
# Voyage: A Journey Through Our Solar System

## Grades 5-8

## Lesson 4: Going through a Phase

On a visit to the National Mall in Washington, DC, one can see monuments of a nation—Memorials to Lincoln, Jefferson, and WWII, the Vietnam Veterans Memorial Wall, and Washington Monument. Standing among them is *Voyage*—a one to 10-billion scale model of our Solar System—spanning 2,000 feet from the National Air and Space Museum to the Smithsonian Castle. *Voyage* provides visitors a powerful understanding of what we know about Earth's place in space and celebrates our ability to know it. It reveals the true nature of humanity's existence—six billion souls occupying a tiny, fragile, beautiful world in a vast space.

*Voyage* is an exhibition that speaks to all humanity. The National Center for Earth and Space Science Education is therefore making replicas of *Voyage* available for permanent installation in communities worldwide (http://voyagesolarsystem.org.)

This lesson is one of many grade K-12 lessons developed to bring the *Voyage* experience to classrooms across the nation through the Center's *Journey through the Universe* program. *Journey through the Universe* takes entire communities to the space frontier (http://journeythroughtheuniverse.org.)

The *Voyage* exhibition on the National Mall was developed by Challenger Center for Space Science Education, the Smithsonian Institution, and NASA.

# Lesson 4: Going through a Phase

## Lesson at a Glance

### Lesson Overview

The varying appearance of the Moon over the course of a month results from changes in the relative positions of the Earth, Moon, and Sun. In the first Activity, daily observations of the Moon over many weeks allow the phase cycle to be observed and characterized, and an explanation to be hypothesized. The hypothesis is tested in the second Activity where students construct a working model of the Earth-Moon-Sun system and determine if they can recreate the observed phase cycle. To truly develop a conceptual understanding of the phenomenon, students explore whether the Earth should exhibit a phase cycle as seen from the Moon, and whether an Earth observer should see other planets exhibiting phase cycles.

### Lesson Duration

Two or three 45-minute classes over a six-week period.

### Core Education Standards

*National Science Education Standards*

Standard D3: Most objects in the solar system are in regular and predictable motion. Those motions explain such phenomena as the day, the year, phases of the moon, and eclipses.

*AAAS Benchmarks for Science Literacy*

Benchmark 4B5:

The moon's orbit around the earth once in about 28 days changes what part of the moon is lighted by the sun and how much of that part can be seen from the earth—the phases of the moon.

Benchmark 1B1:

Scientists differ greatly in what phenomena they study and how they go about their work. Scientific investigations usually involve the collection of relevant data, the use of logical reasoning, and the application of imagination in devising hypotheses and explanations to make sense of the collected data.

## Essential Question

- Why do we see different phases of Solar System objects?

## Concepts

Students will learn the following concepts:

- The Moon rises and sets at different times, depending on its phase.
- A great deal can be learned about the Moon and its position in the sky just by observing it.
- The phases of the Moon are caused by the reflection of the Sun's light off the surface of the Moon and the location of the Earth, Moon, and Sun relative to each other.
- Any body orbiting another can appear to go through phases, depending on their positions in space relative to the Sun (or another light source).

## Objectives

Students will be able to do the following:

- Record observations while viewing the Moon.
- Predict the phases of the Moon.
- Explain why the Moon appears to go through phases as seen from Earth, as well as why the Earth appears to go through phases as seen from the Moon.
- Explain whether other Solar System objects appear to go through phases.

## Science Overview

The Moon, Earth's closest neighbor in space, is the easiest astronomical object to observe. The only "scientific instrument" you need is your eyes. The Moon is the only object in the sky (other than the Sun and occasionally comets that pass very close by the Earth) that does not look like a point of light or an indistinct fuzzy patch to the unaided eye. The way the Moon looks to us here on Earth continually changes. Keeping track of its appearance from night to night (or day to day) is a fascinating way to start getting acquainted with the patterns of change in the sky.

### Appearance of the Moon

The Moon is small, only about a quarter the size of Earth. Early astronomers who studied the Moon with the first telescopes thought that the dark areas were vast oceans, and so they named them mare, the Latin word for "sea." We now know there is no liquid water on the Moon, though there are small amounts of water ice on the Moon's north and south poles, where ice can stay shaded from heating sunlight in deep dark basins and craters. In fact, the Moon is an arid, airless world, not hospitable to any kind of life. The maria (the plural form of the word "mare") are actually large impact craters filled with lava that solidified to form the smooth plains on the surface today.

*Figure 1. The Moon. (Image credit: http://liftoff.msfc.nasa.gov/Academy/UNIVERSE/The_Moon.jpg)*

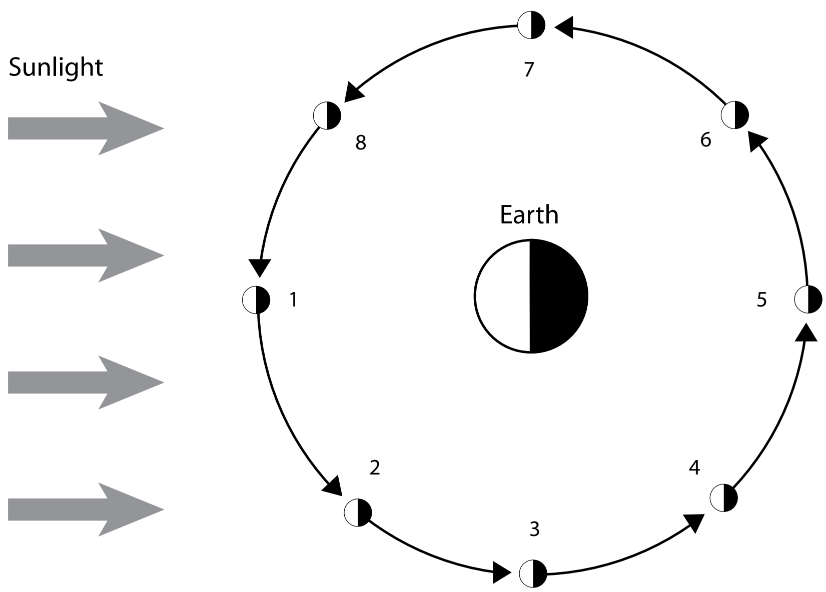
The lighter areas on the surface of the Moon are rocky regions covered with old craters—circular pits or basins blasted out by high-speed impacts from rocks of varying sizes (from objects the size of small cities down to pebbles). Most of the craters bear silent witness to a time, billions of years ago, when collisions between such debris and planets were much more common. The Earth, too, experienced a similar bombardment, but erosion by wind, water, and the movement of the Earth's crust has largely erased ancient craters from the Earth's surface. While the heavy bombardment period is over, impacts still occur. An example of a large crater created fairly recently (about 50,000 years ago) is the roughly 1.2-kilometer (three-fourths of a mile) wide Meteor Crater (also called the Barringer Crater) in Arizona. On the Moon there is no wind or rain to wash away the evidence, and so the cosmic history of our "neighborhood" is preserved for humans to study.

### The Moon's Rotation

During the course of a month the Moon circles once around the Earth; the exact time for the Moon to go once around the Earth is 27 ⅓ days. Over the millennia, the Moon has become "locked" into a special kind of motion around the Earth. The gravitational interaction between the Earth and the Moon has slowed down the rotation of the Moon so that it is now in what is called synchronous rotation. This means that it takes the Moon as long to rotate once around its axis as it takes it to orbit once around Earth. As a result, the same side of the Moon is always facing the Earth throughout its orbit. This is why astronomers speak of the "near side" (the side we see from the Earth) and the "far side" (the side we never see from the Earth) of the Moon. Indeed, it was not until 1959 that the far side of the Moon was first seen, when Luna 3 spacecraft flew around the Moon and took pictures of the previously unseen side of our celestial neighbor.

