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THE SCIENCE OF SLEEP AND DAILY RHYTHMS

INQUIRY

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TEACHER'S GUIDE

Nancy P. Moreno, Ph.D., Barbara Z. Tharp, M.S., and Gregory L. Vogt, Ed.D.

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by

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RESOURCES

For online presentations of each activity and downloadable slide sets for classroom use, visit http://www.bioedonline.org or http://www.k8science.org.

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Contents

Education is an important part of the National Space Biomedical Research Institute (NSBRI), which is teaming with some of the nation's finest biomedical researchers to create new strategies for safe human exploration and development of space.

Scientists supported by NSBRI are studying sleep, human factors and performance to benefit not only NASA and space travelers, but also people right here on Earth.

For more information about all NSBRI research areas, visit the NSBRI website at http://www.nsbri.org/.

TEAMING WITH BENEFITS

by Jeffrey P. Sutton, M.D., Ph.D., Director, National Space Biomedical Research Institute (NSBRI)

Dr. Jeffrey P. Sutton

Space is a challenging environment for the human body. With long-duration missions, the physical and psychological stresses and risks to astronauts are significant. Finding answers to these health concerns is at the heart of the National Space Biomedical Research Institute's program. In turn, the Institute's research is helping to enhance medical care on Earth.

The NSBRI, a unique partnership between NASA and the academic and industrial communities, is advancing biomedical research with the goal of ensuring a safe and productive long-term human presence in space. By developing new approaches and countermeasures to prevent, minimize and reverse critical risks to health, the Institute plays an essential, enabling role for NASA. The NSBRI bridges the research, technological and clinical expertise of the biomedical community with the scientific, engineering and operational expertise of NASA.

With nearly 60 science, technology and education projects, the NSBRI engages investigators at leading institutions across the nation to conduct goal-directed, peer-reviewed research in a team approach. Key working relationships have been established with end users, including astronauts and flight surgeons at Johnson Space Center, NASA scientists and engineers, other federal agencies, industry and international partners. The value of these collaborations and revolutionary research advances that result from them is enormous and unprecedented, with substantial benefits for both the space program and the American people.

Through our strategic plan, the NSBRI takes a leadership role in countermeasure development and space life sciences education. The results-oriented research and development program is integrated and implemented using focused teams, with scientific and management directives that are innovative and dynamic. An active Board of Directors, External Advisory Council, Board of Scientific Counselors, User Panel, Industry Forum and academic Consortium help guide the Institute in achieving its goals and objectives.

It will become necessary to perform more investigations in the unique environment of space. The vision of using extended exposure to microgravity as a laboratory for discovery and exploration builds upon the legacy of NASA and our quest to push the frontier of human understanding about nature and ourselves.

The NSBRI is maturing in an era of unparalleled scientific and technological advancement and opportunity. We are excited by the challenges confronting us, and by our collective ability to enhance human health and well-being in space, and on Earth.

NSBRI RESEARCH AREAS

CARDIOVASCULAR PROBLEMS

The amount of blood in the body is reduced when astronauts are in microgravity. The heart grows smaller and weaker, which makes astronauts feel dizzy and weak when they return to Earth. Heart failure and diabetes, experienced by many people on Earth, lead to similar problems.

HUMAN FACTORS AND PERFORMANCE

Many factors can impact an astronaut's ability to work well in space or on the lunar surface. NSBRI is studying ways to improve daily living and keep crewmembers healthy, productive and safe during exploration missions. Efforts focus on reducing performance errors, improving nutrition, examining ways to improve sleep and scheduling of work shifts, and studying how specific types of lighting in the craft and habitat can improve alertness and performance.

MUSCLE AND BONE LOSS

When muscles and bones do not have to work against gravity, they weaken and begin to waste away. Special exercises and other strategies to help astronauts' bones and muscles stay strong in space also may help older and bedridden people, who experience similar problems on Earth, as well as people whose work requires intense physical exertion, like firefighters and construction workers.

NEUROBEHAVIORAL AND STRESS FACTORS

To ensure astronaut readiness for space flight, preflight prevention programs are being developed to avoid as many risks as possible to individual and group behavioral health during flight and post flight. People on Earth can benefit from relevant assessment tests, monitoring and intervention.

RADIATION EFFECTS AND CANCER

Exploration missions will expose astronauts to greater levels and more varied types of radiation. Radiation exposure can lead to many health problems, including acute effects such as nausea, vomiting, fatigue, skin injury and changes to white blood cell counts and the immune system. Longer-term effects include damage to the eyes, gastrointestinal system, lungs and central nervous system, and increased cancer risk. Learning how to keep astronauts safe from radiation may improve cancer treatments for people on Earth.

SENSORIMOTOR AND BALANCE ISSUES

During their first days in space, astronauts can become dizzy and nauseous. Eventually they adjust, but once they return to Earth, they have a hard time walking and standing upright. Finding ways to counteract these effects could benefit millions of Americans with balance disorders.

SMART MEDICAL SYSTEMS AND TECHNOLOGY

Since astronauts on long-duration missions will not be able to return quickly to Earth, new methods of remote medical diagnosis and treatment are necessary. These systems must be small, low-power, noninvasive and versatile. Portable medical care systems that monitor, diagnose and treat major illness and trauma during flight will have immediate benefits to medical care on Earth.

For current, in-depth information on NSBRI's cutting-edge research and innovative technologies, visit www.nsbri.org.

Overview

Students will make a "mini-globe" to investigate the causes of day and night on our planet. Earth rotates completely on its axis about every 24 hours. This rotation, in combination with Earth's position relative to the sun, produces the cycles of day and night.

Activity 1

Modeling Day and Night

Our lives, and those of other organisms on Earth, are shaped in countless ways by the cycle of day and night. This repeating sequence of light and darkness is caused by the spinning of our planet and its position relative to the sun.

Earth, like other planets in our solar system, revolves around the sun in a slightly elliptical orbit. It takes about 365 days—one year—for Earth to go around the sun. Other planets require more or less time to complete their orbits, and their years are correspondingly longer or shorter than Earth's. In any case, a year is defined as the amount of time it takes a planet to make one complete revolution around the sun.

SCIENCE EDUCATION CONTENT STANDARDS*
GRADES 6-12

PHYSICAL SCIENCE
- The motion of an object can be described by its position, direction of motion and speed.

EARTH AND SPACE SCIENCE
- 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.

SCIENCE, HEALTH & MATH SKILLS
- Observing
- Measuring
- Modeling
- Mapping
- Drawing conclusions

* National Research Council. 1996. National Science Education Standards. Washington, D.C., National Academies Press.

As Earth orbits the sun, it also rotates, or spins, on its axis. It takes about 24 hours—one day—for Earth to complete a single rotation. As students will discover through the activities in this unit, the functions of living organisms on Earth are linked to this 24-hour cycle.

During each 24-hour period, most locations on Earth will experience several hours of sunlight (day) followed by a period of darkness (night). Solar noon is the moment at which the sun reaches its highest point in the sky in a given location. It rarely coincides with the "noon hour" on a clock. Many factors—location (longitude) on Earth, time of year, time zone, and whether daylight savings time is in effect—influence what "clock time" it will be when solar noon occurs. Midnight occurs 12 hours before and after noon.

As viewed from the North Pole, Earth spins counterclockwise. This is why the sun appears to rise in the east and set in the west. In reality, of course, the sun remains relatively stationary, while Earth rotates in its orbit. The following activity uses a simple model to help students visualize Earth's rotation about its axis, the slight tilt in Earth's axis, and the cycle that produces day and night.

TIME

20 minutes for setup; 30 minutes to conduct activity

Continued

A.M. and P.M.

The common abbreviation for morning, "a.m.," comes from the Latin *ante meridiem*, which means "before noon." The abbreviation, "p.m.," comes from the Latin *post meridiem*, meaning "after noon."

Teacher Resources

Downloadable activities in PDF format, annotated slide sets for classroom use, and other resources are available free at http://www.bioedonline.org/ or http://www.k8science.org/.

Image Citations

Source URLs are available at the front of this guide.

USING COOPERATIVE GROUPS IN THE CLASSROOM

Cooperative learning is a systematic way for students to work together in groups of two to four. It provides organized group interaction and enables students to share ideas and to learn from one another. Students in such an environment are more likely to take responsibility for their own learning. Cooperative groups enable the teacher to conduct hands-on investigations with fewer materials.

Organization is essential for cooperative learning to occur in a hands-on science classroom. Materials must be managed, investigations conducted, results recorded, and clean-up directed and carried out. Each student must have a specific role, or chaos may result.

The Teaming Up! model* provides an efficient system for cooperative learning. Four "jobs" entail specific duties. Students wear job badges that describe their duties. Tasks are rotated within each group for different activities, so that each student has a chance to experience all roles. For groups with fewer than four students, job assignments can be combined.

Once a cooperative model for learning is established in the classroom, students are able to conduct science activities in an organized and effective manner. The job titles and responsibilities are as follow.

Principal Investigator
- Reads the directions
- Asks questions of the instructor/teacher
- Checks the work

Maintenance Director
- Ensures that safety rules are followed
- Directs the cleanup
- Asks others to help

Reporter
- Records observations and results
- Shares results with group or class
- Tells the teacher when the investigation is complete

Materials Manager
- Picks up the materials
- Directs use of equipment
- Returns the materials

* Jones, R.M. 1990. Teaming Up! LaPorte, Texas: ITGROUP.

MATERIALS

Each group will need:
- Large paper clip
- Table tennis (ping-pong) ball or round foam ball (diameter of 1/2 in.)
- Colored markers or pencils
- Sheet of cardstock (8.5 in. x 11 in.)
- 2-3 strips of masking or clear tape
- Copy of student sheets (pp. 4–5)

SAFETY

Always follow district and school laboratory safety procedures. It is a good idea for students to wash their hands with soap and water before and after any science activity.

SETUP & MANAGEMENT

Unless noted, each activity in this guide is designed for students working in groups of four (see "Using Cooperative Groups in the Classroom," above).

Before the activity, follow the instructions on the "Earth Model" sheet (p. 4), to build a demonstration "mini-globe." If using table tennis balls for the activity, use a pushpin to make a small hole in the bottom of each ball before distributing to students. For younger students, you also may want to straighten the paper clip, as directed.

Place the materials in a central location for materials managers to pick up.

PROCEDURE

1. Challenge students to think about what causes night and day on Earth. Conduct a discussion and list students' ideas on the board. Ask, *Is day always followed by night? Does the sun shine at night? Why does the sun appear in the east in the morning and disappear in the west in the evening? Do the combined hours of light and darkness in a day always equal 24?* List any other questions posed by students.
2. Tell students they will be conducting an investigation that will help to answer many questions about day and night on Earth. Explain that each group will construct a model Earth and investigate what happens when light shines on the model.

Biological Clocks and Human Health

Research on biological clocks inside cells is helping to improve treatments for many diseases, including cancer. Physicians now are able to time the administration of chemotherapy drugs with points in the day when cancer cells are least likely to be able to reverse the medications' action.

Ancient Beliefs

Over the course of history, different civilizations explained the cycle of night and day in different ways. For example, some ancient priests of India believed that Earth is supported by 12 huge pillars. At nighttime, the sun was believed to pass beneath our planet.

Aristotle, a Greek philosopher, was certain that the entire sky revolved around the Earth. This Earth-centered view of the universe prevailed in Europe until the 16th Century.

Copernicus, a Polish clergyman and scientist, is credited with providing the world with a more accurate theory of the solar system, in which planets (including Earth) revolve around the sun.

Time to Travel

The moon is about 226,000 miles from Earth at its closest point. The distance from Earth to Mars is about 35 million miles. It takes astronauts about three days to reach the moon, and it is estimated that it would take at least six months to travel to Mars.

Speed of Rotation

Earth rotates at a speed of about 1,600 kilometers per hour at the equator. As it rotates, our planet also revolves around the sun. Both of these movements determine day length.

Each day on Earth lasts about 24 hours, when measured according to the position of the sun in the sky. Day lengths are different on other planets, depending on the velocity with which the planet spins on its axis. On Mars, one rotation (day) takes 24.6 Earth hours; one rotation of Jupiter is 9.9 Earth hours; and one rotation of Venus takes 243 Earth days!

A Matter of Degrees

Rotation (turning around a center point or axis) is measured in degrees. One complete rotation is 360°. As seen from the North Pole, the Earth rotates in a counterclockwise direction—from west to east.

3. Show students the globe model you made in advance (see Setup). The model can be as simple or as elaborate as you choose, depending on grade level. Tell students they will create similar models for their investigations. Distribute the "Earth Model" sheets and ask materials managers to pick up their supplies.
4. Have groups follow the instructions and build their models.
5. Next, have students identify which end of the model Earth represents the North Pole. Then, have them determine the direction in which their model Earth must spin if it is to rotate counterclockwise when viewed from above the North Pole. (To review clockwise and counterclockwise, have the class stand and face the same direction, and then turn in place, first clockwise, then counterclockwise.)
6. Distribute copies of the "Rotation Observations" page and have each group work through the questions.
7. Point out how the Earth models appear slightly tilted. This tilt in Earth's axis affects day length throughout the year and causes the seasons, which are explored in Activity Two.
8. Prompt students to reconsider the questions asked at the beginning of the activity, and to use their Earth models to obtain the answers. Ask, *Is day always followed by night?* Yes, in most locations. However, during the summer at the North and South Poles, the sun is visible all day long. *Does the sun shine at night?* Yes, the sun always is shining, even when your part of the planet is in darkness. Similarly, one part of Earth always is facing away from the sun and in darkness. *Why does the sun appear in the east in the morning and disappear in the east in the evening?* The direction of Earth's rotation creates the illusion that the sun rises in the east and sets in the west. In fact, the sun remains relatively still, while Earth rotates. *Do the combined hours of light and darkness in a day equal 24?* Yes, because the Earth rotates completely relative to the sun once every 24 hours.

