

SCIENCE CURRICULUM

Machu Picchu: Unveiling the Mystery of the Incas

By Carol P. Merriman
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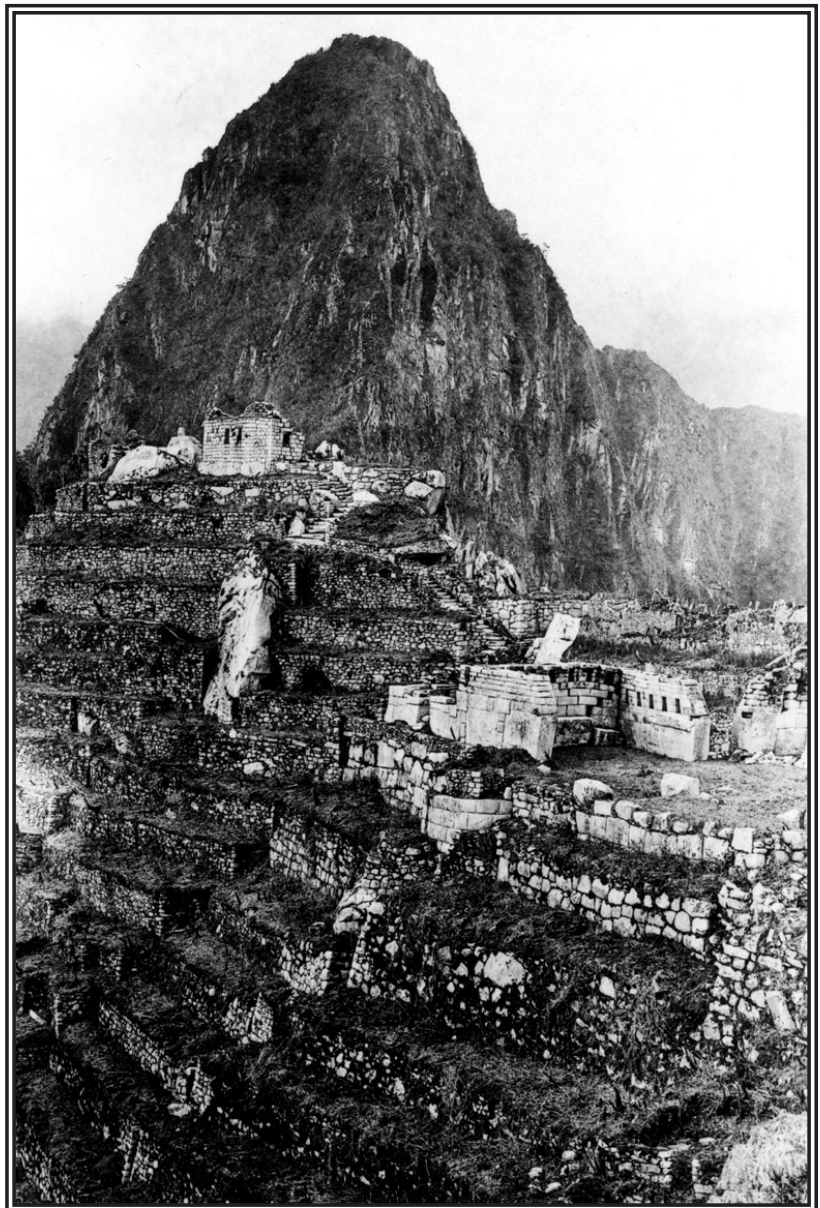
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I. To the Teacher

This curriculum has been developed to deepen students' understanding of the exhibition *Machu Picchu: Unveiling the Mystery of the Incas*. It is designed to be used in middle school science classes to enrich the study of:

- 1) astronomy and space science;
- 2) earth science and environmental studies; and
- 3) human biology and health.

Each guide in the curriculum includes several lesson plans, which can be used individually or in sequence.

If possible, visit the exhibition before you go there with your class. Check the sequence of exhibition rooms. (Because the exhibition is being held at several venues, rooms may be laid out slightly differently at different locations.) Determine which questions on the Student Guide (Section V) to the exhibition are most relevant to your subject.

The guides are designed to enhance students' appreciation of how scientists make and test hypotheses. Each lesson begins with an inquiry question to focus student thinking.

Lesson plans include hands-on activities and optional enrichment activities that require more time and materials. Some lessons refer to kits that must be purchased in advance. (See Resources.) Unless indicated, the kits are not necessary to complete the activity.

A separate social studies curriculum is available at <http://www.peabody.yale.edu/education/pages/topic.html#arch>. If your school's scheduling permits, consider working with social studies teachers to create an interdisciplinary project on Machu Picchu and the Inca Empire.

Note: Answers to questions are in brackets.

II. Lesson Plans: Astronomy

A. The Sun

Homework

A few days before the unit is introduced:

Have students spend 10 minutes looking at the night sky. If the sky is cloudy, have them repeat the exercise on a clear night.

The day before the unit is introduced:

Have students read the background article, “The Incas” (Section VII).

Lesson 1: Skywatchers

Objective

To encourage students to understand why the sky, including the sun, moon, stars and planets, was important to ancient people, including the Incas.

Inquiry question

Why was the sky important to ancient people? What beliefs did they have about the sun, moon, planets and stars?

Materials

Handout 1: The Coricancha, *Miro in the Kingdom of the Sun*, by Jane Kurtz. Boston: Houghton Mifflin, 1966.

Procedures

1. *Introduction:* Ask students how they felt when they viewed the sky last night. Have them imagine they are living hundreds or thousands of years ago. How might their ideas about the night sky be different?
2. Ask students to cite examples of what ancient people believed about the sky. [For example, the Egyptians worshipped the sun, the Greeks studied constellations and associated the planets with gods.]
3. Observe that many ancient people worshipped the sun, moon, and stars. Their religious leaders were “skywatchers” who studied the sun, moon and stars in the sky, interpreting their movements as “divine speech.” These skywatchers observed that the sun, moon, stars and planets move about the sky in regular, predictable ways. They believed that by carefully observing these movements, they could predict the future.
4. Explain that like many ancient peoples, the Incas worshipped the sun, moon and stars. Their most important god was Wiracocha, the creator of the earth. He could not be seen by humans. Next came Inti, the sun god, who was depicted on a golden disk with sun rays around the edge. Mama-Quilla, the moon mother, was Inti’s wife. Apu Illapa, the god of thunder, was believed to

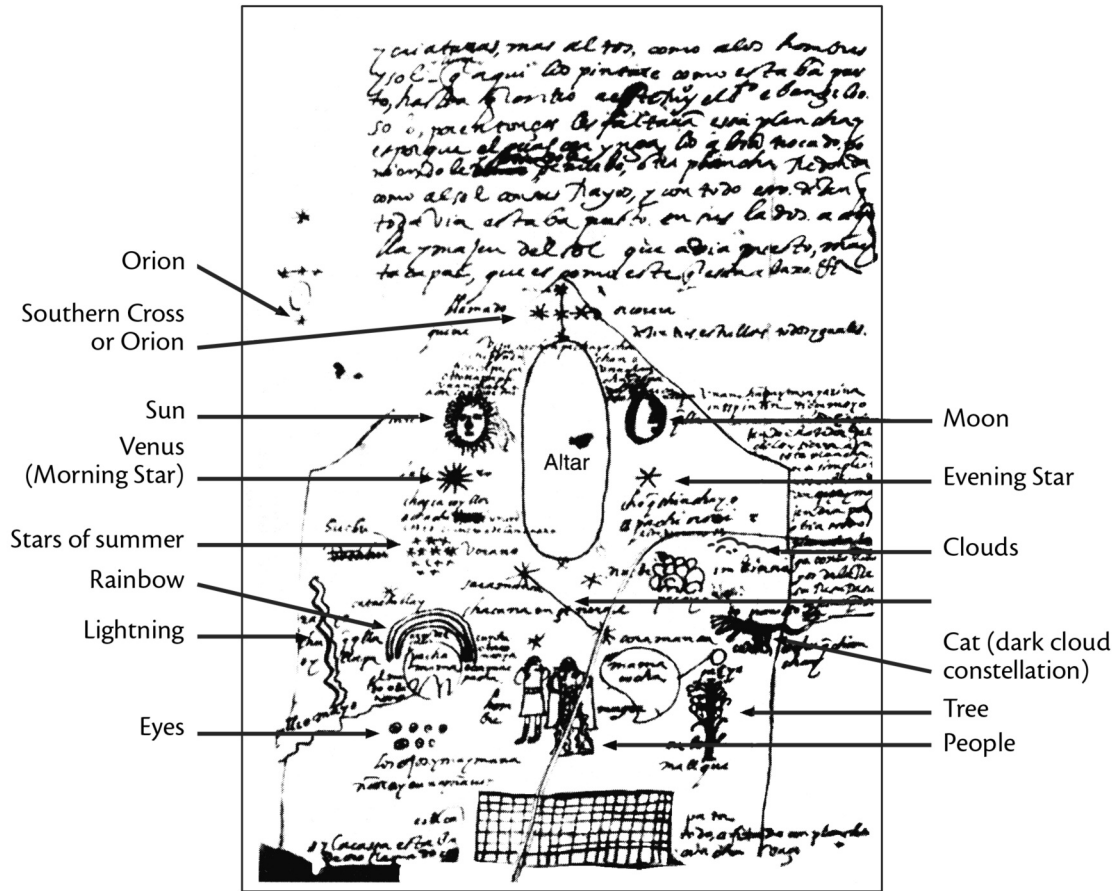
give rain, so important in the dry Andean climate. The planet Venus, which is visible only at sunrise and sunset, was believed to be the sun's page because it always went before or after him. The Pleiades, a star cluster, was worshipped because its appearance and disappearance in the night sky coincided with the planting and harvesting of crops in Cuzco.

5. *Activity A* (older grades): Distribute Handout 1: The Coricancha. The Coricancha, located in Cuzco, was the most important Inca temple. (The Coricancha is described in the introduction to the background article "The Incas," Section VII). The diagram in Handout 1 identifies the celestial objects that were worshipped in the Coricancha. Ask students to identify elements of the sky shown in the diagram. [Starting in the upper left and going clockwise: the sun, a constellation, the moon, the evening star (Venus), the Southern Cross (a constellation), a cat (a dark cloud constellation), eyes (thought to be the Pleiades), lightning, a rainbow, the stars of summer, Venus (morning star), Orion.]

Activity B (younger grades): Read *Miro in the Kingdom of the Sun*, by Jane Kurtz. What does the story tell us about Inca beliefs concerning the sun, moon and stars? [The emperor was named the "Sun King," people used constellations to guide them when they traveled, they observed the morning star (Venus), and believed the moon was the wife of the sun.] What else does the story teach us about Inca life?

6. *Assessment*: Have students write a paragraph contrasting our beliefs about the sun, moon and stars with those of the Incas.

Handout 1: The Coricancha



Source: *Stairways to the Stars*, by Anthony Aveni, p. 51. Copyright 1997 John Wiley & Sons, Inc. Reprinted by permission.

The Coricancha, called the Temple of the Sun by the Spanish, was the most important temple in the Inca Empire. Its outside walls were covered with gold plates. The wall facing east displayed a huge golden sun disk that glowed in the rising sun. Archaeologists believe that the Inca emperor and priests observed the sun from the Coricancha. The temple was dedicated to the heavenly bodies worshipped by the Incas, including the sun, the moon, Venus and the Pleiades. Individual rooms in the temple were dedicated to the moon, Venus and the stars. This diagram, drawn by the Spanish chronicler Joan Santa Cruz Pachacuti Yanqui, shows a wall of the Coricancha. How many heavenly objects can you find depicted in the drawing?

Lesson 2: Location, Location, Location

Objective

Students will understand how Peru's location near the equator affects its seasons.

Inquiry question

How does Peru's position on the globe affect its seasons?

Materials

A globe that tilts at 23.5 degrees, a flashlight. Optional: Order "Earth, Moon, and Stars," a GEMS kit (see Kits listed under Resources on page 55). The kit contains a plastic globe on a tilted stand for each student, a light bulb, and moons. You can use the plastic globes and light bulb to allow each student to carry out the following activities.

Procedures

1. A quick review of the earth's movement around the sun.
 - a) *Teacher demonstration:* Remind students that the earth revolves around the sun in a 365.25-day cycle. The earth is tilted on its axis at an angle of 23.5 degrees.

Ask students if they remember how warm the sun's rays are on their skin on a bright summer afternoon. This is because the sun is shining directly overhead, and the rays are concentrated in a circle on your skin. In winter, the rays fall on the skin at an angle, and are spread out in an oval pattern.

When a given hemisphere is tilted toward the sun, the rays are more concentrated. When the Southern Hemisphere is tilted toward the sun, the sun's rays are more direct and it is summer (in December). (Demonstrate the Southern Hemisphere being tilted toward the sun.) When the Southern Hemisphere is tilted away from the sun, in June, the sun's rays are less concentrated and it is winter there. (Move the globe to other side of the table, maintaining the 23.5 degree angle. The Southern Hemisphere will now be oriented away from the sun.) What season is it in South America? [winter]
 - b) Have a student locate Peru on the globe. What is its latitude? [13 degrees south] What impact would Peru's location near the equator have on its climate?

Explain that because Peru is located near the equator, there is less temperature change between summer and winter than there is in our latitudes.

Note: Students may assume that Peru would have a hot climate since it is so near the equator. Prompt them to realize that Peru's high elevation creates a relatively cool climate.
2. *Assessment:* Have students draw a picture of the earth revolving around the sun at about a 23 degree angle. Ask them to draw rough outlines of North and South America on the earth. Have them indicate approximately where their town is located and where Peru is. Have them indicate which season it is in each hemisphere.

Lesson 3: Days and Seasons

Objective

To enable students to understand how a country's position on the globe determines the variation in length of day and night throughout the year.

Inquiry question

Why are the days longer in summer than in winter?

Materials

A globe that tilts at a 23.5 degree angle, a bright light, string, adhesive tape.

Procedures

1. *Teacher demonstration* (with assistance from students):
 - a) Place a globe that is tilted on its axis at 23.5 degrees on the edge of a large (preferably circular) table. Have a bright light in the center of the table. Place the globe in a position where the Southern Hemisphere is tilted toward the sun. What season is it there? [summer] When during the year does this occur in the Southern Hemisphere? [December] Dim the lights. Now take a string and have it run through Peru parallel to the equator. (Use adhesive tape to hold the string in place.) Pull the string around the globe and mark on the string where the shadow begins on each side of Peru.
 - b) Now put the globe at the opposite side of the table, maintaining the same 23.5 degree angle. Rotate the globe on its axis so Peru is exposed to the light. This time the Southern Hemisphere will be tilted away from the sun. What season is it in the Southern Hemisphere now? [winter] Why? [The sun's rays are more indirect.]
 - c) Do the same exercise with the string. How much shorter is the string? Estimate how many fewer hours of sunlight Peru has in the winter than in the summer. (Hint: One 15 degree segment of longitude equals one hour; total longitude equals 360 degrees)
 - d) Now do the same exercise for your latitude. Which location has the greater difference in length of day in summer versus winter? [our location] Why? [Because it is farther away from the equator.]
 - e) Which parts of the world have the greatest difference in the length of the day between winter and summer? [extreme northern and southern latitudes] Why? [They are located farther from the equator.]

Lesson 4: Solstices and Equinoxes

A. Solstices

Objective

Students will understand why the sun's path across the sky appears to change position and what a solstice is.

Inquiry question

What is a solstice? How can it be used as a calendar?

Materials

Paper plate, pencil, modeling clay.

Procedures

1. *Introduction:* The change in the earth's orientation toward the sun during the course of a year alters the sun's apparent position in the sky. You may have noticed that in the winter, the sun appears very low on the horizon and does not provide very much heat. In the summer, on the other hand, the sun is high overhead and its rays are very warm. The different paths the sun appears to take throughout the year mean that the sun rises and sets at different places on the horizon: in the summer it rises more to the north of due east, and in the winter more to the south of due east.
2. Explain that the word solstice means "stand still." It is the point where the sun is either highest or lowest in the sky. These are the most extreme points along the sun's journey. One solstice occurs on about June 21 and the other on about December 21. Ask students: What seasons begin on these dates in our hemisphere? [June 21: summer; December 21: winter] In the Southern Hemisphere? [June 21: winter; December 21: summer]
3. Explain that the Incas constructed pillars along the horizon to track the progress of the sunrise and sunset during the year. They used this device as a sort of calendar to indicate when to plant crops—when the sun rose behind a certain pillar, it was time to plant crops in that region. Students will learn later how the Incas used direct observation to predict the solstice (see Lesson 5).

B. Equinox

Objective

Students will understand what an equinox is and why the sun casts shadows at various latitudes.

Inquiry question

What is an equinox? Or, does the sun cast a shadow at the equator?

Procedures

1. *Introduction:* Ask students to brainstorm about what the word “equinox” means. [“equal night” in Latin]
2. *Teacher explanation:* What is the equinox? [It is the point at which the sun is halfway between the summer solstice and the winter solstice.] Ask students what dates that would be. [The equinoxes are halfway between December 21 and June 21, or March 21 and September 21.] Which seasons begin on these dates? [spring and fall]

The equinox occurs twice each year when the sun is shining directly on the equator. At this point neither hemisphere is tilted toward or away from the sun. People living near the equator do not see a shadow at noon during the equinox. But people living far away from the equator still see a shadow even at noon because, due to the curvature of the earth, the sun’s rays always strike the earth’s surface at an angle there, and the sun is never directly overhead.
3. *Teacher demonstration:* Construct a simple sundial by sticking a pencil in modeling clay on a paper plate. Ask students if a shadow will be cast at noon. At noon, look to see if there is a shadow. [yes] Why? [Because at our latitude, the sun always strikes the earth at an angle, causing the sun to cast a shadow even at noon.] Would you get the same result if you lived on the equator? [No, the sun is more directly overhead so little shadow is cast. Therefore, only a slight shadow usually appears on the sundial at noon at the equator.]
4. Ask students when the sundial would cast no shadow on the equator. [at the equinox]
5. *Assessment:* Have students find the latitude of Quito, Ecuador. If they made a sundial in Quito, would there be a shadow cast at noon at the equinox? Have them write a paragraph explaining why or why not. [Quito lies on the equator, therefore the sundial would not cast a shadow at noon at the equinox.]

