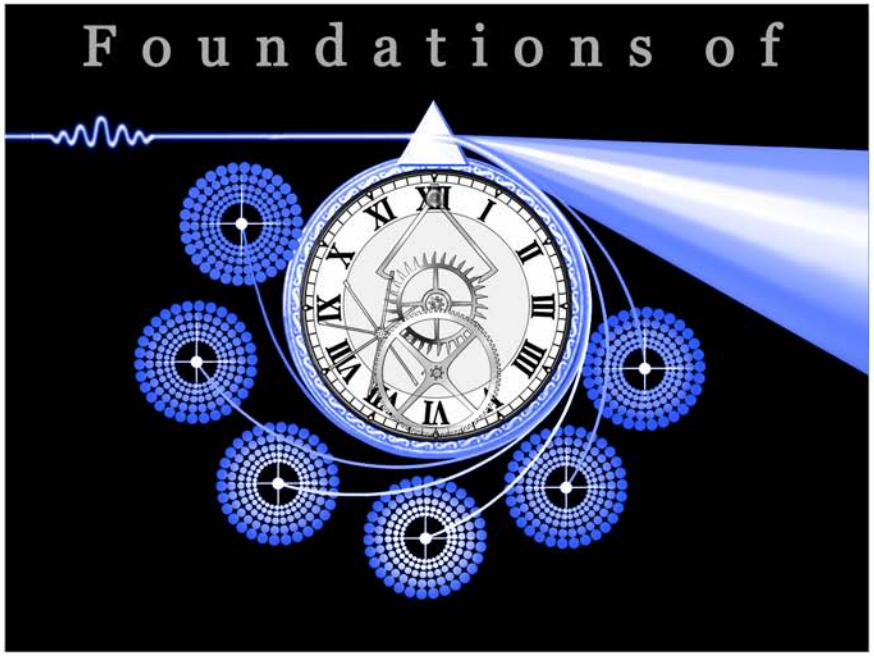


Physical Science

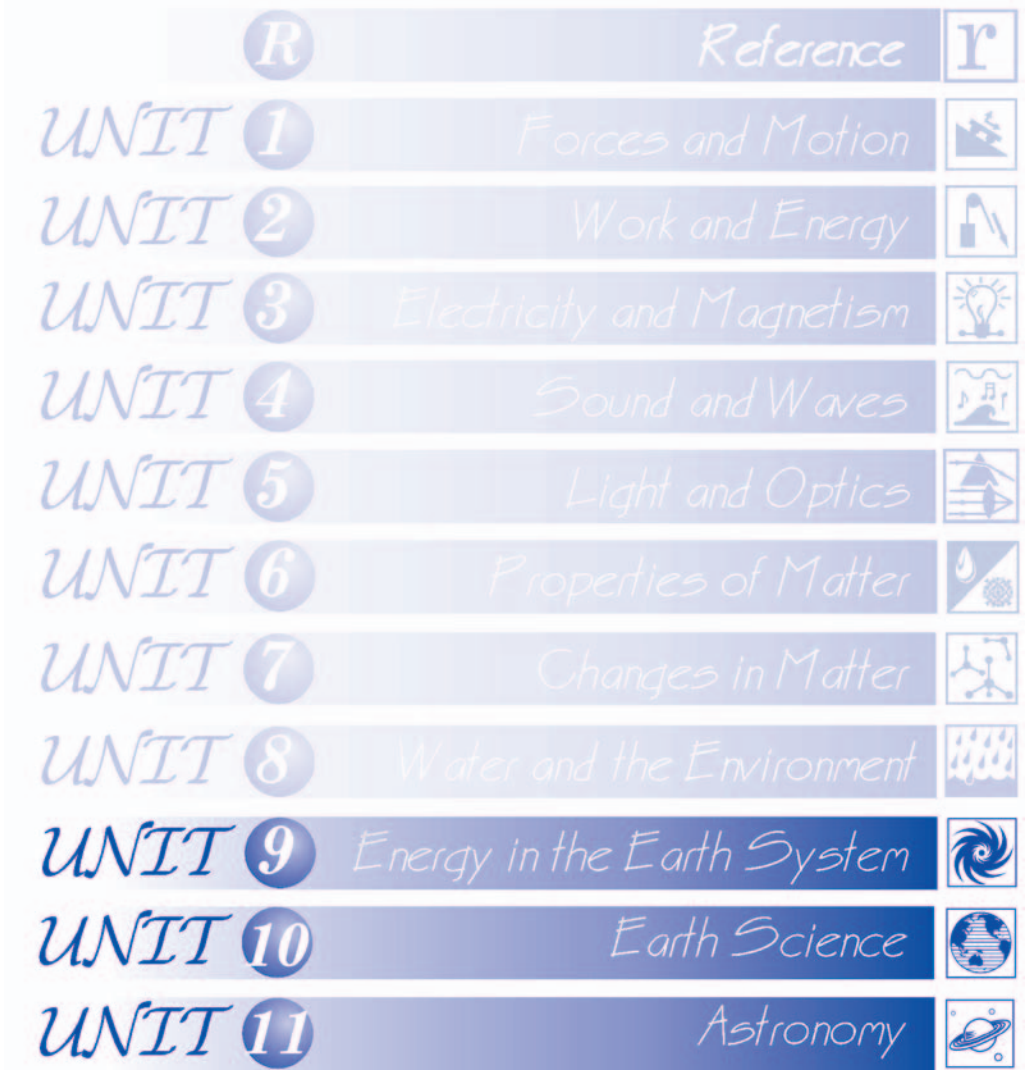
with Earth and Space Science

Tom Hsu, Ph.D.

FIRST EDITION
CPO Science
Peabody, Massachusetts 01960

cpo science

Contents



27.1 Variations in the Heating and Cooling of Earth

Learning Goals

- Model seasonal variation of light intensity on Earth by examining the effects of Earth's orbit.
- Model seasonal variation of light intensity on Earth by examining the effects of axial tilt.

Key question:
What causes the seasons?

Leading questions:
- What is a season?
- How is Earth's orbit and axial tilt related to the seasons?
- Why does winter occur in January in the northern hemisphere, but winter occurs in July in the southern hemisphere?

Reading Synopsis

There are many reasons why Earth isn't heated evenly by the sun. To understand this complex system requires a knowledge of heat transfer (radiation, convection, and conduction), and specific heat.

The hottest place on Earth is near the equator, where the sun is closest to directly overhead year round. Sunlight is more direct and intense. At the north and south poles, temperatures are much colder. Sunlight is spread out and less intense.