Astronaut Jeffrey S. Ashby, Mission Commander, STS-112, and crewmembers sleep in special sleeping bags while in orbit. Since the day/night cycle is only 90 minutes long, astronauts sleep poorly, averaging about two hours less of sleep each day in orbit than when they are on the ground.

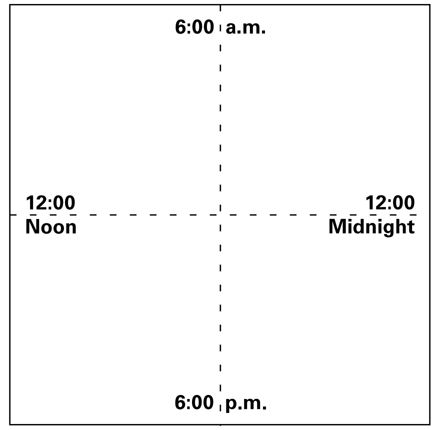
Photo courtesy of NASA.

EXTENSIONS

- Have students track the times of sunrise and sunset in their town for several weeks. This information is available from newspapers, weather broadcasts or the Internet. Have students compare these times to those for a city in the southern hemisphere at the same south latitude.
- Have students find the latitude, longitude and time zone of the location in which they live. Then, lead a class discussion about the importance of standardized time zones. Students can find the times of solar noon and apparent sunrise and sunset in their location—and other places around the world—with the Sunrise/Sunset Calculator created by the National Oceanic and Atmospheric Administration (NOAA) (www.srrb.noaa.gov/highlights/sunrise/sunrise.html). This would be a good time to explain the difference between solar noon and chronological noon.
- Astronauts on the space station orbit Earth every 90 minutes. Have students calculate the number of day/night cycles that a crew in orbit experiences during a 24-hour period.

ACTIVITY 1
EARTH MODEL

Make a model of Earth by following the steps below. You will need a table tennis (ping-pong) ball or foam ball, colored markers, a sheet of heavy paper or cardstock, a large paper clip and several pieces of tape.

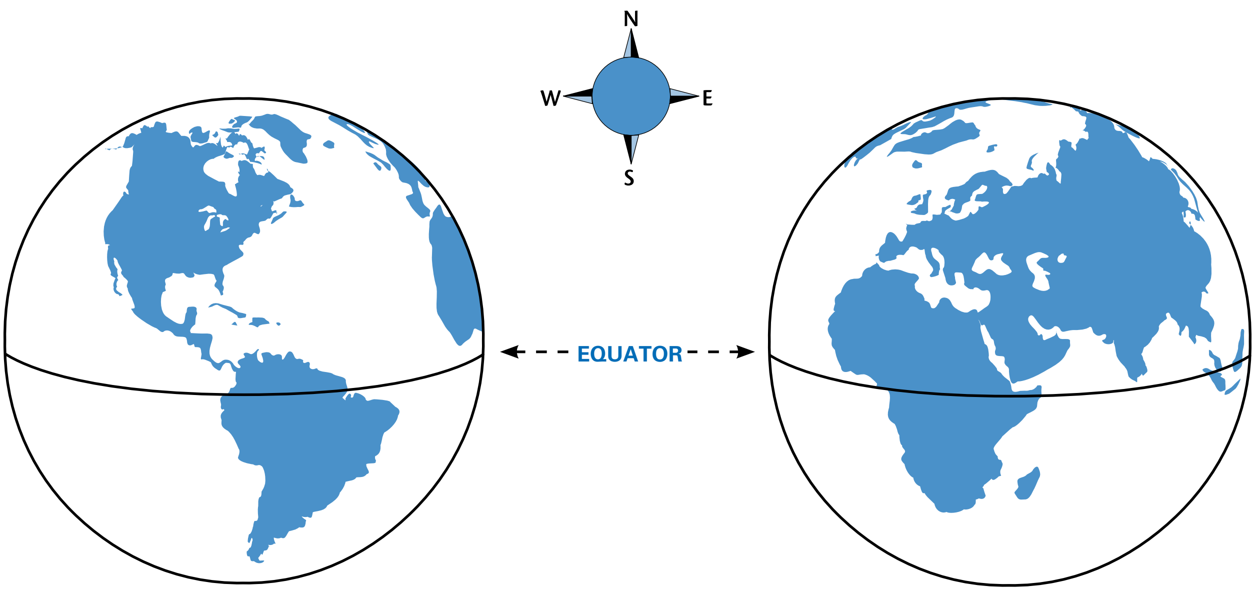


Instructions

1. Fold the heavy paper in half twice. This will make four equal sections. Then, smooth the sheet back out and label the folds, as shown to the right.

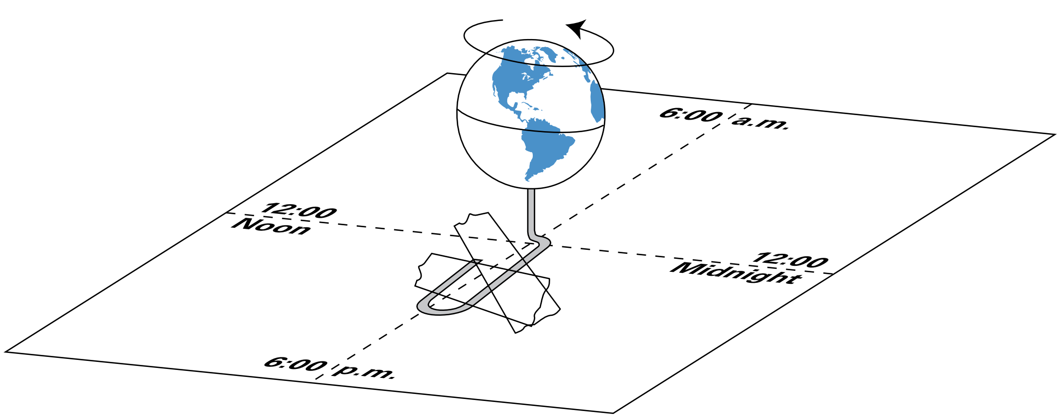
2. Draw a line around the widest part of the ball using a pencil or marker. This represents the equator on your Earth model.

3. Draw the continents on your "Earth," using the diagrams below as guides. Write an "N" at the North Pole and an "S" at the South Pole.



4. Straighten (unfold) one loop of the paper clip. Tape the other half onto the center point of the folds of your paper.

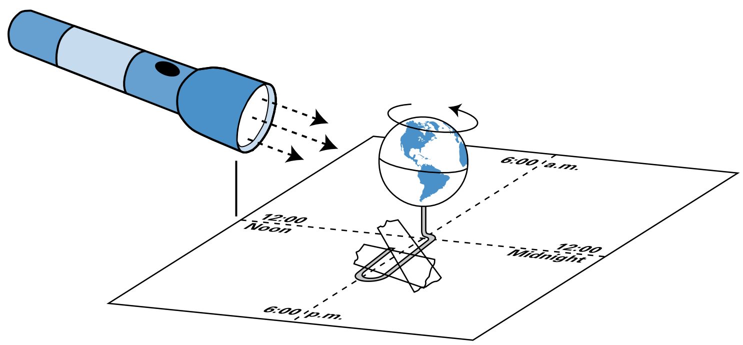
5. Push your Earth globe over the straightened part of the paper clip, with the North Pole facing almost upward. Your model should look like the drawing below.



ACTIVITY 1

ROTATION OBSERVATIONS

You will use your group's Earth model and a flashlight to demonstrate how the sun shines toward Earth. Follow the directions and answer the questions below.



1. Place a small dot on the Earth model to show where you live. You will observe what happens to this dot as the Earth model rotates.

2. Hold the flashlight so that it points toward your Earth model along the marking for 12:00 noon.

3. Rotate the Earth model counterclockwise until the dot is at 6:00 a.m. This represents early morning in your location. Notice where the sun (flashlight) is at this time.

    a. Is the dot in the light or in the dark? ____________________

    b. Does the light shine directly toward the dot, or to one side? ____________________

4. Rotate the Earth model 90 degrees (1/4 of a circle) in a counterclockwise direction. Notice where the sun (flashlight) is.

    a. What is the time in your location when the model is at this position? ____________________

    b. Is the dot in the light or in the dark? ____________________

    c. Does the light shine directly toward the dot, or to one side? ____________________

5. Rotate the Earth model another 90 degrees (1/4 of a circle) in a counterclockwise direction. Notice where the sun (flashlight) is.

    a. What is the time in your location when the model is at this position? ____________________

    b. Is the dot in the light or in the dark? ____________________

    c. Does the light shine directly toward the dot, or to one side? ____________________

6. Rotate the Earth model another 90 degrees (1/4 of a circle) in a counterclockwise direction. Notice where the sun (flashlight) is.

    a. What is the time in your location when the model is at this position? ____________________

    b. Is the dot in the light or in the dark? ____________________

    c. Does the light shine directly toward the dot, or to one side? ____________________

7. Based on your observations, write a paragraph describing why the sun appears overhead at noon, is visible in the western part of the sky in the evening, and cannot be seen at midnight. Use the back of this sheet or a separate sheet of paper to record your answer.

OVERVIEW

Students will plot the path of the sun's apparent movement across the sky on two days, with the second day occurring two or three months after the first.

The inclination of Earth's axis to its orbit creates the four seasons. Days are longer and sunlight more direct in summer than in winter. At any given time of year, the northern hemisphere experiences seasons opposite to those being experienced in the southern hemisphere.

ACTIVITY 2

REASON FOR THE SEASONS

Many students (and adults) mistakenly believe the seasons are due to the changing distance between Earth and the sun as our planet progresses in its orbit. According to this (incorrect) scenario, Earth experiences summer when it is closer to the sun and winter when it is farther away. Earth's distance from the sun does vary over the course of a year. At its near point (perihelion), Earth is 147.9 million kilometers from the sun; at its far point (aphelion), it is 152.09 million kilometers away. However, the difference between the perihelion and aphelion is small—less than 3%.

In fact, the varying distance between Earth and the sun has little impact on our seasons. Perihelion (when Earth is closest to the sun) occurs in early January, when it is winter in the northern hemisphere. Aphelion (when Earth is furthest away) occurs in early July, during summer in the northern hemisphere. But remember, summer in the northern hemisphere occurs when it is winter in the southern hemisphere, and vice versa. Since Earth experiences winter and summer simultaneously, the seasons must not be determined by Earth's distance to the sun.

The seasons are caused by Earth's rotation around an axis, an imaginary line through the center of Earth that connects the North Pole to the South Pole. This axis is tilted about 23.5° from a vertical position, relative to its orbit around the sun. During summer in the northern hemisphere, Earth's North Pole leans toward the sun, while the South Pole leans away. When it is winter in the northern hemisphere, the South Pole leans toward the sun and the North Pole leans away. In between winter and

SCIENCE EDUCATION CONTENT STANDARDS*
GRADES 6-12

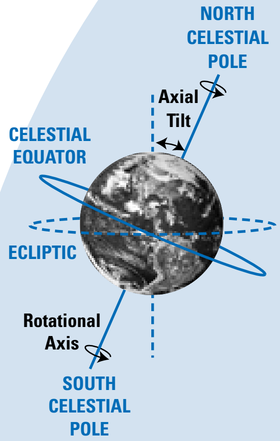
PHYSICAL SCIENCE
- The motion of an object can be described by its position, direction of motion and speed. That motion can be represented and measured on a graph.
- The sun is a major source of energy for changes on the Earth's surface.

EARTH AND SPACE SCIENCE
- The sun, an average star, is the central and largest body in the solar system.
- Most objects in the solar system are in regular and predictable motion.
- Seasons result from variations in the amount of the sun's energy hitting the Earth's surface, due to the tilt of the Earth's rotation on its axis and the length of day.

SCIENCE, HEALTH & MATH SKILLS
- Data collection
- Measuring
- Observing
- Drawing conclusions

* National Research Council. 1996. National Science Education Standards. Washington, D.C., National Academies Press.

Effects of 23.5°

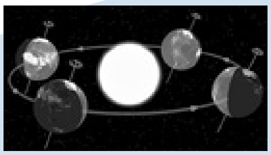


The tilt of Earth's axis alters the hours of daylight and the apparent angle of the sun in the sky.

Illustration courtesy of Dna-webmaster courtesy of Wikipedia Commons. Earth photo courtesy of NASA.

Seasonal Tilt

When Earth's North Pole leans toward the sun, it is summer in the northern hemisphere and winter in the southern hemisphere.



Earth's seasons, as seen from the north.

Three months later (one-quarter of the way through Earth's orbit), neither Pole leans toward the sun. It is spring in the northern hemisphere and fall in the southern hemisphere.

Three months after that, (one-quarter turn in orbit), the North Pole leans away from the sun. It is winter in the northern hemisphere and summer in the southern hemisphere.

