beetles
Science and Teaching for Field Instructors

Student Activity Guide

Moon Balls

In this Night Sky Activity, students use a simple indoor Earth-Moon-Sun model to explore and learn about Moon phases and eclipses. Many children (and adults) have misconceptions about what causes the phases of the Moon, and helping them confront those misconceptions with evidence makes this activity pretty enthralling. While it's pretty easy to see the phases of the Moon in the sky, it's not possible from our perspective to observe the entire system, which often leads to inaccurate explanations of what's going on, most commonly that Moon phases are caused by Earth's shadow. It's a perfect situation to use a scientific model. Students are challenged to use the model to struggle to figure out, develop understanding of, and explain the phases of the Moon, discuss ideas with others, then adjust their ideas based on evidence from the model. This activity usually includes a lot of big, "aha's!" as participants encounter evidence while using the model that often contradicts what they previously thought was going on.

Students will...

- **Understand how the Moon's shape appears to change in a predictable pattern.**
- **Use a model and peer-to-peer discussion to explain what causes the phases of the Moon and eclipses.**
- **Understand three different parts of shadows**

Grade Level:
Grades 3-8. Adaptable for younger or older students.

Timing:
about 60 minutes

Related Activities:
Double Take, Night Hike Scavenger Hunt, How Big & How Far, Double Take

Materials:
Materials are outlined on page 3

Tips:
To ensure a successful experience, review the teaching tips found on page 2 and throughout this guide.

Setting:
A completely darkened room. (This is harder to create during the day; draw curtains or tape black paper to the windows)

NEXT GENERATION SCIENCE STANDARDS

FEATURED PRACTICE	FEATURED CROSSCUTTING CONCEPT	DISCIPLINARY CORE IDEAS
Developing and Using Models	Patterns	Earth and the Solar System

For additional information about NGSS, go to page 14 of this guide.

THE LAWRENCE HALL OF SCIENCE
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Moon Balls

ACTIVITY OVERVIEW

Moon Balls	Learning Cycle Stages	Estimated Time
Introducing the Activity	Invitation	10 mins.
Exploring Shadows	Exploration	5 mins.
Investigation Moon Phases	Exploration, Concept Invention	15 mins.
Modeling Moon Phases	Concept Invention, Application	15 mins.
Modeling Solar and Lunar Eclipses	Concept Invention, Application	10 mins.
Reflecting on Evidence and Explanations	Reflection	5 mins
Total:		**45+ minutes**

TEACHING TIPS

Field Card. On page 16 of this guide is a pocket-sized version of this lesson that you can use in the field.

Read the Instructor Support Section. Beginning on page 10, you'll find more information about pedagogy, student misconceptions, science background, and standards.

Don't replace a night hike with this activity! An outdoor night hike can be a highly memorable and impactful experience. This is an indoor activity and is not intended to replace rich outdoor experiences, such as a night hike. It can be used as a rainy night option, or during other indoor time in your program's schedule. See *How Big & How Far*, *Night Sky Scavenger Hunt,* and *Double Take* for outdoor night sky activities.

Try to keep the activity as learner-centered as you can. Read more in the Instructor Support section on page 10.

Using the model outdoors. On a clear sunny day, the moon balls model can be presented outside. Instead of gathering in a circle facing a bulb, the students line up and face the direction of the actual sun and move the moon balls around their heads (Earth) to see the shadows on the moon balls. If you choose to do the activity outdoors, you should practice with the moon balls first yourself. It is also very important to warn students not to look directly at the Sun.

PREPARATION

1. **Prepare the room.** Find a room you can darken completely by drawing curtains or taping black paper over the windows. This is usually easier to do at night. Use the extension cord to plug in the lamp. Make sure the cord is long enough for the lamp to be placed in the center of the room. Tape the cord to the floor for safety. Have a box of balls and a bag of pencils on hand to give your students.
2. **Purchase and prepare Moon Balls.** See the note below for more information.
3. **Test to see which light bulb to use.** Before the session, decide whether the 40-watt or the 75-watt is best for your situation, by darkening the room, and placing one of them in the socket. Stand the same distance from the lamp as your students will. Hold a "Moon ball" in your hand and move it to one side until you see a crescent. Observe the contrast between dark and light sides of the ball, then change the bulb and again observe the contrast. Brighter light bulbs usually provide more contrast if you have a large room, or if there is some light coming into the room from outside. Dimmer bulbs provide greater contrast on the "Moon balls" if you have a smaller room with white walls.
4. **Explore the model yourself ahead of time.** To be able to instruct students how to manipulate their models successfully, make time to use the model yourself ahead of time.
5. **Make a Moon phase explanation poster.** Draw the phases of the Moon across the top of the poster (or use the moon phases photo on page 20). Underneath the phases, write the following prompt and 4 possible explanations:

> **When we look at the Moon in the sky, it appears to change shape throughout a month. Which do you think is the best explanation for this?**
> - The Moon itself changes shape
> - The shadow of the Earth darkens parts of the Moon
> - Clouds block parts of the Moon
> - Another explanation

6. **[optional] Laminate the poster to preserve it, and so students can make erasable marks to indicate what they think is the best explanation before and after the activity.**

Notes on Materials:

Moon Balls: Although any smooth, light-colored opaque ball will generally work for this activity, we've found that smooth, white, polystyrene balls work best. The white color makes it easier for the model to look like the Moon than a colored ball, you can stick pencils in them, they're lightweight, and can be used again and again. The kind of Styrofoam balls with a rough surface, often sold in craft stores, do not work well because they don't have a smooth enough surface to clearly see lines of the edges of dark and light like they appear on the Moon. These balls can work, though, if painted with white latex or other water-based paint to give them a smoother surface.

Lightbulb: A smaller light source makes a crisper boundary between the dark side and the illuminated side of the ball. That's why we suggest an unfrosted incandescent bulb where the light comes directly from the filament rather than being diffused by the glass. The optimal brightness of the bulb depends on the room you are working in. A brighter bulb (75 W) is suitable for larger rooms with dark walls. In smaller rooms, or rooms with light-colored walls, light reflecting off the walls can reduce the impact of the effect if the bulb is too bright. In that case a less powerful bulb works better.

MATERIALS

For the group:
- 1 lamp socket (a lamp with no shade) that can be plugged in
- 1 25-foot extension cord
- 1 40-watt or 75-watt clear light bulb
- A "Moon Phases & Explanations" poster (see example on page 19)
- A few dry or wet erase pens

For each student:
- 1 two-inch polystyrene ball, with a hole big enough for a pencil
- 1 pencil to hold polystyrene ball

TEACHING NOTES

Introducing the Activity

1. **Ask students to share with a partner anything they've noticed about the Moon as it appears in the sky.** Tell them to think about a time when they saw the Moon in the sky and try to remember what it looked like.