One of the main reasons for the uneven heating of Earth is its axial tilt. This tilt is the reason for the seasons, not the fact that there are very slight variations in the distance of Earth from the sun during its orbit. Because of the axial tilt, in June, the northern hemisphere is facing toward the sun while the southern hemisphere is facing away from the sun. As a result, it is summer in the north, and winter in the south. Six months later, in January, the opposite is true.

Sequence: Students complete the reading after the Investigation.

Materials and Setup

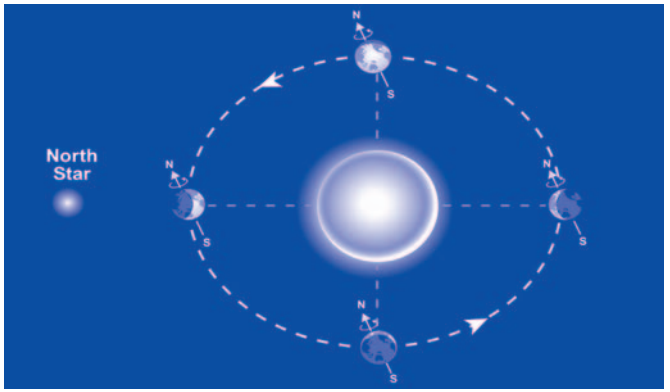
- Earth globe
- Solar cell
- Electric meter that measures current in milliamps
- Metric measuring tape
- Masking tape for marking positions
- Marker for marking positions
- At least four to five tables that are all the same height
- Light source with a 100-watt light bulb (one per class)

Duration: One to two class periods

27.1 Variations in the Heating and Cooling of Earth

Key Question: What causes the seasons?

Students investigate whether or not Earth's orbit or orientation in space causes the seasons. They begin the Investigation with a hypothesis. The hypothesis is tested by measuring the intensity of light from a light bulb. The students measure the effects of distance from the light source and axial tilt on the amount of light that reaches Earth. Differences in light intensity are used to indicate the different seasons.