### Phases of the Moon

The side of the Moon facing the Sun is always illuminated by sunlight; but the illuminated side does not always face the Earth. As the Moon orbits the Earth, the amount of the side of the Moon that is facing us and also illuminated by the Sun varies, changing how much of the lunar surface appears bright and how much is in darkness, as seen from the Earth (see Fig. 2). The changes are known as phases, and they repeat in a specific cycle each month. There are four primary phases: New Moon, First Quarter, Full Moon, and Third Quarter. Each of these primary phases occurs about a week apart, with the Third Quarter followed by another New Moon, which begins the cycle anew (it actually takes 29 ½ days to go from one New Moon to the next).



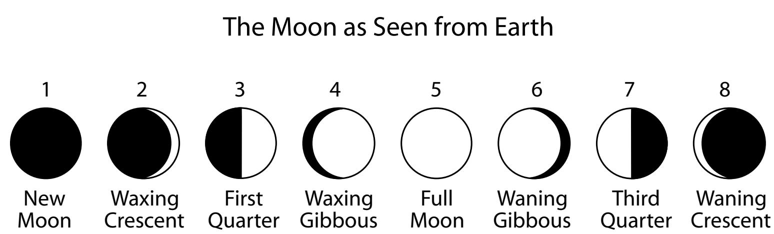




*Figure 2. The Moon as seen from Earth. The word "crescent" means that less than half of the side of the Moon visible to Earth is illuminated by sunlight; the word "gibbous" means that more than half of but less than the full visible side is illuminated. The word "waxing" means that the illuminated portion of the side of the Moon visible to Earth is increasing gradually in size; the word "waning" means that the illuminated portion of the visible side is decreasing gradually in size.*

There are several points about the Moon's phases that need to be emphasized. First, during the week it takes for the Moon to move from one phase to another, the amount of the Moon's surface illuminated by the Sun changes gradually; it is not an abrupt change from one phase to the next. Second, the Moon can be seen during the day, as well as at night. Near both First and Third Quarter the Moon can be seen during the daytime; see Table 1 for more on when the Moon is visible. Finally, it is worth emphasizing that the phases of the Moon do not occur because different amounts of the lunar surface are illuminated by the Sun—half of the Moon is always illuminated by sunlight. The phases of the Moon arise because of changes in how much of the lunar

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surface that is illuminated by sunlight can be seen from Earth as the Moon orbits around our planet. The same is true in reverse: the Earth appears to go through phases when viewed from the Moon.

| Phase of the Moon | The Moon Rises | The Moon is in the Eastern Sky | The Moon is Highest in Sky | The Moon is in the Western Sky | The Moon Sets |
|---|---|---|---|---|---|
| New Moon | sunrise | morning | noon | afternoon | sunset |
| Waxing Crescent | just after sunrise | morning | just after noon | afternoon | just after sunset |
| First Quarter | noon | afternoon | sunset | evening | midnight |
| Waxing Gibbous | afternoon | sunset | night (p.m.) | midnight | night (a.m.) |
| Full Moon | sunset | night (p.m.) | midnight | night (a.m.) | sunrise |
| Waning Gibbous | night (p.m.) | midnight | night (a.m.) | sunrise | morning |
| Third Quarter | midnight | night (a.m.) | sunrise | morning | noon |
| Waning Crescent | just before sunrise | morning | just before noon | afternoon | just before sunset |

*Table 1. The location of the Moon in the sky as seen from Earth during different phases.*

### Eclipses

Even though the Sun and Moon are very different in size, the Moon is so much closer to the Earth than the Sun that the angular size (the angle of the sky they appear to cover) of the two objects as seen from Earth are the same. As a result, the interaction between the two objects in the sky as seen from the surface of the Earth gives rise to eclipses. An eclipse occurs because an object comes in front of a light source. In a solar eclipse, the Moon comes in front of the Sun as seen from Earth. In a lunar eclipse, the Earth comes between the Sun and the Moon and casts a shadow on the Moon.

The Earth's shadow plays no role in the Moon's phases. But Earth's shadow does darken the Moon during a lunar eclipse, at which time the Moon travels through the Earth's shadow in space, and sunlight does not illuminate the Moon as it usually does. The frequency of the lunar eclipses are regulated by the orientations of the orbit of the Earth around the Sun and the orbit of the Moon around the Earth. The Earth orbits the Sun once per year. The plane of the Earth's orbit in space is called the ecliptic. The Sun, the Earth and the Earth's shadow all fall within the plane of the ecliptic. The Moon orbits the Earth once in 27 ⅓ days, or, roughly, once per month. The plane of the Moon's orbit is tilted a little bit (5 degrees) from the plane of the ecliptic. When the Moon is on the side of the Earth away from the Sun (Full Moon; Phase 5 in Fig. 2), it passes very close to the Earth's shadow; in principle, there is a chance of an eclipse every month. But because its orbit is tilted, the Moon usually passes just above or below the Earth's shadow, and no lunar eclipse takes place. About once every six months, however, the Moon goes right through the shadow of the Earth, creating a lunar eclipse (see Fig. 3). However, there are anywhere from 0 to 3 lunar eclipses each year.

While in the Earth's shadow, the Moon looks reddish-orange. This deep color comes about because instead of being illuminated by direct sunlight (as it usually is), the Moon is now illuminated by indirect sunlight passed through the Earth's atmosphere. The Earth's atmosphere filters out most of the blue part of sunlight, causing the light that gets through the atmosphere and is bent toward the Moon to be red or orange in color. How dark the Moon appears during the eclipse depends on which part of the Earth's shadow the Moon is crossing through, as well as on the amount of clouds, dust, or pollution in the Earth's atmosphere.

*Figure 3. A lunar eclipse. (Image credit: science.nasa.gov)*

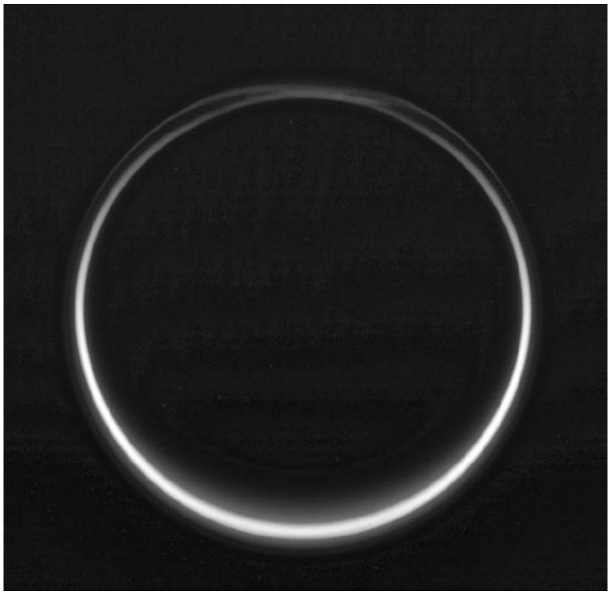

*Figure 4. An annular solar eclipse occurs when the Moon's angular size is slightly less than the Sun's angular size. Therefore, when the Moon is directly in front of the Sun as seen from Earth, the edges of the Sun are still visible. (Image credit: NASA Photojournal; www.photojournal.jpl.nasa.gov)*



In an amazing coincidence, the Sun and the Moon appear to us to be almost the same size in the sky. Although the Moon is actually hundreds of times smaller in size than the Sun, it is just as many hundreds of times closer to the Earth. Because of this, if the Moon happens to pass directly between the Earth and Sun, it can momentarily block out the Sun, creating a solar eclipse. This happens when the Moon is on the same side of the Earth as the Sun (New Moon; Phase 1 in Fig. 2). Again, because of the tilt of the Moon's orbit, it usually passes just above or below the Sun's position at this time. But, about every six months the Moon passes directly between the Earth and the Sun and casts a shadow on the surface of Earth. Inside this shadow, a total solar eclipse can be observed. Because the Moon's shadow is small, however, only a small portion of the Earth's surface will see the Moon completely block out the Sun; this so-called path of totality is typically thousands of kilometers long but only at most 267 km (166 miles) wide. Outside this path, in an area about 8,000 km (5,000 miles) wide, people will see the Moon block only part of the Sun's surface, which creates a partial solar eclipse; it looks like a "bite" has been taken out of the Sun. Beyond this area, no eclipse is seen.

