THE SCIENCE OF SLEEP AND DAILY RHYTHMS

Modeling Day and Night

by
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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 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

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 www.bioedonline.org or 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

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, 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.

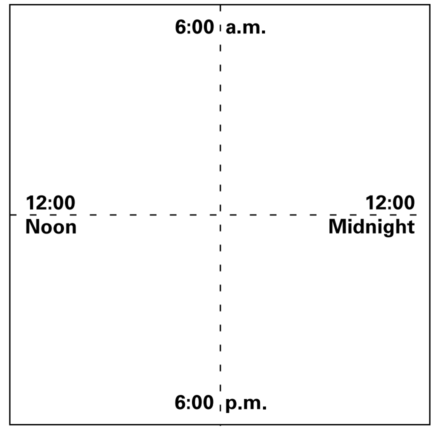
EXTENSIONS

- 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

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.

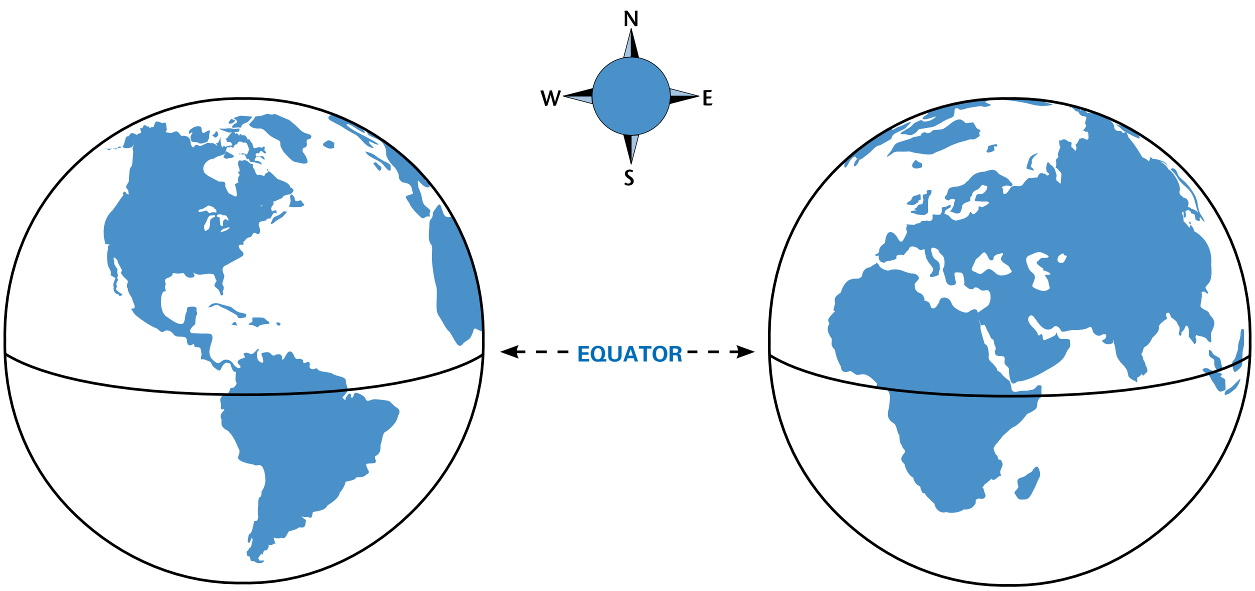


Instructions

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.

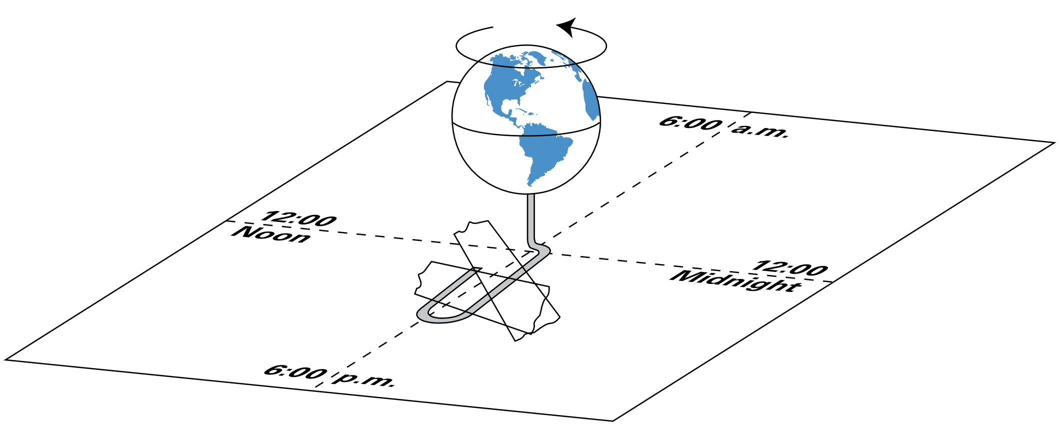
2. Draw a line around the widest part of the ball using a pencil or marker. This represents the equator on your Earth model.

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.

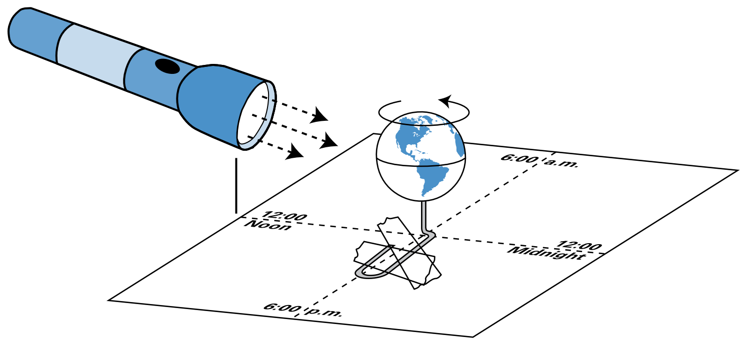
5. Push your Earth globe over the straightened part of the paper clip, with the North Pole facing almost upward. Your model should look like the drawing below.



ACTIVITY

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.