick” area.
2. Tuesday (Round 2): The students who shook hands with the original “sick” student with the “flu” are “infected.” These two “sick” students should shake hands with two more students closest to them, then go to the designated “sick” area with the original student.
3. Wednesday and Thursday (Rounds 3 and 4): Repeat the process for these two rounds. The “sick” students from previous rounds will stay in the designated “sick” area. The newly “infected” students should shake hands with the two students nearest them, then go join others in the designated “sick” area.
4. Friday (Round 5): Repeat the process one more time. Those four students “infected” in this last round can go immediately to the “sick” area.

At the end of Round 5, observe how many students are in the designated “sick” area and where they sat in relation to the original “sick” student. Record these observations in the “Simulation One” section of your graphic organizer. Write down what happened in each round.
**Simulation 2**

Before starting Simulation Two, all students will close their eyes. Your teacher will secretly tap five students on the head, and if you are selected, you need to keep it a secret from other students. If you were tapped on the head, you received a “flu shot.”

**What do you think will happen during Simulation Two if some students have a “flu shot?”**

Repeat the steps of Simulation One. However, in Simulation Two the kids with “flu shots” do not get “sick” or go to the “sick” area when they shake hands with an “infected” student. Instead, these students will remain in the game as if nothing happened.

Also, “sick” students can now choose to infect any student in the room, not just those nearest to them.

Once again, keep track of the results of each round in your graphic organizer. How many kids are “sick” at the end of the last round? Where did those “sick” students sit in relation to the original “sick” student?

Now, compare and contrast the results of Simulation One with those of Simulation Two. Were there more healthy students in one simulation than in the other? Did you notice any different patterns between the two simulations? Write your answers and observations in the graphic organizer.

This simulation is similar to how scientists create and use models. They use known facts to create logical predictions about a situation, the spreading of disease in this case, to predict what will likely happen. However, like the students with “flu shots,” exceptions create differences between the modeled result and the actual result. We would expect students who sit near the “sick” students to be “infected” first, but a sick student may choose to go visit and “infect” a friend who doesn’t sit close by in class. This interaction creates another difference between the assumption we used to make our predictions and the real number of students left at the end of the simulation.

What does this activity tell you about the use of models in science? How can models be helpful? What are some challenges of using models? How does this FACTivity compare with what you learned in the “Cave Conundrum” article?
Name: ________________________________________

**Cave Conundrum Graphic Organizer**

<table>
<thead>
<tr>
<th>Simulation One</th>
<th>Day 1</th>
<th>Day 2</th>
<th>Day 3</th>
<th>Day 4</th>
<th>Day 5</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>What do you think will happen?</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>What happened?</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Simulation Two</th>
<th>Day 1</th>
<th>Day 2</th>
<th>Day 3</th>
<th>Day 4</th>
<th>Day 5</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>What do you think will happen?</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>What happened?</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Compare and contrast the results of Simulation One and Simulation Two:**
What's in a Name?

This article’s title, “Cave Conundrum,” refers to the conundrum WNS presents to scientists. A conundrum is a confusing or difficult problem.

Web Resources

Science News for Students: An enemy in the cave https://www.sciencenewsforstudents.org/article/enemy-cave

USDA Forest Service: Fighting the Battle for the Bats Story Map https://usfs.maps.arcgis.com/apps/MapJournal/index.html?appid=82d483795c1e45c89f3378554e062ad2

USDA Forest Service: Battle For Bats: Surviving White-Nose Syndrome (video) https://vimeo.com/76705033


You may want to reference these Natural Inquirer resources for additional information and FACTivities:

► For more information on bats, read “The Trees Have Gone Batty! How Bat Scat Helped Restore a Tropical Forest” in the Natural Inquirer Tropical edition.

► For more on fungal pathogens, read “Moving Spore-adically: The Spread of Sudden Oak Death in California Forests” in the Natural Inquirer Invasive Species edition.

These resources, along with others, can be found at http://www.naturalinquirer.org/all-issues.html.

If you are a trained Project Learning Tree educator, you may use “Life on the Edge,” “Dynamic Duos,” “Our Changing World,” and “Earth Manners” as additional resources.
Tropic Topic:

What Is Known About the Limestone Zone?

Photo courtesy of Ernesto Medina
Meet the Scientists

- Ernesto Medina, Plant Ecophysiologist: My favorite science experience is being outside in the field, observing how plants respond physiologically to their environment. I like designing experiments to answer the questions that arise from observations, and then working with the data and writing the manuscript that explains it all. Photo courtesy of Ernesto Medina, University of Puerto Rico.

- Elvira Cuevas, Ecologist: My favorite science experience is working outside in the field. I can see how the vegetation is interacting with the environment and measure those interactions. It is fascinating to be able to put numbers on those interactions. Photo courtesy of Elvira Cuevas, University of Puerto Rico.

- Ariel Lugo, Tropical Ecologist: My favorite science experience was conducting science camps for high school students in the karst zone of Puerto Rico. We had a fabulous time and conducted cool research that we published in science journals. Photo courtesy of Ariel Lugo, USDA Forest Service.

Glossary words are bold and are defined on page 30.
Thinking About Science

Plants receive nutrients from air, water, and soil. Chemicals move throughout the air, water, and soil, and then into plants. Plants absorb 14 nutrients from the soil. Plants have a disadvantage when faced with unfavorable conditions, such as poor soil conditions. They cannot move quickly to a new environment when conditions are unfavorable. When soil or rainfall conditions are not optimum for plant growth, plants must adapt to thrive. When conditions are not favorable for plants, one way they may adapt is to increase the percentage of their root structure compared with the rest of the plant’s aboveground structure. They may grow their roots deeper and spread them out farther away from the main root stem.

The scientists in this study were interested in how trees growing in similar soil types, but living in different rainfall conditions, adapt so they can thrive. To understand such tree adaptation, the scientists compared the soil’s chemical content with the tree leaves’ chemical content. Studying the chemical content of soil and leaves helps scientists understand how plants adapt to their environment.

Thinking About the Environment

Karst is a geochemical landform from which caves and sinkholes are formed (figures 1 and 2). Karst is made up of limestone and other soluble rocks. Limestone erodes easily, especially when groundwater or rainfall is slightly acidic. As limestone erodes, water seeps into the ground and further erodes the limestone underneath. This erosion forms sinkholes, caves, and underground streams and lakes.

What Kinds of Scientists Did This Research?

ecologist: This scientist studies the relationship of living things with their living and nonliving environment.

tropical ecologist: A tropical ecologist studies the relationship of living things with their environment in the tropics. The tropics make up the region between the Tropic of Cancer and the Tropic of Capricorn (see Figure 5).

plant ecophysiologist (ē kō fi zē ă la jist): A plant ecophysiologist studies how the environment, both physical and biological, interacts with the physiology of an organism. It includes the effects of climate and nutrients on physiological processes, or normal functioning, in plants.