Reading Synopsis

Students read section 27.1 Variations in the Heating and Cooling of Earth after the investigation.

There are many reasons why Earth isn't heated evenly by the sun. To understand this complex system requires a knowledge of heat transfer (radiation, convection, and conduction), and specific heat.

The hottest place on Earth is near the equator, where the sun is closest to directly overhead year round. Sunlight is more direct and intense. At the north and south poles, temperatures are much colder. Sunlight is spread out and less intense.

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The Investigation

Leading Questions

- What is a season?
- How are Earth's orbit and axial tilt related to the seasons?
- Why does winter occur in January in the northern hemisphere, but winter occurs in July in the southern hemisphere?

Learning Goals

By the end of the Investigation, students will be able to:

- Model seasonal variations of light intensity on Earth by examining the effects of Earth's orbit.
- Model seasonal variations of light intensity on Earth by examining the effects of axial tilt.

Key Vocabulary

axial tilt, orbit, Polaris, revolution, rotation, seasons, solar cell

Setup and Materials

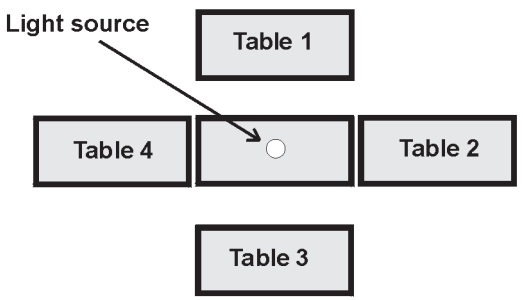
Divide your class into four groups. Each group will work at a table.

Each group should have:

- Earth globe
- Solar cell
- Electric meter that measures current in milliamps
- Metric measuring tape
- Masking tape for marking positions
- Marker for marking positions
- At least four to five tables that are all the same height

For the class, you should have a light source with a 100-watt light bulb. The source should not have a lamp shade or cover over the light bulb. The light source should be placed on a table at the center of the classroom. Place the light source on books if necessary so that the light bulb is level with the equator on the Earth globe. Four tables should be placed around the light source as shown in the diagram below:

Classroom set up (view from above)



Arrange tables around the light source to allow for a distance of 150 cm from the light source, to the student work space at each table.

Details

Time One to two class periods

Preparation Gather the materials and try out the experiment yourself before the Investigation.

Assignments Section 27.1 Variations in the Heating and Cooling of Earth in the **Student Edition** after the Investigation.

Skill Sheet Skill Builder: Using an Electric Meter

27-A Degree Days

Reference Guide Equipment Setup: Earth and Space Sciences Kit (Globe, solar cell)

Teaching Tools: Materials Management

Teaching the Investigation

1 Introduction
2 Developing a hypothesis about the seasons
3 Setting up your model of Earth's orbit around the sun
4 How does the distance of Earth from the sun affect its intensity?
5 How does Earth's tilt affect the sun's intensity?
6 Applying your knowledge

Introduction

What is a season?

When it is wintertime in our hemisphere, is it wintertime all around the world?

Ask students to think of images from around the world that they may see during the December holidays.

Let's begin this Investigation with a discussion about seasons. What is a season?

Have students brainstorm their answers to this question. For example, you could have students come up with a definition in groups and then have each group present their definition.

We have four seasons—winter, spring, summer, and fall. Each of these is characterized by a certain range of temperatures and weather. In the wintertime, depending on where you live, it might snow. In the summertime, it can be so hot that you want to swim. When it is winter here, is it winter all around the world?

To answer this question, have students think about images from around the world that are shown during the December holidays. In the northeastern U.S., it might be cold, but in Australia, it will be hot.

Developing a hypothesis about the seasons

Students investigate the role of distance from the sun and axial tilt in causing seasons on Earth.

1

Look at the first page of the Investigation. Read the text in Part 1 and discuss the graphic with your group. Come up with a hypothesis stating why you think the seasons occur and answer questions 1a and 1b.

Circulate around the room. Encourage students to think about each of the features of the graphic. You may need to take some time to explain the axial tilt of Earth. The axis of Earth is tilted at a 23.5-degree angle from vertical.

From your work, what two factors will you be Investigating to discover the cause of seasons?

The two factors are Earth's distance from the sun and the axial tilt.

Having completed the questions, you have a hypothesis for why the seasons occur and a prediction of the position at which it is summertime in the northern hemisphere. Who would like to share their hypothesis?

