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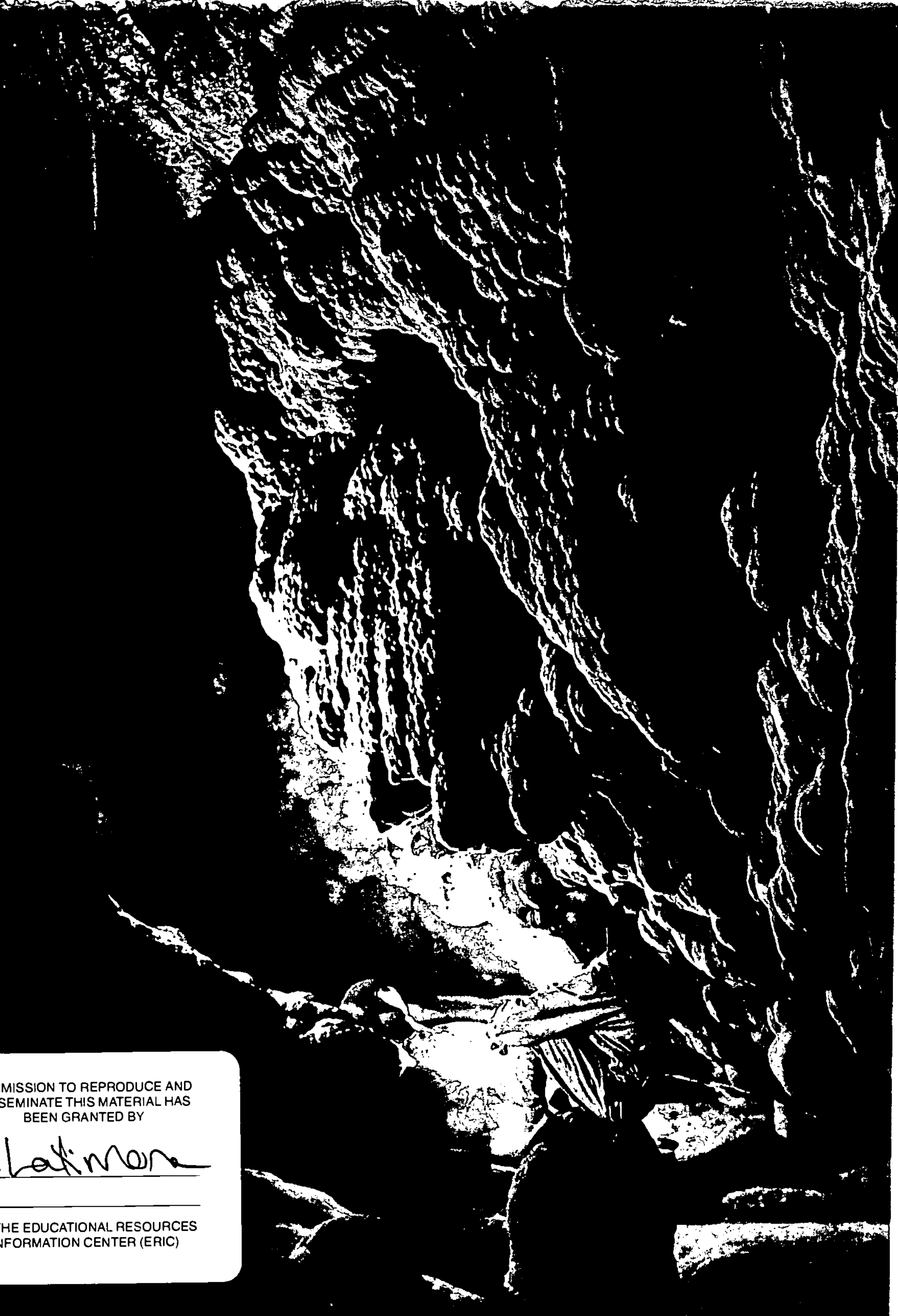
ABSTRACT

This NOVA teacher's guide presents activities, information, and teaching ideas from the Public Broadcasting System's (PBS) NOVA television program series. Episodes include: (1) "Mysterious Life of Caves" which investigates the role microbes play in the creation of some limestone caves; (2) "Lost Roman Treasure" which follows archaeologists working on artifacts in Turkey's ancient city of Zeugma; (3) "Galileo's Battle for the Heavens" which explores the story of Galileo Galilei; (4) "Volcano's Deadly Warning" which describes how volcanologists predict eruptions; and (5) "Sinking City of Venice" which examines the threat from floods Venice, Italy faces. Each activity includes suggestions for instructional strategies to be used before and after watching the programs. Standards are provided for grade levels 5-8 and 9-12. (YDS)

NOVA®

Fall 2002 Teacher's Guide

Major funding is provided by PARK FOUNDATION Sprint. Northwestern Mutual Foundation



Mysterious Life of Caves

Airs October 1, 2002

www.pbs.org/nova/

The Park Foundation is committed to education and quality television. We are pleased to be able to advance the work of NOVA, the preeminent television series in science education. As you know, through study of science, young people acquire skills, knowledge, and—most of all—an intellectual curiosity.

We wish to salute you, as teachers of science, for fostering that intellectual curiosity and passion for investigation among your students. Those skills will serve them well for a lifetime. It is our hope that this NOVA guide will assist you in your effort.

We are grateful for your commitment to teaching.

PARK FOUNDATION

Communication and education go hand-in-hand. As a teacher, there is clearly nothing more important than connecting directly with your students. That's why Sprint is proud to support the newest generation of programs in the informative, award-winning NOVA series.

Soon to enter its 30th year, NOVA offers a unique virtual window into the high-tech world in which we live and work. The series remains at the forefront of science, educating and inspiring with an in-depth look at the latest discoveries and innovations.

Since 1997, Sprint has connected thousands of teachers, parents, and students across the country through a variety of community relations programs. We are pleased to continue opening the lines of communication and exploration in the classroom and beyond through our sponsorship of the *NOVA Teacher's Guide*.

Sincerely,

Charles E. Levine
President
Sprint, PCS Division

Sprint®

Contents & Broadcast Schedule

NOVA Teacher's Guide Fall 2002

Because of schedule changes, some NOVA programs do not have lessons.

- * one-year off-air taping rights
- ** seven-day off-air taping rights
- + program title may change
- (R) repeat program
- 📘 lesson within this guide
- 💻 lesson online at: www.pbs.org/nova/teachers/

NOVA in the Classroom

Scientists Who Dare to Be Different

Dear Educators,

Science is born out of curiosity, and thrives on the persistence and determination of its creators. This season NOVA showcases two stories in science—one historical and one present-day—in which scientists breathe life into controversial theories that result in new ways of understanding the universe, and our place within it.

With his new instrument, the telescope, Galileo Galilei found evidence for a Sun-centered universe. This flew in the face of religious teachings that, in Renaissance Italy, held that Earth was the center of all things. Eventually, Galileo was brought before the Inquisition and forced to recant. But his legacy survived and his ideas laid the foundation for modern physics and astronomy. Learn his story in "Galileo's Battle for the Heavens."

Even in modern times scientific revolutions occur. For example, until recently, most scientists believed that all caves were formed by the same process: rainwater seeping underground formed a weak carbonic acid which, over time, carved out even the most massive and complex cave systems. But recently, a small group of scientists discovered tiny microbes that consume toxic gases and produce corrosive acid, resulting in caverns of majestic size and beauty. Most researchers now accept that biology, not just geology, plays a role in forming some of nature's underground wonders. "Mysterious Life of Caves" tells this story of discovery.

I believe these programs will show your students the importance of independent thinking. As Galileo wrote, "If reasoning were like hauling I should agree that several reasoners would be worth more than one, just as several horses can haul more sacks of grain than one can. But reasoning is like racing and not like hauling, and a single Barbary steed can outrun a hundred dray horses." These words are as true today as they were when Galileo penned them almost 400 years ago.

Paula S. Apsell

Paula S. Apsell
NOVA Executive Producer

Visit NOVA Online's Teachers Site www.pbs.org/nova/teachers/

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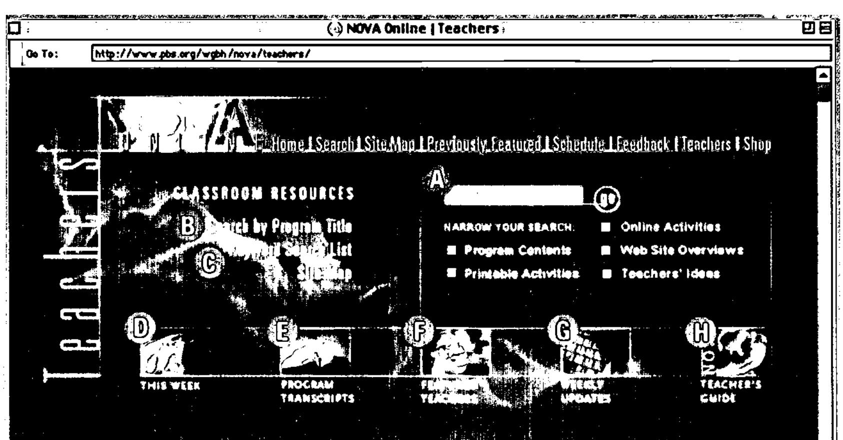


NOVA Featured Teacher

Teaching Science and Literacy

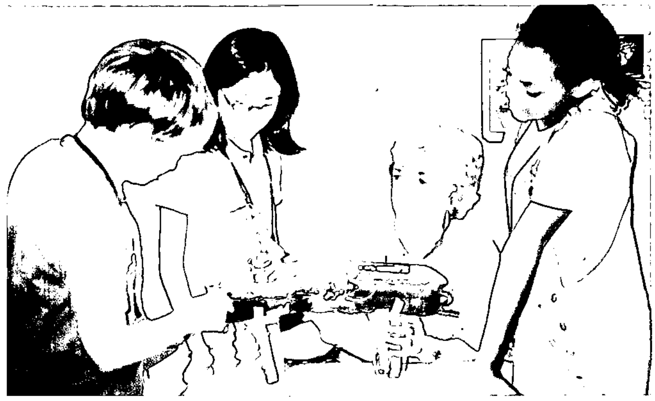
Kathleen Poe recently turned to Jules Verne to help her teach science. A district-wide emphasis to increase students' reading abilities led Poe to Verne's *From the Earth to the Moon*, which she combined with NOVA's "To the Moon" program and hands-on activities to create a unit that combines science and literacy.

