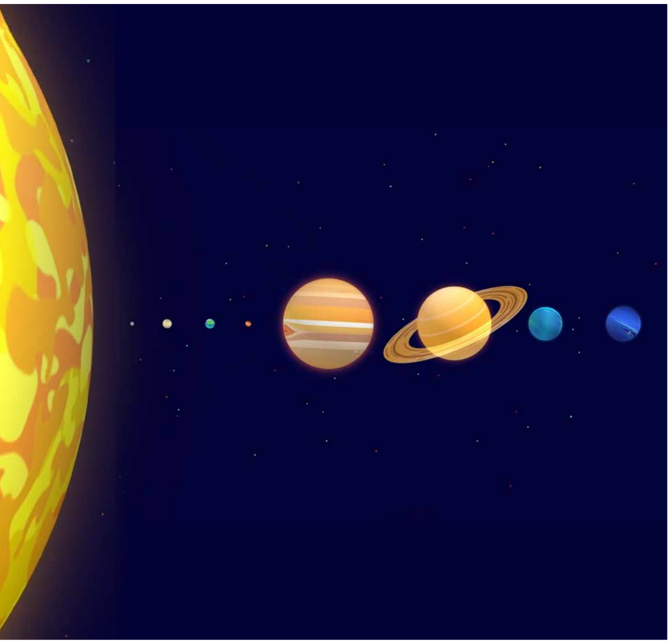
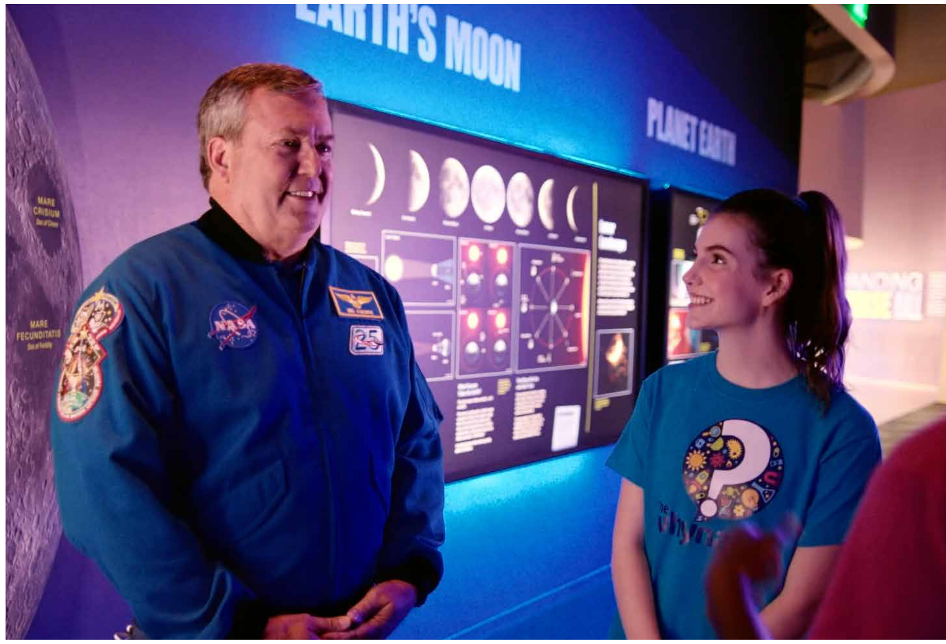
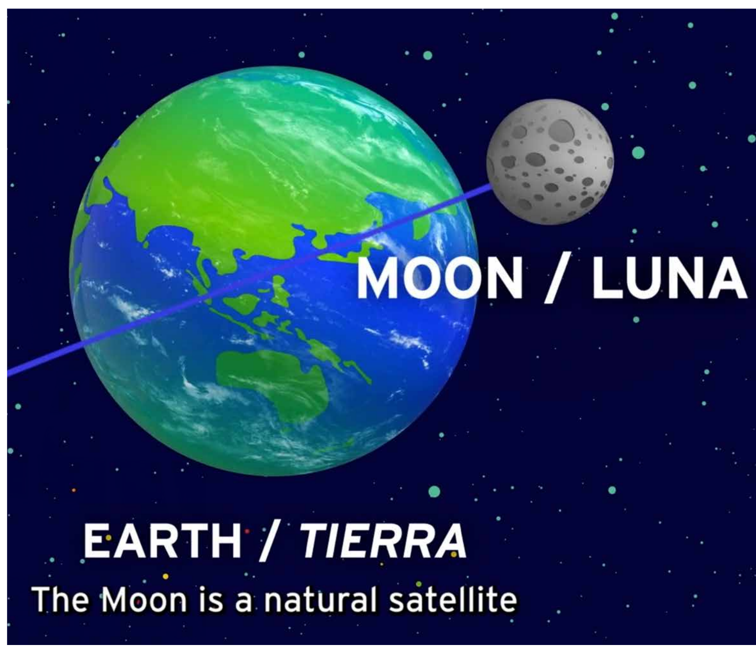
THE WHYNAUTS:

Episode 6: Exploring Our Solar System

EDUCATOR GUIDE SUGGESTED GRADE LEVELS 6-8







The Whynauts

Perot Museum of Nature and Science

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INTRODUCTION

HOW TO USE THIS GUIDE

The Whynauts "**Exploring Our Solar System**" Video explores the relative sizes and distances of the objects in our solar system and how gravity governs their motion. This guide is designed to help you incorporate the video into a complete learning experience for your students. It is composed of three main sections:

The **Viewing Strategies and Tools** section includes suggested discussion questions and a pre- and post-assessment to track student learning.

The **Supplemental Activities** section includes four activities that can be used in any order or combination.

The **Additional Resources** section includes a glossary, reading list, and links to continue learning.

LEARNING OBJECTIVES

Students will be able to:

- Describe Earth's place in relation to the other objects in our solar system.
- Explain how gravity is the force that governs the motion of our solar system.
- Identify the characteristics that allow life to exist on Earth.

TEKS ALIGNMENT

SCIENTIFIC AND ENGINEERING PRACTICES

6-8.2A. Identify advantages and limitations of models such as their size, scale, properties, and materials.

SCIENCE CONCEPTS

7.9A. Describe the physical properties, locations, and movements of the Sun, planets, moons, meteors, asteroids, comets, Kuiper belt, and Oort cloud.

7.9B. Describe how gravity governs motion within Earth's solar system.

7.9C. Analyze the characteristics of Earth that allow life to exist such as the proximity of the Sun, presence of water, and composition of the atmosphere.

MATH

6.5A. Represent mathematical and real-world problems involving ratios and rates using scale factors, tables, graphs, and proportions.

NGSS ALIGNMENT

MS-ESS1-2. Develop and use a model to describe the role of gravity in the motions within galaxies and the solar system.

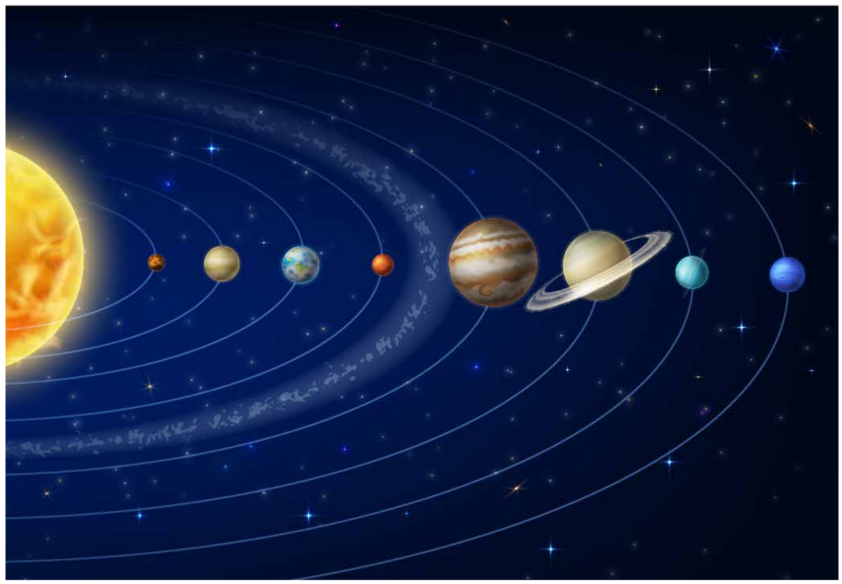
MS-ESS1-3. Analyze and interpret data to determine scale properties of objects in the solar system.

BACKGROUND INFORMATION

Gravity – What Holds our Universe Together

Gravity is one of the most easily observable forces in daily life. Whenever you jump up, you feel the force of the Earth's gravity pulling you back down. **Gravity** is a force of attraction that pulls matter together. **Matter** refers to any substance that has mass and takes up space. It is basically all of the 'stuff' that makes up the **universe** – which is everything in existence. Earth's gravity comes from its mass. **Mass** is the amount of matter that an object is made of, and anything that has mass has its own gravitational pull. However, only the Earth noticeably pulls things towards it because it is so massive compared to anything on it.

On a much larger scale, though, the effect of gravity becomes much clearer. The closest star to Earth, the **Sun**, is the most massive thing around for billions of miles. Literally. It contains 99.8% of the mass in the surrounding space. Thus, its gravity is strong enough to hold all of the planets, dwarf planets, moons, asteroids, comets, and meteoroids in the surrounding space in orbit around it, forming our **solar system**. Our system is named after our Sun (anything related to the Sun is called 'solar'), so while there are many, many planetary systems throughout the universe, there is only one solar system.



Our Solar System

There are eight very diverse planets in orbit around our Sun: Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, and Neptune. An **orbit** is the curved path an object takes as it revolves around another object. A **revolution** is the time it takes to complete one full orbit around an object. Earth takes about 365 days, or a year, to make one revolution around the Sun, and 24 hours, or a day, to make one full rotation on its axis. The Moon is Earth's only natural **satellite**, or an object which orbits another object. Each of the other planets – except for Mercury and Venus – have moons as well. Saturn and Jupiter have the most moons, with dozens apiece.