Figure 1. Karst is mainly a carbonate landform from which caves and underground waterways are formed. Illustration by Stephanie Pfeiffer.
Karst landscapes are found worldwide, covering about 20 percent of Earth’s land surface. All of Florida, for example, is karst (figure 3). Karst landscapes are an important source of drinking water, provide wildlife habitat, and provide outdoor recreation opportunities such as caving. In this study, the scientists were interested in learning about forests growing on karst in Puerto Rico.

**Introduction**

Puerto Rico is an island in the Caribbean and is located in Earth’s tropical region (figures 4 and 5). The northern region of Puerto Rico experiences a lot of rainfall. The southern region of Puerto Rico, in contrast, is semi-arid, an area with light rainfall (figure 6).

About 27 percent of Puerto Rico contains karst landscapes (see “Thinking About the Environment”). Karst is found in both Puerto Rico and many other locations around the world. Figure 2 shows mogotes, which are unusual karst landforms. Mogotes are found in tropical and subtropical regions, including Puerto Rico, Cuba, and parts of China. The sides of some mogotes are almost vertical. Photo courtesy of Ernesto Medina, University of Puerto Rico.

![Figure 2. Mogotes are an unusual karst landform. Mogotes are found in tropical and subtropical regions, including Puerto Rico, Cuba, and parts of China. The sides of some mogotes are almost vertical. Photo courtesy of Ernesto Medina, University of Puerto Rico.](image)

Figure 3. Karst landscapes are found across the United States. Map by Carey Burda and Stephanie Pfeiffer.

[Image 315x515 to 577x757]
Rico’s northern wet region and its southern dry region. Karst soils are shallow, and most karst soil is built from the leaves that fall from forest trees (figure 7). Soils in Puerto Rico’s southern dry karst forests build slowly in the crevices between the pavement sections (figures 8 and 9).

The scientists in this study wanted to compare the chemistry of soils and leaves in Puerto Rico’s northern wet and southern dry karst forests. The northern wet karst forests receive an average of between 1,000 and 1,500 mm of rainfall every year. The southern dry karst forests receive an average of less than 1,000 mm of rainfall every year. The scientists wondered whether southern dry karst forests, since they grow in a semi-arid region, use water more efficiently than northern wet karst forests.

**Number Crunch**

- How many inches of rain do each of the karst regions receive on average every year?

*Hint: Multiply the amounts in millimeters by 0.039 to find out.*

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**Figure 4.** Puerto Rico is a United States territory. Map by Carey Burda and Stephanie Pfeiffer.

**Figure 5.** Puerto Rico is located in Earth’s warm tropical region. Illustration by Stephanie Pfeiffer.
**Figure 6.** Puerto Rico is wet in the north and dry in the south due to the rain shadow effect. The rain shadow effect is the result of a large barrier, like a mountain range, that causes rain to fall on one side of the mountain range while the other side of the mountain remains dry. Illustration by Stephanie Pfeiffer.

**Figure 7.** In some karst areas with mogotes, most of the soil is found in the valleys between the steep mogote hills. Photo courtesy of Ernesto Medina, University of Puerto Rico.

**Figure 8.** Soil is thin in the southern dry karst forests of Puerto Rico. Photo courtesy of Clare McFadden.
Figure 9. Exposed limestone karst pavement is flat and looks similar to concrete pavement. In karst pavement areas, soil is built in the crevices between the pavement blocks. Photo courtesy of Ernesto Medina.

**Reflection Section**

- **Examine figures 7-9.** The northern wet karst forests contain mogote landforms, and the southern dry karst forests have ridges and pavement landforms. Do you think the soil chemistry is similar between these two karst areas? Why or why not?

- Do you think that trees in the southern dry karst forests use water more efficiently than the trees in the northern wet karst forests? Why or why not?

**Methods**

The scientists collected leaves from trees growing in both the northern wet and southern dry karst forests. Leaves from the northern wet karst forest were collected from trees on the mogote tops. Leaves from the southern dry karst forest were collected from trees growing on the ridges and pavement. All leaves were collected from tree canopies.
Recall that the scientists were also interested in the differences in how trees use water in northern wet and southern dry karst forests. After the scientists collected the leaves, they dried the leaves in an oven for 3 to 7 days and then finely ground the leaves. The scientists used specialized equipment to determine which chemicals were found in the leaves collected from the two karst regions. Measuring the chemical content of leaves enabled the scientists to compare leaf chemistry with the chemical content of the soil. This comparison helped the scientists to determine how trees growing in similar soils, but different environmental conditions, adapted to those conditions. The scientists tested leaves for the presence of:

- Carbon
- Nitrogen
- Phosphorus
- Sulfur
- Potassium
- Calcium
- Magnesium
- Aluminum
- Manganese
- Iron

The scientists were also interested in stomatal conductance. The word stomatal comes from the fact that leaves have small openings, called stomata, through which gases enter and exit the leaf (Figure 10). You can see in Figure 10 that carbon enters the leaf as carbon dioxide gas.

Carbon atoms have different atomic masses. Carbon atoms are either Carbon 12, a lighter atom, or Carbon 13, a heavier atom. Carbon 12 atoms are the most plentiful on Earth, making up 98.93 percent of all carbon atoms. When plants have plenty of water, they open their stomata completely. The plant enzyme responsible for the uptake of CO2 in most plants readily takes up the more plentiful Carbon 12 atoms entering the leaf, preferring Carbon 12 atoms to the heavier Carbon 13 atoms.

When plants have a limited supply of water, the stomata do not open completely. In this case, the plant enzyme responsible for the uptake of CO2 will take up all available carbon atoms. Plants in water-restricted environments, therefore, may be more likely to have a greater amount of Carbon 13. The scientists measured the proportion of Carbon 13 to that of Carbon 12 in the leaf tissues. The ratio of Carbon 13 to Carbon 12, therefore, is an indicator of how efficiently uses water.

Figure 10. Small openings that open and close, called stomata, allow gases to enter and exit leaves. Illustration by Stephanie Pfeiffer.
Reflection Section

- Leaves have small openings called stomata. Gases, including water vapor, exit leaves through the stomatal openings. How do you think stomata respond in drier environmental conditions?
- Why do you think soil is built slowly in the southern dry karst forest of Puerto Rico in figure 9?

Findings

For the most part, leaves were similar in Puerto Rico’s two karst regions. Leaves from the northern wet and southern dry karst forests contained similar amounts of magnesium, phosphorus, and nitrogen. Leaves in both the northern wet and southern dry karst forests contained large amounts of calcium. The scientists also found that leaves in both Puerto Rico’s northern wet and southern dry karst forests are limited in phosphorus. Leaves in the southern dry karst forests, however, contain more potassium than leaves in the northern wet karst forests. The scientists believe this difference is because higher rainfall in the northern wet karst region leaches potassium from the soil.