Poe teamed up with English teacher Jon Kern to develop the unit that asks students to read a fictional work for information. Students at Fletcher Middle School in Jacksonville Beach, Florida, begin by reading Verne's 1865 book at home or in class. For example, students read the character Barbicane's statement, "It is perhaps reserved for us to be the Columbuses of that unknown world. If you understand my plan and do everything in your power to carry it out, I will lead you in the conquest of the Moon..." Then Poe plays the segment of the NOVA program where John F. Kennedy says, "I believe that this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the Moon and returning him safely to the Earth."

Class discussions focus on both literary interpretation and scientific content. As students start to make sense of the real and the fiction, they use the John Fitzgerald Kennedy Library and Museum Web site to listen to Kennedy's full speech at **www.jfklibrary.org/j052561.htm**. This serves as a springboard for making flipbooks to animate lunar phases or looking at maps of physical features on the lunar surface.

In another example, the book characters send a letter to an observatory asking for information about the Moon. This leads to a class study of the Moon with activities illustrating how craters formed, studying the Apollo landing sites, and comparing Earth's rocks with lunar rocks. Students view the segment of the NOVA program in which geologist Jack Schmitt visits the Moon on Apollo 17.

In a third example, students discuss the fictional characters' plan for supplies needed on their journey and view the segment from the NOVA program on Apollo 13. This leads to a class discussion about survival needs in space. Students design and build a biome in a 2-liter bottle to support two living organisms over their 10-day spring break.



From left, Adam Hansford, Meng Liu, teacher Kathleen Poe, and Leah Copeland talk about the biome students were instructed to build. Their task was to create an environment that contained no less than two life forms that would survive during spring break.

Poe, who has been teaching for 31 years, says students are often surprised at the similarities between the fictional 1865 work and the history of the U.S. space program. Poe has anecdotal information that this interdisciplinary work is leading to a greater interest in reading (for example, students are checking out more books) and the district emphasis is leading to improved reading scores.

For more information about Poe's project, you can e-mail her at: **skyteachr@aol.com**

Become a NOVA Featured Teacher

We'd like to hear from YOU! Tell us how you're using a NOVA program, the *NOVA Teacher's Guide*, or NOVA Online in your classroom. Your lesson idea will become a part of our Teachers' Ideas section online and you will become eligible to become a NOVA Featured Teacher. If you are chosen, we'll send you and your students six free NOVA videos or two Classroom Field Trip kits of your choice.

Send your ideas to:
Erica Thrall
WGBH
125 Western Avenue
Boston, MA 02134
erica_thrall@wgbh.org

Or post them at:
www.pbs.org/nova/teachers/ideas/send.html

Mysterious Life of Caves

Airs Tuesday, October 1, 2002 • www.pbs.org/nova/caves/

Program Contents

NOVA follows geologists and microbiologists as they explore caves in various stages of formation to investigate the role microbes play in the creation of some limestone caves.

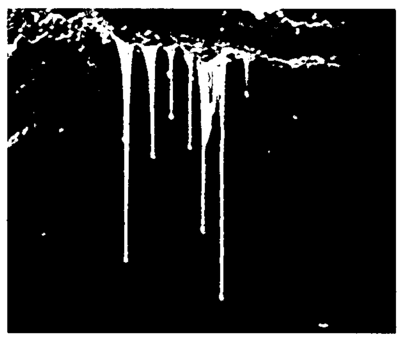
The program:

- reviews the traditional theory that caves form when weak carbonic acid—created when flowing rain and groundwater pick up carbon dioxide from the air and soil—penetrates cracks in rocks and dissolves the limestone.
- introduces the theory that microbial processes are responsible for the production of sulfuric acid that forms some caves.
- examines how researchers studying caves in New Mexico's Guadalupe Mountains came to theorize that microbes feeding on oil far beneath the caves produced hydrogen sulfide gas that seeped into the rock above, mixed with oxygen in the groundwater, and formed limestone-dissolving sulfuric acid.
- reviews other environments in which microbes live in extreme heat, pressure, and darkness.
- presents the discovery of microbes in caves that survive solely on chemical nutrients, including a type that eats hydrogen sulfide gas and excretes sulfuric acid.

Before Watching

1. Ask students what they think it is like to do cave research. How much light might there be? How hot or cold do they imagine it is? How cramped or open?

2. Researchers in this program find a variety of microbes living in extreme environments. Have students take notes about where microbes are found and what role they play in the life of the cave.



Cueva de Villa Luz in southeastern Mexico features hanging mucus-like columns such as these. The columns contain sulfur-eating bacteria that produce sulfuric acid.

After Watching

1. Discuss with students the conditions of working in a cave. What was the environment like? What seemed like the most difficult part of the expedition? What kind of precautions did researchers take?

2. Review students' notes about the different kinds of microbes researchers discovered. Where did researchers find microbes? What processes, if any, did the microbes perform? What questions do researchers still have about the microbes?

Activity Setup

Objective

To understand that microorganisms can survive in many different environments and that microorganisms live in places where conditions are suitable for their growth.

Materials for each group

- copy of the *Microbial Townhouse* activity sheet on page 6
- 4-inch square of black-and-white newspaper
- hard-boiled egg
- 5 cups of mud
- 1 cup of de-chlorinated water
- bucket
- large stirring spoon
- 1 tablespoon powdered chalk
- 2-liter clear plastic bottle with top cut off
- paper cup
- plastic wrap
- rubber band
- sheet of red cellophane or acetate (for one group only)

Procedure

1. Tell students that they will be studying how microorganism populations grow in different mediums and how they change the environment in which they live. They will be creating three mud columns to study how different microbes will inhabit different environments, depending on the conditions that exist.

2. Have students collect mud. The best mud comes from the margins of fresh or saltwater ponds or marshes. Moist field soils can be used, but are less likely to produce easily observed microorganisms.

3. Cut off the plastic bottle tops. Hard boil the eggs. Organize students into three groups and distribute a copy of the *Microbial Townhouse* activity sheet and a set of materials to each group.

4. Have students follow activity sheet instructions to create their columns. Have one group add red cellophane or acetate around its column. After the columns are made, ask students to predict what, if any, changes they think will occur over time and why.

5. Students will study the columns under three variables: light, darkness, and filtered light. Have one group place its column in a well-lit place, but not in direct sunlight. Have the group making the red-acetate-wrapped column do the same. Have the final group place its column in the dark.

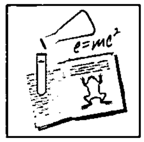
6. Have students observe the columns daily for six weeks. Students should record and describe their observations. Ask students what might have caused the layers they see. Why might the layers be different? Why might different microorganisms grow in different places? What are the differences among the three columns? What might be responsible for those differences?

7. As an *extension*, have students re-create the experiment using moist soils from other locations, such as their backyard, forest area, or garden.

Standards Connection

The activity found on page 6 aligns with the following *National Science Education Standards*.

Grades 5–8



Science Standard A:
Science as Inquiry

Understanding scientific inquiry

- Scientific explanations emphasize evidence, have logically consistent arguments, and use scientific principles, models, and theories. The scientific community accepts and uses such explanations until displaced by better scientific ones. When such displacement occurs, science advances.
- Science advances through legitimate skepticism. Asking questions and querying other scientists' explanations is part of scientific inquiry. Scientists evaluate the explanations proposed by other scientists by examining evidence, comparing evidence, identifying faulty reasoning, pointing out statements that go beyond the evidence, and suggesting alternative explanations for the same observations.

Grades 9–12

Science Standard G:
History and Nature of Science

Nature of scientific knowledge

- Science distinguishes itself from other ways of knowing and from other bodies of knowledge through the use of empirical standards, logical arguments, and skepticism, as scientists strive for the best possible explanations about the natural world.
- Because all scientific ideas depend on experimental and observational confirmation, all scientific knowledge is, in principle, subject to change as new evidence becomes available.

What Is That Smell?

Is that rotten eggs? The columns may smell that way after a few weeks once microbial colonies create a sufficient amount of hydrogen sulfide. Keep the bottles in a well-ventilated space to disperse the odor. Keep the bottles sealed and prepare students for a strong smell when they are reopened.

Microbial Townhouse

NOVA Activity **Mysterious Life of Caves**

Researchers are finding that microorganisms can live in places they never expected, like deep in the ocean or far below Earth's surface in caves where sunlight fails to penetrate or where poisonous gases exist. In this activity, you will see how microorganisms can develop in different environments depending on what they need to live.

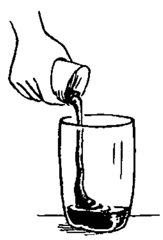
Procedure

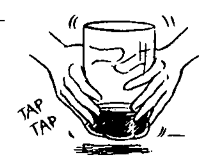
1. Begin by ripping a newspaper square into tiny bits.
2. Crack the hard-boiled egg and break the yolk into bits. Discard the white and the shell.
3. Combine the mud and just enough water in the bucket to make a thick mud soup. Use the spoon to mix thoroughly. When the mud and water are combined, stir in the newspaper, egg yolk, and chalk.
4. Add the mixture to the bottle with a paper cup to one inch from the top. Tap the bottle on the table between additions to remove air bubbles.
5. Let stand for 30 minutes. Gently add enough water so that there is a top layer of water about a half-inch deep above the mud surface.
6. Cover the top of the bottle with plastic wrap and secure with the rubber band. The gas produced by the microorganisms is very smelly, so keep the plastic wrap on at all times.
7. Stand your bottle either in a well-lit place or in a dark place as directed by your teacher. Do not move the bottle.
8. Do not let the bottle dry out. Add or remove water to the top to maintain the half-inch depth.
9. Observe and record changes with sketches and descriptions each day for six weeks. After the six-week period is over, answer the questions below.

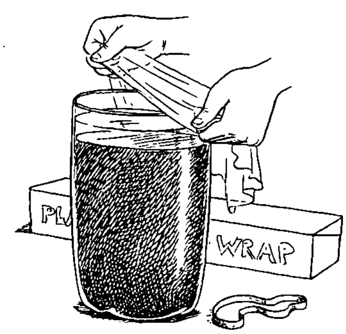
Questions

Write your answers on a separate sheet of paper.

1. Did any changes occur in the bottle? If so, what is your evidence?
2. How many different life forms seem to exist?
3. Propose an explanation for the existence of the different things that you see in the bottle.