Three months later, (one-quarter turn in orbit), neither Pole leans toward the sun. It is the autumn in the northern hemisphere and spring in the southern hemisphere.

Finally, another three months brings Earth back to its starting point. A full year has passed, and the North Pole once again leans toward the sun.

Illustration courtesy of Tau'olonga, Wikipedia Commons.

summer, when Earth experiences spring and fall, neither Pole leans toward the sun.

The tilt of Earth's axis alters the hours of daylight and the apparent angle of the sun in the sky. During summer, there are more of hours of daylight and the sun is higher in the sky than during winter. Thus, summer brings more heating, longer days, and more intense light. Conversely, winter is characterized by fewer hours of daylight and a lower angle of the sun, which combine to produce cooler, shorter days.

The hours of nighttime also affect the seasons. In winter, days are shorter than nights, so there is more time for Earth's surface to radiate heat back into space. This causes a net decrease in heat in locations experiencing winter. But in summer, days are longer than nights, so there is a net increase in heat in Earth's surface.

In the northern hemisphere, the longest day of summer, known as the summer solstice, occurs around June 21; the shortest day, or winter solstice, occurs on or around December 21. Between summer and winter, during the seasons of spring and fall, neither of Earth's poles leans toward the sun. Days and nights are exactly 12 hours long on both the first day of spring (spring equinox) and the first day of fall (autumn equinox).

TIME

Part 1: 10 minutes for setup; 30 minutes to conduct activity
Part 2: 10 minutes for setup; 30 minutes to conduct activity
Part 3a: One hour to create and learn how to use a sun tracking board
Part 3b: Two days scheduled two to three months apart. For each day, four or more 10-minute sessions will be conducted at 15-minute intervals.

The second sun tracking day must be held at least two to three months after the first. It is important that both observation days take place either before or after the first day of winter (December 21).

MATERIALS

Teacher (see Setup)
- Earth globe (with axial tilt) on a portable stand
- Yellow ball, about 8 in. diameter, to serve as a sun model
- 2 small, blue glass "pony" beads (available from craft stores)
- 2 toothpicks or wooden skewers
- Twine or string, approximately 75 ft
- Glue

Each student or group of two students will need:
- 8-in. square of cardboard
- 8-in. length of string
- Clear plastic dome-shaped lid (as used to cover whipped toppings on coffee or frozen drinks)
- Fine-point marker, black
- Pencil
- Protractor
- Ruler
- Several pieces of masking tape
- Copies of student sheets (pp. 10–11)

SAFETY

Always follow district and school laboratory safety procedures. It is a good idea for students to wash their hands with soap and water before and after any science activity.

SETUP & MANAGEMENT

Part 1: Prepare two small Earth models ahead of time, each comprised of a single blue "pony" bead glued to the end of a toothpick or wooden skewer. To conduct the activity, you will need an open space about 75 feet long (e.g., a long hallway, football field, etc.).

Part 3: Select two dates on which to conduct observations. Students will need to be outside, in an area that provides a wide, unobstructed view of the sky. Be aware that the activity will not work on a

Continued

dark or cloudy day because shadows will not be clearly visible.

Students will need to align their sun tracking boards on the same point of the same east-west line for all measurements. Seek out a permanent east-west feature (e.g., painted line on a playground, edge of sidewalk, south-facing window ledge, etc.). If no such line is available, use a magnetic compass to sight an east-west line on a permanent concrete or asphalt surface. Mark the line with chalk.

On each appointed day, students will take two or three measurements in the morning and two or three more in the afternoon. Make sure students understand how to mark the position of the sun on the plastic dome.

PROCEDURE

Part 1: Earth and Sun Models

1. Take your students into an open area (long hallway, open outdoor area, etc.), and ask one student to hold the 8-inch yellow ball. This represents the sun. Then, ask a second student to hold an Earth model.
2. Tell your students the two models are to scale (the sun's diameter is 110 times that of Earth). Ask, *To show proper scale, how far apart should the sun and Earth models be from each other?* Encourage students to discuss their ideas.
3. Wrap the string around the sun model 33.5 times (see "Modeling Distances," sidebar, right). Then hold one end of the string next to the sun and have the "Earth" student take the other end of the string and walk away from the "sun" student until the string is fully extended. At that point, you have created an accurate scale model—size and distance—of Earth and the sun.
4. Give another student the second Earth model. Have him or her walk to the first "Earth" student, and then step about 60 centimeters (2 feet) further away from the sun.
5. Have students observe the positioning of the three models. Explain that the two blue beads represent Earth, the yellow ball represents the sun, and the positioning of the models represents the nearest and furthest distances between Earth and the sun. Explain perihelion and aphelion to your students. Mention that the bead closer to the sun represents Earth at the near point (perihelion) in its orbit, which occurs during the northern hemisphere winter/southern hemisphere summer. The more distant bead represents Earth at its far point (aphelion), which occurs during the northern hemisphere summer/southern hemisphere winter.
6. Ask, *Does the distance between Earth and the sun cause the seasons?* You may help your students to visualize the question by giving the "perihelion Earth" student a small sign that reads "Northern Hemisphere Winter" and the "aphelion Earth" student a sign that reads "Northern Hemisphere Summer."

Part 2: Tilted Earth

1. Return to the classroom with your students. Place the yellow ball representing the sun on a stool in the center of the classroom. Ask for a volunteer to hold the Earth globe that shows the tilt of the axis. Point out that the distances and sizes of the sun model and Earth globe will not be to scale in this part of the activity.
2. Have the student holding the globe walk in a circular counterclockwise pattern around the sun. This pattern represents Earth's orbit. At all times during the "orbit," the student should ensure that the globe's North Pole axis is pointing in the same direction (i.e., toward the same side of the room). Also, have the student gently spin the globe while he or she "orbits," to remind the class that Earth rotates while it circles the sun.
3. Over the course of several complete orbits, have all students observe how

Modeling Distances

Wrapping the string around the sun model 33.5 times illustrates the ratio of the sun's circumference to the distance between Earth and the sun, when Earth is at the perihelion of its orbit. In other words, the distance at perihelion is approximately 33.5 times the circumference of the sun. [Perihelion distance (147.09 million km)/sun circumference (4.39 million km) = 33.5.] The ratio at aphelion (farthest from the sun) is 34.6.

Perihelion and Aphelion

Perihelion: The point at which Earth is at its nearest orbital point to the sun. Earth's perihelion is reached during the northern hemisphere winter and southern hemisphere summer.

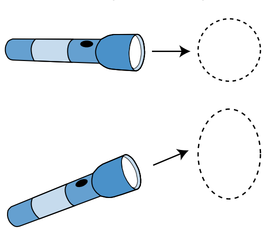
Aphelion: The point at which Earth is at its farthest orbital point to the sun. Earth's aphelion is reached during the northern hemisphere summer and southern hemisphere winter.

Seasonal Daylight Effects

- **Summer:** Longer days with more direct rays from the sun mean more heating.
- **Winter:** Shorter days with less direct rays from the sun mean less heating.
- **Spring/Fall:** Medium length days with medium direct rays from the sun mean medium heating.

Direct and Indirect Rays

Use a flashlight to demonstrate how and why direct rays are more efficient than indirect rays in heating Earth. Darken the room and aim the light directly at a wall. Observe the brightness of the flashlight circle on the wall. Redirect the flashlight at an angle and shine the beam on the same location. The beam will spread out and the indirect beams of light will form an elliptical shape.



Again, observe the brightness of the spot. It will be dimmer. In a similar way, direct rays concentrate the sun's heat, while indirect rays spread the heat.

Earth's axis always leans in the same direction. At one point during Earth's orbit, the northern end of the axis will lean toward the sun, and the southern end will lean away. Stop the student who is carrying the globe and make sure everyone notes the position of the northern axis at this time. Then, have the "orbiting" student continue. Stop him or her again when he or she reaches the opposite side of the sun. Students now will observe that the north axis leans away from—while the southern axis leans toward—the sun. In between these two positions, the northern and southern axes lean neither toward nor away from the sun.

4. Review the seasons with your class as the student and Earth "globe" orbit the sun (see "Seasonal Tilt," sidebar, p. 7).
5. Discuss as a class how Earth's tilt affects the seasons. Give students a list of cities around the world (e.g., Minneapolis, Sydney, Beijing, Buenos Aires, and Moscow). Have students predict whether residents of each city experience winter or summer in July. Then, have students use the globe to locate each city and verify their predictions.

Part 3a: Build a Sun Tracking Board

1. Provide each student or team of two students with materials and copies of the "Sun Tracking Board" student sheet.
2. Have students follow the instructions to build their sun tracking boards.

Part 3b: Tracking the Sun

1. Provide each student or team of two students with a copy of the "Sun Tracking Data" sheet. Before noon, take students outside to the preselected location (see Setup). Have students place their boards on the ground, with the "south" edge squarely on the east-west line identified previously.
2. Have students follow the instructions on the student sheet. They should record the location of the sun's shadow on the dome of the sun tracking board and record the time of their measurement. Have students use a protractor to estimate the angle of the sun above the horizon, and record the value.
3. Take students outside three or more times that same day (at least twice before noon and twice after noon), and have them make new measurements.
4. After all measurements have been recorded on the dome, have students draw a curved line connecting the dots on the dome and extend the line to the east and west horizons. (It is best to demonstrate this step before the students try it.) Put the boards away in a place where they will not be disturbed.
5. Repeat the steps above two to three months later. This time, students will record a new path on the domes of their tracking boards.
6. After the second set of observations, have students analyze the two paths on their domes by answering the questions at the bottom of the "Sun Tracking Data" sheet.

EXTENSION

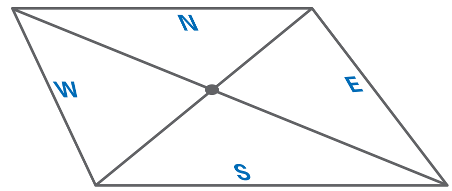
- Challenge students to provide possible reasons why portions of the Arctic are known as the "Land of the Midnight Sun." Help them understand that, during summer in the northern hemisphere, the North Pole and Arctic regions face the sun. At this time of year, areas above the Arctic Circle experience continuous light throughout the day and night (including midnight). Have students hypothesize what happens when the South Pole and Antarctic regions are tilted toward the sun, and what happens in these regions during winter months. Ask students what it would be like to live in continuous light or dark for several months.

ACTIVITY 2

SUN TRACKING BOARD

Make a Sun Tracking Board

You will need one 8-inch square of cardboard, one 8-inch length of string, a clear plastic dome-shaped lid (as used to cover whipped toppings on coffee or frozen drinks), one black, fine-point marker and a pencil, a protractor and a ruler, and several pieces of masking tape.



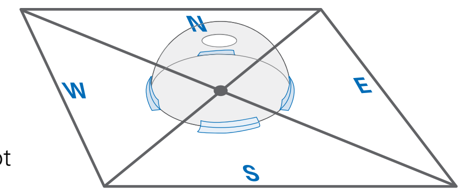
1. Use the ruler to draw two pencil lines in the shape of an "X" across the cardboard (see illustration, right).

2. Use the pencil to make a small, dark dot at the center point where the two lines intersect. This is the center of your sun tracking board.

3. Write the compass direction letters, "N," "S," "E," and "W," as shown in the illustration to the right.

4. Place the clear plastic dome over the board and center it directly above the dot you drew. Use small pieces of masking tape to secure the dome to the board.

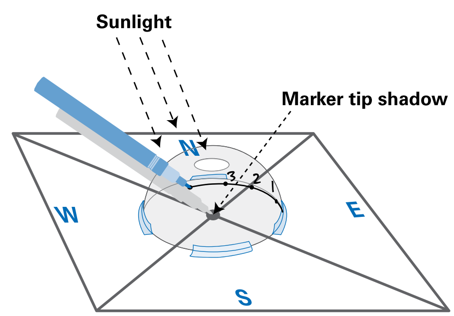
5. Write your name(s) on one corner of the board.



Sun Tracking Day 1

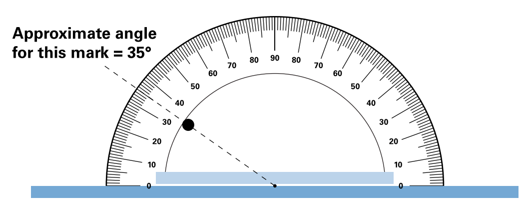
1. Take your sun tracking board and a marker outside and place the south edge of the board exactly on the line, as directed by your teacher.

2. Hold your marker tip just above the plastic dome (without touching it) and look for the shadow of the tip. Move the marker so that the shadow of the tip falls directly over the dark dot in the center of the board. Carefully make a small dot on the plastic dome at this point. If you have done this correctly, the shadow of the mark will fall exactly on the center dot of the sun tracking board.



3. Write a small number "1" near the dot on the dome, and record the time of this measurement on your Sun Tracking Data sheet. If daylight savings time is in effect, add one hour to your recorded time.

4. Hold the protractor behind the dome and estimate the degree of the dot on the dome. This angle is about the same as the angle of the sun above the horizon. Record this angle on your data sheet.