### Humans on the Moon

The Moon is the only place in the entire Solar System, other than Earth, which human beings have visited. The astronauts who landed on the Moon in the late 1960s and early 1970s returned with samples of rocks taken from the Moon's surface. Studies of these lunar samples continue to yield important information about the early history of the Moon, the Earth, and the inner Solar System. For example, the lunar rocks analyzed in laboratories here on Earth showed the composition of the Moon to be similar to the Earth's crust. Combined with recent computer simulations, these results suggest that the Moon was probably formed from the debris blasted into space from the Earth when our planet was struck by a Mars-sized object billions of years ago.

### Phases of Other Objects in the Solar System

Venus is an inferior planet to the Earth; that is, it orbits the Sun at a closer distance than the Earth. Because of this, Venus appears to go through similar phases as the Moon when observed from Earth. The reason for the phases is the same as for the Moon—we can see different amounts of the object's surface that is illuminated by sunlight, but the geometry of the Venus-Earth-Sun system that causes the phases (see Fig. 5) is different from the Moon-Earth-Sun system (Fig. 2). Since Venus appears to be bigger in the sky when Earth and Venus are on the same side of the Sun in their orbits, and smaller when they are on the opposite sides of their orbits, the size of Venus, as seen in the sky, corresponds to the phase of the planet. As shown in Figure 5, when Venus is going through a full phase, it is farther from the Earth and appears smaller than when it is going through a crescent phase and is closer to Earth. When the Moon goes through phases, the distance from Earth varies very little, so this effect is not nearly as apparent as it is for Venus.

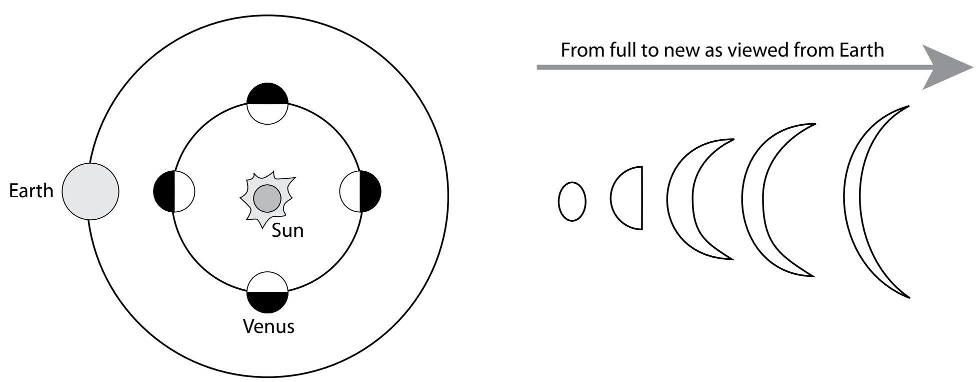


*Figure 5. The phases of Venus as seen from Earth. Venus appears to wax and wane as viewed from the Earth, similar to what the Moon looks like during its phases. When Venus is full, we cannot see it because it is on the opposite side of the Sun, and the Sun blocks our view of the planet. As Venus wanes from the full phase, it also appears to get bigger because it is approaching us. When it is closest to us—and would appear as new Venus—we cannot see it because no light from the planet is reflected toward us. (Note: Not to scale)*

Mercury's orbit, like Venus's, is inside the Earth's. As a result, Mercury appears to go through a complex set of phases, quite distinct from those of the Moon and Venus, though the basic cause of the phases is the same: we can see varying amounts of the side of the object that is illuminated by sunlight (see Fig. 6).

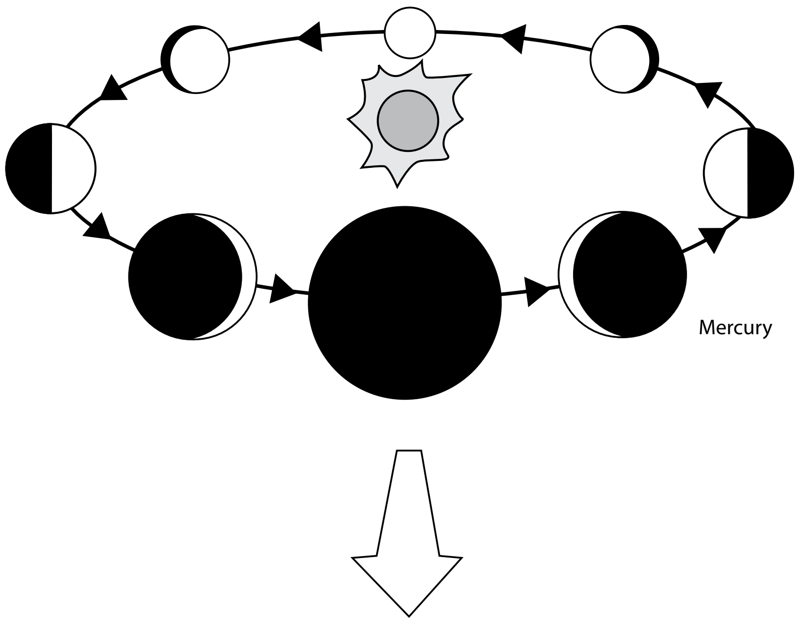


*Figure 6. The phases of Mercury as seen from Earth. Just like Venus, Mercury appears to wax and wane as it orbits the Sun. When Mercury is full, we cannot see it because it is on the opposite side of the Sun. When it wanes from full, the planet appears to grow bigger because it is approaching Earth. When Mercury would appear new, we cannot see it because no light is reflected from the planet toward us. (Note: Not to scale)*

The superior planets (those whose orbits are further away from the Sun than Earth's orbit) do not go through phases as viewed from Earth because when viewing these planets from Earth, the Sun is always illuminating the same side of the planet that is viewable from Earth. However, if you were on one of these planets, their moons would go through phases; or, if you were on one of their moons, the planet would appear to go through phases. In addition, if you were on any outer planet and looked at a planet inferior to it, the inferior planet would go through phases for the exact same reasons that Venus and Mercury go through phases as seen from Earth.

# Conducting the Lesson

## Warm-Up & Pre-Assessment

The students brainstorm and create a Thinking Web that demonstrates the students' knowledge of the Moon. This is an opening exercise to introduce the study of the Moon to students and to assess prior knowledge.

### Student Materials (per student)

- Thinking Web Worksheet (located in the back of the lesson)

### Preparation & Procedures

1. Make copies of the Thinking Web Worksheet, one per student.

2. Have students complete each sentence on the Worksheet and encourage them to draw illustrations to go with their answers.