2. **Show the poster of Moon phases and tell students they'll be trying to figure out why we see these different shapes throughout a month.** Point out that the shape of the Moon as we see it in the sky seems to change over time. Tell them that these changes are called the phases of the Moon.

3. **Explain that many people have different ideas about how the Moon phases occur and read each explanation out loud.** Tell them these represent some ideas adults and students have shared when asked about the phases of the Moon.

4. **Ask students to think about which explanation they think is the best explanation for what causes the phases of the Moon.**

See the BEETLES Discussion Routines write-up for more information on leading *Turn and Talk*.

5. **Tell students to *Turn and Talk* with at least two different people about what they think causes the phases of the Moon (or what they've heard causes the phases of the Moon).**

6. **After a few minutes of students talking about explanations with others, tell students to draw a dot on the poster under the explanation they think is best.** If they have a different explanation they think is better, they can put their dot under, "another explanation." If you have prepared a laminated poster, you can have them use a dry erase pen that you can erase later for re-use.

7. **Point out what the poster says about the group's ideas.** Get the attention of the whole group, and ask them to point out what the chart shows about the group's ideas. For example: "It looks like 13 of the people in our group think the Earth's shadow is the best explanation, 2 people think the Moon changes shape, and 4 people have a different explanation they think is better."

8. **Explain that it can be helpful to remember where you begin with your thinking and explanations.** Now that they've reviewed their current thinking, they can return to these ideas after they learn a bit more about the Moon. Tell them they'll come back to this poster after they've used a model to explore some of these explanations, and they'll see if their ideas have changed.

Why focus on shadows before modeling the phases? Many students think of shadows only as what they see cast on a wall or the ground. To understand how the Earth's shadow on itself causes the darkness we experience at night and the Moon's shadow on itself causes the phases we see, students need to be aware of the other parts of a shadow.

Exploring Shadows

1. **Gather students in a large circle around light bulb in a darkened room.** Set up the light bulb in the center of the room, and turn it on. Darken the room so the only source of light is the light bulb. Tell students to make one large circle around the bulb (depending on the room you're in, you may need to move some tables and/or chairs).

2. **Tell students to explore shadows in the room for a minute or so, and to learn anything they can about shadows during that time.** Encourage

students to be creative (but safe), to play around, and share their discoveries with each other.

3. **Ask a few students to share out what they discovered.** After about a minute, get the whole group's attention, and ask a few students to share some discoveries.

4. **Explain that there are 3 parts of a shadow: the "end" (the shadow of your hand on the wall); the "beginning" (the side of your hand facing away from the light); and the "middle" (the area between the "beginning" and "end" of your hand's shadow).** This is the part of a shadow most people notice.
   - ▶ *One part of a shadow is the shadow cast by one object on another object*
   - [Hold up your hand, and point out the shadow of your hand on the wall]. We can call this the "end" of the shadow.

5. **Ask students if they notice any other parts of your hand's shadow, & point out the "beginning" and "middle" of the shadow if needed.**
   - ▶ *Another part of the shadow is on the side of my hand facing away from the light; the side of my hand that's dark. We can call this the "beginning" of the shadow. It's the hands' shadow on itself.*
   - ▶ *We can call the area in the air between your hand and the "end" of the shadow the "middle" of the shadow.*
   - Draw attention to this part of the shadow by putting a finger (from your other hand) in the shadowed space between your hand and the wall.
   - Explain: The finger is in the shadow, and this part of the shadow can only be seen when you move an object into it.

6. **Ask students to explore and find the 3 parts of each of their heads' shadows with a partner.**

Investigating Moon Phases

1. **Start exploring shadows of moonballs.** Pass out one Moon ball with a pencil "handle" to each participant. Show students how to stick their pencil in their Moon ball, then tell them to find the three parts of their Moon ball's shadow.

2. **Explain how the model works:**
   - ▶ *In this model, the ball represents the Moon, the bulb represents the Sun, and the Earth is your head.*

3. **Explain that every model is inaccurate in some way, and discuss the inaccuracies of their Sun-Earth-Moon model.** Explain to students that every model is inaccurate in some way- if a model weren't inaccurate, it would be the real thing. Ask students to brainstorm inaccuracies of the model they will use during the activity.

4. **Ask students to explore and learn about the phases of the Moon by using the model and discussing their observations.** Tell students to try moving their Moon balls around in the light from the "Sun," and discussing what

TEACHING NOTES

Seeing the Earth's "middle shadow" at sunset or sunrise. After enjoying a sunset, turn around and face the opposite horizon. You may see a pink glow made by backscattering of reddened sunlight, called the "Belt of Venus." Beneath this is often a dark band of blue, which is the Earth's middle shadow (or "dark segment") cast on the atmosphere! Yes, you can actually easily see the Earth's shadow! Check it out! And you can also see the Earth's shadow well after the Sun has set and it has become dark. It's called, "night."

Astronomers use different vocabulary to describe parts of a shadow, specifically during eclipses. The latin word "umbra" means shadow, and is used to refer to the darkest part of the shadow cast by a celestial object. The "penumbra" refers to the lighter part of a cast shadow where some light gets past the blocking object.

Make a habit of discussing inaccuracies in models. All models are inaccurate in at least one way, otherwise they wouldn't be models – they'd be the real thing. If the inaccuracies and limits of a model aren't discussed, a model can easily lead students to misconceptions. Whenever you use any model in science instruction, including games and other simulations, ask students to brainstorm what's accurate about the model and what's inaccurate. This can help students avoid building misconceptions around the inaccurate parts of the model- and students often enjoy pointing out inaccuracies!

TEACHING NOTES

happens with a partner. Encourage students to work with others, and to talk to each other while they explore the model. Circulate to make sure no one is left out, and to encourage exploration and discussion.

5. **Call for the group's attention, and ask a few students to share their discoveries.** After a few minutes, get the whole group's attention. Ask students to share what they discovered about moon phases. If any students have used this model before or seem to be very solid in their understanding of what causes the phases of the moon, ask them to refrain from answering to give other students a chance to share their ideas.

6. **When a student shares an idea or discovery, ask the group to use their Moon balls to check out what the student is describing.** As each participant shares their discoveries, encourage others to use their own Moon balls to try to replicate the observation.

