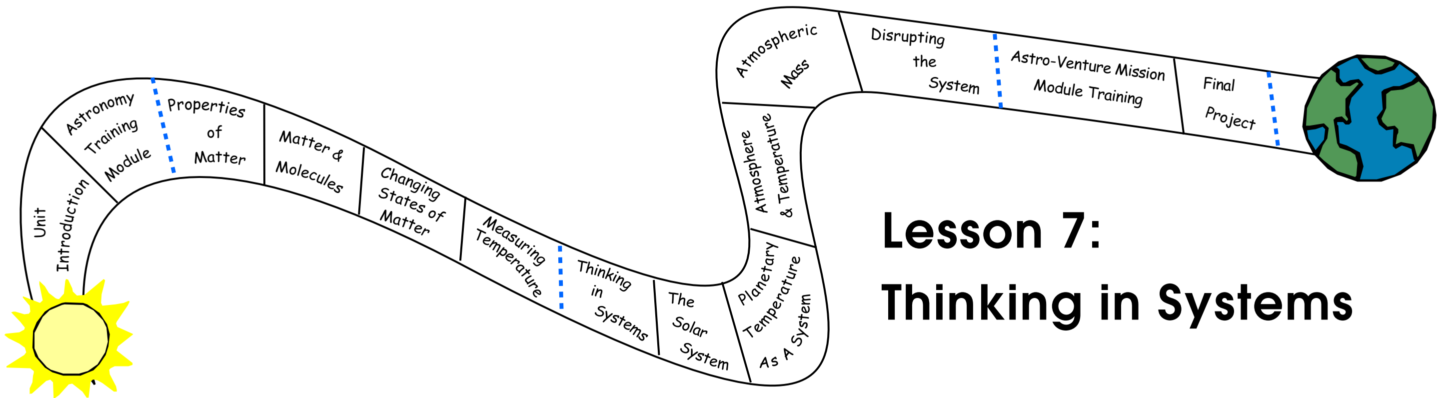
Part 3: Astronomical Factors



Lesson 7: Thinking in Systems

Students explore the planetary temperature system. They further explore how each part influences the system and the consequences of disrupting that system.

Main Lesson Concept: Systems consist of many parts. The parts usually influence each other. A system may not work as well (or at all) if a part of it is missing, broken, worn out, mismatched or misconnected. Thinking about things as systems means looking for how every part relates to other parts. Any system is usually connected to other systems.

Scientific Question: What are the characteristics of a system?

Objectives	Standards
Students will explain: how a system is made up of interacting parts, that when parts of the system change it affects the system, and that systems are often related to other systems.	**Meets**: 2061: 11A 3-5 #1, #2 2061: 11A 6-8 #2, #3 NSES: UCP K-12 #1 **Addresses**: NSES: A 5-8 #1

Assessment	Write-ups in Astro Journal.
Abstract of Lesson	Students explore the characteristics of systems in terms of the human body. They then choose another system to explore and create a concept map of this system. Finally, they summarize the characteristics of a system.

Prerequisite Concepts	Major Concepts
• Most things are made of parts. • Something may not work if some of its parts are missing. • In a system when parts are put together, they can do things that they could not do by themselves.	• A system consists of many parts that usually influence each other and can be part of another system.

Suggested Timeline (45 minute periods):

Day 1: Engage and Explore Sections
Day 2: Extend and Evaluate Sections

Materials and Equipment:

- A class set of Astro Journals Lesson 7: Thinking in Systems*
- Chart paper/ overhead projector/board

Preparation:

- Duplicate a class set of Astro Journals Lesson 7: Thinking in Systems
- Prepare chart paper or overhead projector to record student responses
- Prepare chart paper with major concept of the lesson to post at the end of the lesson.

*Note to Teacher: A generic Astro Journal and Scientific Rubric are included at the end of this part. If you prefer, you can have students use the generic Astro Journal instead of the ones designed to go with each lesson. This might be especially useful for older students who are already familiar with the inquiry method.

Differentiation:

Accommodations

For students who may have special needs, provide physical systems for students to explore such as a stereo system or a model car that can be taken apart to have its system explored.

Advanced Extensions

Investigate non-physical systems such as processes that accomplish a goal. Create a concept map of a process and show how the characteristics of a system relate to a process.

Engage (approximately 15 minutes)

1. Review Part 1 and 2.

- Question: Now that we've finished Part 2, what is an essential factor or variable in determining whether or not a planet can have water in a liquid form on its surface?
- *Answer: An essential variable needed to determine if a planet could have water in liquid form, would be temperature.*

- Question: Why is temperature an essential variable?
- *Answer: If the temperature of the planet is too low, the water will freeze. If the temperature of the planet is too high, the water will boil away.*

- Question: Remind me, why are a moderate temperature and liquid water important?
- *Answer: We need a moderate temperature and liquid water to survive.*

2. Bridge to this lesson.

- Question: What causes a planet to have the temperature that it does?
- Record responses on the board/chart/overhead.
- Have the students discuss and evaluate the responses.

- Question: Which of these ideas are likely causes for the temperature of a planet and why?
- *Answer: Have the students explain their reasons. Accept all reasonable answers.*

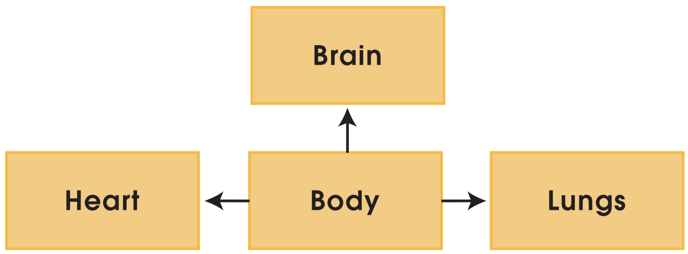
- Question: Which one of these ideas is most likely the cause of temperature on a planet?
  Note to Teacher: Yes, this is a trick question.
- *Answer: There is no single cause for the temperature of a planet. There are many variables, which affect the temperature of a planet.*
- Say: There are many variables, which affect the temperature of a planet. No single one of them is enough to affect the temperature of a planet. In later lessons, we'll be looking at the essential variables that affect the temperature of a planet.

3. Introduce the Scientific Question and purpose of the lesson.

- Say: In order to understand how different variables work together in a system, we need to better understand the characteristics of a system. The scientific question that we will be exploring is "What are the characteristics of a system?"
- Say: We're going to be looking at other situations like the planetary temperature system where different parts of a system work together. This will help us to better understand systems and how systems relate to supporting human life.

- Create a concept map of the human body as an example of a system.
- Question: What are some of the parts of the human body that help keep you alive?
- *Answer: samples –The brain, heart, lungs, veins, arteries, nerves, etc.*

- Record student responses on board/overhead/chart paper.
  Note to Teacher: Clustering/webbing/concept mapping might be a good way to record student responses.



- Question: Is there any one of these parts that could keep you alive without the others?
- *Answer: No. All of these parts are needed to keep us alive.*

- Question: Are these parts separate, or do they work together?
- *Answer: All these parts work together.*

- Question: Let's be more specific. How does the heart work with the veins and arteries?
  Note to Teacher: The goal of Steps 3 – 7 is to have the students discover the characteristics of systems from the national education standards by thinking about the human body as a system. You may substitute different parts of the body if you think your students will know those better, or you may substitute another system if you think that would be more appropriate.
- *Answer: The heart pumps blood through the veins and arteries.*

- Question: How does the brain work with the rest of the body?
- *Answer: The brain tells the rest of the body what to do by sending messages through the spinal column and nerves.*
- Say: All of the parts of the body work together, and no single one of the parts could keep you alive without the others. When there is a situation in which there are several parts to something that have to work together to accomplish a task or to make a product or outcome, we call it a system. We're going to explore some characteristics of systems.

Explore (approximately 30 minutes)

1. Explore the first characteristic of a system:

In systems that consist of many parts, the parts usually influence each other.

- Inform students that they will be thinking about the temperature of a planet as a system in later lessons.
- Question: Based on what we have learned so far, what would you say is an important characteristic of systems?
- *Answer: An important characteristic of a system is that the parts work together.*
- Question: If parts are working together, does that mean that they could be influencing or affecting each other?
- *Answer: Yes, the parts could be influencing or affecting each other.*

- Question: How does the heart affect or influence the brain?
- *Answer: The heart pumps blood to the brain so that the brain can survive.*

- Question: How does the brain affect or influence the heart?
- *Answer: The brain tells the heart when to beat.*

- Have students explain this characteristic and brainstorm other examples of systems. Possible systems might include science systems such as a body system (nervous, respiratory, digestive, etc.) or an ecosystem; social systems such as the government system or justice system; mechanical systems such as a car, a factory or a clock.
- Have them draw a concept map of a chosen system and its parts in their Astro Journals.

2. Explore the second characteristic of a system:

Something may not work as well (or at all) if a part of the system is missing, broken, worn out, mismatched or misconnected.

- Question: Could a person live if something happened to his heart and it stopped beating?
- *Answer: No. He couldn't live unless something was able to start it again.*

- Question: Could a person live if her lungs were so severely damaged that they were no longer able to work?
- *Answer: No, a person could not live if her lungs were severely damaged.*

- Question: What would happen if a person's veins or arteries became more and more clogged?
- *Answer: If a person's arteries became clogged the blood would have a harder time flowing. If the arteries kept getting clogged, the person would probably die.*

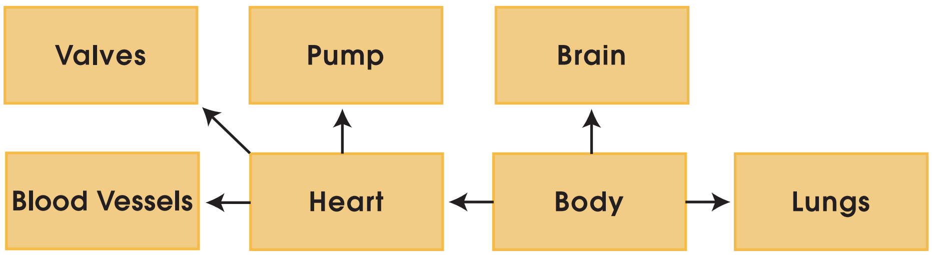
- Question: What would happen if the brain were suddenly no longer connected to the rest of the body?
- *Answer: The body would die if the brain were no longer connected to the rest of the body.*

- Question: Based on these examples, what could we say about systems?
- *Answer: A system may not work as well (or at all) if a part of it is missing, broken, worn out, mismatched or misconnected.*

- Have students explain this characteristic by describing the effects of one part of their chosen system being damaged or taken away in their Astro Journals.

3. **Explore the third characteristic of a system:**
   Thinking about things as systems means looking for how every part relates to each other.

- Question: Let's think about one part of the system: the heart. How does the heart relate to the arteries and veins?
- Branch off of the original concept map to show the parts of the circulatory system.
- *Answer: The heart pumps blood through the arteries and veins.*



- Question: How does the heart relate to the lungs?
- *Answer: The heart pumps blood to the lungs so that the blood can get oxygen.*

- Question: How does the heart relate to the brain?
- *Answer: The heart pumps blood to the brain which needs oxygen to survive.*

- Question: If we chose another part of the body, could we find ways to relate that part to other parts of the body?
- *Answer: Yes, we probably could find ways to relate that chosen part of the body to other parts of the body.*

- Question: Based on these examples, what could we say about systems?
- *Answer: Thinking about things as systems means looking for how every part relates to others.*
- Have students explain this characteristic by explaining how the parts of their chosen system relate to each other in their Astro Journals.

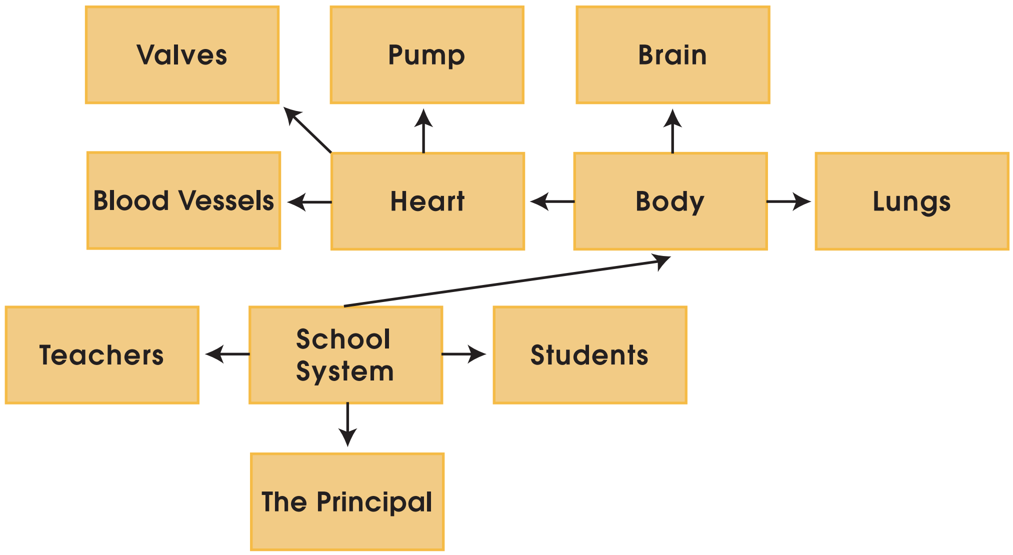
4. **Explore the fourth characteristic of a system:**
   Any system is usually connected to other systems.

- Question: If we think of the human body as a system that keeps a person alive, does that system ever come into contact with other systems? If so, what might those other systems be?
- *Answer: Yes, humans contact other people, each of whom is a separate system.*

- Question: Could people be parts in a larger system?
- *Answer: Yes, people could be parts of a larger system.*

- Question: What are some examples of systems that have people as parts?
- *Answer: Some examples of systems are families, school systems, justice systems, government systems, etc.*

- Question: Let's use the school as an example. What are the different types of people in a school?
- Build on the previous concept map of the human body to show how this is a sub-system of another system.
- *Answer: The different types of people in a school are teachers, students, and the principal.*



- Discuss the role of the principal in regards to a system

- Question: How would you say that the people in a school affect or influence each other?
- *Answer: The principals set the goals. The teachers teach the students based on the goals set by the principal. And the students learn from teachers.*

- Question: Would the system work, if we took one group of people away?
- *Answer: No, the system would not work, if we took one group away.*

- Question: Based on these examples, what could we say about systems?
- *Answer: Many systems are usually connected to other systems.*

- Have students explain this characteristic by building on their concept map to show how it is a subsystem of another system in their Astro Journals.

Extend/Apply (approximately 30 minutes)

1. Engage students in an activity on other examples of systems.

- Review the characteristics of systems and how they apply to individual people as systems, and groups of people as systems.
- Have students design their own system that fulfills some important function such as making breakfast and explain how the characteristics of a system are displayed by the system.

Evaluate (approximately 15 minutes)

1. Discuss the characteristics of systems.

- Have students share their chosen system with their group and how the characteristics of a system relate to this chosen system.
  - Question: What is a system?
  - *Answer: A system consists of many parts that usually influence each other to produce some result. Systems can be part of another system and may not work as well or at all if some part is broken or damaged.*

2. Assess students' Astro Journals to ensure that they have mastered the characteristics of systems.

Note to Teacher: After each lesson, consider posting the main concept of the lesson some place in your classroom. As you move through the unit, you and the students can refer to the 'conceptual flow' and reflect on the progression of the learning. This may be logistically difficult, but it is a powerful tool for building understanding.

Astro Journal Lesson 7: Thinking in Systems

System Chosen:

1. The first characteristic of a system is:

2. Draw a concept map of the parts of your chosen system.

3. The second characteristic of a system is:

Name:

Date:

4. What would happen if one part of your system was damaged or taken away?

5. The third characteristic of a system is:

6. How do the parts of your system relate to each other?

Astro Journal Lesson 7: Thinking in Systems

System Chosen:

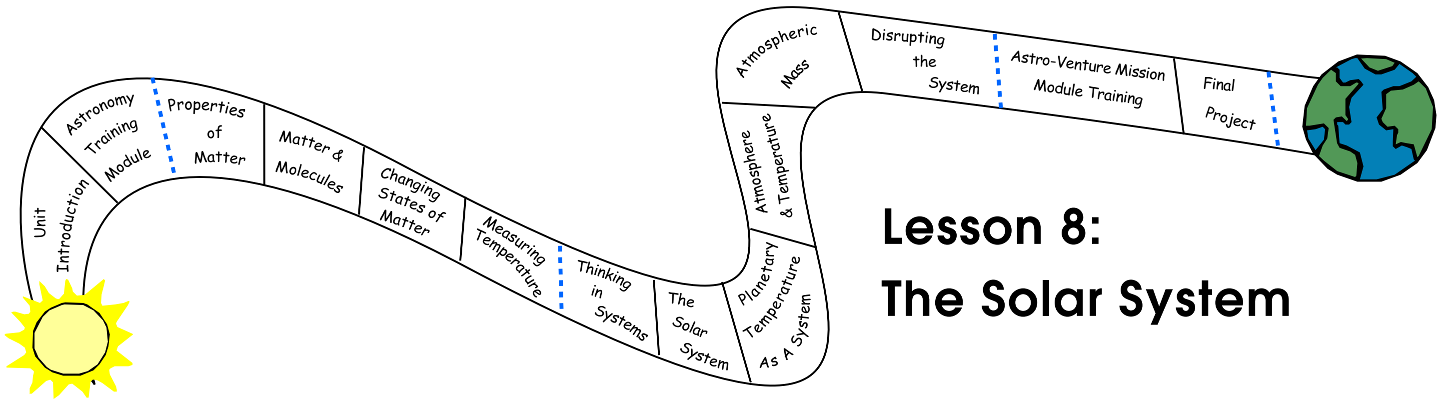
Name:

Date:

7. The fourth characteristic of a system is:

8. Draw a concept map of your system and how it is a part of another system.

9. Design a system that would perform an important or helpful function such as making your breakfast. Draw the system and explain how the characteristics of a system apply to your system.



Lesson 8: The Solar System

Students explore the planetary temperature system. They explore how each aspect (e.g., mass, temperature and gravity) influences the system and the consequences of disrupting that system.

Main Lesson Concept: The Solar System is a system. One of the ways that the parts of the Solar System interact with each other is through gravity.

Scientific Question: How do the parts of the Solar System interact with each other?