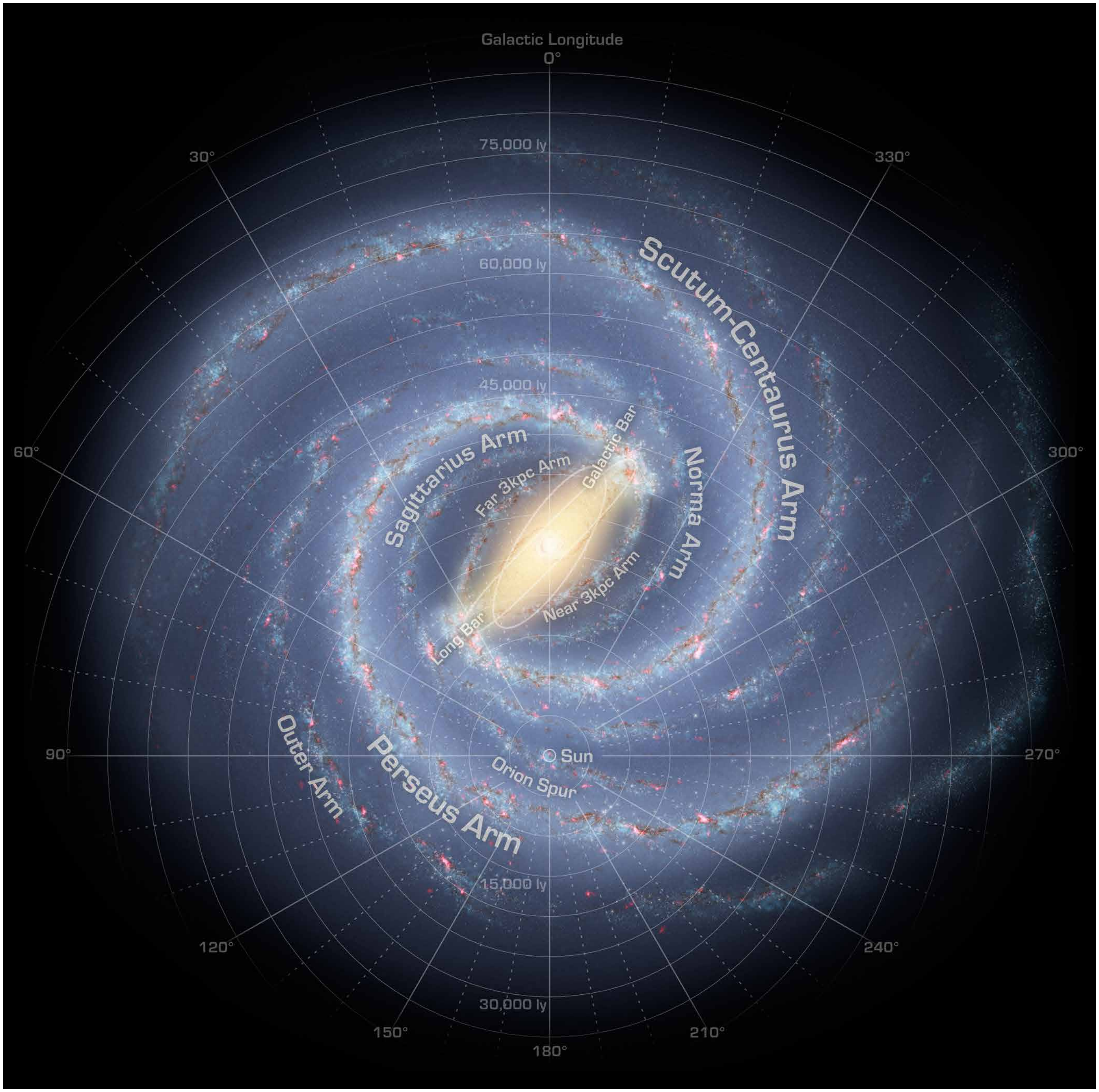
Closest to the Sun are the four rocky inner planets: Mercury, Venus, Earth, and Mars. Just beyond Mars lies the Asteroid Belt, where most asteroids are located. **Asteroids** are relatively small rocky objects left over from the formation of our solar system that also orbit the Sun. Beyond the asteroid belt are the four outer planets: the gas giants, Jupiter and Saturn, and the ice giants, Uranus and Neptune.

A **planet** is a celestial object that orbits a star and is big enough for its gravity to compact it into a roughly spherical shape and clear its orbit of other objects. Pluto was demoted to a **dwarf planet** because it does not keep its orbit clear of other objects. (Revolve in peace, Pluto.) Other dwarf planets in our solar system include Ceres, Eris, Haumea, and Makemake. Most dwarf planets (apart from Ceres) are located in and around the **Kuiper Belt**, a region of icy objects just beyond the orbit of Neptune.

Earth's Place in the Universe

Our solar system is just one of MANY planetary systems that make up the **Milky Way Galaxy**. A **galaxy** is a collection of billions of stars, dust, and gas held together by gravity. The Hubble Space Telescope looked at just a small patch of space and found 10,000 galaxies of all shapes and sizes! Scientists estimate there are billions of galaxies in the universe.

There are three general types of galaxies: elliptical, spiral, and irregular. The Milky Way is a four-arm, spiral-shaped galaxy. All the stars we observe in the night sky from Earth are also a part of the Milky Way. On average, each of these stars has a least one **exoplanet** orbiting it, which means there are thousands of planetary systems in our galaxy to explore!



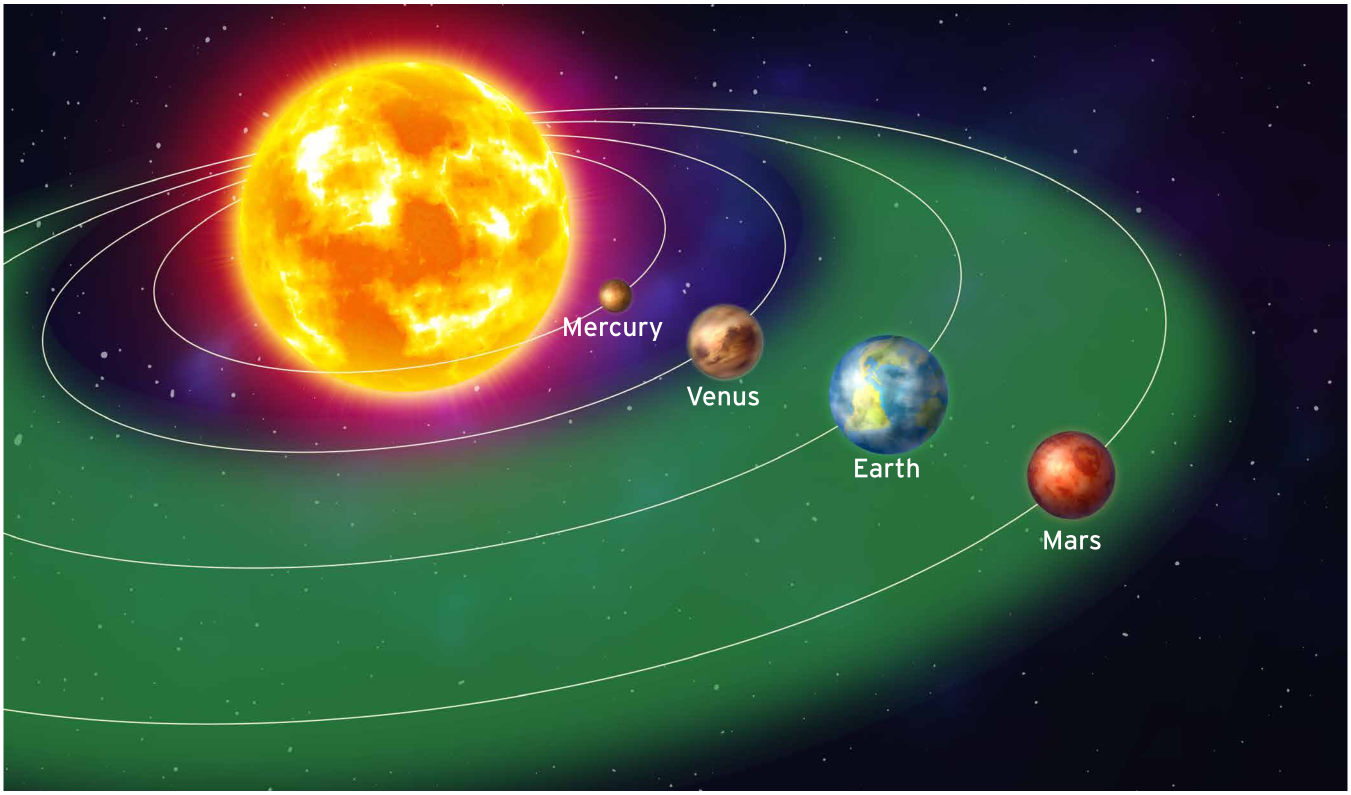
Credit: NASA / JPL-Caltech / R. Hurt (SSC-Caltech)

The Habitable Zone and Search for Life

So far, we only know of life on Earth, but we are looking for evidence of more everywhere we can, past or present. Scientists have identified a few conditions necessary for life as we know it to exist:

- Presence of liquid water
- Certain chemical elements, such as carbon, nitrogen, and phosphorus
- An energy source

Our primary energy source is the Sun. The Sun's gravity keeps Earth in orbit at a comfortable distance (about 93 million miles away) to enjoy the Sun's light and heat. This is known as the "Goldilocks Zone," or habitable zone, because it is the area around a star that is neither too hot nor too cold, but just the right temperature range for liquid water to exist on the surface of a planet. Venus, the hottest planet in our solar system, sits just inside the inner edge of the habitable zone, while cold Mars is on the outer edge.



As liquid water is necessary for life as we know it, that is one of the key ingredients we are searching for on other planetary bodies. Mars is a frozen desert now, but there is evidence it once had more liquid water in the past. One of the primary mission goals of NASA's Perseverance Rover, which landed on Mars in February 2021, is to seek out signs of past microbial life on Mars.

And while the habitable zone is a great place to start exploring (beginning with what we know can work), that does not exclude the possibility that life can exist beyond the habitable zone. One of Jupiter's moons, Europa, and one of Saturn's moons, Enceladus, both hold potential for microbial life with subsurface oceans below their icy exteriors.

However, more than the basic ingredients are necessary for complex life to thrive in diverse ecosystems like those of our home planet – an **atmosphere** and **magnetic field** are also needed. Earth's molten outer core generates a magnetic field that protects us from harmful solar radiation, while Earth's gravity holds down our insulating atmosphere and the air we need to breathe. Our atmosphere also protects us from incoming **meteoroids**, most of which break up upon entry.

VIEWING STRATEGIES AND TOOLS

DISCUSSION QUESTIONS

SECTION 1: GRAVITATIONAL FORCE [BEGINNING – 5:01]

1. What do you think would happen if the Sun suddenly disappeared?

Short answer: death. Long answer: If the Sun suddenly disappeared, the planets would drift apart in straight lines. Without the light and heat from the Sun, all life on the planet would die. There would be no liquid water, and our atmosphere would drift away. Gravity is what holds our world together.