3. Ask students to share their answers with the class.

Use the Thinking Web Worksheet as a starting point to create a KWL Chart. Once the students have thought just about the Moon in the Warm-Up, the KWL chart will get them to start thinking about the relationship between the Moon, the Earth, and the Sun. As a class, fill in the first two columns before beginning Activity 1, and fill in the last column at the end of the lesson in order to assess what students have learned about the Earth-Moon-Sun relationship.

| What I Know | What I Want to Know | What I Learned |
|---|---|---|
| List everything you know already about how the Moon, Earth, and the Sun interact. | Write down the questions you have about the Moon, the Earth, and the Sun. | This section will be completed once you have finished the Earth-Moon-Sun activity. |
| | | |

## NOTES:

## Activity 1: Viewing the Moon

This activity focuses students' attention on the appearance of the Moon, and the observed changes over a month. Most students only have a rudimentary understanding of this obvious phenomenon in the night sky. After observing the phase cycle they will hypothesize why it occurs, and see if their hypothesis is correct in Activity 2.

### Student Materials (per student)

- Student Worksheet 1 (located in the back of the lesson)
- *Phases of the Moon Picture* (optional; located in the back of the lesson)
- Pencil or black crayon

### Preparation & Procedures

1. Make copies of Student Worksheet 1, one for each student.

2. Ask students if anyone noticed the Moon that day or the day before, and what it looked like. Discuss how it looked, what shape it was, whether you could see it in the daytime, etc.

3. Lead the students to the idea of keeping a Moon Journal to observe how the appearance of the Moon changes from one day to another. You can use the following questions to facilitate your discussion:

   If you looked at the Moon tomorrow, would it look the same as today? (*Desired answer: no*) Why? (*Desired answer: the appearance of the Moon changes; sometimes the Moon looks full, sometimes it looks like a sliver*) When will it look the same as it does today? (*Desired answer: in about one month*) How do you know this? (*Desired answer: we learned it in school, or my parents*

#### Teaching Tip

Alternatively, if you do not want to take the time to have the students observe the Moon, you can give students the *Phases of the Moon Picture* located in the back of the lesson and have them answer the questions on Student Worksheet 1 based on the picture rather than their observations. As is, the activity can be started on any day of the week or during any phase of the Moon, and can be continued for as long as one month or as little as one week.

*told me*) How could find out for yourselves how long it takes for the Moon to look the same as today? (*Desired answer: check how the Moon looks each day until it looks the same. This is how scientists figure out how long it takes for a sequence like this to occur—they make observations until they see the pattern.*) This way the students might feel more that they are doing their own experiment rather than replicating something people have done in the past.

3. Tell the students that they will be keeping a Moon Journal to help them figure out what the Moon looks like and when it will look the same as it does today. Hand out Student Worksheet 1 and have students complete the Moon Journal over the next month. Be sure the students understand that they need to color in the portion of the Moon that is NOT easily visible every day using a pencil or black crayon. The students will have to skip days when the Moon is not visible in the sky (such as cloudy or rainy days).

4. Ask the students to predict what the Moon will look like tomorrow, next week, and in one month, and write down their responses. Ask students to also predict why this happens. For example, does the Moon actually change its shape, and that is why we see it changing? Or is it our perspective of the Moon from Earth? What exactly is it that is making the Moon appear to change shape? Write down the responses.

### Teaching Tip

If students are not able to do this activity at home, you can take a minute at the end of the class period every day to fill in Student Worksheet 1 as a class. The Moon may be visible during your class period, and you just have to look out the window to see it. If it is not, you can tell the class to try and observe the Moon in the sky every day so that everyone can remember what it looked like when you fill in the chart together.

### Curriculum Connections

*Language Arts:* As part of the students' Moon Journal, have them write a paragraph every day or every week explaining in detail what the Moon looked like, if they were confused or curious about why the Moon was visible when it was, etc.

## Reflection & Discussion

1. After the activity, lead a class discussion about the questions on Student Worksheet 1 so that the students may interpret what they have learned. You can use the following questions to facilitate your discussion:

   How did the appearance of the Moon change during the observation period? (*Desired answer: the Moon appeared to get fuller until it looked like a circle, then it got smaller again until you could not see it anymore, and then it appeared to grow again; depending on when the students began and ended their study, this answer may vary.*)

   How long did it take (or you think it takes) for the Moon to go through one complete cycle of changing appearance? (*Desired answer: about one month*). How do you know this? (*Desired answer: if students watched the Moon for one month, the Moon should have completed a cycle and now look like it did when they started. If students watched the Moon for less than one month, it should have gone from full to new in two weeks, for example, and they should understand that it will take two more weeks to complete the cycle.*)

   What exactly is changing—is the Moon really getting bigger and smaller? (*Desired answer: no, the Moon is always shaped the same way, but we are looking at it differently.*) How can you tell? (*Desired answer: answers may vary; the Moon can't just disappear. Sometimes you can see the outline of the rest of the Moon when it is just a sliver. It looks like a shadow on the Moon that is covering it up. The dark side is just not lit up like the light side is.*)

   Did you notice a connection as to when the Moon rose and set versus what the Moon looked like? (*Desired answer: Half Moons where the right side is lit—First Quarter—are high in the sky around sunset. Full Moons are high in the sky around midnight. Half Moons where the left side is lit—Third Quarter—are high in the sky early in the morning. You can use Table 1 in the* Science Overview *to see how the phase of the Moon corresponds to the times the Moon can be viewed at different parts of the sky.*)

2. Compare the predictions the students made before the activity to the results. Ask the students to explain any discrepancies between the two.

### Transfer of Knowledge

Ask students to predict what the Moon will look like one week from today. Make sure they justify their answer.

*Answer:*

| If the phase of the Moon today is: | In one week the phase of the Moon will be: |
|---|---|
| Full | Third Quarter |
| Third Quarter | New |
| New | First Quarter |
| First Quarter | Full |

### Extensions

- Have students find out whether the Moon would look the same for people on the other side of the Earth. Does the Moon rise and set at the same times everywhere? Is the phase the same everywhere when it rises and sets on a specific day?

### Placing the Activity Within the Lesson

Students have now observed the Moon and have hypothesized why and how the phases of the Moon occur. Have the students discuss with a partner any differences in their hypotheses, and how they could possibly test those differences in the classroom. In the next activity, the students will be doing exactly that, testing their hypotheses.

### Lesson Adaptations

*ESL:* Non-English speaking students can draw a picture of what the Moon will look like in one week rather than coming up with the name of the phase.

## Assessment Criteria for Activity 1

4 Points

- Student completed the Moon Journal in Student Worksheet 1.
- Student answered the questions in Student Worksheet 1 correctly.
- Student answered *Transfer of Knowledge* correctly.
- Student justified his or her answer to the *Transfer of Knowledge*.

3 Points

- Student completed three of the four assessment criteria above.

2 Points

- Student completed two of the four assessment criteria above.

1 Point

- Student completed one of the four assessment criteria above.

0 Points

- No work completed.

## Notes on Activity 1:

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## Activity 2: The Earth-Moon-Sun System

Students will construct a small model of the Moon's orbit around Earth. Light from an overhead projector will be used to represent light from the Sun. By moving a model Moon in its orbit around Earth, students will be able to see the phases of the Moon and gain a conceptual understanding of the phenomenon.