- Mass is the measure of the quantity of matter.
- Gravity is a force of attraction that exists between objects. The greater the mass the greater its gravitational pull.
- The Sun's gravitational pull holds Earth and other planets in their orbits, just as the planets' gravitational pull keeps the planets' moons in orbit around them.
- Everything on or near the Earth is pulled towards Earth's center by gravitational force.
- Earth is one of several planets that orbits the Sun.
- A system consists of many parts that usually influence each other. (Lesson 7)
- An orbit is the path of an object around another object, caused by gravity.
- Two objects orbit around their center of mass.

Suggested Timeline (45-minute periods):

Day 1: Engage, Explore, and Explain Sections
Day 2: Extend/Apply Section
Day 3: Evaluate Section

Materials and Equipment:

- A class set of Astro Journal Lesson 8: The Solar System*
- A class set of Solar System Illustration Activity
- A tennis (or other) ball with a string securely attached
- An overhead transparency of Center of Mass
- Scientific Inquiry Evaluation Rubric
- Container of clay or play dough for each group
- A ruler for each student
- A scale for each group or string
- 2 Styrofoam™ balls (optional)
- 2 barbecue skewers (optional)
- Computer with browser and Internet connection
- Construction paper or butcher paper for each student.
- Chart paper

Preparation:

- Gather materials (e.g., string, tennis ball, clay or play dough, rulers, scales, string, Styrofoam™ balls, barbecue skewers, construction paper).
- Duplicate a class set of Astro Journals and Solar System Illustration Activity.
- Make overhead transparency of Center of Mass.
- Verify Links for Orrery Sites.
- Optional: Find more materials on orreries
- Prepare chart paper with major concept of the lesson to post at the end of the lesson.

*Note to Teacher: A generic Astro Journal and Scientific Rubric are included at the end of this part. If you prefer, you can have students use the generic Astro Journal instead of the ones designed to go with each lesson. This might be especially useful for older students who are already familiar with the inquiry method.

Differentiation:

Accommodations

For students who may have special needs, have students give an oral report or more limited writing assignment.

Advanced Extensions

Research star systems discovered outside of our own.

- How are they like our system?
- How are they different?

Engage (approximately 5 minutes)

1. Review systems.

- Question: When we're thinking in terms of systems, what should we be thinking about?
- *Answer: Systems consist of many parts. The parts usually influence each other. A system may not work as well (or at all) if a part of it is missing, broken, worn out, mismatched or misconnected. Thinking about things as systems means looking for how every part relates to other parts. Any system is usually connected to other systems.*

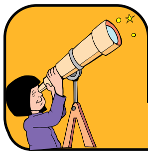
- Question: Let's think about our Solar System for a minute. What are the parts of the system?
- *Answer: The parts of the Solar System are planets, moons, the Sun, asteroids, etc.*

2. Go over the Scientific Question with students and state the purpose of the lesson.

- Scientific Question: How do the parts of the Solar System interact with each other?
- Question: Why are we interested in how the parts of the Solar System interact with each other?
- *Answer: How the parts of the Solar System interact affects the Earth's ability to support human life. Understanding this system will help us to understand how our planet and star system meet our survival needs.*

3. Record student responses on board/overheard/chart paper.

- Students record their Predictions in their Astro Journals.



Explore (approximately 25 minutes)

1. Introduce the demonstration.

- Say: There are many ways that the parts of the Solar System interact with each other. We're going to explore one of them.

2. Swing the ball attached to the string around.

- Question: Does this look like anything that occurs in the Solar System?
- *Answer: It looks like a planet travelling around the Sun or a moon travelling around a planet.*

- Question: Are there actually strings tying the planets to the Sun?
- *Answer: No, there are not any strings that tie the planets to the Sun.*

- Question: So what is keeping the planets moving around the Sun?
- *Answer: The Sun's gravitational pull is keeping the planets moving around the Sun.*

- Question: What is gravity?
- *Answer: Gravity is a force of attraction that exists between objects. The greater the mass of an object, the greater its gravitational pull.*

- Say: When an object moves around another object because of gravity, that movement is called an orbit.

- Say: We're going to take a closer look at how objects orbit around each other.

3. Students engage in "Finding A Balance" activity.

- Demonstration: Balance a ruler on your finger.
- Question: Why is this ruler balancing?
- *Answer: There is equal mass on both sides of your finger.*

MISCONCEPTION: Students tend to confuse mass and weight. The mass of an object refers to the quantity of matter in that object. Its weight is a measure of the gravitational attraction between it and the body that it's on. Mass is an absolute quantity. It does not change when the object is on different bodies or even floating out in space. Weight will change. That is why the astronauts on the moon were able to make those long and high jumps. The discussion below will help to reveal this misconception.

- Question: On another planet would these balls have a different weight? How do you know?
- *Answer: Yes. Astronauts on the moon weigh less, so they bounce when they walk.*

- Question: On another planet, would these balls have a different mass? Explain.
- *Answer: No. The balls would have the same amount of matter.*

- Question: So what causes the change in weight?
- *Answer: The gravitational pull causes the change in weight.*

- Say: The reason these two balls balance is because they have the same amount of matter in them. Because they have the same amount of matter, they also have the same weight. On a different planet they would have a different weight. In space, they would have so little weight that you could barely detect it. No matter what the weight, they would always have the same amount of matter in them.

- Question: If I were to put a small ball of clay on one end of this ruler, what would I have to do to keep the ruler balanced?
- *Answer: You would have to put a ball of equal mass on the other end.*

- Question: What if the balls of clay did not have equal mass? Could I still balance the ruler?
- *Answer: Yes. You'd have to move the balls to different parts of the ruler or your finger.*

- Question: If we made the rule that the balls of clay had to stay at the ends of the ruler, where do you think your finger would have to be in order to balance two balls with these comparisons:
  - two balls of equal size
  - one ball that is twice the size of the other
  - one ball that is four times the size of the other
  - one ball that is eight times the size of the other
  - Put students into groups.
  - Give each group one container of clay or clay dough, and a ruler.
  - Have students divide their clay dough into two equal parts and roll them into balls.
  - If you have scales, have students weigh the balls to make sure they are the same size. If you don't have scales, students could use a string and ruler to measure the circumference of each ball.

  Note to Teacher: Warn students against compressing their clay too much if you can't weigh the balls. They may look the same size, but have different densities, which could alter the results.

MISCONCEPTION: Students tend to believe that two objects of the same size have the same mass. To bring out this misconception, ask students what would happen if you had a marshmallow on one end and a clay ball of the same size on the other end and why. Help them observe that the clay is more massive than the marshmallow even though they are the same size.

- Have students balance the ruler with the balls on their finger, making sure to put the balls on either side of the ruler at the same distance from the ends.
- Have students record in their Astro Journals the number on the ruler at which the balls balance.
- Repeat this procedure for the other sizes, by having students divide one of the balls in half each time.
- Students fill in the Materials and Procedures sections of the Astro Journal.

Explain (approximately 20 minutes)

1. **Have students share their findings with others in their group to see if they got similar results.**
   Ask them to explain in their own words what is happening and record it in their Astro Journals.

- Question: What would happen if we kept reducing the size of the smaller ball?
- *Answer: Without the weight of the ruler interfering, eventually the balancing point would be under the larger ball.*

2. **Show students the Center of Mass overhead transparency.**
   Explain to students that orbits are caused by gravity and that the balancing points they have found are called the center of mass. The center of mass is the point in between the centers of both objects, where the two masses balance. Explain that when two objects orbit each other, they orbit around their center of mass.
   Note to Teacher: The equation for figuring out where the center of mass would be is: $m_1 * r_1 = m_2 * r_2$ where m_1 is the mass of the star, m_2 is the mass of the planet, r_1 is the distance from the star to the center of mass and r_2 is the distance from the planet to the center of mass.

- Question: Where is the center of mass between Earth and the Sun, if the Sun's mass is 334,000 times that of Earth.
- *Answer: The center of mass would be near the center of the Sun.*

- Question: Does the Sun orbit?
- *Answer: Yes. The Sun appears to be stationary, but actually does move around. This is because the Sun and the planets orbit around their center of mass. For our Solar System, the center of mass happens to be just outside the Sun.*
- Say: The Sun is only 1,050 times the mass of Jupiter (considerably less than 334,000 times), so that this center of mass moves out enough to cause our Sun to move considerably more. This movement is called a wobble. When scientists detect a star that wobbles noticeably, they know that the star has a large planet orbiting it. You'll see this in the Astro-Venture Astronomy Mission Module.

3. (Optional) Show students a model of this wobble.

- Take a large styrofoam ball and insert a skewer off center. Attach another, smaller styrofoam ball with another skewer at a right angle to the first skewer. Spin the larger ball on its skewer. Explain that it wobbles, because the center of mass is outside its own center. This is the same reason that the Sun wobbles, as Jupiter moves around it.

4. Students fill in the "Finding the Balance" Results and Conclusions section in their Astro Journals.

Extend/Apply (approximately 45 minutes)

1. Students model the Solar System.

- Question: Since it sometimes helps to understand something if we can visualize it, are there ways we can model our Solar System?
- *Answer: There are many ways to model our Solar System including planetaria, illustrations, etc.*

- Tell the students that in the early 1700s, an Irish nobleman, the Earl of Orrery, hired a watchmaker to build him a machine that would accurately show the movements of the planets.

- Question: Why would someone hire a watchmaker to make such a machine?
- *Answer: Many of the earliest "clocks" marked the passage of time using the movement of astronomical bodies (the sun, the moon, and various planets). One of those clocks, the sundial became the model for the clock. It would not be that great of a stretch for a watchmaker to model the movement of astronomical bodies.*
  Note to Teacher: An orrery is a limited model that shows the relative positions of the planets and an estimation of their movement. It will be contrasted later with a gravity simulator that can model the Solar System in a more realistic way - by simulating the gravitational effects of large bodies on each other.

- Tell the students that they are going to be focusing on the distance of the planets from the sun. They will make a scale drawing of the planets in the Solar System from Mercury to Saturn.
  Note to Teacher: The distances will be to scale, but the planet sizes will not. The scale is also the reason we're stopping at Saturn. The planets beyond Saturn would make the drawing too large.

- Have students do the 'Solar System Illustration' activity, which is included with the Lesson 8 Astro Journal.

- Introduce the 'Solar System Illustration' activity by reading over the directions with students. If students have not experienced working with scale, you may want to help them generate a chart that translates each distance into centimeters as follows:
  - Question: If Earth is 1 Astronomical Unit (AU) from the Sun, and in this scale, 1 AU is 2 centimeters (cm), how far away would we draw Earth?
  - *Answer: Earth would be drawn 2 centimeters from the Sun.*

  - Question: If Mercury is 0.4 AU from the Sun, how many centimeters would that be?
  - *Answer: We multiply 2 centimeters times 0.4, which is 0.8 centimeters.*

- Continue for each distance to generate the following chart.

Planet	Distance from Sun in AU's	Distance in cm (Scale: 1 AU = 2 cm)
Mercury	0.4	0.8
Venus	0.7	1.4
Earth	1	2
Mars	1.5	3
Jupiter	5.2	10.4
Saturn	9.6	19.2

Note to Teacher: Advanced students might also calculate and show center of mass using the formula: $m_1 * r_1 = m_2 * r_2$ where m_1 is the mass of the star, m_2 is the mass of the planet, r_1 is the distance from the star to the center of mass and r_2 is the distance from the planet to the center of mass.

MISCONCEPTION: Because of the difficulty of representing the Solar System to scale with both size and distance, students often do not have a true sense of relative sizes. For example, students often believe that Jupiter is close to the same size as the Sun. Ask students how big the Sun is compared to Jupiter (the Sun is about 10x the diameter of Jupiter). Ask students how big Jupiter is compared to Earth (Jupiter is about 10x the diameter of Earth. Discuss with students whether they will draw the planets and Sun to scale or not and why or why not. Discuss the importance of indicating that an image is not to scale.

- While the students are working on their illustrations, have them visit the following links about orreries.
  Note to Teacher: Links are active as of August 2001. Check before using with students. Other resources about orreries can also be included. Have students focus on the idea that an orrery is a system. The mechanical orrery uses gears and cogs to model the mathematical relationships. The digital ones use calculations and images.
  - Mechanical Orreries
    - http://www.geocities.com/CapeCanaveral/Hall/3551/ingle27.htm
    - Carlos Croce is a clock-maker who has built an orrery. The written information is too complex for most students at the 5th to 8th grade level, but the pictures are beautiful and show some of the inner workings. He also shares some of the trials he went through in building the orrery.
  - Digital Orreries
    - http://www.schoolsobservatory.org.uk/uninow/orrery/
      This is a basic orrery simulation written in Java, which shows the position of the planets on a given date then allows you to move forward or backward in time.
    - http://www.scienceu.com/observatory/handson/orr/orr.html
      This is an orrery with a twist. It allows you to view the planets from many points of view (including from other planets).

Evaluate (approximately 45 minutes)

1. Have students share their illustrations and explain to a partner or in a small group how the Solar System has the characteristics of systems.

2. Have students do the Results section for the lesson in their Astro Journals.

- Go over rubric for essay (on the assignment sheet).
  Note to Teacher: You may want to be more specific with your students about the lengths of their essays. The students will be using one period for this. Plan essay length accordingly.

3. Discuss students' essays.

- Question: Explain the Solar System as a system.
- *Answer: The Solar System is made up of parts, which include the Sun, planets, moons and asteroids. These parts are held together by gravity, which causes an attraction between all of the different parts and which keeps the parts of the system in their orbits. The system is pretty stable and balanced, as the parts of the system all orbit around their center of mass. Planets, moons and asteroids all stay in their orbits. However, if an object, such as a large planet, came into the Solar System from outside, it could disrupt the balance. It might run into another planet and change the orbits of the objects in the system.*

  Note to Teacher: After each lesson, consider posting the main concept of the lesson some place in your classroom. As you move through the unit, you and the students can refer to the 'conceptual flow' and reflect on the progression of the learning. This may be logistically difficult, but it is a powerful tool for building understanding.

Astro Journal Lesson 8: The Solar System

Class/Period:

1. Scientific Question:

How do the parts of the solar system interact with each other?

2. Hypothesis/Prediction: How do you think the parts of the solar system interact with each other?

Name:

Date:

3. Results: On a separate sheet of paper, write a short essay that explains the solar system as a system.

Essays must include reference to the characteristics of systems:

- In systems that consist of many parts, the parts usually influence each other.
- A system may not work as well (or at all) if a part of it is missing, broken, worn out, mismatched or misconnected.
- Thinking about things as systems means looking for how every part relates to others.
- Any system is usually connected to other systems.

Also make sure to include orbits, center of mass and the role of gravity in the system. You may use your experiences with orreries to help your explanations.

Your essay will be evaluated using the following rubric.

4
- Essay clearly and accurately explains how the Solar System is a system.
- Essay has all required parts and uses examples and reasoning to create an exceptionally powerful and detailed explanation.

3
- Essay clearly and accurately explains how the Solar System is a system.
- Essay has all required parts, makes specific references to examples, and uses good reasoning in explanations.

2
- Essay is not completely clear or accurate in explaining how the Solar System is a system.
- Essay has most required parts, makes some specific references to examples, and uses some good reasoning in explanations.

1
- Essay is not clear or accurate in explaining how the Solar System is a system.
- Essay is not clear or accurate in explaining how the Solar System is a system. Essay is missing several parts, makes few specific references to examples, and uses little or no good reasoning.

Solar System Illustration Activity

Create an illustration that shows the Sun, the planets from Mercury to Saturn and their orbits around the Sun. The distances of the planets from the Sun should be drawn to scale. The size of the Sun and planets should reflect their relative sizes (Jupiter is larger than the Earth. The Sun is the largest of the bodies.), but a precise scale is not required. If planets and the Sun are not drawn to scale, be sure to indicate this. The illustration should include:

- a key
- a caption which explains orbits, center of mass, and the role of gravity in the Solar System

The chart below has the distance of the planets from the Sun using a scale called Astronomical Units or AU for short. One Astronomical Unit is the distance of the Earth from the Sun (149,637,000 kilometers or 93,000,000 miles). Please note that these distances are the average distance from the Sun. Depending on where the planet is in its orbit around the Sun, the actual distance may be greater or lesser.

Planet	**Distance from Sun in AU's**
Mercury	0.4
Venus	0.7
Earth	1
Mars	1.5
Jupiter	5.2
Saturn	9.6

The most direct way to make your drawing to scale is to have 1 AU be equivalent to 2 centimeters (cm) or 1 inch. Using this scale, Earth would orbit 2 cm away from the Sun. **You <u>must</u> include your scale in your key and indicate which elements are to scale and which are not.**

Uranus, Neptune and Pluto have been left off because their distance would make the illustration too large.

Your illustration will be assessed using the following rubric.

4	• The planets and orbits are accurately, creatively and elegantly portrayed in the illustration. The caption clearly and accurately portrays orbits, center of mass, and the role of gravity in the Solar System. • Elements on the poster are spaced appropriately and design elements (color, lines, shapes, and content illustrations) make the poster exceptionally clear and easy to understand.
3	• The planets and orbits are clearly and accurately portrayed in the illustration. The caption clearly and accurately portrays orbits, center of mass, and the role of gravity in the Solar System. • Elements on the illustration are spaced appropriately, and design elements (color, lines, shapes, and content illustrations) make the illustration easy to read and understand.
2	• The planets and orbits are not completely clear or accurately portrayed in the illustration. The caption does not completely clearly or accurately orbits, center of mass, and the role of gravity in the Solar System. • Elements on the illustration could be better spaced and design elements (color, lines, shapes, and content illustrations) make the illustration a little difficult to read.
1	• The planets and orbits are unclear or inaccurate in the illustration. The caption does not clearly and accurately explain orbits, center of mass, and the role of gravity in the Solar System. • Elements on the illustration are either squashed together or large spaces are empty, and design elements (color, lines, shapes, and content illustrations) make the illustration difficult to read.

Illustration Self-Evaluation

Evaluate your work using the rubric. Give your work a score and then explain why you think the work deserves that score. Make references to specific parts of your illustration when explaining your score.