7. **If an interesting idea or question comes up, challenge the group to use their models to explore and discuss with a partner.** After each exploration, regain the group's attention, and encourage additional sharing of their discoveries and questions. For example:
   - ▶ *Carla noticed the shadow on the Moon ball changes size when you move it around in the light from the "Sun?" OK everyone, hold your Moon ball how Carla is holding hers, then move it in the same way she is. Can you observe what Carla discovered?*

Modeling Moon Phases

1. **After exploring and discussing a few of their discoveries, ask the students to hold their Moon balls out in front of them, directly in front of the "Sun."**

2. **Begin demonstrating the Moon phases.** Tell students the Moon orbits the Earth. Then, instruct students to move the Moon ball to their left until they can see a thin, bright crescent lit up on the ball, and then stop. Tell students this is the crescent Moon phase.

3. **Make sure all students can see the crescent phase, and help those who are struggling.** Tell students to show the crescent on their Moon ball to the person next to them. Check to make sure everyone can see the crescent-shaped light on the Moon ball. Sometimes students have trouble with this. The most common error students make is not moving the Moon ball far enough to the left. Another error is looking at the light bulb and ignoring the "Moon."

4. **When everyone can see the crescent of light, ask:**
   - ▶ *Is the bright, curved edge of your Moon facing toward the Sun, or away from it? [Toward]*

5. **Demonstrate the quarter Moon phase.** Tell students to continue moving their Moons just a little bit more around their heads in the same direction as before until exactly half of the "Moon" appears to be lit from the perspective of their "Earth" heads. (Students need to turn their bodies to the left, too.) Tell students this is the quarter Moon phase.

6. **Ask students the following questions:**
   - ▶ *As the lit part of the Moon becomes more full, does it move toward the Sun or away from it?*
     - [Away from it]
   - ▶ *Does the lit edge of the Moon that's curved like the edge of a ball face toward or away from the Sun.*
     - [Toward]
7. **Demonstrate the gibbous Moon phase.** Keep orbiting your Moon ball a tiny bit in the same direction. This is the gibbous Moon phase. Tell students to continue turning their body and orbiting their Moon ball a tiny bit in the same direction, until it's halfway between a quarter Moon and a full Moon. Tell them this is the gibbous Moon phase.
8. **Demonstrate the full Moon phase.** Tell students to continue moving the Moon ball along its orbit until the part they see is fully lit. Their backs should be facing the light bulb. Explain that they will have to hold the Moon ball just above the shadow of their heads. Ask:
   - ▶ *When the Moon is full, where is it in relation to the Earth? Is it on the opposite side of the Earth from the Sun, or between the Sun and the Earth?*
     - [It's on the opposite side of Earth from the Sun.]
9. **Demonstrate the gibbous phase, again.** Tell students to continue moving the Moon ball in its orbit until it's in gibbous phase once again.
10. **Demonstrate the quarter Moon phase, again.** Tell students to continue moving the Moon ball in its orbit until it's in quarter phase once again. Ask:
    - ▶ *Is the curved side facing toward or away from the Sun?*
      - [Toward the Sun]
    - ▶ *As the Moon moves toward the Sun, does it appear fuller or thinner?*
      - [Thinner]
11. **Demonstrate crescent and new Moon phases.** Finally, tell students to continue to move their Moon balls so they see a very thin crescent again, then to move the Moon ball to where it is entirely in shadow. Tell students that when the Moon cannot be seen at all in the sky, this phase is called the new Moon.
12. **Tell students they've modeled one full orbit of the Moon.** Explain that the Moon completes a full cycle of its phases during one orbit around the Earth.
13. **Direct students to go through another complete orbit of the Moon while discussing with a partner.** This time, instruct them to focus on what is making the bright part of the Moon bright, and what is making the dark part dark.
14. **Get the groups' attention and ask:**
    - ▶ *What is making the bright side of the Moon bright?*
      - [Light from the Sun]

TEACHING NOTES

Addressing a misconception. The questions asked here are important because many students (and adults) think the dark part is caused by the shadow of the Earth. If a student continues to say Earth's shadow causes Moon phases, you might ask them to use the models to show how that works. Often, this helps them see why that explanation is inaccurate.

TEACHING NOTES

Include peer-to-peer discussion. Much of student learning comes from peer-to-peer discussion about ideas. The discussion of ideas during observation and manipulation of this model are crucial for students to build an accurate understanding of Moon phases. Generally, the more opportunities you can give students for discussion in any educational experience, the better it is for the learners.

You may have them close one eye so they aren't "blinded" by the lightbulb.)

Mount Nose and Lake Earie. For fun, you may want to use this version of one of the questions. "Remember your head represents the Earth. The people who live where your eye is, would see an eclipse of the Sun, but what about the people who live on your chin? On Mt. Nose, Lake Earie?"

Learning what causes eclipses helps students understand Moon phases. Since so many people inaccurately explain Moon phases as caused by the Earth's shadow, and because Earth's shadow does cause eclipses, using the model to show eclipses also helps students understand Moon phases. Understanding that Earth's shadow does sometimes darken the Moon can partially validate their ideas, as well as help them rule this out as an explanation for the Moon phases.

- If a student says that the Sun's light is being reflected by the Moon, ask them to explain what they mean by "reflected." Many students think only objects like mirrors, glass or water can create reflections, so the idea of a rocky object like the Moon reflecting may be confusing to some.

▶ *What is making the dark side of the Moon dark?*
  - [The beginning of the Moon's own shadow.]
- This is an important question to ask students, because many students (and adults) think the dark part is caused by the shadow of the Earth.

▶ *In this model, your head is the Earth. Point to the shadow of your "Earth." Is Earth's shadow darkening the Moon? [Nope.] Then what is? [Moon's shadow on itself]*

15. **Explain that one complete orbit of the Moon takes one month.** Tell students that as the Moon ball changes from crescent to full, this models the two-week period when the Moon is moving away from the Sun. A full circle around the Earth takes about a month (more precisely, 29.53 days). This is why we see a repeating pattern of one full cycle of Moon phases every month.

Modeling Solar & Lunar Eclipses

1. **Demonstrate a solar eclipse.** When it seems that the students understand the phases of the Moon, ask them to move their Moon balls directly in front of the Sun to create an eclipse of the "Sun".