### Teacher Materials

- Overhead projector

### Student Materials (per pair of students)

- Student Worksheet 2
- *Phases of the Moon Diagram* (located in the back of the lesson)
- Gum ball (or ball of light-colored modeling clay about the size of a gumball [1 ½ cm or ½ in. diameter])
- Small piece of modeling clay
- 1 paper fastener
- Scissors
- Tape (three or four strips)
- Desk or table

### Preparation & Procedures

1. Make copies of Student Worksheet 2 and *Phases of the Moon Diagram*, one for each pair of students.

2. Facilitate a discussion about the phases of the Moon. You can use the following series of questions in order to lead the students to the desired conclusion: Does the Moon shine its own light or is it illuminated by the Sun? (*Desired answer: it is illuminated by the Sun. You could lead them to guess the Sun if you draw the comparison to the Earth—does the Earth shine its own light? If students say yes, why can't we see as well at night as we see during the day? Because it is sunlight that illuminates the Earth and causes day and night.*)

   What does the Moon look like when you observe it from Earth? (*Desired answer: The appearance of the Moon changes; the Moon goes through phases. Answers will likely vary, because students will each have different mental models of what the Moon looks like. Sometimes it is a fully illuminated disk, while at other times it is only a crescent. Because the Moon goes through phases, many different answers may be correct.*)

The orbital period of the Moon is about one month, which means it takes about one month for the Moon to orbit the Earth. Do you think the orbit of the Moon might have anything to do with the phases? (*Desired answer: yes, especially because it is roughly the same time as the cycle of phases.*)

Ask for hypotheses for the appearance of the Moon. If students do not suggest the connection between Moon's orbital motion and the phases, you could ask if the Moon stays in one place in space (*Desired answer: no, it orbits the Earth*) One hypothesis that should come out in the conversation is the idea that the Moon is reflecting the Sun's light, and we see the Moon in different phases as a result of the Moon orbiting the Earth.

Tell the students that everyone will first be experimenting with this idea, and that they can experiment with other ideas at a later time. Ask the class if anyone can think of a way that we could investigate how the Earth-Moon-Sun relationship works right here in the classroom to test this hypothesis. (*Desired answer: Students can construct a model of the Earth-Moon-Sun system, using a light to represent the Sun and a ball to represent the Moon. We can take the place of the Earth, so that our eyes represent the viewpoint of an observer on the Earth*)

3. Place students into pairs. Lower the overhead projector light so that it is almost level with the students' tables. Darken the room. Hand out Student Worksheet 2 to each pair of students, as well as the student materials.

### Reflection & Discussion

1. Ask the students to share their results. Are the answers consistent with what they observed in Activity 1? If not, discuss why not.

2. If there were any other hypotheses given by the students as to why there may be phases of the Moon, ask students how they could test those hypotheses, as well. A few examples are included in the *Teacher Answer Key*.

3. Hand out the Phases of the Moon Diagram to introduce the names of the phases of the Moon, i.e., New Moon, Waxing Crescent, First Quarter, Waxing Gibbous, Full Moon, Waning Gibbous, Third Quarter, Waning Crescent.

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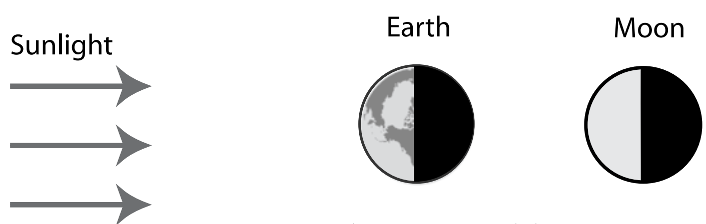
## Transfer of Knowledge

Discuss with students the fact that just as the Moon goes through phases as seen from Earth, so does the Earth when seen from the Moon. Ask students to write an answer to the following questions:

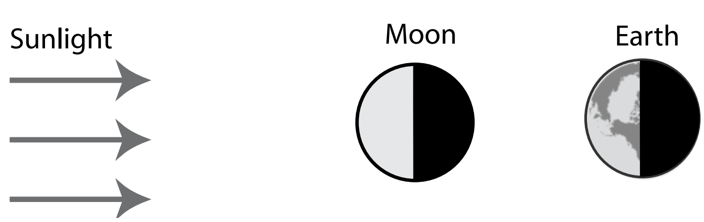
a) If you look up in the sky and see a Full Moon, what phase would the Earth appear to be in if you were an astronaut on the Moon? b) What if the viewer on Earth sees a New Moon? c) First Quarter Moon? Explain your answers and how you came to your conclusions. Draw a picture to help you explain.

*Answers: (Note that in the following pictures, Earth is seen from above its north pole.)*
*a) If the entire sunlit side of the Moon (the side of the Moon facing the Sun) is visible to an observer on Earth—that is, it is Full Moon—then the configuration is the following. In this case, none of the sunlit side of Earth (the side of Earth facing the Sun) is visible to the Moon, and so it would appear to be a new Earth to an observer on the Moon.*



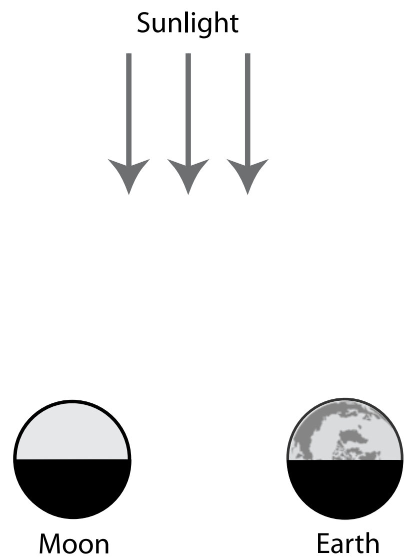

*(Note: sizes and distances not to scale.)*

*b) If none of the sunlit side of the Moon (the side of the Moon facing the Sun) is visible to an observer on Earth—that is, it is New Moon—then the configuration is the following. In this case, the entire sunlit side of Earth (the side of Earth facing the Sun) is visible to the Moon, and the phase would therefore be a full Earth to an observer on the Moon.*




*(Note: sizes and distances not to scale.)*

*c) If half of the sunlit side of the Moon (the side of the Moon facing the Sun) is visible to an observer on Earth, and that half is to the observer's right—that is, it is First Quarter Moon—then the configuration is the following. In this case, half of the sunlit side of Earth (the side of Earth facing the Sun) is visible to an observer on the Moon, and since that half is to the observer's left, the phase would be a Third Quarter Earth.*




*(Note: sizes and distances not to scale.)*

### Extensions

- Review with students the reasons for solar and lunar eclipses; see the *Science Overview* for details.
- Ask students to write an answer to the following questions:

  When the Moon appears to cover the Sun as seen from the Earth, this is called a solar eclipse. When we see a solar eclipse, the Moon must be at which phase? *Answer: New Moon*

  When the Earth's shadow appears to cover the Moon, as seen from the Earth, this is called a lunar eclipse. When we see a lunar eclipse, the Moon must be at which phase? *Answer: Full Moon*

### Placing the Activity Within the Lesson

Discuss with the students how this model relates to the actual positions of the Earth, the Moon, and the Sun. Remind the students that while the Moon orbits the Earth, the Earth-Moon system also orbits the Sun. Also discuss how you could create a model to look at phases that other planets appear to go through as seen from Earth.

Going Through a Phase
Lesson at a Glance
Science Overview
Conducting the Lesson
*Warm Up & Pre-Assessment*
*Activity 1: Viewing the Moon*
*Activity 2: The Earth-Moon-Sun System*
*Lesson Wrap-Up*
Resources

## Assessment Criteria for Activity 2

4 Points

- Student completed all eight phases of the Moon in Student Worksheet 2 correctly.
- Student answered the *Transfer of Knowledge* correctly for parts a, b, and c.
- Student explained her/his answer to the *Transfer of Knowledge*.

3 Points

- Student completed at least six of the eight phases of the Moon in Student Worksheet 2 correctly.
- Student answered the *Transfer of Knowledge* correctly for two of the three parts (a, b, and c.)
- Student explained her/his answer to the *Transfer of Knowledge*.