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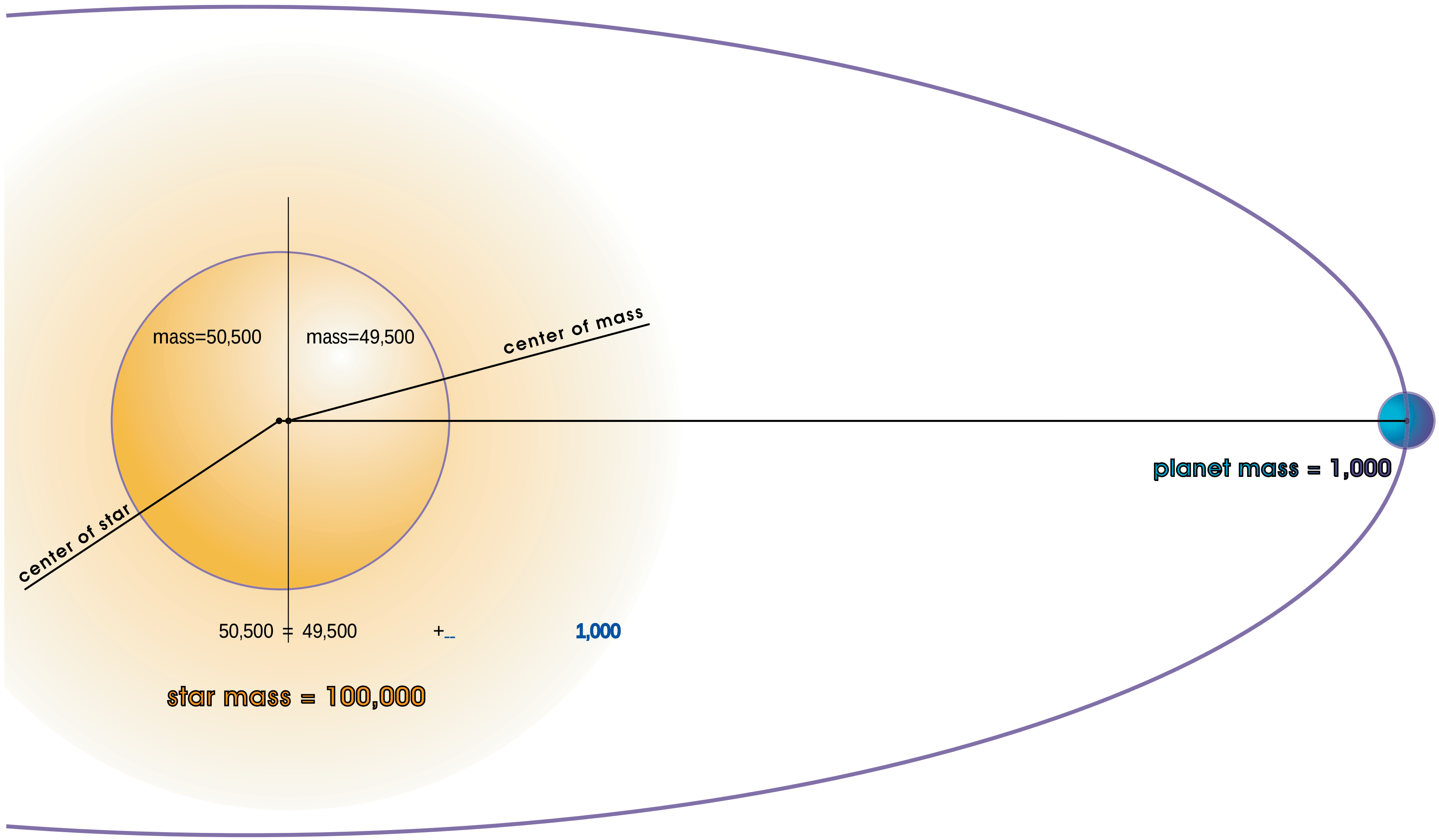
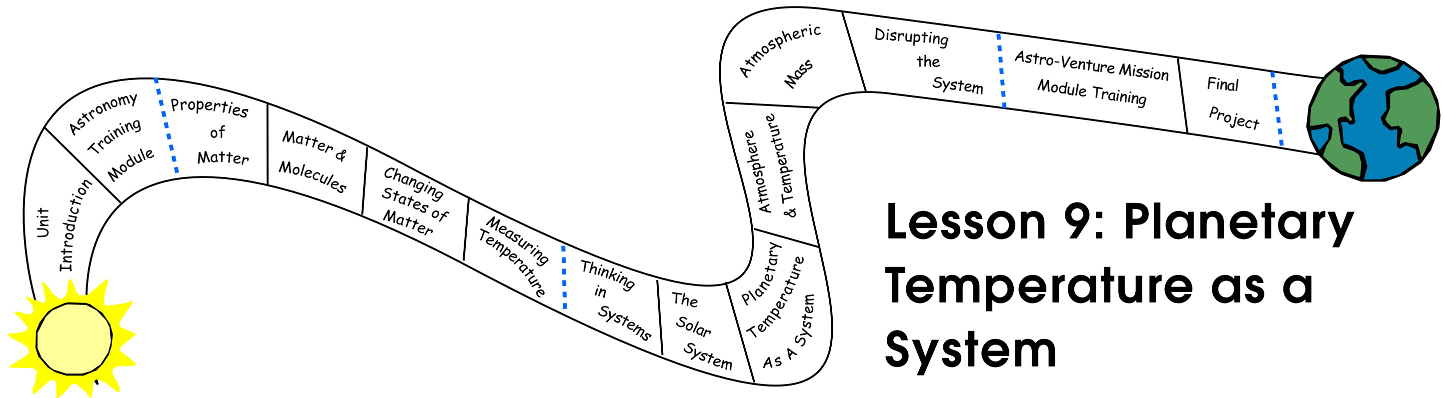
Center of Mass



Center of Mass. The balancing point between two masses.



Lesson 9: Planetary Temperature as a System

Students explore the planetary temperature system. They further explore how each part influences the system and the consequences of disrupting that system.

Main Lesson Concept: The type of star and the distance of a planet from the star affects two major parts of the system that controls the surface temperature of a planet (planetary temperature system). The hotter a star is, the further the planet needs to orbit in order to maintain liquid water on its surface.

Scientific Question: What are two important parts of the planetary temperature system? How do these parts work together to determine a planet's surface temperature?

Objectives	Standards
Students will explain how star type and the distance of a planet from its star work together to affect the planetary temperature system.	**Meets**: 2061: 11A 6-8 #2 NSES: UCP1 K-12 **Addresses**: NSES: A 5-8 #1 NCTM: 2, 5, 9
Students will categorize stars on a Hertzsprung-Russell (HR) Diagram. They will also model the relationship of star type and orbital distance and will draw conclusions about the stars most suitable for supporting human life.	

Assessment	Write-up in Astro Journal, Diagram of a star and its Habitable Zone.
Abstract of Lesson	Students categorize stars on a HR diagram and explore the characteristics of the types of stars most suitable for supporting human life. They then explore the interaction of star type and orbital distance in determining the temperature of a planet by modeling this interaction.

Prerequisite Concepts

- The Sun's gravitational pull holds Earth and other planets in their orbits, just as the planets' gravitational pull keeps their moons in orbit around them.
- A system consists of many parts that usually influence each other. (Lesson 7)
- An orbit is the path of an object as it moves around another object because of gravity. (Lesson 8)
- An Astronomical Unit (AU) is the average distance between the Sun and Earth and is equivalent to 149,598,770 kilometers or 93,000,000 miles.
- Temperature is the measure of the average kinetic energy (or movement) of the molecules of a system. (Lesson 6)
- Luminosity is the brightness of a star.

Major Concepts

- Scientists categorize stars by their temperature and brightness or luminosity.
- Stars in the middle of the main sequence on the HR Diagram (yellow stars) are ideal for human life, as they burn at a moderate temperature that remains relatively stable over time.
- The Habitable Zone is the area around a star in which a planet could maintain liquid water on or near its surface. This zone changes in distance from the star and in the width of the zone depending on the temperature of the star.
- The temperature of a star and the orbital distance of a planet work together to affect the planet's surface temperature.

Suggested Timeline (45-minute periods):

Day 1: Engage and Explore Sections
Day 2: Explain Section
Day 3: Extend/Apply and Evaluate Sections

Materials and Equipment:

- A class set of Astro Journals Lesson 9: Planetary Temperature as a System*
- Grouping Star Cards for each group
- One copy of Are You My Type (cut so that each student has one)
- Overhead transparency of Blank HR Diagram
- Overhead transparency of Completed HR Diagram
- Transparency pens of different colors (blue, red, orange, yellow)
- A class set of Star Type Reading
- A class set of Habitable Zone Reading
- Chart paper/board
- Overhead projector
- Class set of scissors

Preparation:

- Prepare overhead for lesson.
- Gather materials (i.e., transparency pens, scissors).
- Create overhead transparencies of Blank HR Diagram and Completed HR Diagram.
- Copy a class set of Astro Journals: Lesson 9, Star Type Reading: Lesson 7 and Habitable Zone Reading: Lesson 5.
- Copy a set of Star Cards for groups.
- Copy and cut a class set of Are You My Type.
- Prepare chart paper with major concept of the lesson to post at the end of the lesson.

*Note to Teacher: A generic Astro Journal and Scientific Rubric are included at the end of this part. If you prefer, you can have students use the generic Astro Journal instead of the ones designed to go with each lesson. This might be especially useful for older students who are already familiar with the inquiry method.

Differentiation:

Accommodations

For students who may have special needs, provide extra support for reading assignment (e.g. partner, read aloud, etc.).

Advanced Extensions

Have students research and report on one of the following questions:

- Is a star the only source of heat for a planet?
- Is a star always the same type throughout its life?
- Is the Habitable Zone the same for microbes? Why or why not?
- What is the Habitable Zone of a galaxy?

(Some advanced students may enjoy reading the book Rare Earth by Peter Ward that goes into many of these topics in much more detail than Astro-Venture.)

Engage (approximately 15 minutes)

1. Review the Solar System as a system.

- Question: How is the Solar System a system?
- *Answer: The Solar System has many parts (the Sun and planets primarily) which are held together by gravity.*

- Question: One of the characteristics of a system is that it is usually connected to other systems or contains smaller systems within it. If we look at the Earth by itself, what systems does the Earth have?
- *Answer: The Earth has many systems such as our weather system, ecosystems, the rock cycle, water cycle, carbon cycle, nitrogen cycle, etc.*
- Say: The system on which we will be focusing is the system that determines the surface temperature on a planet.

2. Present the Scientific Question(s):

- What are two important parts of the system that controls the surface temperature of a planet (planetary temperature system)? How do these parts work together to determine a planet's surface temperature?

3. Record student responses on board/overheard/chart paper.

- Students record their predictions in the Prediction section of their Astro Journals.

4. Introduce the planetary temperature system.

- Question: We're going to be looking at the system that controls the surface temperature of a planet or the "planetary temperature system". What determines the surface temperature of a planet ?
- *Answer: The most important part of the planetary temperature system is to have a source of heat, which is usually a star. (Other parts of the system that students may or may not bring up are the distance of a planet from its star and the amount and composition of its atmosphere.)*

Note to Teacher: Another source of heat could be the internal heat of a planet. Microbes on Earth obtain heat and energy from the heat vents on the ocean floor. This heat comes from inside the Earth. In fact, Jupiter and Saturn radiate more heat than they receive from the Sun. The source of this heat is internal and originates from the formation of the planet. Similarly heat on some satellites such as Jupiter's moon, Europa, is caused by tidal friction, as Europa expands and contracts when the gravitational pull of another satellite increases and decreases as it orbits close to and then far away from Europa. The gravitational pull on Europa fluctuates so much that it causes the planet to flex, generating heat in the process.

- Question: Let's pretend that our heat source is a campfire and that we are planets around the campfire. What other factor is going to determine how hot or cold we are?
- *Answer: The other factor, which will determine how hot or cold we become is our distance from the campfire.*

- Question: What happens when we go closer to the campfire?
- *Answer: When we move closer to the campfire we feel warmer.*

- Question: What happens when we go further away from the campfire?
- *Answer: When we move further away from the campfire, we feel colder.*

5. Introduce the Purpose of the lesson.

- Question: Why do we care about the temperature of a planet?
- *Answer: Planetary temperature is important in order for humans to survive. Humans need a stable temperature that allows water to be liquid at all times.*

- Say: Today we will be looking at two important parts of the planetary temperature system and how they work together. We will first focus on stars, the different types of stars there are and decide which would be the best kind to have in our system. We will then look at how orbital distance works with star type to determine the temperature of a planet and which star type and distance are ideal for human habitability.

Explore (approximately 30 minutes)

1. Introduce star type.

- Question: In the Astronomy Training Module, what kind of star was needed to support human life?
- *Answer: A yellow star was needed to support human life.*
- Tell students that they're going to be exploring what that concept means in a little more depth.

MISCONCEPTION: People sometimes confuse stars and planets or do not make the connection that the Sun is actually a star.

- Question: How are stars different from planets?
- *Answer: A star is a large, hot ball of gases, which gives off its own light. A planet is a large body that does not give off its own light and is orbiting a star. A planet is generally much smaller than a star and can be made of solid, liquid and/or gas.*

2. Discuss star categorizing.

- Say: Often times we put things into categories based on certain characteristics. For example, we can categorize automobiles by type (car, truck, SUV), by color, by size (sub-compact, compact, mid-size, luxury) or any number of other characteristics.
- Question: What characteristics do you think scientists would use to categorize stars?
- Record students' ideas on the board.

3. Engage students in star categorizing activity.

Note to Teacher: If students are not familiar with the term "luminosity", discuss this concept before beginning the activity. Luminosity is the brightness of a star.

- Put students into groups and give each group a copy of Grouping Stars Cards.
- Have students cut out the cards and put them in categories. As an example, use distance from Earth to sort the stars. Sample categories might be: less than 10 light years, 10 to 100 light years and more than 100 light years. Have students list the star names that fit in each category.
- Have groups come up with as many different categories as they can and then have them list the categories and the stars that fit in each category.
- Have students share their categories. List the different categories on the board/chart/overhead.
- Possible categories might include Main Sequence stars and giants; temperature ranges of 0-3500 Kelvins, 3501-6,000 Kelvins, 6,001-10,000 Kelvins and over 10,000 Kelvins; star diameter ranges of 1 to 3 Suns, 4 to 12 Suns and more than 100 Suns.

POSSIBLE CONFUSION We're focusing on both systems and categories in this lesson. This may initially cause confusion, but in exploring their similarities and differences, students can gain a better understanding of both systems and categories.

- Question: How are categories and systems different?
- *Answer: Categories are groupings based on characteristics. Systems are groupings based on the interactions of the parts of the system.*

- Question: How are systems and categories similar?
- *Answer: Systems and categories are similar in that they are both ways of grouping things.*

4. Discuss categories.

- Have students share their categories and list them on the board. Discuss which categories students think are best and why.
- Tell students that scientists classify stars by their temperature and brightness or luminosity. By graphing stars according to luminosity over temperature, they have observed groups of stars. Students will observe this in the following activity.

Explain (approximately 30 minutes)

1. Engage students in the HR Diagram activity.

- Hand out an Are You My Type? Card to each student.

- Have students group themselves with others in the class that have similar temperature and luminosity.

- Project the Blank HR diagram on an overhead projector.

- Have students come up and using transparency pens, draw a star where it would go on the HR diagram. Encourage students to use the color pen that fits the section of the HR diagram where the star is located. If their star is a giant, encourage them to draw a larger star. White stars can be drawn as unfilled circles. Have them label the star with its name.
  Note to Teacher: Alternative methods of having students plot their stars are to :
  - Recreate a large version of the HR Diagram on chart paper. Post the chart on a bulletin board, and have students use pushpins or stickers for stars.
  - Draw the HR Diagram with sidewalk chalk outside, and have students place themselves on the diagram.

• Stars should be grouped as follows:

Yellow stars	Red/orange stars	Blue/white stars	Supergiants
Sol Cen A Christinaurus Rex Donaldix Doserb Geofferan	Ross 154 Ross 248 UV Cet B Grb 34 A 2398 A Lac 9352 Samuelsonian Mattrix Sundownus Alisan	Hoedus II Furud Castor	Aludra Rigel
Yellow/orange giants	**Red giants**	**White dwarfs**	
Pollux Nihal Ain	Hassaleh Propus Aldebaran	V. maanen' s star Luyten	

Note to Teacher: Some of the above stars are factual, and some are fabricated for this lesson.

2. Discuss with students the patterns they observe on the HR Diagram.

- Question: What groups of stars do you observe on the diagram?
- *Answer:*
  - *There is a band of stars that stretches from the top left corner to the bottom right.*
  - *There are two clusters of stars in the top right.*
  - *There is another cluster of stars in the bottom left.*

- Post the transparency of the Completed HR Diagram.
- Say: We call the band of stars that stretches at a diagonal, Main Sequence stars. The two clusters in the top right are called giants and supergiants. The bottom left cluster of stars is called the white dwarfs. We'll learn more about these different types of stars in our reading.
- Post the Blank HR Diagram again.

- Question: Is there a relationship between temperature and luminosity? (In particular, look at the Main Sequence stars) If so, how do you know?
- *Answer: Yes, there is a relationship between temperature and luminosity. The stars show a definite pattern instead of being scattered all over the diagram.*

- Question: What is the relationship between temperature and luminosity?
- *Answer: The hotter a star is, the greater its luminosity.*

- Question: Is there a relationship between the number of stars and their temperature and luminosity? If so, what is it?
- *Answer: There are more stars that are cool and dim than there are stars that are hot and bright.*

- Question: Why do you think this might be?
- *Answer: Cooler, dimmer red stars live longer (hundreds of billions of years) compared to hotter, brighter blue stars that live only tens of millions of years.*
  Note to Teacher: When we look up in the sky, we mostly see brighter stars, because the dimmer red stars cannot be easily seen. However, there are actually far more red stars than brighter stars.

- Question: What else do you notice about the number of stars in each group?
- *Answer: Most of the stars are on the Main Sequence.*

3. Read with students the Star Type Reading.

- Discuss the different kinds of stars and how scientists categorize them.
- Have students answer the comprehension questions.

4. Discuss conclusions about star type and bridge to Habitable Zone Activity.

- Question: What kind of star is ideal for human life? Why?
- *Answer: A moderate, yellow star in the middle of the Main Sequence is ideal for human life, because it has a moderate temperature that remains pretty stable.*

- Question: Would it be possible to have a different star type and just move my planet to a different distance?
- *Answer: That scenario may be possible in some cases.*

Extend/Apply (approximately 35 minutes)

- Say: We will look at this possibility in the next activity.