Lesson 5: How the Incas Used the Sun

Objective

Students will understand how the Incas used direct observation of the sun, moon, stars and planets as a calendar.

Inquiry question

Imagine that your culture does not have writing and therefore does not have a written calendar. How could you use the movements of the sun to keep track of the seasons?

Materials

Paper plate, Handout 2, The Spanish Chronicles.

Procedures

1. *Introduction:* Ask students to discuss how people have used the movements of the sun, moon and stars in the past. [Some cultures used sundials to tell time, navigators used stars to guide ships, North American Native Americans used the stars to guide them across featureless plains.]
2. Explain that, because they worshipped the sun, the Incas developed many rituals in its honor. Some of these rituals took place at the equinox or solstice. They observed the passage of the sun on the horizon and predicted equinoxes and solstices to determine when to celebrate these festivals.
3. *Activity:* Ask student to do Handout 2: The Spanish Chronicles. Have students read the accounts and fill in the blanks to identify which celestial event or process served as the basis of each ritual.
4. *Assessment:* (assign as homework) Have students write a three-paragraph essay contrasting how we use the sun with how the Incas used it.

Handout 2: The Spanish Chronicles

After the Spanish Conquest, several observers wrote descriptions of daily life in the former Inca Empire. These descriptions, written by priests, government officials and native Peruvians, are known as “The Spanish Chronicles.” Although they are sometimes inaccurate because observers did not always have a thorough understanding of what they observed, they are our best source about life in Inca times.

Here is what some of the Spanish chroniclers said about Inca astronomy:

Directions

Read the following description of Inca astronomy and tell what astronomical phenomenon the Inca astronomers were observing.

1. Felipé Guamán Poma de Ayala describes how horizon pillars and windows were used to observe the changing rays of the sun:

In the sowing of the crops, they follow the month, the day, the hour, and the point where the Sun moves; they watch the high hills in the morning, the brightness, and the rays that the Sun aims at the window; by this clock they sow and harvest each year in this domain.

[Answer: movement of the sun on the horizon]

2. Garcilaso de la Vega describes how the Incas observed shadows:

[T]hey had columns of richly worked stone, placed in the patios or plazas in front of the temples of the sun;...(T)he priests took care to look every day at the shadow that the column made. They had the columns in the center of a circle which was very large and took the whole width of the plaza or patio; in the middle of the circle they made a line from east to west with string, because of long experience they knew where to put each point. By the shadow that the column made on the line they saw that the _____ was approaching; and when the shadow bisected the line, from where the Sun rose to where it set, and at noon the light of the Sun bathed the entire column all around without making a shadow on any part, they said that that day was the _____.

[Answer: equinox]

3. Bernabe Cobo describes markers around Cuzco, including:

Chinchincalla, is a large hill where there were two markers; when the sun reached them, it was time to plant. _____

[Answer: movement of the sun on the horizon]

Quiangalla is a hill which is on the Yucay road. On it were two markers or pillars which they regarded as indication that, when the Sun reached there, it was the beginning of the summer. _____

[Answer: summer solstice]

4. An anonymous chronicler describes pillars used as *huacas* near Cuzco as follows:

Sucanca. It was a hill by way of which the water channel from Chinchero comes. On it there were two markers as an indication that when the Sun arrived there, they had to begin to plant the maize. The sacrifice that was made there was directed to the Sun, asking him to arrive there at a time which would be appropriate for planting, and they sacrificed to him sheep [llamas], clothing, and small miniature lambs [baby llamas] of gold and silver.

[Answer: movement of the sun on the horizon]

Source: "Here Comes the Sun: The Cuzco-Machu Picchu Connection," by David S. P. Dearborn and Katharina J. Schreiber, pp. 16, 20. Copyright 1986 *Archaeoastronomy*.

Lesson 6: Think Like an Archaeoastronomer

Objective

To introduce students to a device that the Inca astronomers might have used to determine when a solstice was about to occur.

Materials

Handout 3: Think Like an Archaeoastronomer!, a plumb bob (available at hardware stores), string.

Procedures

1. *Introduction:* Show students a plumb bob hung from a string. Ask them if they know how carpenters use a plumb bob today. [A plumb bob is used to mark a line that is exactly perpendicular to the ground.] Explain that at the exhibition *Machu Picchu: Unveiling the Mystery of the Incas* students will be learning about how Inca astronomers might have used a plumb bob for an entirely different purpose—to predict when the solstice would occur.
2. *Activity:* Explain that at the exhibition students will learn about how archaeologists study buildings to determine their purpose. Students can practice thinking like an archaeologist by doing Handout 3: Think Like an Archaeoastronomer! as a class before they visit the exhibition.

Handout 3: Think Like an Archaeoastronomer!

Imagine you are an archaeologist who is studying Machu Picchu. You are especially interested in a building next to the emperor's residence called the Torreón. You want to determine what it was used for. Here are some clues:

1. It is made of beautifully shaped stones that have been polished.
2. It has an unusual curved wall.
3. A platform connects the building with an adjacent house where priests lived.
4. There is a beautifully crafted stone in the middle of the room that includes a carving of a cat.
On a few mornings each year, sunlight enters the east-facing window to illuminate the stone.
5. On the exterior of the east-facing window are pegs that could have held a rod.

Brainstorm as a class about what the Torreón was used for. When you visit the exhibition, listen carefully to the Curator's Tour. Lucy Salazar will explain what archaeologists think the Torreón was used for. Also view the video on archaeoastronomy. It will show the Torreón and explain its special features.

At the exhibition

Have students complete the Student Guide to *Machu Picchu: Unveiling the Mystery of the Incas* (Section V) as they view the exhibition. Explain that they will be seeing a video on archaeoastronomy and should be sure to answer all the questions on the handout pertaining to the video. (Students may want to view the video more than once.)

Lesson 7: Shadow Casting

Objective

Students will understand how changes in the shadow cast by the sun can be used to determine when the solstice occurs.

Inquiry question

How did the Incas make a calendar to schedule public festivals in the absence of a written language?

Procedures

1. *Introduction:* Observe that the Incas did not have writing or scientific instruments for measurement. Ask students to think about how the Incas used direct observation of the sun to create a calendar of important events.
2. *Discussion:* Have students refer to the Student Guide (Section V) they filled out at the exhibition.
 - a) What buildings at Machu Picchu were used as observatories? [Torreón, Intimachay]
 - b) Why do archaeologists think the Torreón was used as a religious temple?

Explanation of Handout 3: Think Like an Archaeoastronomer!:

Archaeologists believe that the Torreón was a temple, in part because it is similar in many ways to the Temple of the Sun in Cuzco. The Torreón has an unusual (and difficult to construct) curved stone wall. The other stone walls are exquisitely crafted. The fact that the building was connected to the priests' house meant that priests could easily enter the building to perform ceremonies. The platform that connected the Torreón to the priests' house may have been used for religious ceremonies.

- c) Discuss why some archaeologists think the Torreón was used as a solar observatory. (Have students refer to their answers to the questions in the Student Guide about the archaeoastronomy video.)

Some archaeologists also believe that the Torreón was used as a solar observatory to observe the June (winter) solstice. The room contains a stone altar and a carving of a cat with a raised edge on its belly. The Torreón has east-facing windows through which morning sunlight passes. Archaeologists believe that the pegs on the outside of the window were used to support a rod. If a plumb bob is suspended from the rod on a cord, the window projects a shadow on the altar. Each day the shadow moves slightly as the angle of the sunrise changes in the sky. During the period before the winter solstice, the shadow nears alignment with the raised edge on the belly of the cat. On the day of the winter solstice, the shadow falls exactly along the raised edge of the cat's belly.

Archaeoastronomers believe that Inca skywatchers, called *yancas*, could predict the arrival of the winter solstice by observing the shadow's position as it approached the raised edge of the cat's belly. These observations were used to determine when to celebrate the important Inca festival of Inti Raymi.

Archaeologists think that the silver plumb bob displayed in the exhibition may have been used to mark the June solstice. The fact that it is solid silver might indicate that it was used in a religious ceremony. Compare this use of a plumb bob to the way carpenters use it today.

3. *Assessment:* Ask students to write a two- to three-paragraph essay on the following topic:

How did the Incas make scientific observations of the sun and stars to keep track of the passage of time? Describe techniques they used to predict: a) when to plant crops, b) when a solstice was approaching, and c) when an equinox was occurring. Draw diagrams to illustrate each explanation. (Display the globe tilted at a 23 degree angle to help students visualize their explanations.)

B. The Night Sky

Homework

A few days before the unit is introduced:

Have students spend 10 minutes looking at the night sky. If the sky is cloudy, have them repeat the exercise on a clear night.

The day before the unit is introduced:

Have students read the background article “The Incas” (Section VII).

Lesson 1: Stargazing

Objective

Students will use sky charts to understand why people in the Southern Hemisphere see different constellations than people in the Northern Hemisphere.

Inquiry question

Do people in Peru see the same stars and constellations as we do?

Materials

An atlas, Internet access.

Procedures

1. *Introduction:* Explain that for thousands of years people have looked at the sky and seen patterns in the stars. These patterns are called constellations. The stars appear to move across the night sky due to the earth's rotation and revolution around the sun. The position of a given constellation appears to rise and set on the horizon at a slightly different point each night and some drop below the horizon for a period of weeks during the year. These movements all occur in a regular, predictable manner.
2. People have made charts of the night sky to record the position of the constellations and to predict future locations of the constellations. As a result of computer technology, you can now see a chart of what the sky looked like from any point on the earth at a given time hundreds of years ago.
3. *Activity:* Go to a good atlas and find the longitude and latitude of Machu Picchu. Be sure to record whether the position is east or west, north or south. [13 degrees S, 73 degrees W]
4. Now find the latitude and longitude of your town. [For example, New Haven, CT is 41 degrees N, 73 degrees W.]

5. On the Internet, find the website “Your Sky” (<http://www.fourmilab.ch/yoursky/>). Plug in the coordinates for Machu Picchu. You will get a picture of what the night sky looks like from Machu Picchu today. Print out the sky chart. Now update the sky chart, using your own town’s latitude and longitude. Print out the sky chart. Label each chart for easier reference.

6. Familiarize yourself with the sky chart. Find a few constellations you recognize. What is the red band with familiar constellations along it? [the path of the zodiac]

7. Examine the two charts and find five constellations that are on both charts. Now find five on each chart that are NOT on the other. In general, where do the two charts overlap? [in the middle] Where are they different? [on the edges]

8. Now we can answer the question: Does the night sky look the same in your town as in Machu Picchu? Why is this so? [The sky looks somewhat different due to the different positions on globe—one is in the Northern Hemisphere, the other in the Southern Hemisphere.]

9. What accounts for the significant overlap in the two charts? (Think about the geographic position of the two locations.) [Peru and North America (especially the East Coast) are at about the same longitude.]

Lesson 2: The Changing Night Sky

Objective

Students will understand how the night sky looks different in Peru than in their town.

Inquiry question

Does the night sky in Peru look the same as it does in your town?

Materials

Record player, two phonograph records.

Procedures

A few days before you begin the unit:

Ask students to go outside or look out a window after dark tonight. They should write down the time. Ask them to find one bright star or constellation on the horizon near a landmark such as a building or tree. Now have them wait two hours and look for the same star. Is it still visible? Has it moved? Have them repeat this process for two more nights.

1. *Introduction:* Discuss the results of the star observation. Explain that students will be learning why stars appear to move in the sky.
2. *Teacher demonstration:* To better understand why stars appear to be moving across the night sky, do this demonstration with a record player and two phonograph records. Put one record on the turntable. This represents the earth. Slowly turn the record counterclockwise to show how the earth spins from west to east as it rotates on its axis over a 24-hour period. Now put another record on the spindle and hold it above the first record. Put a sticky star on the edge of the top record. Ask a student to move the bottom record as done previously. Have students imagine they are standing on the bottom record looking up. How does the star appear to move? [from east to west] Explain that in both hemispheres, the stars appear to be moving from east to west when facing north.
3. *Homework:* Have students do research on the Internet or in the library on the difference between a star cluster and a constellation.

Lesson 3: Star Movements

Objective

Students will understand why the stars appear to move across the sky.

Inquiry question

Why do the stars appear to move across the night sky?

Materials

Three large umbrellas, star stickers.

Procedures

1. *Introduction:* Observe that students have learned that the stars appear to move across the sky due to the earth's rotation around its axis. Depending on their position in the sky, individual stars and constellations sometimes appear to rise and set on the horizon just as the sun does. The place on the horizon where the star rises and sets changes throughout the year in a predictable pattern. Many constellations drop below the horizon for several weeks during the year.
2. *Activity:* Umbrella exercise
 - a) Divide the class into three groups. Assign one of the following constellations or star clusters to each group: the Southern Cross, the Pleiades, and the Big Dipper. Have the groups conduct research on their assigned topic. Each group should make a drawing of their constellation or star cluster and write a brief report as to why it is important. How many stars does it have? What myths are associated with it? Was it used for a specific purpose in the past?
 - b) Now have each group depict the pattern of its constellation or star cluster by putting sticky stars on the inside edge of a black umbrella. (Make umbrella A the Big Dipper and North Star, umbrella B the Pleiades, umbrella C the Southern Cross.)
 - c) Position one person in a chair in the middle of the room. Have another student hold umbrella A overhead, another hold umbrella B to the side, and a third hold umbrella C near the ground. Have the person in the chair look straight ahead. He or she can see A and B but can't see C. This is the view of the sky from the middle latitudes of the Northern Hemisphere. Now reverse umbrellas A and C. This is the view from the middle latitudes of the Southern Hemisphere. He or she can see B and C, but not A. (A person on the equator can see all three through the period of one year.)
 - d) Now have a student place umbrella B on a table, with the handle flat on the table and the umbrella hanging over the edge. Have the student rotate the umbrella slowly so that the constellation rises, moves across the sky, and drops below the horizon.
3. *Assessment:* (assign as homework) Ask students to write a paragraph answering the following question: How could you use the rising and setting of the stars to make a sky calendar?

Lesson 4: The Sky Calendar

Objective

Students will understand how the Incas used the constellations as a calendar to regulate the planting and harvesting of crops.

Inquiry question

How did the Incas use the constellations as a sky calendar to indicate when to plant and harvest crops?

Materials

Handout 1: The Coricancha.

Procedures

1. Have students refer to Handout 1: The Coricancha. Ask them what the Coricancha was. [the most sacred temple of the Inca religion]
2. *Discussion:* Locate the “Stars of Summer.” This was the Inca name for the Pleiades, a star cluster visible in both the Northern and the Southern Hemispheres. How many stars are shown in the drawing? [13] How many of the Pleiades stars are visible to us? [6] Why do you think the Incas could see more stars than we can? (Hint: Think about their geographic location.) [Peru’s highland atmosphere is less dense due to high altitude, so there is less distortion of light waves entering earth’s atmosphere. The dry climate also makes stars more easily visible.]

There is a reason the Incas observed the Pleiades with special interest. People realized that the reappearance of the constellation in the eastern sky occurred when it was time to plant crops in the Cuzco region. Its disappearance below the horizon coincided with the beginning of the harvest season. The constellation disappeared for 37 days. This was the so-called “dead” period between the harvest and planting season. The Inca calendar did not record this period. When the Pleiades appeared again it was time to plant the next crop. So, people living in the Cuzco region observed the rising and setting of the Pleiades to know when to plant and harvest their crops. It is perhaps for this reason that the Incas came to worship the constellation and refer to it as *collca* (storehouse).

3. *Assessment:* Have students write a story explaining how someone used a constellation to anticipate an important seasonal event.

Lesson 5: The Milky Way

Objective

Students will understand how the Incas used their observation of the Milky Way in their myths and religious beliefs.

Inquiry question

Does the Milky Way look different in the Andes?

Materials

Internet access, Handout 4: Dark Cloud Constellations, *Miro in the Kingdom of the Sun*, by Jane Kurtz. Boston: Houghton Mifflin, 1966.

Homework

Before you begin the unit:

Have students do research and write a paragraph on the Milky Way. Do Internet research to find photographs of the Milky Way as seen from the Southern and Northern Hemispheres. (See, for example, NASA's Astronomy Picture of the Day web site by doing a search for "NASA Astronomy Picture of the Day." Then search the archive for images of the Milky Way as seen from the Northern and Southern Hemispheres.)