2. Gravity is an attractive force that acts between two masses. The more mass an object has, the greater its gravitational pull. The force of attraction between you and the Earth (or another planet) is called your weight. On what planet in our solar system would you weigh the least? Why?

Mercury, because it is the planet with the least mass and therefore the smallest gravitational pull. If you weighed 100 lbs. on Earth, you would weigh 37.8 lbs. on Mercury.

■ SECTION 2: OUR SOLAR SYSTEM [5:01 – 13:50]

1. What planet do you relate to and why?

2. What are the advantages and disadvantages of the solar system models shown in the episode?

Answers will vary. Some answers could include:

- Advantages: Visually able to conceptualize vast distances and sizes by comparing to known, relatable distances and sizes. Can see the whole solar system on one screen to get a sense of how the parts make up the whole and move in relation to each other.
- Disadvantages: The scaled items chosen were not all spherical. Depending on the basis of the scale chosen, it may be hard to find items in the right sizes, big or small. The planets in the solar system orbit the Sun and thus are not at fixed points or in a line.

3. Why is it important to understand accurate sizes and distances of the planets in our solar system?

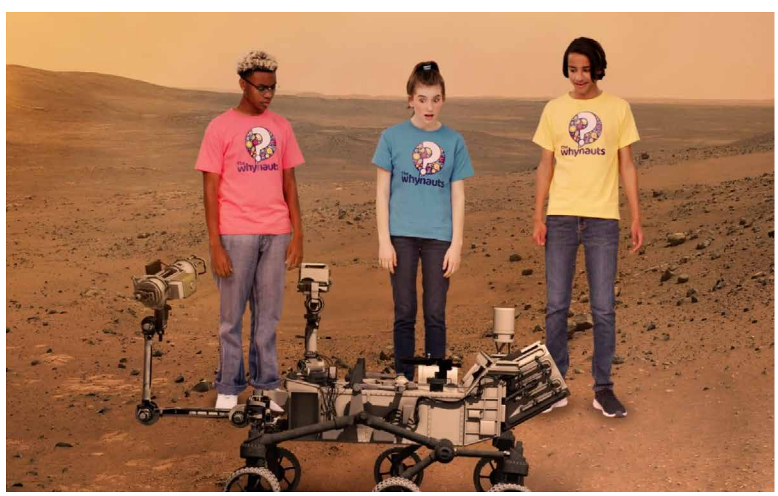
Answers will vary. Ultimately, it is tied to our ability to understand how the universe works.

■ SECTION 3: HABITABLE CHARACTERISTICS AND GUEST ASTRONAUT [13:50 - END]

1. After Mars, where do you think we should travel next? Why?

Answers will vary and could take into consideration the length of travel time, scientific goals, or conditions at the surface of the planet, moon, or asteroid.

2. What do you think life on other planets could look like?



Pre- and Post-Video Assessment

1. Our solar system is located in the ______________________________ galaxy, which is a ________________________-shaped galaxy.

2. Our Sun is:

A. The closest star to us

B. A medium yellow dwarf star

C. Composed of mostly hydrogen and helium

D. All of the above

3. How does gravity affect the motion of objects in the solar system?

4. What conditions are needed for life as we know it to exist?

ANSWER KEY

Pre- and Post-Video Assessment

1. Our solar system is located in the Milky Way galaxy, which is a spiral-shaped galaxy.

2. Our Sun is:

A. The closest star to us

B. A medium yellow dwarf star

C. Composed of mostly hydrogen and helium

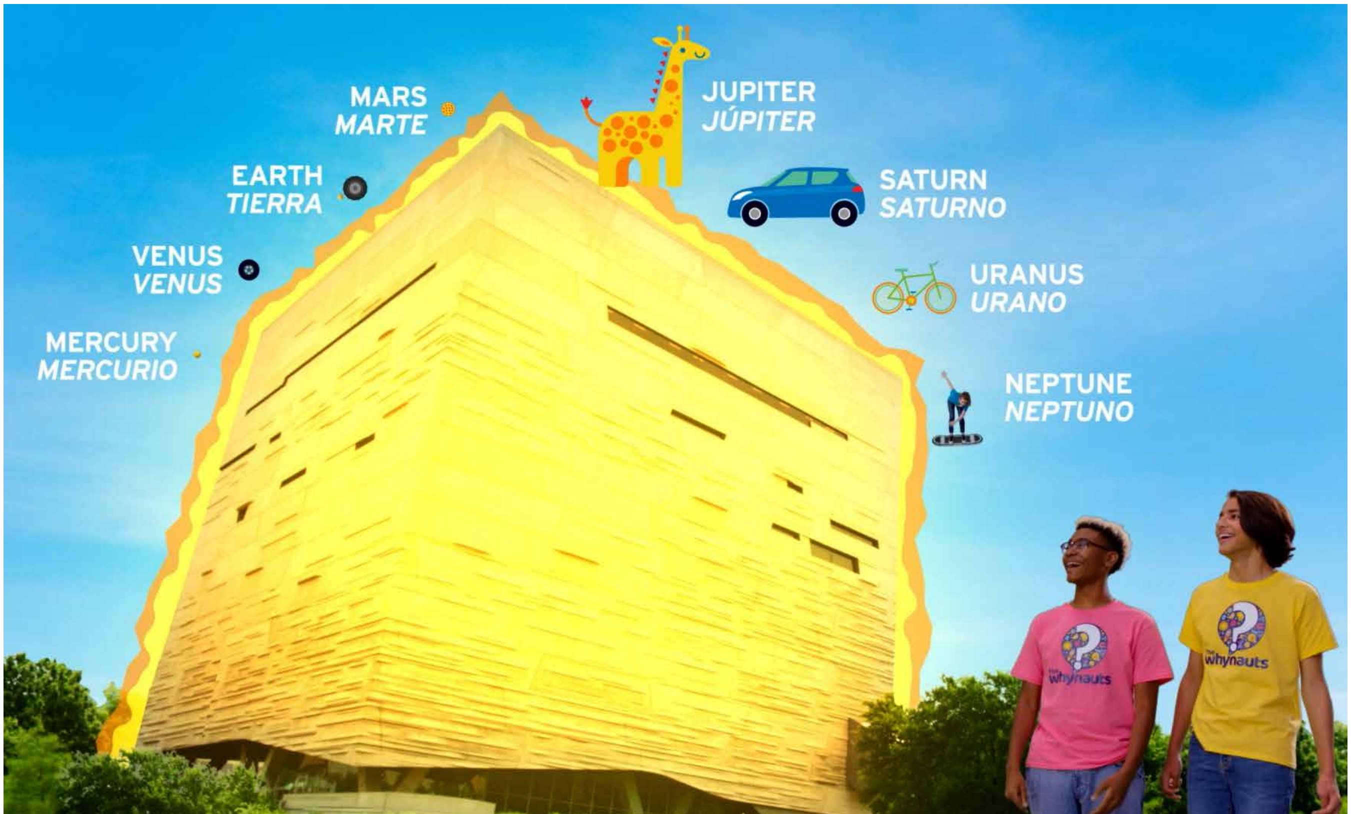
D. All of the above

3. How does gravity affect the motion of objects in the solar system?

Every object exerts a gravitational pull on every other object. The Sun's gravity holds all of the objects in our solar system in orbit around it, and the Earth's gravity holds the Moon in orbit around it.

4. What conditions are needed for life as we know it to exist?

- Right distance from the Sun. The "Goldilocks Zone" is the area around a star where it is not too hot and not too cold for liquid water to exist.
- Protected from harmful solar radiation by a magnetic field.
- Kept warm by an insulating atmosphere.
- Has the right chemical ingredients for life, including liquid water and carbon.



SUPPLEMENTAL ACTIVITIES

DIY Gravity Well

Going the Distance

Scaling for Size

Interplanetary Weather Report

DIY Gravity Well

WHY DO PLANETS ORBIT THE SUN?

Objective:
Students will create a model of gravitational attraction between two objects in space and observe how objects can revolve around other objects.

Materials:
For demo:
• Yo-yo, or a ball with a tightly attached string

For each group:
• Large bowl
• Stretchy fabric, like a cotton blend or spandex
• One heavy ball, like a golf ball or big marble
• Two smaller balls or marbles of different sizes and/or weights
• Binder clips, big enough to go on the lip of the bowl

Lesson Outline:

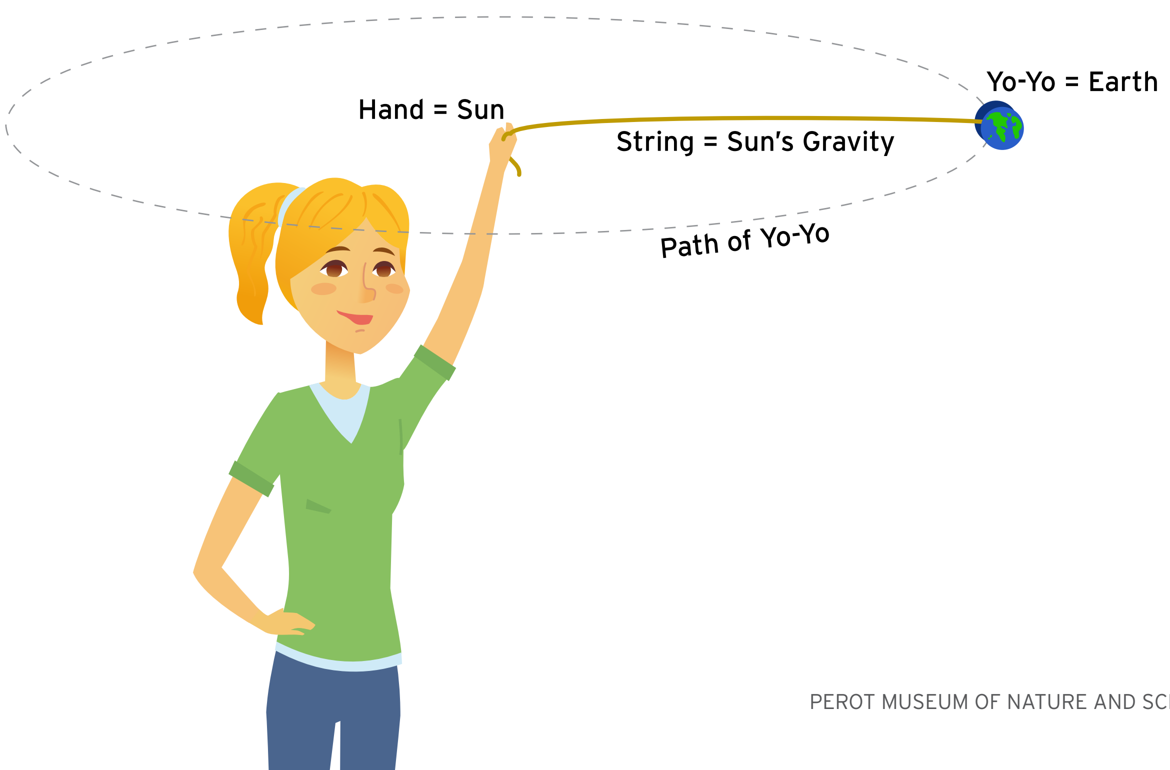
1. Ask students to provide examples of how gravity affects their daily lives.