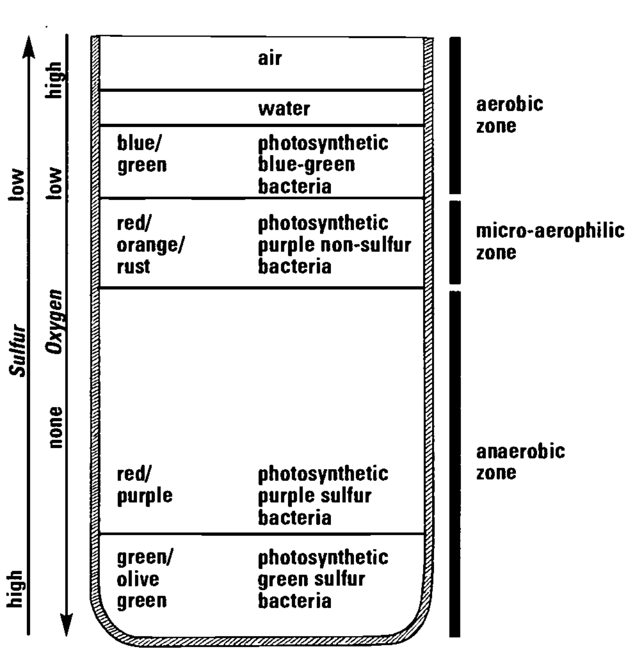
Activity Answer

Students developed a mud column known as a Winogradsky column. It is named after Sergei Winogradsky who devised it in the 1880s to study microorganisms in the soil. Different microorganisms will grow in each column depending upon their environmental needs.

Column in sunlight

Many of the microorganisms that developed in this column are photosynthetic; that is, they use light to give them energy to make food. However, the colonies throughout the column differ by their light, oxygen, and nutrient needs. Those at the top (cyanobacteria and any green algae) use visible light wavelengths to survive while those below use sulfur from the egg yolk or carbon from the newspaper and chalk as their energy source.

After the columns are set up, the metabolic activity of the original microorganisms in the mud soon reduces the oxygen level throughout the column. At the top, enough oxygen diffuses through the plastic wrap and water to sustain a high oxygen zone. This creates an oxygen gradient in the column; high oxygen near the top, low oxygen near the bottom. This oxygen gradient favors the growth of oxygen-dependent organisms near the top, while the growth of bacteria that don't need oxygen is favored near the bottom. Non-oxygen dependent bacteria that use sulfur for energy also produce smelly and toxic hydrogen sulfide gas. These bottom bacteria create a second, opposite, gradient of hydrogen sulfide; high near the bottom and low near the top. These gradients produce specific zones of opportunity for different microorganisms. Students will observe these zones, and the growth of the microorganisms in them, as colored bands.



Possible Sunlight Column Results

Column in sunlight with red cellophane

Students likely will see some of the types that grow in the sunlight column because, like some of the microorganisms that grew in the clear plastic bottle, the ones that grow in this column need red light wavelengths to survive. (The red cellophane will absorb all other light wavelengths.)

Column in dark

Students may see types of non-photosynthetic bacteria growing in this environment.

Resources

Books

Taylor, Michael.
Lechuguilla: Jewel of the Underground.
Huntsville, AL: National Speleological Society, 1998.
Discusses the biological research and mapping efforts taking place in Lechuguilla.

Wolfe, David.
Tales from the Underground:
A Natural History of Subterranean Life.
Cambridge, MA: Perseus Publishing, 2002.
Presents a glimpse of a mysterious underground world and the scientists who study it.

Article

Eliot, John.
"Deadly Haven: Mexico's Poisonous Cave."
National Geographic, May 2001, pages 70–85.
Explores Villa Luz, home to microbial colonies called snottites and other forms of life that live on sulfur.

Web Sites

NOVA Online—Mysterious Life of Caves
www.pbs.org/nova/caves/
Provides program-related articles, interviews, interactive activities, and resources.

Biospeleology
www.utexas.edu/depts/tnhc/.www/biospeleology/
Explores the world of cave biology.

Investigating Bacteria with the Winogradsky Column
www.woodrow.org/teachers/bi/2000/Winogradsky_Column/winogradsky_column.html
Provides in-depth information about building a Winogradsky column and identifying the microorganisms within.

Lost Roman Treasure

Airs Tuesday, October 8, 2002 • www.pbs.org/nova/zeugma/

Program Contents

NOVA follows an international team of archaeologists as they work to save artifacts from Turkey's ancient city of Zeugma, which will be flooded when a new dam is filled.

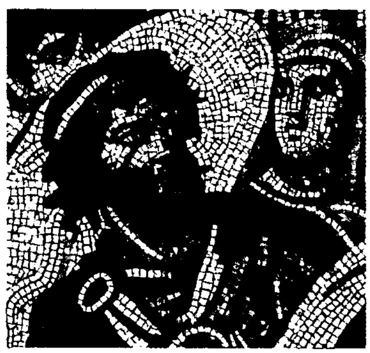
The program:

- details Zeugma's strategic location on the banks of the Euphrates River and the Silk Road.
- describes how magnetometers and ground-penetrating radar were used to map the city's buried walls, streets, and buildings.
- recounts the uncovering of an extensive sewer network and ancient Roman villa.
- presents the historical and artistic treasures removed by archaeologists, including elaborate Greek mythology mosaics.
- illustrates the variety of expertise needed to locate, excavate, and interpret historical artifacts.
- describes the conflicting goals of the residents, government officials, and archaeologists.
- details how 30,000 people were relocated and how the artifacts and mosaics not excavated were inundated by floodwaters when the dam was opened in 2000.

Before Watching

1. Help students locate Zeugma on a contemporary world map or globe *(it is near Nizip in Turkey's Gaziantep province).*

2. Organize students into three groups. Assign groups to take notes on the opinions about the dam as viewed by 1) the government officials, 2) the archaeologists, and 3) the people being displaced from their homes.



Some mosaics found on site were removed for display elsewhere; others were recorded in myriad ways, including being photographed and traced full-size on acetate film.

After Watching

1. Have students revisit their notes about how each group viewed the building of the dam. What was the impact of the dam? What were the advantages and disadvantages for each group? What were the human costs and benefits?

Activity Setup

Objective
To consider what future archaeologists might assume about a present-day city.

Materials for each group
- copy of the *Uncovering Your City* activity sheet on page 10
- local city map with grid

Procedure

1. Tell students that they are archaeologists working in the year 4000 A.D. They have been assigned to excavate an area that was buried by an earthquake in the year 2002 A.D. Ground-penetrating radar studies have revealed the street layout, and historic maps of the city have helped identify the streets and surrounding structures. Funds are limited so only certain parts of the city can be excavated. In their role as archaeologists, students will identify those areas based on which area they think may reveal the most information. Their objective is to figure out what would still exist and in what context it would exist in.

2. Organize students into groups and provide each group with a copy of the *Uncovering Your City* activity sheet and a local city map.

3. Have each group choose a one-quadrant area of the map (or a section of a quadrant, depending upon the complexity of the map). In choosing their section, students should consider what they might find in each section and what it could tell them about the community.

4. After students choose their section, have them redraw their chosen area onto the activity sheet. Have them create a new map scale for the resized version of their chosen area.

5. Now have students carefully study the section they have chosen. If they were to excavate it, what might they find? What would most likely be gone after 2,000 years of being buried? What might be left? What conclusions might students draw from the artifacts about the city and its inhabitants? Students may want to categorize their finds in groups such as transportation, climate, food, family structures, occupations, and social activities.

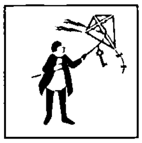
6. To conclude, have each group report what they think they would find. Then have the class look at all the evidence collected. Would any groups make additional inferences now that they have a larger context in which to consider the items they found?

7. As an *extension*, have students consider what they might put in a vacuum-sealed time capsule to best represent their community.

Standards Connection

The activity found on page 10 aligns with the following *National Science Education Standards.*

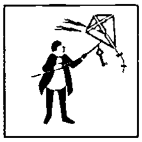
Grades 5–8



Science Standard G:
History and Nature of Science

Science as a human endeavor
- Science requires different abilities, depending on such factors as the field of study and type of inquiry. Science is very much a human endeavor, and the work of science relies on basic human qualities, such as reasoning, insight, energy, skill, and creativity—as well as on scientific habits of mind, such as intellectual honesty, tolerance of ambiguity, skepticism and openness to new ideas.

Grades 9–12



Science Standard G:
History and Nature of Science

- **Science as a human endeavor**
Individuals and teams have contributed and will continue to contribute to the scientific enterprise. Doing science or engineering can be as simple as an individual conducting field studies or as complex as hundreds of people working on a major scientific question or technological problem.

Uncovering Your City

NOVA Activity **Lost Roman Treasure**

You are an archaeologist in the year 4000, assigned to excavate a part of your city that was buried by an earthquake in the year 2002. You will be assigned a four-quadrant area on your map and, because of limited funds, must choose which section of that area to excavate. Once you choose what part of the city to uncover, think about what might be left after almost 2,000 years and what it would say about your city and its inhabitants.

Procedure

① Look closely at the map you have been assigned. You can only excavate one quadrant of this area. In choosing your excavation area, consider what you might find and what it could tell you about this community.

② Once you have chosen your section, redraw your chosen area on a separate sheet of paper. Create a new map scale for your resized version of your chosen area.

③ Carefully study the section you have chosen and record the objects you think you might find there. Consider whether each item you might find would have survived for almost 2,000 years.

Questions

Write your answers on a separate sheet of paper.

① What were your reasons for choosing your selected section?

② If your city were buried as it is today, not everything would survive for 2,000 years. What do you think would survive? What do you think would not survive?

③ What might you conclude about the city and its people from the surviving artifacts?

④ Using present-day archaeological methods, list some ways you might discover more information about the artifacts you found.

Activity Answer

Students should consider what they might find when choosing their area to excavate. An area containing a sports field may reveal information about social rituals but little else. A housing area may reveal the same information (from some of the sports equipment found in childrens' rooms) as well as additional information about family life.

As students consider what might be left and the context in which it might exist, they should think about how the earthquake might have altered city structures and infrastructures, such as buildings and sewer systems. Many other items also may not be found intact, such as motorcycle or car engine parts. These could have multiple origins and would need other artifacts to put them into context.

Students may have different opinions about what might survive or about how the artifact was used. Archaeologists sometimes disagree in their interpretations of artifacts. Since they usually are working from fragmentary evidence, additional evidence is often needed to substantiate or refute current theories.

Unless destroyed by fire or other event, there would likely be many material remains that could reveal information about the city, including:

- building foundations
- infrastructure for sewer, water, and cable systems
- household appliances such as stoves, microwaves, washing machines, and furnaces
- business appliances, such as restaurant soda dispensers, dry cleaning equipment, and postal sorting machines
- statues and other stone or metal structures
- human and animal remains

Unless they were properly stored or trapped in a preserving material, organic materials such as cloth, paper, and food would no longer exist.