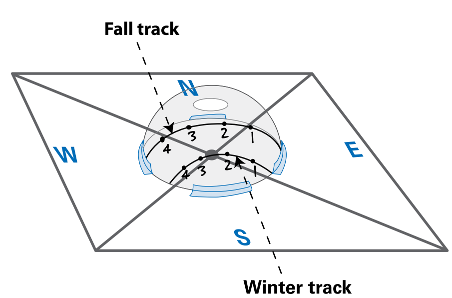


5. On your data sheet, record the general direction of the sun.

6. Repeat steps 1–5, as instructed by your teacher. After each observation, add a dot to the plastic dome to show the position of the sun at that time. Also, be sure to record all observation times on your Sun Tracking Data sheet.

7. After you have completed all the day's measurements, draw a smooth line connecting all the dots on the plastic dome. This line shows the apparent movement of the sun across the sky during the day.

8. Extend the ends of the line to the east and west edges (horizons) of the dome. Store your sun tracking board as instructed by your teacher.



Sun Tracking Day 2

1. Repeat steps 1–8.

2. Lay the piece of string over the dome and measure the lengths of the two lines you drew for the sun's path. Then, answer the questions at the bottom of the Sun Tracking Data sheet.

Activity 2

Sun Tracking Data

Sun Tracking Day 1:

Date ____________________ Season ____________________

OBSERVATION NUMBER	TIME (add 1 hour if daylight savings time is in effect)	DIRECTION OF THE SUN (east, southeast, south, southwest, west)	ANGLE OF THE SUN ABOVE THE HORIZON (approximate)

Sun Tracking Day 2:

Date ____________________ Season ____________________

OBSERVATION NUMBER	TIME (add 1 hour if daylight savings time is in effect)	DIRECTION OF THE SUN (east, southeast, south, southwest, west)	ANGLE OF THE SUN ABOVE THE HORIZON (approximate)

Summarize your observations about the sun's apparent movements and the seasons by answering the following questions in your science notebook, or on the back of this sheet.

1. How long was the sun's path on each of the two days you took measurements?
2. What does the length of each line represent?
3. Which line is longer? During what season was this line drawn?
4. How high did the sun rise above the southern horizon on each day?
5. Which line rises higher in the sky? During what season was this line drawn?
6. Using your data above, explain why Earth has seasons.

OVERVIEW

It is possible to measure time via the relative positions of Earth and the sun. Students will make a sundial (shadow clock) appropriate for their geographic location in the northern hemisphere and use it to tell time.

ACTIVITY 3

USING A SUNDIAL

For centuries, people relied on the position of the sun in the sky to estimate the time of day. Noon or midday was designated as the time when the sun was at its highest point in the sky. We now know, of course, that the sun does not move across the sky. Rather, Earth rotates as it revolves around the sun.

One of the earliest tools used to measure time was the movement of shadows on the ground over the course of a day. Since shadows move the same way each day, they can be used to estimate time. Simple sundials—perhaps only a stick placed vertically in the ground—used shadows to tell time in Egypt more than 3,000 years ago.

When humans first began keeping track of time, an hour was calculated as 1/12 of the period of daylight on any given day. Thus, the length of an hour varied with the seasons. Now, we divide each day into 24 equal hours, which remain unchanged regardless of the time of year. In modern society, time also is standardized from place to place. Before 1884, every town set its clocks to the highest position of the sun (noon). As a result, each town ran on a different time, and there was great confusion. Today, the world is sectioned into 24 standard, uniform time zones. Each time zone accounts for 15 degrees longitude and 60 minutes of Universal Time.

SCIENCE EDUCATION CONTENT STANDARDS*
GRADES 6-12

PHYSICAL SCIENCE
- The motion of an object can be described by its position, direction of motion and speed. That motion can be represented and measured on a graph.
- The sun is a major source of energy for changes on Earth's surface. The sun's energy arrives as light.

EARTH AND SPACE SCIENCE
- The sun, an average star, is the central and largest body in the solar system.
- Most objects in the solar system are in regular and predictable motion.

SCIENCE, HEALTH & MATH SKILLS
- Measuring
- Locating cardinal directions
- Making a model
- Observing
- Drawing conclusions

* National Research Council. 1996. National Science Education Standards. Washington, D.C., National Academies Press.

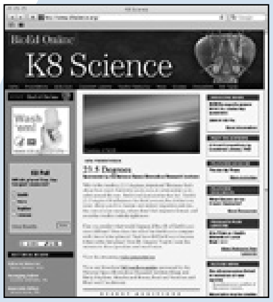
TIME
10 minutes for setup; two 30–45 minute periods to conduct activity

MATERIALS
Teacher (see Setup)
- 24 sheets of white cardstock
- Flashlight
- Globe or map with latitude markings
- Sundial template (p. 15)

Each group of students will need:
- Flashlight
- Hole punch
- Magnetic compass

Each student will need:
- Fine-tip ballpoint pen
- Opaque drinking straw

Apparent Time
The sun's apparent position in the sky depends on your location on Earth's surface, the day of the year, and the time of day.

Teacher Resources


Downloadable activities in PDF format, annotated slide sets for classroom use, and other resources are available free at www.bioedonline.org/ or www.k8science.org/.

Universal Time

In 1972, Universal Time replaced Greenwich Mean Time as the standard reference for telling time. Universal Time, also known as International Atomic Time, is measured by an atomic clock, which uses the extremely regular vibrations that occur within atoms to measure time.

Meridians

The imaginary great circles passing through the North and South Poles are referred to as lines of longitude, or meridians.

Parallels

Circles or lines of latitude sometimes are referred to as parallels, because they are parallel to one another.

LATITUDE AND LONGITUDE

Any location on Earth can be pinpointed using the imaginary lines of latitude and longitude. Both measurements are described in degrees. Each degree is divided into 60 minutes, and each minute is divided into 60 seconds.

Image © Cartesia MapArt.

Latitude is measured with parallel imaginary lines that circle Earth, both north and south of the equator (which has a latitude of 0°). In addition to the equator, there are four key lines of latitude related to the relative positions of Earth and the sun.

- Arctic Circle: 66° 33′ 39″ N (read as 66 degrees, 33 minutes, 39 seconds)
- Tropic of Cancer: 23° 26′ 21″ N
- Tropic of Capricorn: 23° 26′ 21″ S
- Antarctic Circle: 66° 33′ 39″ S

At latitudes between the Tropics, the sun may be seen directly overhead at noon on the June solstice (in the northern hemisphere) or December solstice (in the southern hemisphere). North of the Arctic Circle and south of the Antarctic Circle, the sun is visible for 24 continuous hours at least one day per year.

Longitude describes east-west position, as measured from the prime meridian in England (which has a longitude of 0°). Lines of longitude extend between Earth's North and South Poles. Longitudes are measured from 0° to 180° east and 180° west (or -180°). Both 180-degree longitudes share the same line, in the middle of the Pacific Ocean. It takes Earth one hour to rotate 15°, which is why the 24 time zones are separated by 15° of longitude.

- Pencil
- Pair of scissors
- Ruler (12-in.)
- Several pieces of clear tape (each about 2–3 in. in length)
- Copy of student sheet (p. 16)
- Prepared copy of sundial on cardstock (p. 15)

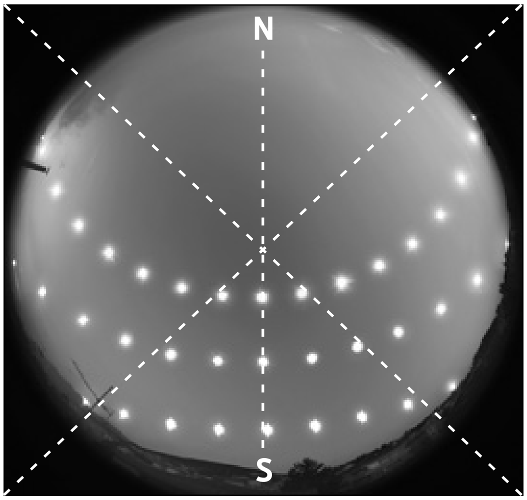
SETUP & MANAGEMENT

Make 24 copies of the sundial template on cardstock. Place materials in a central area for materials managers to collect. Students should work in groups of four to share materials, but each student should construct his/her own sundial.

PROCEDURE

1. Have students observe while you darken the room and use a flashlight to make a shadow of your hand. Then turn flashlight off, and ask, *Where is the shadow?* Students should understand that an object in front of a light source blocks the light, causing an area of darkness—a shadow. Encourage students to create different shadows using their flashlights.
2. Challenge students to envision what happens to shadows outdoors as the position of the sun changes, relative to the Earth's surface. Ask, *Are shadows always the same size? Why or why not? When are the shadows we see outside smallest? When are they largest? Can we always see shadows outside?* Ask students if there is a predictable pattern to the different sizes of shadows made by the sun (shadows are longest in the morning and evening, and shortest at midday). Using flashlights and pencils, have students make shadows of different lengths. Ask them to identify variables that affect shadow length (for example, height of pencil and angle of light).

Continued



This all-sky composite image taken in Bursa, Turkey, shows the daily trail of the sun in three strings, sunrise-to-sunset, during the summer solstice (June, top string), the vernal equinox (March, middle string), and the winter solstice (December, bottom string). The sun's path is about the same for both the vernal equinox and autumnal equinox (September).

North is at the top of the image. The point where the "X" shaped lines intersect is Bursa's longitude projected in the sky. (Hold the picture over your head to see why.)

Download a larger version of the image from NASA's Astronomy Picture of the Day website (http://antwrp.gsfc.nasa.gov/apod/ap080922.html/) for use with this activity's first Extension (below).

3. Explain to students that they will be investigating and using patterns in shadow movement to solve a practical problem: how to tell time.
4. Distribute copies of the student sheet. Students will need to know the latitude of their location to build their sundials properly. Use a globe or map, or have students find this information on the Internet.
5. Have students test their sundials by placing the dials outside on the ground, with the gnomon (part of the sundial that casts the shadow) pointed directly north. To obtain a more accurate reading, students should use a magnetic compass to orient their sundials toward the north. They also can check and correct for the magnetic declination where they live, to ensure that their sundials are pointed toward "true north," (see "Magnetic Declination, sidebar, right).
6. Once the sundial's gnomon is pointing in the correct direction, students should locate where the sun's shadow crosses the dial and estimate the time, based on their reading. Then, have students compare the time indicated by their sundials to actual "clock time." If daylight savings time is in effect, subtract one hour from the "sundial time."
7. Conduct a class discussion or have students write about the accuracy of their sundials. Ask, *How well did your sundial measure time, compared to a watch or clock? Why do you think your sundial did (or did not) measure time as accurately as other clocks do?* Also, ask students to consider if there are times a sundial might not be useful. Examples: nighttime (too dark); or when skies are cloudy (no shadows).

EXTENSIONS

- Using a copy of the image above, have students draw the lines as shown. The mid-point is Bursa's longitude line projected in the sky. Have students start from the "east," and count the number of hours of daylight for each string. Ask, *Which season does each string represent? During which season is the sun higher in the sky? Lower? What do these observations tell us about Earth's seasons?*
- Have students try using shadow length to tell the time.
- Have students think about why time zones, each of which accounts for a one-hour time difference, are separated by 15° of longitude.
- Have students figure out what time it is in other parts of the world when it is 8:00 am in their own location.

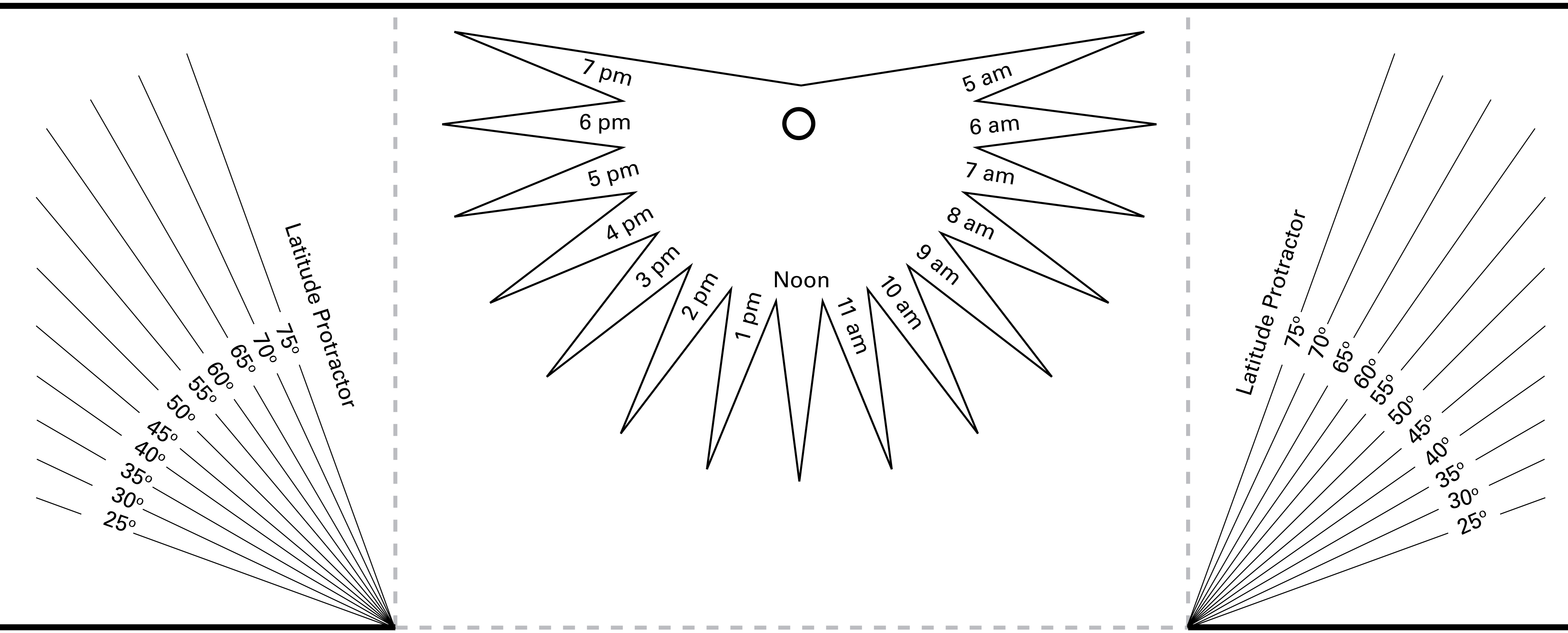
Finding Latitude and Longitude

The Internet is a good resource to find latitude and longitude calculators. One such website, iTouchMap.com, will provide coordinates of any street address in degrees, minutes and seconds. To find the latitude and longitude of any given address, or to access other features, go to http://itouchmap.com/.