2 Points

- Student completed at least six of the eight phases of the Moon in Student Worksheet 2 correctly.
- Student answered the *Transfer of Knowledge* correctly for one of the three parts (a, b, or c.)
- Student explained her/his answer to *Transfer of Knowledge*.

1 Point

- Student completed at least four of the eight phases of the Moon in Student Worksheet 2 correctly.
- Student attempted to answer the *Transfer of Knowledge* for parts a, b, and c.
- Student attempted to explain her/his answer for *Transfer of Knowledge*.

0 Points

- No work completed.

## Notes on Activity 2:

## Lesson Wrap-Up

### Transfer of Knowledge for the Lesson

Ask the students which planets, as viewed from the Earth, appear to go through phases. You can have the students create a new model, or have them draw pictures to help visualize this. Make sure the students remember the order of the planets from the Sun.

Now ask the students to figure out which planets experience phases as seen from Jupiter. When this is done, ask them if they can think of a "rule of phases." They should come up with the fact that planets that orbit the Sun closer to the Sun than the planet on which the observer is located will experience phases, and planets further away will not.

### Lesson Closure

Students have now demonstrated for themselves the reasons for the phases of the Moon. Discuss with them how early scientists would have had to figure this out using the exact same process that they used. They observed the Moon, created a hypothesis for why the Moon appeared to go through phases, and then had to come up with a way to test that hypothesis. If some evidence came along that disputed their hypothesis, they would have to come up with a new one and test that, as well.

Be sure to discuss the *Transfer of Knowledge for the Lesson* with the students. You may also want to discuss eclipses in greater detail; for example, why we do not see an eclipse every month. You can use the *Science Overview* for a reference. Finally, complete the KWL chart you started during the *Warm-Up & Pre-Assessment*.

## Assessment Criteria for the Lesson



4 Points
- Student indicates that Mercury and Venus appear to go through phases as seen from Earth.
- Student indicates that Mercury, Venus, Earth, and Mars appear to go through phases as seen from Jupiter.
- Student indicates a correct "rule of phases."

3 Points
- Student indicates that Mercury and Venus appear to go through phases as seen from Earth.
- Student indicates that Mercury, Venus, Earth, and Mars appear to go through phases as seen from Jupiter.
- Students attempts to indicate a "rule of phases."

2 Points
- Student indicates that Mercury and Venus appear to go through phases as seen from Earth.
- Student does not come up with the correct list of planets that will go through phases as seen from Jupiter.
- Student attempts to indicate a "rule of phases."

1 Point
- Student does not come up with the correct list of planets that will go through phases as seen from Earth.
- Student does not come up with the correct list of planets that will go through phases as seen from Jupiter.
- Student attempts to indicate a "rule of phases."

0 Points
- No work completed.

# Resources

## Internet Resources & References

*Student-Friendly Web Sites:*

Apollo 11 Video Clips
space.about.com/od/apollo11videos/

Google Moon
www.google.com/moon/

Lunar Phase Animation
www.solarviews.com/cap/moon/vmoon2.htm

Science Netlinks Moon Challenge
www.sciencenetlinks.com/interactives/moon/moon_challenge/moon_challenge.html

*Teacher-Oriented Web Sites*

American Association for the Advancement of Science Benchmarks for Science Literacy
www.project2061.org/publications/bsl/online/bolintro.htm

The Full Moon Atlas
www.lunarrepublic.com/atlas/index.shtml

NASA Eclipses Web Site
eclipse.gsfc.nasa.gov

National Science Education Standards
www.nap.edu/html/nses/

National Space Science Data Center – The Moon
nssdc.gsfc.nasa.gov/planetary/planets/moonpage.html

Nine Planets – The Moon
www.nineplanets.org/luna.html

U.S. Naval Observatory Astronomical Applications Department's Data Services: Moon Phase, Moonrise and Moonset Times
aa.usno.navy.mil/data/

Voyage: A Journey through Our Solar System
www.voyagesolarsystem.org

Journey through the Universe
www.journeythroughtheuniverse.org

## Teacher Answer Key

### Student Worksheet 1

1. Sample answer: The Moon appears to change in shape during the month. It got fuller until it looked like a circle, then it got smaller again until you could not really see it anymore, and then it appeared to grow again. The surface of the Moon looked the same, however, and it appeared that the same part of the Moon was facing the Earth the entire time. Some students might even remark that even when the whole Moon was not brightly lit (such as during Half Moon or Crescent Moon), you can see the rest of the Moon, just not as easily as when more of the Moon appears bright. Also, some students may note that you always see the same features on the surface — they all may not just be in the bright part of the Moon at all times.

2. If the students observe the Moon for one month, they will find out that the lunar cycle is about one month (29.5 days). If students observe the Moon for less than one month, they should see that, for example, it took one week for the Moon to go from Full Moon to Half Moon. So it should take another week to disappear completely (New Moon), then another week to go back to Half Moon, then full again—four full weeks, (which would lead to the estimate of 28 days), or about one month.

3. If you observe carefully, you will notice that the size of the Moon is not changing, only its apparent shape. In fact, when the Moon is only a crescent, you can sometimes see the outline of the other side of the Moon. This change in shape is due to the amount of the Moon illuminated by sunlight that can be seen from Earth. You can see this because the surface of the Moon looked the same; the features on the Moon's surface never changed places. If the Moon was rotating at a different pace than what it takes for the Moon to orbit once around the Earth, for example, then we would see different parts of the Moon at different times. So, it is not the shape of the Moon that is changing, it is just the amount of the Moon illuminated by sunlight that we can see here on Earth that is changing. (Remember that the amount of the Moon that is illuminated by sunlight is always the same; it is just the amount of the sunlit side that is visible from Earth that changes.)

4. The Full Moon rises at sunset and is high in the sky around midnight. Half moons where the right side is lit—First Quarter—rise at noon and are high in the sky around sunset. Half moons where the left

side is illuminated—Third Quarter—rise at midnight and are high in the sky early in the morning, around sunrise.
[Note: A lot of leeway should be given to the actual answers. You may not want to have the students staying up until midnight to observe the Moon. You can use Table 1 in *Science Overview* to check the students' answers for other times. Note also that if you have not introduced the terms for the different phases to the students, they probably will not use terms like "First Quarter", etc.]