2. **Ask students to observe the Moon's shadow on the "Earth" and discuss questions.** While students observe this eclipse of the Sun, tell them to hold their Moon balls exactly where they are, to glance at the faces of other students around the room and to consider the following questions:

   ▶ *See the shadows over everyone's eyes - what's making these shadows?*

   ▶ *Remember your head represents the Earth. The people who live where your eye is, would see an eclipse of the Sun, but what about the people who live on your chin? Or your ear?*

   ▶ *Only people who live on your eye can see an eclipse of the Sun—the people on your ear or chin still see the full Sun. That's why people sometimes travel to see a Solar eclipse.*

3. **Demonstrate a lunar eclipse.** Ask students to move their Moon balls around in a circle, as before, until they reach the full Moon phase. This time, tell them to move their Moons into the shadow of their head.

4. **Tell students to focus on the Earth's shadow on the Moon.** While the Moon balls are still in the shadow of students' heads, explain that this represents an eclipse of the Moon. Ask:

   ▶ *Can you see the shape of your hair/head when the Moon moves into eclipse?*

   - Point out that when there's an eclipse of the real Moon, you can see that the shape of the Earth is round, because it always makes a curved shadow.

5. **Explain that anyone on Earth can see a lunar eclipse.** While students

continue to observe the eclipse of the Moon, point out that everyone who lives on the side of the Earth facing the Moon during the eclipse can see the Moon in the Earth's shadow.

6. **Ask students to identify phases of the Moon surrounding eclipse events.** Ask students to continue moving their Moon balls around their heads until they again see an eclipse of the Sun. Ask them to consider and discuss with their partner the following questions:
   - ▶ *What phase is the Moon just before or just after an eclipse of the Sun?*
     - [Thin crescent or new moon phase]
   - ▶ *What phase is the Moon just before or just after an eclipse of the Moon?"*
     - [Almost Full]

Reflecting on Explanations & Evidence

1. **Give students a moment to look back at the Moon phases poster and think about how their ideas might have changed.**
2. ***Turn & Talk*: How have your ideas about the phases of the Moon shifted?**
3. **Tell students it's just as important to know why wrong explanations are not accurate, as it is to know the accurate explanation.** Have them share out some evidence they collected from the model that contradicts explanations on the poster. Ask:
   - ▶ *Why are these explanations for the phases of the Moon not correct?*
4. **Challenge them to put into words a more accurate explanation for the phases of the Moon.**
5. **Point out that whenever they look at the Moon from now on, they can try to figure out where the Sun is, and why certain parts are lit up and certain parts are in shadow.**
6. **Tell students that there are many more questions that can be investigated using the model if they had more time.** If they have further questions, encourage them to explore the model on their own (all you need is a light, your head, and a ball (or even a round piece of fruit).

TEACHING NOTES

It's difficult to verbalize what causes the phases of the Moon. The correct explanation for Moon phases is actually pretty challenging to put into words that make sense to someone else. This is one reason why we have not included a written, accurate explanation for the Moon's phases. The point of this activity is that, through the act of trying to come up with an explanation with the model in hand, all learners can build a more accurate understanding of this complex concept. By attempting to put their explanation into words, it will help students clarify their thinking.

Question for students to investigate: Can we see a full Moon during the day? If you have time, an interesting question for students to investigate is, "Can we see a full Moon during the day?" Give the question to your students, and challenge them to attempt to figure it out using their moon ball models, and previous observations as evidence. Encourage them to work together, and talk to each other. Then have individuals share their ideas and evidence in the large group. Don't tell them an answer (it's not important content), but encourage them to make observations of the real Moon to answer it.

Seeing the Moon in the daytime. If you're out with students during the day and the Moon is visible, point it out and ask students to try to explain why it looks the way it does and what phase it may be in. If you happen to have apple snacks handy, they can use apples as models to try to explain it.

TEACHING NOTES

Instructor Support

Teaching Knowledge

This activity is designed to provide students with a series of engaging investigations rich with opportunities for students to use a model, their minds, and discussion to gradually help them build understanding. Throughout the write-up, there are select concepts and vocabulary to be introduced to students that can provide the necessary context for their learning experience. But if you over direct students or quickly answer their questions as they come up, they miss the opportunity to struggle with these ideas in a meaningful way. Encourage students to take charge of their own learning by guiding them to "ask the objects" and use the models to answer their own questions. This kind of learning takes time but allows for deeper understanding. This is why we strongly suggest you resist the temptation to abbreviate the activity and just quickly lead them through a demonstration of the phases of the moon using the model.

Conceptual Knowledge

The science background information included here is for the instructor, and is not meant to be read aloud to students. The information found here is designed to help instructors respond to students' questions, and be more aware of inaccurate ideas that students may bring to learning experiences.

Explaining Moon Phases and Eclipses. You'll likely find that the most useful science background on Moon phases is comes from looking at the actual Moon periodically, and exploring the Moon/ball, Sun/light bulb, Earth/head model yourself. In fact, if students ask questions about Moon phases or eclipses, the best response is often to tell them to "ask the objects," and to attempt to use the model to figure out the answer themselves.

Common Misconceptions about Shadows:

It can be difficult for a learner to understand what causes Moon phases if they harbor misconceptions about shadows, such as these:

- **Misconception:** A shadow is only the dark shape cast by one object on another object; it does not include the dark side of the object that is blocking the light, or the three-dimensional area behind the dark side of the object. (most common)
- **Misconception:** Shadows are independent of the objects causing them.
- **Misconception:** Shadows are the reflections of objects.
- **Misconception:** Shadows are dark light.

More accurate information: What is a Shadow? When talking about Moon phases, it's helpful to have a discussion about shadows— what causes them and what is and is not considered a shadow. It's important for learners to understand that a shadow is more than the dark shape cast by one object on another object. A shadow also includes the dark side of the object that is blocking the light. For example, it is the Moon itself that is blocking the sunlight from reaching the part of the Moon that looks dark. (One of the most common misconceptions about the phases of the Moon is that they are caused by the shadow of the Earth on the Moon.) A shadow also includes a third part: the three-dimensional area behind the dark side of the object. This part of a shadow can be seen if an object, like a finger, is inserted into it. In space, this part of the shadow can be seen when an object like a spaceship is inserted into it.

Common Misconceptions about Moon Phases:

- **Misconception:** The phases of the Moon are caused by the shadow of the Earth on the Moon (the most common by far!)
- **Misconception:** The shape of the Moon always appears the same.
- **Misconception:** The Moon can be seen only at night.
- **Misconception:** The phases of the Moon are caused by clouds.
- **Misconception:** The phases of the Moon are caused by the Moon moving into the Sun's shadow.