2. Then have them hypothesize how gravity governs the motion of our solar system.

- Why don't all the planets just fall into the Sun, like a thrown football falls to the Earth?
  A moving planet has forward momentum, preventing it from falling straight into the Sun.
- Why do you think the planets follow an elliptical orbit?
  The Sun's gravity pulls on the planet in the direction perpendicular to its forward motion, preventing it from flying off into space in a straight line. The resulting motion is a path around the Sun. These two factors are not exactly balanced at every point along the planet's path, resulting in an elliptical orbit.

3. Demo: Take a yo-yo and swing overhead in an open space, making sure not to hit anyone or anything. The yo-yo will soon start to swing in a circular path without help.

MODEL OF SUN AND EARTH



4. Ask students:

- What forces are acting on the yo-yo to make it follow this path? The pull of the string and the force applied to give it forward motion.
- In which direction are the forces pulling the yo-yo? The balance of these two forces causes the yo-yo to revolve around your hand.
- Imagine the yo-yo was a planet in our solar system. What are the forces acting on the planet? The gravitational pull of the Sun and forward motion of the planet (or inertia).

5. Have students work in pairs or small groups. Instruct them to complete the DIY Gravity Well activity and answer the reflection questions.

Extensions:

- Using an online orbit simulator such as Phet Interactive Simulations | Gravity and Orbits, have students experiment with changing the positions of a star and planet to see how it affects the path of the orbit and gravitational force.
- **Contributions of Scientists** - Research the story of a STEM leader, past or present, who has helped expand our understanding of how the universe works. Share your report using a visual platform such as Flipgrid or PowerPoint.

  Some possible choices:

  - Johannes Kepler (1571-1630)
  - Sir Isaac Newton (1643-1727)
  - William (1738-1822) and Caroline Herschel (1750-1848)
  - Henrietta Leavitt (1868-1921)
  - Albert Einstein (1879-1955)
  - Edwin Hubble (1889-1953)
  - Annie Cannon (1863-1941)
  - Cecilia Payne-Gaposchkin (1900-1979)
  - Subrahmanyan Chandrasekhar (1910-1995)
  - Katherine Johnson (1918-2020)
  - Vera Rubin (1928-2016)
  - Carl Sagan (1934-1996)
  - Margaret Hamilton
  - Stephen Hawking (1942-2018)
  - Jocelyn Bell Burnell
  - Gibor Basri
  - Heidi Hammel
  - Wanda Diaz-Merced
  - Elisa Quintana
  - Katherine Bouman
  - Burçin Mutlu-Pakdil
  - Jessica Esquivel

DIY Gravity Well

WHY DO PLANETS ORBIT THE SUN?

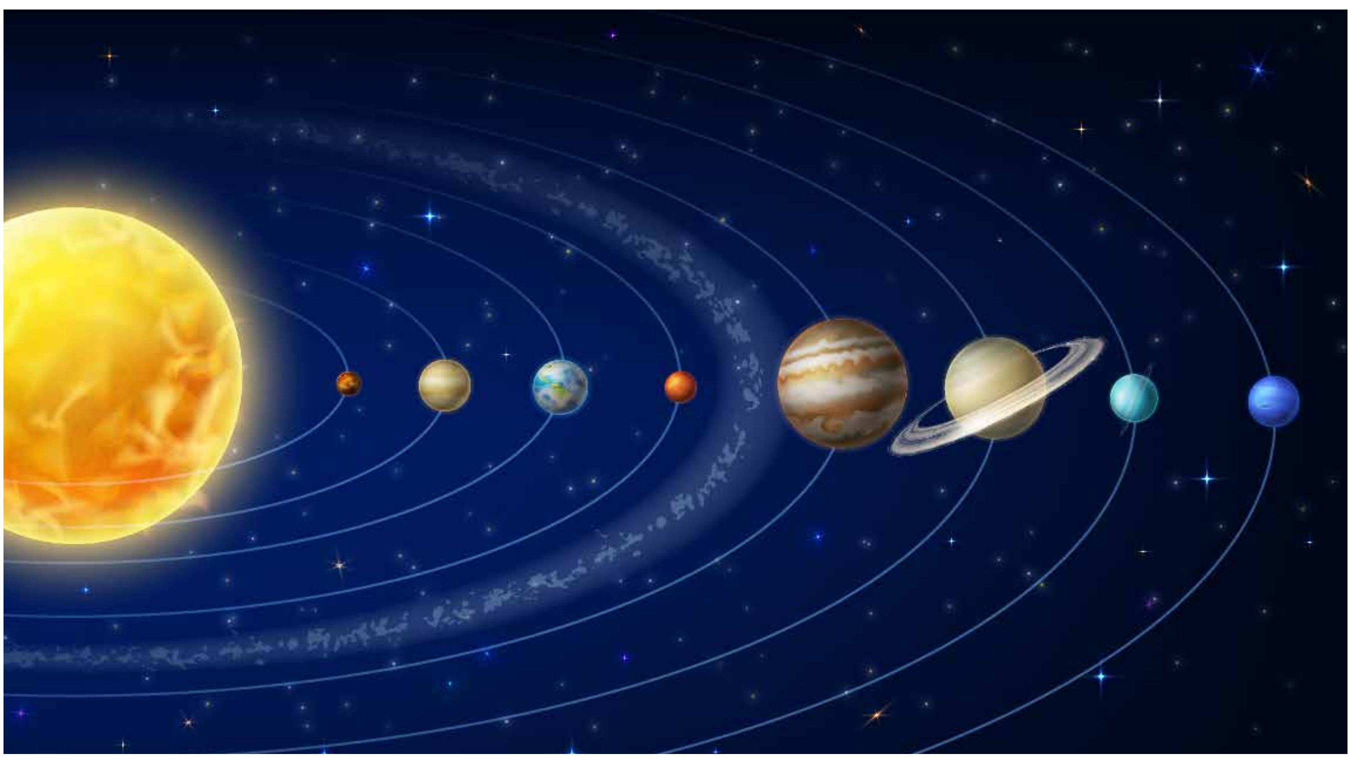
Materials:

- Large bowl
- Stretchy fabric, like a cotton blend or spandex
- One heavy ball, like a golf ball or big marble
- Two smaller balls or marbles of different weights
- Binder clips, big enough to go on the lip of the bowl

INTRODUCTION:

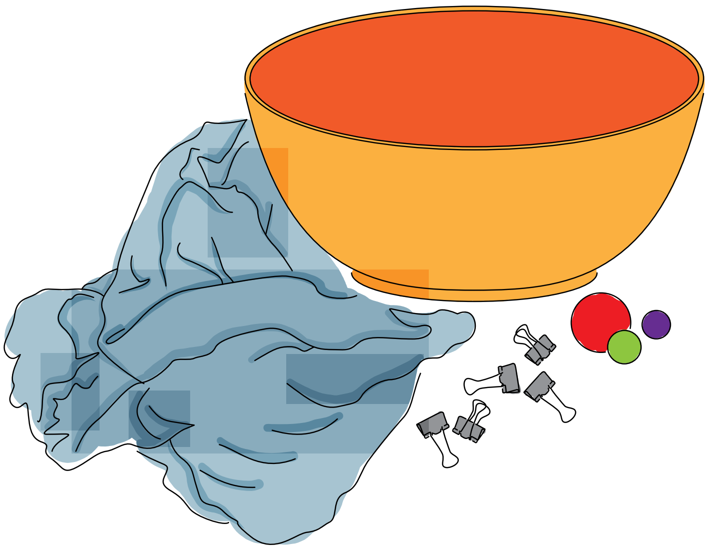
Gravity is a force of attraction that pulls matter together. **Matter** refers to any substance that has mass and takes up space - it's basically all of the 'stuff' that makes up the universe. Earth's gravity comes from its mass. **Mass** is the amount of matter that an object is made of. Anything that has matter has its own gravitational pull.

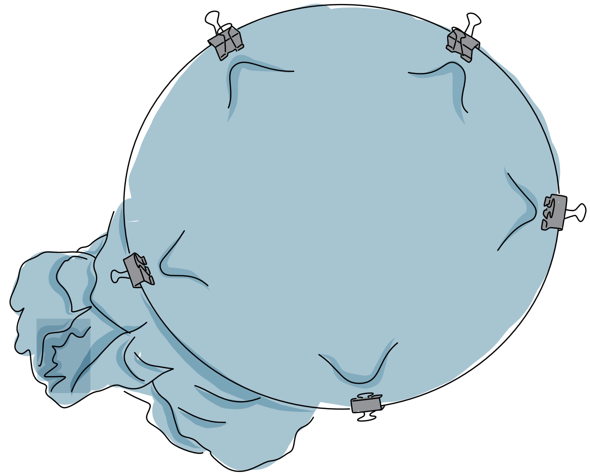
The closest star to Earth, the **Sun**, is the most massive thing around for billions of miles. It contains 99.8% of the mass in the surrounding space. Thus, its gravity is strong enough to hold all of the planets, dwarf planets, moons, asteroids, comets, and meteoroids in the surrounding space in orbit around it, forming our **solar system**. An **orbit** is the curved path an object takes as it revolves around another object. A **revolution** is the time it takes to complete one full orbit around an object.



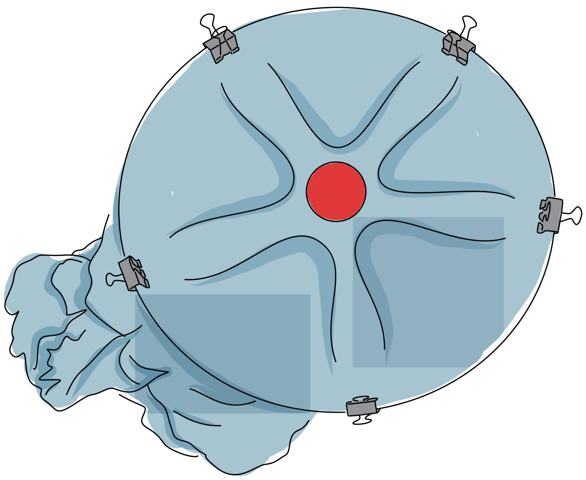
PROCEDURE:

1. Build a gravity well by placing the stretchy fabric over the top of the bowl and securing in place using the blinder clips. Make sure the fabric is taut (pulled tightly).