Procedures

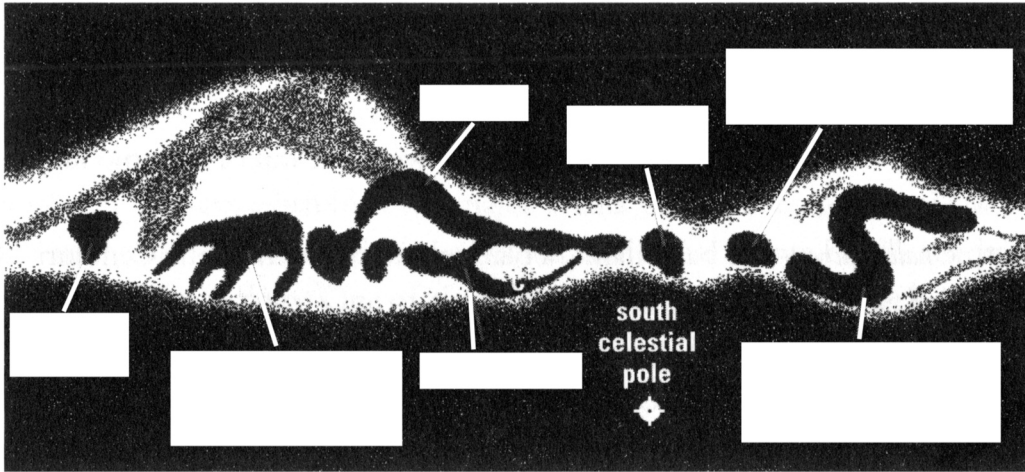
1. *Introduction:* Explain that the Milky Way looks different in the Southern Hemisphere than it appears to us in the Northern Hemisphere. Because people living in the Southern Hemisphere are looking more toward the center of the galaxy, the Milky Way looks much denser to them, with pronounced black spaces. In Peru, the Milky Way looks like a huge white path across the night sky. The Inca people thought of it as a celestial road or river.
2. Explain that Andean skywatchers observed the Milky Way and saw the outlines of animals in the dark areas. These "dark cloud constellations" appear and disappear throughout the year just as regular constellations do. The Andean skywatchers identified the dark cloud constellations they saw in the Milky Way with animals that were important to them. These constellations were paired with animals whose birthing cycles corresponded with the appearance and disappearance of the dark cloud constellations in the night sky. For example, the dark cloud constellation representing the llama appeared in December. The breeding period for llamas begins in late December and the animals give birth 11 months later. Two stars, called the eyes of the llama, rise on the horizon during the birthing season.
3. Explain that the Milky Way was also viewed as a river by the Andean people. The Incas believed that the Milky Way was the shadow of the god Apu Illapu, the rain giver. Temples to the rain god were usually in the mountains, where rain clouds often form. The Incas believed that Apu Illapu took rainwater from the Milky Way.
4. *Activity A* (older students): Have students name the blank spaces in the "Milky Way Band" image from NASA (see above) after an animal or other object in their daily life. OR:

Distribute Handout 4: Dark Cloud Constellations. Have students match dark cloud constellations with animals associated with them by Andean people.

Activity B (younger age groups): Read *Miro in the Kingdom of the Sun* by Jane Kurtz. Questions for discussion: What can you learn about life during Inca times from the story? How is the Incas' interest in objects found in the sky reflected in the story? [The king was named the Sun King; Miro is comforted by the moon, who is believed to be the wife of the sun.] What animal characters in the story are also part of the Andean view of the Milky Way? [llama and baby, boa constrictor (serpent)]

5. *Assessment:* (assign as homework) Have students write a three-part essay on how the Incas used observation of the sky to create a calendar. The essay should include a discussion of the sun, the Pleiades, and the Milky Way. Students should include an explanation of the astronomical phenomena underlying each observation. Optional: Have students draw diagrams to illustrate at least one observation.

Handout 4: Dark Cloud Constellations



(label images A, B,C,D,E,F,G)

___ toad

___ fox

___ snake

___ partridge

___ partridge

___ llama

___ baby llama

Source: *Stairways to the Stars*, by Anthony Aveni, p. 152. Copyright 1997 John Wiley & Sons, Inc. Reprinted by permission.

Teacher's Key: A, partridge; B, fox; C, llama; D, baby llama; E, partridge; F, toad; G, snake.

III. Lesson Plans: Inca Builders

Note: This unit is designed to be used after visiting the exhibition.

Before visiting the exhibition:

1. Order a free archaeological map of Machu Picchu (see Materials below).
2. Have students read the background article “The Incas” (Section VII).

View the exhibition *Machu Picchu: Unveiling the Mystery of the Incas*. Have students fill out the Student Guide (Section V) as they view the exhibition.

Lesson 1: Machu Picchu’s Challenging Site

Objective

Students will examine the problems Inca engineers faced in building a royal retreat at Machu Picchu’s site.

Inquiry question

How were Inca builders able to overcome the obstacles posed by Machu Picchu’s challenging location to build a complex of buildings that has remained almost completely intact for over 500 years?

Materials

Archaeological map of Machu Picchu (order a free copy from: Wright Water Engineers, 2490 West 26th Avenue, Suite 10-A, Denver, CO 80211; phone 303-480-1700), Handout 1: Contour Map of Machu Picchu.

Procedures

1. *Introduction:* Write on the board: “The Incas were good engineers.” Explain that Hiram Bingham made this statement in an article he published in 1913 in *National Geographic*. Ask students if they agree with Bingham’s statement. Have them cite examples of Inca engineering they saw in the exhibition *Machu Picchu: Unveiling the Mystery of the Incas*. [buildings, canal, terraces, roads, overcoming obstacles posed by remote site on top of mountain]
2. Discuss Machu Picchu’s site. (Have students refer to the Curator’s Tour section of the Student Guide they filled out during their visit to the exhibition.) What engineering challenges did Inca builders face due to Machu Picchu’s setting? [remote location, steep slopes, high elevation, river acts as barrier, where to obtain water, lack of soil for agriculture]

3. *Activity:* Working with a contour map

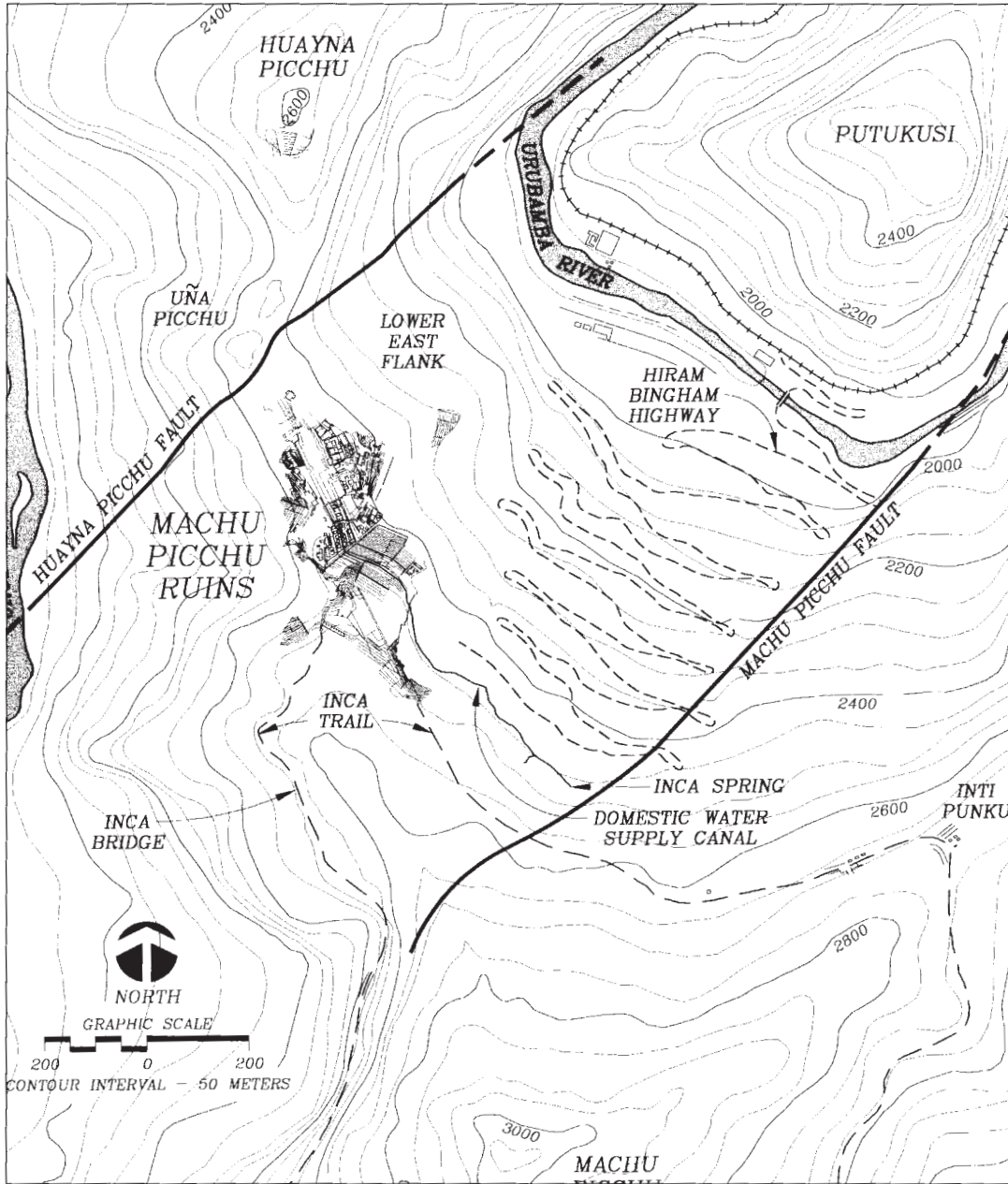
- a) Post the archaeological map of Machu Picchu on the bulletin board for reference.
- b) Pass out Handout 1: Contour Map of Machu Picchu. Explain the purpose of a contour map. [to show physical features like mountains and valleys on a flat surface] Each curved line represents 50 meters of elevation. Have students orient themselves by locating the river (lowest elevation) and tracing the Hiram Bingham Highway as it twists up the mountain to Machu Picchu.
- c) Ask students to identify important geological features on the map. [river, mountains (name them—how high is each?)] Ask students what a fault line is. What does the presence of two fault lines mean for builders? [likelihood of earthquakes—need to make buildings strong enough to withstand earthquakes; risk of landslides, especially in mountainous area]
- d) Explain to students that Machu Picchu's location in an earthquake-prone area was in one way an advantage to builders—repeated earthquakes produced rock fractures that caused landslides and rock falls that created blocks of granite of all sizes. The Inca builders were lucky to have these building blocks on site.
- e) What man-made structures are shown on the map? [Machu Picchu, the Inca Trail, railroad (The Inca Trail was there when Hiram Bingham visited, the railroad was not.)]

4. *Assessment:* (assign as homework) Have students write a three-paragraph essay on the following topic: Based on what you learned in the background article, your visit to the exhibition, and study of the contour map, why do you think the Incas chose this location to build Machu Picchu?

Possible responses:

- a) The Incas considered water and mountains to be sacred (*huacas*). Machu Picchu is surrounded on three sides by water (river) and has a view of three sacred mountains.
- b) Machu Picchu was relatively close to Cuzco, but had a better climate (drier, warmer than Cuzco in winter).
- c) The site was easily defended (has sheer cliffs on three sides).
- d) A spring was available for water.
- e) Many large building blocks that had been produced by recurring earthquakes were already on site.

Handout 1: Contour Map of Machu Picchu



Source: *Machu Picchu: A Civil Engineering Marvel*, by Kenneth R. Wright and Alfredo Valencia Zegarra, p. 5. Copyright 2000 ASCE Press, Reston, VA. Reproduced with the permission of ASCE.

Lesson 2: Machu Picchu's Water Supply

Objective

Students will determine whether Inca engineers were able to provide sufficient water to the site's residents.

Inquiry question

Where did the residents of Machu Picchu get their water?

Materials

Handout 1: Contour Map of Machu Picchu, Handout 2: Rainfall at Machu Picchu, sink with a faucet, gallon milk containers.

Procedures

1. *Introduction:* Where did residents of Machu Picchu get their water? Ruth Wright, a lawyer and photographer who has studied Machu Picchu extensively, asked this question in 1974. She and her husband, Kenneth Wright, spent the next two decades answering this question. Her husband was well qualified to study the problem—he is a civil engineer with a company that specializes in hydrology, of the study of water flow. The Wrights have spent many years exploring Machu Picchu and have written several books about the site (see Sources in Section VII).
2. *Activity*
 - a) Contour map
 - i) On Handout 1: Contour Map of Machu Picchu have students locate two geological features that could provide a source of water for Machu Picchu. [spring, river] What is shown leading away from the spring? [a domestic water supply canal]
 - ii) Explain that earthquakes created conditions favorable to the creation of a spring. Fractures caused by earthquakes make the rocks more permeable to water. Rainfall infiltrates the rocks and percolates down until it emerges from other rock fractures as a spring.
 - iii) Have a student trace the canal on the archaeological map of Machu Picchu. Where did excess water drain? [the main drain]
 - iv) Discuss the 16 fountains. What was their purpose? [They provided drinking water, and may have also had a ceremonial purpose.]
 - b) Measuring water flow
 - i) Explain that students will be analyzing whether Machu Picchu's water supply was sufficient to provide for the needs of everyone when the emperor and his attendants were in residence.
 - ii) Have students measure flow from a faucet by running the water for 30 seconds at full blast into one-gallon plastic milk containers. Estimate the amount of water in the containers. Multiply by 2. This equals water flow per minute from the faucet.
 - iii) Have students study Table 1 in Handout 2: Rainfall at Machu Picchu. This table compares

monthly rainfall at Machu Picchu (in millimeters) to the amount of water flowing from the spring (in liters). What can you say about the relationship between rainfall and water flow from the spring? [The amount of rain did influence the amount of water flowing from the spring, but there was a time lag between when the amount of rain declined and when the amount of water from the spring declined.] Which four months had the greatest amount of rainfall? [December, January, February, March] The least? [May, June, July, August]

iv) Remind students that the Inca emperor and his attendants were in residence at Machu Picchu during their winter (June to September). How much water was available from the spring then? [23 to 85 liters per minute]

v) Archaeologists believe that about 300 people were permanent residents of Machu Picchu. Kenneth Wright estimates that in order to meet the drinking water needs of 300 residents, water flow from the spring would need to be at least 10 liters per minute. According to the table, would the spring have provided sufficient water during the months when the emperor was *not* in residence (October to May)? [yes]

vi) Archaeologists think that about 600 people lived at Machu Picchu when the emperor and his relatives, friends and servants were in residence. Ask students to calculate how much water would be required when the emperor and his attendants were at Machu Picchu. [Divide 600 by 300, which equals 2. They would need 2 times as much water, or 20 liters per minute.]

vii) Would water flow from the spring be sufficient during all the months when the emperor was in residence (June to September)? [In normal years, rainfall would have been sufficient. But residents might have experienced a water shortage in September during periods of drought.]

viii) Return to Handout 1: Contour Map of Machu Picchu. Where else might residents have obtained water? [the Urubamba River]

ix) Ask students what objects in the exhibition could have been used to carry water. [large pottery jars called *aryballos*] Who usually carried water? [women]

x) Estimate the amount of water a large *aryballo* would hold. Divide the class into groups of four students. Give each group a one-gallon plastic milk container and ask a student in each group to empty his or her backpack. Have each group fill their milk container with water. Have students take turns carrying the water in the backpack. Note: Inca women would have carried the water up a 1,640-foot path that went almost straight up!

c) Drainage

Inca builders also had to build structures to carry away excess water. This was especially important because Machu Picchu has periods of heavy rainfall between October and April (refer to Handout 2, Table 1, “Monthly Rainfall and Spring Flow”). The second table in Handout 2, “Urban Surface Runoff for Typical Wall Drainage Outlets,” shows how a modern-day civil engineer would calculate the size and capacity of drains necessary to handle excess rainwater. The Incas created an efficient system for water drainage using only a *quipu* and a counting tray!

Enrichment

Materials

Neo/SCI kit “Investigating Water Pollutants and Water Analysis” (see Kits under Resources), Handout 3: Water Quality of Machu Picchu’s Spring.

Inquiry question

Which type of water is purer, standing water or running water?

1. Using the Neo/SCI kit, have students analyze the water quality of their local water supply. Have them record their data on the chart provided in Activity 7 of the kit. Then have them test water samples from a local river (running water) and a local pond or lake (standing water).
2. Have students add information to their chart about the quality of water from Machu Picchu's spring (provided on Handout 3).
3. Which water source supplies the purest water? The least pure water? Why?
4. *Assessment:* Have students write a paragraph comparing the water quality at Machu Picchu with one of the standing water sources they analyzed. Which type of water is purer, standing water or running water?