The scientists found that leaves in the southern dry karst forests contained more carbon-13 than leaves in the northern wet karst forests. Leaves that use water more efficiently contain higher levels of carbon-13. Therefore, the leaves from the southern dry karst forests use water more efficiently, meaning that leaf stomata do not completely open, and less water vapor exits the leaves.

Reflection Section

- Based on the findings, what are the two main differences between the chemical content of leaves in Puerto Rico’s northern wet and southern dry karst forests?
- How are the differences you identified in the first “Findings” reflection question above advantageous to southern dry karst forests?

Discussion

The soils in northern wet and southern dry karst forests were similar. Soils from both regions contained limited phosphorus. Low phosphorus levels limit the growth of karst forests in Puerto Rico. The soil in both regions contained high amounts of calcium. Calcium aids plants by holding cell walls together. The southern dry karst forest soils contained more potassium than northern wet karst forest soils. Northern wet and southern dry karst forests can primarily be distinguished by the amount of rainfall they receive.

Why Do Plants Need Potassium?

Potassium is one of 17 essential plant nutrients. Plants absorb potassium from the soil through their root hairs and root tips. Among other uses, plants use potassium in photosynthesis. During photosynthesis, potassium regulates the opening and closing of stomata, and therefore regulates carbon dioxide uptake and water vapor loss.
Reflection Section

- Puerto Rico has a rainforest in its northeastern region. The Puerto Rican rainforest contains large trees and thick vegetation. Based on this research, what might be one difference between the northern wet karst region and the rainforest of Puerto Rico?

- Plants adapt to their environmental conditions. Do you think the presence of more carbon-13 in the southern dry karst region is an adaptation? If so, to what environmental condition are the trees adapting?

Glossary

- **acidic** (a si dik): Containing acid.
- **advantageous** (ad van tā jǝs): Giving an advantage.
- **canopy** (ka nǝ pē): (1) Anything that covers like a roof; (2) On a tree, the upper area of leaves that cover the ground.
- **conductance** (kan dak tǝn(t)s): The readiness with which gases pass into and out of a leaf’s surface.
- **crevice** (kre vǝs): A narrow opening caused by a crack or a split.
- **erode** (i rōd): (1) To wear away; (2) To wear away by water or wind.
- **geochemical** (jē ǝ ke mi kal): Having to do the chemical composition of and chemical changes in the solid matter of the earth or a celestial body (such as the moon).
- **leach** (lēch): To draw out from the soil.
- **nutrient** (nū trē ant): (1) Any of the substances found in food that are needed for the life and growth of plants and animals.
- **optimum** (äp tǝ mam): The amount or degree of something that is most favorable to some end.
- **physiologically** (fi zē a lā ji ka lē): Related to an organism’s healthy or normal functioning.
- **semi-arid** (se mī a rād): An area that receives very little rainfall.
- **sinkhole** (siŋk hōl): A hollow in a limestone region that is related to a cave or underground passage.
- **soluble** (sǝl ǝ bal): Capable of being dissolved in or as if in a liquid, especially water.

Accented syllables are in bold. Marks and definitions are from http://www.merriam-webster.com.
Definitions are limited to the word’s meaning in the article.

Note: This FACTivity was adapted from the USDA Natural Resources Conservation Service and Project Learning Tree.

**Time Needed**

2 class periods (20 minutes of each class period, 24 hours apart)

**Materials**

(for each student or group of students)

- One small succulent (sǝ kǝ lǝnt) house plant for each student pair (figures 11a and 11b)
- One small philodendron house plant for each student pair
- One quart-size “zippable” plastic bag for each plant
- Permanent marker

Leaves take in carbon dioxide and release water vapor and oxygen through small holes on their surface. In dry environments, trees have adapted to conserve the lesser amount of water available to them. In this research, the scientists were interested in the difference between karst forests growing in the wet North and the dry South of Puerto Rico. One of the primary differences between the forests is the amount of average rainfall.

In this FACTivity, you will answer the question: What is the difference between how much water is transpired by different types of plant leaves during the day? Transpiration happens when the water that entered a tree’s roots travels up the tree’s trunk, through its branches, to its leaves, and out of the leaves through small pores called stomata.

**Methods**

**Preparation**

You or your teacher will water all of the plants using an equal amounts of water on the day before beginning the FACTivity.

Figures 11a and 11b. Two easy-to-find succulent house plants are mother-in-law’s tongue and aloe. Photos courtesy of Babs McDonald.
**FACTivity Continued**

**Day One**

Your teacher will divide your class into pairs of students and will give each pair two plastic bags that can be tightly closed. Write your name on the plastic bags. Your teacher will give you one of each type of plant.

Note that one of the plants is a succulent. Succulent plants require less water because they hold water in their leaves. Succulent plants are found in dry environments.

Place the plastic bag on a leaf of each plant and seal the bag as tight as possible. The bag must be applied as early as possible in the day (figure 12). Place the plants with the plastic bags in a sunny location.

Allow the plastic bag to stay on the leaf the remainder of the day. Leaves do not transpire at night, however, you may leave the plastic bags on overnight.

**Day Two**

Being careful not to spill any water that you might find, remove the plastic bags from the leaves. Compare the amount of water transpired from the succulent plant with that of the philodendron. Is there a difference? Why do you think you found the results you did?

As a class, discuss how this FACTivity relates to the article you just read. Which type of house plant would be most likely to be found in either the dry karst forest or the wet karst forest?
You may want to reference these *Natural Inquirer* resources for additional information and FACTivities:

- For more information about tree leaf chemistry, read “Leaf Me Alone!” in the *Natural Inquirer* Tropical edition and “Don’t Litter the Stream” in the *Natural Inquirer* Hawai‘i-Pacific Islands edition.

These resources, along with others, can be found at [http://www.naturalinquirer.org/all-issues.html](http://www.naturalinquirer.org/all-issues.html).

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If you are a trained Project Learning Tree educator, you may use “Every Tree For Itself,” “Rain Reasons,” “How Plants Grow,” “Field, Forest and Stream,” and “Soil Stories” as additional resources.
The Whole Kit and Kaboodle:

Exploring the Relationship Between Land Otters, Tlingit People, and Kit’n’Kaboodle Site

Photo courtesy of stephanjezek, istockphoto.com.
Meet the Scientist

Madonna Moss, Anthropological Archaeologist: One of my favorite science experiences was when I worked at the archaeological site of Nunalleq in 2015. At Nunalleq, wood artifact preservation is fantastic. As I was digging, I found what looked like a toy kayak, but when I rotated it, I saw a deeply incised face. Rotating it again, I could see the face of a walrus. It was described by a Quinhagak elder as a spirit figure and combined the three images into one carving.

What Kind of Scientist Did This Research?

anthropological (an(t) thrə pə lā ji kəl)
archaeologist (är kē ā la jist): This scientist studies the ancient and recent human past through material remains. Material remains are things left behind like bones, ceramics, shells, and other artifacts.