More accurate information about moon phases:

What causes the phases of the Moon? The Moon appears to go through phases as it orbits the Earth. The Moon's shadow on itself causes parts of it to be dark (see What is a Shadow, below). The amount of the Moon that we can see changes over time in a cyclic period that repeats itself about once a month. (The actual period of this cycle is approximately 29.5 Earth days.) The cause of these phases is the positions of the Sun, Earth, and Moon relative to one another. No matter what phase the Moon is in, HALF of it is ALWAYS lit by the Sun. (Which half is always lit? The half that is facing the Sun!) The reason the Moon doesn't always appear half lit to us is because of Earth's position relative to the Moon and the Sun. As the Moon moves in its orbit, different parts of it appear (to us) to be lit up as we look at it from Earth. That's why we see lunar phases. When the Moon is between the Earth and the Sun, the lit side is facing away from us, and the shaded side is toward the Earth, so we don't see a moon in the sky (we call that a "new moon"). When the Moon has orbited one quarter of the way around the Earth, we see half of it lit by the Sun, and half shaded. Sound confusing? It's much easier to understand with the model in your hands.

The important point is that the Moon doesn't change its shape, nor does the amount of the Moon that is lit by the Sun change. The only thing that changes is the position of the Moon relative to the Earth and the Sun. This change in position affects how we view the Moon from Earth and causes the apparent phases of the Moon throughout the month.

Does the Moon make its own light? The Moon does not make any light of its own. The Sun lights up the side of the Moon that faces toward it; the other side is dark. When we see the Moon from Earth, we see different amounts of the light side and the dark side, depending on where the Moon is in its orbit around Earth.

Does the Moon rotate? If so, how is it possible that we always see the same side of the Moon from Earth? The Moon keeps the same face toward Earth as it orbits the Earth, because over millions of years, it has become "gravitationally locked" with Earth. The pull of gravity between the Earth and Moon has slowed down the Moon's spin to exactly once each time it makes one orbit around Earth. From Earth, it can seem like the Moon is not rotating at all, but

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if you were on the Moon, you would see the stars go around in the sky once a month, complete with a sunrise and a sunset. The far side of the Moon was not seen until it was photographed by spacecraft. This can be pretty confusing for folks, even when you act it out with the model.

Is there a dark side of the Moon? This term may have come from reference to the far side of the Moon, which is always the same side, and which is always facing away from the Earth. But actually, the far side of the Moon gets just as much sunshine as the side that faces Earth. There's always a dark side of the Moon, just as there's always a dark side of the Earth—that's where it's night time. But, as with Earth, the side that's dark is constantly changing. During a new Moon, the far side of the Moon is fully lit by the Sun. Sometimes the part of the Moon that's not directly lit by the Sun is visible. This happens most often just after a new Moon, when you can see the full circular shape of the Moon with the crescent shape lit up on one edge by the Sun. The light that makes the darker part of the Moon visible is also from the Sun, but it's Earth-shine—sunlight that is reflected off Earth.

Why does the Moon appear to change size? Since the Moon does not orbit Earth in a perfect circle, its distance from Earth changes slightly. This makes the Moon look slightly different sizes at different times. The difference between the apparent diameter of the Moon at its largest and smallest is about 10 percent. When the Moon is near the horizon, it can seem larger, but this is an illusion. No one is sure why, but the height of the Moon above the horizon, and the other objects that can be seen with the Moon, such as distant trees and hills, affect the way our brains interpret the Moon's size. Even when the Moon looks huge, if you stretch out your arm, the tip of your pinky finger can still easily cover the Moon.

What causes eclipses? The processes that cause eclipses often are confused with the processes that cause Moon phases. Sometimes the processes that cause eclipses are even confused with the processes that cause day and night. The orbit of the Moon is tilted a little bit (about 5 degrees) from the orbit of Earth around the Sun. This means that during each full moon and each new moon, it's very unlikely that the Sun, Earth, and Moon will be exactly lined up. In the rare cases when they do line up, there's an eclipse.

What causes Lunar Eclipses? Lunar eclipses can only happen during a full moon. They occur when the Moon passes through the shadow of Earth. During a total lunar eclipse, the Earth gets in the way of sunlight headed toward the Moon. The full, bright disk of the Moon becomes darkened as Earth blocks its light. It lasts for a few minutes to a few hours, depending on the path of the Moon through Earth's shadow. Lunar eclipses are much easier to see than solar eclipses. If you can see the Moon, you can see the eclipse, so people in one half of the world can see lunar eclipses, while people in much smaller parts of the world can see solar eclipses (see below). There are no special safety precautions needed for observing a lunar eclipse (there are for solar eclipses).

Why does the Moon look orangish or brownish during a lunar eclipse? In a total eclipse of the Moon, sunlight passes through the Earth's atmosphere, which filters out most of the blue colored light and also bends or refracts some of this light so that a small fraction of it can reach and illuminate the

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Moon. The remaining light is a deep red or orange color, and is much dimmer than pure white sunlight. The total eclipse stage of a lunar eclipse is so interesting and beautiful precisely because of the filtering and refracting effect of the Earth's atmosphere. If the Earth had no atmosphere, then the Moon would be completely black during a total eclipse. Instead, the Moon can take on a range of colors from dark brown and red to bright orange and yellow. The exact appearance depends on how much dust and clouds are present in the Earth's atmosphere.

What causes solar eclipses? Solar eclipses can happen during a new Moon when the Moon blocks our view of the Sun. The Moon actually casts a "Moon shadow" on Earth. Only people in the shadow see the eclipse. The sky darkens, bright stars and planets are visible, and the glowing gases around the Sun (the solar corona) become visible (because they're not drowned out by the brightness of the Sun). Birds accustomed to singing at sundown may start to sing during a solar eclipse.

Unlike total lunar eclipses, which can be seen from half of the Earth (the night side) at a given time, total eclipses of the Sun can be seen only along a narrow "path of totality," which is, at most, 270 kilometers wide. The path of totality is the shadow of the Moon on the Earth's surface, and it moves from west to east at about 1,700 kilometers per hour. The shadow of the Moon covers only a small portion of Earth, so only people in the right locations can see a totally eclipsed Sun. People in a larger part of Earth can see the Sun partly covered by the Moon. They see a partial eclipse. On most of Earth, the eclipse cannot be seen at all for most people, and it takes, on average, four centuries for a path of totality to touch a given place on the Earth. So avid eclipse watchers typically need to travel to far reaches of the globe.

What is waxing & waning? When the lighted part of the Moon—as we see it from Earth—increases each night, the Moon is said to be waxing. When it decreases each night, the Moon is said to be waning. You can also tell if the Moon is waxing or waning without watching it night after night. If the left side of the Moon is dark, the Moon is waxing. If the right side is dark, then it's waning. (This is the case in the Northern Hemisphere; in the Southern Hemisphere, it's just the opposite.) Astronomers distinguish among the repeated phases of the Moon by referring to the waxing or waning crescent, half, and gibbous phases.