Have one group or each group share their hypothesis. Discuss the answers to 1b. At this point in the Investigation, it is important that each idea and hypothesis is validated.

Setting up your model of Earth's orbit around the sun

In this part of the Investigation, one student moves the globe around the light. At each position, A - D. the student should match the orientation of the globe to the graphic. The north pole tilts toward the North Star at each position.

2

The sun in our Investigation will be represented by a lamp with an uncovered light bulb which I will place in the center of the classroom. Why is this a good setup for representing the sun?

An uncovered light bulb emits light in nearly all directions. It is important that light source emit light equally in all directions like the sun does.

You will use an electric meter and solar cell to measure the intensity of light emitted by the light bulb. The solar cell will collect the light and transform it into current that will be measured by an electric meter. Using this technique, the intensity of the light will be measured in milliamps (mA).

We will use a globe to represent Earth. To get the right orientation of Earth relative to the sun, let's choose one wall of our classroom to represent the North Star.

Have students select a wall that will represent the direction of the North Star. Tape a sign to this wall that says "North Star."

First, we will demonstrate Earth's orbit. Who would like to move the globe around the light source?

One student moves the globe around the light. At each position, A - D. The student should match the orientation of the globe to the graphic. The north pole tilts toward the North Star at each position.

What does a complete orbit around the sun represent? What happens to Earth as it revolves around the sun?

One complete orbit is called one revolution and it equals one year. Earth spins on its axis.

Now, each group will use a globe and answer the questions.

Circulate around the room. Encourage students to discuss and answer the questions as a group.

27.1 Variations in the Heating and Cooling of Earth

Question: What causes the seasons?

In this Investigation, you will:

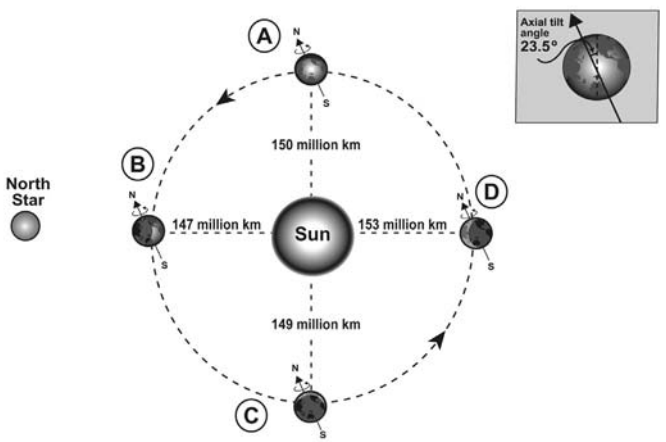
1. Learn how Earth's orbit affects the seasonal variation of light intensity on Earth.
2. Learn how Earth's axial tilt affects the seasonal variation of light intensity on Earth.

Why do the seasons occur? In the summertime, it is hotter, the days are longer, and sunlight is intense. In wintertime, it is cold, the days are shorter, and the sunlight is less intense. What causes these variations in the heating and cooling of Earth so that seasons occur?

1 Developing a hypothesis about the seasons

The graphic below shows you what Earth's orbit around the sun looks like. The orbit is slightly elliptical so that at certain times of the year, Earth is a little closer to or farther from the sun than at other times. Also, Earth is tilted as it moves around the sun. Could distance or Earth's tilt be the cause of seasons?

To start the Investigation, come up with a hypothesis stating why you think the seasons occur. Do you think they are caused by Earth's distance from the sun? Do you think Earth's tilt causes the seasons? Do you think both of these factors play a role? Or do you think other factors cause the seasons?



a. Why do seasons occur? What is your hypothesis?

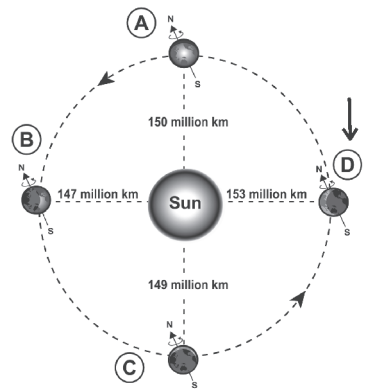
b. At which point in Earth's orbit is it summer in the northern hemisphere? Draw a diagram to answer this question. Be sure to justify your answer.