Thinking About Science

The world of science is made up of many different disciplines. In this research, the scientist is an anthropological archaeologist. Anthropology is the study of human cultures or learned behavior patterns of humans. Archaeology is the study of the ancient and recent human past through items that have been left behind. Archaeology is a part of the larger field of anthropology. In

Did You Know?

Tlingit is the language of coastal Southeastern Alaska from Yakutat south to Ketchikan. The total Tlingit population in Alaska is about 10,000 people, who live in 16 communities. Approximately 500 of these people speak the Tlingit language.

Glossary words are bold and are defined on page 43.
this research, the scientist studied the long-term history of Native Americans and First Nations of the Northwest Coast of North America, with a special focus on Tlingit (tliŋ ət) people. The Tlingit people lived along the Pacific Northwest coast and are an indigenous tribe of Alaska.

Because science incorporates many diverse research areas, many new and interesting ways are used to examine something. In this research, the scientist applied her knowledge of Tlingit people, anthropology, archaeology, and animals to a cave that was discovered in southeast Alaska.

**Thinking About the Environment**

Caves are a unique formation that are often found in karst landscapes. Karst is a geochemical landform from which caves and sinkholes are formed (figure 1). Karst is made up of limestone and other soluble rocks. Limestone erodes easily, especially when groundwater or rainfall is slightly acidic. As limestone erodes, water seeps into the ground and further erodes the limestone underneath. This erosion forms caves as well as other features such as sinkholes and underground streams (figure 2a-2d).
In this study, the scientist was interested in a particular site, called Kit’n’Kaboodle, located on Western Dall Island in the Alexander Archipelago (ərˈka pə lə go) (Figure 3). An archipelago is a group of islands. The cave is located in the Tongass National Forest and protected under Federal laws (Figure 4).

Kit’n’Kaboodle Cave was discovered in 1992 by a team from the USDA Forest Service. This cave and others in this area contain remains that interest many different types of scientists. For example, paleontologists, biologists, and archaeologists all have interest in the remains left in these caves. Since 1993, the Tongass National Forest has supported interdisciplinary research to document the caves and the resources they contain.
Introduction

The Tlingit people have many stories and beliefs about the land otter. The land otter, also known as the North American river otter, is a member of the weasel family (figure 5). Traditionally, the Tlingit people believed that all animals had souls and were once people. They believed that land otters had supernatural power. Some Tlingit people believed that land otters could transform into people, and people could transform into land otters. The land otters were deeply respected and feared. The Tlingit people primarily avoided the land otter. However, the spiritual leaders of the Tribe, shamans, sought out the land otters. The land otter was a strong spirit helper for the shaman.

The scientist in this study was interested in learning about whether the Kit’n’Kaboodle site was occupied by land otters at times when people were not present. The scientist also wanted to know if the shells and animal bones left by people differ from the shells and animal bones left by land otters. Additionally, the scientist studied whether land otter behavior affected the beliefs of Tlingit people about the land otter.

Figure 5. North American river otter is a member of the weasel family. The Tlingit people called this animal a land otter. Photo courtesy of stephanjezek, istockphoto.com.

Reflection Section

- All people have stories and traditions that are passed down from generation to generation. What is one story or tradition that has been passed down in your family?
- State in your own words what the scientist was interested in learning.
Method

The Kit’n’Kaboodle site is located at the head of Gold Harbor. Gold Harbor is a bay on Dall Island that is largely sheltered from the heavy storms and surf that are present on the outer coast of the island. The cave has at least four entrances. Three of these entrances show evidence of humans having lived there, including the remains of large fish like halibut or salmon, larger mammals, and bird remains (figure 6).

During 3 field trips to the cave in 1994, 1996, and 1998, the scientist and her team collected 11 samples from 3 different areas in the site. The samples were about 1 gallon in size and contained shells, bones, and other material. These samples were taken to a lab for analysis.

A total of 5,035 bones were analyzed. The scientist identified which bones belonged to which animal. Living things are classified in the following way: Kingdom - Phylum - Class - Order - Family - Genus - Species (figure 7). For some of the bones, the scientist could make identifications to the genus or species level. She counted, weighed, and noted the age and any damage or modification to the bones. The scientist and her team took fine sediment and sifted it over fine-mesh screens. From this, they gathered small bones to be identified.

Figure 6. Salmon are found in many places in the Pacific Northwest. Photo courtesy of U.S. Fish and Wildlife Service.

Figure 7. Examine the way living things are classified. What is the genus and species for a dog? Illustration by Stephanie Pfeiffer.
vegetated shoreline areas. In terms of food, land otters in this area ate fish and mussels (Figure 9).

Since 1978, the scientist has worked with Tlingit people in Southeast Alaska. They taught her a lot about Tlingit culture, but she also studied many books and research papers about this culture. Additionally, the scientist learned from her colleagues who are also students of Tlingit culture.

The team also observed land otter scat, remains of fish and birds, mussel shells, and physical evidence for the presence of land otters. The scientist knew that land otters like to be in areas that have steep, vegetated shorelines (Figure 8). Land otters like to be close to water but minimize exposure to predators by hiding in steep

The team also observed land otter scat, remains of fish and birds, mussel shells, and physical evidence for the presence of land otters. The scientist knew that land otters like to be in areas that have steep, vegetated shorelines (Figure 8). Land otters like to be close to water but minimize exposure to predators by hiding in steep

Findings

Out of the 5,035 bones, the scientists identified bones from 71 vertebrate taxa including 44 fish, 18 birds, and 9 mammals. The bones were identified to the family, genus, or species level. From the samples, the most commonly identified animals were rockfish and Sitka black-tailed deer (Figure 10). However, harbor seal, sea otter, black bear, Pacific cod, lingcod, halibut, tufted puffin, common murre, and pelagic cormorant were also identified (Figures 11 a-d). Some of these remains, such as halibut and harbor seal, would have been from humans using the cave as a shelter. Some of the smaller fish that occupy tidepools in the

Reflection Section

- Material was collected from three different areas of the site. Why do you think it was important for the scientist to collect information from multiple locations?

- Think about the last time you did research on a specific topic at school. Did you use books, the Internet, information from teachers to learn about the topic, or another method? If so, what method of gathering information did you find most useful? Why?
Figure 10. Sitka-black tailed deer are found in coastal rainforests of southeast Alaska and north coastal British Columbia. Photo courtesy of Tongass National Forest, MacDougall.

Figure 11a. Pelagic cormorant is a bird that is found along shorelines. The bird prefers inland shorelines as opposed to open water areas. Photo courtesy of U.S. Fish and Wildlife Service, via Flickr.

Figure 11b. A Common Murre is a bird that is found near oceans. This bird’s diet largely consists of fish and small marine invertebrates. Photo courtesy of U.S. Fish and Wildlife Service, Lowe, via Flickr.

Figure 11c. Lingcod is found only off the west coast of North America. Photo courtesy of Eduardo Baena, istockphoto.com.