Can the Moon be seen during the day? Students may have noticed that the there are many times during its monthly cycle that the Moon is visible during the day. In fact the Moon is visible in the daylight nearly every day, with the exception being around the new moon phase when it is too small or too close to the Sun. It's a common misconception that the Moon is always directly opposite the Sun in the sky. The only time when that happens is during the full moon phase, when the Moon appears at 180 degrees from the setting or rising Sun. It's only during the full moon phase that the Moon is out all night.

Connections to the Next Generation Science Standards (NGSS)

BEETLES student activities are designed to provide opportunities for the "three-dimensional" learning called for in the NGSS. To experience three-dimensional learning, students need to engage in scientific practices to learn important science concepts (Disciplinary Core Ideas) and make connections to the big ideas in science (Crosscutting Concepts). In short, students should be using the tools of science to explore and investigate rich phenomena, trying to figure out how the natural world works.

In Moon Balls, students engage in the practice of Developing and Using Models. They also have the opportunity to relate what they learn about Moon phases to the crosscutting concept of Patterns. Depending on their observations, prior knowledge, and the instructor's focus, students can build a foundational understanding of disciplinary core ideas related to Earth and the Solar System.

Featured Science and Engineering Practices.

Engaging students in Developing and Using Models. According to NRC's A Framework for K-12 Science Education, scientists use conceptual models to investigate parts of a system not visible to the naked eye to better visualize and understand phenomena. Students should be developing models that represent their current understanding of a system or process under study, in order to help develop explanations and communicate ideas to others. Moon Balls is a wonderful opportunity for students to use a model as asked for in NGSS! In Moon Balls, students actively use the model of the Sun, Moon, and Earth to answer their own questions and explain the phases of the Moon to each other. They're asked to articulate how the model is accurate or inaccurate, as they discuss how the model represents their current understanding of Moon phases. Throughout the activity they build understanding of the interactions of light and shadows on celestial objects that result in the way that we view them from Earth. Through discussing ideas with peers, they revise their own internal model of the phases of the Moon. Later, students revisit their original thinking about Moon phases, which allows them to use their observations from manipulating the Moon Ball models to evaluate incorrect explanations. By referring to concrete examples in their discussion of the model with a partner, students are able to deepen their understanding of moon phases and adjust their own mental models accordingly.

Featured Crosscutting Concepts

Learning science through the lens of Patterns. The Framework states that a significant part of helping students see the value in this crosscutting concept is discussing how looking at patterns can help us understand more about how things work. Noticing patterns is often the first thing that causes scientists to ask a question or wonder about an explanation for a phenomenon they encounter. Tracking the changes in the Moon's appearance in the night sky and noticing the repeating patterns throughout each month, has helped scientists understand what causes the phases of the Moon. Moon Balls focuses on describing those patterns of Moon phases and connecting them with the model of the Earth, Moon and Sun, which can help students better understand and

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About the Next Generation Science Standards (NGSS): The development of the Next Generation Science Standards followed closely on the movement to adopt nationwide English language arts and mathematics Common Core standards. In the case of the science standards, the National Research Council (NRC) first wrote a Framework for K-12 Science Education that beautifully describes an updated and comprehensive vision for proficiency in science across our nation. The Framework–validated by science researchers, educators and cognitive scientists–was then the basis for the development of the NGSS. As our understanding of how children learn has grown dramatically since the last science standards were published, the NGSS has pushed the science education community further towards engaging students in the practices used by scientists and engineers, and using the "big ideas" of science to actively learn about the natural world. Research shows that teaching science as a process of inquiry and explanation helps students to form a deeper understanding of science concepts and better recognize how science applies to everyday life. In order to emphasize these important aspects of science, the NGSS are organized into three dimensions of learning: Science and Engineering Practices, Crosscutting Concepts and Disciplinary Core Ideas (DCI's). The DCI's are divided into four disciplines: Life Science (LS), Physical Science (PS), Earth and Space Science (ESS) and Engineering, Technology and Applied Science (ETS).

Importance of teaching science practices: "Engaging in the practices of science helps students understand how scientific knowledge develops...It can also pique students' curiosity, capture their interest, and motivate their continued study..." -National Research Council, A Framework for K-12 Science Education. Focus on these science practices will help to ensure a more scientifically literate public who will be better able to make thoughtful decisions.

use this thinking tool. As students discuss how the relative positions of the Earth, Moon, and Sun affect the way the moon appears to us, they're beginning to make important connections between recognizing patterns and explaining phenomena. In grades 3-5 students should begin to identify cyclical patterns related to time and use them to make predictions. In this activity, students use what they've learned about the cycle of moon phases and the timing of the Moon's orbit around the Earth every month, to explain the occurrences of lunar and solar eclipses.

Featured Disciplinary Core Ideas

Building a foundation for understanding Disciplinary Core Ideas. The NGSS make it clear that students need multiple learning experiences to build their understanding of disciplinary core ideas. Moon Balls provides students with an opportunity to develop some understanding of the disciplinary core ideas related to ESS1.B Earth and the Solar System. In fifth grade students should learn that the orbits of Earth around the Sun, and of the Moon around Earth, along with the rotation of Earth, cause observable patterns. These include day and night; daily changes in the length and direction of shadows; and different positions of the Sun, Moon, and stars at different times of the day, month, and year (5-ESS1-2). Manipulating and discussing the Moon Balls model provides a solid foundation for developing these core disciplinary ideas.

Performance Expectations to Work Towards

The NGSS represent complex knowledge and multi-faceted thinking abilities for students. No single activity can adequately prepare someone for an NGSS performance expectation. Performance expectations are examples of things students should be able to do, after engaging in multiple learning experiences or long-term instructional units, to demonstrate their understanding of important core ideas and science practices, as well as their ability to apply the crosscutting concepts. As such, they do not represent a "curriculum" to be taught to students. Below are some of the performance expectations that the Moon Balls activity can help students work towards.

5-ESS1-2 Represent data in graphical displays to reveal patterns of daily changes in length and direction of shadows, day and night, and the seasonal appearance of some stars in the night sky.

MS-ESS1-1 Develop and use a model of the Earth-Sun-Moon system to describe the cyclic patterns of lunar phases, eclipses of the sun and moon and the seasons.

Activity Connections

Using Walk & Talk before and after this activity will assess prior knowledge, engage students in the topic, and allow for reflection of learning. Other (outdoor) night sky activities include: How Big and How Far, Night Sky Scavenger Hunt and Double Take.