Handout 2: Rainfall at Machu Picchu

Table 1: Monthly Rainfall and Spring Flow

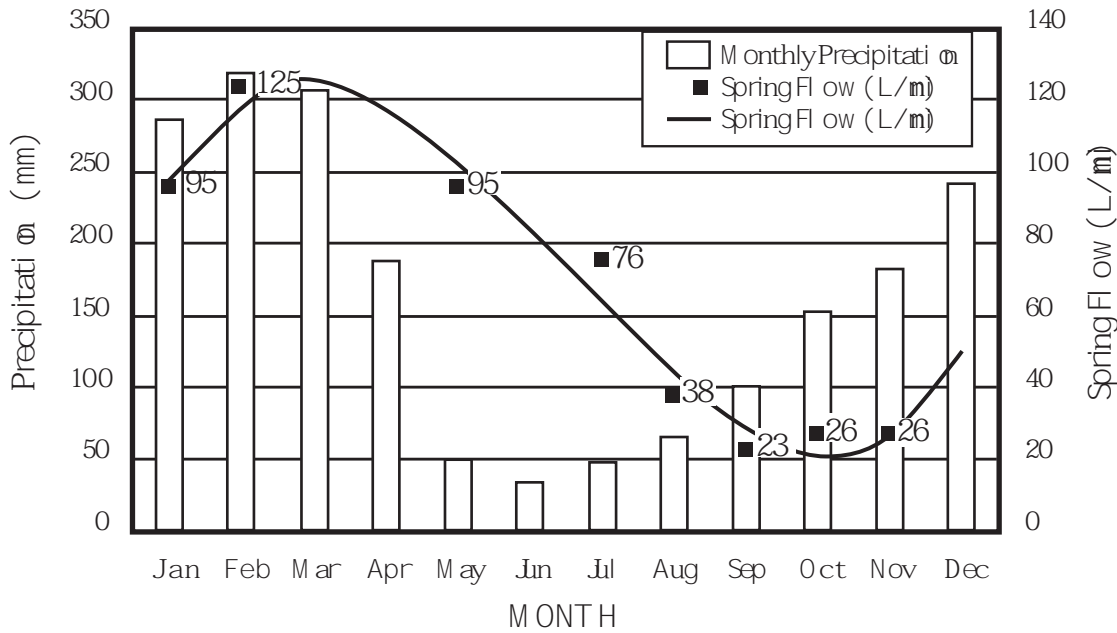


Table 2: Urban Surface Runoff for Typical Wall Drainage Outlets

Primary	Magnitude
Tributary area per drainage outlet	200 square meters
Drainage outlet size, typical	10 cm by 13 cm
Drainage outlet capacity, maximum	650 liters per minute
Design rainfall intensity	200 millimeters per hour
Design flow per drainage outlet	500 liters per minute

Source: Adapted from *Machu Picchu: A Civil Engineering Marvel*, by Kenneth R. Wright and Alfredo Valencia Zegarra, p. 30. Copyright 2000 ASCE Press, Reston, VA. Reproduced with the permission of ASCE.

Handout 3: Water Quality of Machu Picchu's Spring

	January 1996 (mg/L)
<i>Inorganics</i>	
Total dissolved solids	35.0
Total alkalinity	14.0
Ammonia	<0.80
Chloride	0.87
Sulfur	4.42
<i>Dissolved metals</i>	
Manganese	<0.004
Copper	<0.003
Zinc	<0.10
Iron	<0.04
Aluminum	<0.12
Sodium	1.80
Potassium	0.58
Calcium	3.60
Magnesium	0.58
<i>Total metals</i>	
Manganese	0.01
Copper	<0.003
Zinc	<0.10
Iron	0.24
Aluminum	0.20
Sodium	3.00
Potassium	0.65
Calcium	4.10
Magnesium	0.74
Field measurements	July 1995
Water temperature	16.0 degrees C
Conductivity	35.0
pH	6.45

Source: *Machu Picchu: A Civil Engineering Marvel*, by Kenneth R. Wright and Alfredo Valencia Zegarra, p. 22. Copyright 2000 ASCE Press, Reston, VA. Reproduced with the permission of ASCE.

Lesson 3: Terraces

Objective

Students will understand how terraces are built to absorb water and prevent erosion.

Inquiry question

Why did the Incas build terraces?

Note to the teacher: If you do not have sufficient time or materials to have students build a model terrace, refer to the Shortcut Activity that describes a simpler terrace-building activity. If you choose the shorter activity, do not refer to terraces as a method of retaining water until the students have completed the activity. Then have the class discuss the questions listed under Procedures, 2 through 6.

Activity: Build a Terrace

Materials

Small stones, gravel, sand, soil, Duplos or other large plastic building blocks, large poster boards with a plasticized surface (one per group), measuring cups, plastic drinking straws, large plastic tubs to collect water.

Procedures

1. *Introduction:* Ask students to recall the terraces they saw in the model and photographs at the exhibition. How were they made? Ask a volunteer to sketch them on the board.
2. Have students get information from the Internet on the average monthly rainfall in their region. Have them plot average monthly rainfall in their region on Handout 2, Table 1, “Monthly Rainfall and Spring Flow.” (Note: Students may have to convert inches of rainfall to millimeters.) How does rainfall in Machu Picchu compare to rainfall in your area? Encourage students to understand that Machu Picchu receives a lot of rainfall, and that the amount varies greatly between the dry and wet seasons.
3. Ask students to think about what problems large amounts of rain would create in a mountainous setting. [Steep slopes would create rapid water runoff during rains, causing soil erosion and landslides.]
4. Ask students how building terraces would prevent water runoff and soil erosion. [Terraces create flat surfaces that allow rainwater to be absorbed into the ground. They also channel water runoff to reduce erosion.]
5. Explain that one reason terraces were especially important at Machu Picchu was that the Incas grew corn there to make *chicha* beer. Because corn has thin, fragile stalks, it grows best in flat fields like

those of the American Midwest. What would happen if corn was planted on a steep slope? [The fragile stalks would break easily in a heavy rainstorm.]

6. Ask students who built the terraces at Machu Picchu. (refer to background article “The Incas,” Section VII) [mita workers]
7. Explain to students that they will be dividing into teams to build an agricultural terrace similar to those at Machu Picchu. Their goal is to build a terrace that will absorb the most water and have the least amount of soil erosion.
8. Divide the class into teams. Tell them that they will have two class periods to design and build a terrace. Their goal is to create a structure that absorbs the most water. The team that builds a terrace that retains the most water wins. Teams will also be scored on how effective their structure is in holding up the straws (stalks of corn). The team with the highest number of straws that wash away loses.
9. Each terrace is to be slanted at a 45-degree angle. Have students prop the poster board on a chair or low table to create a 45-degree angle. The lower end of the poster board should be in the plastic tub that will catch water when it is poured over the terrace.
10. Allow time for teams to design and construct their terraces.
11. During the last 15 minutes of the second class period, have students take turns pouring water down their terrace (slowly, one cup at a time). Each group should measure the water runoff from their terrace. Which group’s terrace had the least runoff? The most straws left standing? They are the winners of the terrace construction contest.

Shortcut Activity

If you choose this activity, do it at the beginning of the lesson before your discussion of terracing.

Materials

Heavy-duty aluminum foil, plasticized poster board, cotton balls, large tub.

Procedures

1. Challenge students to build a structure on a sloping surface that will absorb the most water possible.
2. Divide the class into teams of four. Give them the plasticized poster board, heavy-duty aluminum foil and cotton balls. Tell them that they are to devise a structure that will absorb the most water possible when the poster board is positioned at a 45-degree angle.
3. During the last 15 minutes of class, have students take turns pouring water down their structure (slowly, one cup at a time). Each group should measure the water runoff from their terrace. Which group’s terrace had the least runoff?
4. *Closure:* Ask students what structure they saw in the exhibition that served the same function as their structure. [terraces]

Lesson 4: Architecture

Objective

Students will learn how Inca architecture was adapted to the extreme environment of the Andean highlands.

Materials

Secrets of Lost Empires: Inca (video), available from WGBH, Boston (cost \$19.95), cotton, wool fibers, llama, alpaca fibers (if available).

Procedures

1. *Introduction:* Show the video *Secrets of Lost Empires: Inca*. Ask students what they learned from the video about how Inca building techniques created strong, earthquake-proof buildings. [They used huge rectangular stones, made tight joints, and created very strong walls.]
2. Ask students what tools the Incas used to shape stones. [stone hammers] To move stones? [a lever, small stones]
3. *Activity:* Challenge students to design a simple house using the materials available to Inca builders (stone or adobe, thatch; wood is scarce in the Andean highlands). The design is to take into account environmental conditions prevalent in the Andean highlands (marked changes in temperatures between day and night) and take advantage of geographic conditions (high elevation creates strong solar heat) to provide warmth.
4. Have students do research on the Internet to find out how much average daily temperature varies in Cuzco. Have students make a graph showing the average high and low temperatures by month for Cuzco. [Daily temperatures vary by about 20 degrees F in the summer and 30 degrees F in the winter.]
5. Challenge students to design a house for an Andean family, given what they know about the environmental conditions in the Andean highlands and the building materials available there. Encourage them to think about how to ensure warmth in the cool highland climate.
6. *Explanation* (discuss after students have designed their houses): [Temperatures in the Andean highlands vary greatly each day—between 20 and 30 degrees F. The sun's rays are very strong during the day, and can heat up stone or adobe surfaces considerably. Andean houses are made of adobe and generally consist of one small windowless room with an open door oriented toward the sun. The roof is generally of thatch. A fire may be lit to cook food. The intense sunlight heating the adobe increases the interior temperature by about 18 degrees F during the day. The temperature gradually decreases during the night. At night, people use heavy blankets and the whole family often sleeps in the same bed to increase warmth.]
7. *Under the microscope:* Have students examine wool and cotton fibers under the microscope. If possible, get llama or alpaca wool and examine it under the microscope. Does the structure of the wool suggest that it would be a better insulator than cotton?

Enrichment Activity

Objective

Students will learn about the greenhouse effect by comparing the temperature in model houses with windows to those without windows.

Materials

“Hot Water and Warm Homes from Sunlight,” a GEMS kit (see Kits under Resources).

Procedures

1. Divide the class into groups of four students. Distribute a GEMS kit to each group. Explain that the class will be learning about the greenhouse effect by comparing houses built with plastic windows and houses built without windows.
2. Have half the students make a house without windows and the other half make houses with two windows. The windows should be covered with clear plastic (use plastic storage bags cut to fit over the window openings, seal with clear adhesive tape). All houses should have one small door.
3. Have each group put its house outdoors in a sunny place with the thermometer (provided in the kit) inside the house.
4. Have students measure the temperature in the two types of houses three times: a) early in the morning; b) at noon; and c) at the end of the school day.
5. Have students record their data on a chart. Which houses have the greatest increase in temperature? [houses with windows] What scientific principle explains this? [greenhouse effect]
6. Now have students answer the following questions:
 - a) What source of energy is used to heat the model houses? [solar energy]
 - b) Where would the effect of solar energy be most pronounced: your geographic location, or Andean location? [Andes, due to the location near equator and high altitude]
 - c) What happens to the temperature in Andean homes during the day? [increases by 18 degrees F]
 - d) What direction should doors in Andean homes face to take advantage of solar heating? [north toward the sun]
 - e) How could energy efficiency in Andean homes be improved? [add glass windows or cover windows with blankets at night]
7. *Closure*
 - a) Look back over these activities. How many involved mathematical calculations? Ask students what kind of mathematical tools the Incas had. [*quipu* and counting trays] Have students discuss how the Incas could have built Machu Picchu and many other engineering marvels with limited mathematical tools.

b) Have students compare the life span of our buildings to those built by the Incas. [The buildings at Machu Picchu have remained almost intact (except for thatched roofs) for about 550 years. Our buildings are built to last 100 to 150 years.]

c) Engineers often stress the importance of building a good foundation. Explain that 60% of the construction effort at Machu Picchu went into building the substructure (below the surface). Ask students to cite examples of substructures. [foundations for buildings, drainage system, soil for terraces]

8. *Assessment:* Ask students to write a one- to two-page essay on the following topic:

Think about your visit to the exhibition *Machu Picchu: Unveiling the Mystery of the Incas*. Describe three techniques you learned about that archaeologists have used to study the Inca people. Hint: Think about these activities that archaeologists do in their work: observing, measuring, hypothesizing, creating a model, excavating, examining through a microscope. Cite examples of how archaeologists carried out these tasks and what they learned as a result.

IV. Lesson Plans: Adjusting to an Extreme Environment

Introduction

Explain that students will be going to the exhibition *Machu Picchu: Unveiling the Mystery of the Incas*. They will be learning about the Inca Empire, a sophisticated civilization that was located in the extreme environment of the Andes Mountains. At the height of its power the Inca Empire controlled an area in South America that stretched over 2,500 miles along the Andes Mountains and ruled between 10 and 14 million people. Descendants of the Incas still live in the Andean highlands. Before they go to the exhibition students will learn about how people living at extremely high altitudes in the Andes have adjusted to their environment.

Lesson 1: Are We Getting Shorter or Taller?

Objective

Students will compare changes in height across generations for Andean people and Americans.

Inquiry question

Ask students if they think they will be taller as adults than their parents. Why or why not?

Before beginning the unit:

1. Explain to students that they will be comparing growth rates between Americans and Andean people over generations. They will conduct a survey to study the increase in height between generations of Americans and learn if the height of Andean people has increased over generations.
2. Ask students to choose two grown people they know who are in the same family. The two people they choose should be of the same sex and of two different generations. One person should be in their forties or fifties and the other (son or daughter) over 18. Have them measure the height of each person and record the measurement.
3. Assign the background article “The Incas” (Section VII) as homework one or two days before you introduce the unit.

Procedures

1. *Height survey:*
 - a) Record the results of the students’ height survey on the board. Make four columns: Height of boys, Height of men, Height of girls, Height of women. Record the height information, one row per family. Each student should record the data in chart form.

- b) Have students calculate the difference in height (plus or minus) of the pairs of boys compared to men and of girls compared to women. Add the differences in height of all pairs and calculate the average difference between the two generations for each sex. On average, how much taller or shorter is the younger generation than the older generation? Have students make a bar graph to compare the average height of different generations for boys and men, and girls and women. Ask students to give hypotheses to account for the differences.
2. Explain that archaeologists have studied the bones of people who were buried at Machu Picchu 400 to 500 years ago. They found that people living then (about A.D. 1500) were about the same height as people living in the Andean highlands today: men living at Machu Picchu averaged 5'2" and women averaged 4'11", compared to 5'2" for men and 4'8" for females today. Have students add this information to their bar graph.
 3. Ask students to speculate as to why Andean people have not increased in height over several generations. [Possible responses: Their diet may be inadequate or unchanging; their small height might be determined genetically; their small size may be more adaptive to high altitudes.]
 4. Explain that over the next few days students will be studying how Andean people have adjusted physically to living in an extremely high altitude environment.

Lesson 2: Human Respiration

Objective

Students will understand the process of respiration, including the exchange of oxygen and carbon dioxide in the lungs. They will make models showing how the human lung works.

Materials

Two large plastic soda bottles per student, two packages of small balloons, hot glue, scissors.

Procedures

Short cut: This activity can also be done as a teacher demonstration.

1. *Introduction:* Explain that the class will be making a model of the human lung to study how changes in air pressure affect respiration.
2. Have students make a model of the human lung with plastic soda bottles and a balloon as follows:
 - a) Cut off the top of one soda bottle about 3 inches below the top.
 - b) Put the cut-off top against the side of another plastic bottle and make a mark around the circle of the cut-off bottle.
 - c) Cut out a hole in the bottle along the marks.
 - d) Glue the two bottles together.
 - e) Put the lid on the cut-off bottle.
 - f) Take the top off the large bottle. Blow up a balloon and twist it to seal the air in.
 - g) Put the balloon over the opening of the large bottle.
 - h) Now have students experiment with how changing air pressure affects inflation of the balloon by carrying out the following experiment:

Step A: Squeeze the large bottle. What happens to the balloon? [It inflates.] Have students take turns squeezing the bottle and observing the result.

Step B: Now have the students let out a little bit of air by loosening the top of the cut-off bottle slightly. Squeeze the bottle again. What happens to the balloon now? [It doesn't inflate as much.]
3. *Homework:* Have students write up this experiment. Ask them to decide which part of the experiment (Step A or B) shows how lungs would operate in a high altitude environment. [Step B—lower air pressure means the balloon inflates less]
4. *Assessment:* Have students write a paragraph explaining how lower air pressure affects respiration. Ask them to think of ways the respiratory system might compensate in high altitude environments with lower air pressure. [the lungs can get larger to take in more air]

Lesson 3: Evolution or Acclimatization?

Objective

Students will understand how living in a high altitude environment affects respiration.

Inquiry question

In what ways would you expect the human body to adjust to the extreme Andean environment?

Materials

Handout 1: Adjusting to an Extreme Environment, atlas or globe.

Procedures

1. *Introduction:* Show the class a map or the globe. Have one student locate Peru. Ask him or her to find Peru's latitude. Then discuss with the class how they think Peru's location near the equator affects its climate. (Many students may think that because Peru is close to the equator, its climate is hot and humid.) Ask students to discuss the major physical feature of Peru. [Andes Mountains; find the highest point, Mt. Huascarán, at 22,205 ft.] How does the presence of this high mountain chain affect Peru's climate? (Refer students to the background article "The Incas," Section VII.) [It makes it cold and dry.]
2. What problems are associated with living in an extremely high altitude environment?
[altitude sickness]
3. Ask students to speculate about how people who live at a high altitude over generations might evolve or adjust to living in a high altitude environment. [Possible responses: They may develop increased body fat to provide added warmth in a cold climate. Their bodies might develop larger lungs to process more oxygen.]
4. Now have students read Handout 1: Adjusting to an Extreme Environment.
5. *Assessment:* (assign as homework) Have students answer the following questions:
 - a) Identify three environmental challenges created by high altitude as described in the handout.
 - b) What are some of the symptoms of altitude sickness?
 - c) What is acclimatization? What physical adjustments do people develop who live in a high altitude environment over a long period of time?

Handout 1: Adjusting to an Extreme Environment

People first arrived in South America relatively late in human history—about 22,000 years ago. By the time humans arrived in the New World, they had evolved into modern *Homo sapiens*. Humans did not evolve significantly in the New World and are genetically similar to people from Africa, Asia and Europe. But as they settled the varied climates of South America, from the frigid cold of Tierra del Fuego to the steamy rainforests of the Amazon, their bodies successfully adjusted to many extreme environments.

People who settled in the highlands of Peru faced an especially challenging environment. At altitudes of 11,300 feet, such as Cuzco, the air is thin and many people from lower elevations experience altitude sickness when they first arrive there. This is because as altitude increases, the concentration of oxygen in the atmosphere decreases due to a lower force of gravity as one moves away from the earth's surface. When people breathe in this "thin" air, they get fewer oxygen molecules per breath. This "thin" atmosphere absorbs fewer of the sun's rays—in fact, exposure to cosmic radiation at 13,000 feet is 10 times that at sea level because of the reduced ozone present at high altitudes.