Figure 11d. Harbor seals spend half their time in water and half their time on land. Photo courtesy of U.S. Fish and Wildlife Service, Lowe, via Flickr.
intertidal zone were only found in the areas with evidence of land otters.

The team found evidence of land otters at the site. The scat had broken down over time leaving mostly bones and shell fragments that the animal could not digest. They found scattered fish and bird bones as well as pieces of mussel shells. The scientists also noted the physical characteristics of the area surrounding the site. Steep vegetated slopes and overstory vegetation were found near the cave. Land otters would prefer the area because there were places to hide from predators, but still be close to the water.

**Discussion**

The scientist and her team found evidence of both humans and land otters at the Kit’n’Kaboodle site. Based on what the team found at the site and the information gathered about the Tlingit people and land otters, the scientist made some **inferences**. The scientist inferred that the Tlingit people’s beliefs about the land otter may in part be due to the fact that the Tlingit people and the land otter shared the same living space, although occupied the space at different times. The Tlingit people developed a lot of knowledge of land otter behavior and activities. This knowledge helped form some of the Tlingit ideas and beliefs surrounding the land otter.

**Reflection Section**

- In the first paragraph of the Findings section, the last sentence states “Some of these remains would have been due to humans using the cave as a shelter.” What remains do you think would indicate the presence of humans? Why?
- Observation is an important characteristic of a scientist. Why was observation important in this study?
- Think of a time that you closely observed something. What did you learn that surprised you?

**Reflection Section**

- The scientist in this study is an anthropological archaeologist. After having read about the study and what the scientist did, what things did you notice that support the fact that the scientist is an anthropological archaeologist?
- The scientist inferred that sharing space helped the Tlingit people understand land otters better and contributed to the land otter’s presence in Tlingit stories and beliefs. Think about a person or animal you share space with, like a cat, dog, or family member. Do you think by sharing common space with this animal or person, even though you may not be in the space at the same time, helps you to understand the person or animal better? What are some examples?
**Glossary**

*acidic* (a si dik): Containing acid.

*artifact* (är ti fakt): An object made by a human being, typically an item of cultural or historical interest.

*geochemical* (jē ō ke mi kal): Having to do with the chemical composition of and chemical changes in the solid matter of the earth or a celestial body (such as the moon).

*incised* (in sīzd): Cut in or engraved.

*indigenous* (in di jə nas): Living naturally in a particular region or environment.

*inference* (in f(a-)ran(t)s): A conclusion or opinion that is formed because of known facts or evidence.

*interdisciplinary* (in tar di sa plə ner ē): Involving two or more academic, scientific, or artistic disciplines.

*overstory* (ō var stör ē): The layer of leaves in a forest canopy.

*paleontologist* (pā lē ān tā la jist): A scientist who studies the life of past geological periods as known from fossil remains.

*pelagic* (pə la jik): Relating to the open sea.

*scat* (skat): An animal fecal dropping.

*sediment* (se də mant): Material deposited by water, wind, or glaciers.

*shaman* (shā mən): Someone who is believed in some cultures to be able to use magic to cure people who are sick, to control future events, etc.

*sinkhole* (sīnk hōl): A hollow in a limestone region that is related to a cave or underground passage.

*soluble* (səl yə bal): Capable of being dissolved in or as if in a liquid, especially water.

*supernatural* (sü pər na chə rəl): Something attributed to some force beyond scientific understanding or the laws of nature.

*taxa* (tak sa): The name applied to a taxonomic group in a formal system of naming.

*vertebrate* (vər tə brət): An animal that has a backbone.

Accented syllables are in **bold**. Marks and definitions are from **http://www.merriam-webster.com**. Definitions are limited to the word’s meaning in the article.

FACTivity

Note: This FACTivity was adapted from the National Park Service Junior Ranger/Junior Archeologist book. For more information, visit https://www.nps.gov/kids/pdf/jrarcheologistandparentguide.pdf.

Time Needed
2 class periods

Materials
(for each student or group of students)
• A container for time capsule materials
• Blank paper
• Time Capsule Graphic Organizer
• Writing utensil

In this FACTivity, you will think about how you live and what artifacts you would like an archeologist to find one day to help explain the time period you live in now.

Methods
1. Your teacher will put you in pairs or small groups. Once you have been divided up, your pair or group needs to brainstorm a list of items you could put in a time capsule. Your pair or group will need to imagine that an archeologist would find this time capsule 200 years from now. Think about what items would best help the archeologist to understand how you live now and what your culture is about. You also need to think about what kind of materials may be able to last for 200 years in a time capsule. Your teacher will give you 20-25 minutes to brainstorm a list.

2. After the brainstorming is complete, your pair or group will need to narrow down the list to only five items. After you choose the five items, complete the Time Capsule Graphic Organizer. You will share the information in the graphic organizer with your class during the next class.

3. During the next class period, your pair or group will share with the class the five items they chose and why. Your teacher will keep a list on chart paper or the board, so everyone can see what items have been proposed.

4. Once all pairs or groups have shared, your teacher will have each student vote for their top five items from the class list. Once your teacher tallies the votes, your teacher will share them with the class.

5. As a concluding activity, the class can create one time capsule with the five items identified.

Web Resources
Tlingit – Alaska Native Language Center
https://www.uaf.edu/anlc/languages/tl/

Tlingit – Smithsonian National Museum of Natural History
https://naturalhistory.si.edu/Arctic/features/croads/tlingit.html#tlingit

Indigenous People and Languages of Alaska – Alaska Native Language Center
http://www.uaf.edu/anla/collections/map/anlmap.png

Kit ‘n’ Kaboodle Cave
http://apps.usd.edu/esci/alaska/kitkab.html
Name: ____________________________________

FACTivity

**Time Capsule Graphic Organizer**

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A Tale of Two Caves:

How Is Hurricane Crawl Cave Different From Crystal Cave?

Photo courtesy of Dave Bunnell, Under Earth Images.
Meet the Scientists

Joel D. Despain, Hydrologist: My favorite scientific experiences involve understanding the **geomorphic** history of a given cave or cave area. Some geomorphic questions are, “Why did the cave form, and why did it form with these particular shapes and patterns? Is it random?”

It turns out that caves form in specific ways that tell us about past conditions. The history of the cave, the structure of the rock, the hydrology of the region, the **gradient**, and other factors all play big roles. Cave geologists are determining different types of caves and how they develop with greater precision every year. They do this through a better understanding of the shapes, forms, and patterns found within caves. This research is creating a much better understanding of caves that then informs our understanding and knowledge of regional geology and geologic history.

Benjamin W. Tobin, Hydrologist: Each science experience is amazing, interesting, and fun in its own way. If I had to choose, however, my favorite would be conducting dye traces at the Grand Canyon. This work involves dumping a colored non-harmful dye into the ground up on the plateau above the canyon, then monitoring springs in the canyon to determine where the dye showed up. This is simple science. But the results tell us an incredible amount about how water moves below our feet and it never seems to do what we expect.