1. Introduce the concept of the Habitable Zone Activity.

- Question: What temperature do we want to have on our planet's surface at all times?
- *Answer: We want a temperature that allows water to be liquid at all time.*

- Question: Why is this important?
- *Answer: Humans need water to survive.*
- Say: We call the distance at which water is a liquid at all times the Habitable Zone. The Habitable Zone for our Sun (a star of mass 1) and an earth-size planet is 0.9 to 1.5 AU.

2. Engage students in physically modeling the planetary temperature system.

- Have the students stand so that they can have one arm out to act as a thermometer. They should start with their arm in a middle position (so their arm can go up and down). Place yourself in the center of the circle. Tell students that they are planets orbiting you, their star.

- Say: Your arm is going to function like a thermometer. It is currently the temperature of a planet that allows water to be a liquid. As I make some changes to the system, make the appropriate change with your arm.
- Say: O.K. You're planet is starting to move closer to its star. What is happening to its temperature?
- *Answer: Arms go up.*

- Say: Now it's moving farther away. What's happening?
- *Answer: Arms go down.*

- Say: What would happen if I were a blue star?
- *Answer: Arms go up.*

- Question: What would you, as planets, need to do to keep the right temperature for liquid water?
- *Answer: We would need to move further away from the star. (Have students do this and move their arms back to the middle position).*
- Say: As it turns out, blue stars are very unstable, so their temperature changes a lot. I'm going to stick out my arm to show you what my temperature is doing, and you show me what you need to do to keep your temperature stable. (Move your arm up and down. Students should move forward and back.)

- Question: Do planets move toward and away from their star as they orbit in the way we just modelled?
- *Answer: No. Planets move in elliptical orbits, so at times may be closer or further from their star, but they don't move in zig-zags.*

- Question: So what can we say about blue stars?
- *Answer: Blue stars are not ideal for human habitability, because their temperature changes too much.*

- Say: Blue stars also burn out much quicker than other stars which is not ideal for human habitability.
- Question: Now, what is going to occur if I am a red star?
- *Answer: Arms go down.*

- Question: What would you need to do to maintain the right temperature for liquid water?
- *Answer: To maintain the right temperature for liquid water, we need to move closer to the star. (Have students move very close to you and move arms to middle position.)*

- Question: Are there any problems with being this close to a star?
- *Answer: Yes. A star puts out a lot of radiation, which would kill humans.*

- Question: So would a red star be ideal for human habitability.
- *Answer: No.*

- Question: What would happen if you planets were in elliptical orbits?
- *Answer: Arms move up and down.*

- Question: Why does your temperature change?
- *Answer: The planets are moving closer and further from the star. When they are far from the star, the temperature decreases. When they are closer to the star, the temperature increases.*

- Question: So what can we say is important about a planet's orbit in order to be habitable?
- *Answer: The planet needs to be in a near circular orbit to be in the Habitable Zone at all times.*
- Question: Do star systems actually change like this?
- *Answer: No.*

- Question: Then why are we doing this?
- *Answer: To model the planetary temperature system.*

3. Read with students the Habitable Zone Reading.

- Discuss the meaning of Habitable Zone and why it's important to life.
- Have students answer the comprehension questions.

4. Discuss conclusions from the Habitable Zone Reading and Activity.

- Question: Is the Habitable Zone the same for all stars? Why not?
- *Answer: No, the Habitable Zone is not the same for all stars, because stars all have different temperatures.*
- Question: Does a star's Habitable Zone stay the same all the time? Why not?
- *Answer: No. Stars' temperature changes over time.*

- Question: Are yellow stars the only stars that can support human life?
- *Answer: We don't know for sure; however, moderate stars like our Sun seem to be ideal to support human life. We do believe that it is very unlikely that blue stars and red stars could support humans.*

5. Have students complete the Results and Conclusions sections of their Astro Journal.

Evaluate (approximately 10 minutes)

1. Discuss students' Results and Conclusions.

- Question: How do star type and orbital distance work together to determine a planet's surface temperature?
- *Answer: The hotter a star is, the further the planet needs to be in order to maintain a moderate temperature.*

- Question: What star type is ideal for human habitability? Why?
- *Answer: The star type that is ideal for human habitability are moderate, yellow stars, because they have a stable, moderate temperature.*

- Question: What is the ideal orbit for a planet to support human life? Why?
- *Answer: The ideal orbit for a planet to support human life is a circular orbit at a distance that falls in the Habitable Zone so that the planet maintains a temperature where water is a liquid at all times. This is important, because humans need water to survive.*

Note to Teacher: After each lesson, consider posting the main concept of the lesson some place in your classroom. As you move through the unit, you and the students can refer to the 'conceptual flow' and reflect on the progression of the learning. This may be logistically difficult, but it is a powerful tool for building understanding.

Astro Journal Lesson 9:
Planetary Temperature as a System

Name:

Date:

1. Scientific Question:

What are two important parts of the planetary temperature system? How do these parts work together to determine a planet's surface temperature?

2. Hypothesis/Prediction: What do you think are two important parts of the planetary temperature system? How do you think these two parts work together to determine a planet's surface temperature?

3. Results: What are two important parts of the planetary temperature system? How do these parts work together to determine a planet's surface temperture?

4. Conclusions: Compare and contrast your hypothesis and results. How did testing your hypothesis and modeling the molecules change your original ideas?

What type of star is ideal for humans? Why?

What is the ideal orbit for a planet to support humans? Why?

Grouping Stars Cards

Star Name: Capella
Distance from Earth (in light years)**:** 44
Luminosity class: giant
Temperature: 5,100 Kelvins
Diameter in suns: 11
Luminosity in suns: 72

Star Name: Betelgeuse
Distance from Earth (in light years)**:** 325
Luminosity class: supergiant
Temperature: 3,400 Kelvins
Diameter in suns: 265
Luminosity in suns: 5,000

Star Name: Hoedus 11
Distance from Earth (in light years)**:** 310
Luminosity class: main-sequence
Temperature: 21,000 Kelvins
Diameter in suns: 3
Luminosity in suns: 377

Star Name: Almaaz
Distance from Earth (in light years)**:** 6,500
Luminosity class: supergiant
Temperature: 7,200 Kelvins
Diameter in suns: 365
Luminosity in suns: 200,000

Star Name: Sirius
Distance from Earth (in light years)**:** 9
Luminosity class: main-sequence
Temperature: 9,700 Kelvins
Diameter in suns: 2
Luminosity in suns: 21

Star Name: Gomeisa
Distance from Earth (in light years)**:** 140
Luminosity class: main-sequence
Temperature: 13,000 Kelvins
Diameter in suns: 2
Luminosity in suns: 95

Star Name: Ross 154
Distance from Earth (in light years)**:** 9.3
Luminosity class: main-sequence
Temperature: 2,800 Kelvins
Diameter in suns: 0.63
Luminosity in suns: 0.02

Star Name: Ross 248
Distance from Earth (in light years)**:** 10.3
Luminosity class: main-sequence
Temperature: 2850 Kelvins
Diameter in suns: 0.32
Luminosity in suns: 14.7

Star Name: Pollux
Distance from Earth (in light years)**:** 35
Luminosity class: giant
Temperature: 4,900 Kelvins
Diameter in suns: 9
Luminosity in suns: 32

Star Name: Alzirr
Distance from Earth (in light years)**:** 59
Luminosity class: giant
Temperature: 6,600 Kelvins
Diameter in suns: 2
Luminosity in suns: 11

Are You My Type of Star? (1 of 3)

Star Name: Sol
Luminosity class: main-sequence
Temperature: 5,800 Kelvins
Luminosity in suns: 1
Absolute Magnitude: +4.74
Star Type:

Star Name: V. Maanen's star
Luminosity class: white dwarf
Temperature: 12,000 Kelvins
Luminosity in suns: 0.002
Absolute Magnitude: +12.4
Star Type:

Star Name: Propus
Luminosity class: giant
Temperature: 3,100 Kelvins
Luminosity in suns: 125
Absolute Magnitude: -0.5
Star Type:

Star Name: Aludra
Luminosity class: supergiant
Temperature: 14,500 Kelvins
Luminosity in suns: 50,000
Absolute Magnitude: -7.0
Star Type:

Star Name: Ross 154
Luminosity class: main-sequence
Temperature: 2,800 Kelvins
Luminosity in suns: 0.02
Absolute Magnitude: +13.3
Star Type:

Star Name: Rex Donaldix
Luminosity class: main-sequence
Temperature: 5770 Kelvins
Luminosity in suns: 0.79
Absolute Magnitude: +5.1
Star Type:

Star Name: Ross 248
Luminosity class: main-sequence
Temperature: 2850 Kelvins
Luminosity in suns: 0.006
Absolute Magnitude: +14.7
Star Type:

Star Name: Samuelsonian
Luminosity class: main-sequence
Temperature: 3,850 Kelvins
Luminosity in suns: 0.077
Absolute Magnitude: +8.8
Star Type:

Star Name: Hoedus II
Luminosity class: main-sequence
Temperature: 21,000 Kelvins
Luminosity in suns: 377
Absolute Magnitude: -1.7
Star Type:

Star Name: Hassaleh
Luminosity class: giant
Temperature: 4,200 Kelvins
Luminosity in suns: 655
Absolute Magnitude: -2.3
Star Type:

Are You My Type of Star? (2 of 3)

Star Name: αCen A
Luminosity class: main-sequence
Temperature: 5830 Kelvins
Luminosity in suns: 1.7
Absolute Magnitude: +4. 4
Star Type: **Star**

Star Name: Luyten
Luminosity class: white dwarf
Temperature: 16,000 Kelvins
Luminosity in suns: 0.002
Absolute Magnitude: +12.5
Star Type:

Name: Amberan
Luminosity class: main-sequence
Temperature: 5,860 Kelvins
Luminosity in suns: 1.1
Absolute Magnitude: +4.7
Star Type:

Star Name: Mattrix
Luminosity class: main-sequence
Temperature: 3,580 Kelvins
Luminosity in suns: 0.045
Absolute Magnitude: +9.9
Star Type:

Star Name: UV Cet B
Luminosity class: main-sequence
Temperature: 2,850 Kelvins
Luminosity in suns: 0.002
Absolute Magnitude: +15.8
Star Type:

Star Name: Rigel
Luminosity class: supergiant
Temperature: 13,000 Kelvins
Luminosity in suns: 55,000
Absolute Magnitude:-7.1
Star Type:

Star Name: Grb 34A
Luminosity class: main-sequence
Temperature: 3680 Kelvins
Luminosity in suns: 0.02
Absolute Magnitude: +10.3
Star Type:

Star Name: Nihal
Luminosity class: giant
Temperature: 5,600 Kelvins
Luminosity in suns: 545
Absolute Magnitude: -2.1
Star Type:

Star Name: Furud
Luminosity class: main-sequence
Temperature: 18,000 Kelvins
Luminosity in suns: 377
Absolute Magnitude: -1.7
Star Type:

Star Name: Pollux
Luminosity class: giant
Temperature: 4,900 Kelvins
Luminosity in suns: 32
Absolute Magnitude: +0.98
Star Type:

Are You My Type of Star? (3 of 3)

Star Name: Christinaurus
Luminosity class: main-sequence
Temperature: 5,900 Kelvins
Luminosity in suns: 0.86
Absolute Magnitude: +5.1
Star Type:

Star Name: Geofferan
Luminosity class: main-sequence
Temperature: 5,570 Kelvins
Luminosity in suns: 0.66
Absolute Magnitude: +5.5
Star Type:

Star Name: Dosereb
Luminosity class: main-sequence
Temperature: 5,770 Kelvins
Luminosity in suns: 0.79
Absolute Magnitude: +5.1
Star Type:

Star Name: Sundownus
Luminosity class: main-sequence
Temperature: 3,370 Kelvins
Luminosity in suns: 0.019
Absolute Magnitude: +11.3
Star Type:

Star Name: Σ2398 A
Luminosity class: main-sequence
Temperature: 3,180 Kelvins
Luminosity in suns: 0.03
Absolute Magnitude: +11.1
Star Type:

Star Name: Alisan
Luminosity class: main-sequence
Temperature: 3,050 Kelvins
Luminosity in suns: 0.005
Absolute Magnitude: +13.5
Star Type:

Star Name: Lac 9352
Luminosity class: main-sequence
Temperature: 3,530 Kelvins
Luminosity in suns: 0.05
Absolute Magnitude: +9.6
Star Type:

Star Name: Ain
Luminosity class: giant
Temperature: 5,000 Kelvins
Luminosity in suns: 65
Absolute Magnitude: +0.2
Star Type:

Star Name: Castor
Luminosity class: main-sequence
Temperature: 9,300 Kelvins
Luminosity in suns: 28
Absolute Magnitude: +1.14
Star Type:

Star Name: Aldebaran
Luminosity class: giant
Temperature: 4,000 Kelvins
Luminosity in suns: 137
Absolute Magnitude: -0.6
Star Type:

Star Type Reading

Star cluster 996

What are the different types of stars?

Stars change over time. Different stages in a star's life represent the different star types. Stars are born from clouds of gas and dust called nebulas and start out as protostars. These young stars eventually become main-sequence stars that burn hydrogen and range from hot, bright, massive blue stars to cooler, dimmer, less massive red dwarfs. Stars spend most of their lives as main-sequence stars.

When a main-sequence star runs out of hydrogen, it can begin using other fuels. Its temperature and luminosity change. This marks the beginning of the end of its life. The end of a star's life is short compared to the amount of time it spends as a main-sequence star.

The manner in which a star's life ends depends upon its mass. Stars of low mass expand into red giants. Red giants eventually shed their outer layers of gas to leave behind the very hot core of the star to become white dwarfs. Those stars with a larger mass expand into supergiants that use up energy so fast that they become unstable and explode into supernovas. A supernova will either become a very dense star called a neutron star or will collapse into a black hole.

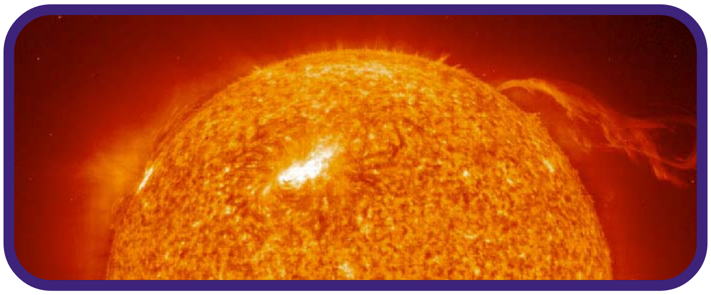
How do scientists decide a star's type?

A star's type is determined by its temperature (measured in Kelvin), mass and luminosity. For main-sequence stars, the Hertzsprung-Russell (H-R) diagram shows that there is a relationship between these features. The larger a main-sequence star is, the hotter and more luminous it is. A star's color is related to its surface temperature. The coolest, smallest, dimmest stars are red dwarfs. Hotter, medium-sized stars are yellow stars, and the hottest, largest, most luminous main-sequence stars are blue stars.

Red Giant, blue and yellow stars

Other star types include giants, white dwarfs and red dwarfs. Giants are very large stars and include red giants and supergiants. White dwarfs and red dwarfs are very small, dim, but hot stars.

What makes the Sun so great?



The Sun is an ideal star for life compared to other main-sequence stars, because it is stable and so keeps Earth's temperature constant. The Sun also burns for a long time.

How will the Sun's life end?

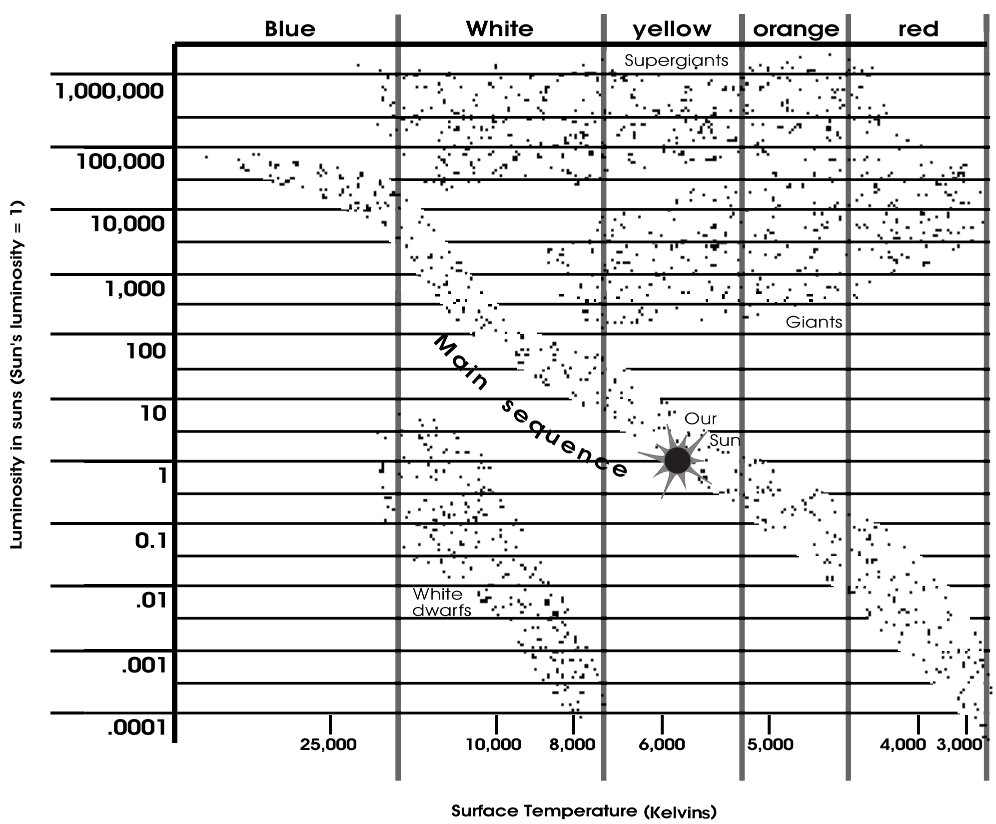
Since scientists have evidence that the Sun will become a red giant in 5 billion years, this is the future we can imagine for our planet.