People who grow up in lower altitudes and visit high altitude areas suffer from hypoxia, or altitude sickness, which is characterized by shortness of breath, fatigue, headache, disrupted sleep patterns, nausea, difficulty in seeing or hearing, faulty short-term memory, dizziness, and sometimes vomiting. After several days (between two days and two weeks, depending on the altitude), a person's body becomes used to the higher altitude and these symptoms decrease. But visitors will probably continue to get tired more quickly when doing physical exercise than people native to the area.

The bodies of people who live at high altitudes over a long period of time gradually adjust to the high elevation. They develop larger lung capacity and larger chests. Their bodies have also developed more efficient respiratory systems. The process of adjusting to a specific extreme climate over time is called acclimatization. These changes occur after birth and are not inherited by subsequent generations.

Lesson 4: The Effect of Altitude on Gas Diffusion

Objective

Students will analyze information about how the respiration of Andean people differs from that of people living at lower elevations.

Inquiry question

In what ways does the human respiratory system adjust to a lack of oxygen at high altitudes?

Materials

Handout 2: The Effect of High Altitude on Oxygen Intake, microscope, blood specimen slides.

Procedures

1. *Activity:* Have students take their pulse rate at rest and after physical activity. Have them record their pulse rates before and after physical activity and draw a graph showing that pulse rate increases with physical activity.
2. Review with students why respiration is more difficult at high altitudes. Explain that they will be analyzing how the bodies of Andean people have changed to obtain oxygen more efficiently.
3. Distribute Handout 2: The Effect of High Altitude on Oxygen Intake and have students read it in class. Then discuss the questions as a group.
4. *Discussion:* Is a more efficient respiratory system inherited or does it develop after birth?

Explanation: Red blood cells carry oxygen from the lungs to the body's cells. Red blood cells are produced in the bone marrow. Scientific studies show that people growing up at high altitudes have bone marrow that produces more red blood cells. This is because their bone marrow grows for a longer period of time. While bone marrow stops growing in sea level dwellers, at age 10 in girls and age 16 in boys, in the highlands bone marrow continues to grow until age 22 for men and 18 for women.

Children who are born at a low altitude but move to a highland environment during their growth years develop greater lung capacity compared to children who continue to live on the coast. Adults who move to a high altitude do not increase lung capacity.

Would this suggest that the more efficient respiratory system is inherited or does it develop after birth? [develops after birth]

5. *Under the microscope:* Have students examine blood specimen slides under a microscope and identify red blood cells.

Handout 2: The Effect of High Altitude on Oxygen Intake

As you know, the earth is enveloped in a thick blanket of air. This blanket is denser at sea level than it is at higher elevations because gravity is stronger near the earth's surface than it is at higher altitudes. As altitude increases, fewer and fewer air molecules are present in the atmosphere. The number of air molecules in the air affects the atmospheric pressure—at sea level, atmospheric pressure is high, and it decreases with increases in altitude.

Our respiratory systems depend on air pressure to function. When we breathe in, the air pressure in our lungs increases. The pressure in the lungs is greater than the pressure in the blood vessels of the lungs, so gas from the lungs permeates the blood vessel walls and enters the blood.

At high altitudes, the difference in pressure between the lungs and the blood vessels is less. Therefore, less oxygen passes through the blood vessel walls into the blood stream.

Oxygen is carried through the blood stream by red blood cells containing hemoglobin, a substance made of iron.

Human beings and other mammals evolved in low altitude environments, where the atmospheric pressure is about 760 millimeters of mercury. At this level of atmospheric pressure, blood passing through the lungs becomes practically saturated with oxygen. At 9,000 feet, the atmospheric pressure is reduced to 550 millimeters mercury. The effects of lowered oxygen is noticeable at 8,000 to 10,000 feet. At 14,000 feet and above, altitude sickness is pronounced. At 18,000 feet the oxygen available in the lungs drops to below half that available at sea level. At this altitude, blood passing through the lungs cannot take up enough oxygen to supply the cells of the body, and fainting or other physical impairment can occur.

The bodies of people who live in very high altitudes have developed ways of processing oxygen more efficiently. Scientists have studied how the bodies of people who have grown up in high altitudes have changed to adjust to lower levels of available oxygen. They did an experiment to see how the bodies of people who grew up in different altitudes react to exercise. They measured the heart rate (pulse) and breathing of people who grew up in the Andean highlands and people who grew up in Lima, Peru, at sea level. Both groups walked on an uphill treadmill. The highland group walked for almost an hour at 1,640 feet, while the group from the seacoast walked for about half an hour near sea level. The table below shows how the two groups responded to physical exercise.

Examine the information in the table. What does it suggest about the physical adjustments the bodies of Andean people have undergone to acclimatize to lowered oxygen levels?

Treadmill Walking

At an 11% grade, 48 feet per minute

	Lima group, near sea level	Highland natives, at 1,640 feet
Ventilation* of lungs, liters per minute	37.5	42.2
Oxygen consumption, liters per minute	1.33	1.17
CO ₂ produced, liters per minute	2.7	2.4
Respiration rate per minute	37.0	36.0
Pulse rate per minute	183.0	160.0
Blood hemoglobin** grams per 100 ml.	16.3	20.1

*Ventilation is the amount of air inhaled per minute

**Hemoglobin is the compound in red blood cells that carries oxygen to the blood cells.

Source: Adapted from Hurtado 1964 in "Ecological and Physiological Adaptations in Indigenous South Americans," by Paul Baker, p. 298, *The Biology of Human Adaptability*, Paul Baker and J. S. Weiner, (ed.). Clarendon Press, Oxford, 1966. Reproduced with permission.

1. What measurements are about the same for highland people compared to those living at sea level? [respiration rate, oxygen consumption, carbon dioxide produced]
2. What measurements are significantly different? What are the biggest differences shown in the chart for highland people compared to people living at sea level? [ventilation (amount of air breathed in), blood hemoglobin, pulse rate]
3. Which group has a more efficient respiratory system? Why? [people living at high altitudes]
4. Ask students to explain why the respiratory systems of people living at high altitudes are more efficient, based on the information contained in the table. [People living at high altitudes breathe in more air because they have larger lung capacity. They also have more hemoglobin in their blood, so the blood can pick up more of the available oxygen in the lungs. They have a lower pulse rate, even though they were on the treadmill for a longer period of time. Therefore they have a more efficient respiratory system.]

Lesson 5: Nutrition: The Food Pyramid

Objective

Students will learn about the main food groups and evaluate the nutritional content of their favorite foods.

Inquiry question

How nutritious are your favorite foods?

Materials

Poster of the food pyramid. (To get the most updated food pyramid, see the “Healthy Eating Pyramid,” developed by Dr. Walter Willett of the Harvard School of Public Health, at the Harvard Health Letter website at <http://www.health.harvard.edu>, go to Back Issues, Features and Tools, Turning the Food Pyramid Upside Down, or see *Newsweek*, January 20, 2003, for an article on the revised food pyramid.)

Procedures

1. *Introduction:* Explain to students that they will be learning about the main food groups and evaluating how nutritious their favorite foods are.
2. Divide the class into six groups.
 - a) Assign each group one of the main food groups: protein; starch; glucose; or fat.
 - b) Have one group study iron, an important component of hemoglobin in the blood, and another group study vitamin C.
 - c) Have each group do research and write a report explaining why their food component is important. What role does it play in the functioning of the human body? What are some foods that are sources of each? Note to teacher: The *World Book* article “Nutrition” has concise information on the food groups and Recommended Daily Allowances of various nutrients.
3. Have each group present its findings to the class. Have them locate foods rich in their food component on the revised food pyramid. Which foods contain protein, starch, glucose, fat?
4. Have students bring in samples of their favorite food (must have a food label). Have each student describe the nutritional content of his or her food and locate it on the food pyramid. Which foods are highest in protein? Fat? Sugar? Sodium? Iron? Vitamin C? What important information is missing from the food label? [vitamins and minerals are often not listed]

Lesson 6: The Andean Diet

Objective

Students will analyze a typical Andean diet and construct a food pyramid illustrating the nutritional content of the diet.

Inquiry question

How do you think the diet of people living in very high altitude environments would be different from ours?

Materials

Handout 3: The Andean Highland Diet.

Procedures

1. Distribute Handout 3: The Andean Highland Diet.
2. Have students read the handout.
3. *Discussion:* Ask students to analyze the diet of Andean people at two different levels of altitude by answering the following questions:
 - a) How many types of food did the people living at 9,000 feet consume? The people living at 13,000 feet? [17, 10]
 - b) What accounts for the smaller variety of food at the higher altitude? [People are more dependent on what they can grow locally; fewer types of plants can grow at high altitudes.]
 - c) Which group had the largest total food consumption (total grams consumed)? Can you think of an explanation for this? [People may have higher calorie requirements at high altitudes.]
 - d) Which group ate the most native foods? Why? [People living at higher altitudes are more dependent on local plants; fewer types of plants can survive at high altitudes.]
 - e) What foods comprised the largest portion of the diet of those living at 9,000 feet? [corn, potatoes, other tubers] At 13,000 feet? [potatoes, *chuño*]
 - f) Do you think that the diet of people living in both villages would vary according to the season? How? [More fresh vegetables would be available after the harvest. Several months after the harvest, people would be more dependent on preserved foods like *chuño*.]
 - g) How much meat did each group eat? Have students compare this to their daily consumption of meat. Note: A quarter-pound hamburger equals about 110 grams.
4. Divide the class into two groups. Have one group construct a food pyramid for each of the village diets listed. Note: They can omit the foods that are consumed in small quantities (one gram). Have one person from each group explain the pyramid and contrast it to the other one.
5. Now compare the diet of people in the two Andean villages to that of Americans by comparing the recommended American food pyramid with the two food pyramids constructed for the

villages. What foods that we eat are missing from the Andean food pyramids? [They eat few dairy products or eggs.] Note: Researchers who conducted the study report that eggs, milk and meat are often sold by villagers to obtain cash, instead of being eaten. [No sugar is consumed in the high altitude village because it would need to be imported and purchased. This would require money, a transportation network, and a store.]

6. Ask students to compare their diet to that of Andean people. Which group seems to have better nutrition? Why? Ask them to evaluate specific components of each diet, including sugars, fat, protein, and iron.
7. *Assessment:* Have students write a one-page essay explaining how the Andean diet is well suited to the needs of people living at a high altitude.

Handout 3: The Andean Highland Diet

As you have learned, different “ecological niches” exist in the Andean highlands. A wider variety of plants can be grown at lower altitudes. As altitude increases, plants must be able to withstand colder temperatures.

In the Andes, the largest settlements are located between 8,000 and 11,500 feet above sea level, where the soil is fertile and weather conditions are favorable to the growth of tubers, legumes, vegetables and fruit. Rice is the most common food up to 6,500 feet, and maize from 6,500 to 11,500 feet.

Above 11,500 feet the soil is poor and thin, and potatoes substitute for cereals as the staple food. Fresh potatoes are common at altitudes of between 10,000 and 12,500 feet, while *chuño* is more common at higher altitudes. Between 13,000 and 15,800 feet, early morning temperatures are often below freezing, so only plants that are frost resistant, such as tubers, *cañihua* and *quinoa*, can be raised. Above 15,800 feet, vegetation is almost absent.

People living today at high altitudes are more reliant on growing their own food, since poor transportation systems make it difficult to import food. They often lack the cash to purchase imported foods.

Researchers have studied the diets of villagers living at different altitudes in the Andes. Vicos lies at an altitude of 9,000 feet, and Nuñoa is at 13,000 feet. Nuñoa is surrounded by grassland and herding is the main economic activity. Most families herd alpacas, llamas, sheep and cattle. They are limited to growing frost-resistant crops such as *quinoa*, *cañihua* and bitter potatoes. Their diet lacks foods high in calcium, but researchers have learned that they get calcium from adding burned limestone as a spice to porridge.

Compare the diets of the people living in the two villages. Which diet is more varied? Tastier? How do these diets differ from the typical American diet?

Food Consumed at Two Different Altitudes in Peru

(Grams per day, rounded to the nearest gram)

Note: Native (Quechua) foods are listed in italics. Consult the glossary for food items you are not familiar with.

Food product	Village of Vicos 9,000 feet	Village of Nuñoa 13,000 feet
Barley	52	53
Corn	151	25
Wheat	107	14
Bread	24	—
<i>Quinoa</i>	—	45
<i>Cañihua</i>	—	45
Broad beans	70	—
Potatoes	347	741
<i>Chuño</i>	—	470
Other tubers	217	28
Meat	41	93
Lard	5	5
Onions	5	—
<i>Rocoto</i>	4	—
Pepper	1	—
Cabbage	12	—
Coleus	1	—
Coriander	1	—
<i>Huacatay</i>	1	—
Sugar	20	—
Total number of foods consumed		
Total grams of food consumed		

Source: Based on data collected by Collazos 1960, and Mazess and Baker 1964, quoted in "The Food and Nutrition of High-Altitude People," by E. Picon-Reategui, p. 221, in *The Biology of High Altitude Peoples*, P. T. Baker, editor. Copyright 1978 Cambridge University Press, Cambridge, U.K. Reprinted with permission.

Glossary of Andean foods

Quinoa: The seed of a leafy plant that is distantly related to spinach, *quinoa* is an excellent source of protein and contains lysine, an essential amino acid. *Quinoa* is also high in iron, potassium and riboflavin. It has been cultivated in the Andes for over 5,000 years.

Kiwicha (amaranth): A grain grown in the Andes that is richer in protein than the major cereals and is a good source of lysine. It is also high in calcium, phosphorus, iron, potassium, zinc, vitamin E, and vitamin B complex.

Cañihua: A high protein grain that grows at high altitudes in the Andes.

Rocoto: A variety of small hot pepper.

Coleus: A member of the mint family, *coleus* is used in Andean cooking as an herb. It also has medicinal uses.

Huacatay: A member of the marigold family, *huacatay* is an herb used in Peruvian cooking.

Chuño: Dehydrated potato.

Lesson 7: Comparing the Nutritional Content of American and Andean Foods

Objective

Students will conduct a scientific experiment to compare the nutritional content of American and Andean foods.

Inquiry question

How nutritious are Andean foods compared to the recommended American diet?

Materials

Two to three weeks before the unit: Order the Kemtec “Food and You” kit for measuring the nutritional content of various foods (see Kits in Resources).

Procedures

Obtain samples of Andean food, including *quinoa*, *kiwicha* and *chuño*, from a South American specialty store or health food store. Get fresh or frozen sweet corn and potatoes from the grocery store.

A few days before the lesson: Ask students to bring in samples of their favorite foods.

In class or as homework: Have students conduct research on the Internet on native Andean foods (*quinoa*, *kiwicha*, *chuño*). Have them write a brief report on the nutritional content of each food.

1. *Introduction:* Show students a sample of *quinoa*, a grain grown in the Andes and a staple of the Andean diet. (Refer back to Handout 3: The Andean Highland Diet.) Explain to students that they will be comparing the nutritional content of Andean and American foods. They will analyze the nutritional content of a variety of Andean foods for protein, starch, glucose, fat, vitamin C and iron, and compare them to American foods.

2. Lab activity

- a) Divide the class into groups of two or three students. Distribute Kemtec lab kits and samples of a variety of Andean and American foods.
- b) Have students follow the directions in the lab manual (see pages 1 to 6) using the vials supplied in the kit. Test solutions for starch, sugar, fats, protein and vitamin C. The substances will change color in the presence of a given nutrient. These vials will be the control group.
- c) Now have the students use the test kit solutions to test the Andean foods (*quinoa*, *kiwicha*, raw potato, *chuño*, corn) for the presence of starch, sugar, fats, protein and vitamin C. Then ask them to test the favorite foods they brought in for the presence of starch, sugar, fats, protein and vitamin C.

- d) Now have the students read the nutritional labels for the Andean foods—*kiwicha*, *quinoa* and *chuño*. Which food is high in iron? [*quinoa*] Why would the presence of iron be especially important for Andean people? (Think back to what you learned about respiration.) [Red blood cells carry oxygen from the lungs to the individual cells. Hemoglobin, the substance that transports the oxygen throughout the body, contains iron. Because they live in a high altitude environment, Andean people require more red blood cells, and hence more iron.]
- e) What other nutrients do *quinoa*, *kiwicha*, and *chuño* provide? [*quinoa* and *kiwicha* are high in protein; *chuño* is high in carbohydrates, but contains no vitamin C]
- f) *Under the microscope*: Have students examine samples of *chuño* under the microscope by scraping off particles and placing them on a microscope slide. They should examine the powdered *chuño* first when it is dry. Then add water. How does the appearance of the *chuño* cells change? Why?
3. *Assessment*: (assign as homework) Have students write a paragraph explaining how the Andean diet is suitable for those living at a high altitude. [The Andean diet is high in iron, protein, and carbohydrates.] Why is iron especially important to people living at high altitudes? [Iron facilitates oxygen transport in the blood.]
4. *Overall assessment*: Describe three ways Andean people have acclimatized to living in a high altitude. Discuss the scientific processes behind each.

Resources

Kits

The following kits provide students with valuable hands on activities relating to the three science guides. Except for the food analysis kit, they are optional—the curriculum can be taught without the suggested kits. Prices listed are for individual kits; sales representatives can often give discounts for kits ordered in quantity.

GEMS Earth, Moon and Stars (optional). Cost: \$131.79.