Greg M. Stock, Geologist: My favorite science experience was mapping caves in Sequoia with Mr. Despain. We used those maps, along with dated **sediment** in the caves, to determine long-term river downcutting rates. The downcutting rate told us the speed at which erosion deepens a channel by removing material from a streambed or valley. It was the perfect mix of field, lab, and computer work, with a neat result.

Glossary words are **bold** and are defined on page 55.
**Thinking About Science**

Science, whether conducted indoors or outdoors, requires some safety precautions. For example, scientists use gloves and safety glasses when using chemicals in a laboratory. A forester may use safety glasses, a hard hat, and boots when working outside in the forest (figure 1). Before starting any activity in science, scientists first evaluate whether they need special equipment to ensure their safety.

The scientists in this study conducted their research in a cave. They needed safety gear specific to the cave environment, such as warm clothes, hard hats, gloves, headlights, and boots. As you read this article, remember to look at the photos of scientists in caves. What safety equipment are they wearing?

Safety, however, is more than just about equipment. Good communication also is important to safety. Whether inside or outside, scientists must communicate when, where, and how they are conducting an experiment. To safely conduct the study described in this monograph, the scientists needed to communicate where and when they were going into the cave. This basic information ensured that the scientists could be helped if a problem occurred.

**What Kinds of Scientists Did This Research?**

- **hydrologist:** A scientist who studies water and the water cycle.
- **geologist:** A scientist who studies Earth, the materials of which Earth is made, the structure of those materials, and the processes acting upon them.

**Thinking About the Environment**

Water moves through and across Earth in a cycle, called the water cycle (figure 2). Water can change as it moves through the water cycle. Water may change forms between a liquid, a solid, and a gas.

Water also can change when it interacts with chemicals within the environment. For example, interactions between water and chemicals can result in the development of caves. Many caves in the United States are formed when groundwater or rainfall absorbs carbon dioxide. The combination of water and carbon dioxide forms carbonic acid, which is slightly acidic. Over time, the water enters cavities in the
rock and slowly dissolves the cavities creating larger open areas.

This process also contributes to the formation of **speleothems (figures 3a-3c)**. The slightly acidic water moves through rocks, dissolving calcite. The water has large amounts of carbon dioxide in it when it enters the cave. The cave air, however, only has a small amount of carbon dioxide, so some or all of carbon dioxide from water is released into the air. This process is similar to when you open a can of soda and the carbon dioxide creates bubbles as it leaves the liquid. The calcite is unable to stay in the water without carbon dioxide, so it is **deposited** onto cave floors, ceilings, and walls forming speleothems.

The scientists in this study found many different speleothems during their research, including large shields, rimstone pools, folia, spar crystals, curtains, and helictites. Some of the speleothems grew so large that they affected the movement of water and sediments through the cave. Speleothems illustrate a portion of the water cycle, as well as how chemicals, like calcium, cycle through the environment.
Introduction

Caves are important natural features in Sequoia and Kings Canyon National Parks in California (figure 4). Past studies of caves in the area have focused on two of the largest caves, Lilburn Cave and Crystal Cave. Studies of these caves revealed information about the area’s mountains, the formation of caves, and the age of rocks.

Another large cave in the area is Hurricane Crawl Cave. Hurricane Crawl Cave was first explored in 1988. Scientists mapped the cave’s approximately 2 miles of passages between 1988 and 1995. The cave has two entrances, multiple levels, two canyons, two mazes, and one large room (figures 5). The main stream that passes through the cave is a sinking stream. This stream starts on Earth’s surface, enters the cave for a period of time, and then returns to Earth’s surface further downhill (figure 6).

The scientists knew that Hurricane Crawl Cave developed under similar conditions to Crystal Cave because they are located near one another. However, the scientists noted that Hurricane Crawl Cave had a different morphology, or structure, than Crystal Cave. Crystal Cave has many levels and mazes, but few canyons. The scientists wanted to know why the morphology is different between Hurricane Crawl Cave and Crystal Cave.

Figure 4. Sequoia and Kings Canyon National Parks are located in the central part of California. Map by Carey Burda and Stephanie Pfeiffer.

Figure 5. Mazes are located near both entrances to Hurricane Crawl Cave. Canyons, named Dusted Canyon and Carotene Canyon, are located near the mazes. The room, called Pumpkin Palace, is located in the middle of the cave. Illustration by Stephanie Pfeiffer.
Methods

To better understand Hurricane Crawl Cave, the scientists collected data regarding the cave’s age. A previous study estimated the age of a rock from inside Hurricane Crawl Cave. From the rock’s location, the scientists measured to the top of the cave and to the bottom of the cave. These measurements enabled them to estimate how long it took for the cave to develop both before and after the rock was deposited.

The scientists also collected information about the past and present movement of water through the cave. Current information about the flow of water was gathered between 2010 and 2012. Specifically, the scientists measured water discharge. The water discharge measurements were taken twice per year at the same location inside the cave, once during June and once during October (figure 7).

Figure 6. A sinking stream is a stream that flows below Earth’s surface for some of its length. This sinking stream is about to go underground at Russell Cave National Monument in Alabama. Photo courtesy of Dale L. Pate, National Park Service.

Reflection Section

• Following the discovery of Hurricane Crawl Cave, scientists mapped the cave and its passages. Why is this an important first step when studying caves?

• Explain in your own words the question the scientists wanted to answer in this research.

Figure 7. The scientists measured water discharge with a pygmy (pig mē) meter. A pygmy meter is placed in a stream and the water spins the bucket. The number of times the bucket spins in a specific amount of time helps determine the flow of water. Illustration by Stephanie Pfeiffer.
The scientists also conducted a dye trace (figure 8). A dye trace involves putting a non-harmful, colored dye in water. Scientists then track and observe the dye to understand the movement of water. Previous research indicated one stream that passed through the cave. In this study, the scientists used a dye trace on multiple streams to confirm if any other streams passed through the cave.

The scientists then chose four transects within Hurricane Crawl Cave to collect data about past water discharge (figure 9). Information about cave scallops and stream cobbles were collected at each transect (figures 10 & 11). You may have heard of animals called scallops, which live in the ocean, but cave scallops are nonliving. Cave scallops are asymmetrical, scoop-like formations on cave surfaces formed by water. Scallops can indicate the direction of water flow and the velocity of water. Stream cobbles are rocks that are carried in the flow of water. A mathematical formula enabled the scientists to determine the velocity of water needed to move the stream cobbles. A total of 327 scallops and 157 stream cobbles were measured across the four transects.

Figure 8. Scientists used a dye trace to track the movement of water. U.S. Geological Survey photo.