Considering archaeological techniques in use today, students might be able to learn more about their artifacts by using dating techniques such as tree-ring dating or carbon dating or other discovery techniques such as chemical analysis. Historical accounts of the period may help reveal what some items were used for or the kinds of social or religious rituals that the community engaged in, including sports and cultural events.

Resources

Book

Stark, Freya.
Rome on the Euphrates.
New York: Transatlantic Arts, 1975.
Recounts the history of Roman warfare along the Euphrates for eight centuries, beginning in about 200 B.C.

Articles

Kinzer, Stephen.
"Dam in Turkey May Soon Flood a '2nd Pompeii.'"
The New York Times, May 7, 2000, page 1.
Describes Zeugma work and raises some questions about the impact of the dam on the archaeological site, residents, and the environment.

Kinzer, Stephen.
"A Race to Save Roman Splendors from Drowning."
The New York Times, July 3, 2000, page 3.
Describes the archaeological project at Zeugma.

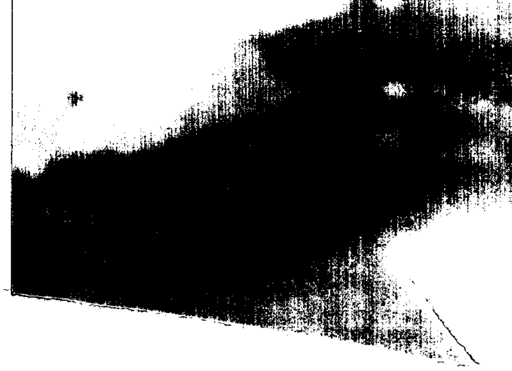
Web Sites

NOVA Online—Lost Roman Treasure
www.pbs.org/nova/zeugma/
Provides program-related articles, interviews, interactive activities, and resources.

Community Archaeology Program Teacher Resources
cap.binghamton.edu/tchresource.html
Offers links to an annotated list of archaeology Web sites and sample lesson plans that incorporate archaeology into the classroom.

Physics and Archaeology
physicsweb.org/article/world/13/5/10
Describes physics-related aspects of archaeological research, including radioisotope and radiocarbon dating, various magnetic imaging techniques, and ground-penetrating radar.

The Zeugma 2000 Archaeological Project
www.zeugma2000.com/zeugma.html
Introduces the archaeologists and excavation project at Zeugma, with links to photo galleries, descriptions of work done, and much more.



Program Contents

NOVA explores the story of Galileo Galilei—his scientific contributions, his clash with the Catholic Church, and his correspondence with his convent daughter.

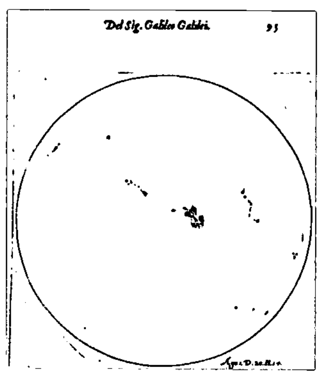
The program:

- provides an historical backdrop of 17th-century Italy, including the spread of the bubonic plague, the role of the Inquisition, and the influence of powerful court families.
- examines Galileo's astronomical discoveries, including four of Jupiter's moons, sunspots, and the rotation of the Sun.
- highlights Galileo's role as founder of modern physics due to his studies of motion and his experiments with inclined planes.
- shows Galileo's talent as an inventor with his improved telescope design.
- tells of Galileo's correspondence with his illegitimate daughter, Maria Celeste, who embraced the tenets of the Catholic Church and became a nun.
- chronicles Galileo's clash with the Catholic Church following publication of his *Dialogue on the Two Chief World Systems,* a rhetorical masterpiece in support of the Copernican Sun-centered system.

Before Watching

1. Ask students what they know about Galileo Galilei. Where and when did he live? *(In Italy during the 16th and 17th centuries.)* What did he do? *(He was considered the first truly modern scientist because of his systematic observation of the real world; his main contributions were in the fields of physics and astronomy.)* What happened to Galileo? *(He was tried and found guilty in 1633 by the Catholic Church's Inquisition for his scientific beliefs.)*

2. Galileo made a number of scientific observations during his lifetime. As they watch, have students take notes on his contrbutions to science. Have students record what Galileo studied, how he studied it, and any conclusions he drew.



Galileo observed sunspots and recorded them in drawings like this. Sunspots represent cooler areas of the Sun's photosphere.

After Watching

1. Lead a discussion about Galileo. What was the most powerful institution in Italy when Galileo lived? How did his discoveries contradict beliefs of his time? What happens when discoveries don't fit into the currently held belief system? How are controversial science research efforts, like fetal tissue research or cloning, handled by today's institutions, such as government or religious organizations?

2. Review students' notes about Galileo's scientific contributions. What areas did he study? Which of his scientific discoveries were the most revolutionary and why?

Activity Setup

Objective

To construct and evaluate graphs of the current sunspot cycle.

Materials for each student

- copy of the *Plotting the Spots* activity sheet on page 14
- 5- or 10-square-per-inch graph paper
- pencil

Procedure

Galileo studied sunspots, sketching pictures of the changing pattern of spots on the Sun over time. In this activity, students will study the nature of sunspot cycles.

Lead a class discussion about sunspots. (See *Activity Answer* on page 15 for detailed information on sunspots.)

Following the discussion, give each student a copy of the *Plotting the Spots* activity sheet.

Review with students the definitions for solar minimum and solar maximum. Have them study the sunspot cycles from 1900 to 1995 on the graph found on the activity sheet. Ask students to look for patterns in the data.

Have students label the graph with an *x* for each solar maximum and an *m* for each solar minimum. Have them estimate the year when each cycle started and when it ended, calculate the length of each cycle, and calculate the average length for the nine cycles shown on the graph. Discuss their results. Be flexible with the accuracy of reading the years of solar maximum and minimum. The average should be approximately 11 years.

Provide students with graph paper. Have them graph the data for Solar Cycle 23. If using 5-quadrille paper, students will each require three sheets; if using 10-quadrille, students will require two sheets.

When students' graphs are complete, discuss their results using the questions on the activity sheet. You might want to make an overhead copy of the graphs to facilitate the discussion.

As an *extension*, have students research whether the year 2000 solar sunspot maximum caused any significant disruptions in communications on Earth. Were any abnormal auroras reported? Were any satellites, Earth-bound communications, or power systems influenced by the solar maximum? For more information, see: **www.exploratorium.edu/solarmax/news.html**

Standards Connection

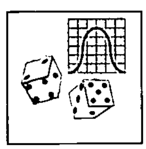
The activity found on page 14 aligns with the following *National Science Education Standards* and *Principles and Standards for School Mathematics.*

Grades 5–8

Science Standard D:
Earth and Space Science

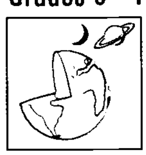
Earth in the solar system

- The Earth is the third planet from the Sun in a system that includes the Moon, the Sun, eight other planets and their moons, and smaller objects, such as asteroids and comets. The Sun, an average star, is the central and largest part in the solar system.



Mathematics Standard:
Data Analysis and Probability

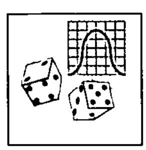
Grades 9–12



Science Standard D:
Earth and Space Science

Energy in the earth system

- Earth systems have internal and external sources of energy, both of which create heat. The Sun is the major external source of energy. Two primary sources of internal energy are the decay of radioactive isotopes and the gravitational energy from the Earth's original formation.



Mathematics Standard:
Data Analysis and Probability

Plotting the Spots

NOVA Activity **Galileo's Battle for the Heavens**

Sunspots are cooler areas on the Sun that appear as dark spots. These spots tend to occur in cycles that start at the solar minimum (when the fewest spots occur), reach their solar maximum (when the most spots occur), and reduce again in number until the cycle begins again. Can these spots and their cycles tell us anything? Do this activity to find out.

Procedure

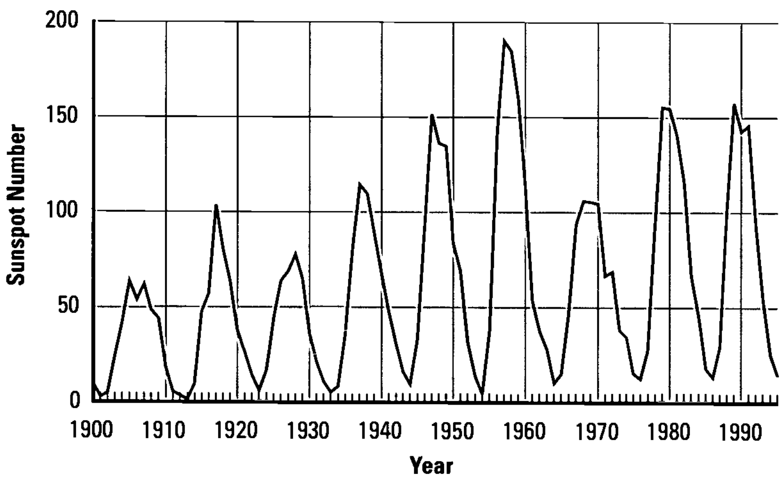
1. Observe the following graph of the sunspot cycles from 1900 to 1995. List any patterns that you notice. How is each cycle similar? How is each cycle different?
2. Label the graph with an *x* for each solar maximum and an *m* for each solar minimum.
3. From the graph, estimate the year when each cycle started and when it ended. Calculate the length of each cycle and the average length for the nine cycles shown.
4. Graph the data from Solar Cycle 23 below on your sheets of graph paper.

Questions

Write your answers on a separate sheet of paper.

1. When did Solar Cycle 23 begin?
2. Did Solar Cycle 23 reach its solar maximum? If so, when did this occur?
3. Based on the average you calculated for the other solar cycles, when do you predict this cycle will end?
4. Can you predict when the next solar maximum might occur? Explain your prediction.