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About Crosscutting Concepts in the NGSS: Crosscutting concepts are considered powerful thinking tools for how scientists make sense of the natural world. The seven "big ideas" listed as crosscutting concepts are: Patterns; Cause & Effect; Scale, Proportion & Quantity; Systems and System Models; Energy & Matter: Flows, Cycles and Conservation; Structure & Function; and Stability & Change. These concepts may sound familiar, as they are quite similar to the themes referred to in science literacy documents as being important ideas that unify all disciplines of science and engineering.

Translating the codes used in the NGSS: Each standard in the NGSS is organized as a collection of performance expectations (PE) for a particular science topic. Each PE has a specific code, provided here so that they can be easily referenced in the NGSS documents. The first number or initial refers to the grade level: K - kindergarten, 1 - first, 2 - second,etc...MS - middle school, and HS - high school. The next letters in the code refer to the science discipline for the standard: LS, PS, ESS, ETS. The number following the discipline denotes the specific core idea within the discipline that is addressed by the PE, and the last digit identifies the number of the PE itself. So...3-LS4-4 means it's part of a third grade standard (3) for life science (LS), addressing the fourth core idea (4), Biological Evolution: Unity and Diversity, within the life science standards, that deals with Biodiversity and Humans. It's also the fourth performance expectation (4) that makes up the complete LS4 standard at this grade level.

We're super grateful to the good folks at GEMS for allowing us to adapt this activity from the GEMS guide, *Earth, Moon, & Stars*, and the GEMS *Space Science Sequence*.

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Moon Balls

INTRODUCING THE ACTIVITY

1. Explain: Share with a partner anything you've noticed about the Moon as it appears in the sky.
2. Show Moon phases poster & explain they'll be trying to figure out why we see these different shapes throughout a month.
3. Read aloud possible explanations for the phases of the Moon.
4. Explain: Think about which is the best explanation for Moon phases.
5. Explain: Share your ideas about what causes the phases of the Moon with at least two different people.
6. Explain: Draw a dot under the explanation you think is best.
7. Point out what the poster says about the group's ideas.
8. Explain that it can be helpful to remember where you begin with your thinking & explanations.

EXPLORING SHADOWS

1. Gather students in a large circle around light bulb in a darkened room.
2. Explain: Try to learn as much as you can by exploring shadows.
3. Ask a few students to share out what they discovered.
4. Explain:There are 3 parts of a shadow: the "end" (the shadow of your hand on the wall); the "beginning" (the side of your hand facing away from the light); & the "middle" (the area between the "beginning" & "end" of your hand's shadow).

   ▶ *One part of a shadow is the shadow cast by one object on another object [Hold up your hand, & point out the shadow of your hand on the wall]. We can call this the "end" of the shadow.*
5. Ask students if they notice any other parts of your hand's shadow, & point out the "beginning" & "middle" of the shadow if needed.

   ▶ *Another part of the shadow is on the side of my hand facing away from the light; the side of my hand that's dark. We can call this the "beginning" of the shadow. It's the hands' shadow on itself.*

   ▶ *We can call the area in the air between your hand & the "end" of the shadow the "middle" of the shadow.*
   - Draw attention to this part of the shadow by putting a finger (from your other hand) in the shadowed space between your hand & the wall.
   - Explain: The finger is in the shadow, & this part of the shadow can only be seen when you move an object into it.
6. Explain: With a partner, explore & find the 3 parts of shadows of each others' heads.

INVESTIGATING MOON PHASES

1. Pass out balls & pencils, then ask students to find the 3 parts of shadows on Moon balls.
2. Explain: In this model, the ball represents the Moon, bulb=Sun, & Earth=head.
3. Explain that every model is inaccurate in some way, then ask students to discuss inaccuracies of their Sun-Earth-Moon model.
4. Ask students to explore & learn about the phases of the Moon by using the model & discussing their observations.
5. Call for the group's attention, & ask a few students to share their discoveries.
   - When a student shares an idea or discovery, ask the group to use their Moon balls to check out what the student is describing.
6. If an interesting idea or question comes up, challenge the group to use their models to explore & discuss with a partner.

   ▶ *Carla noticed the shadow on the Moon ball changes size when you move it around in the light. OK everyone, hold your Moon ball how Carla is holding hers, then move it in the same way she is. Can you observe what Carla noticed?*

MODELING MOON PHASES

1. Explain: Face the "Sun" & hold up your Moon balls.
2. Tell students they'll use the model to observe the Moon's orbit around the Earth, & demonstrate moving ball slightly TO THEIR LEFT into the crescent Moon phase.
3. Make sure all students can see the crescent phase, & help those who are struggling.

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4. Ask students which way the bright side of the Moon ball faces. Ask:

   ▶ *Is the bright, curved edge of your Moon facing toward the Sun, or away from it? [Toward]*
5. Explain: Keep "orbiting" your Moon balls a tiny bit until you reach the quarter Moon phase.
6. Ask:

   ▶ *As the lit part of the Moon becomes more full, does it move toward the Sun or away from it? [Away from it.]*

   ▶ *Does the lit edge of the Moon that's curved like the edge of a ball face toward or away from the Sun. [Toward.]*
7. Explain: Keep orbiting your Moon ball a tiny bit in the same direction. This is the gibbous Moon phase.
8. Explain: Keep "orbiting" your Moon ball until it is fully lit (they will have to hold it just above the shadow of their heads). This is the full Moon phase. Ask:

   ▶ *When the Moon is full, where is it in relation to the Earth? Is it on the opposite side of the Earth from the Sun, or between the Sun and the Earth? [It's on the opposite side of Earth from the Sun.]*
9. Explain: Keep orbiting your Moon balls in the same direction, till you reach the gibbous Moon phase again.
10. Explain: Keep orbiting your Moon ball in the same direction to show a quarter Moon phase.

    ▶ *Is the curved side facing toward or away from the Sun? [Toward the Sun.]*

    ▶ *As the Moon moves toward the Sun, does it appear fuller or thinner? [Thinner.]*
11. Tell students to model the crescent phase & then new Moon phase.
12. Explain: You have modeled one full cycle of the Moon.
13. Explain: With your partner, model another Moon orbit, discussing what makes the bright part of the Moon bright, & what makes the dark side dark.
14. Get the groups' attention & ask:

    ▶ *What is making the bright side of the Moon bright? [Light from the Sun]*

    ▶ *What is making the dark side of the Moon dark? [The beginning of the Moon's own shadow.]*

    ▶ *In this model, your head is the Earth. Point to the shadow of your "Earth." Is Earth's shadow darkening the Moon? [Nope.] Then what is? [Moon's shadow on itself]*
15. Explain: One complete orbit of the Moon takes one month, so we see this repeating pattern of cycling through phases.