Contains a plastic globe tilted at a 23.5 degree angle for each student, a bright light to represent the sun, and plastic moons. Available from: VWR Sargent-Welch, P.O. Box 5229, Buffalo Grove, IL 60089-5229; 1-800-727-4368; www.sargentwelch.com.

Investigating Water Pollutants and Water Analysis (#20-1503) (enrichment). Cost: \$311.49.

Available from: Neo/SCI, P.O. Box 22729, Rochester, NY 14692-2729; www.neosci.com.

GEMS Hot Water and Warm Homes from Sunlight (enrichment). Cost: \$192.49.

Available from: VWR Sargent-Welch, P.O. Box 5229, Buffalo Grove, IL 60089-5229; 1-800-727-4368; www.sargentwelch.com.

Kemtec Food and You: Introduction to Food Analysis (required for food analysis activity). Cost: \$72.95.

Available from: Kemtec T&S Educational, Inc., 8944 Beckett Road, West Chester, OH 45069; 513-860-4949.

V. Student Guide to Machu Picchu: Unveiling the Mystery of the Incas

This guide is designed to help you learn as much as you can during your visit to *Machu Picchu: Unveiling the Mystery of the Incas*. You are to write down answers to the questions as you walk through each room of the exhibition. You will be graded on how complete your answers are. Questions labeled “EC” are more difficult and will earn extra credit points. Bring the handout to your next class—it will serve as the basis for discussion.

Film: Unveiling the Mystery of the Incas

View the introductory film and answer the following questions:

1. Where is Machu Picchu located?
2. Give the approximate dates for the beginning and end of the Inca Empire.
3. Who brought Machu Picchu to the world’s attention in 1911?

Excavation

1. Who are the two men shown in the diorama?
2. What are they doing?

3. When does the scene take place?
4. Look at the background photograph. How is Machu Picchu different today than when Hiram Bingham discovered it? How would it have looked when the Inca emperor lived there?
5. What is the hole at the right of the scene? What is inside?
6. Look in the display case across the room. It shows some of the objects found in the grave. What was found there?
7. This room shows Hiram Bingham and his assistant in the process of *excavating* Machu Picchu. Write a sentence describing what excavation is.

Go into the next room to view the video.

Curators' Tour

Listen to the six-minute video *Curators' Tour of Machu Picchu* and look at the model of the site as each part is lit. Be sure to get in at the beginning of the video. You may want to hear it twice.

1. Describe Machu Picchu's geographic setting. (Look at the photographs to the left and right of the model.)

2. According to the video's narrator, what was the purpose of Machu Picchu?

3. According to Richard Burger, how was the Inca emperor's residence designed to show he was important? (list three features)

4. According to Lucy Salazar, what was the Torreón?

5. Why do archaeologists think it served this purpose?

6. According to Lucy Salazar, what evidence is there that metal objects were made at Machu Picchu?

7. According to Richard Burger, how was Machu Picchu defended? (list three ways)

8. According to Lucy Salazar, where did the residents of Machu Picchu get their water?

9. What structures were built at Machu Picchu to carry water?

10. According to Lucy Salazar, what did the Incas believe about water?

11. Look at the model. What engineering challenges did the Inca builders and engineers face? (list at least three)

Go into the room that is paved like an Inca road.

Inca Road

1. Look at the huge photo of Machu Picchu. What does it show about Machu Picchu's climate?

2. What are the walls that look like stairs called? Why were they built?

3. Look at the map on the left of the Inca road system. On the map at the right, estimate the length of the Inca Empire from top to bottom, using the key.

4. (EC) Who would have built and maintained this road system?

5. What is shown in the black and white drawing?

6. Why were bridges necessary in the Inca Empire?

7. (EC) Read the paragraph about the llama in the right-hand corner. List one advantage and one disadvantage of llama transport.

8. Look at the Inca road in the photo on the left. Does it help explain why the Inca did not use the wheel?

9. Study the objects in the cases. What are they made of?

10. Choose three objects you like best. What were they used for?

Go forward toward the recreated house. Before you enter, note how Inca buildings were made.

11. What are the walls made of? Was mortar used?

12. Inca buildings were very resistant to earthquakes. Can you see why?

13. Look up at the roof. What is it made of?

14. Would this roofing material last very long?

Inca Emperor's Residence

1. Which man is the Inca emperor? How do you know?

Note: Refer to the written explanation to help answer the following two questions.

2. Listen to the language the emperor and his advisor are speaking. What is it?

3. Is it still spoken today?

4. (EC) What do you think the emperor and his advisor are talking about?

5. Where do you think the Inca emperor's pets came from?

6. Look at the *quipu* in the large display case. What is it made of?

7. Write a brief description of the *quipu*.

8. What were *quipus* used for?

9. What does the word *quipu* mean?

Enter the large room with many glass cases.

1. What is the kneeling man on the left doing?

2. Metalworkers sometimes pound soft metals like silver and gold into sheets and hammer it to change its shape. Find an example of hammered silver or gold objects in the case.

3. Metalworkers also pour hot metal into molds to make objects. Find three examples in this room of metal objects that were made this way.

4. (EC) Look at the carved piece of wood to the far right in the display case that looks like a man's face. Did you see something elsewhere in the exhibition that could have been made from a form like this?

5. (EC) How do you think the object was made: by pouring hot metal into a mold, or by making a sheet of metal and hammering it?

6. Find three examples of things made out of pottery and describe what they were used for.

7. Look at the label about "Everyday Life." Look carefully to see who the man is. What is he doing?

8. How many people lived at Machu Picchu when the Inca emperor and his attendants were there?

9. When did the emperor and his attendants stay there?

10. Find the plumb bob in the display case to the left of the video screen. What is it made of? What does this tell you about its importance?

11. Listen carefully to the video on archaeoastronomy and find out what archaeoastronomers think the plumb bob was used for.
12. (For astronomy unit) Watch the video on archaeoastronomy.
- A. What was the Inca name for the sun god?
 - B. What did women worship?
 - C. What did the Incas use astronomy for? (name three things)
 - D. What do archaeoastronomers think the Torreón was used for?
 - E. Who were the *yancas*?
 - F. What happens on the June solstice?
 - G. What was the cave called the Intimachay used for?
 - H. What festival was celebrated at the time of the December solstice?
 - I. Why did the Incas observe the star cluster known as the Pleiades?
 - J. What shapes did the Inca skywatchers see in dark cloud constellations?
 - K. What solar event did Inca *yancas* predict by using a plumb bob suspended on a string?
 - L. Look again at the plumb bob in the display case to the left of the video screen. Archaeologists think that this plumb bob might have been used in the shadow casting activities described in the video.

13. Llama lookout: How many examples of llamas can you find in this room?

14. Go to the display case with everyday items in it, across from the three video screens. What things in the case are still used today?

15. What things used by the Incas in daily life are not used today? Why not?

Interactive Explorer/Ongoing Investigations
(this room and next)

Divide into four groups. Three groups can explore Machu Picchu on the three "Interactive Explorer" videos. (Note: The large screen on the right can be used by large groups to watch what is being shown on the smaller video screen.)

The fourth group should go into the next room and answer the following questions. Be sure your group does the activities in both rooms.

Rediscovery Room

Each group will choose one archaeologist to report on by answering the following questions.

1. Watch the video on the screen to your right and choose one archaeologist. What is his or her name?

2. Describe what he or she is studying.

3. What archaeological techniques is he or she using?

4. What new information has he or she obtained about the daily life of the Incas from this research?

5. Look at the models of skulls in the case. Compare the shapes of the three skulls.

6. How did parents shape the skulls of babies?

7. Do you think this hurt the babies?

8. Do you think it made them less smart?

9. Why do you think parents might have wanted to shape their children's skulls in this way?

10. Find the photograph of terraces. What crops were grown in terraces at Machu Picchu?

11. Do you think enough food could be grown on these terraces to feed 600 people?

12. (EC) Look at “Daily Diet and Bone Chemistry” in the far corner. Read the explanation of how bones can be analyzed to see what people ate at Machu Picchu. What does this bone analysis show about the diet of people who lived there?

Epilogue

1. Look at the graph on the left. How did the Inca population decline around the time of the Spanish Conquest?

2. What were some of the diseases that caused this sudden drop in population?

3. When did the native population of the former Inca Empire finally recover?

4. Find three examples of how modern Peru is a mixture of Spanish and Inca cultures.

Homework Assignment

Write a paragraph on one of the following questions:

1. Why was Machu Picchu built?
2. What was your favorite part of the exhibition?
3. What did you learn about Inca people?
4. How do archaeologists find out about Inca life?

VI. Teacher's Key to Student Guide to Machu Picchu: Unveiling the Mystery of the Incas

This guide is designed to help students learn as much as they can during their visit to *Machu Picchu: Unveiling the Mystery of the Incas*. Have them write down answers to the questions as they walk through each room of the exhibition. Tell them that they will be graded on how complete their answers are. Questions labeled "EC" are more difficult and will earn extra credit points. Have them bring the handout to the next class—it will serve as the basis for discussion.

Entry Room

Before you enter the exhibition, look at the life-sized llama on display. As they view the exhibition, have students find as many examples as possible of how the llama was used by the Incas in art and everyday life.

Below are answers to questions contained in the Student Guide to the exhibition (Section V).

Film: Unveiling the Mystery of the Incas

View the film *Unveiling the Mystery of the Incas* and answer the following questions:

1. Where is Machu Picchu located?

[Andes Mountains of present-day Peru, South America]

2. Give the approximate dates for the beginning and end of the Inca Empire.

[A.D. 1430 to 1532]

3. Who brought Machu Picchu to the world's attention in 1911?

[Hiram Bingham, a professor of Latin American history at Yale]

Excavation

1. Who are the two men shown in the diorama?

[Hiram Bingham and his assistant Alvarez]

2. What are they doing?

[Hiram Bingham is taking photographs, his assistant is sweeping earth from artifacts]

3. When does the scene take place?

[1912]

4. Look at the background photograph. How is Machu Picchu different today than when Hiram Bingham discovered it? How would it have looked when the Inca emperor lived there?

[When he discovered it, it was overgrown with vegetation. When the Inca emperor lived there it looked more like it does today, except that buildings had roofs.]

5. What is the hole at the right of the scene?

[a grave]

What is inside?

[bones, pottery]

6. Look in the display case across the room. It shows some of the objects found in the grave. What was found there?

[pottery, bones, shawl pins]

7. This room shows Hiram Bingham and his assistant in the process of *excavating* Machu Picchu. Write a sentence describing what excavation is.

[Excavation is the process of carefully digging up artifacts.]

Go into the next room to view the video.

Curators' Tour

Listen to the six-minute video *Curators' Tour of Machu Picchu* and look at the model of the site as each part is lit. Be sure to get in at the beginning of the video. You may want to hear it twice.

1. Describe Machu Picchu's geographic setting. (Look at the photographs to the left and right of the model.)

[very mountainous terrain]

2. According to the video's narrator, what was the purpose of Machu Picchu?

[It was a country palace or royal estate for the Inca emperor.]

3. According to Richard Burger, how was the Inca emperor's residence designed to show he was important? (list three features)

[it was isolated, had a private garden, was made of fine stone construction, had fountains to supply water, had private bath]

4. According to Lucy Salazar, what was the Torreón?

[a religious temple]

5. Why do archaeologists think it served this purpose?

[it is similar to a religious temple in Cuzco, has fine stone walls that are curved, has a cave with niches for religious objects]

6. According to Lucy Salazar, what evidence is there that metal objects were made at Machu Picchu?

[many metal objects were found at the site, evidence that metal workers lived and worked on site]

7. According to Richard Burger, how was Machu Picchu defended? (list three ways)

[it has steep cliffs on three sides, a guard tower, a moat, and only one entrance]

8. According to Lucy Salazar, where did the residents of Machu Picchu get their water?

[a spring]

9. What structures were built at Machu Picchu to carry water?

[16 stone fountains, canal]

10. According to Lucy Salazar, what did the Incas believe about water?

[The Incas believed that water cycled through the universe and ensured fertility.]

11. Look at the model. What engineering challenges did Inca builders face? (list at least three)

[it is in a remote location, it is built on steep cliffs, it has a lot of water run off, it was hard to carry stones up steep cliffs, sources of water, soil and stone had to be found]

Go into the room that is paved like an Inca road.

Inca Road

1. Look at the huge photo of Machu Picchu. What does it show about Machu Picchu's climate?

[cloudy, moist, cool]

2. What are the walls that look like stairs called?

[terraces]

Why were they built?

[to create a flat surface for growing crops]

3. Look at the map on the left of the Inca road system. On the map at the right, estimate the length of the Inca Empire from top to bottom, using the key.

[2,500 miles]

4. (EC) Who would have built and maintained this road system?

[laborers doing *mita* work]

5. What is shown in the black and white drawing?

[a bridge]

6. Why were bridges necessary in the Inca Empire?

[geography was very mountainous, many rivers]

7. (EC) Read the paragraph about the llama in the right-hand corner. List one advantage and one disadvantage of llama transport.

[advantage: llamas follow a lead animal and require little supervision by people; disadvantage: a llama can carry only about 100 pounds, cannot carry adults]

8. Look at the Inca road in the photo on the left. Does it help explain why the Inca did not use the wheel?

[Yes, the road is very steep and rocky, making it difficult to use a wheeled cart.]

9. Study the objects in the cases. What are they made of?

[gold, silver, stone, pottery, wood]

10. Choose three objects you like best. What were they used for?

[answers will vary]

Go forward toward the recreated house. Before you enter, note how Inca buildings were made.

11. What are the walls made of?

[stone]

Was mortar used?

[no]

12. Inca buildings were very resistant to earthquakes. Can you see why?

[they are built of large rectangular blocks of stone that are tightly fit together]

13. Look up at the roof. What is it made of?

[thatch or grass]

14. Would this roofing material last very long?

[no, this explains why buildings at Machu Picchu do not have roofs]

Inca Emperor's Residence

1. Which man is the Inca emperor? How do you know?

[the seated man; he is wearing a special headdress used only by the emperor, he has gold earrings and sandals, he is being served a drink in a gold cup]

Note: Refer to the written explanation to help answer the following two questions.

2. Listen to the language the emperor and his advisor are speaking. What is it?

[Quechua]

3. Is it still spoken today?

[yes]

4. (EC) What do you think the emperor and his advisor are talking about?

[They are discussing the *quipu*; the emperor is concerned about defending nearby gold mines; he orders that the amount of coca leaves brought to Machu Picchu be doubled.]

5. Where do you think the Inca emperor's pets came from?

[Amazon River region]

6. Look at the *quipu* in the large display case. What is it made of?

[wool or cotton]

7. Write a brief description of the *quipu*.

[It is a long string with many shorter strings attached. Some strings have knots tied in them.]

8. What were *quipus* used for?

[recording information about census figures, taxes paid, keeping oral histories]

10. What does the word *quipu* mean?

[knot]

Enter the large room with many glass cases.

1. What is the kneeling man on the left doing?

[pounding metal with a stone hammer]

2. Metalworkers sometimes pound soft metals like silver and gold into sheets and hammer it to change its shape. Find an example of hammered silver or gold objects in the case.

3. Metalworkers also pour hot metal into molds to make objects. Find three examples in this room of metal objects that were made this way.

4. (EC) Look at the carved piece of wood to the far right in the display case that looks like a man's face. Did you see something elsewhere in the exhibition that could have been made from a form like this?

[gold and silver drinking vessels shaped like a human face]

5. (EC) How do you think the object was made: by pouring hot metal into a mold, or by making a sheet of metal and hammering it?

[by hammering a sheet of metal]

6. Find three examples of things made out of pottery and describe what they were used for.

[answers will vary]

7. Look at the label about "Everyday Life." Look carefully to see who the man is. What is he doing?

[The man is Guamán Poma de Ayala. He is walking through Peru finding information for his book.]

8. How many people lived at Machu Picchu when the Inca emperor and his attendants were there?

[about 600]

9. When did the emperor and his attendants stay there?

[May to September, the dry season (winter)]

10. Find the plumb bob in the display case to the left of the video screen. What is it made of?

[solid silver]

What does this tell you about its importance?

[It must have been considered important.]

If you are doing the astronomy unit, have students watch the video on archaeoastronomy and answer the following questions:

11. Listen carefully to the video on archaeoastronomy and find out what archaeoastronomers think the plumb bob was used for.

12. (For astronomy unit) Watch the video on archaeoastronomy.

A. What was the Inca name for the sun god?

[Inti]

B. What did women worship?

[the moon]

C. What did the Incas use astronomy for? (name three things)

[to forecast the seasons, to decide when to plant and harvest crops, to decide when to schedule important public events]

D. What do archaeoastronomers think the Torreón was used for?

[a solar observatory]

E. Who were the *yancas*?

[trained Inca skywatchers]

F. What happens on the June solstice?

[the shadow falls exactly along the carved cat's belly]

G. What was the cave called the Intimachay used for?

[observing the December solstice]

H. What festival was celebrated at the time of the December solstice?

[Capac Raymi, a celebration for young men reaching adulthood]

I. Why did the Incas observe the star cluster known as the Pleiades?

[to tell them when to plant and harvest maize]

J. What shapes did Inca skywatchers see in dark cloud constellations?

[animal shapes, including a llama and its baby]

K. What solar event did Inca *yancas* predict by using the plumb bob suspended on a string?

[June (winter) solstice]

L. Look again at the plumb bob in the display case to the left of the video screen. Archaeologists think that this plumb bob might have been used in the shadow casting activities described in the video.

13. Llama lookout: How many examples of llamas can you find in this room?

14. Go to the display case with everyday items in it, across from the three video screens. What things in the case are still used today?