Sunspot Cycles 1900–1995



Source: National Geophysical Data Center Sunspot Numbers Web site at: **www.ngdc.noaa.gov/stp/SOLAR/SSN/ssn.html**

Solar Cycle 23

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1995	24.2	29.9	31.1	14.0	14.5	15.6	14.5	14.3	11.8	21.1	9.0	10.0
1996	11.5	4.4	9.2	4.8	5.5	11.8	8.8	14.4	1.6	0.9	17.9	13.3
1997	5.7	7.6	8.7	15.5	18.5	12.7	10.4	24.4	51.3	22.8	39.0	41.2
1998	31.9	40.3	54.8	53.4	56.3	70.7	66.6	92.2	92.9	55.5	74.0	81.9
1999	62.0	66.3	68.8	63.7	106.4	137.7	113.5	93.7	71.5	116.7	133.2	84.6
2000	90.1	112.9	138.5	125.5	121.6	124.9	170.1	130.5	109.7	99.4	106.8	104.4
2001	95.6	80.6	113.5	107.7	96.6	134.0	81.8	106.4	150.7	125.5	106.5	132.2
2002*	114.1	107.4	98.4	120.4	120.8	88.5	88.2	85.7	83.2	80.7	78.1	75.6
2003*	73.0	70.5	67.9	65.4	62.9	60.4	58.0	55.6	53.2	50.9	48.6	46.4

*Years 2002–2003 contain estimated and predicted values.

Source: National Geophysical Data Center/Solar Terrestrial Physics at: **ftp://ftp.ngdc.noaa.gov/STP/SOLAR_OATA/SUNSPOT_NUMBERS/**

Activity Answer

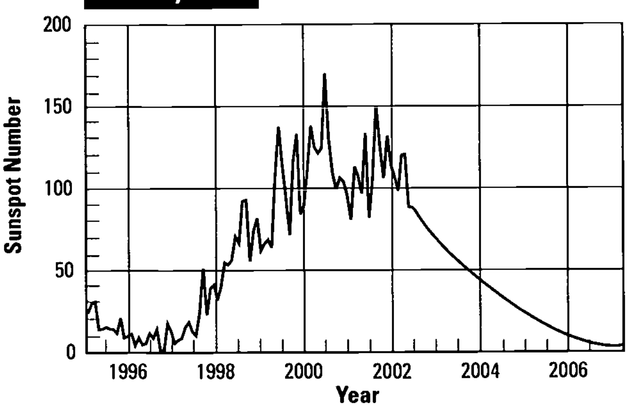
Historical records show that sunspots may have been observed as dark spots on the Sun at least 2,000 years ago. Ancient people might have seen these dark spots when the Sun was low on the horizon and partially obscured by clouds or mist, since it would have been impossible to look directly at the bright Sun without damaging the eyes. It was not until about 1610, following the invention of the telescope, that Galileo and others began observing and writing about the dark spots they observed.

Sunspots are cooler areas on the Sun that appear as dark spots. While most of the visible surface of the Sun has a temperature of about 5700°K, sunspots are only about 4,000°K. Though they vary in size, most are larger in size than the diameter of Earth. Scientists say sunspots would be expected to glow orange in the sky, many times brighter than the full Moon, if pulled away from the Sun. They theorize that the spots are the result of magnetic fields. The number of sunspots is cyclical, with periods of many sunspots (solar maximum) and periods of fewer sunspots (solar minimum). Solar flares, or explosions on the Sun, often occur near sunspots.

Students will notice the cyclical nature of the sunspot cycle. Each cycle is similar in shape and lasts about the same amount of time. The number of sunspots observed at solar maximum varies, however, from a maximum of nearly 200 sunspots to a low of about 60 (sunspot numbers are averaged monthly).

Students will have to estimate from the graph exactly the year and month. The average will be approximately 11 years.

Solar Cycle 23



Source: NASA Solar Physics Web site at: **science.msfc.nasa.gov/ssl/pad/solar/predict.htm**
Data for part of 2002 and all of 2003–2006 represent estimated predictions.

Solar Cycle 23 began about mid-1996, and reached solar minimum about October 1996. Solar maximum occurred about mid-2000. The next solar minimum is predicted to occur sometime about 2006 and peak sometime about 2010. Predictions are based on approximate 11-year cycles with solar maximum occurring on average a bit less than halfway through each cycle.

Resources

Books

Drake, Stillman.
Galileo: A Very Short Introduction.
New York: Oxford University Press, 2001.
Presents a short introduction to Galileo's life and achievements focusing on his conflicts with theologians but supporting the hypothesis that he was a zealot for, rather than against, the Catholic Church.

MacLachlan, James.
Galileo Galilei: First Physicist.
New York: Oxford University Press, 1997.
Contains a detailed chronology of Galileo's life and sidebars explaining his scientific contributions.

Reston, James, Jr.
Galileo: A Life.
New York: HarperCollins Publishers, 1994.
Chronicles the rise and fall of Galileo, focusing on his political instincts, his intellectual self-assurance, and his trials with the Catholic Church.

Sobel, Dava.
Galileo's Daughter: A Historical Memoir of Science, Faith, and Love.
New York: Walker and Company, 1999.
Presents a human picture of Galileo the scientist and Galileo the father.

Web Sites

NOVA Online—Galileo's Battle for the Heavens
www.pbs.org/nova/galileo/
Learn all about Galileo, from his place in science to his mistaken belief that Earth's daily rotation and its annual orbit around the Sun triggered ocean tides. Includes online activities.

The Galileo Project of Rice University
es.rice.edu/ES/humsoc/Galileo/
Contains an illustrated biography of Galileo, translations of letters from his daughter, information about other scientists of his time, a portrait gallery, and links to other resources.

Program Contents

Scientists have long worked to find reliable prediction methods for volcanic eruptions. NOVA chronicles scientists' efforts in this area, focusing on one volcanologist's unique way of predicting eruptions.

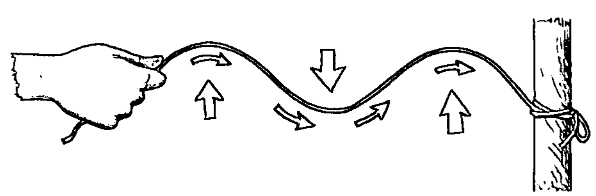
The program:

- recounts the 1985 eruption of the Nevado del Ruiz volcano in Colombia, Mexico, which killed 25,000 people.
- explains different methods used to predict eruptions, such as looking at distinct seismic signals and surface gas monitoring.
- introduces Dr. Bernard Chouet, who looks at a unique kind of seismic signal to predict eruptions, called a long-period event, that is characterized by a slow onset and gradual ending.
- indicates how long-period events may signal pressure buildup created by magma and gas pushing into a volcano.
- describes how researchers monitoring surface gas data concluded that Colombia's Galeras volcano was safe to visit; the volcano later erupted, killing nine people.
- chronicles the successful evacuation, based on the use of Chouet's method, of villages near Mexico's Popocatépetl volcano before its December 2000 eruption.

Before Watching

1. Ask students to compare and contrast volcanoes and earthquakes. What causes a volcano to erupt? *(Magma flowing from Earth's interior)*. What causes an earthquake to happen? *(Continental plate movements cause most earthquakes.)* What is similar about both? *(They both involve seismic waves, can cause major destruction, and can be difficult to predict)*.

2. Waves are a way of transmitting energy. While energy is transferred by a wave, the matter through which the wave moves does not travel with the wave. This can be demonstrated by shaking a piece of string up and down. (See illustration.) Explain to students that the volcanic seismic waves discussed in this program represent one way that energy is transmitted from Earth's interior to its surface.



The string moves up and down while the energy is transferred along its length.

After Watching

1. Scientists must decide when to evacuate towns near a volcano that appears to be about to blow. If people are evacuated and the volcano does not erupt, they are less likely to trust the next evacuation request. Have students consider what they would do if they were asked to evacuate for an indefinite period. How would they decide whether to go? What would they bring?

Activity Setup

Objective

To explore constructive and destructive interference of sine waves and plot a complex wave.

Materials for each team

- copies of the *Sine Wave Science* activity sheet on page 18
- copies of the *About Sine Waves* activity sheet on page 19
- copies of the *Combining Sine Waves* activity sheet on page 20
- pencils with erasers
- rulers

Procedure

1 The seismic signals from volcanoes are complex waves that result from multiple single waves that occur simultaneously. To help students understand how a complex wave is formed, tell them that in this activity they will be combining two simple sine waves.

2 Organize students into teams and distribute copies of the *Sine Wave Science*, *About Sine Waves*, and *Combining Sine Waves* activity sheets and other materials to *each* team member.

3 Review with students what a sine wave is and how sine waves are combined, as described on the *Combining Sine Waves* activity sheet. Explain to students that each complex wave point is determined one at a time. Have students plot the point for the sum of sine waves 1 and 2 before connecting their points into a wave. Have each student in the team plot her or his own wave, but allow team members to help each other understand the activity concepts.

4 After they have plotted all the summative points, have students connect the points to create the resulting complex wave.

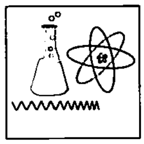
5 Once students have successfully drawn their complex wave, have them answer the questions listed on the activity sheet. What features do they observe about each of the waves they worked with?

6 As an *extension*, have student teams plot new complex waves by picking different values for wavelength and amplitude. Students may notice that the closer the original sine wave wavelengths are, the longer the resulting complex wave wavelength will be.

Standards Connection

The activity found on pages 18–20 aligns with the following *National Science Education Standards* and *Principles and Standards for School Mathematics*.

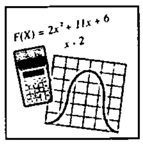
Grades 5–8



Science Standard B:
Physical Science

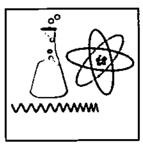
Transfer of energy

- Energy is a property of many substances and is associated with heat, light, electricity, mechanical motion, sound, nuclei, and the nature of a chemical. Energy is transferred in many ways.



Mathematics Standard:
Algebra

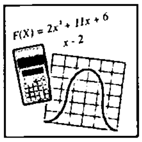
Grades 9–12



Science Standard B:
Physical Science

Interactions of energy and matter

- Waves, including sound and seismic waves, waves on water, and light waves, have energy and can transfer energy when they interact with matter.



Mathematics Standard:
Algebra

Sine Wave Science

NOVA Activity **Volcano's Deadly Warning**

Some volcanic eruptions have been accurately predicted by looking at the complex sine waves created by small earthquakes within volcanoes. But what is a complex sine wave? Find out in this activity.

Procedure

① Acquaint yourself with how to combine two simple sine waves to create a complex wave by reading the *About Sine Waves* activity sheet.

② You will now combine two simple sine waves to create a complex wave. Using your *Combining Sine Waves* activity sheet, add the amplitudes for sine waves 1 and 2 on each vertical graph line and mark the result on the complex sine wave baseline.

③ Plot your complex sine wave points to the end of the wave's baseline. When you have plotted the points, connect them with a smooth curving line.