Questions

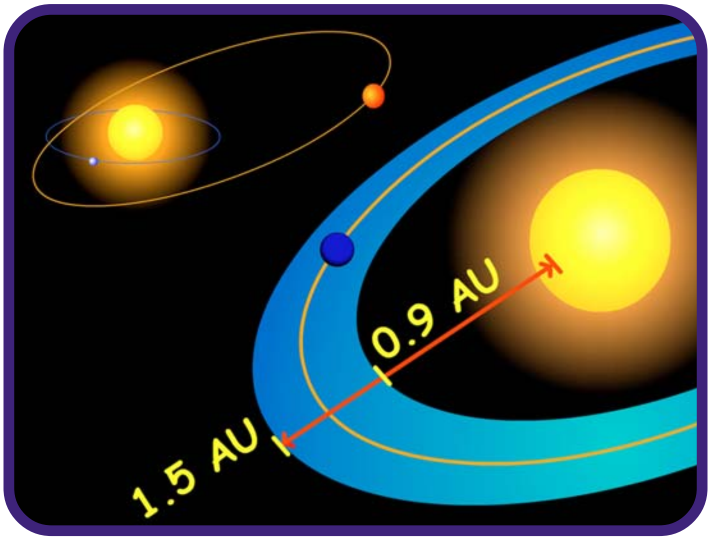
(Answer on a separate sheet of paper)

1. What are the stages in a low-mass star's life?
2. What are the stages in a high-mass star's life?
3. What determines a star's type?
4. What makes the Sun an ideal star for life?
5. Is the Sun a low-mass or high-mass star?
6. Looking at the H-R diagram, what are the:
    - hottest, dimmest stars?
    - coolest, dimmest stars?
    - brightest, hottest stars?
    - brightest, coolest stars?

Hertzsprung-Russell Diagram



Habitable Zone Reading



What is the Habitable Zone?

Life as we know it needs liquid water to survive. The Habitable Zone is the distance from a star where liquid water can exist on a planet's surface. If a planet is too far from its star, water freezes. If a planet is too close to its star, water evaporates. A planet must stay in the Habitable-Zone throughout its orbit in order for water to remain a liquid.

Where is the Habitable Zone?

The distance at which a planet can have water is determined by how much energy is given off by the star. This distance is measured in astronomical units or AU. An astronomical unit is the average distance from Earth to the Sun, which is equal to 149,598,770 km or 93,000,000 miles. For cooler red dwarfs, the Habitable Zone is so close to the star that solar flares and radiation from the star would destroy life. For very hot blue stars, the Habitable Zone is further away. These stars tend to burn at such high temperatures that they have very short lives, lasting only a few million years. (It took 700 million years for life to become established on Earth). Our Sun's Habitable Zone for larger life forms including humans is between 0.9 AU to 1.5 AU.

Is the Habitable Zone always in the same place?

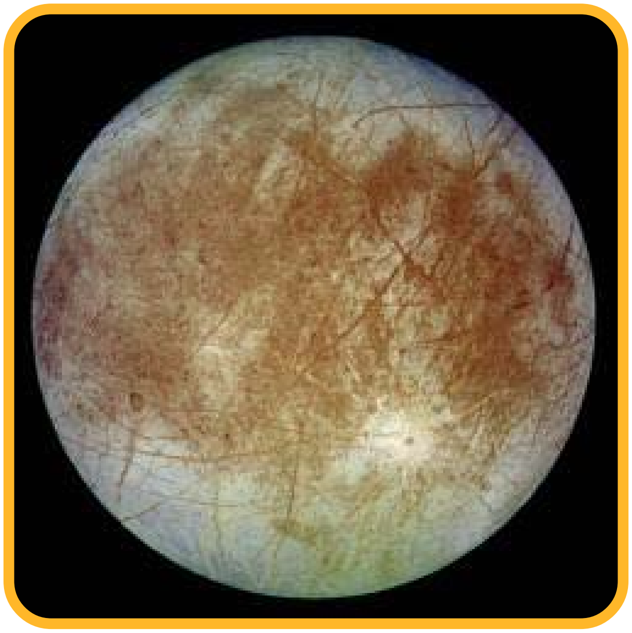
The Habitable Zone can move as a star changes. As a star grows older, it grows hotter causing the zone to mover further away from the star. At one time, Earth was on the outer edge of the Sun's Habitable Zone, but now the zone has moved further away, so Venus is no longer in the Habitable Zone. Since stars change, it is important to have a star has a temperature that stays about the same for a long time. It's also important that the orbit of an Earth-size planet be in the area of the zone that remains in the zone as the zone changes.

If I'm in the Zone, is Survival Guaranteed?

Even if a planet is in the Habitable Zone throughout its entire orbit, human survival is not guaranteed. The planet may not even have water on it to begin with, or the water it has may not be liquid. Mars, for example, has such a low surface pressure that its water cannot be a liquid on the surface. Water goes from a solid to a gas without ever being liquid.

Also, the planet may not have the right kind of atmosphere and may not be the right size to hold on to the atmosphere that humans need. Without the right kind of atmosphere to trap heat and maintain a stable temperature, surface water would not be found on a planet. Furthermore, the planet may not host plant and animal life that humans can eat. Finally, there may be other dangers, such as large planets, solar flares or radiation, from which humans need protection.

Is the Habitable Zone the same for all life?



Jupiter's moon, Europa

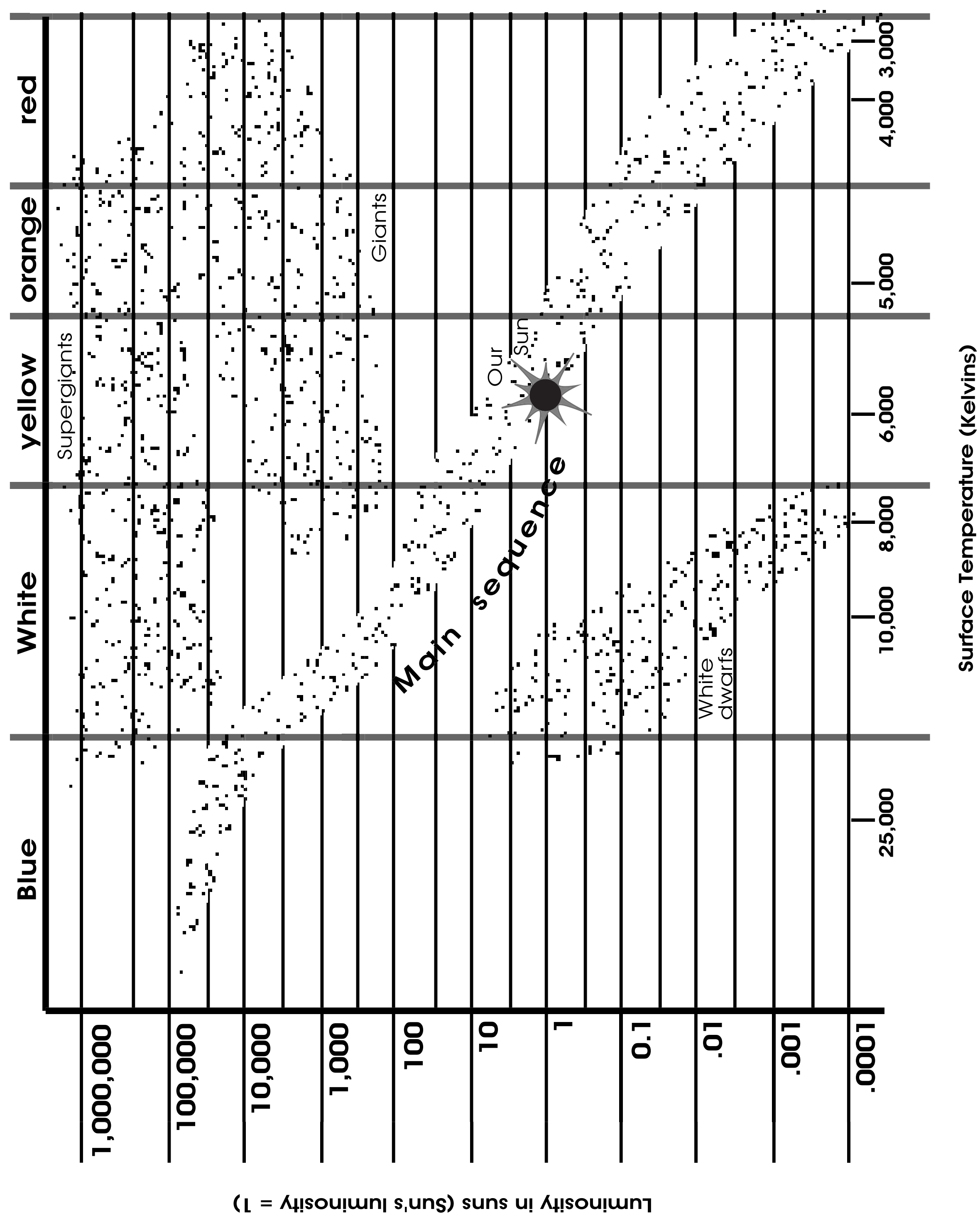
The Habitable-Zone for **microbes** is much larger than the Habitable-Zone for humans, because microbes can survive under conditions that humans cannot. A microbe is an animal or plant so small it can be seen only with a **microscope**. A bacterium is an example of a microbe. There are microbes that can survive in the frozen ice of Antarctica and in the extremely hot, thermal vents on the ocean floor. That's why scientists are looking for life on Mars and one of Jupiter's moons, **Europa**.

Questions

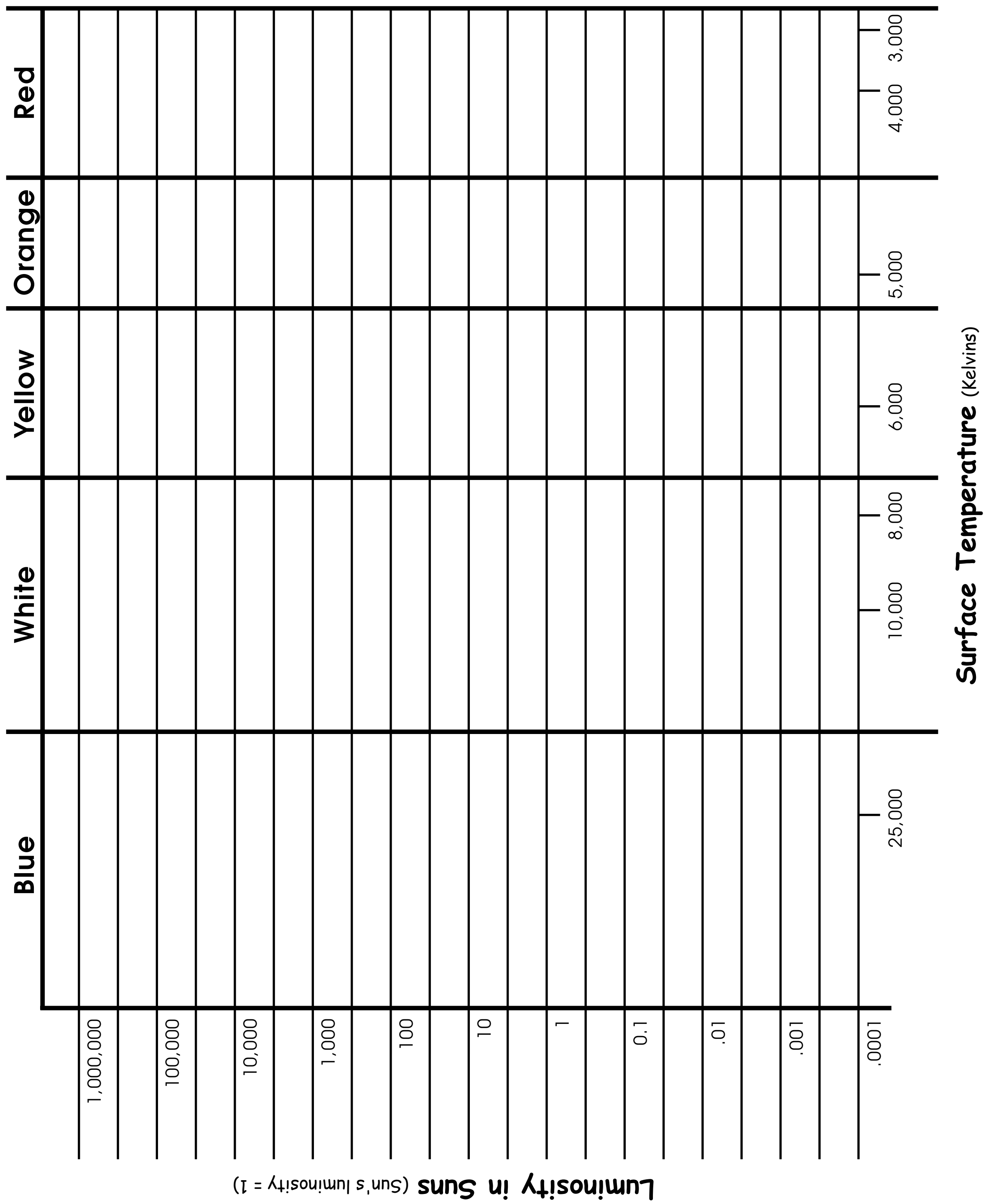
(Answer on a separate sheet of paper)

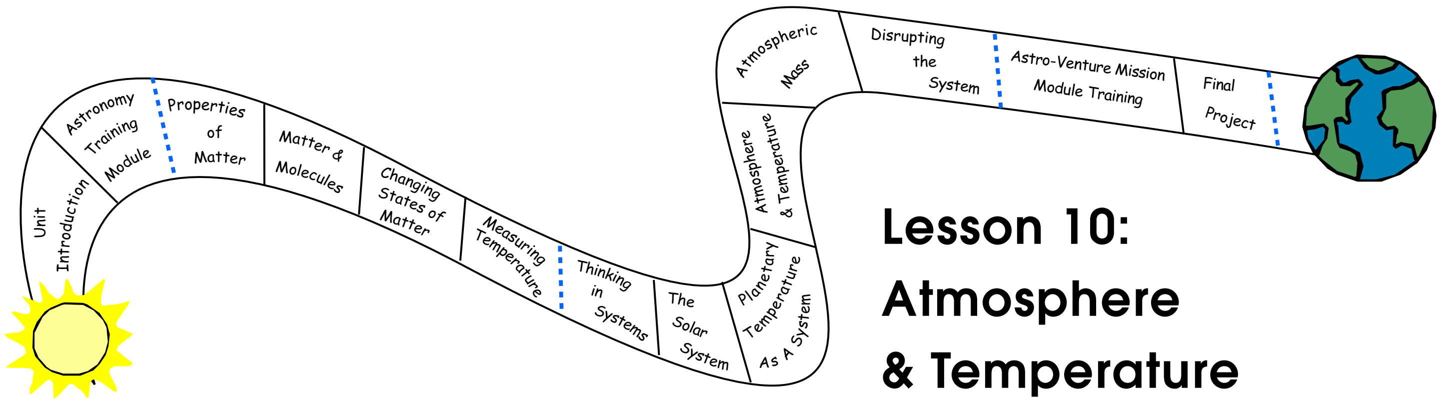
1. What is the definition of Habitable Zone?
2. Are all stars' Habitable Zones at the same distance? Why or why not?
3. What would happen if a planet weren't in the Habitable Zone?
4. Would a microbe's Habitable Zone be closer or further from a star than a human's Habitable Zone? Explain your answer.

Hertzsprung-Russell (HR) Diagram



Blank Hertzsprung-Russell (HR) Diagram





Lesson 10: Atmosphere & Temperature

Students explore the planetary temperature system. They explore how each aspect (e.g., mass, temperature and gravity) influences the system and the consequences of disrupting that system.

Main Lesson Concept: The atmosphere of a planet affects the planetary temperature system, which determines the temperature of that planet.

Scientific Question: How does the atmosphere of a planet affect the planetary temperature system?

Objectives	Standards
Students will explain and illustrate that atmosphere can raise the temperature of a planet.	**Meets**: 2061: 11A 6-8 #2 NSES: UCP K-12 #1 NSES: A 5-8 #1 **Addresses**: NSES: A 5-8 #1 NCTM: 4, 5, 9
Students put together a concept map that shows the parts of the planetary temperature system.	
Students will explain why atmosphere is important to habitability and how star type, distance and atmosphere all work together to determine a planet's temperature system.	

Assessment	Write-up in Astro Journal: Concept Map of Temperature System
Abstract of Lesson	Students use the inquiry process to explore the affect of atmosphere on the temperature of a planet. They create a model of the system to test. They then create a concept map of the planetary temperature system.

Prerequisite Concepts	Major Concepts
• Temperature measures the motion of molecules in a substance. (Lesson 6) • Atmosphere is the blanket of gases that surrounds some planets and moons.	• Atmosphere traps heat, which increases and sustains the temperature of the planet. • A planet's temperature is determined by a combination of factors including the temperature of the star, the distance of the planet from the star and the amount and composition of the planet's atmosphere.

Suggested Timeline (45-minute periods):

Day 1: Engage and Explore Day 1 Sections
Day 2: Explore Day 2, Explain, Extend/Apply and Evaluate Sections

Materials and Equipment:

- A class set of Astro Journals Lesson 10: Atmosphere and Temperature*
- A class set of Planetary Comparison Charts
- Thermometers
- Plastic Wrap
- Mountable lights (to function as a heat source)
- Chart paper

Preparation:

- Gather materials (e.g., thermometers, saran wrap, mountable lights)
- Copy class set of Astro Journals Lesson 10: Atmosphere and Temperature
- Copy a class set of Planetary Comparison Charts
- Prepare chart paper with major concept of the lesson to post at the end of the lesson.

*Note to Teacher: A generic Astro Journal and Scientific Rubric are included at the end of this part. If you prefer, you can have students use the generic Astro Journal instead of the ones designed to go with each lesson. This might be especially useful for older students who are already familiar with the inquiry method.

Differentiation:

Accommodations

For students who may have special needs, use a more guided inquiry process.

Advanced Extensions

Have students set up multiple test planets with increasing levels of atmosphere (multiple layers of plastic wrap) and graph the results. Is the relationship linear?