Magnetic Declination

Magnetic declination is the angle between the local magnetic field—the direction pointed by the north end of a compass—and geographic north. You can find your magnetic declination at the National Geophysical Data Center's (NGDC) website, http://www.ngdc.noaa.gov/geomagmodels/Declination.jsp/. To correct the reading given by the magnetic compass, add or subtract the appropriate number of degrees from your reading. The NGDC website displays a map with the appropriate correction.

Cut along the thick line to remove this edge of the paper.



Cut *only* on the thick line.

Cut *only* on the thick line.

DO NOT CUT THE DASHED LINES.

After cutting along the thick, solid lines, fold the paper along the dashed lines.

Base

Adapted by G.L. Vogt from the *Space Educator's Handbook*, NASA Johnson Space Center.

Activity 3

Making and Using a Sundial

Your teacher will give you a piece of cardstock with a sundial pattern printed on it. You also will need a 12-inch ruler, a pair of scissors, a fine-tip ballpoint pen, a hole punch, one opaque drinking straw, clear tape and a magnetic compass.

Instructions

1. Cut the pattern on the solid lines, as indicated. Extend the cuts to the edges of the paper. *Do not cut the dashed lines.*

2. Using a ruler and a fine-tip ballpoint pen, score the dashed "fold lines." (Press the pen point into the paper while tracing along the edge of the ruler. This forms a groove that enables a straight fold.)

3. Determine the latitude of your location by searching for your city name and latitude on the Internet, or by checking a map or globe.

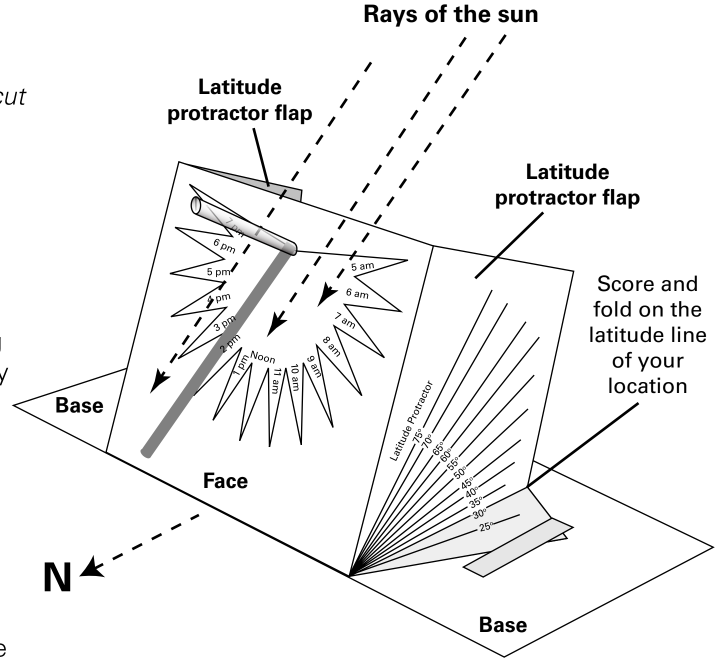
4. Score the lines on each latitude protractor that are nearest the latitude of your location.

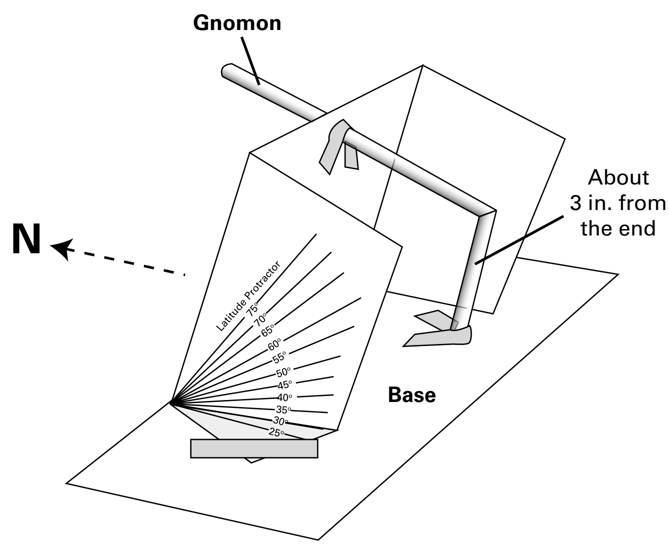
5. Fold the paper along all the scored lines. Fold the sundial rectangle and the latitude protractor flaps backward. Fold the lower corner of the latitude protractors upward along the angle line for your latitude (the latitude shown in the example is 30°).

6. Tape the corners of the latitude flaps to the base.

7. Use a hole punch to make a hole in the circle on the face of the sundial.

8. Slip a straw through the hole and bend the straw about three inches from the inside end, as shown to the right. The end of the straw sticking out from the face of the sundial is called a gnomon (noh-mon). Tilt the gnomon so that it is perpendicular (at a 90° angle) to the face of the sundial. Use tape to anchor the folded end of the straw to the base. Also, tape the straw to the back of the sundial so that the gnomon can't slip.





Adapted by M.S. Young and G.L. Vogt from the *Space Educator's Handbook*, NASA Johnson Space Center.

Using the Sundial

1. Place the dial on the ground and point the gnomon directly north. If you use a magnetic compass to determine north, be sure to check and correct for the magnetic declination where you live. Magnetic declination is the difference between magnetic north and true north for your location. You can find your magnetic declination at the following site: http://www.ngdc.noaa.gov/geomagmodels/Declination.jsp/.

2. Once your sundial's gnomon is pointing in the correct direction, locate where the sun's shadow crosses the dial and estimate the time. If daylight savings time is in effect, subtract one hour from your sundial's time.

OVERVIEW

Students will observe that some behaviors and functions of living organisms vary predictably every 24 hours. Many regular functions are governed by internal "clocks," which run independently but are cued or reset by the environment.

ACTIVITY 4

LIVING CLOCKS

Most living things behave predictably in cycles of about 24 hours, the period required for Earth to complete one full rotation. These cycles are called circadian, from the Latin words for "about" (*circa*) and "day" (*dies*). In this activity, students will explore circadian patterns in humans, animals and plants.

There are many familiar circadian rhythms in nature. Well-known examples include the flowering of morning glories at dawn and the nighttime hunting routines of owls. These behaviors are governed by internal mechanisms, often called "biological clocks," within the cells of living organisms. Biological clocks that run on a 24-hour cycle also are known as "circadian clocks."

SCIENCE EDUCATION CONTENT STANDARDS*
GRADES 6-12

LIFE SCIENCE
- Regulation of an organism's internal environment involves sensing the internal environment and changing physiological activities to keep conditions within the range required to survive.
- Behavior is one kind of response an organism can make to an internal or environmental stimulus.

EARTH AND SPACE SCIENCE
- 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.

SCIENCE, HEALTH & MATH SKILLS
- Measuring
- Observing
- Drawing conclusions

* National Research Council. 1996. National Science Education Standards. Washington, D.C., National Academies Press.

The circadian timing system is complex and operates throughout the body. In fact, circadian clocks are part of our genetic code, and they govern virtually all functions of the human body. Examples include alertness, waking and sleeping, body temperature (lower in the morning just after waking, and higher in the afternoon), physical performance and hand/eye coordination, secretion of some hormones, and urine production. These cycles occur regularly over intervals of approximately 24 hours. Without cues from the environment, the human circadian clock eventually drifts into a cycle that is slightly longer than 24 hours.

TIME

Several 30-minute sessions, depending on the options selected

MATERIALS

Materials required for each student group will vary, depending on the investigation(s) being conducted.

Each group will need:

Body Temperature Investigation

- Digital thermometer with several sterile covers (and access to a fever thermometers at home)
- Copy of student sheet (p. 20)

Bean Leaf Investigation

- Source of natural sunlight, or fluorescent "grow light" with timer
- 4 bean plants per group (purchase or grow in small pots from seed)

Continued

Discovery: Biological Clocks

In 1729, French scientist, Jean-Jacques de Mairan, was the first to notice that daily movements of certain plants' leaves continued even when the plants were kept in constant dim light. Other plant activities that occur at specific times of day include the opening of flowers, the release of fragrances, and the opening and closing of pores in the leaves.

The Tiniest Clocks

A group of nerve cells, which acts as a biological clock, was first identified in the brains of house sparrows. Biological clocks now have been identified in vertebrates, such as mammals, reptiles and some amphibians—and even invertebrates, such as fruit flies, cockroaches, crickets and mollusks. "Clocks" also have been found in single-celled organisms, including mold and bacteria.

Animal Behavior Investigation

- Study animals that can be observed in the classroom throughout the day (gerbils, birds, crickets, etc.)
- Science journal or graph paper

Alertness, Heart Rate (or other student selected investigation)

- Stopwatch or timer (if necessary)
- Science journal or graph paper
- Other materials as needed

BODY CLOCK INVESTIGATIONS

BODY TEMPERATURE INVESTIGATION

Have students measure their body temperature at three different times per day and repeat the process over three days. Times should be selected in advance and temperatures taken at the same time each day. Suggested times: immediately after waking in the morning, eight hours after waking (about 2:00 p.m.), and just before going to bed in the evening. Measurements should be recorded as degrees F, and should be made no less than 15 minutes after students eat, drink or brush their teeth. Have each student calculate and graph the average temperature of his or her group for each time of day (see p. 20).

Note: For class, use a digital thermometer and provide a sterile cover for each student.

What students will observe: Body temperature can be as much as one to two degrees lower in the very early morning than in the mid to late afternoon. This pattern is relatively consistent across individuals. Depending on levels of activity during the day, and the particular activities undertaken, student results may vary. Results also will be affected by the specific times at which temperature is measured.

ANIMAL BEHAVIOR INVESTIGATION

If you have a hamster or gerbil with an exercise wheel in your classroom, your students can observe and record the times of day when the rodent is active. Or, have students observe and record the daily behaviors of other classroom animals, such as fish, crickets (will chirp at approximately the same time each day) or birds. Students should record eating, resting and active times over several days to determine if the animals' activities follow a predictable pattern. The best results will be obtained if student observations do not disturb the animal subjects, and if the animals are exposed to a consistent cycle of light and darkness each day.

What students will observe: Animals may show a variety of predictable behaviors. For example, most animals are active at certain times of the day and more inclined to rest at others; birds and crickets will sing or chirp at similar times each day; and most animals tend to feed at particular times of the day.

BEAN LEAF INVESTIGATION

Grow young bean plants from seed, or purchase them from a greenhouse. Before using plants grown from seed, be sure they have at least two leaves in addition to the cotyledons (fleshy seed leaves). Place the plants in a sunny window or a growth chamber with a light timer. Have students note the orientation of the larger leaves as early as possible in the morning and again later in the afternoon. In particular, students should notice whether the leaves are extended outward or folded downward toward the stem. Have students repeat their observations over several days. Then, place the plants in a darkened corner of the room or cupboard, and have students observe and record the position of the leaves at the same times as before.

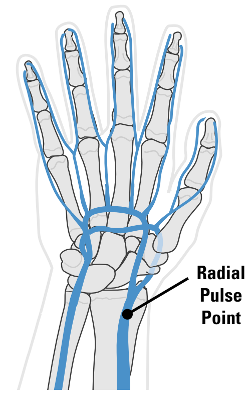
What students will observe: Leaves will be dropped toward the stem very early in the day and fully extended (horizontal) later in the day, whether the plants are exposed to the sun or artificial light. These patterns will continue when the plants are kept in the dark (see "Bean Leaf Movement," sidebar, right).

Note. Students may notice that their plants' stems curve toward the source of light. This movement is governed by chemicals inside the plant that cause cells on the side away from the light to lengthen more than cells on the side facing the light. This phenomenon is different from daily leaf movements, because it produces a permanent change in the shape of the stems.

ALERTNESS, HEART RATE (OR OTHER STUDENT SELECTED INVESTIGATION)

Many physical activities and abilities—among humans and non-human organisms—vary predictably by time of day. For example, students may choose to observe and chart whether they feel alert (wide-awake; fully aware and attentive) or drowsy (sleepy) on an hourly basis over the course of several days; measure and record their resting heart rate at different times of day (see "Radial Pulse Point," sidebar, upper right); or observe their "brain power" by timing how long it takes to mentally add columns of 50 single-digit numbers at different times of day.