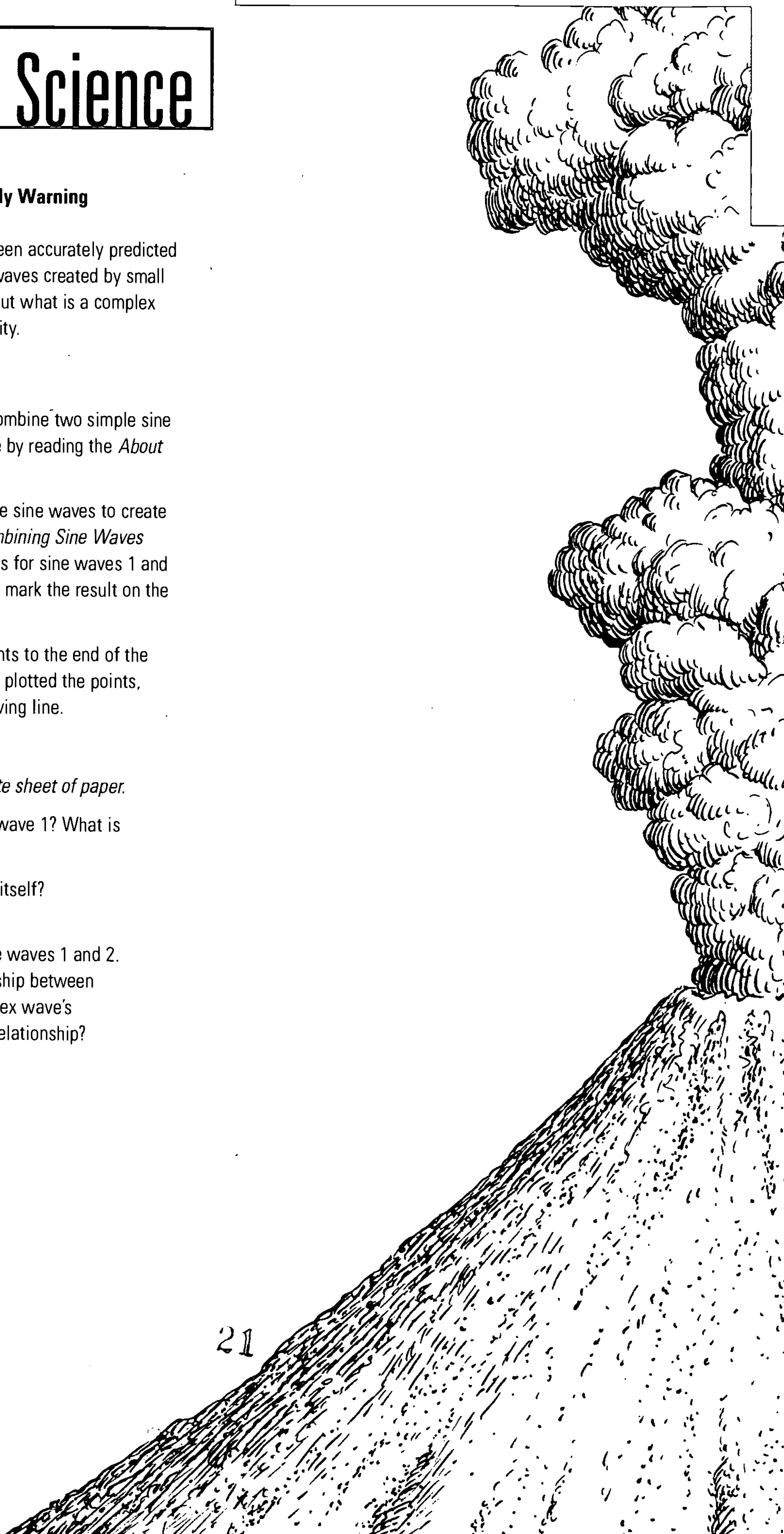
Questions

Write your answers on a separate sheet of paper.

① What is the wavelength of sine wave 1? What is the wavelength of sine wave 2?

② Does your complex wave repeat itself? If so, what is its wavelength?

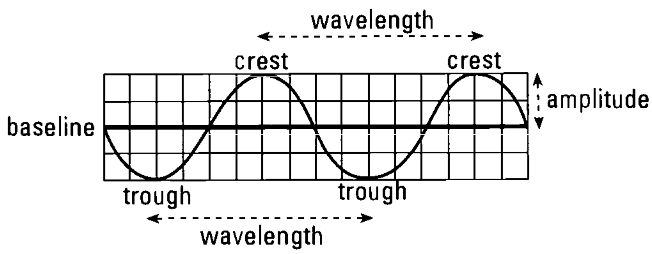
③ Examine the wavelengths of sine waves 1 and 2. Is there a mathematical relationship between their wavelengths and the complex wave's wavelength? If so, what is that relationship?



About Sine Waves

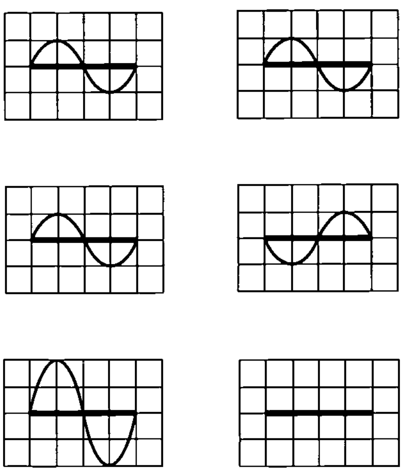
NOVA Activity **Volcano's Deadly Warning**

A sine wave represents a wave, whether it be a water wave traveling toward a beach or a sound wave created by a single musical note. The figure below shows the components of a simple sine wave. In a volcano, many such waves combine, creating complex sine waves.



Wave Interference

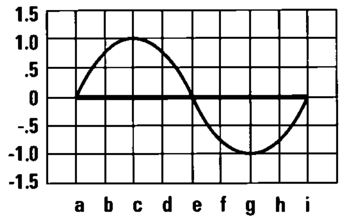
When waves overlap they interfere with each other, forming what is called an interference pattern. If the waves' crests and troughs overlap, the resulting effect is that the waves reinforce each other. This is called *constructive interference*. If the opposite occurs and one wave's crest overlaps the other's trough, the waves cancel out each other. This is known as *destructive interference*.

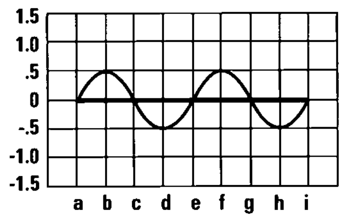


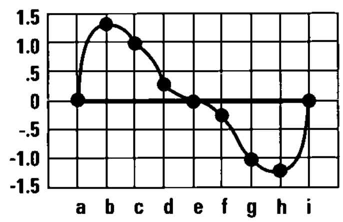
Constructive Interference **Destructive Interference**

Adding Sine Waves

This example shows how points on two simple sine waves can be combined to determine the point on the complex sine wave. Values above the baseline are positive; those below are negative.



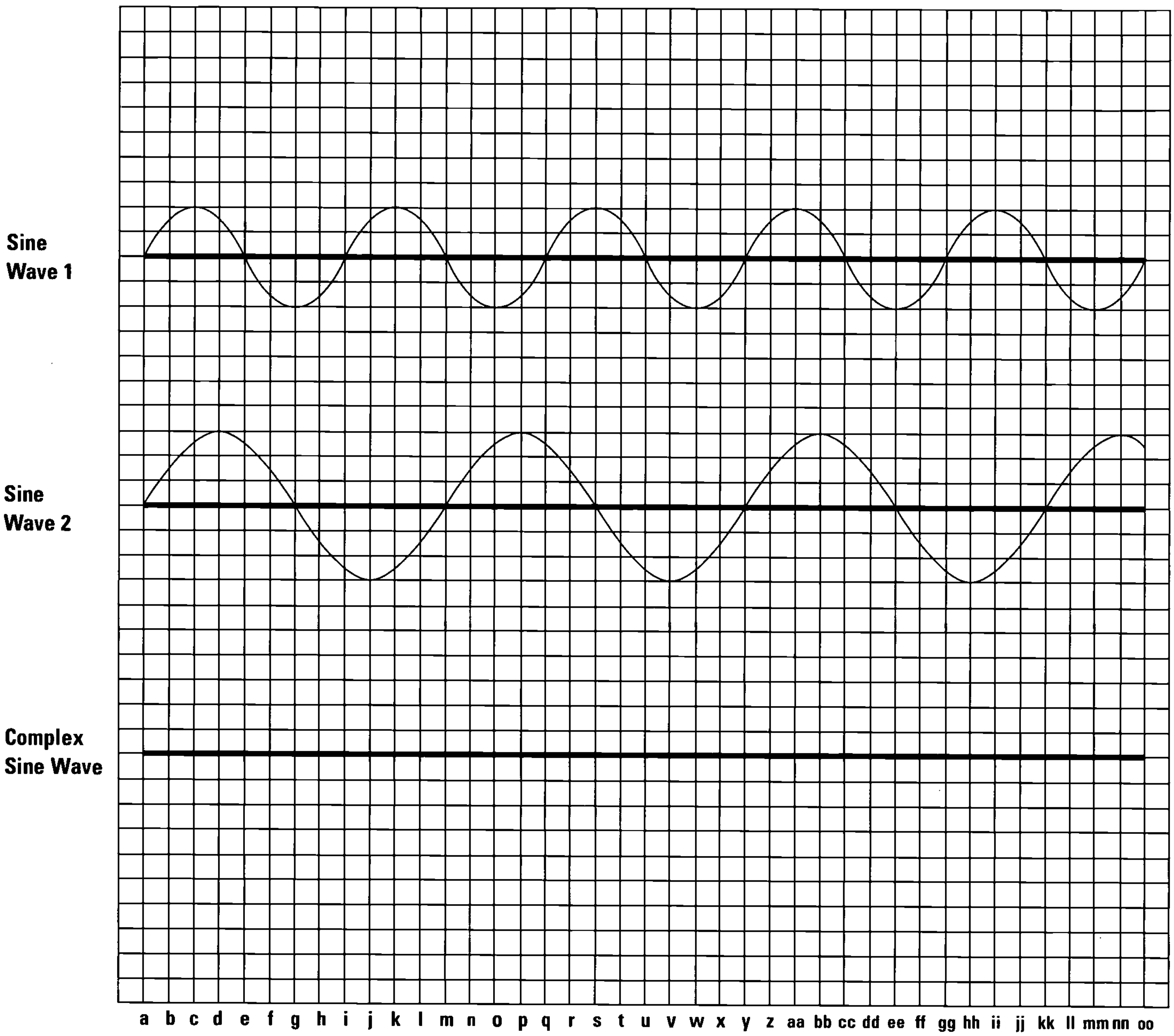




a	0.00 + 0.00 = 0.00
b	1.50 + 1.00 = 2.50
c	2.00 + 0.00 = 2.00
d	1.50 + -1.00 = 0.50
e	0.00 + 0.00 = 0.00
f	-1.50 + 1.00 = -0.50
g	-2.00 + 0.00 = -2.00
h	-1.50 + -1.00 = -2.50
i	0.00 + 0.00 = 0.00