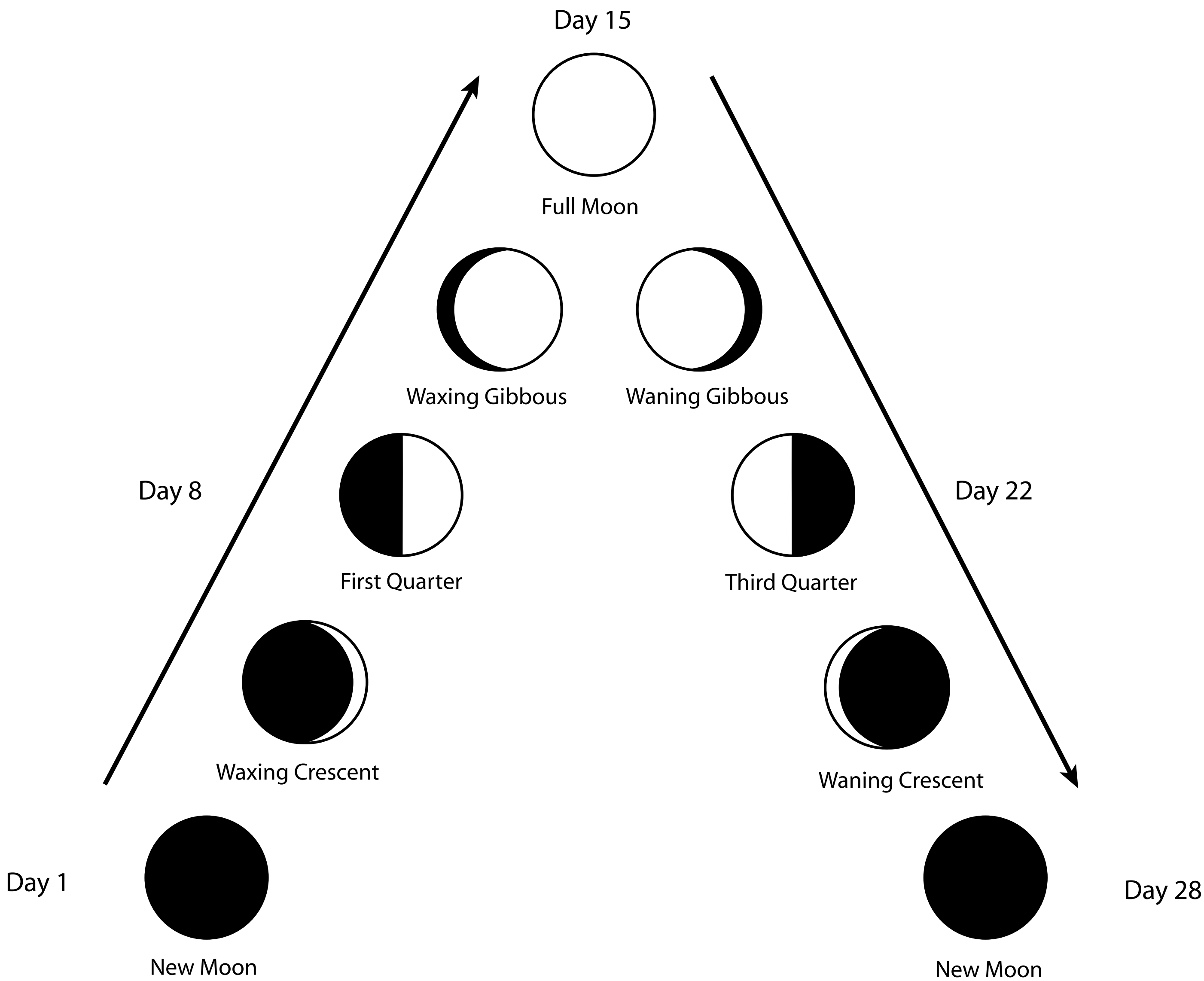
5. Answers will vary. The important part is that the student explains why there was or was not a difference.

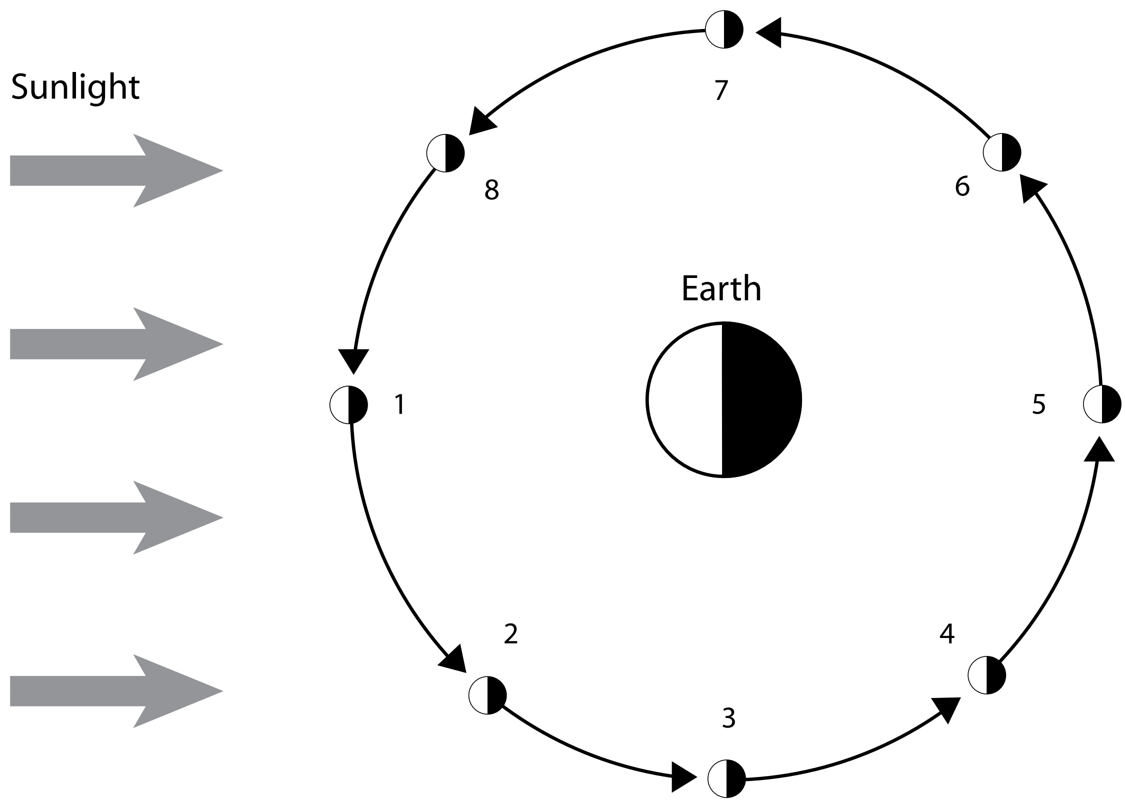
### Student Worksheet 2

1. Answers will vary. The important part is that the student explains why the results are consistent (or not.)

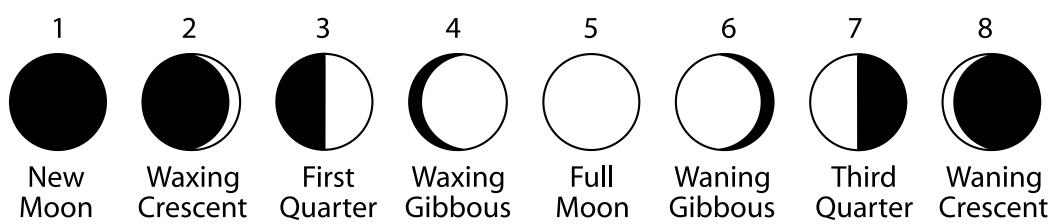
2. Students can be creative with their answers. One possibility is that the Moon actually disappears slowly over a couple of weeks and then slowly reappears. In order to test whether this were true, students could send a robot to the Moon to check if there is actually something there when it disappears, for example. Or students could use a telescope to see whether the Moon disappears during New Moon, or whether they can see anything on the part of the Moon's surface that is not illuminated during a Crescent Moon, for example. Students should be able to reason that this is not the case, as from their every-day experiences, they should understand that things do not usually just disappear and reappear. Another hypothesis could be that half of the Moon is permanently dark and the other half is giving off light (rather than being illuminated by sunlight), and we see phases because the Moon is rotating. Students could test this hypothesis, as well. (Note: this hypothesis does not work for many reasons, which can be a part of student discussion. For example, we notice that the same side of the Moon is facing the Earth at all times, so the same side cannot be dark all the time since we see the same area of the Moon appear illuminated and dark during the lunar cycle. We also know that the Moon does not give off light of its own; it just reflects sunlight, so this hypothesis does not work for that reason, either.)
[Note, however, that it is not necessary for students to come up with an alternative hypothesis, since the one they tested is correct. This question is intended just to remind students of the scientifc process where many hypothesis may be considered before the correct one is discovered and agreen upon.]