2 Page two of the Investigation is not shown.

Example Answers

1a. Our hypothesis is that seasons are caused by how Earth tilts toward the sun at different positions in its orbit around the sun.

1b. It is summer in the northern hemisphere at position D..



2a. As Earth revolves around the sun it is spinning on its axis.

2b. The side facing the sun represents daytime. The side facing away from the sun represents nighttime.

2c. Our latitude is 42° North.

2d. The northern hemisphere points toward the sun at position D. The southern hemisphere points away from the sun at position B.

How does the distance of Earth from the sun affect its intensity?

To get students ready for the Investigation, you may want to have them complete the skill sheet, Using an Electric Meter.

The scale distance that will be used in the Investigation is:

1 centimeter = 1 million kilometers

Using this scale students will figure out how far to place the globe from the light source at each position (A-D).

The solar cell is placed on the Velcro® dot at the equator for each distance.

How does Earth's tilt affect the sun's intensity?

For this part of the Investigation, the solar cell is placed on the Velcro® dots. There are three pairs—one pair in the northern hemisphere, one pair at the equator, and one pair in the southern hemisphere.

Applying your knowledge

3

In this part of the Investigation, we will measure the intensity of light from the bulb at different distances from it. To get started, who would like to read the introductory paragraphs of Part 3?

Have a student read these paragraphs aloud. Go over the term scale distance. The scale used in the Investigation is one centimeter equals one million kilometers. Have students record the scale distances for each position (A-D) in the table at the bottom of page 3 of the Investigation.

These scale distances will help you test whether distance from the sun is responsible for causing seasons. Setup the experiment as shown in the graphic. Read the directions carefully. Here, you will not move the globe around the light source. Keep in it one position and measure distances to represent each position. I will come around to help each group as needed.

The setup for the experiment is straight forward. Allow students time to read and follow the directions carefully. The solar cells attaches to the globe at the Velcro® dots found on the equator of the globe. Make sure they measure from the center of the light bulb to the surface of the solar cell for each distance. The solar cell is placed at the equator for this exercise.

If the students are not familiar with using an electric meter you may have to do a quick tutorial with them. Alternatively, get them ready for this Investigation by having them working through the skill sheet, Using an Electric Meter. Students connect the leads from the electric meter to the solar cell. The electric meter should be set to measure current, in milliamps (mA).

4

In this part of the Investigation, you will measure light intensity at different places on the globe as you move the globe around the light source. Keep in mind that relatively low light-intensity readings represent winter-like conditions, and relatively high light-intensity readings represent summer-like conditions.

This part of the Investigation is similar to Part 3. However, here, students are moving the solar cell to different locations on the globe. There are a total of three Velcro® dots on the globe—one in the northern hemisphere, one at the equator, and one in the southern hemisphere. Student fill in their data on the diagram.

Make sure you understand the directions before beginning. Do your work carefully and work together in your groups. I will come around to answer questions.

Circulate and answer questions.

5

When you have finished collecting your data, answer the questions for Part 4.
Then, complete the questions in Part 5. Discuss and answer the questions with your group.

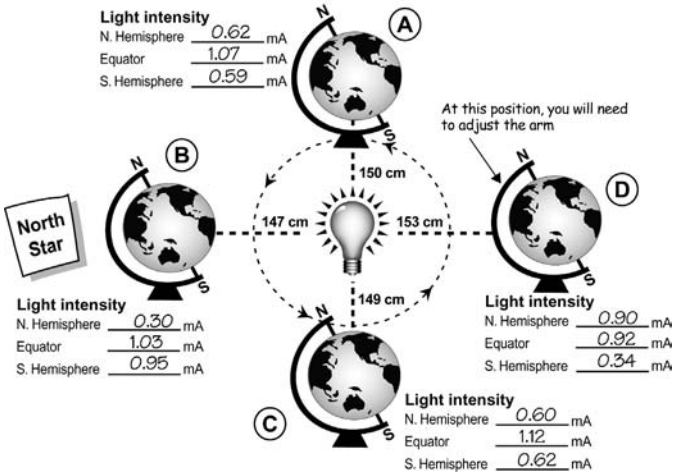
If time is limited, assign the questions for homework.