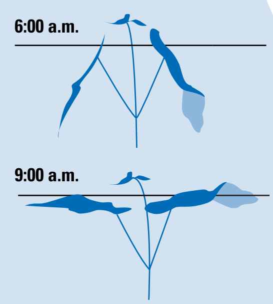
Radial Pulse Point



The safest and most common site to check pulse is on the thumb-side of the wrist (radial pulse).* Use the middle finger and ring finger together to apply slight pressure at the location shown above.

* Pulse site recommended for the general public by the National Heart, Lung, and Blood Institute, National Institutes of Health.

Bean Leaf Movement



Circadian Advantage

Because many variables related to athletic performance—respiration, heart rate, strength, flexibility and reaction time—peak late in the day, some coaches have concluded that well-trained athletes may derive a "circadian advantage" from competing at certain times of day.

Resetting the Clock

Bright light, particularly blue enriched light, can help to set the human body's internal clock. This spectrum of light is used to help regulate the sleep schedules of astronauts in space, and to aid people on Earth who have insomnia.

External Triggers

Natural changes in day length require animals' circadian clocks to "reprogram" themselves over the course of the year, to stay in sync with the external environment.

Cycle Length

Some cycles in living organisms are longer or shorter than 24 hours. Longer cycles include monthly hormone fluctuations in humans, once-yearly flowering periods of many plants, and the multi-year dormancy of insects known as cicadas. Shorter cycles include the cardiac cycle (heartbeat) and the internal stages of sleep (sleep cycle).

SAFETY

Follow proper care guidelines for any animals in the classroom.[1] Always follow district and school laboratory safety procedures. It is a good idea for students to wash their hands with soap and water before and after any science activity.

SETUP & MANAGEMENT

Read "Body Clock Investigations," (p. 18). Students should work in groups of 2–4. Conduct discussions as a class.

PROCEDURE

1. To prompt students' thinking about daily rhythms in themselves and other organisms, ask, *What are some animal behaviors that follow the same pattern every day?* (Rooster crowing, birds singing in the morning, bats coming out at night, etc.) *Are you more alert or sleepy at certain times each day? Have you observed flowers that are open only in the morning?*
2. Discuss as a class how behaviors of living organisms are tied to the 24-hour cycle of night and day on Earth.
3. Tell students that they will be investigating different daily cycles in plants, animals or themselves. You may assign each group an investigation from the list of activities given in Body Clock Investigations," (p. 18), or allow groups to devise their own topics for investigation.
4. Have the members of each group decide upon a central question that will guide their "research." For example, students conducting the body temperature investigation might ask, *Is body temperature constant throughout the day?*
5. Students should plan the times of day at which they will conduct their measurements, the instrument(s) needed (thermometer, stopwatch, "grow light," etc.), and the recorded units of measurement (degrees F, seconds, etc.).

   A sample data sheet for the body temperature investigation is included at the end of this activity. Students will need to create their own data-recording tables for other investigations.
6. Have students work in collaborative groups to conduct their investigations over several days.
7. After students have concluded their investigations, have each group present its question and observations to the class. Students should be able to describe the behaviors or body functions observed, methods used to measure the behaviors or functions (recording leaf movement, checking temperature, observing active times, etc.), and the pattern or patterns they discerned.
8. Discuss the results of the different investigations with the class. Ask questions to prompt students' thinking: *What did all of the cycles you observed have in common? Did any of the patterns occur without the presence of normal sunlight? Do you think something other than sunlight controls the patterns you observed?* Help students to reach the conclusion that something inside each organism controls plant and animal behaviors. Point out that most organisms have internal "timers" that regulate many aspects of their lives, and that these "timers" have a genetic basis.

EXTENSION

Indiana University's "Plants-In-Motion Theater" website offers time-lapse video of circadian movements of plant leaves (http://plantsinmotion.bio.indiana.edu/). Have students compare the behaviors shown on the website with those observed in their own plants.

1 See National Science Teachers Association, Position Statement on Responsible Use of Live Animals and Dissection in the Science Classroom, www.nsta.org/about/positions/animals.aspx/.

Activity 4

Body Temperature Investigation

1. You will need to take your temperature (in °F) three times per day, over the course of several days. For best results, take the first reading just after waking in the morning, the second reading around 2:00 p.m., and the third reading just before going to sleep at night. Wait at least 15 minutes after eating or drinking anything to take a measurement.

2. Record the body temperature (Temp.) and the time the temperature was taken for each member of your group in the chart below. Repeat the process over the next three days.

3. On a separate sheet of paper, calculate the average temperature for each person in your group at each time of day. Graph your results. Write a paragraph describing your findings.

	Morning: Just after waking		Time during the day		Evening: Just before bed	
Name ______	**Time**	**Temp.**	**Time**	**Temp.**	**Time**	**Temp.**
Date ______						
Date ______						
Date ______						
Date ______						

	Morning: Just after waking		Time during the day		Evening: Just before bed	
Name ______	**Time**	**Temp.**	**Time**	**Temp.**	**Time**	**Temp.**
Date ______						
Date ______						
Date ______						
Date ______						

	Morning: Just after waking		Time during the day		Evening: Just before bed	
Name ______	**Time**	**Temp.**	**Time**	**Temp.**	**Time**	**Temp.**
Date ______						
Date ______						
Date ______						
Date ______						

	Morning: Just after waking		Time during the day		Evening: Just before bed	
Name ______	**Time**	**Temp.**	**Time**	**Temp.**	**Time**	**Temp.**
Date ______						
Date ______						
Date ______						
Date ______						

OVERVIEW

All mammals, including humans and many other kinds of animals, need sleep. Most people have regular patterns of sleeping and waking times. Students will collect data about their own sleep cycles and use a fraction wheel to examine their data.

ACTIVITY 5

Sleep Patterns

All mammals—including humans and most vertebrates—sleep. In fact, we spend about one-third of our lives sleeping, but many aspects of sleep still are not understood. Once viewed as a passive shutting-down of most body systems, sleep now is believed to have important functions related to the processing of information by the brain, and the repair and maintenance of body systems. In humans, sleep is known to consist of several stages, each characterized by different levels of brain and muscle activity.

Many people vary their sleep patterns using external alarm clocks to meet school or work schedules. Without an alarm, most individuals sleep about the same number of hours and wake at about the same time each day. This occurs because humans' natural daily wake-up times are governed by an internal "clock," consisting of about 10,000 nerve cells deep inside the brain.

Even without any light or sound cues, most people sleep and wake in roughly 24-hour cycles. And while sleep patterns are stable (they change little, or very slowly), scientists have found that the amount of sleep required to be alert differs considerably from one individual to another. These differences are believed to be inherited as genetic traits.

Sleep patterns also vary by age. For instance, newborns sleep 16–18 hours each day, including several naps. At age one, children average 12–14 hours of sleep daily, including two naps. Twelve-year-olds generally sleep nine or ten hours each day, without naps. Adults sleep six to eight hours per day. The urge to nap in the afternoon is normal for all teenagers and adults, but most people override this urge by remaining active.

Sleep deprived individuals perform less effectively, remember less information, and think less clearly than those who are well rested. In some professions (truck driver, police officer, etc.), sleep deprivation can contribute to accidents. Regardless of the job, a good night's sleep is key to performing at one's best.

TIME

30 minutes to conduct initial class discussion; 3–7 days for students to collect sleep data; 30 minutes to discuss results

Continued

SCIENCE EDUCATION CONTENT STANDARDS*

GRADES 6-12

LIFE SCIENCE

- Behavior is one kind of response an organism can make to an internal or external stimulus.
- Behavioral response is a set of actions determined in part by heredity and in part from experience.

SCIENCE, HEALTH & MATH SKILLS

- Observing
- Collecting data
- Graphing
- Drawing conclusions
- Learning to identify and practice healthy behaviors

* National Research Council. 1996. National Science Education Standards. Washington, D.C., National Academies Press.

A Variety of Sleep Patterns

Courtesy of OAR, NURP, NOAA.

Sleep patterns vary among different animals, but all animals rest between periods of activity. Rabbits, for example, sleep just a few minutes at a time. Dolphins have a unique form of sleep: while one half of the dolphin brain sleeps, the other half remains alert and awake. Other animals, such as cats, are crepuscular, meaning they are active at dawn, but sleepy during the day. Cats typically sleep between 13 and 16 hours per day.

MATERIALS

Each student will need:

- Sheet of heavy white paper
- Sheet of lightly-colored, heavy paper
- Drawing compass
- Protractor
- Markers (different colors)
- Pair of scissors
- Pen or pencil
- Log or journal
- Copy of student sheet (p. 24)

SETUP & MANAGEMENT

Begin the activity with a class discussion. Working individually, students will collect sleep data on themselves and possibly their family members. Next, working in groups of four, they will examine their data and share results.

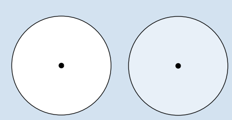
PROCEDURE

Part 1: Sleep Observations

1. Challenge the class to think about all the different things they do during a typical 24-hour period. Let each student suggest one or more activities and create a list on the board.
2. Now ask, *What activities could you leave off this list without affecting your health or how you feel? What activities must stay on the list? Why do you think so?*
3. Explain to students that they will be examining an essential activity on the list: sleep. Then, encourage them to share what they know about sleep. Ask, *When do you usually sleep? How long do you sleep? What makes you wake up?* Tell students that they will be investigating their own sleep patterns to answer the question, "Does my sleep follow a regular pattern?"
4. Have each student create a journal, or "Sleep Log," to record the times that he or she goes to sleep and wakes up each day, for a period of seven days. The Sleep Log should include: bedtime; how the student felt at bedtime; waking time; how the student felt when waking; whether the student used an alarm to wake up; and how the student felt during the day (tired, well rested, etc.). If possible, time the activity so that students are able to compare weeknight and weekend sleep patterns. Students may want to ask other members of their families to participate, and to record those family members' sleep data as well.

Part 2: Looking at Data

1. After students have completed seven days of observations, have them plot their data on the "Sleeping Patterns Graph," (p. 24), and calculate their average number of hours of sleep per night.
2. Have students share and compare their graphs and journals with other members of their groups. Help them to identify similarities, differences, and patterns in their graphs. Ask questions like, *Do most people go to bed and wake up at about the same time each day? Did you feel particularly sleepy on any day? If so, why do you think that is? Do you see anything different about the part of the graph corresponding to that day? Did you notice a difference between days you used an alarm to wake up and days you slept until you woke naturally?*
3. Ask students, *What are some other ways to represent your sleep data?* Mention that fractions can help us to represent and study data. In this case, fractions can be used to illustrate how much of each student's day is spent sleeping.
4. Have the materials managers pick up their supplies. Show students how to make a circle with the compass. Have students make a circle with a 16-cm diameter on each piece of paper, mark the center of each circle with a dot, and then cut out the circles.



5. Tell students they will divide one circle into 24 equal sections. Ask, *Why do you think the circle needs to be divided into 24 sections?* (to represent a 24-hour day). As a class, discuss how to divide

Sleep Phases

Scientists are just beginning to understand why humans sleep, and what happens when we sleep. They know that sleep consists of two different phases. One phase, called non-Rapid Eye Movement (REM) sleep, is characterized by slow brain activity, no eye movement, and very low muscle tone. The second phase of sleep, REM, is characterized by an active brain, bursts of eye movements, and paralyzed muscles (which makes it safe to dream!).

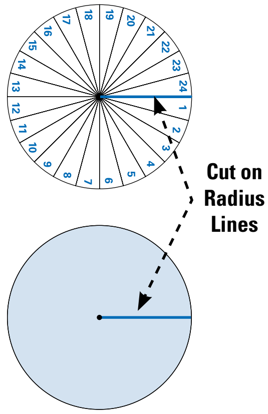
Dreams are prevalent during REM sleep. Scientists have different ideas about the purpose of dreams. Some believe the brain consolidates important (and erases unneeded) information during dreams.

Individual Needs

Some people need more sleep than others—even other members of the same family—and there is quite a bit of variability among individual responses to inadequate sleep.

A Fraction Wheel

Components



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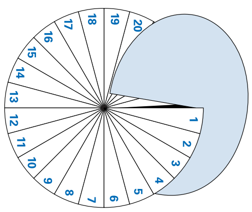


Fraction wheel adapted by M.S. Young from The Right Ratio of Rest, NASA CONECT™.

Astronauts and Sleep

Astronauts in space frequently have difficulty sleeping, partly because their internal clocks are not synchronized to the light conditions they experience during a mission, and also because the stresses of space flight and their hectic work schedules affect the quality of sleep. NSBRI and other researchers are seeking ways to address these problems. Results of their work will benefit astronauts and many people on Earth with sleep disorders.

the circle (see "A Fraction Wheel" illustrations, left sidebar). Have students progressively divide the circle into halves, fourths, and eighths; then use the protractor to create three equal sections of 15 degrees within each eighth. Instruct students to number the sections 1-24.