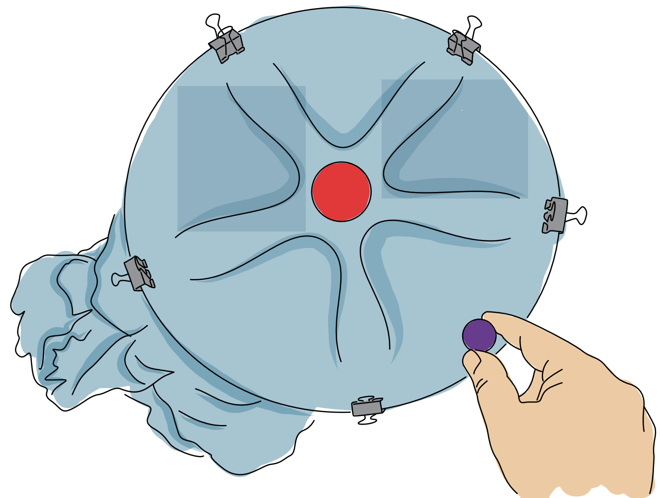




2. Place the heavy ball in the center of the fabric well. Observe how the object's gravity affects the fabric.



3. Place the small marble on the edge of the bowl and let go. Observe what path the marble follows.



4. Then, starting near the rim, gently roll the marble along the edge of the bowl (so that it does not roll off the well). This may take some practice. Observe the path the marble follows.

5. Experiment with balls of different weights. What happens if you put a less heavy ball in the middle of the well?

Note: The fabric may loosen over time; if this happens, adjust the clips and pull taut again.

QUESTIONS:

1. Sketch your model and label the components. What did each of the components of this model solar system represent?

2. What happened when you placed the marble on the edge of the bowl and just let go? Why do you think the marble behaved that way?

3. What happened when you gently rolled the marble along the edge of the bowl? Why do you think this happened?

4. What did you notice when you experimented with marbles of different weights?

5. What were the advantages and limitations of this model?

QUESTIONS:

1. Sketch your model and label the components. What did each of the components of this model solar system represent?

Heavy ball: the Sun

Smaller marbles: planets

Stretchy fabric: "fabric" of space-time

2. What happened when you placed the marble on the edge of the bowl and just let go? Why do you think the marble behaved that way?

The marble should have rolled towards and collided with the heavy ball because gravity pulled the ball towards the center of the well.

3. What happened when you gently rolled the marble along the edge of the bowl? Why do you think this happened?

The marble should have briefly started to orbit the heavy ball in an elliptical path before dropping into the well and colliding with the heavy ball. You gave the marble forward motion, which prevented it from falling straight into the well. The resulting motion due to both gravity and this forward push was a path around the heavy ball until friction slowed the ball down and caused it to drop into the well.

4. What did you notice when you experimented with marbles of different weights?

Answers will vary, but students may notice that if they put a lighter ball in the center, it pulls on the fabric less. It may or may not create enough of a well to influence another marble's path. If they try to roll the heavy ball around a lighter ball, they may notice that the lighter ball will start to orbit the heavier ball instead.

5. What were the advantages and limitations of this model?

Advantage: The motions of our solar system are difficult to observe in full scale. This activity lets us experiment with gravity and observe the way objects can revolve around other objects.

Limitation: In this model, the small marble does not stay in motion long due to friction between the marble and the fabric, slowing the marble down and causing it to drop into the well. But in space, there is very little friction.

Going the Distance

(Adapted from the NASA/JPL Solar System Scroll Activity)

HOW FAR APART ARE THE PLANETS IN OUR SOLAR SYSTEM?

Objective:
Students will create a scale model to visualize relative distances between the planets in our solar system.

Materials:
- White printer paper, or strips of white butcher paper
- Colored pencils
- Pencils
- Tape

Lesson Outline:

1. If using butcher paper, cut out the strips prior to beginning the activity. You will need one strip of paper per student.

2. Begin with a class discussion about our solar system.
   - What is our solar system?
     The Sun (a star) and all the objects orbiting the Sun.
   - What is the order of the planets in our solar system?
     Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, and Neptune.
   - What is a fun way to remember this order?
     My Very Educated Mother Just Served Us Nachos
   - What other objects are in our solar system besides planets?
     Asteroids, moons, man-made satellites, dwarf planets, comets
   - Why are models of the solar system often not shown to scale?
     Often the relative distance and size of the Sun and the planets in our own solar system cannot be modeled at the same time due to the vastness of space between the planets.

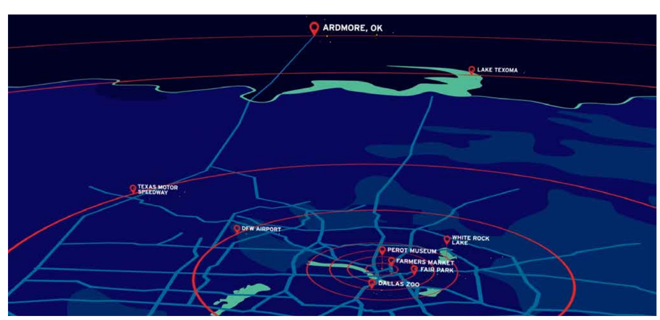
3. Have students work in small groups to complete the activity. Ask students to first brainstorm what they think the relative distances are for the objects between the Sun and the Kuiper Belt, and have them mark their guesses on their strips of paper.

4. Next, students will complete the activity to find the actual relative distances between the objects in our solar system.

5. End the lesson with a class discussion reviewing the students' responses to the reflection questions.

Extensions:

- Try this activity outside! Recreate your own solar system model in your neighborhood using the Map a Model Solar System calculator.
- **Career Connection** – connect your students with an astronomer or astrophysicist! You can reach out to scientists in your community or use a resource such as skypeascientist.com



Going the Distance

(Adapted from the NASA/JPL Solar System Scroll Activity)

HOW FAR APART ARE THE PLANETS IN OUR SOLAR SYSTEM?

Materials:

- White printer paper
- Colored pencils
- Pencils
- Tape

INTRODUCTION:

Our solar system is composed of the **Sun** and all matter in orbit around it. There are eight **planets** in **orbit** around our Sun: Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, and Neptune. The asteroid belt is located between Mars and Jupiter, separating the inner planets from the outer planets. The **Kuiper Belt** lies just beyond the orbit of Neptune.

It is hard to grasp just how MUCH space is in space. Often the relative distance and size of the Sun and the planets in our own solar system cannot be modeled at the same time due to the vastness of space between the planets. Neptune, the last planet in our solar system, is an average of about 2.8 BILLION miles from the Sun. That is more than 30 times as far from the Sun as Earth!

The Whynauts traveled about 106 miles in the Whynautcopter to create their solar system model. In this activity, you will create your own scale model representing the distance between the planets in our solar system.

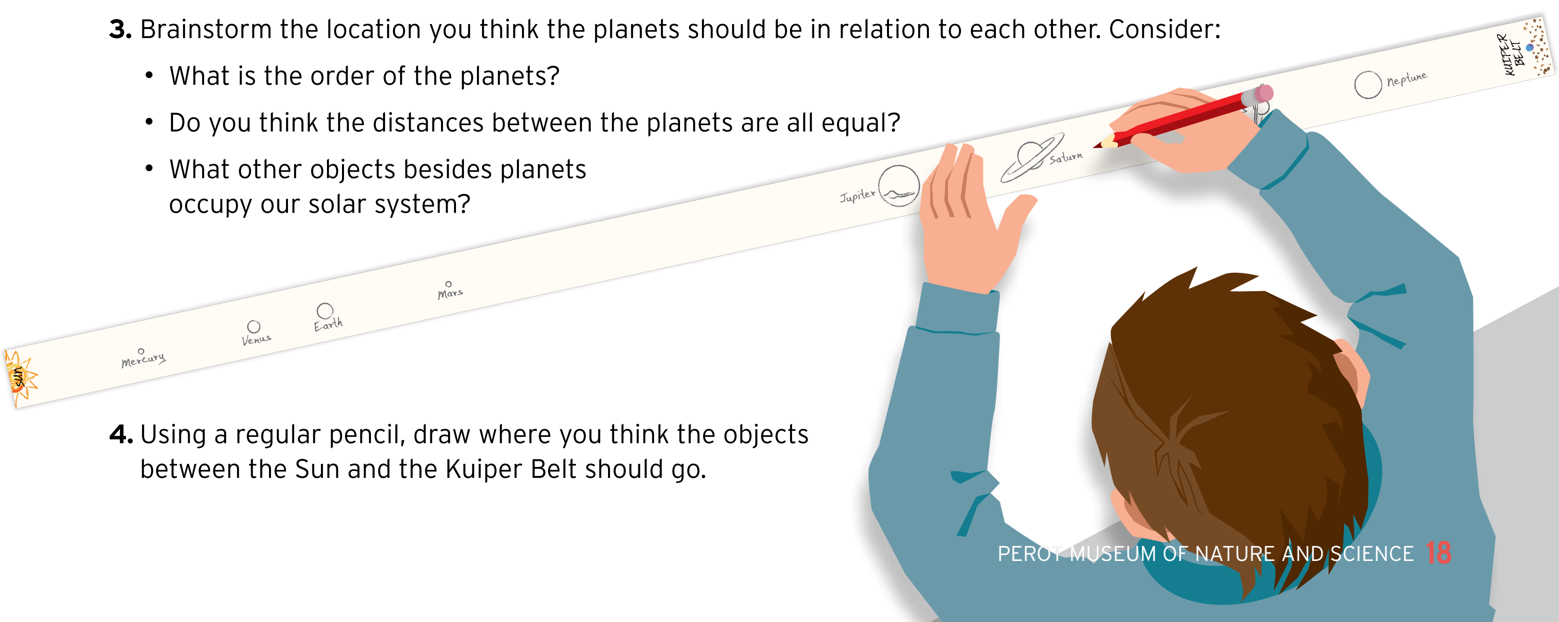
PROCEDURE:

1. Cut the white printer paper in about 6 cm wide strips. Tape the ends of the paper together to get one long strip of paper that is about 160 cm in length.