Figure 9. The transect locations in Hurricane Crawl Cave as viewed from the side. Illustration by Stephanie Pfeiffer.
Figure 10. Scallops, like the ones pictured here on the ceiling and wall of the cave, can indicate the water velocity. Large scallops indicate slower flow of water, while small scallops indicate faster flow of water. Photo courtesy of Dave Bunnell, Under Earth Images.

Figure 11. Stream cobbles, like those at this person’s feet, are often carried into and through a cave by water. The scientists measured the largest cobbles along each transect because they suggest the maximum velocity of the water. Photo courtesy of Dave Bunnell, Under Earth Images.

Reflection Section

- The scientists repeated a dye trace. How can scientists benefit from confirming the results of a previous study? What did they do to gather new information?
- Review figure 9, focusing specifically on the four transects. What do you notice about these transects? How are they similar or different? Why would the scientists choose these areas for transects to collect data?

Results

The scientists’ observations, combined with the estimated age of the rocks, indicated that Hurricane Crawl Cave is approximately 1.4 million years old. Recall that the scientists also wanted to compare past and present water discharge in the cave.

Scallop measurements at the four transects indicated that the direction of water flow is similar between the past and present. Scallop measurements and stream cobbles both indicated that past discharge of water was greater than current discharge (table 1 and figure 12). Past discharge did not vary across the four transects. Instead, past discharge varied by passage type. Specifically, the wide, upper passages of the cave had very high discharge in the past.

When the scientists completed the dye trace, they found that one sinking stream could be traced through the cave. This finding confirmed previous research results. However, they also found other streams that began in the cave.
Table 1. Mean past discharge was different depending on the type of passage being measured. However, mean past discharge in all passages was higher than current discharge. The scientists measured the water discharge in meters cubed per second, or \( \text{m}^3 \text{s}^{-1} \).

<table>
<thead>
<tr>
<th>Current Discharge</th>
<th>0.002 – 0.042 ( \text{m}^3 \text{s}^{-1} )</th>
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</table>
| Past Discharge (Mean) | 2.7 \( \text{m}^3 \text{s}^{-1} \) (canyons)  
27 \( \text{m}^3 \text{s}^{-1} \) (wide, upper passages) |

**Reflection Section**

- The scientists found additional streams that began inside the cave. How do you think streams form inside the cave? Do you think these streams contributed to the cave development? Why? (Hint: Think about the water cycle.)
- Are you surprised that the direction of water flow is similar between the past and present? Why or why not?

**Discussion**

The scientists determined that Hurricane Crawl Cave likely formed under two different conditions over the past approximately 1.4 million years. First, the wide, upper passages were formed at a time when the cave passages were full of water. The slightly acidic water sloshed like water in a pool, slowly enlarging the passages. Second, the narrow parts of the cave, like canyons and mazes, were formed as water moved downhill under the influence of gravity. The slightly acidic water and the stream cobbles also helped to enlarge the passages. This condition is most similar to what is occurring in the cave today.

**Reflection Section**

- The scientists determined that sediment was a major factor in differences between Hurricane Crawl and Crystal Caves. Do you think sediment has a role in the formation of caves? If so, how?
- Why do you believe it is important to know about how caves formed?

Figure 12. The scientists measured discharge in meters cubed per second. One meter cubed is equal to about 264 gallons. Illustration by Stephanie Pfeiffer.

In both of these past conditions, the high-water discharge was likely because climate conditions were different than current climate conditions. Past climate was cooler and wetter than at the present.

Although Hurricane Crawl Cave and Crystal Cave are located near one another and developed under similar conditions, their morphologies differ. The scientists concluded that the differences in morphology are likely a result of differing amounts of sediment transported through the caves.
Number Crunches

0.002 m$^3$ s$^{-1}$ = 0.528 gallons per second
0.042 m$^3$ s$^{-1}$ = ____ gallons per second
2.7 m$^3$ s$^{-1}$ = ____ gallons per second
27 m$^3$ s$^{-1}$ = ____ gallons per second

(Hint: Filling each blank requires that you first divide, then multiply. For example, divide 0.042 by 0.002, then multiply the result by 0.528.)

Glossary

acidic (a si dik): Containing acid.

asymmetrical (ā sa me tri kəl): Having two sides or halves that are not the same.

cavity (ka və tē): A hollowed-out space.

climate (kli mat): The average condition of the weather over large areas, over a long time, or both.

deposit (de pə zit): To let fall (something, such as sediment).

discharge (dis chärj): To give forth fluid or other contents.

gemorphic (jē a mör fik): Relating to the form of the landscape and other natural features of the earth’s surface.

gradient (grā dē ənt): A part sloping upward or downward.

morphology (mör fā lə jē): (1) Structure; (2) Form.

precaution (pri kō shən): A measure taken beforehand to prevent harm or to bring about a good result.

dediment (se də mənt): Matter set down by wind or water, such as sand or soil.

speleothem (spē lē ō thēm): A cave formation formed by groundwater.

transect (tran(t) sekt): A sample area usually in the form of a long continuous strip.

velocity (və lä sə tē): Speed of movement.

Accented syllables are in bold. Marks and definitions are from http://www.merriam-webster.com. Definitions are limited to the word’s meaning in the article.

FACTivity

Note: This FACTivity was adapted from the National Park Service “Grow Your Own Stalactite” Lesson Plan. For more information, visit: https://www.nps.gov/ozar/learn/education/growown.htm.

Time Needed
Set-up: One class period
Follow-up: 5-10 minutes per day for 4 days

Materials
(for each student or group of students)
• Pictures of decorated cave passages
• Epsom salts, washing soda, or baking soda (Epsom salts and washing soda are more likely to form larger formations)
• Warm water
• 2 plastic cups the same size (preferably clear/see-through)
• 1 piece of aluminum foil to make a “tray” or a small plate/saucer
• 1 spoon
• 1 piece of cotton string or yarn (30-50 cm in length)
• 2 paper clips
• Permanent markers

Caves are well known for the formations that grow inside of them, called speleothems. In “A Tale of Two Caves,” the scientists noted that speleothems were common and diverse in Hurricane Crawl Cave. They were so common, in fact, that some speleothems blocked the movement of water and sediment through the cave. Review the images of the speleothems from the “Thinking About the Environment” section.

Speleothems are formed when groundwater and rainwater absorb carbon dioxide, making the water slightly acidic. The acidic water dissolves calcite from nearby rocks as it moves through the Earth into the cave. When the water enters a cave, the carbon dioxide moves from the water, and the calcite is deposited on cave surfaces. This process is an important reminder of the natural cycling of water and chemicals through the environment.

At the end of this FACTivity, you answer the following question: What does this activity tell us about the formation of speleothems?

