BioEd℠

THE SCIENCE OF SLEEP AND DAILY RHYTHMS

Reason for the Seasons

by

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RESOURCES

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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 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

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.

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

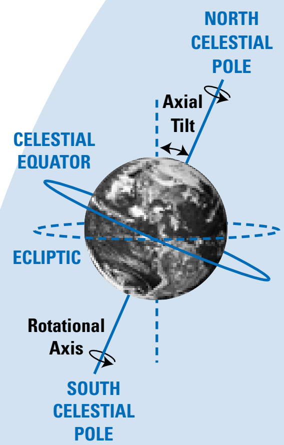
* National Research Council. 1996. National Science Education Standards. Washington, D.C., National Academies Press.

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

Effects of 23.5°

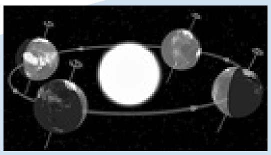


The tilt of Earth's axis alters the hours of daylight and the apparent angle of the sun in the sky.

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'olunga, 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

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.

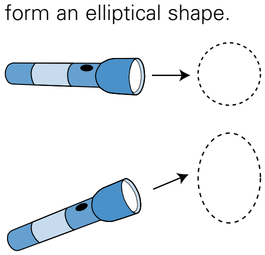
Aphelion: The point at which Earth is at its farthest orbital point to the sun. Earth's aphelion is reached during the northern hemisphere summer and southern hemisphere winter.

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.
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

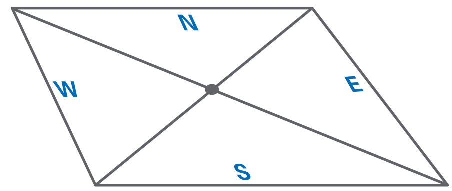
- Challenge students to provide possible reasons why portions of the Arctic are known as the "Land of the Midnight Sun." Help them understand that, during summer in the northern hemisphere, the North Pole and Arctic regions face the sun. At this time of year, areas above the Arctic Circle experience 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

SUN TRACKING BOARD

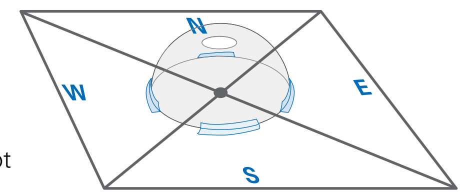
Make a Sun Tracking Board

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.



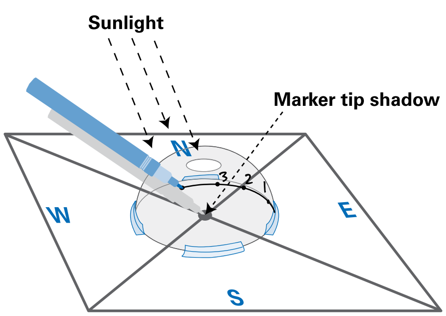
3. Write the compass direction letters, "N," "S," "E," and "W," as shown in the illustration to the right.

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.

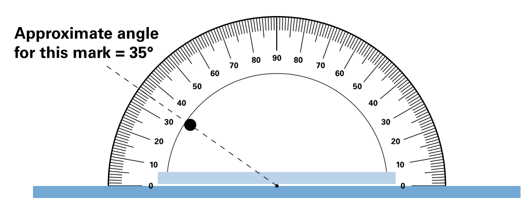
Sun Tracking Day 1

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.

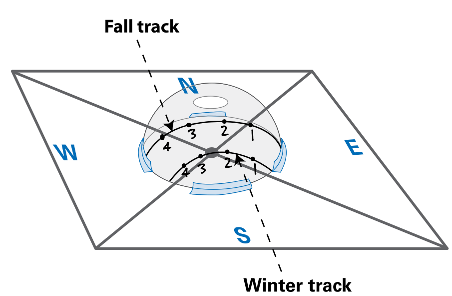
3. Write a small number "1" near the dot on the dome, and record the time of this measurement on your Sun Tracking Data sheet. If daylight savings time is in effect, add one hour to your recorded time.



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

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.