2. Draw the Sun on one end of the paper and the Kuiper Belt on the opposite side.

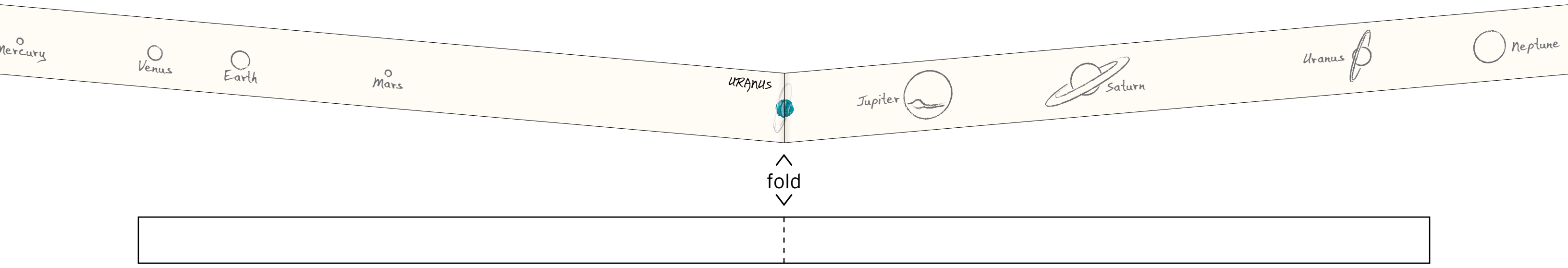
3. Brainstorm the location you think the planets should be in relation to each other. Consider:

- What is the order of the planets?
- Do you think the distances between the planets are all equal?
- What other objects besides planets occupy our solar system?



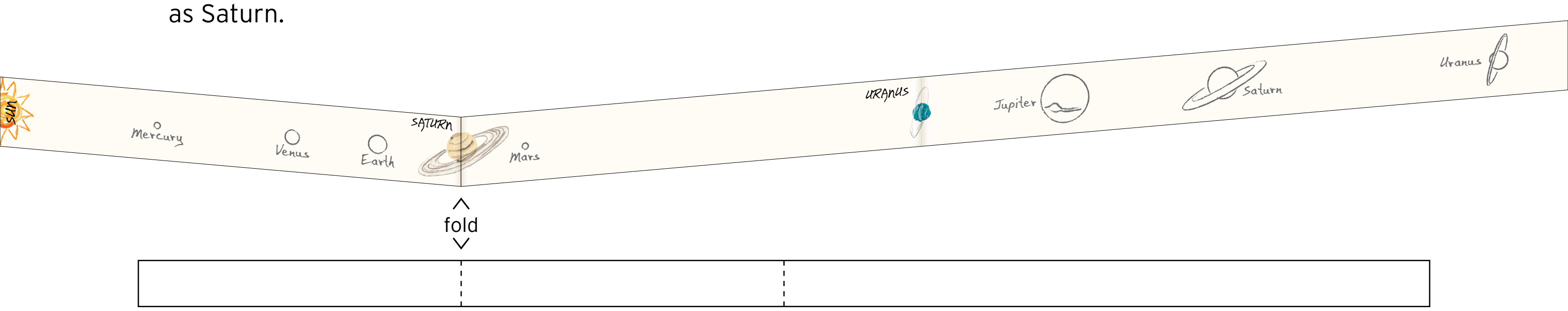
4. Using a regular pencil, draw where you think the objects between the Sun and the Kuiper Belt should go.

5. Now we are going to locate the actual distances between the planets. For the first step, fold the strip of paper in half. Open the paper back up and on the folded line, draw and label Uranus using the colored pencils.



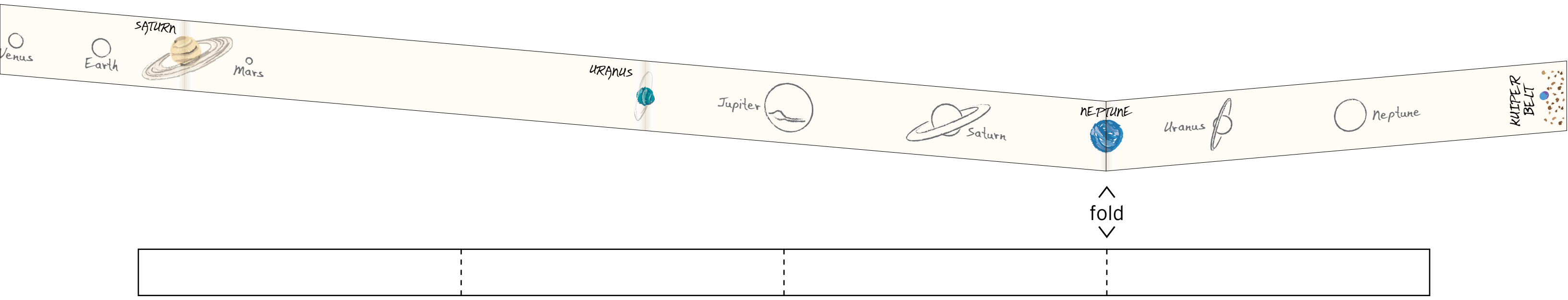
Length: 160cm

6. Fold the paper to match the Sun to the correct location of Uranus. Open the paper back up and label this fold as Saturn.



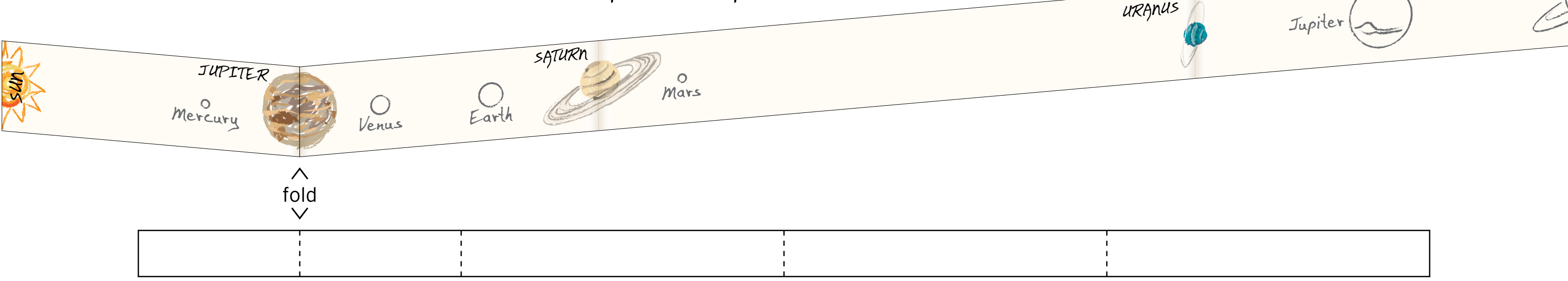
Length: 160cm

7. Next, fold the paper to match the Kuiper Belt with the correct location of Uranus. Open the paper back up and label this fold as Neptune.



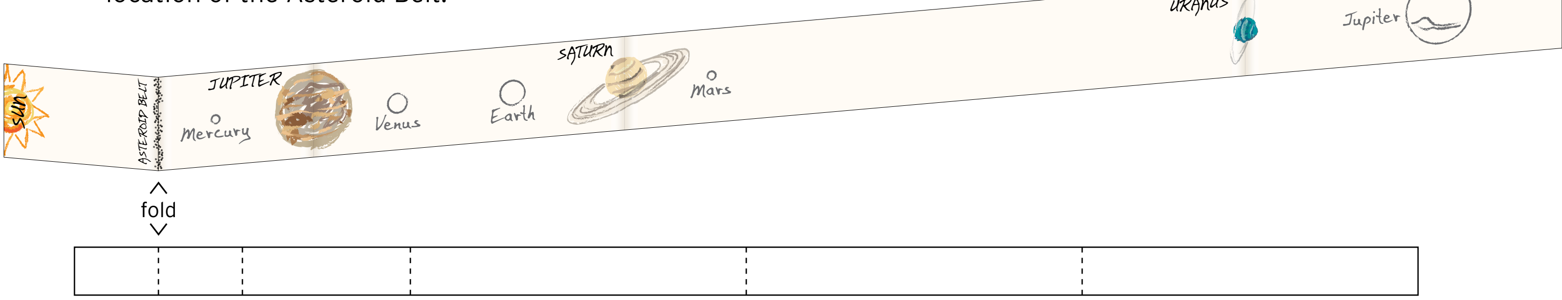
Length: 160cm

8. Moving back to the Sun, fold the strip of paper to match the Sun with the correct location of Saturn. The new fold will represent Jupiter.



Length: 160cm

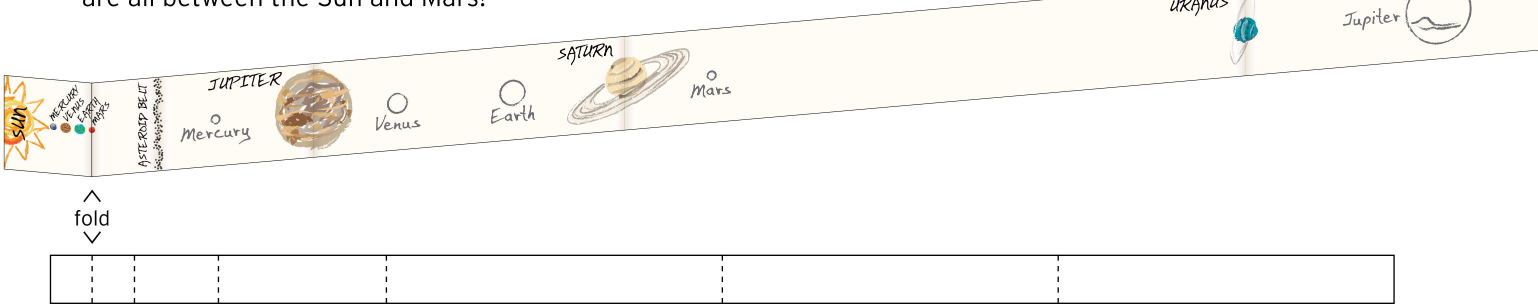
9. Match the Sun to the correct location of Jupiter. This fold will represent the location of the Asteroid Belt.



Length: 160cm

10. Next, match the Sun to the Asteroid Belt to make the final fold. This fold represents the location of Mars.

11. The remaining inner planets – Mercury, Venus, and Earth – are all between the Sun and Mars!



Length: 160cm

12. Lastly, create a key to illustrate which marks are the correct locations and which ones are the original guesses.

QUESTIONS:

1. Compare your predictions with the actual distances of the planets. What, if anything, surprised you about the results?

2. What are some of the challenges in studying things far away?

3. What were the advantages and limitations of this model?

4. Brainstorm another way to model the distances between the planets. What materials would you use and why?

QUESTIONS:

1. Compare your predictions with the actual distances of the planets. What, if anything, surprised you about the results?

   Answers will vary.