Methods
1. Using a spoon, dissolve as much of the chosen material (Epsom salt, washing soda, or baking soda) as possible into two cups that are filled at least halfway with very warm water. It will be easier to see the material being dissolved if the cups are clear/see-through, but it is not necessary. Repeat this process until the solution is well concentrated. A 2:1 ratio of material to water is best.
2. Mark the water level of each cup using a permanent marker. The water levels should be similar between the two cups.
3. Tie a paperclip to each end of the piece of cotton string.
4. Soak the piece of string in the solution until it is completely saturated. Set the cup and the string aside.
5. Fold the piece of aluminum foil to form a small tray. This can be done by folding in the edges and molding the corners. Alternatively, use a small plate or saucer.
6. Your teacher will pick a couple of different locations within the classroom where you can place your tray and cups. Regardless of location, ensure that it is a place that will remain undisturbed for a few days.
7. Lay the string on the cup so that one end of the string (with paperclip) is well inside the solution in one cup and the other end of the string (with paperclip) is well inside the solution in the other cup. The middle section of the piece of string needs to dip below the water levels in the cups (figure 13).
Figure 13. The string should be saturated, and the middle section should dip just below the water level of the cups. Illustration by Stephanie Pfeiffer.

8. Adjust the distance between the middle section of the piece of string and the tray to minimize the amount of splattering that may occur. This distance will depend on the height of the cups being used.

9. Place a small amount of dry material (Epsom salt, washing soda or baking soda depending on the solution being used) on the tray directly beneath the lowest part of the string.

10. Leave the cups for about 4 days.

11. Revisit the experiment to compare results with other students or groups of students. If the results are different, how? Why?

12. Your teacher will discuss with you how speleothem growth is dependent on a number of factors, including air temperature in the cave, precipitation on Earth’s surface, the amount of calcium dissolved by groundwater, and the amount of carbon dioxide absorbed by groundwater.

13. How does this experiment, and the differences between the results, illustrate the potential differences in speleothem growth? Were there differences in the location of the experiments? Check the water level marked by permanent marker. Were the original water levels different between groups? Did the water drip or splash?
What's in a Name?

The title “A Tale of Two Caves” was adapted from Charles Dickens’ famous novel, *A Tale of Two Cities*, which is set in both London, England and Paris, France.

Web Resources

- Sequoia and Kings Canyon National Parks
  https://www.nps.gov/seki/index.htm
- Speleothems (Cave Formations) – Great Basin National Park
  https://www.nps.gov/grba/learn/nature/speleothems-cave-formations.htm
- Learn About Caves – National Caves Association
  http://cavern.com/Learn/
- Cave Safety and Techniques – National Speleological Society
  http://caves.org/safety/

You may want to reference these *Natural Inquirer* resources for additional information and FACTivities:

- To learn more about groundwater, read “Under Where” in the *Natural Inquirer* Freshwater edition.

This journal, along with others, can be found at: http://www.naturalinquirer.org/all-issues.html.

If you are a trained Project Learning Tree educator, you may use “Water Wonders” as an additional resources.
Complete the crossword puzzle below.

ACROSS
4. An organism that causes disease.
5. Relating to the form of the landscape and other natural features of the earth’s surface.
7. Shelters occupied during the winter by a dormant animal.
9. Speed of movement.
10. The area of leaves that cover the ground like a roof.
11. The process of transferring from one person, animal, or place, to another.
16. Capable of being dissolved in or as if in a liquid, especially water.
17. A hollow in a limestone region that is related to a cave or underground passage.
19. Something attributed to some force beyond scientific understanding or the laws of nature
20. A cave formation formed by groundwater.

DOWN
1. The name applied to a taxonomic group in a formal system of nomenclature.
2. The readiness with which gases pass into and out of a leaf’s surface.
3. Any of the substances found in food that are needed for the life and growth of plants and animals.
6. A scientist who studies the life of past geological periods as known from fossil remains.
8. An animal fecal dropping.
12. An organism that feeds mainly on insects.
13. The average condition of the weather over large areas, over a long time, or both.
14. To wear away by water or wind.
15. Material deposited by water, wind, or glaciers.
18. To draw out from the soil.

Created using the Crossword Maker on TheTeachersCorner.net
Caves and Karst eyChallenge

Explain what each of these photos represents. You may write your explanation or hold a class discussion. If you write your explanation, use complete sentences, proper spelling and grammar, and appropriate punctuation.

Photo courtesy of Marvin Morality, U.S. Fish and Wildlife Service.

Photo courtesy of Ernesto Medina.

Photo courtesy of Dr. Andrew Rypel.

Photo courtesy of Jonathan Mays, Maine Department of Inland Fisheries and Wildlife, via U.S. Fish and Wildlife Service.

Photo courtesy of Dave Bunnell, Under Earth Images.
Pygmy water meter

Illustration by Stephanie Pfeiffer.

Rain shadow

Illustration by Stephanie Pfeiffer.


Photo courtesy of stephanjezek, istockphoto.com

Illustration by Stephanie Pfeiffer.
### National Education Standards

For more detailed correlations of this *Natural Inquirer* journal to National Education Standards, visit the *Natural Inquirer* website (http://www.naturalinquirer.org).

#### Which National Science Education Standards Can These Articles Address?

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<th>The Whole Kit and Kaboodle</th>
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### Which National Curriculum Standards for Social Studies Can These Articles Address?

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*Photo courtesy of Brian Cooke*
What Is the Forest Service?

The Forest Service is part of the United States Department of Agriculture (USDA). The Forest Service is made up of thousands of people who care for the Nation’s forest land. The Forest Service manages 154 national forests and 20 national grasslands. These are large areas of trees, streams, and grasslands. National forests are similar in some ways to national parks. Both are public lands, meaning they are owned by the public and managed for the public’s use and benefit. Both national forests and national parks provide clean water, homes for the animals that live in the wild, and places for people to do fun things in the outdoors. National forests also provide resources for people to use, such as trees for lumber, minerals, and plants used for medicines. Some people in the Forest Service are scientists whose work is presented in this journal. Forest Service scientists work to solve problems and provide new information about natural resources so that we can make sure our natural environment is healthy, now and into the future.

http://www.fs.fed.us

What Is the Cradle of Forestry in America Interpretive Association?

The Cradle of Forestry in America Interpretive Association is a 501(c)(3) nonprofit organization based in Pisgah Forest, North Carolina. The interpretive association strives to help people better understand ecology through recreation and education opportunities. Their projects include the following:

- Campground and recreation area management
- Educational programs and services, including *Natural Inquirer, Investigator, Natural Inquirer Reader Series, NSI: Nature Science Investigator*, scientist cards, and *Leaf Prints* (formerly *Nature-Oriented Parenting*)
- Sales of forest-related gifts and educational materials
- Workshops, newsletters, and publications
- Partnership with the Forest Service to provide programming at the Cradle of Forestry Historic Site

http://www.cfaia.org
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Persons with disabilities who require alternative means of communication for program information (e.g., Braille, large print, audiotape, American Sign Language, etc.) should contact the responsible Agency or USDA’s TARGET Center at (202) 720-2600 (voice and TTY) or contact USDA through the Federal Relay Service at (800) 877-8339.

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Web Site Resources

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