6. Have students draw and cut a radius line (line from the center point to the edge) on both circles.
7. To complete the fraction wheel, have students slip the cut line of one circle into the cut line of the other, so that the circles are joined and one circle slides around the other.
8. Ask students to set their fraction wheels to show the average number of hours of daylight within Earth's light-dark cycle (12 hours), and then write the number as a fraction (12/24). Have students identify fractions equivalent to 12/24, using the segments on their fraction wheels as a guide.
9. Have students move their fraction wheels to the average number of hours they slept per day during the previous week.
10. Remind students that fractions are only one way to represent the parts of a whole, and that fractions also can be written as a decimal or percentage. For example, the entire circle on the fraction wheel represents one day, or 24 hours, and can be written as 24/24, or 1.0 (since 24 divided by 24 is 1.0). Because 24 hours represent the entire circle, they also represent 100% of the hours in a day.
11. Conclude the activity with a class discussion of the guiding question, "Does each person's sleep follow a regular pattern?" Or, have students answer this question with a short essay in their journals. Have them include evidence to support their answers.

Astronaut Jerry Linenger, M.D., Ph.D., STS-81, NASA 4 (Mir), measures his temperature while participating in sleep experiments. He is wearing the Night Headband Monitoring System designed to record head and eyelid movement during sleep. Experiment data is downloaded to a laptop computer.

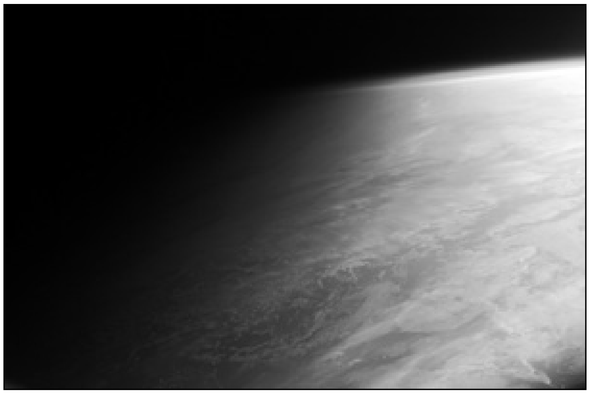
Photo courtesy of NASA.

EXTENSIONS

- If students need additional practice converting fractions to decimals and percentages, have them complete an equivalency chart by writing each hour of the 24-hour cycle. For example: Hour (23), fraction (23/24), decimal (0.958), percent (96.8%).
- Have students track other essential activities in their journals, such as eating or exercising.
- Have students investigate the sleeping habits of different kinds of animals: Where do they sleep, and for how long? Do they sleep at night or during the day?
- Discuss how students' sleep patterns change when they do not have to go to school (for example, during summer). Do students stay up later? Do they wake at the same time every day? Do they sleep according to a regular schedule?
- Have students discuss the following questions in their groups. If an astronaut is orbiting Earth, how many times must he or she circle our planet to get the same amount of sleep that you get each night? If the astronaut slept the same percentage of time per day as you do, how much sleep, in minutes, would he or she get per 90 minutes? If the night/day cycle on Mars lasts about 25 hours, how many hours per day would you sleep if you lived on a space station there?

Activity 5
Sleeping Patterns Graph

Photo courtesy of NASA.



The Earth at Twilight. As shown in this image taken from the International Space Station, no sudden, sharp boundary marks the passage of day into night on Earth. Instead, the shadow line shows the gradual transition to darkness we experience as twilight. Darkness is just one of the cues that signal our biological clocks when it is time for us to sleep.

1. Color in the square representing your bedtime and the square corresponding to your wake time for each day recorded in your journal. Use a different color to fill in the squares between bedtimes and wake times. Fill in additional squares to represent any naps. Record dates of the week and hours slept. Notice that any given "night" will overlap between two dates.

2. Record the total number of hours slept for each 24-hour period in the table below.

Date	Hours Slept

Dates								
12:00 a.m. Midnight								
1:00 a.m.								
2:00 a.m.								
3:00 a.m.								
4:00 a.m.								
5:00 a.m.								
6:00 a.m.								
7:00 a.m.								
8:00 a.m.								
9:00 a.m.								
10:00 a.m.								
11:00 a.m.								
12:00 p.m. Noon								
1:00 p.m.								
2:00 p.m.								
3:00 p.m.								
4:00 p.m.								
5:00 p.m.								
6:00 p.m.								
7:00 p.m.								
8:00 p.m.								
9:00 p.m.								
10:00 p.m.								
11:00 p.m.								

OVERVIEW

Sleeping and waking are governed by the body's "internal clock," which, in turn, is influenced by external cues. Changes in daily routines and schedules sometimes conflict with our internal clocks. Students will investigate how changing the time they go to bed impacts their own sleep patterns.

ACTIVITY 6

Investigating Sleep

As students learned earlier, most people go to sleep and wake up at about the same times each day. This sleep/wake cycle is regulated by a group of nerve cells inside the brain, called the suprachiasmatic nuclei, which act as a timer, or "biological clock." These cells receive time cues from the outside environment. For example, special cells in the retina (the part of the eye that has receptors for light) detect sunlight and send messages to the brain in humans and other mammals, saying, "Wake up. It's daytime." In fact, daily exposure to sunlight is an important cue to synchronize the body's sleep cycle.

SCIENCE EDUCATION CONTENT STANDARDS*
GRADES 6-12

LIFE SCIENCE
- Behavior is one kind of response an organism can make to an internal or external stimulus.
- Behavioral response is a set of actions determined in part by heredity and in part from experience.

SCIENCE IN PERSONAL AND SOCIAL PERSPECTIVES
- The potential for accidents and the existence of hazards imposes the need for injury prevention.
- Important personal and social decisions are made based on perceptions of benefits and risks.

SCIENCE, HEALTH & MATH SKILLS
- Predicting
- Observing
- Drawing conclusions

* National Research Council. 1996. National Science Education Standards. Washington, D.C., National Academies Press.

Abrupt changes in one's sleep cycle, such those caused by a new work schedule or travel across time zones, can make it difficult to fall asleep or stay awake, because external cues conflict with messages being sent by the body's internal clock. The brain says, "Sleep," but outside conditions signal, "Be active, it's morning!" Other factors that can affect, or interfere with, the sleep cycle include physical exercise, medicines, meal times and stimulants (such as caffeine in coffee, tea and soft drinks).

This activity allows students to investigate their own internal clocks. For one night, students will go to bed one hour earlier than usual. They will observe and record any impacts that this change has on their abilities to fall asleep, and on their usual wake times the next morning.

TIME

30-60 minutes to conduct initial class discussion; 30-60 minutes to summarize findings the following day

MATERIALS

Each student will need:
- Copies of student sheet (p. 27)

SAFETY

Always follow district and school laboratory safety procedures. It is a good idea for students to wash their hands with soap and water before and after any science activity.

Continued

A Sleep Chemical

Melatonin is a chemical messenger secreted in humans and other mammals during periods of darkness. It is an important aid in synchronizing the circadian biological clock. It also plays a role in triggering some animals' seasonal behaviors, such as coat development and hibernation.

Effects of Daylight Savings Time

In most of the US, people move their clocks ahead one hour—switching to Daylight Savings Time (DST)—in the spring and back one hour in the fall. These changes can cause temporary problems for some people because their sleeping times are changed by one hour. Recently, it has been found that there is an increase in the number of work-related accidents on the day following the switch to DST.

SETUP & MANAGEMENT

Lead a class discussion about the steps and purpose of the activity. Students will carry out their own investigations at home and report back the following day.

PROCEDURE

Day One

1. Remind students of previous activities. Ask, *Did the bean plant leaves move the same way each day? How about the animals you observed? Did their behaviors show a daily pattern? Do you do certain things at about the same time each day?* Have students refer to their sleep journals. Ask, *Do you think a biological clock regulates some of your behaviors?*
2. Explain to students that they will be investigating their own biological clocks. One night, they will go to bed one hour earlier than usual, then observe and record what happens.
3. Mention the observations that students will make: whether it was easy or hard to fall asleep at the earlier time and if they woke at the usual time the next morning. Students also should record how they felt the next day: more/less tired than normal, etc. Explain that results will vary from person to person.
4. Distribute copies of the "Sleep Observations" sheet, on which students will record their data. If possible, have each student enlist the help of a household member to observe and record the actual time the student falls asleep.

Day Two

1. Have students summarize their experiences in short paragraphs. Ask, *Did going to bed earlier make it easier or more difficult than usual to fall asleep? When you went to bed, did you notice noises and other people more or less than you usually would? How did you feel the next morning? Did you wake at your usual time?*
2. Have students share their paragraphs by reading them aloud, or by posting them in the classroom. Initiate a class discussion of the results. Point out that some students may have had difficulty falling asleep because their bodies were used to a later bedtime. However, students may have woken at their usual times in the morning, even after receiving an extra hour of sleep, due to the programming of their internal clocks. Some students may feel better after receiving the extra sleep.
3. Discuss possible outcomes of going to bed one hour later than usual, instead of earlier. Ask, *How do you think you would you feel after getting less sleep than usual? How might a reduction in sleep affect your daily life?* Initiate a class discussion about the normal amount of sleep required by people of different ages (see page 21), and the ways insufficient sleep can impair performance on both mental and physical tasks. For example, lack of sleep, like alcohol intoxication, can make physical reactions slower.

EXTENSIONS

- Have students continue with their earlier bedtimes for several days. Do they eventually become programmed to the earlier times?
- Invite another teacher or a parent who has traveled across several time zones (e.g., across the continental US, to Asia, or to Europe) to talk with the class about how he or she felt physically during the first day or two in the new location. Was it easy to sleep? Was he or she more tired or alert than usual? Did he or she have to readjust to the "normal" schedule after returning home?
- Invite a policeman, fireman or someone else who routinely works a night shift to talk to the class about how he or she has adapted to the stresses of a nocturnal work schedule.

Teens and Sleep

Teenagers' sleep cycles often get shifted, causing their internally programmed sleep time to begin around midnight. Such shifts may make it difficult for them to get enough sleep.

Light Sensitivity

Rods and cones in the retina of the eye contain light-sensing pigments, which are very sensitive to movement (rods) and color (cones). Recently, scientists discovered a new pigment, called melanopsin, in peripheral cells of the retina. Unlike rod and cone cells, receptors cells with melanopsin detect intensity or changing levels of light. For example, when light becomes brighter in the morning, melanopsin triggers the brain's master biological clock (suprachiasmatic nuclei) to shift into an active pattern. While rod and cone cells respond best to full spectrum white light, cells containing melanopsin respond most strongly to blue light (446-477 nanometers).

Common Sleep Disorders

Sleep disorders affect up to 70 million people in the US. Insomnia is a common sleep disorder that causes people to have difficulty falling or staying asleep. Apnea is a disorder that makes it difficult for people to breath while asleep.

ACTIVITY 6

SLEEP OBSERVATIONS

Ask a family member or friend to help with this experiment. For one night, you will go to bed one hour earlier than usual. Write your answers in the spaces below.

1. What time did you go to bed? ________________
2. What time did you fall asleep? (If possible, have someone observe and record the time for you.) ________________
3. How did you feel when you went to bed early? ____

   ____
4. What time did you wake up the next morning? ________________
5. How did you feel when you woke up? ____

   ____
6. How did you feel during the next day? ____

   ____
7. In the space below, write a paragraph about your experiment and the results.

   ____

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OVERVIEW

Language arts activity in which students learn from times they have had difficulty sleeping, read about how astronauts sleep in space, and write about unusual places in which they have slept. Many different factors affect the quality of sleep. Astronauts traveling in space experience many disruptions to their normal sleep patterns.

ACTIVITY 7

SLEEPING IN SPACE

Many factors can impact the quality of sleep, and everyone has difficulty sleeping from time to time. Excitement, anxiety or stress, consumption of stimulants or certain foods close to bedtime, unusual surroundings, noises, travel across time zones, or changes in daily schedules can make sleeping difficult. Insomnia—an ongoing inability to get enough sleep to feel rested during the day—occurs when sleep problems extend beyond a night or two. More than 50% of Americans suffer from occasional bouts of insomnia or other sleep disorders.

Astronauts may experience more disruptions of normal sleep patterns than anyone else. The intense work schedule, unusual surroundings, occasional space motion sickness, cramped work quarters, stress, and excitement of being in space all can make it difficult to sleep. In addition, many visual cues on Earth, including the normal 24-hour cycle of light and darkness that provides time cues to the body's internal clock, are different in space, or absent altogether.

Since lack of sleep can seriously affect performance on physical and mental tasks, it is important to help astronauts overcome sleeping problems. Several days before launching into space, for example, they are exposed to bright lights at specific times, a controlled environment, and programmed meal periods to help reset their bodies' internal clocks to match the schedules followed in space. Research has shown that it is possible to program humans to a day/night cycle similar to the one on Mars (24.65 Earth hours). Research to help astronauts sleep better also can help people on Earth with similar sleep problems.

SCIENCE EDUCATION CONTENT STANDARDS*
GRADES 6-12

LIFE SCIENCE
- Behavior is one kind of response an organism can make to an internal or external stimulus.

SCIENCE IN PERSONAL AND SOCIAL PERSPECTIVES
- The potential for accidents and the existence of hazards impose the need for injury prevention.

SCIENCE, HEALTH & MATH SKILLS
- Identifying common elements
- Making extensions to new situations

* National Research Council. 1996. National Science Education Standards. Washington, D.C., National Academies Press.