Engage (approximately 15 minutes)

1. Review Habitable Zone and systems.

- Question: What role does the distance of a planet from its star play in the planet's temperature?
- *Answer: The closer a planet is to its star, the higher its average temperature.*

- Question: What is the Habitable Zone?
- *Answer: The Habitable Zone is the distance from a star in which a planet could maintain liquid water on or near its surface.*

- Question: What would happen if a planet were closer to a star than to the Habitable Zone?
- *Answer: The planet would be too hot, and the water would be a gas (steam).*

- Question: What would happen if a planet orbited beyond the Habitable Zone?
- *Answer: The planet would be too cold, and any water present would be solid ice.*

- Question: Based on what we know so far, how would you describe the planetary temperature system?
- *Answer: The temperature depends on the type of star and the distance of the planet from that star.*

2. Bridge to this lesson.

- Question: When we looked at Venus, how similar was it to the Earth?
- *Answer: Venus was very similar, but the average temperatures of Earth and Venus are very different. In fact, Venus' surface is so hot that it can melt led.*

- Have students take out their Planetary Comparison Charts.
- Question: Are there any planets closer to the Sun than Venus?
- *Answer: Yes, the planet closer to the Sun is Mercury.*

- Question: Based on what we've learned, how should Mercury's temperature compare with Venus' and why?
- *Answer: Since Mercury is closer to the sun, it should have a higher average temperature.*

- Question: Does Mercury have a higher average temperature?
- *Answer: No.*

- Question: How and why is this occurring?
- *Answer: This is occurring, because the system is incomplete. There are factors we have not yet considered.*

- Question: Let's look at Venus and Earth again. Does Venus generally have larger or smaller values than Earth?
- *Answer: Venus generally has smaller values than Earth.*

- Question: Besides temperature, are there any that are larger?
- *Answer: Yes. Atmospheric mass is another value, which is larger.*

3. Introduce the Scientific Question and purpose of the lesson.

- Question: How does atmosphere affect the planetary temperature system?

- Students record their hypotheses in the Hypothesis/Prediction section of their Astro Journals.

- Question: Why do we want to explore how atmosphere affects a planet's temperature?
- *Answer: We want to understand all of the factors that affect a planet's temperature system and how they work together.*

- Question: Why are we interested in the temperature of a planet?
- *Answer: The temperature of a planet determines its ability to maintain liquid water, which is essential for life.*

Explore Day 1 - (approximately 30 minutes)

1. Students design experiments that test their hypotheses.

- Question: How could we test your hypotheses?
- *Answer (Record student responses on chart paper. One way to test this in the classroom is to make a model and test the model to verify the hypotheses.)*

- Question: If we were going to build a model of this system, what parts would we need, and what could we use to model them?
- *Answer: (Answers may vary. One possible experiment might be: a star represented by a light or lamp; the planet represented by a box; and the atmosphere represented by plastic wrap or some other clear covering.)*

- Question: How will you know that your "atmosphere" affects the temperature of the system?
- *Answer: We'll need to compare it to another system with no "atmosphere". (If the above model is used, a second box and lamp can be used for comparison. Thermometers will be needed in each to measure temperatures.)*

- Question: How will you know that the difference between the two systems is because of the "atmosphere"?
- *Answer: We'll need to make sure that the two situations we are comparing are exactly the same except for that one has an "atmosphere" and one doesn't.*

  Note to Teacher: Be sure to discuss with students the importance of having everything exactly the same except for the atmosphere. These ideas can be discussed without even using the terms: "variables" and "controls".

2. Students plan and set up their experiments.

- Put students into groups to refine hypotheses and plan experiments to test them.
  Review "testing for the hypothesis," and demonstrate how the materials, procedures, and data for the test will be recorded in the Astro Journal for this lesson.

  Note to Teacher: Make sure that the students are thinking in terms of data – what data they will be collecting how they will be measuring it, and how that it is either going to confirm or refute their hypotheses.

- Have students share their hypotheses, and experiment plans.
  Ask questions to help groups clarify aspects of their plan, but try to avoid giving them the answers.
  - Sample questions might include:
    - How does this experiment test your hypothesis?
    - What specific data are you collecting?
    - How will this data confirm or refute your hypothesis?
    - How are you going to measure your data?

Note to Teacher: Corrections should be focused on science process, not the correctness of the hypothesis. An incorrect hypothesis with a solid experimental plan is fine. A correct hypothesis without a solid experimental plan should be corrected.

3. Students should set up their experiments and record their Materials and Procedures in their Astro Journals.

Explore Day 2 - (approximately 20 minutes)

1. Students conduct their experiments in which they measure and record the temperature of their two systems over time.

Note to Teacher: If students have chosen an experiment that uses a good metaphor for atmosphere, they should observe that the temperature of the system with "atmosphere" is higher than the system without.

Explain (approximately 10 minutes)

1. Students fill out the Results and Conclusions sections of their Astro Journals.

2. Have students share their findings.

- Question: What did your experiment show about how the atmosphere of a planet affects its temperature? Why?
- *Answer: The atmosphere causes the temperature to rise, because it traps heat.*

3. Review the campfire metaphor and extend it to include atmosphere.

- Question: What happens when we move closer to a campfire?
- *Answer: We feel warmer.*

- Question: What is this modeling?
- *Answer: It models the Habitable Zone. The campfire is like our Sun and we are like a planet.*

- Question: Imagine you take a step away from the fire, but then put on a heavy parka. Now what happens to your temperature?
- *Answer: You feel warmer. You could even be warmer than when you were closer to the fire.*

- Question: So what does the parka symbolize or model?
- *Answer: The parka is like an atmosphere around a planet.*

- Question: How is this like Venus and Mercury?
- *Answer: Even though Mercury is closer to the Sun, it is not as warm as Venus, because of Venus' thick atmosphere.*

Extend/Apply (approximately 10 minutes)

1. **Have students draw a basic concept map of the planetary temperature system in their Astro Journal.** (See Lesson 7 for a sample).

2. **Physically model the system.**

- Have the students stand so that they can have one arm out to act as a thermometer. They should start with their arm in a middle position (can go up and down).
- Say: Your arm is going to function like a thermometer. It is currently the temperature of a planet. As I make some changes to this planet, make the appropriate change with your arm.

- Say: O.K. You're planet is starting to move closer to its star. What is happening to its temperature?
- *Answer: Arms go up.*

- Say: Now it's moving farther away. What's happening?
- *Answer: Arms go down.*

- Say: Now the star is changing. Its surface temperature is rising. What's happening?
- *Answer: Arms go up.*

- Say: Now the atmosphere is disappearing. What's happening?
- *Answer: Arms go down.*

- Keep changing parts to the system until everyone is correctly responding to the changes.

- Say: Now, your goal is going to be to have a moderate temperature where your arm is out in front of you. What happens if the star type changes and becomes very hot?
- *Answer: Arms go up.*

- Say: What could you do to your system so that you could keep a moderate temperature?
- *Answer: The planet could be further away from the star, or there could be less of an atmosphere on the planet. (Move arms back to the middle position).*

- Say: What if your planet moves further away from the star?
- Arms go down.

- Say: What can you do to keep a moderate temperature?
- *Answer: The star could be hotter or there could be more of an atmosphere around the planet. (Move arms back to middle position).*

- Say: Now, your atmosphere has become thinner. What's happening?
- *Answer: Arms go up.*
  Note to Teacher: Discuss with students what happens to temperature when there is a very thin atmosphere like Mars. Discuss that because there is so little atmosphere to trap the heat, as soon as the Sun goes down, heat escapes, and it becomes very cold. As a result, Mars experiences extreme temperature changes. Discuss that, thus, any life living on a planet would have to be able to stand big temperature changes.

- Say: What can you do to keep a moderate temperature?
- *Answer: We could have a cooler star or the planet could be closer to the star.*

- Question: Does what the atmosphere is made of make a difference?
- *Answer: Yes. Certain gases trap more heat than other gases. (Venus is so hot, because it's atmosphere is largely composed of Carbon Dioxide.)*

- Question: Do planets actually change like this?
- *Answer: No.*

- Question: Then why are we doing this?
- *Answer: To model the planetary temperature system.*

Evaluate (approximately 10 minutes)

1. Have students share their responses to the Conclusion questions.

- Question: Why is atmosphere important to human life? How much of an atmosphere do we need? Why?
- *Answer: Atmosphere helps to trap heat, which helps to keep the temperature from becoming too hot or too cold. However, if we have too much of an atmosphere, or if the atmosphere is made of gases that trap too much heat, then the planet will become too hot for humans to live on.*

- Question: What is needed for a planet to have the right temperature for human habitation?
- *Answer: In order for a planet to have the right temperature for human habitation, there must be: a moderate star; a planet that is orbiting at a distance where the heat from the star provides a temperature that allows water to be a liquid on the planet's surface at all times; and an atmosphere that traps enough heat to maintain a stable temperature but not so much heat that the temperature would be too hot for liquid water.*

Note to Teacher: After each lesson, consider posting the main concept of the lesson some place in your classroom. As you move through the unit, you and the students can refer to the 'conceptual flow' and reflect on the progression of the learning. This may be logistically difficult, but it is a powerful tool for building understanding.

Astro Journal Lesson 10: Atmosphere and Temperature

Name:

Class/Period:

Date:

1. Scientific Question:

How does the atmosphere of a planet affect the planetary temperature system?

2. Hypothesis/Prediction: What do you think causes the change in the planetary temperature system? Why?

3. Materials: What materials will you use to test your hypothesis or prediction?

4. Data:

Astro Journal Lesson 10: Atmosphere and Temperature

Class/Period:

Name:

Date:

5. Results: How does the atmosphere of a planet affect the planetary temperature system? Why?

Charts/Graphs:

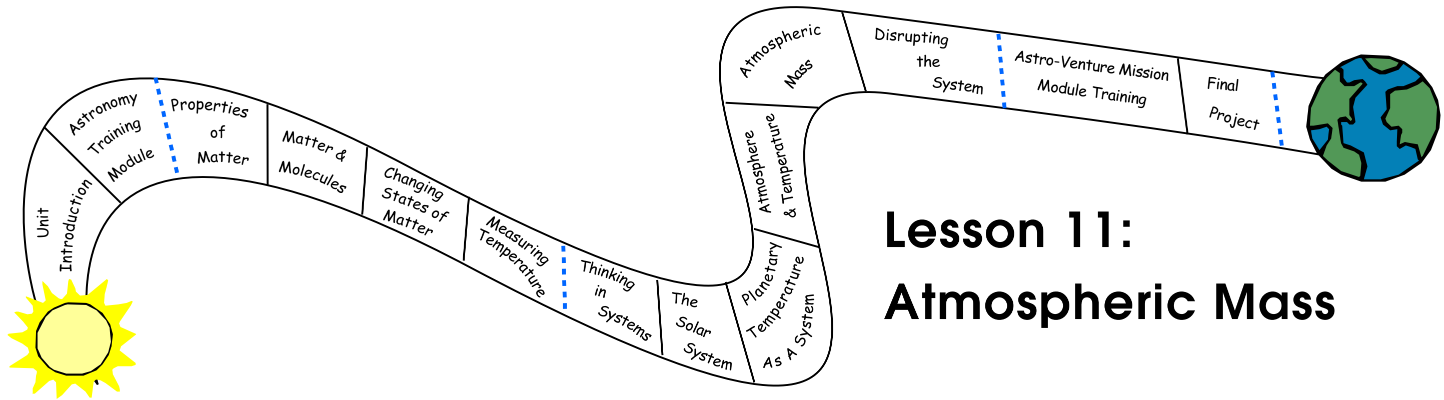
6. Conclusions: Compare and contrast your hypothesis and results. How did testing your hypothesis and modeling the atmosphere change your original ideas?

Why is atmosphere important to human life? How much atmosphere do we need? Why?

What is needed for a planet to have the right temperature for human habitation?

Planetary Comparison Chart

Planet	Atmo-sphere	Mass Earth = 1	Diameter *(Radius)* (km)	Density gm/ m^3	Liquid Water	Average Temperature	Force of Gravity Earth = 1	Atmospheric Mass (kg)
Mercury	very little: argon, neon and helium	0.06	4,878 *(2,439)*	5,430	too hot for surface water	day: 350°C/662° F night -170°C/ -274°F	0.38	2.03×10^8
Venus	carbon dioxide	0.82	12,104 *(6,052)*	5,250	too hot for surface water	465°C/869°F	0.90	1.41×10^{21}
Earth	nitrogen, oxygen	1.00	12,755 *(6,378)*	5,520	liquid water on the surface	15°C/59°F	1.00	5.33×10^{18}
Moon	none	0.01	3,476 *(1,738)*	3,300	no liquid water	sunlit side: 134°C/ 273°F dark side: -153°C/-243°F	0.17	0
Mars	carbon dioxide	0.11	6,790 *(3,395)*	3,940	Mars may have once had surface water, but doesn't now. Ice has been detected at the North Pole.	-23°C/-9.4°F	0.39	3.09×10^{16}
Jupiter	hydrogen, helium	318	142,796 *(71,398)*	1,314	some water vapor and ice crystals in the atmosphere	-150°C/-238°F	2.53	2.6×10^{22}
Saturn	hydrogen, helium	95	120,660 *(60,330)*	690	some water vapor and ice crystals in the atmosphere	-180°C/-292°F	1.06	4.4×10^{22}
Uranus	hydrogen, helium	15	51,118 *(25,559)*	1,290	some water vapor and ice crystals in the atmosphere	-221°C/-391°F	0.93	7.8×10^{21}
Neptune	hydrogen, helium	17	49,528 *(24,764)*	1,640	some water vapor and ice crystals in the atmosphere	-235°C/-391°F	1.18	7.4×10^{21}
Pluto	methane	0.002	2,300 approx. *(1,150)*	2,030	Any water is frozen as ice.	-220°C/-364°F	0.07	variable



Lesson 11: Atmospheric Mass

Students explore the planetary temperature system. They explore how each aspect (e.g., mass, temperature and gravity) influence the system and the consequences of disrupting that system.

Main Lesson Concept: The amount of atmosphere on a planet depends on the planet's gravity, which is determined by the planet's mass.

Scientific Question: What determines the amount of atmosphere on a planet?

<table>
<tr><th>Objectives</th><th>Standards</th></tr>
<tr><td>Students will explain and illustrate how planetary mass affects atmosphere to effect a change in the temperature of a planet.</td><td rowspan="2">Meets:
2061: 11A 6-8 #2
NSES: UCP K-12 #1

Addresses:
NSES: A 5-8 #1
NCTM: 2, 5, 9</td></tr>
<tr><td>Students will explain why 1/4 to 4 times Earth's mass is a requirement for habitability.</td></tr>
</table>

Assessment	Write-up in Astro Journal.
Abstract of Lesson	Students learn to compare characteristics from the Planetary Comparison Chart to see if there is a relationship between the characteristics of the planets. They use that knowledge to figure out which characteristics have a strong relationship with atmospheric mass. When the results are not completely conclusive, the students explore possible causes of discrepancies in the data. They conclude that gravity, mass and diameter all have a role in determining atmospheric mass.

<table>
<tr><th>Prerequisite Concepts</th><th>Major Concepts</th></tr>
<tr><td>

Atmosphere is the blanket of gases that surrounds some planets and moons
Atmosphere traps heat, which increases and sustains the temperature of the planet. (Lesson 10)
A system consists of many parts that usually influence each other and can be part of another system. (Lesson 7)
Temperature measures the motion of molecules in a substance. (Lesson 6)
Mass is the measure of the quantity of matter.
Gravity is a force of attraction that exists between objects. The greater the mass, the greater its gravitational pull.

</td><td>

Atmospheric mass is the amount of atmosphere on a planet.
Gravity is a function of mass and diameter.
Gravity is a major factor in determining the amount of atmosphere around a planet.

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Suggested Timeline (45 minute periods):

Day 1: Engage and Explore Sections
Day 2: Explain
Day 3: Extend/Apply and Evaluate Sections

Materials & Equipment:

- A class set of Astro Journals Lesson 11: Atmospheric Mass *
- A class set of Planetary Temperature System Concept Map Activity
- A class set of Planetary Comparison Charts
- A class set of the Gravity and Atmosphere Reading
- Chart Paper

Preparation:

- Gather materials.
- Duplicate Astro Journals, Planetary Comparison Charts and Gravity, Planetary Temperature System Concept Map Activity and Atmosphere Reading.
- Put up distance vs. temperature chart (See step 2)
- Prepare chart paper with major concept of the lesson to post at the end of the lesson.

*Note to Teacher: A generic Astro Journal and Scientific Rubric are included at the end of this part. If you prefer, you can have students use the generic Astro Journal instead of the ones designed to go with each lesson. This might be especially useful for older students who are already familiar with the inquiry method.

Differentiation:

Accommodations

See the following note to teacher about a simpler version of this lesson that would be more appropriate for fifth or sixth grade students.

Advanced Extensions

Students use the comparing technique presented in the lesson and the planetary comparison chart (and any other planetary data that they can find) to look for interesting patterns, ask questions, and find answers about other relationships.

Variation:

Note to Teacher: This lesson is most appropriate for seventh and eighth graders. Some advanced sixth graders might benefit from it as well. For others, do the following sequence.

1. Drop a book on the ground.

- Question: Why did this book go in the direction that it did?
- *Answer: Gravity.*

- Question: So gravity holds matter to the surface of Earth. We just observed it holding solid matter. Does it also hold liquid matter?
- *Answer: Yes.*

- Question: Does it hold a gas?
- *Answer: Yes.*

Note to Teacher: Students may debate this. Allow them to. Have them use the language of molecular bonds and motion that they learned in Part 2. Even though the molecules have more molecular motion and are moving more quickly and freely, there is still a force of attraction between them and the planet. It will also be important to keep reminding them that gravity exists between pieces of matter.

- Question: Let's go back to the book for a second. Is Earth pulling on the book or is the book pulling on Earth?
- *Answer: Both.*

- Question: What else does gravity hold to the Earth?
- *Answer: Gases. Water.*

- Question: Do all planets have the same amount of gravity? How do you know?
- *Answer: No. The moon has less gravity. That is why the astronauts bounce when they walk there.*

- Question: What determines the amount of gravity a planet has?
- *Answer: The mass of a planet. The larger the mass, the greater the gravity.*

- Question: So how do mass and gravity change what the planet has on its surface?
- *Answer: More gases are attracted to larger planets. Fewer gases are attracted to smaller planets. Therefore, the larger a planet, the more atmosphere it will have.*

Note to Teacher: Skip to step 6 in the Explain section and complete the rest of this lesson. Omit discussion of diameter.