MODELING SOLAR & LUNAR ECLIPSES

1. Explain: Make a solar eclipse by moving your Moon balls in front of the "Sun."
2. Discuss:

   ▶ *See the shadows over everyone's eyes - what's making these shadows?*

   ▶ *Remember your head represents Earth. The people who live where your eye is, would see an eclipse of the Sun, but what about the people who live on your chin? Or your ear?*

   ▶ *Only people who live on your eye can see an eclipse of the Sun—the people on your ear or chin still see the full Sun. That's why people sometimes travel to see a solar eclipse.*
3. Explain: Make a lunar eclipse by moving your Moon balls into the full Moon phase.
4. Have students focus on the Earth's shadow on the Moon. Ask:

   ▶ *Can you see the shape of your hair/head when the Moon moves into eclipse?*
   - Point out that when there's an eclipse of the real Moon, you can see that the shape of the Earth is round, because it always makes a curved shadow.
5. Explain: Anyone on Earth can see a lunar eclipse.
6. Ask:

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▶ *What phase is the Moon just before or just after an eclipse of the Sun? [Thin crescent or new moon phase]*

▶ *What phase is the Moon just before or just after an eclipse of the Moon?" [Almost Full]*

REFLECTING ON EXPLANATIONS & EVIDENCE

1. Explain: Take a moment to look back at the Moon phases poster & think about how your ideas may have changed.
2. Explain: Discuss with a partner how your ideas have changed, & what evidence made them change.

   ▶ *Ask: Why are these explanations for the phases of the Moon not correct?*
3. Explain: Try to put into words a more accurate explanation for the phases of the Moon.
4. Explain: You can apply this knowledge whenever you see the real Moon.
5. Explain: This experience was short, but you can keep learning by using this model.

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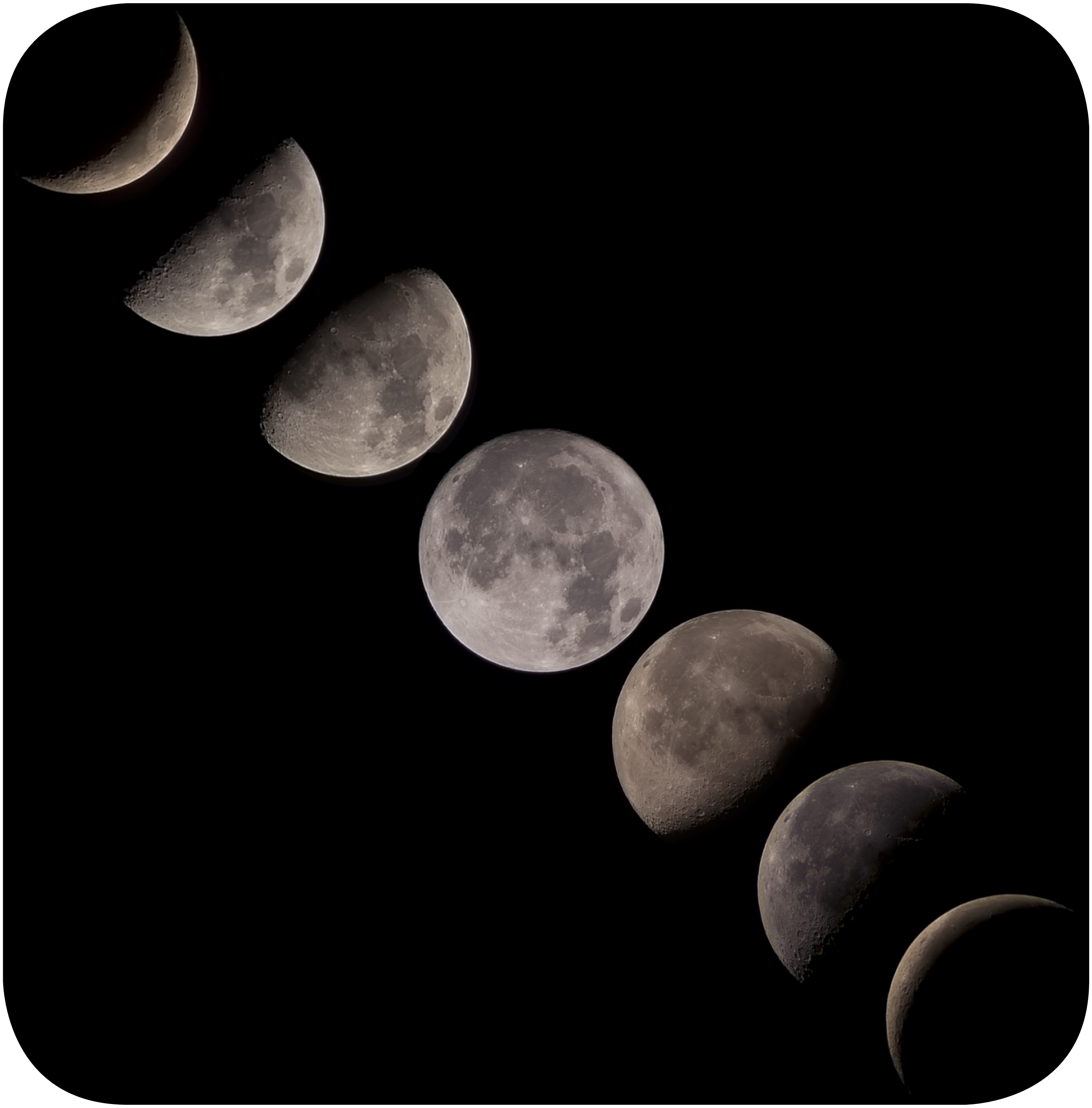
When we look at the Moon in the sky, it appears to change shape throughout a month. Which do you think is the best explanation for this?

- The Moon itself changes shape
- The shadow of the Earth darkens parts of the Moon
- Clouds block parts of the Moon
- Another explanation

Moon Phases Photo



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BEETLES™ (Better Environmental Education Teaching, Learning, and Expertise Sharing) is a program of The Lawrence Hall of Science at the University of California, Berkeley, that provides professional learning sessions, student activities, and supporting resources for outdoor science program leaders and their staff. The goal is to infuse outdoor science programs everywhere with research-based approaches and tools to science teaching and learning that help them continually improve their programs.

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