Notes:


Day 15
Full Moon
Waxing Gibbous
Waning Gibbous
Day 8
First Quarter
Third Quarter
Day 22
Waxing Crescent
Waning Crescent
Day 1
New Moon
New Moon
Day 28




## The Moon as Seen from Earth




The Moon as seen from Earth. The word "crescent" means that less than half of the side of the Moon visible to Earth is illuminated by sunlight; the word “gibbous” means that more than half of but less than the full visible side is illuminated. The word “waxing” means that the illuminated portion of the side of the Moon visible to Earth is increasing gradually in size; the word “waning” means that the illuminated portion of the visible side is decreasing gradually in size.

JOURNEY through the UNIVERSE

The Moon looks like...

I know the Moon is...

Sometimes the Moon is...

If I went to the Moon I would study...

## Student Worksheet 1
## The Moon Journal

For the next month, look for the Moon each day. Observe it closely. Draw the shape of the Moon in the circle. Leave the part you can see white, and shade the rest of the circle with a pencil or black crayon. Write down the time you saw the Moon. If it is cloudy, write "cloudy" on that day's log record. If the weather is not cloudy, but you do not see the Moon at all while you are awake, fill in the circle entirely.

| Day 1 | Day 2 | Day 3 | Day 4 | Day 5 | Day 6 |
|---|---|---|---|---|---|
| Date: Time: | Date: Time: | Date: Time: | Date: Time: | Date: Time: | Date: Time: |
| **Day 7** | **Day 8** | **Day 9** | **Day 10** | **Day 11** | **Day 12** |
| Date: Time: | Date: Time: | Date: Time: | Date: Time: | Date: Time: | Date: Time: |
| **Day 13** | **Day 14** | **Day 15** | **Day 16** | **Day 17** | **Day 18** |
| Date: Time: | Date: Time: | Date: Time: | Date: Time: | Date: Time: | Date: Time: |
| **Day 19** | **Day 20** | **Day 21** | **Day 22** | **Day 23** | **Day 24** |
| Date: Time: | Date: Time: | Date: Time: | Date: Time: | Date: Time: | Date: Time: |
| **Day 25** | **Day 26** | **Day 27** | **Day 28** | **Day 29** | **Day 30** |
| Date: Time: | Date: Time: | Date: Time: | Date: Time: | Date: Time: | Date: Time: |

JOURNEY through the UNIVERSE

After you have completed The Moon Journal for as many days as your teacher instructed, answer the following questions:

1. How did the Moon change during the time you observed it in The Moon Journal?

2. How long did it take (or you think it takes) for the Moon to make one complete cycle? How do you know this?

3. What exactly is changing—is the Moon really getting bigger and smaller? How can you tell?

4. Did you notice a connection as to when the Moon rose and set, or when it was high in the sky, versus what the Moon looked like?

5. Compare your predictions from before you started The Moon Journal to your answers here. Are there any differences? Explain why or why not.

## Student Worksheet 2:
## Why Do We See Different Phases of the Moon?

Name ______________________________________________ Date ___________

### Student Materials (per pair of students)

- Gumball (or ball of light-colored modeling clay about the size of a gumball [1 ½ cm or ½ in. diameter])
- Small piece of modeling clay
- 1 paper fastener
- Scissors
- Tape (three or four strips)
- Desk or table

### Procedures

1. Cut out Circle A as close to the circle as you can but leaving the entire picture intact.
2. Push the paper fastener through the center of Circle A (front to back.)
3. Push the paper fastener through the center of Circle B (front to back), so that Circle A is on top of Circle B and the figures and texts on both Circles are visible.
4. Spread the flaps of the paper fastener apart so that they are flat against the paper and tape them to the paper.
5. Tape your model to the table or a piece of cardboard so that the part labeled SUNLIGHT is facing the overhead projector.
6. Push the small piece of clay onto the spot that says "Gum Ball" on circle A.
7. Next, push the gum ball into the clay so that it is secure. This gum ball is your model Moon.
8. Line up the model Moon with the number one (1) in Circle B.
9. Lean down so that you are eye level with the table and look at the model Moon from the point of view of the observer on the model Earth. This viewing spot allows you to observe the Moon as it would look from the observer's point of view from Earth.
10. Draw a picture of what you see in the box directly BEHIND the model Moon.
11. Rotate the Circle A disk so that the model Moon moves to number two (2), and repeat steps 9 and 10. Note: do not block the light from the overhead projector illuminating the model Moon.
12. Repeat steps 9 through 11 for position numbers three (3), four (4), five (5), six (6), seven (7), and eight (8).

Note that the sizes and distances in the activity are not to scale. Below is an actual picture of the Earth and the Moon taken from space. As you can see, the Earth is about 4 Moon diameters wide, and you could fit about 100 Moons in the distance between the Earth and the Moon. For this activity, the model Earth and the model Moons are bigger than they should be so that you can more easily see how the phases of the Moon occur.

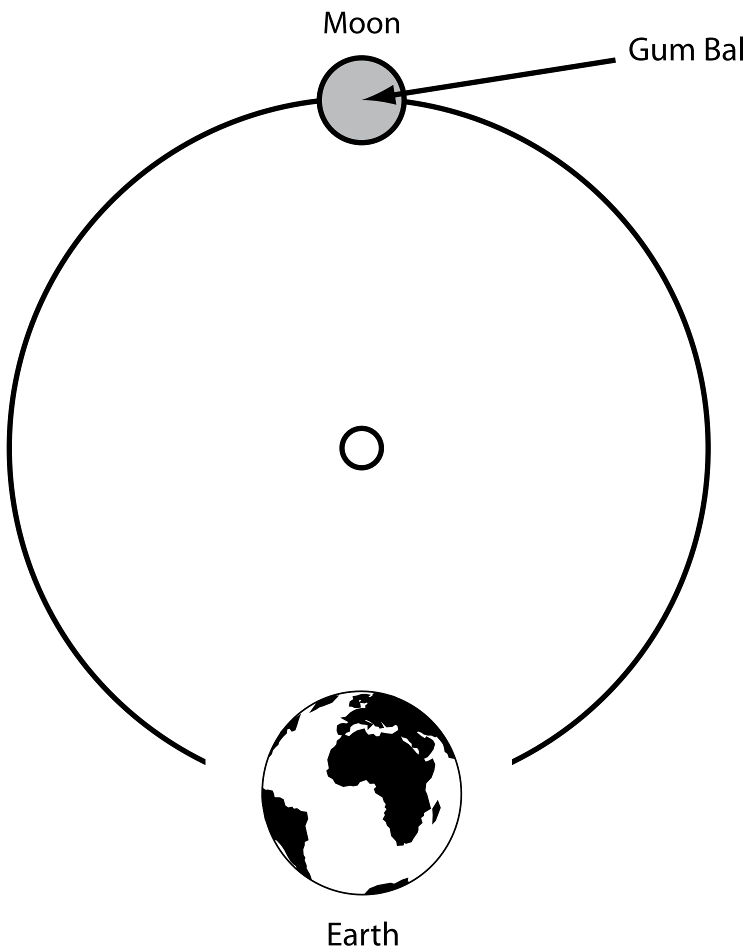
*(Image credit: http://photojournal.jpl.nasa.gov/)*

## Questions

1. Are your results consistent with what you observed and recorded in your Moon Journal? Explain.

2. Can you think of another explanation for the phases of the Moon other than what you have just experimented with? If so, explain why another hypothesis may be correct or incorrect, and explain how you could make an experiment to demonstrate whether or not this is true.

# Circle A



# Circle B