When students have completed the questions, return to the connection between light intensity and weather. Axial tilt is the key reason for why seasons occur. This is because a hemisphere experiences more intense sunlight (summer conditions) when it is tilted toward the sun, and less intense, more diffuse sunlight (winter conditions) when it is tilted away from the sun. These two extremes happen at two positions in Earth's orbit. Between these two extremes, the weather is more mild with spring conditions following winter as a hemisphere approaches the sun. Fall conditions follow summer as a hemisphere becomes more distant from the sun. It is important to note that the hemispheres do not move toward or away from the sun. Rather, the combination of Earth's orbit and its permanent tilt toward the North Star cause the hemispheres to become nearer or father away from the sun.

4 How does Earth's tilt affect the sun's intensity?

In this experiment you will simulate the effect that Earth's axial tilt has on the intensity of the sun's light. This time, you will model Earth's orbit around the sun, in addition to its distance at the four positions shown below.

1. For the northern hemisphere measurement, you will place the solar cell at 45 degrees north latitude. For the southern hemisphere, you will place the solar cell at 45 degrees south latitude. For the equator, you will place the solar cell as you did in Part 3. Your globe has Velcro® dots attached at each of these positions.
2. Measure each distance from the center of the light bulb to the surface of the solar cell, as you did in Part 3.
3. At each position, make sure the north pole of the globe points **toward** the North Star. Measure light intensity in milliamps. Record your data in the blanks of the graphic. At position D, you will need to move the arm of the globe slightly to the left or right in order to place the solar cell correctly.



a. What role does axial tilt play in the intensity of light on Earth?

b. At which position (A, B, C, or D) and latitude (northern hemisphere, equator, and southern hemisphere) does Earth receive the most light? The least light?

5 Applying your knowledge

a. Of the two factors—distance from the light source and axial tilt—which plays the most significant role in causing the seasons? Was your hypothesis supported by your results?

b. Based on your results, which position (A-D) represents the first day of summer in the northern hemisphere? Which position represents the first day of winter in the northern hemisphere?

c. Which quarter of Earth's orbit represents summer in the northern hemisphere (from A to B, B to C, C to D, or D to A)? Explain your answer based on your results from the Investigation.

3 Page three of the Investigation is not shown.

Sample student data:

	Distance from the sun (km)	Scale distance from the sun (cm)	Light intensity (mA)
A	150,000,000	150	1.07
B	147,000,000	147	1.02
C	149,000,000	149	1.09
D	153,000,000	153	0.98

Example Answers

3a. There are small differences in distance.
3b. Light intensity does not change much.
3c. Because light intensity and distance do not change much, I do not think distance from the sun is the cause of seasons.
4a. Axial tilt seems to be the cause for high or low light intensity on Earth's surface.
4b. Earth receives the most light at the equator at position C. Earth receives the least light in the southern hemisphere in position D.
5a. Axial tilt plays the most significant role in causing seasons. My hypothesis was supported by the results.
5b. First day of summer in the northern hemisphere occurs at position D. First day of winter in the northern hemisphere occurs at position B.
5c. Positions D to A represent the summer season in the northern hemisphere. The other positions represent the seasons as follows: A to B represents fall, B to C represents winter, C to D represents spring. These positions are supported by the light intensity data collected at each position A-D. Lower light intensity represents cool or winter-like weather. Higher light intensity represents warm or summer-like weather.

The cover colorfully combines illustrations of the forces of nature studied in the various fields of the physical sciences. Here, the "evolving tapestry of conceptual thinking" begins with water. Water droplets dance with the planets including our own watery planet and Saturn with its icy rings. Water reappears in the combustion reaction of methane, as the substance on which plants depend, as pounding waves, and, on the back cover, as the darkening clouds of a coming storm. From this cycle of water, a modern bicycle rolls into a graphical interpretation of white light split into its rainbow of wavelengths and a fiber optic. You may lose yourself in many of these images which represent hundreds of years of scientific and technological innovation. Nevertheless, that our innovations are inextricably woven into and from the natural world is illustrated by the images of Earth and the spiral connection between the DNA helix and a bicyclist ever-moving forward. On the back cover, images from physics, chemistry, and earth and space science move around a chambered nautilus seen through the windows of the Golden Rectangle. We at CPO Science with Bruce Holloway, the spirited illustrator of the cover, hope these images will inspire your interest and excitement about the discovery of science.

The CPO Science Development Team

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