Engage (approximately 20 minutes)

1. Review the planetary temperature system.

- Question: So far, what are the key parts of the planetary temperature system that we've explored?
- *Answer: We have explored star type, distance from star and atmosphere.*

- Question: So, given planets surrounding the same star, what would be the significant parts?
- *Answer: Distance and atmosphere.*

- Question: What would the general trend be for the distance from the star?
- *Answer: The closer to the star the planet is, the higher its average temperature*

- Question: Is there any way we could test that?
- *Answer: We could look at planets in our Solar System and compare their temperatures and distances from the Sun.*

2. Model and provide guided practice of observing relationships.

- Refer to distance vs. temperature chart .
- Say: Here we have two listings of the planets. One is based on the distance of the planets from the Sun and goes from the closest planet to the Sun to the most distant planet. The other list is based on the average temperatures of the planets and goes from the highest average temperature to the lowest.

Distance from Sun	Average Temperature
Mercury	Venus
Venus	Mercury
Earth	Earth
Mars	Mars
Jupiter	Jupiter
Saturn	Saturn
Uranus	Uranus
Neptune	Pluto
Pluto	Neptune

- Question: When you look at these two lists, what do you notice?
- *Answer: Many of the planets line up exactly with themselves in the other list. Others are just one line different.*

- Question: Why does this happen?
- *Answer: This happens, because there is a relationship between the temperature of a planet and its distance from its star (in this case, the Sun).*

- Say: Let's see if we can't make this relationship look a little clearer.
- Draw a line from each planet from one list, to itself in the other list so that your chart looks like the following.

Distance from Sun	Average Temperature
Mercury	Venus
Venus	Mercury
Earth	Earth
Mars	Mars
Jupiter	Jupiter
Saturn	Saturn
Uranus	Uranus
Neptune	Pluto
Pluto	Neptune

- Question: There are only two places where the connecting lines cross. What does that say to you about the strength of the relationship between a planet's distance from its star and its average temperature?
- *Answer: It's a strong relationship.*

- Have students list the planets in order by force of gravity from least to greatest.
- *Answer: Pluto, Mercury, Mars, Venus, Uranus, Earth, Saturn, Neptune, Jupiter*

Have the students compare the 'force of gravity' list with the 'distance from sun list' by connecting each planet in the two lists.

- Question: How many lines cross each other?
- *Answer: Many.*

Note to Teacher: Depending on how the lines are drawn, the exact number will vary. The important point is that there are many lines that cross so there is little relationship between these characteristics. If your students are comfortable with the term "variables," you may use it with them.

- Have students reverse the order of one of the lists and redo the comparison.

Note to Teacher: If it is appropriate for your students, you can talk about direct and inverse relationships here.

- Question: How many lines cross each other?
- *Answer: Again, many.*

- Question: What do these two comparisons suggest to you about the relationship between a planet's distance from its star and the force of gravity on that planet?
- *Answer: There's little relationship.*

- Say: What we are doing with these lists can be done much more precisely with certain mathematical equations. We can see general trends in the relationships between certain characteristics by using this method.

- Question: Given all the comparisons we've made so far, what do you think is the general rule for comparing lists in this way?
- *Answer: The fewer lines that cross, the stronger the relationship.*

Note to Teacher: What we're approximating here is correlation. This topic is beyond most fifth through eighth graders, but by counting the points at which the lines cross, they can at least see that certain characteristics are more or less related. That should be sufficient for the purposes of this lesson.

3. Introduce the Scientific Question and purpose of the lesson.

- Tell the students that they'll be using this method to explore this lesson's scientific question.
- Scientific Question: What determines the amount of atmosphere on a planet?

- Question: Why do we want to know what determines the amount of atmosphere on a planet?
- *Answer: Because atmosphere affects the temperature.*

- Question: Why are we interested in temperature?
- *Answer: Temperature determines the presence of liquid water.*

- Question: Why do we want liquid water?
- *Answer: Humans need it to survive.*

Explore (approximately 25 minutes)

1. Have students predict the characteristics from the Planetary Comparison Chart that they think will have a relationship with the atmospheric mass characteristic.

They should record their predictions under the Hypothesis/Prediction section in their Astro Journals.

Note to Teacher: Since we do not have atmospheric mass for Pluto, students should include the moon in their list instead.

2. Students test their predictions by setting up comparisons between atmospheric mass and other characteristics, connecting planets, and counting line crosses.

They fill out the Materials, Procedure and Data sections of their Astro Journals.

Explain (approximately 45 minutes)

1. **Students share their results with a partner or small group and discuss what they think the data mean.**

2. **Approximate results are as follows:**
   Note to Teacher: These numbers include the use of the moon in the lists. If the students don't include the moon in their lists, the numbers may be different. Remember, the numbers don't need to be exact, it's the trend that's important.
   - Atmospheric Mass and Gravity – 5 line crosses
   - Atmospheric Mass and Mass (Planet) – 3 line crosses
   - Atmospheric Mass and Diameter (Radius) – 2 line crosses
   - Atmospheric Mass and Density – many line crosses

3. **Students fill in the Results sections of their Astro Journals**

4. **Question: So what do these results mean?**
   Note to Teacher: This is where it gets complicated. Gravity is the force that retains atmosphere, but the relationship between it and atmospheric mass does not appear to be that strong. Adding to the complexity is the fact that both mass and diameter have strong relationships with atmospheric mass. Since gravity is a function of mass and diameter, the comparison between gravity and atmospheric mass seems less comprehensible. This is an opportunity to explore with students the fact that scientists often face this very situation. Rather than finding out that their hypotheses or predictions are exactly right or exactly wrong, they sometimes have to think about their results and what those results really mean. The following questions are to get the students thinking about possible ways of analyzing their results.

List student thoughts on board/chart paper
- Question: What kind of relationship did gravity have with atmospheric mass?
- *Answer: not that strong – 5 line crosses*

- Question: What kind of relationship did mass have with atmospheric mass?
- *Answer: pretty strong – 3 line crosses*

- Question: What kind of relationship did diameter (radius) have with atmospheric mass?
- *Answer: pretty strong – 2 line crosses*

- Question: What determines the gravity of a body?
- *Answer: mass and radius (diameter)*

- Question: So what is going on?
- Record student responses.

  Note to Teacher: There are a few possibilities here.
  - There may be a problem with the data (accuracy).
  - There may be not be enough data points to work with (if there were more planets, the trends might be clearer)
  - There may be a problem with the procedure (the line cross method definitely does have limits).
  - There may be problems with the interpretation (maybe the difference between two or three line crosses and five line crosses isn't significant).
  - There may be a factor that has not been taken into account.
  - Atmospheric mass may be caused by multiple factors, so that there is not a one to one relationship.
  - There may be other possible problems.

  Regardless of the reason for the problem, the process for resolving the problem is to examine all parts of the experiment and test further.
  - Some questions to suggest these possibilities to students include:
    - How do we know our data is accurate?
    - If we had more planets to compare in the lists, would this make the data more clear? Why?
    - Could there be a problem with the procedure we used to compare the lists?
    - Is there really a difference between two to three line crosses and five? How do we know?
    - Could there be something else affecting one or more of the characteristics that we haven't considered?

- Question: What could we do to get a more conclusive answer?
- *Answer: Do more tests in order to increase the amount of data to arrive at a conclusive answer.*

5. Have students fill out the Conclusion sections of their Astro Journals.

6. Read the Gravity and Atmosphere Reading with students.

Have them answer the comprehension questions.

7. Tell students that gravity is what holds the atmosphere on a planet:

Although, there are other factors that have an influence (which may partially account for the odd results of the comparisons). One factor that can influence atmospheric mass is the gases that were available when the planet was formed. Gravity is a function of mass and density, so both influence the amount of atmosphere a planet will have.

8. Discuss the importance of having the right amount of gravity.

- Question: What happens if we have too much atmosphere?
- *Answer: It will be too hot which will cause ice caps to melt and then water to evaporate.*

- Question: What happens if we have too little atmosphere?
- *Answer: There won't be greenhouse gases to trap heat, which will cause cooler temperatures that could freeze any water, if present. Water vapor can also escape so that there might not be water.*

Extend/Apply (approximately 10 minutes)

1. Have students physically model the planetary temperature system.
Have the students stand so that they can have one arm out to act as a thermometer. They should start with their arm in a middle position (can go up and down).

- Say: Your arm is going to function like a thermometer. It is currently the temperature of a planet. As I make some changes to this planet, make the appropriate change with your arm.

- Say: O.K. You're planet is starting to move closer to its star. What is happening to its temperature?
- *Answer: Arms go up.*

- Say: Now it's moving farther away. What's happening?
- *Answer: Arms go down.*

- Say: Now the star is changing. Its surface temperature is decreasing. What's happening?
- *Answer: Arms go down.*

- Say: Now the mass of the planet is increasing. What's happening?
- *Answer: Arms go up.*

- Question: Why does the temperature increase when we increased mass?
- *Answer: The gravity of the planet increases which attracts more atmosphere trapping more heat.*

- Say: Now the radius (diameter) of the planet is shrinking. What's happening?
- *Answer: Arms go down.*

- Question: Why does temperature decrease when we decreased the radius (diameter) of the planet?
- *Answer: The gravity of the planet decreases, so greenhouse gases escape trapping less heat.*

Keep changing parts to the system (star type/temperature, distance from star, gravity, mass, diameter) until everyone is correctly responding to the changes.

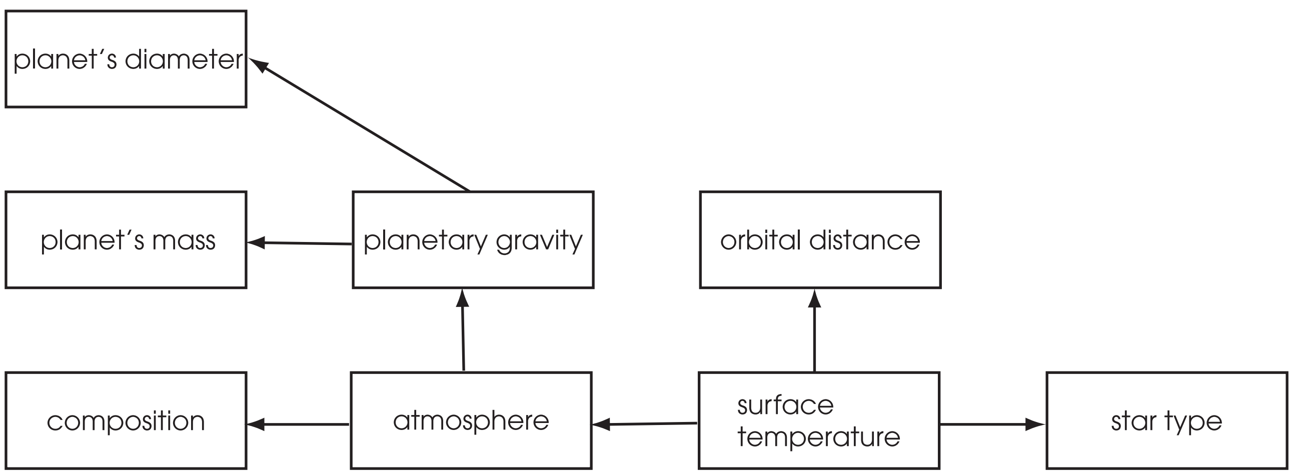
- Question: Do planets and stars actually change like this?
- *Answer: No.*

- Question: Then why are we doing this?
- *Answer: To model the planetary temperature system and to show how a change in one part of the system affects the temperature.*

Evaluate (approximately 25 minutes)

1. Have students draw a concept map of the planetary temperature system that identifies the parts of the system and the sub-system, which determines atmosphere.

Have them explain this system using the characteristics of a system in their explanation. The concept map should look something like the following diagram.



2. Discuss with students their Astro Journal results and conclusions.

Ensure that they have a solid understanding of the importance of having the right amount of gravity. Assess their understanding of this concept.

- Question: If gravity determines the amount of atmosphere on a planet, what determines the amount of gravity we have?
- *Answer: Mass is a major factor that determines gravity. Radius is also a factor. So if you predicted that, gravity, mass or radius determines the amount of atmosphere on a planet, you were right.*
  Note to Teacher: Relate this to something with which students might have experience, such as why the astronauts bounce on the moon or what we would weigh on Jupiter. Students will likely see a relationship between the size or mass of a planet and its gravity.

- Question: Why do we need to have a planet that is between 1/4 and 4 times Earth's mass?
- *Answer: We must have the right amount of gravity to hold onto the right atmosphere. Too much mass or gravity would attract too many greenhouse gases trapping heat and causing water to evaporate. Too little mass or gravity would attract too little greenhouse gases so that heat would not be trapped and water would freeze or escape.*

Note to Teacher: After each lesson, consider posting the main concept of the lesson some place in your classroom. As you move through the unit, you and the students can refer to the 'conceptual flow' and reflect on the progression of the learning. This may be logistically difficult, but it is a powerful tool for building understanding.

Astro Journal Lesson 11: Atmospheric Mass

Class/Period:

1. Scientific Question:

What determines the amount of atmosphere on a planet?

2. Hypothesis/Prediction: What do you think determines the amount of atmosphere on a planet? Why?

3. Materials: Where did you obtain the data for this activity?

Name:

Date:

4. Procedure: What steps will you take to compare characteristics?

Astro Journal Lesson 11: Atmospheric Mass

Name:

Class/Period:

Date:

5. Data Collection: Show the relationships between planets using different factors.

6. Results: What determines the amount of atmosphere on a planet?

7. Conclusions: Compare and contrast your hypothesis and results. How did testing your hypothesis/prediction and drawing relationships change your original ideas?

Planetary Temperature System Concept Map Activity

On a separate sheet of paper, draw a concept map of the planetary temperature system and sub-systems and explain how the different parts of the system influence each other in determining a planet's temperature. Explanations must include references to the characteristics of systems:

1. Explain what the parts of the system and sub-systems are and how they influence each other.
2. Explain what happens to the temperature if one part changes. Give specific examples.
3. Explain the sub-system(s) contained in the system.
4. In particular, explain the role of atmosphere in determining the temperature of a planet.
5. Explain why it is necessary for humans to have a planet that is between 1/4 and 4 times Earth's mass.

Your concept map will be evaluated using the following rubric.

4	• Concept map clearly and accurately explains the planetary temperature system. • Concept map has all required parts and uses examples and reasoning to create an exceptionally powerful and detailed explanation.
3	• Concept map clearly and accurately explains the planetary temperature system. • Concept map has all required parts, makes specific references to examples, and uses good reasoning in explanations.
2	• Concept map is not completely clear or accurate in explaining how the planetary temperature system. • Concept map has most required parts, makes some specific references to examples, and uses some good reasoning in explanations.
1	• Concept map is not clear or accurate in explaining the planetary temperature system. • Concept map is not clear or accurate in explaining how the Solar System is a system and is missing several parts, makes few specific references to examples, and uses little or no good reasoning.

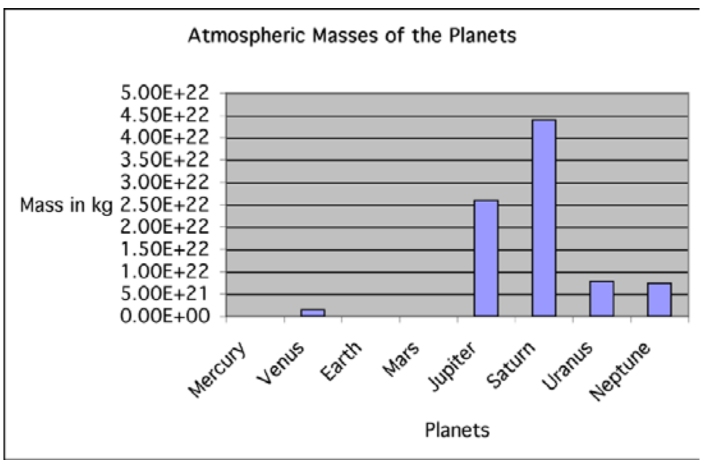
Gravity and Atmosphere Reading

What is gravity?

Gravity is a force of attraction that exists between objects. Gravity is related to the **mass** and **density** of an object or **planet**. The greater a planet's mass, the greater its gravity.

What does gravity have to do with atmosphere?

A certain amount of gravity is needed to hold on to the kind of **atmosphere** we have on Earth. With less gravity, a planet cannot hold on to the atmosphere that we need to survive. With more gravity, the planet attracts more atmosphere. This atmosphere would trap a lot of heat and cause the **temperature** to rise very high. In time, this would cause the polar ice caps to melt, submerging much of the land and causing the oceans to **evaporate**. A planet with more gravity would also attract poisonous gases in its atmosphere.



Is gravity the only factor that affects having the right kind of atmosphere?

Having the right amount of mass and the right amount of gravity doesn't guarantee the planet will have the right kind of atmosphere. The atmosphere may not be made of the right amount and kind of elements that humans need. Venus is a good example of this. Although Venus's mass is very close to Earth's mass, Venus's surface temperature is hot enough to melt lead! This is because Venus's atmosphere is mostly carbon dioxide, which traps heat from the Sun instead of letting the heat bounce back into space. Earth's atmosphere is mostly nitrogen and oxygen.