2. What are some of the challenges in studying things far away?

   Answers may vary. When sending spacecraft to the Moon or Mars, or probes to the outer planets of our solar system, it takes a long time to get there. Launched in 1977, it took Voyager 1 two years to fly by Jupiter, another year to fly by Saturn, and another 32 years to reach interstellar space! Once a spacecraft is that far away, it is beyond our reach to fix it if something should break.

   Compared to many scientists who can analyze and handle the materials or objects they study, the majority of astronomers are limited to what they can observe from a vast distance. (Very few extraterrestrial materials have been collected and brought to Earth as of 2021, but this may change in coming decades.) Even then, views can be hidden by cosmic gas and dust or blocked by clouds in Earth's atmosphere.

3. What were the advantages and limitations of this model?

   Advantage: Taking distances that are too big to see and scaling them down so that the entire solar system can be viewed at once to show the relative distances between the planets.

   Limitations: This model shows the relative distances between planets, but not the relative sizes of the planets or the Sun. The planets are not all in a line – they are in constant motion in orbit around the Sun.

4. Brainstorm another way to model the distances between the planets. What materials would you use and why?

   Answers will vary.

Scaling the Solar System

(Data from NASA/JPL)

HOW BIG ARE THE PLANETS IN OUR SOLAR SYSTEM?

Objective:
Students will create a scale model to visualize the relative sizes of the Sun and planets in our solar system.

Materials:
- Pencil
- Meter stick
- Random objects of students choosing
- Science notebook or paper

Lesson Outline:

1. Begin by referring back to the Whynauts "**Exploring the Solar System**" video. How were models used to demonstrate the size of the Sun and the planets in the video?
   The Whynauts used the height of the Perot Museum as the basis for the scale and to represent the Sun. Using proportions, they then calculated the scaled-down sizes of the objects in our solar system and found everyday items of comparable size.

2. Show some examples of solar system models which are not to scale and engage in a class discussion about why this often occurs.

3. Students will work in small groups to complete the scale model activity. Before they begin, explain the math and model the calculation process using the example scale size chart.

4. Pass out the scale size chart to each group, and give students time to complete the activity.

5. Once all groups have completed their charts, ask each group to share what objects they chose for their scale model and why.

Extensions:

- Try this activity outside! All you need are your calculations, a meter stick, sidewalk chalk, and a place to write. Draw each planet and the Sun on the sidewalk using the scale diameter you determined. Use images of the planets and the Sun to make each planet look as realistic as possible.
- Look up the sizes of other objects in the solar system (such as moons or asteroids) or the universe (such as stars or exoplanets). How big would these objects be in your scale model?

	Scale Diameter (cm)	Actual Diameter (km)	Object
Sun	(1 * 1,391,400) / 12,756=109	1,391,400	A Meter Stick
Mercury	(1 * 4,876) / 12,756=0.38	4,879	A Peppercorn
Venus	(1 * 12,104) / 12,756=0.95	12,104	Width of a Pen
Earth	1	12,756	A Staple
Mars	(1 * 6,792) / 12,756=0.53	6,792	Width of a Pencil
Jupiter	(1 * 142,984) / 12,756=11.2	142,984	Length of a Popsicle Stick
Saturn	(1 * 120,536) / 12,756=9.45	120,536	Length of a Toilet Paper Roll
Uranus	(1 * 51,118) / 12,756=4	51,118	Width of a Ritz Cracker
Neptune	(1 * 49,528) / 12,756=3.8	49,528	Width of a Walnut

Scaling the Solar System

(Data from NASA/JPL)

HOW BIG ARE THE PLANETS IN OUR SOLAR SYSTEM?

Materials:

- Pencil
- Meter stick
- Random objects of your choosing
- Science notebook or paper

INTRODUCTION:

When we say that the **Sun** is MASSIVE, how big do we really mean? Due to the incredible sizes of the Sun and planets in our **solar system**, it can be difficult to comprehend how the sizes of the objects in our solar system compare. Using a simple equation to determine relative scale, everyday objects can be used to model the proportional sizes of the Sun and the planets.

In this activity, you will calculate the scale diameter of the Sun and planets in our solar system and then identify objects that represent these comparative sizes.

PROCEDURE:

1. Start with Earth and choose a number (2-4) to start as the scale diameter. Record this number next to Earth in the Scale Size chart.

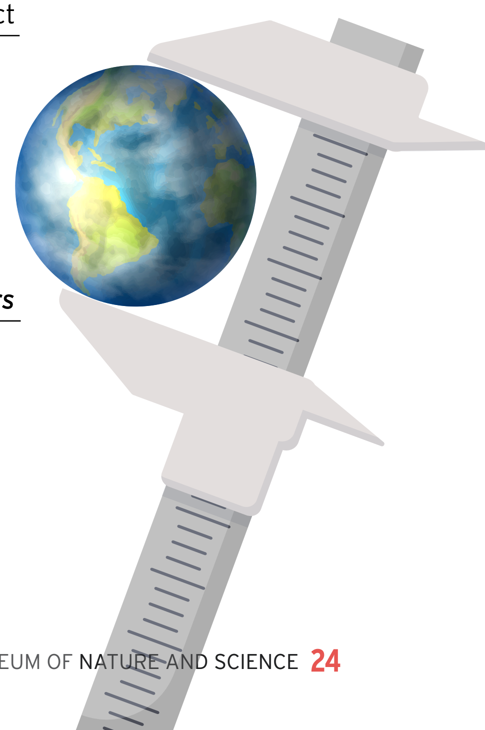
Note: A number above 4 may make identifying comparable objects difficult, as the largest object will need to be quite large.

2. Use the equation below to calculate the scale diameters of the Sun and other planets. Record in the chart.

$$\text{Scale Diameter of Object} = \frac{\text{Scale Diameter of Earth} \times \text{Actual Diameter of Object}}{\text{Actual Diameter of Earth}}$$

For example, if the scale diameter of Earth is 1 cm in diameter, then based on the calculations, the scale diameter of Mars would be 0.53 cm.

$$\underset{\text{Scale Diameter of }\textit{Mars}}{\textbf{0.53 cm}} = \frac{\underset{\text{Scale Diameter of }\textit{Earth}}{\textbf{1 cm}} \times \underset{\text{Actual Diameter of }\textit{Mars}}{\textbf{6,792 km}}}{\underset{\text{Actual Diameter of }\textit{Earth}}{\textbf{12,756 km}}}$$



3. Next, locate objects that represent the diameters of each planet and include the name of that object in the chart. For example, for Mars, the width of a pencil is approximately half a centimeter.

4. If needed, look up the sizes of objects that may not be readily available to you to help you complete the chart.

SCALE SIZE CHART	Scale Diameter (cm)	Actual Diameter (km)	Object
Sun		1,391,400	
Mercury		4,879	
Venus		12,104	
Earth		12,756	
Mars		6,792	
Jupiter		142,984	
Saturn		120,536	
Uranus		51,118	
Neptune		49,528	

QUESTIONS:

1. Think of a category of objects, such as fruits or sports balls. Which objects do you think would best represent the sizes of the planets and the Sun in our solar system? Use your calculations from your chart to help you decide.

2. What were the advantages and limitations of this model?

QUESTIONS:

1. Think of a category of objects, such as fruits or sports balls. Which objects do you think would best represent the sizes of the planets and the Sun in our solar system? Use your calculations from your chart to help you decide.

Answers will vary but could take into account the general shape of the objects as well as how many different-sized items are within the category.

2. What were the advantages and limitations of this model?

Advantages: Using proportions to create a scale model is a great way to show the difference in size between the Sun and planets of our solar system. Using relatable, everyday objects as models helps us conceptualize and contextualize unimaginably large sizes better than images on a page.

Limitations: Ideally, the model objects would be spherical, like our planets and the Sun; however, there is a limited number of round objects in our everyday lives. In addition, due to the vast size differences between the planets and the Sun, the basis for the scale must be kept relatively small; otherwise, it can become much harder to find items in the right sizes.

Interplanetary Weather Report

WHY IS EARTH THE MOST HABITABLE PLANET IN OUR SOLAR SYSTEM?

Objective:
Students will be able to identify the characteristics that make Earth habitable, describe the differences in the physical properties of the planets in our solar system, and develop skills in independent research, creative writing, and public speaking.

Materials:
- Paper and writing supplies

Lesson Outline:

1. Start a class discussion about habitable characteristics of Earth that the students can relate to in their everyday lives.
   - What is the temperature today?
   - Was there rain in the forecast?
   - What was the Air Quality Index (AQI)?

2. Then compare and contrast the conditions on Earth with what they might be like on other planets.

   Review the difference between climate and weather if needed.
   - Weather is the current state of the atmosphere in regards to wind, temperature, cloudiness, moisture, or pressure at a specific time and place.
   - Climate describes the weather patterns over a long period of time (30 years) in a specific place. When scientists talk about climate, they look at averages of precipitation, temperature, humidity, sunshine, or wind speed.

   - How does the average temperature on each planet relate to its distance from the Sun? What could affect this pattern? Planets tend to be hotter the closer they are to the Sun. A planet's chemical makeup and atmospheric density can also affect temperature.
   - Why is the atmosphere of each planet so different? Size, chemical makeup, and temperature are all variables that can affect an atmosphere on a planet.
   - What would happen if we tried to live on another planet? How would we survive? We are adapted to life on Earth, so we could not survive on other planets without re-creating the conditions we have on Earth: access to fresh water, a relatively stable and warm temperature, and a thick, oxygen-rich atmosphere.

3. Split students into seven groups. Allow them to choose, or assign each group one of the following planets: Mercury, Venus, Mars, Jupiter, Saturn, Uranus, and Neptune.

4. Go over the goal of the assignment and the activity requirements. Give an example presentation using the example script as a guideline. Encourage creativity in their presentation!

5. Give time to complete the research and preparation of their script.
   - This activity requires research, so you may want to assign this project to be done over multiple days.

6. Groups may present their skit using their script; memorization is not required. Make sure they include the answers to at least three of the guiding questions.

7. Wrap up the lesson by asking the students to reflect on their classmates' presentations.
   - Based on another group's presentation, why do you think life could or could not exist on their planet?
     - What adaptations might life forms need to survive there?
     - What accommodations would humans need to survive if we could get there?