[dice, tweezers, pottery cups, dishes, dolls, needles, plumb bob]

15. What things used by the Incas in daily life are not used today? Why not?

[shawl pins—we don't need them because we have buttons, zippers]

Interactive Explorer/Ongoing Investigations

(this room and next)

Divide into four groups. Three groups can explore Machu Picchu on the three “Interactive Explorer” videos. (Note: The large screen on the right can be used by large groups to watch what is being shown on the smaller video screen.)

The fourth group should go into the next room and answer the following questions. Be sure your group does the activities in both rooms.

Rediscovery Room

Each group will choose one archaeologist to report on by answering the following questions.

1. Watch the video on the screen to your right and choose one archaeologist. What is his or her name?
2. Describe what he or she is studying.
3. What archaeological techniques is he or she using?
4. What new information has he or she obtained about the daily life of the Incas from this research?
5. Look at the models of skulls in the case. Compare the shapes of the three skulls.

[The one on the left is normally shaped, the one in the center has a flattened forehead, the one on the right is more cone-shaped than normal.]

6. How did parents shape the skulls of babies?

[They wrapped them in cloth or bound them to a cradle board.]

7. Do you think this hurt the babies?

[no]

8. Do you think it made them less smart?

[no]

9. Why do you think parents might have wanted to shape their children's skulls in this way?

[to show they belonged to a certain cultural group]

10. Find the photograph of terraces. What crops were grown in terraces at Machu Picchu?

[maize, potatoes, beans]

11. Do you think enough food could be grown on these terraces to feed 600 people?

[No, food had to be carried from Cuzco when emperor was in residence.]

12. (EC) Look at "Daily Diet and Bone Chemistry" in the far corner. Read the explanation of how bones can be analyzed to see what people ate at Machu Picchu. What does this bone analysis show about the diet of people who lived there?

[They ate a lot of maize, which was 65% of their diet.]

Epilogue

1. Look at the graph on the left. How did the Inca population decline around the time of the Spanish Conquest?

[It declined from 14 million to 5 million.]

2. What were some of the diseases that caused this sudden drop in population?

[smallpox, measles, typhus, scarlet fever, pneumonia, plague]

3. When did the native population of the former Inca Empire finally recover?

[mid-20th century]

4. Find three examples of how modern Peru is a mixture of Spanish and Inca cultures.

[religious festivals, intermarriage, art has mixture of Spanish, Inca styles]

Summing Up

After the Exhibition

1. Discuss the handout questions.

2. Have groups report on their archaeologist.

Homework Assignment

Have students write a paragraph on one of the following questions:

1. Why was Machu Picchu built?
2. What was your favorite part of the exhibition?
3. What did you learn about Inca people?
4. How do archaeologists find out about Inca life?

VII. Background Article: “The Incas”

Note: Words in bold are defined in the Glossary.

1. Introduction

At about the time Christopher Columbus landed on a tiny island in the Caribbean Sea, Huayna Capac, a powerful emperor and warrior, was battling to expand his **empire** thousands of miles to the south, in what is now Ecuador and Colombia. He and his father and grandfather had fought to create an empire that at its peak extended over a vast area along the rugged **Andes Mountains** of South America. Probably the largest nation in the world at that time, the **Inca Empire** was suddenly conquered by a small band of Spanish soldiers in 1532.

The Inca people originated in the Cuzco Valley of what is modern-day Peru in about A.D. 1000, and gradually conquered neighboring tribes. The empire expanded rapidly under three Inca emperors between 1438 and 1527 until at its height it stretched from what is now the border between Colombia and Ecuador to central Chile—a distance of over 2,500 miles. At its height, the Inca people, who numbered only about 100,000, ruled from 10 to 14 million people from at least 86 ethnic groups with their own languages, traditions and religious beliefs.

The empire encompassed wildly contrasting geographic regions, ranging from towering snow-capped mountains to coastal deserts to Amazonian jungles. The heart of the empire, centered around **Cuzco**, was located at such a high elevation that people unaccustomed to high altitudes suffered from altitude sickness, whose symptoms include headaches, fatigue, dizziness and upset stomach. The empire was often plagued with a variety of natural disasters, such as earthquakes, volcanoes, droughts and devastating floods.

2. Inca Gold

The Spanish **conquistadores**, or conquerors, came to what they called the New World in search of gold. Francisco Pizarro, who first came to the Americas in 1502, had heard rumors of a land filled with gold to the south of Mexico. He and a small band of Spanish soldiers landed on the shores of what is now Ecuador in 1531. They had arrived in **Tahuantinsuyu**, the “Land of the Four Quarters,” known to us as the Inca Empire.

When Pizarro’s men arrived in the Inca capital of Cuzco, they saw a splendid city with palaces, halls, and temples made of huge stones carefully fit together without **mortar**. Most incredible of all were the temples decorated with gold, silver and precious jewels. The most important temple was the **Coricancha**, or “House of the Sun,” dedicated to the Inca sun god, named **Inti**. Its walls and doorways were covered with gold, both inside and out. One building within the complex contained a large statue of the sun, made of solid gold and embedded with precious stones. More fantastic still was the garden. A Spanish eyewitness, **Pedro de Cieza de León**, describes the sight as follows:

They had also a garden, the **clods** of which were made of pieces of fine gold; and it was artificially sown with golden **maize**, the stalks, as well as the leaves and cobs, being of that metal...[T]hey had more than twenty golden sheep [**llamas**] with their lambs, and the shepherds with their slings and crooks to watch them, all made of the same metal.

Pedro de Cieza de León, *Chronicles of Peru*, quoted in *The Incas and Their Ancestors: The Archaeology of Peru*, by Michael Moseley, London: Thames and Hudson, 1992, p. 8.

Early Spanish observers described the Andean people as well fed, healthy and clean. When they arrived, the Inca emperor and his assistants supervised a highly organized government that controlled an area of 135,000 square miles. The Spanish must have been surprised to learn that the Inca Empire ran very efficiently without three inventions considered essential by Europeans—writing, money, and the wheel.

3. Extreme Environment

The Andes—the second highest mountain chain in the world—create an environment of extreme climate and weather conditions. A mountain range is created when one **plate** slides under another, creating pressure that lifts and squeezes the land above them, like a tablecloth being pushed up by a heavy plate. The Andes mountain range was created over a period of millions of years, as the plate under the Pacific Ocean, called the Nazca Plate, slid eastward under the South American plate, raising the mountains and creating a deep trench off the coast. The movement of these plates strains the rocks along the plate boundaries, creating a series of faults. Stresses build up over time along both sides of the fault lines, occasionally causing severe earthquakes. For example, in May of 1970, a devastating earthquake, followed by avalanches and mudslides, killed 70,000 people in the central Andes. In the mountainous terrain, earthquakes can cause mudslides and avalanches. The same earthquake loosened a huge block of ice that caused a landslide that buried an entire town, killing 4,000 people. Periodic volcanic eruptions have also claimed the lives of thousands.

The region's climate is influenced by water and air currents that flow north from Antarctica along the Pacific coast. The ocean current, called the **Peru or Humboldt Current**, brings extremely cold but nutrient-filled water to the surface, supporting a rich supply of fish, birds and sea mammals. But the cold Peru Current causes clouds to release moisture before they reach land, creating one of the driest deserts in the world along the west coast of South America. The winds, cooled by the Peru Current, then warmed by the coastal plains, do not precipitate enough water to produce significant amounts of rain until they rise high into the Andes, where rain falls seasonally in the mountain valleys of the western slope. On the eastern slopes, on the other hand, equatorial winds blowing from the east over the Amazon River hit the mountains, cool, and produce large amounts of rain. The well-watered eastern slopes of the Andes support lush, tropical vegetation as they drop to the Amazonian basin.

At irregular intervals, a warm ocean current runs south along the Peruvian coast, pushing the Peruvian Current farther west. This recurring current, called **El Niño**, causes heavy rain in the desert coastal areas and drought in the southern Andes. In 1982, the worst El Niño in 100 years produced heavy flooding in coastal cities, destroying roads and irrigation systems, while drought in the mountains killed thousands of animals.

4. The Vertical Economy

The Andes Mountains stretch from Colombia to Chile, creating three distinct geographic areas—the **costa** (coast), the **sierra** (mountains), and the **selva** (tropical rainforest). The **costa** is a narrow strip of land bordered by the Pacific Ocean to the west. One of the driest deserts in the world, it is crossed by many rivers that run down from the mountains and can be harnessed for **irrigation**.

The western slope of the **sierra** is extremely dry. Between the two mountain slopes lies the **alti-plano**, a dry, high-altitude plain in southern Peru and northern Bolivia. Areas at altitudes above 10,000 feet are called the **highlands**. They are above the treeline and consist of rolling grassland. Villages extend up to about 1750 feet. The eastern slopes of the Andes, called the **ceja de selva** ("eyebrow of the rainforest"), enjoy warmer, humid weather that supports thick, low vegetation. Machu Picchu is located in this region of the Andes, at an altitude of about 8,000 feet. Its climate is drier and warmer in the winter months than the climate of Cuzco, which is located in the highlands at an elevation of 10,300 feet. To the east lies the **selva**, the beginning of the Amazonian rainforest.

Although the rugged Andes Mountains create extreme weather conditions and make transportation difficult, they have hidden advantages that Andean people learned to exploit. The difference in altitude between the peaks and valley bottoms can be thousands of feet, creating wide variations in temperature and rainfall at different altitudes. The varying **topography** of the mountains creates a variety of **ecological niches**, which are zones stacked one on top of another where different types of animals and plants can survive. So, instead of having to travel hundreds of miles to arrive in a different climate, Andean people can walk as little as 60 miles to go from a tropical forest in the lowlands to the frozen **tundra** of the highlands. An Andean family group might make its base in the temperate **quechua zone** located in the highlands, where family members would grow maize, beans, garden vegetables, **quinoa** (a high-protein grain), potatoes and Asian grains such as wheat and barley. Some family members descend to the **ceja de selva** on the eastern slopes of the Andes to tend fields of maize, **coca**, fruit, pepper, and other staples. They can descend farther onto the plains of the Amazon forest to cultivate **manioc**, a root crop. They also maintain herds of llama and **alpaca** in the higher pasturelands. Plants with different planting and harvesting times can be grown at different altitudes. Various plots of land farmed by one family group might be two or three days apart by foot.

This system, called a "**vertical economy**," had many advantages in the harsh Andean climate. First, it gives a community access to a wide variety of foods and other products. Second, it protects them against the impact of harsh and unpredictable weather conditions—if frost or drought destroy the crop at one elevation, the community can fall back on the harvest in another ecological niche. Andean farmers also plant several (sometimes dozens) of varieties of one crop like potatoes in a single field so that at least some plants will survive the season's unpredictable temperature and rainfall.

Andean people developed a technique for food storage that actually turned their harsh environment into an asset. Living at altitudes of about two miles above sea level, they had as many as 300 nights of frost and heat from strong sunlight during the day. They used this combination of hot and cold to "freeze dry" meat and potatoes that were left outside to alternately freeze and dry over a long period of time. The Incas called the dried meat **charqui**. It lent its name to the dried meat we call beef jerky. Andean people also made **chuño** by softening potatoes in water and leaving them outside to freeze at night. During the day they dried in the hot sun. The freeze-dried foods could be stored in warehouses for several years and used during periods of drought or other natural disasters. The ability to store food was crucial, since frequent frosts, hail and drought often led to crop failures in two or three years out of four.

5. Administering a Vast Empire

An empire is a government that controls a huge territory and millions of people. It usually encompasses many different ethnic groups. Empires usually gain control over other areas by military force, but control can also be economic or political. The leaders of empires need to develop certain mechanisms to exert control over their vast territory, such as a road system, a common lan-

guage, an administrative system and an army.

One reason the Inca Empire ran smoothly is that the Inca rulers took traditions that already existed in the Andes region and altered them to serve in the administration of the Inca state. For example, a road system had already been built by previous civilizations in various parts of the Inca Empire. The Inca emperors expanded it so that it connected the entire empire. Inca emperors also used the traditional **mita system** of sharing labor as the basis for obtaining labor services from all households. (See Section 8, The *Mita* System.)

6. Connecting an Empire

The Inca rulers needed a system of communicating with all parts of the empire. So they expanded the existing roads into an elaborate road system that ran throughout the empire. The road system was over 25,000 miles long. One road ran along the coast, and another lay inland along the Andes Mountains. Bridges crossed broad rivers as well as rushing streams that cut through deep mountain valleys. Shorter roads linked the two main roads.

The road system was used almost entirely by people on official business—the Inca emperor and his court examining the realm, caravans of llama herders transporting goods to be housed in storehouses, soldiers marching to put down an uprising in a rebellious province, administrators on official business, and runners delivering messages. Ordinary people could use the roads only if granted official permission.

Runners, called **chasquis**, lived in small huts that were built every four to six miles along the road. The messengers would run to the next way station, shouting the message to the next *chasqui*. Messages could travel about 150 miles a day in this manner. The messengers probably carried **quipus** to assure that the information did not get distorted by frequent repetition. *Chasquis* also carried goods to the emperor, bringing fish from the coast to Cuzco in just two days.

Inca armies used the roads in time of war to move quickly into battle. Storehouses built along the way held weapons, including lances and darts, dried food, blankets and even sandals for soldiers to use in time of war. If crops failed in one area, food was distributed to area residents from the warehouses. The local community was expected to refill the storage houses when crops were plentiful.

7. Irrigation and Terracing

The land along the Pacific coast and in the highlands is dry and requires irrigation to produce reliable crop yields. People living in the **arid** deserts along the coast had built elaborate irrigation systems to harness the many rivers that flowed from the mountains to the ocean. The Incas expanded this system to make it more productive.

In the highlands, farmers had long built terraces to create more surface area for farming. Terracing involves building large retaining walls on a mountain slope and filling in the space between the wall and the slope above with soil. Terracing prevents soil erosion and rainfall runoff. Channels divert spring water and streams to water the tiny fields. Farmers had been terracing the slopes of the Andes for centuries, and the Incas greatly expanded the amount of agricultural land by building terraces in conquered lands throughout the Andes. At the height of the Inca empire, about 2.47 million acres of irrigated terraces were in cultivation. Andean farmers still use some of these terraces today, but many have fallen into ruin.

Building terraces, irrigation systems and roads requires a high level of organization and the labor

of many workers. Where did Inca administrators find workers to carry out these major engineering projects?

8. The *Mita* System

As we have seen, the Incas did not have money, and so the government could not collect taxes as we know them. Instead, Inca administrators required adult men to work for the state for a certain number of days per year. This system is called the *mita* system. As soon as a man married, he became the head of a household and was obligated to perform *mita* work. Each person was assigned a specific job according to his skills. For example, a skilled weaver would be assigned to make cloth, and a fast runner would be assigned to be a *chasqui* runner. The foot soldiers in the Inca army were farmers who were serving their *mita* labor obligation. Pachacuti rebuilt Cuzco by calling 30,000 men to contribute *mita* labor. Other activities carried out with *mita* labor included farming, mining, road and bridge building, building temples and other public monuments, transportation of goods, building canals, terraces and irrigation systems, and making pottery and metalwork. Some ethnic groups were considered to be especially skilled at certain tasks and these were therefore assigned to them. For example, one group was thought to be especially good at carrying litters (a sort of platform on railings used to carry the Inca emperor and other important people). Others were gifted stonemasons, dancers or warriors. Some groups were considered “good for nothing,” but they were assigned *mita* work anyway. One group was required to gather reeds, and another to turn in a basket of live lice every four months!

Although every man was expected to contribute work each year for the empire, only a few men in a village would be called to work at one time so that other family members could take over his work at home. Both women and men were required to weave a certain amount of cloth for the state each year. The length of time a person was expected to do *mita* work varied according to the task assigned, but usually lasted no more than two to three months per year. The person assigned a specific task could get family members to help him in order to make the length of *mita* service shorter, so it was beneficial to have a large family. Although *mita* work was required, and probably resented by non-Inca ethnic groups who became incorporated into the empire, it was really an extension of the Andean custom of each individual working for the group. Now each head of household was performing labor for a certain period of time for the Inca state.

Workers and their families received something in return for the labor they contributed to the state. Both *curacas* and the Inca emperor hosted festivals periodically, in which they gave food and drink to everyone in the community. These festivals were rewards after workers had completed plowing, planting, harvest and canal cleaning chores. The emperor also gave textiles and metal objects as an expression of generosity and to symbolize his gratitude for *mita* labor. For example, soldiers received blankets.

The Inca Empire also employed full-time skilled craftsmen to produce luxury textiles, elegant pottery and exquisite objects of gold and silver. The emperor gave these luxury goods to leaders of conquered people, to members of the Inca nobility and to Inca religious leaders. They were also placed in the graves of important people.

9. *Quipu*

The Inca used an ingenious tool that had been developed by an earlier civilization in the region for keeping track of all kinds of information. The object, called a *quipu*, is simply a long string held horizontally with shorter strings of many colors tied to it. Each of these strings can have other strings

tied to it. The strings have different types of knots to represent the numbers 0 to 9. Where a knot is located on a string determines the place value of the knot. For example, knots closest to the main string might represent thousands, those three inches from the main string might represent hundreds, those six inches from the main string might stand for tens, and those nine inches from the main string might represent ones. Different colored strings represented different things—for example, a yellow string might represent gold, and a white string, silver.

Quipus could not be used to add, subtract or multiply. Specially trained administrators called **quipucamayocs** learned to “read” the *quipus*. They also used stones and counting trays similar to the **abacus** for doing calculations, and then transferred the information back to the *quipu*.