TIME

10 minutes for setup; 30 minutes to conduct activity

MATERIALS

- Copy of student sheet (p. 30)

SETUP & MANAGEMENT

Conduct this activity with the entire class. Students may read the story, "Sleeping in Space," individually, or they may work in teams.

Why Do We Sleep?

Scientists still are trying to answer this question. Some people believe that by slowing metabolism, sleep helps the body recover from activities carried out during waking hours, and that sleep also helps us form memories. Some animals may sleep to save energy during hours when it is too dark or too dangerous to hunt for food.

Effects of Sleeplessness

Sleeplessness diminishes mental and physical performance. Just one sleepless night can impair performance as much as being intoxicated from alcohol. In addition, we are more susceptible to the effects of drugs and alcohol when we're sleepy than when we are well-rested. Sleepiness can build up day after day, creating a sleep "debt" that may be hard to "pay back." Many nights of good sleep may be needed to recover.

Tips for Students

Students can do several things to make sure they are rested and ready to perform well in school.

- Avoid soft drinks or foods with caffeine (e.g., chocolate, some carbonated beverages, coffee, tea), especially close to bedtime. Nicotine (from smoking) and alcohol also interfere with sleep.
- Stick to a regular schedule for going to bed and waking up, and get bright light in the morning to help program your biological clock.
- Do some light exercise in the late afternoon (but not in the evening before going to bed).
- Recognize that most students need at least nine to ten hours of continuous sleep per night, and plan schedules accordingly.
- If you have trouble falling asleep, drink a glass of warm milk, which contains tryptophan, an amino acid that can aid sleep.

PROCEDURE

1. Ask students to remember an occasion when they had difficulty sleeping. Have them share their experiences with the rest of the class, and list the experiences on the board or on an overhead. Scenarios suggested by students might include: the night before an exciting event, such as a birthday party; trying to sleep in the car during a long trip; or being awakened by strange or frightening noises at night.
2. Encourage students to think carefully about the list and to identify common elements among the events. Such elements could include: sleeping in places other than home; sleeping before or after unusual events; sleeping when one's physical state is not normal (sick with an itchy rash, etc.).
3. Mention to students that they will be reading about a situation in which it is very difficult to sleep—being an astronaut in space. Ask, *Do you think astronauts can sleep as well in space as they do at home? What might be different about sleeping in space? How do you think the space station environment affects astronauts' physical and mental performance? How might microgravity—and the feeling of weightlessness experienced while orbiting Earth—affect sleep?*
4. After students have offered their comments, distribute the student sheets.
5. Students may read the essay and complete the writing extensions on their own or in small groups.
6. Allow students to share their work by having them read their paragraphs or by displaying their paragraphs somewhere in class.
7. Conduct a class discussion about the importance of getting enough sleep. Begin by telling students that when you don't get enough sleep, it can be hard to stay alert, especially if you work at night. Ask, *What could happen if someone drives or operates dangerous equipment when he or she is drowsy?* Help students understand the connection between sleep and performance on mental or physical tasks.

Photo by Kris Snibbe/*Harvard News Office.*

Certain wavelengths in the blue portion of the visible spectrum alter melatonin production, thereby affecting the human circadian rhythm. "Blue light" lamps may help to promote a more normal, healthy sleep cycle for astronauts living and working in space. On Earth, blue lighting can be modified for people with sleep disorders and to help shift workers adjust their biological clocks.

EXTENSIONS

- Have students create drawings to accompany and illustrate their paragraphs on sleeping.
- Encourage students to learn more about living and working in space by visiting websites of the National Space Biomedical Research Institute (www.nsbri.org) and NASA (www.nasa.gov); and/or have them investigate research on the relationship between sleep and performance at Harvard University's Healthy Sleep website (http://healthysleep.med.harvard.edu).
- Scientists are using mathematical models to predict alertness levels for astronauts and airplane pilots under a variety of conditions. These predictions can increase safety by enabling astronauts and pilots to know when they are most prone to mistakes caused by sleepiness. Have students think of other ways we use mathematical models to make predictions (weather predictions, stock market predictions, etc.).

ACTIVITY 7

SLEEPING IN SPACE

Read the article, then complete the items beneath it on a separate sheet of paper.

Have you ever slept in a sleeping bag? Maybe when you went camping or slept over at a friend's house? When astronauts sleep on the space shuttle or the International Space Station (ISS), they fasten themselves into special sleeping bags. In space,

Astronaut Daniel Tani, NASA ISS Expedition 16 flight engineer, sleeps while floating in his sleeping bag on the space station. It can be difficult to sleep in cramped, unfamiliar quarters.

there is no "up" or "down," and the effects of gravity are minimized. As a result, astronauts feel weightless, and can sleep in any orientation. But they have to attach themselves to a seat or wall inside the crew cabin or sleeping compartment, so they don't float around and bump into something while they sleep.

Generally, astronauts are scheduled for eight hours of sleep each mission day. But like on Earth, they may wake up in the middle of their sleep period, or stay up late to look out the window. The excitement of being in space, motion sickness, and other factors can disrupt an astronaut's sleep pattern. Crewmembers easily can hear each other, so they may need to wear earplugs during their sleep periods.

Astronaut Michael E. Lopez-Alegria, NASA STS-113 mission specialist, is about to take his first of three spacewalks during this mission. *Could you sleep the night before your own spacewalk?*

Sleeping in the shuttle's cockpit is especially difficult because the sun "rises" every 90 minutes while the shuttle orbits Earth. The sunlight and warmth entering the cockpit window are enough to disturb a sleeper who is not wearing a blindfold. When it is time to wake up on the space shuttle, the Mission Control Center in Houston, Texas, plays music to the crew. The ISS crew must use an alarm to wake up.

Astronaut Tracy Caldwell, NASA STS-118 mission specialist, referring to checklists as she operates the shuttle's remote robotic arm. Astronauts' complex tasks require that they get enough sleep to function at their best.

Getting enough sleep is a priority for astronauts in space. Without sufficient sleep, they are more likely to make mistakes and may not perform well during their complex tasks. Researchers with the National Space Biomedical Research Institute are working to improve astronauts' sleep and scheduling of work shifts. For instance, these scientists are learning how specific types of light can increase alertness and performance in space. Their findings also will help people on Earth who have sleep problems.

1. List at least three ways in which sleeping in space is just like sleeping on Earth.
2. List at least three ways in which sleeping in space is different from sleeping on Earth.
3. Write a paragraph about the most unusual place in which you ever have slept. Include answers to the following questions.
   a. Where did you sleep?
   b. How well did you sleep?
   c. How did you feel when you woke up?
   d. Would you like to sleep there every day?

Adapted from "Space Sleep," NASA, http://space flight.nasa.gov/living/spacesleep/index.html/. Photos courtesy of NASA, http://www.nasaimages.org/.

OVERVIEW

Summative assessment activity in which students will review concepts about sleep and daily cycles, and will create their own illustrated poems.

ACTIVITY 8

SLEEP: ASSESSMENT

Cycles and rhythms can be found in all organisms on Earth. Many are synchronized to the 24-hour cycle of Earth's rotation about its axis. In general, 24-hour cycles are called circadian, from the Latin words for "about" (circa) and "day" (dies).

People's schedule of sleeping and waking is determined, to a large extent, by an "internal clock" in our brains. Environmental cues, particularly light, keep this clock synchronized to external conditions. However, the clock will continue to run on approximate 24-hour cycles, even without changes in the environment.

The human cycle of sleeping and waking can be disrupted by changes in external conditions. Such changes occur when travelers move across time zones, or when astronauts travel in space. Not getting enough sleep can contribute to poor performance on mental or physical tasks, and may even lead to dangerous accidents.

Space life scientists are seeking ways to help astronauts achieve the sleep they need to function well under the stresses of long-term space flight. Their research also will help to solve sleep-related problems for people on Earth.

TIME

10 minutes for setup; 45 minutes to conduct activity

MATERIALS

Each student will need:

- Writing paper
- Markers, pencils

SETUP & MANAGEMENT

Conduct discussion with the entire class. Students should work independently or in small groups to write their poems.

PROCEDURE

1. Review the major concepts to which students were exposed in this unit.
2. Read or have students read the poem, "Tick-Tock, Tick-Tock." Lead a class discussion about the poem's key concepts.
3. Have students create their own illustrated poems about sleep and/or circadian rhythms. Each poem should include at least one new concept that students learned about this topic from the activities in this unit. Possible approaches are given below.
   - After the poem is read, have students write their own poems about sleep and/or circadian clocks.
   - Read a few verses of the poem to get students started, and then have them write their own verses to complete the poem.
   - Share the first line of each verse and have students complete the verses with their own words.

Reliable Sources

Reliable information about sleep and related topics is available online at the following Web sites.

Healthy Sleep
http://healthysleep.med.harvard.edu/

MedLine Plus*
http://medlineplus.gov/

NASA CONNECT™
http://www.knowitall.org/nasa/connect/index.html

National Heart, Lung, and Blood Institute
http://www.nhlbi.nih.gov/

*Health information is available in more than 40 languages.

ACTIVITY 8
TICK-TOCK, TICK-TOCK

Tick-tock, tick-tock, tick-tock, tick-tock.
Did you know you have a "brain clock?"

Like the sundial's shadow-line
your inside clock can measure time.

It tells you when it's time to eat,
and even when to go to sleep!

But people aren't the only ones
who know it's time for rest or fun.

Plants know when it's time to bloom.
They know that springtime's coming soon!

At dawn, most birds begin to sing
without alarms that ring-a-ling.

Frogs know when to leap and croak,
or chase some flies... or take a soak!

Barn owls hunt when your day's done.
They rarely ever see the sun.

How do they always know the time
without a clock or watch like mine?

How can we solve this mystery?
The answer's in our cells, you see.

People, plants and animals
have "inside clocks" that send a call.

The clocks tune in to many cues
like, "When it's dark, it's time to snooze!"

Now you know that you're a clock,
so shout it out: *Tick-tock, Tick-tock!*

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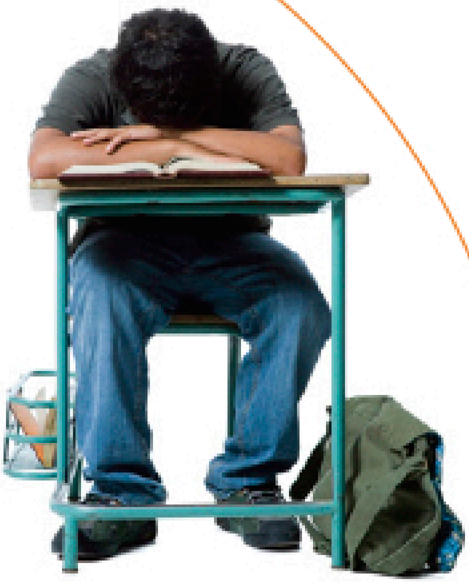
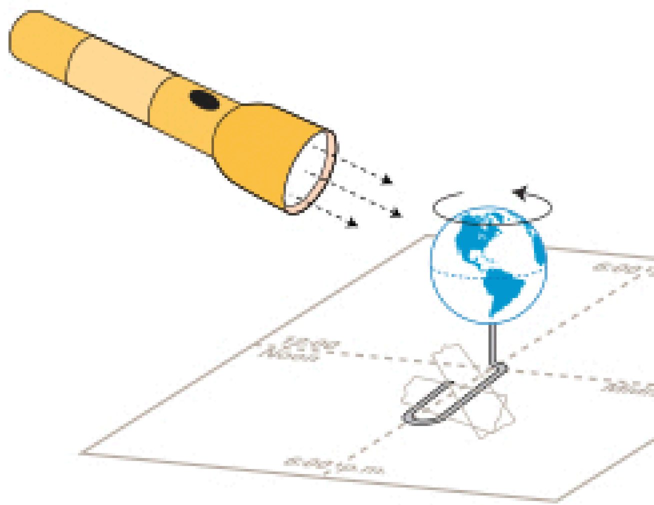
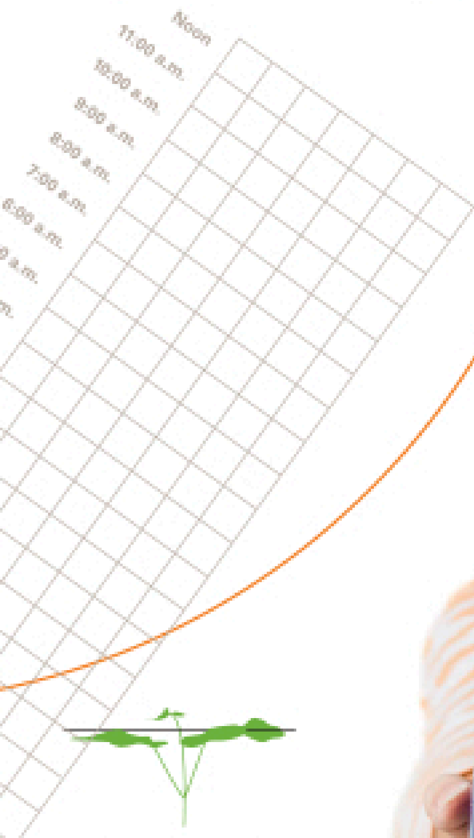
Teacher Resources *from* the
Center *for* Educational Outreach
Baylor College *of* Medicine







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