Combining Sine Waves

NOVA Activity **Volcano's Deadly Warning**



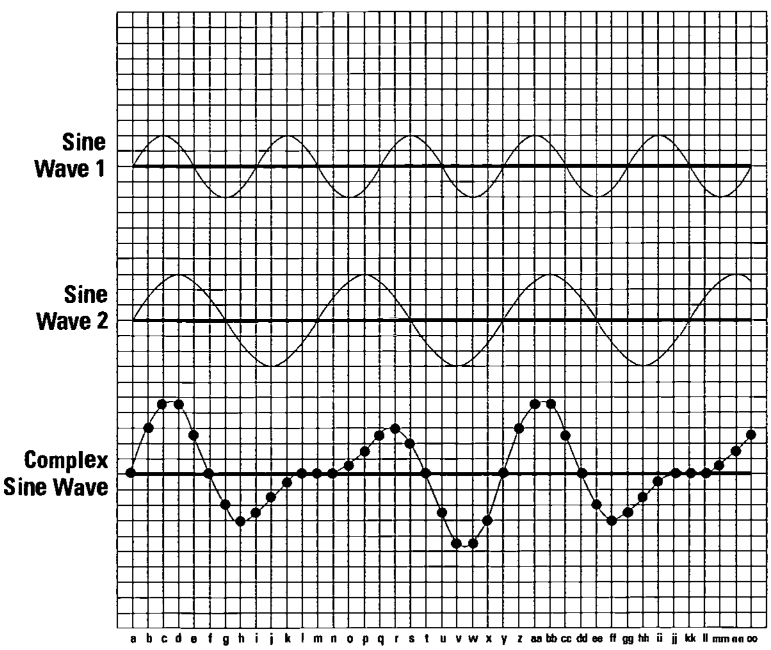
Activity Answer

Small earthquakes within volcanoes, which occur as magma rises to the surface of a volcano, create sine waves that seismographs can record. The complex sine waves Bernard Chouet studied were a combination of multiple sine waves. Although students create a complex wave by summing only two simple sine waves, the concept of constructive and destructive interference is readily grasped. When the waves being summed reinforce each other, it is constructive interference; when the waves reduce each other, it is destructive interference.

Students experience complex waves every day. Anyone who has swum at an ocean beach has experienced large waves created by constructive interference and waited through the lulls caused by destructive interference. But have any of your students ever timed the arrival of the large waves? What might they predict based on their observation of the complex sine wave they created? If they expect that the time between the arrival of large waves would be constant, they would be right.

Here are almost two cycles of the resulting complex sine wave.

Combining Sine Waves



Students will plot almost two complete cycles of the complex wave on their activity sheet. They will be able to see that the wave repeats after 24 baseline units.

The first wave has a wavelength of 8 units, the second, 12 units. The complex wave has a wavelength of 24 units. Many middle and high school students will realize that 24 is the Lowest Common Multiple (LCM) of the two sine waves. This is a characteristic of complex waves; the wavelength of a complex wave is equal to the LCM of the wavelengths of the constituent sine waves.

The LCM correctly suggests that there are mathematical relationships that can be used to reveal the sine waves imbedded in a seismic record. Today, seismic records are digitized, allowing computerized analysis.

Resources

Books

Bruce, Victoria.
No Apparent Danger:
The True Story of Volcanic Disaster at Galeras and Nevado del Ruiz.
New York: HarperCollins, 2001.
Tells the story of volcanologists' struggles to predict the eruptions of Nevado del Ruiz and Galeras in Colombia.

Williams, Stanley and Fen Montaigne.
Surviving Galeras.
Boston, MA: Houghton Mifflin, 2001.
Recounts Williams' escape from the eruption of Galeras and discusses the study of volcanology.

Web Sites

NOVA Online—Volcano's Deadly Warning
www.pbs.org/nova/volcano/
Provides program-related articles, interviews, interactive activities, and resources.

Global Volcanism Program
www.volcano.si.edu/gvp/
Archives weekly and monthly volcanic activity reports on volcanoes around the world.

Volcano World
volcano.und.nodak.edu/
Displays satellite imaging of volcanoes around the world and outlines the steps toward becoming a volcanologist.

Sinking City of Venice

Airs Tuesday, November 19, 2002 • www.pbs.org/nova/venice/

Program Contents

Venice, Italy, faces threats to its art, architecture, and history from an increasing frequency of floods. NOVA explores the debate about how to best control these high water occurrences.

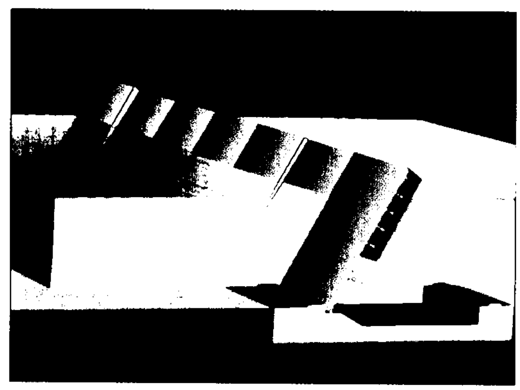
The program:

- recalls the 1966 flood that deluged Venice, Italy, for 15 hours.
- describes the geography of Venice that makes it vulnerable to flooding.
- reviews reasons for present-day flooding, including storm surges, mean sea level rise, and the sinking of Venice.
- chronicles measures taken in The Netherlands and London, England, to prevent flooding in those areas.
- introduces the design currently under development—a series of mobile floodgates situated at the three lagoon entrances that would be raised with compressed air when the city is threatened by extremely high tides.
- presents both sides of the active debate concerning the floodgates, including the key issue of how often the gates would be deployed and what effects the closings would have on the lagoon's health.

Before Watching

1. Have students use a map to locate the lagoon of Venice, Italy. Tell students the lagoon meets the Adriatic Sea at three inlets. To help students understand the size of the coast that protects the lagoon, have them use a nonstandard form of measurement (such as the length of a football field) to understand the length of the coastal barrier *(about 37 miles, or 60 kilometers)* and the width of each inlet: Lido *(about 875 yards, or 800 meters)*, and Malamocco and Chioggia *(about 438 yards, or 400 meters each)*.

2. Venice officials are faced with a difficult decision—how to keep the city safe from increasing incidences of high-water floods. To help students understand the complexity of this problem, have them take notes on the topics outlined in the Water Logged activity setup on page 23.



After being raised with compressed air, the mobile flood gates are designed to swing back and forth to share wave load with the seawater.

After Watching

1. Have students consider other ways that humans intervene in order to control environments, such as seeding clouds during a drought, building seawalls to minimize shoreline erosion, or digging canals for transportation routes. Can students think of any local changes that have been made? What, if any, criteria should exist for altering the natural environments or processes?

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Activity Setup

Objective
To help students understand the complexity of finding a solution to Venice's floodwater problems.

Materials for each student
- copy of the *Water Logged* activity sheet on page 24

Procedure

1 Venice is confronted with the problem of how to control the flooding of its city, a problem that is predicted to increase over time. But experts cannot agree about how often flooding will occur or how high floodwaters will be. To help students understand this complex issue, have them keep a log of the various aspects of the issue as they watch the program.

2 Provide each student with a copy of the *Water Logged* activity sheet. Review the activity sheet with students, noting the locations of Venice, the lagoon, the barrier islands, the city's port, and the other features.

3 Organize students into four groups. As they watch, have one group take notes on the causes for Venice's flooding problems. Have the second group focus on the arguments for the installation of the mobile floodgates. Have a third group record the arguments against the gates. Have the final group note any alternate solutions that have been proposed.

4 Have students use the map to mark the areas affected by the problems and the areas where solutions or proposed solutions have or would occur.

5 After watching, discuss the causes for Venice's water problems, the arguments for and against the floodgates, and the alternate solutions that have been proposed, summarizing them on the chalkboard.

6 Discuss with students the advantages and disadvantages of the mobile floodgates and the alternate solutions that have been proposed.

7 To conclude, have students consider the following:
- Of the problems Venice currently faces, which are most immediate?
- Of the solutions given for Venice's current flooding problems, which do you think is the most sound? Why?
- What scientific information do officials need to make decisions regarding saving Venice from flooding?
- What role does science play in solving Venice's water problems? What role does the government play?

8 As an *extension*, have students research lagoon environments within the United States. Where are most of the lagoons located? What issues, if any, do they face?

Standards Connection

The activity found on page 24 aligns with the following *National Science Education Standards.*

Grades 5–8

Science Standard F:
Science in Personal and Social Perspectives

Natural hazards
- Internal and external processes of the earth system cause natural hazards, events that change or destroy human and wildlife habitats, damage property, and harm or kill humans. Natural hazards include earthquakes, landslides, wildfires, volcanic eruptions, floods, storms, and even possible impact of asteroids.
- Natural hazards can present personal and societal challenges because misidentifying the change or incorrectly estimating the rate of scale of change may result in either too little attention and significant human costs or too much cost for unneeded preventive measures.