10. Inca Religion

Perhaps because they lived in a harsh and unpredictable environment, the Inca practiced religious rituals designed to win the favor of the gods, who were often associated with natural forces such as the sun, water, or weather. The Inca people gave precious things to the gods to earn their favor.

The Inca religion grew out of the beliefs of Andean people regarding natural forces. Andean people have long worshipped the natural world around them, including mountains, rivers, lakes, the ocean, and constellations. They identify natural features such as especially high mountains, springs and large stones as sacred places, called **huacas**. The Incas worshipped the sun as the ultimate giver of life and celebrate festivals to assure that the sun will continue to appear each day. They used felines and snakes as symbols in their religious art.

Pachacuti, who ruled from A.D. 1438 to 1471, greatly expanded the Inca Empire and rebuilt Cuzco. He also reorganized the Inca religion. He created a special relationship between himself and the sun, proclaiming that the Inca emperor was the sun’s son. Pachacuti built the elaborate temple to the Sun in Cuzco that awed the Spanish. **Wiracocha** was the god of creation who was believed to have created all things, including the sun, moon and stars, as well as the earth and human beings. The Inca people believed that Illapa, the thunder or weather god, controlled rain. He was asked to provide enough rainfall at critical points during the agricultural cycle. Mama-Quilla, the moon god, was the wife of the sun. The festival of the moon was held near the spring equinox, at the beginning of the planting season. Pachamama, the god of the earth, and Mama-Cocha, the god of the sea, were also female gods. Many other local **deities** existed to protect herds of llamas, wild animals and crops.

A large group of male and female priests worshipped the many gods and maintained their shrines. The highest priest, usually the brother or uncle of the emperor, worshipped the sun. A group of women called **aqllakuna** made textiles and **chicha** for the temples. The priests and attendants of Inca gods were supported by the agricultural goods produced by the third of the land under Inca control.

Inca beliefs required people to observe many rituals tied to the agricultural calendar. These rituals involved the sacrifice of precious objects, including textiles, coca, **chicha**, and llamas. Children were sacrificed only on rare occasions after natural disasters, war or during the crowning of a new emperor.

Major festivals took place in December at the beginning of the rainy season, and included dancing, drinking and sacrifice. Another important festival occurred in May to celebrate the corn harvest. Many llamas were sacrificed, and the meat was either eaten or burned. In June, a festival to the sun god Inti took place near Cuzco. Only royal Inca men could participate. The festival included llama sacrifices, dancing, and drinking **chicha**.

11. Learning About the Incas

Because the Incas had no written language, scholars studying them have had to rely on other sources of information. These include:

1. Reports made by Spanish observers who conquered the Incas (referred to as the Spanish Chronicles);
2. Archaeological remains left by the Inca people, such as buildings, pottery, textiles, tools, metal objects and burial sites; and
3. Studies of people living today in the Andes who still practice some Inca traditions.

Each source of information has **biases** or other limitations. Biases arise from the observer's opinions or points of view. The Spanish officials, soldiers and priests were biased in their reporting of Inca life, because they wanted to justify their conquest of the Inca. Most portrayed Andean religion unfavorably and some exaggerated the scope of human sacrifice.

Archaeologists have studied the physical remains of the Inca culture extensively. They have reconstructed the elaborate road system, examined gravesites to learn about burial customs and religious beliefs, and studied Inca crafts such as pottery, metal objects and textiles. They have studied skeletal remains to determine the health and longevity of various ethnic groups living in the Inca Empire. They have also excavated Inca cities to learn about how people lived. This source of information, while valuable, is incomplete.

12. Modern-day Andean People

Today, millions of people still live in the Andean highlands. They use some of the crops and subsistence practices developed in Inca times. Using terraces built by the Inca, they grow corn, herd llamas and alpacas, and weave beautiful textiles. Some continue Inca traditions such as drinking *chicha* and eating *cuyes* (guinea pigs) during religious festivals. Seven million also continue to speak Quechua, the language of the Inca state.

Social scientists called **anthropologists** study these people to learn about cultural traditions that may go back to Inca times. But many traditions have been modified by contact with Spanish culture as well as modern influences. For example, an Indian group called the **Qero** still produces beautiful textiles. They hold a religious ceremony at Easter that involves blessing the finest textiles produced during the year. The festival begins with people parading two crosses under an arch hung with textiles and continues with a ceremony where participants drink *chicha* beer made from corn. In another festival, known as **Qoylluri Riti**, Quechua-speaking farmers make a pilgrimage to a snow-capped peak. The shrine near the summit, however, is dedicated to the Virgin Mary, thus combining Catholicism with earlier traditions of mountain worship. These festivals illustrate how Inca customs and Spanish traditions are often blended into a new ritual. Anthropologists have to determine how these practices and their meanings have changed over time.

Today, the people who live in the Andes Mountains have a culture that is a mixture of Inca, colonial Spanish and more modern influences. Isolated by imposing mountains, some villages have preserved their culture more than many other native groups in the Americas.

But many highland traditions are disappearing. Many highland people have moved to the coastal cities in search of an easier way of life and greater opportunities for their children. They are replacing their diet of potatoes and *quinoa*, a high-protein grain, with imported pasta and rice, which, while cheaper to prepare, is less nutritious. They drink bottled beer rather than locally made *chicha*. Others remain in the mountains but adopt modern practices such as wearing machine-made clothing rather than weaving their own textiles.

13. Conclusion

The Inca Empire was one of the most highly developed civilizations of its time. Unlike the Roman Empire, it was at its peak when it was conquered by outsiders. The invaders had superior weapons and the horse, which gave them an advantage on the battlefield. European diseases introduced by the Spanish far to the north decimated the Inca people even before the invaders arrived on their shores.

The Inca culture is of interest to scholars because its leaders developed a highly organized state that ruled over millions of people living in a vast territory without the aid of money, writing or the wheel. By building on indigenous institutions, such as the *ayllu*, *mita* labor, the *quipu* and the vertical economy, Inca rulers controlled a vast empire, created great art, developed sophisticated engineering and scientific principles and managed to provide basic shelter and food for millions of people in an environment of harsh extremes.

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VIII. Glossary

Note: Words are in bold the first time they appear in the text of the background article “The Incas” (Section VII). Foreign words are italicized.

abacus: A method for adding and subtracting using rows of beads.

alpaca: A South American animal related to the camel and llama. Its wool is very soft and is used to make fine textiles.

altiplano: A high, dry plateau between the two major Andean ranges located in Bolivia and northwestern Argentina.

Andes Mountains: Mountain chain running along the western coast of South America.

anthropologist: A social scientist who studies modern people who live as people did in prehistoric cultures.

aqllakuna: The “Chosen Women” who wove cloth and made *chicha* that was consumed in religious rituals.

archaeologist: A scientist who studies life in prehistoric times, usually by examining physical remains such as buildings, pottery, tools and other objects.

arid: Very dry.

bias: Opinions or values held by a person that influence the way he or she interprets other cultures.

ceja de selva: “Eyebrow of the rainforest,” the area with lush vegetation just above the rainforest on the eastern side of the Andes Mountains.

charqui: An Andean freeze-dried meat that can be stored for long periods and easily transported.

chasqui: A messenger who relayed official messages.

chicha: A beer made of corn, *chicha* is often used by Andean people in festivals and religious ceremonies.

chuño: Freeze-dried potatoes that can be stored for long periods.

clods: Lumps of dirt.

coca: A plant native to South America containing a chemical that is a narcotic. Andean people chew the leaves to dull hunger pangs, provide energy and to receive nutrients. Coca is grown and processed to make cocaine, a powerful illegal drug.

conquistadores: Spanish soldiers who conquered the Inca Empire and other Native American groups in North and South America.

Coricancha: The temple to Inti, the Sun God, built by Pachacuti in Cuzco.

costa: Coast.

Cuzco: A city in present-day Peru, Cuzco was the capital of the Inca Empire.

deity: A god.

ecological niches: Small areas that support a specific mix of plant and animal life. Mountainous regions have many ecological niches since variations in altitude create different temperature and rainfall conditions.

El Niño: A warm ocean current that runs south along the Peruvian coast, pushing the Peru Current out to sea. El Niño causes extreme weather-related disturbances in South America, including drought, torrential rains, mudslides and avalanches.

Empire: A government that controls a huge territory and millions of people, often encompassing many different ethnic groups. Control may be military, political or economic.

highlands: Land above about 10,000 feet in altitude.

huaca: A site considered sacred to the Incas, such as a mountain, lake, river or rock.

Inca Empire: Empire that governed between 10 and 12 million subjects in the Andes region of South America between about A.D. 1438 and 1532. The Inca Empire lasted less than 100 years.

indigenous: Originating in the region or country where found; native.

Inti: The Inca Sun God. He was the second most important god after Wiracocha.

irrigation: A system of canals and ditches that carry water to fields so that crops can grow.

llama: An animal native to South America, related to the camel. The llama is used in the Andes region to carry heavy loads. Its wool is used to weave cloth, its hide is used to make leather, and its meat is eaten.

maize: Corn. Maize was a very important part of the Inca diet and was also used to make *chicha*, or corn beer.

manioc: A tropical plant with starchy roots used in making tapioca. A type of manioc called sweet cassava can be eaten like potatoes.

mita system: The requirement that all male family heads work for a certain number of days for the Inca Empire. Duties included farming, serving in the army, textile weaving, building towns, terraces, irrigation systems and roads, working in mines, and carrying messages.

montaña: High, humid, forested environmental zone on the eastern slope of the Andes.

mortar: A building material made of sand, water and lime, similar to cement, for holding stones together.

mummy: A dead body preserved from decay, usually by wrapping in cloth.

Pedro de Cieza de León: A Spanish soldier who wrote about the Inca Empire about 20 years after the Spanish Conquest.

Peru Current (Humboldt Current): A frigid ocean current that flows north along the west coast of South America, carrying cold, nutrient-filled water that supports a rich supply of fish, birds and sea mammals.

plates: Huge sections of the earth's crust that grind over and under each other, occasionally causing earthquakes.

Qero: A Quechua-speaking ethnic group living in the high mountains about 100 miles from Cuzco who still practice agricultural and herding techniques used during the Inca Empire. They weave beautiful textiles from alpaca wool. Their economic activities encompass three ecological zones, alpaca pastures, potato fields and maize fields.

Qoylluri Riti: A festival still observed by Quechua-speaking people who climb to mountain-top shrines to make offerings to ancient gods that are believed to inhabit the landscape. The shrine near the summit of the mountain is dedicated to the Virgin Mary.

quechua zone: The highly productive temperate zone on the western slopes and inter-mountain valleys of the Andes.

quinoa: A high-protein grain grown in the highlands of the Andes.

quipu: A device for recording numbers and probably events, developed in South America and used extensively by the Inca emperor to gather information on the Inca empire. The *quipu* is a long horizontal string with shorter strings extending vertically along it. Knots on the strings stand for different numbers and units. Different colors probably stood for different things that were being counted.

quipucamayoc: A person trained to read a *quipu*.

selva: Rainforest.

sierra: Mountains.

Tahuantinsuyu: The Quechua word for the Inca Empire.

topography: Surface features of a place or region, including mountains, hills and valleys.

tundra: Land in a very cold or high altitude region that remains frozen year-round.

vertical economy: In mountainous regions, different animals and crops can be raised at different altitudes. People can produce a variety of foods and other products within a relatively short distance by taking advantages of different ecological niches.

Wiracocha: The Inca god of creation.

IX. Recommended Books

The following books have been reviewed and recommended by the Youth Review Board of the Stratford, Connecticut, Library Association.

Middle School

Miro in the Kingdom of the Sun, by Jane Kurtz. Houghton Mifflin Co., 1996 (Folktale) (Grades 3–5).

Peru (Enchantment of the World Series), by Emilie U. Lepthien. Children’s Press, 1992 (Grades 6–8).*

Metropolis: Inca Town, by Fiona MacDonald and Mark Bergin. Franklin Watts, 1998 (Grades 6–7).

Machu Picchu, by Elizabeth Mann. Makaya Press, 2000 (Grades 6–8).

Peru (Enchantment of the World, Second Series), by Marion Morrison. Children’s Press, 2000 (Grades 6–8).

The Incas, by Shirlee P. Newman. Franklin Watts, 1992 (Grades 6–8).

The Incas, by Barbara L. Peck. Franklin Watts, 1983 (Grades 6–8).

The World of the Incas, by William Prescott. Minerva, 1970 (grades 7–12).

Middle School/High School

The Incas, by William Prescott. Crescent Books, 1981 (Grades 7–10).*

Lost Civilizations, Incas: Lords of Gold and Glory, by the Editors of Time-Life Books, 1992 (Grades 7–10).*

High School

Explorer of Machu Picchu: Portrait of Hiram Bingham, by Alfred M. Bingham. Triune Books, 2000 (Grades 9–12).

Lost City of the Incas, by Hiram Bingham. Duell, Sloan and Pearce, 1948 (Grades 9–12).

Daily Life in the Inca Empire, by Michael A. Malpass. Greenwood Press, 1996 (Grades 7–12).

The History of the Incas, by Alfred Mettraux. Schocken Books, 1970 (Grades 9–12).*

Machu Picchu: A Civil Engineering Marvel, by Kenneth R. Wright and Alfredo Valencia Zegarra. American Society of Civil Engineers, 2000 (Grades 9–12).

The Machu Picchu Guidebook: A Self-guided Tour, by Ruth M. Wright. Johnson Books, 2001 (Grades 9–12).

*Currently out of print; however, check with your local library for availability.

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X. Connections to National Science Education Standards

The three science units contained in this curriculum support the following strands contained in the National Science Education Standards.

Content Standards, Grades 5–8

Science as Inquiry

As a result of activities in grades 5 to 8, all students should develop:

Abilities necessary to do scientific inquiry

- use appropriate tools and techniques to gather, analyze and interpret data;
- develop descriptions, explanations, predictions, and models using evidence;
- think critically and logically to make the relationships between evidence and explanations
- recognize and analyze alternative explanations and predictions;
- use mathematics in all aspects of scientific inquiry.

Understandings about Scientific Inquiry

Different kinds of questions suggest different kinds of scientific investigations.

Different scientific domains employ different methods, core theories, and standards to advance scientific knowledge and understanding.

1. Unit on Adjusting to an Extreme Environment

Life Science

As a result of activities in grades 5 to 8, all students should develop an understanding of:

Structure and function in living systems

The human organism has systems for digestion, respiration, reproduction, circulation, excretion, movement, control, and coordination, and for protection from disease. These systems interact with one another.

Reproduction and heredity

The characteristics of an organism can be described in terms of a combination of traits. Some traits are inherited and others result from interactions with the environment.

Regulation and behavior

All organisms must be able to obtain and use resources, grow, reproduce, and maintain stable internal conditions while living in a constantly changing environment.

An organism's behavior evolves through adaptation to its environment.

Populations and ecosystems

The number of organisms an ecosystem can support depends on the resources available and abiotic factors, such as quantity of light and water, range of temperatures, and soil composition.... Lack of resources and other factors, such as predation and climate, limit the growth of populations in specific niches in the ecosystem.

Science in Personal and Social Perspectives

As a result of activities in grades 5 to 8, all students should develop an understanding of:

Personal health

Food provides energy and nutrients for growth and development. Nutrition requirements vary with body weight, age, sex, activity, and body functioning.

2. Archaeoastronomy Unit*Structure of the Earth System*

As a result of activities in grades 5 to 8, all students should develop an understanding of:

Lithospheric plates on the scales of continents and oceans constantly move at rates of centimeters per year in response to movements in the mantle. Major geological events, such as earthquakes, volcanic eruptions, and mountain building, result from these plate motions.

The atmosphere is a mixture of nitrogen, oxygen, and trace gases that include water vapor. The atmosphere has different properties at different elevations.

Earth and Space Science

As a result of activities in grades 5 to 8, all students should develop:

An understanding of the earth in the solar system

Most objects in the solar system are in regular and predictable motion. Those motions explain such phenomena as the day, the year, phases of the moon, and eclipses.

Seasons result from variations in the amount of the sun's energy hitting the surface, due to the tilt of the earth's rotation on its axis and the length of the day.

3. Unit on Inca Builders

Science and technology

As a result of activities in grades 5 to 8, all students should develop:

Abilities of technological design, [including]

- identify appropriate problems for technological design;
- design a solution or product;
- implement a proposed design;
- evaluate completed technological designs or products;
- communicate the process of technological design.

Understanding about science and technology

Many different people in different cultures have made and continue to make contributions to science and technology.

Science and technology in society

Science and technology have advanced through contributions of many different people, in different cultures, at different times in history. Science and technology have contributed enormously to economic growth and productivity among societies and groups within societies.

Scientists and engineers work in many different settings.

Science cannot answer all questions and technology cannot solve all human problems or meet all human needs. Students should understand the difference between scientific and other questions.

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 impacts of asteroids.

History and Nature of Science

As a result of activities in grades 5 to 8, all students should develop an understanding of:

Science as a human endeavor

Women and men of various social and ethnic backgrounds—and with diverse interests, talents, qualities, and motivations—engage in the activities of science, engineering, and related fields.

Science requires different abilities, depending on such factors as the field of study and type of inquiry.

Nature of science

Scientists formulate and test their explanations of nature using observation, experiments, and theoretical and mathematical models.

History of science

Many individuals have contributed to the traditions of science. Studying some of these individuals provides further understanding of scientific inquiry, science as a human endeavor, the nature of science, and the relationships between science and society.

In historical perspective, science has been practiced by different individuals in different cultures. In looking at the history of many peoples, one finds that scientists and engineers of high achievement are considered to be among the most valued contributors to their culture