Resources:
Example Data that could be included in presentations:

Planet	Type	Day length (in Earth hours)	Year length (in Earth days)	Average Temperature (°Celsius)
Mercury	Terrestrial	1,408	88	-180° (night) to 430° (day)
Venus	Terrestrial	5,832	225	around 471°
Mars	Terrestrial	25	687	-28°
Jupiter	Gas giant	10	4,333	-108° at 1 bar
Saturn	Gas giant	11	10,759	-138° at 1 bar
Uranus	Ice giant	17	30,687	-195° at 1 bar
Neptune	Ice giant	16	60,190	-201° at 1 bar

Extensions:

- Imagine a creature that could survive the extreme environment on your chosen planet! What physical and behavioral adaptations does your creature have?
- **Art Extension** - Which planet should we travel to next? Create a travel poster to promote it! Check out these Space Tourism Posters by NASA/Jet Propulsion Laboratory-Caltech as inspiration.

Interplanetary Weather Report

WHY IS EARTH THE MOST HABITABLE PLANET IN OUR SOLAR SYSTEM?

Materials:

- Paper and writing supplies

INTRODUCTION:

Our **solar system** is full of unique and interesting objects orbiting the **Sun**, including **comets**, **asteroids**, **moons**, and **planets**. While there are only eight planets, each one is incredibly different from the next. They have vastly different sizes, colors, orbits, axes, and, importantly, climates.

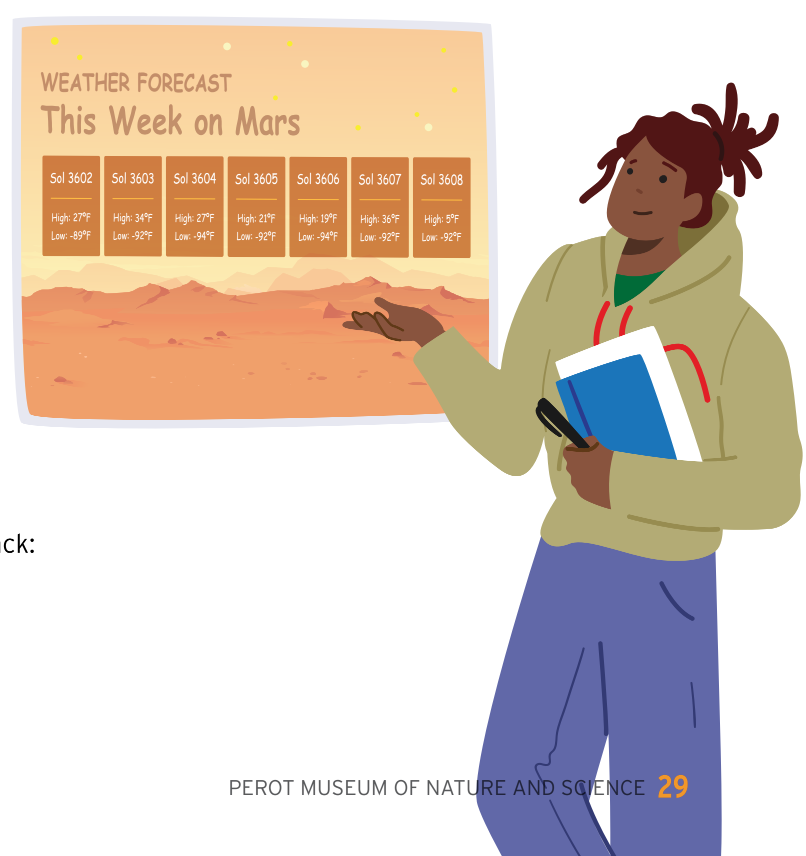
The climate on each planet is unimaginably different from that on Earth. This is due to a variety of factors, including the planet's **atmosphere**, distance from the Sun, and chemical makeup. Just like on Earth, weather varies from place to place and time to time, whereas climate is the long-term weather patterns. If there is life on any of these other planets, it must be very different from the types of living things we have discovered on Earth to be able to survive such extreme environments.

In this activity, you will write and present a weather report as if you were on the surface of another planet.

PROCEDURE:

1. Choose a planet to research. Your weather report must cover **at least 3** of the guiding questions on the next page.

2. When researching, try to find your information from **at least 3** different sources. Here are some good places to start:
   - **IPAC/Caltech**
     Cool Cosmos | Ask an Astronomer
   - **NASA**
     Solar System Exploration: Planets
     Ten Things: Planetary Atmospheres
     What is the Weather Like on Other Planets?
   - **TED-Ed**
     Could We Actually Live on Mars?



3. Decide how you will present your weather report. Be creative! You may want to incorporate props, write a song, or even do a skit.

4. Present your weather report. Ask viewers for feedback:
   - What is something you liked?
   - What is something you learned?
   - What is something to improve?

Guiding Questions

1. How long is a day on this planet? How long is a year?

2. What is the composition of the surface? Is it a terrestrial planet, a gas giant, or an ice giant?

3. What does the planet look like on the surface? For example, are there craters, mountains, or just gas?

4. What is the atmosphere like? How dense or thick is it?

5. What do the Sun and horizon look like from the surface? Are there any moons in the sky?

6. What is the climate like there? Remember to specify temperatures in degrees Fahrenheit, Celsius, or Kelvin.

7. Are there any interesting weather patterns there? For example, windstorms, dust storms, clouds, rain, etc.

8. How strong is the gravity there?

Example Script:

"Hello, everyone, and welcome to the WHY Action News Solar Channel! I'm coming to you live with a weather report straight from the surface of the Sun. As you can see, it's nice and sunny today, with a temperature of a warm 5,500 degrees Celsius here at the photosphere. In fact, I'm not sure how I'm standing here now, as the entire Sun is made of hydrogen gas heated so hot that it becomes plasma, the fourth state of matter. You can expect relatively clear skies today, with a small chance of giant solar flares, which erupt out of the surface and release massive amounts of radiation into space. Good thing I brought my sunscreen! Anyway, back to you in the studio, Jeri."

QUESTIONS:

1. Based on your presentation, why do you think life could or could not exist here?

2. What adaptations might life forms need to survive here?

3. What accommodations would humans need to survive if we could get there?

ADDITIONAL RESOURCES

GLOSSARY

Asteroid - relatively small rocky object left over from the formation of our solar system. Most are found orbiting the Sun between Mars and Jupiter in the region known as the Asteroid Belt. Asteroids are smaller than dwarf planets and bigger than meteoroids.

Atmosphere - the gases held by gravity around a planet

Comet - an icy rock, which may form tails of gas and dust when its orbit brings it close to the Sun

Dwarf planet - objects that are round and orbit the Sun but do not have enough gravity to clear their path around the Sun as a planet does. Dwarf planets are much smaller than planets.

Exoplanet - a planet outside our solar system

Galaxy - a collection of billions of stars, gas, and dust held together by gravity. We live in the Milky Way galaxy.

Gravity – a force of attraction that pulls matter together

Kuiper Belt - a ring of icy objects beyond the orbit of Neptune. Pluto is located in this region.

Magnetic field - the space around a magnet where the magnetic force is active. Earth's active, molten outer core generates its magnetic field, which helps protect us from harmful solar radiation.

Mass - the amount of matter something is made of

Matter - any substance that has mass and takes up space

Meteor - or a "shooting star"; when a meteoroid burns up as it enters a planet's atmosphere creating a streak of light

Meteoroid - a piece of rock floating out in space that is smaller than an asteroid

Milky Way Galaxy - the spiral-shaped galaxy that our solar system is a part of. There is a supermassive black hole at the center of our galaxy.

Moon - a natural object that travels around a bigger natural object. Planets, dwarf planets, and even some asteroids have moons.

Orbit - the curved path that a planet, satellite, or spacecraft takes around another object

Planet - a large object in outer space that:

- orbits a star
- is big enough (has enough mass) to have enough gravity to force it into a spherical shape
- has cleared away any other objects of a similar size near its orbit around the star

Revolution - the time it takes to complete one full orbit around an object

Satellite - an object that orbits another object. A moon is a natural satellite. We also say satellite to refer to spacecraft built by people that orbit Earth or other objects out in space.

Solar system - our Sun and all of the objects that orbit it, including planets, moons, asteroids, and comets

Star - a ball of shining gas and plasma, composed mostly of hydrogen and helium and held together by its own gravity

Sun - the star in the center of our solar system. Our Sun is a medium-sized yellow dwarf star.

Universe - all of space and time, and everything in it

READING LIST

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ONLINE ARTICLES

FRONTIERS FOR YOUNG MINDS

An open-access scientific journal written by scientists and reviewed by a board of kids and teens

- "Are There Other Earths Out There? Astronomers' First Clues to an Answer Date Back 100 Years" by Benjamin Zuckerman (2016)
- "How to Discover a Planet Orbiting a Distant Star" by Brett M. Morris (2019)
- "Measuring Distances to Galaxies" by Jonathan D. Davis (2019)
- "The New Astronomy: Observing Our Universe with Light and Gravity" by Joey Shapiro Key and LIGO Scientific Collaboration (2019)
- "TRAPPIST-1: A Dark Star With a Bright Future" by Brett M Morris (2019)
- "Why Put Telescopes at the Top of Mountains and Other Strange Places?" by Edward Gomez (2019)

SCIENCE JOURNAL FOR KIDS AND TEENS

Peer-reviewed science research adapted for students and their teachers

- "How Can Dust Make Planets More Suitable for Life?" (July 2020)

ONLINE RESOURCES

PEROT MUSEUM

NASA

- Artemis Program – Preparing for the Next Giant Leap
- Astrobiology at NASA
- Exoplanet Travel Bureau | Explore
- James Webb Space Telescope STEM Toolkit
- Mars 2020 Mission: Perseverance Rover
- NASA Science Space Place | What is the Weather Like on Other Planets?
- NASA STEM @ Home for Students Grades 5-8
- Planetary Fact Sheet
- Solar System Exploration
- Solar System Size and Distance

SOLAR SYSTEM

- Center for Astrophysics, Harvard & Smithsonian | Current Night Sky
- Genius by Stephen Hawking on PBS | "Where Are We?"
- International Dark Sky Association | Find a Dark Sky Place
- International Dark Sky Texas Parks
    - Big Bend Ranch State Park (West Texas)
    - Copper Breaks State Park (Panhandle Plains)
    - Enchanted Rock State Park (Hill Country)
    - South Llano River State Park (Hill Country)
- Map a Model Solar System
- McDonald Observatory
- Phet Interactive Simulations | Gravity and Orbits

STEM CAREERS

- Exploring Careers @NASA – Students
- IF/THEN Collection
    - Erika Hamden, Astrophysicist
    - Dana Bolles, NASA Spaceflight Engineer
    - Kelly Korreck, Astrophysicist
    - Miriam Fuchs, Telescope System Specialist for the James Clerk Maxwell Telescope
- "So You Want to Be an Astronaut?" by Lyle Tavernier, Educational Technology Specialist, NASA/JPL Edu (updated 2020).
- Skype a Scientist

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