Grades 9–12

Science Standard F:
Science in Personal and Social Perspectives

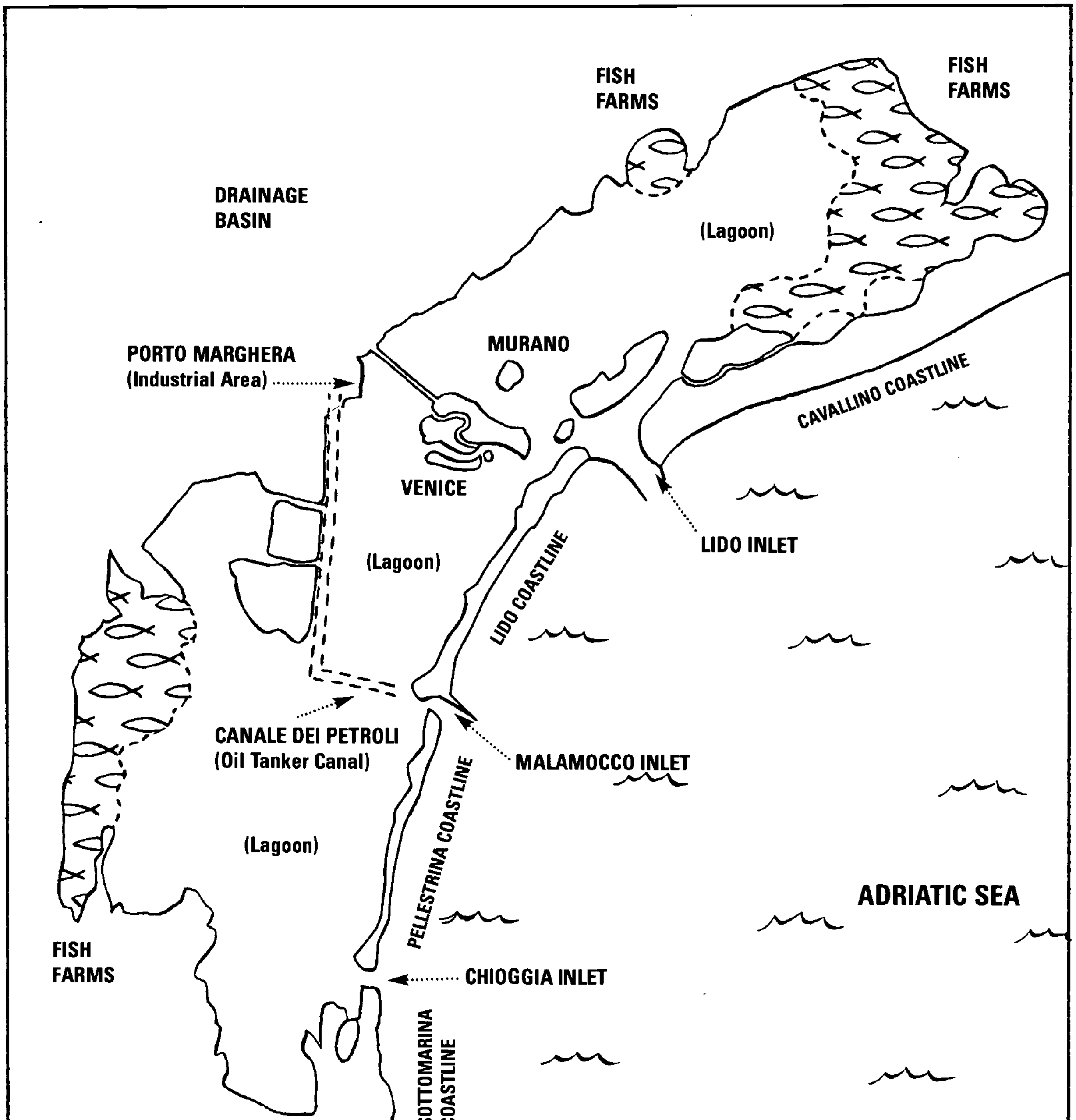
Science and technology in local, national, and global challenges
- Progress in science and technology can be affected by social issues and challenges. Funding priorities for specific health problems serve as examples of ways that social issues influence science and technology.
- Individuals and society must decide on proposals involving new research and the introduction of new technologies into society. Decisions involve assessment of alternatives, risks, costs, and benefits and consideration of who benefits and who suffers, who pays and gains, and what the risks are and who bears them. Students should understand the appropriateness and value of basic questions—"What can happen?"—"What are the odds?"—and "How do scientists and engineers know what will happen?"

26

Water Logged

NOVA Activity **Sinking City of Venice**

The floodwaters that threaten Venice are not new. This ancient city has been facing flood problems for centuries. But scientists predict the problem will become more severe in the near future. What, if any, measures should Venice officials take to protect the city against increasing flooding? Use this map to help you identify some of the many aspects of this complex issue as you watch "Sinking City of Venice."



Activity Answer

The key issue surrounding the mobile floodgates is the question of how often the gates would need to be deployed. Opponents fear that without the cleansing effect of the tides, the lagoon's pollution problems will be exacerbated. (Pollution sources include industrial waste disposal, sewage outflow from the city's drainage system, and agricultural runoff of fertilizers. Additional risks include oil spills from tankers serving a major petrochemical center.)

Some of the causes of Venice's flooding

Severe storms are more frequent. A rise in mean sea level is predicted, although estimates vary from a rise of 1.57 inches to 19.69 inches (4 centimeters to 50 centimeters). The sediment under Venice is slowly compacting. In addition, for several decades local industry pumped millions of gallons of water out of the ground, resulting in added soil compaction. These factors threaten Venice with increasing high-water problems.

Some of the arguments for the mobile floodgates:

- The gates meet the guidelines set down by law.
- They provide a workable solution that can be implemented now before the problem gets too severe.
- The gates will be high enough to counter the high water expected by sea level rise.
- The number of closures will not be enough to harm the lagoon's ecosystem.

Some of the arguments against the mobile floodgates:

- The gates are expensive and are taking money away from a more workable solution.
- The gates will not solve the problem long-term. Much of the problem can be solved with alternative measures in the short run, providing additional time to plan a permanent solution.
- They won't be high enough to counter the high water expected by sea level change.
- The number of closures will harm the lagoon's already stressed ecosystem.

Some of the alternative measures proposed:

Less technological approaches include narrowing the shipping lanes or opening the fish farms to receive water to expand the lagoon's surface area. Other proposals include raising city sidewalks and canal walls by a foot or less. More drastic measures include: closing off Venice's industrial sector; decreasing the size of the lagoon; closing the lagoon off permanently from the sea and turning it into a freshwater lake; or building permanent structures at the inlets to control water exchange.

Some of the information officials need to make decisions regarding the lagoon includes: short- and long-term meteorological forecasts to help predict storms and future sea level rise; water quality reports to track pollution levels within the lagoon; ecological data to help understand lagoon and sand bank dynamics; and water quality models to predict potential outcomes of various proposed solutions.

Resources

Book

Keahey, John.
Venice Against the Sea: A City Besieged.
New York: T. Dunn Books/St. Martins Press, 2002.
Explains how the city and its 177 canals were built and what has led up to the current flooding crisis. Also explores the various options currently being considered for solving the problem and chronicles the ongoing debate among scientists, engineers, and politicians about the pros and cons of potential solutions.

Articles

Barker, Don.
"Saving Venice."
Architecture Week, August 15, 2001, page B1.
Provides an overview of Venice's flooding problems. Also online at: ***www.architectureweek.com/2001/0815/building_1-1.html***

"Measuring Water Exchange between the Venetian Lagoon and the Open Sea."
EOS, May 14, 2002, page 1.
Details preliminary results of current measurements in all three lagoon inlets; includes articles for and against the mobile floodgates.

Web Sites

NOVA Online—Sinking City of Venice
www.pbs.org/nova/venice/
Provides program-related articles, interviews, interactive activities, and resources.

Safeguarding of Venice
www.salve.it/uk/
Includes information on the problems and solutions for Venice's lagoon, extensive resources about the lagoon's ecosystem, and a glossary of lagoon terminology.

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Available 11/26/02.
2 hrs. WG35823 $19.95

Killer Disease on Campus
NOVA explains why the silent and lightning-fast killer meningococcal meningitis is targeting American college students, and asks why American health officials haven't followed Britain's lead of mass vaccination. *Available 10/1/02.*
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Mysterious Life of Caves
Take a dramatic and often hazardous journey underground with top scientists as they explore the fragile and pristine caves of Carlsbad Caverns and Lechuguilla, New Mexico.
Available 11/5/02.
1 hr. WG36523 $19.95

Sinking City of Venice
Today's tourists often need wading boots to explore the architectural wonders of Venice. Will they one day need diving suits? *NOVA* covers the battle to keep the world's most unusual city from drowning beneath the rising tides of the Adriatic Sea.
Available 1/7/03.
1 hr. WG35593 $19.95

Volcano's Deadly Warning
After a Colombian volcano erupted in 1985 killing 25,000 people, scientists feverishly pursued a way to more accurately predict eruptions. Now geophysicist Bernard Chouet may have discovered a mysterious type of seismic signal given off by quaking volcanoes that may be a key warning sign before an eruption. Explore the race to predict deadly volcanic eruptions, and meet the man whose scientific breakthrough could save thousands of lives.
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Recently declassified documents prove that as many as 30 Americans may have spied for the Soviets during World War II. See the startling new evidence kept hidden from the American public for over 50 years.
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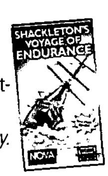

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Through rare footage, photos, interviews, and more, retrace Sir Ernest Shackleton's dramatic and courageous voyage on the *Endurance*. *AV market only.*
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Titanic's Lost Sister
Four years after its sister ship, the *Titanic*, went down, the *Britannic* sank in just one hour, despite an overhaul to meet new safety standards. Search for the wreck and explore why it sank.
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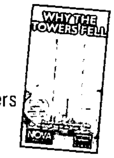

NEW! Why the Towers Fell
In the gray wasteland of smoke and mangled steel left after the collapse of the World Trade Center towers, forensic engineers began sifting the wreckage for answers and *NOVA* has been there from the beginning. *Why the Towers Fell* presents the engineers' conclusions of how and why the towers collapsed, as well as the stories of several survivors.
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VHS: 1 hr. WG35773 $19.95

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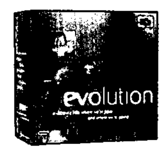

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VHS: 8 hrs. WG1158 $99.95

Lost Tribes of Israel
NOVA dispels myth and fantasy in a dramatic genealogical quest to find the descendants of Israel's Lost Tribes nearly 3,000 years after banishment.
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NEW! The Missing Link
Join scientific detectives in a remarkable search across the globe for the fossilized remains of a mysterious creature that may be the ancestor of all four-limbed animals.
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Mystery of the First Americans
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Neanderthals on Trial
Were Neanderthals human ancestors or an evolutionary dead end? Exploring one of the most contentious debates about human origins, *NOVA* offers a surprising look at how science works, and how investigators can fool themselves into seeing what they want to see.
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Siberian Ice Maiden
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Dying to Be Thin
Meet some compelling young women who are waging a deadly battle to achieve an impossible standard of beauty, and explore new therapies that may help the millions of Americans afflicted with eating disorders.
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The Miracle of Life
This Emmy Award-winning classic takes you along on a microphotographic voyage through the human body as a new life begins.
DVD: 1hr. WG799 $19.95
VHS: 1 hr. WG001 $19.95

Secrets of the Mind
A blind man can see. Another feels pain in his missing arm. One believes he's God. In this remarkable *NOVA*, pioneering brain detective and doctor V.S. Ramachandran, hailed as "the Sherlock Holmes of neuroscience," tackles mysterious cases and delivers mind-boggling conclusions.
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Sex: Unknown
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NEW! Fireworks!
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