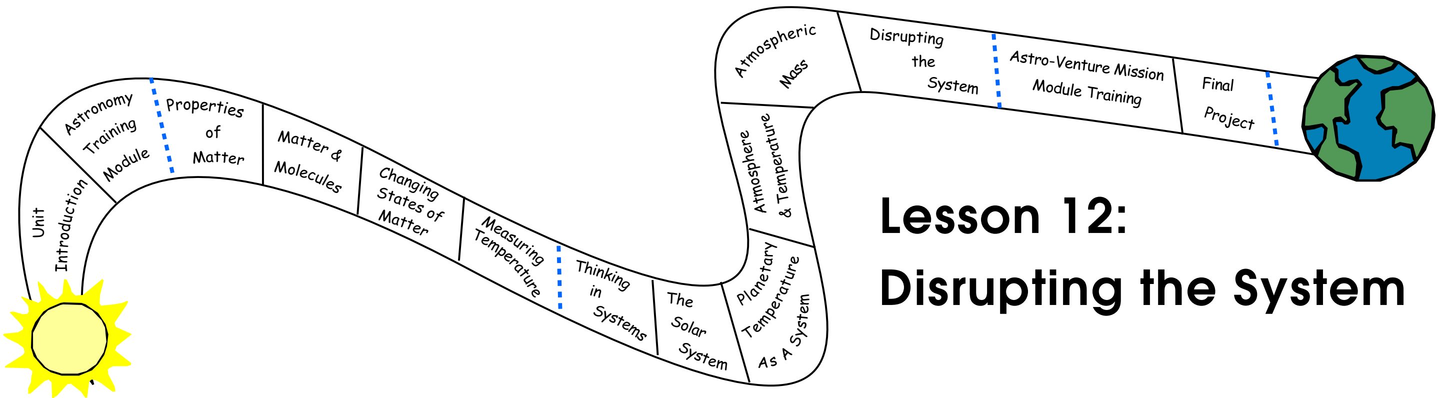
Questions

(Answer on a separate sheet of paper)

1. What is gravity?
2. How is gravity related to atmosphere?
3. What happens to planets with large mass?
4. What happens to planets with small mass?
5. Can you have the right mass but still have the wrong atmosphere for human survival? Explain.

Planetary Comparison Chart

Planet	Atmo-sphere	Mass Earth = 1	Diameter *(Radius)* (km)	Density gm/ m^3	Liquid Water	Average Temperature	Force of Gravity Earth = 1	Atmospheric Mass (kg)
Mercury	very little: argon, neon and helium	0.06	4,878 *(2,439)*	5,430	too hot for surface water	day: 350°C/662° F night -170°C/ -274°F	0.38	2.03×10^{8}
Venus	carbon dioxide	0.82	12,104 *(6,052)*	5,250	too hot for surface water	465°C/869°F	0.90	1.41×10^{21}
Earth	nitrogen, oxygen	1.00	12,755 *(6,378)*	5,520	liquid water on the surface	15°C/59°F	1.00	5.33×10^{18}
Moon	none	0.01	3,476 *(1,738)*	3,300	no liquid water	sunlit side: 134°C/ 273°F dark side: -153°C/-243°F	0.17	0
Mars	carbon dioxide	0.11	6,790 *(3,395)*	3,940	Mars may have once had surface water, but doesn't now. Ice has been detected at the North Pole.	-23°C/-9.4°F	0.39	3.09×10^{16}
Jupiter	hydrogen, helium	318	142,796 *(71,398)*	1,314	some water vapor and ice crystals in the atmosphere	-150°C/-238°F	2.53	2.6×10^{22}
Saturn	hydrogen, helium	95	120,660 *(60,330)*	690	some water vapor and ice crystals in the atmosphere	-180°C/-292°F	1.06	4.4×10^{22}
Uranus	hydrogen, helium	15	51,118 *(25,559)*	1,290	some water vapor and ice crystals in the atmosphere	-221°C/-391°F	0.93	7.8×10^{21}
Neptune	hydrogen, helium	17	49,528 *(24,764)*	1,640	some water vapor and ice crystals in the atmosphere	-235°C/-391°F	1.18	7.4×10^{21}
Pluto	methane	0.002	2,300 approx. *(1,150)*	2,030	Any water is frozen as ice.	-220°C/-364°F	0.07	variable



Lesson 12: Disrupting the System

Students explore the planetary temperature system. They conduct in-depth exploration into how each aspect of the system influences the planetary system and the consequences of disrupting that system.

Main Lesson Concept: If Jupiter were in an elliptical orbit at 1 AU, it could cause a change in Earth's orbit, which would have consequences for the planetary temperature system.

Scientific Question: What could happen if Jupiter were in an elliptical orbit at 1 AU?

Objectives	Standards
Students explain how a planet's orbit could be disrupted.	Meets: 2061: 11A 6-8 #2 NSES: UCP K-12 #1 Addresses: NSES: A 5-8 #1 ISTE: 3, 5
Students explore the implications of such a disruption on the planetary temperature system and on human habitability.	

Assessment	Jupiter's in illustration or animation form.
Abstract of Lesson	Students explore what could happen to the Earth if Jupiter's orbit were different. They illustrate or animate the possibilities.

Prerequisite Concepts	Major Concepts
• Mass is the measure of the quantity of matter. • Gravity is a force of attraction that exists between objects. The greater the mass the greater its gravitational pull. • An orbit is the path of an object as it moves around another object because of gravity. (Lesson 8) • The Sun's gravitational pull holds Earth and other planets in their orbits, just as the planets' gravitational pull keeps their moons in orbit around them. • A system consists of many parts that usually influence each other. (Lesson 7)	• A disruption to a system such as the planetary temperature system can disrupt its ability to maintain a temperature suitable for human life.

Suggested Timeline (45 minute periods):

Day 1: Engage, Explore and Explain Sections
Days 2 – 6 (Depending on Project Choice): Extend/Apply Sections
Final Day: Evaluation for Part 3

Materials and Equipment:

- A class set of Jupiter's Orbits Diagram Student Version
- An over head of Jupiter's Orbit's Diagram Teacher Version
- A class set of Jupiter and Earth cut-outs 1
- Chart paper
- A class set of Disrupting Jupiter's Orbit Activity
- (optional) One Jupiter Orbit's Diagram to scale printed and taped

Preparation:

- Gather materials.
- Duplicate Jupiter's Orbits Diagram Student Version and Disrupting Jupiter's Orbit Activity.
- Make an overhead transparency of the Jupiter's Orbits Diagram (Teacher Version).
- Cut out the smallest planets from the Jupiter and Earth cut-outs 1 for Explore, Step 1.
- Check the link for the optional activity in Explore, Step 2.
- Prepare chart paper with major concept of the lesson to post at the end of the lesson.
- (optional) Print the nine-page Jupiter Orbit's Diagram to scale, tape and display on a wall in your classroom.

Differentiation:

Accommodations

Assign students to heterogeneous groups for projects.

Advanced Extensions

If the students have access to a gravity simulation program, they could try to model the Jupiter/Earth relationship in it. (See Explore, Step 2)

Engage (approximately 15 minutes)

1. Review the planetary temperature system and introduce the purpose.

- Do the temperature modeling activity from Lesson 11 (Extend/Apply Section)
- Be sure to change all of the characteristics: star type, distance from star, atmosphere, planetary mass, and diameter.

- Question: Why is it important that the planet's temperature system remain stable?
- *Answer: We couldn't survive if the system were disrupted.*

- Say: Today we're going to look at things that might disrupt the system so we can better understand how our system remains stable.

2. Bridge to this lesson.

- Say: Let's change things around a little bit. I'm going to give you different scenarios for planetary system change. (Model) You should respond with the same arm movements. Reset your arms to the neutral position.
- Say: The star that your planet orbits is growing older. It is changing from a yellow Main Sequence star to a red giant. What happens?
- *Answer: Arms go up.*

- Question: Over time, what is likely to happen to water on this planet?
- *Answer: It will boil off into steam.*

- Question: How will that effect the ability of the planet to support human life?
- *Answer: It will limit it.*

- Have students reset their arms to neutral.
- Say: Let's assume now that your planet's star is yellow and stable again. Now, however, something is happening on your planet that is putting more gas into the atmosphere. Not only is the atmospheric mass increasing, but also the gases are greenhouse gases. They retain more heat than other types of gases.
  Note to Teacher: There are several possible sources for such gases including volcanic eruptions. Use what you've done with your students to be more specific if you want. What's happening?
- *Answer: Arms go up.*

- Question: Over time, what is likely to happen to water on this planet?
- *Answer: It will boil off into steam.*

- Question: How will that effect the ability of the planet to support human life?
- *Answer: It will limit it.*
- Students may drop their arms.

- Question: Is there any way for a planet to change its distance from its star?
- Record student responses.

- Question: What holds the parts of the Solar System together?
- *Answer: gravity*

- Question: What causes gravity?
- *Answer: The mass of the bodies.*

- Question: What could disrupt the gravity between two bodies with great mass?
- *Answer: Another body with great mass.*

3. Introduce the Scientific Question:
- Question: What could happen if Jupiter were in a highly elliptical orbit at 1 AU?

Explore (approximately 15 minutes)

1. Address the misconception of the shape of Earth's orbit.

MISCONCEPTION:

Because of the way our Solar System is often depicted in images, a commonly held misconception is that the planets in our Solar System are in highly elliptical orbits. The reality is that their orbits are near circular. This is an important point for Earth's habitability, since it helps to maintain a moderate temperature. To bring out this misconception, draw several diagrams of the Earth's orbit around the Sun as follows:

- Earth is in a highly elliptical orbit with the Sun in the middle.
- Earth is in a near circular orbit with the Sun in the middle.
- Earth is in a highly elliptical orbit coming very close to the Sun on one side.

- Ask students which diagram is closest to the Earth's actual orbit and why they think so. After some discussion, point out that the circular orbit is the closest, but that when pictures in books depict the Solar System from the side, it makes the orbits look very elliptical. Explain that the orbits of the planets in our Solar System are, in fact, elliptical. However, they tend to be very close to circles. When we refer to elliptical orbits in this lesson and in the multimedia, we are referring to highly elliptical orbits as have been observed of planets in other systems or of comets.

2. Put Jupiter's Orbits Diagram onto overhead
- Tell the students that the diagram shows Earth's actual orbit, Jupiter's actual orbit and a hypothetical (made up, but possible) elliptical orbit for Jupiter.
- Put the cut out Earth onto the diagram and demonstrate the orbit of Earth around the Sun.

MISCONCEPTION:

There are many commonly held misconceptions regarding the size and distances of the planets due to the difficulty of portraying these to scale. It is important to draw students' attention to these misconceptions as modeled in the following discussion and activities.

- Question: Do you think this diagram is to scale? Why or why not?
- *Answer: The orbits are to scale, but the planets and the Sun are not. We would not be able to see the Sun and planets if they were drawn to scale. Since Jupiter is about ten times the diameter of Earth, and the Sun is about ten times the diameter of Jupiter, the Sun would need to be 500 times smaller!*
- Question: If Jupiter is about ten times the diameter of Earth, and the Sun is about ten times the diameter of the Sun, how much smaller would they need to be at this scale compared to the Sun?
- *Answer: Jupiter would need to be 5,000 times smaller than the current diameter of the Sun, and Earth would need to be 50,000 times smaller than the current diameter of the Sun.*

  Note to Teacher: To show the actual diameters to scale, have students draw an Earth that is one inch in diameter, a Jupiter that is ten inches in diameter, and ask what the size the Sun would be. Students will quickly see that to draw a Sun at a diameter of one hundred inches would be very difficult. To show a scale diagram of the orbits, assemble the nine-page Jupiter Orbit's Diagram to scale included at the end of this lesson. The sun will be to scale, but the planets will not be.

- Say: It's important when presenting an illustration to inform the viewer whether or not the image is to scale. In this case, the orbits are to scale. The size of the planets and the Sun are not.

- Add the cut out Jupiter to the diagram on its real orbit and demonstrate its movement around the Sun.

- Question: What is holding the parts of the Solar System together?
- *Answer: Gravity.*

- Question: Could there be any times when Jupiter and Earth were being pulled towards each other by gravity? If so, when?
- *Answer: Yes, when the planets' orbits bring them in line with each other.*

- Have a student demonstrate on the overhead.
- Move Jupiter onto the elliptical orbit. Demonstrate its movement.
- Question: If Jupiter were on this orbit, what would happen to it in relation to Earth?
- *Answer: It would move closer to Earth.*

- Have a student demonstrate on the overhead.
- Question: What would happen to the attraction between the planets as they got closer?
- *Answer: The attraction would increase.*

- If Earth is not already between the Sun and Jupiter, move it there now.
- Question: What is Earth being attracted to in this situation?
- *Answer: Both Jupiter and the Sun.*

- Question: What could happen to the Earth's orbit?
- *Answer: Earth could be pulled out of its orbit.*

3. (Optional) Engage students in the following gravity simulator exploration.

- Question: Could we use an orrery (a mechanical model of the Solar System) to model this possibility? Why or why not?
- *Answer: We couldn't because an orrery is based on the known, real movement of the planets.*

- Question: In the real Solar System, what holds the planets together?
- *Answer: Gravity.*
- Question: What would it take for a computer program to be able to model the Solar System and make changes to it?
- *Answer: It would have to model gravity.*

- The following link goes to "Gravitation 3.8" a web page with a Java applet that simulates gravity. While students are working on their projects, they can rotate through and experiment with the program. http://arachnoid.com/gravitation/

- http://burtleburtle.net/bob/java/orbit/ also has an orbit simulator written in Java, but it is mostly for demonstration purposes. This link, http://burtleburtle.net/bob/physics/orbit101.html, has several demonstrations, but they can't be altered by students. The text is for high level physics students.

Explain (approximately 15 minutes)

1. Discuss the possible effects of Earth being pulled out of its orbit.

- Question: If Earth were pulled out of its orbit, what do you think could happen?
- Record student responses

  Possible Outcomes:
  - Earth could be ejected from the Solar System.
  - Earth could be sent into the Sun.
  - Earth could become a moon of Jupiter.
  - Earth could be pulled into Jupiter.
  - Earth could reestablish an orbit with the Sun at a greater distance from the Sun.
  - Earth's orbit could become highly elliptical.

Extend/Apply (1 to 4 Class Periods Depending on Project)

1. Students illustrate and animate the disruption to the planetary temperature system.

- Put students into groups.

- Assign or have each group choose a potential outcome to illustrate or animate. This activity has two options, a series of illustrations or an animation that uses a computer, some free programs, and a digital camera. With a little ingenuity, other methods of creating the animations can be used. If the animation activity is not doable, the series of illustrations or a flipbook will suffice.

- See the Disrupting Earth's Orbit Activity for detailed instructions for this activity.

- If the students are going to create animations, go over the basics of animation with them especially the part about frame rates. They will need to understand this concept to create a successful animation.

- Pass out the Disrupting Earth's Orbit Activity sheets to the students.

- Go over the project options.

- Discuss whether it will be feasible to draw the planets to scale or why not. (See the Misconception discussed in Explore, Step 2.)

2. Go over the basics of animation.

- Animation works by displaying a series of images which change slightly giving the illusion of movement.
- Each image is called a frame. The frames can be drawn by hand, drawn or painted on a computer, or models can be photographed (often called "claymation").
- The most basic way to animate is to create a flipbook. A flipbook is simply a stack of paper attached together. Each page is hand drawn with slight movement changes between each page. The animation is viewed by "flipping" through the pages using your thumb. The problem with this is that even elements that are not changing or moving from frame to frame need to be redrawn on each successive page.
- Cel animation takes care of this problem. The part of the animation that moves is drawn on to clear "cels" which are placed over backgrounds. Elements that do not move or change only need to be created once saving time and energy.
- Computer animation uses these same ideas and adds some features to make the process easier.
- To create animations for this activity, the students will use cutouts of Earth and Jupiter against the Jupiter's Orbits Diagram to create the animation (sort of a blend between cel animation and Claymation). They will need a digital camera and a program for taking a series of images and putting them into an animation.
- There are several free programs that create animations in different formats including: animated GIF's (the standard animation format for web pages), QuickTime movies (Macintosh platform), or Avi movies (Windows platform). Search your favorite shareware or freeware site for "animation" and your desired format (GIF, QuickTime, or Avi) and you should be given several options. Try a few until you find one that will work for your students. Please note, more powerful animation programs will be able to do more, but will also require more effort to learn. The advantage to the free ones (in addition to their being free) is that the students have to focus on the basic principles of animation. This will better prepare them to use more powerful programs in the future.
- One of the most significant factors in creating any animation is frame rate. This is the speed at which the frames are displayed. It is measured in frames per second. In general, the higher the frame rate (the more frames showing each second), the smoother the animation looks. Of course, the higher the frame rate, the more frames you need to create. In a flipbook, the frame rate is determined by how quickly the pages are flipped. In the animation programs, you choose the rate at which the frames are displayed. Standard video (on television etc.) shows at 29.5 frames per second (or fps). Movies shown in a theater tend to use 24 fps. Five frames per second tends to look a little choppy while ten frames per second can look almost smooth. The choice of frame rate will most likely depend on the length of the animation. A 5-second animation will require 25 frames at 5 fps and 50 frames at 10 fps.
    - The formula for frames is : $f = s * r$
    - f = number of frames in the animation
    - s = number of seconds in the animation
    - r = the frame rate (in frames per second)
    - the * sign indicates multiplication

3. Encourage the students to think in terms of the time for their animation.

Not only will this help them to choose an appropriate frame rate, but also it will help them to make their changes from frame to frame more evenly. For example, if they know that they have 10 frames to move Jupiter from point A to point B, then they know that they need to move Jupiter one tenth of that distance from frame to frame in order to get even movement and to be sure Jupiter is at the right point at the right time/frame.

Note to Teacher: The instructions for this activity are on the Disrupting Earth's Orbit Activity sheet at the end of this lesson.

Evaluate (approximately 45 minutes)

1. Have students share their animations and explain the effects of the disruption on Earth, Earth's temperature system, life on Earth and why.

- Question: Which part of the Earth's temperature system is being disrupted?
- *Answer: The orbital distance from the Sun.*

- Question: What effect does this have on Earth's surface temperature?
- *Answer: It depends on the result:*
  - *If Earth were ejected from the Solar System, the temperature would grow very cold and water would freeze.*
  - *If Earth were sent into the Sun, it would burn up.*
  - *If Earth became a moon of Jupiter, it would be in the same highly elliptical orbit that Jupiter is in. Therefore, its temperature would not remain stable and would fluctuate between all water being frozen and boiling off into steam.*
  - *If Earth were pulled into Jupiter, it would be engulfed as a part of Jupiter.*
  - *If Earth reestablished an orbit with the Sun at a greater distance from the Sun, it would probably be outside of the Habitable Zone causing temperatures to fall and water to freeze.*
  - *If Earth's orbit became highly elliptical, its temperature would not remain stable and would fluctuate between all water being frozen and boiling off into steam.*

- Question: So, in order for a planet like Earth to maintain a stable temperature that supports human life, what needs to happen?
- *Answer: A large object such as Jupiter must not be in a highly elliptical orbit in which it could disrupt the habitable planet's orbit. There must be no large objects or the large object must orbit in a more circular orbit that is at a good distance from the habitable planet.*

Note to Teacher: Scientists do not agree on whether a large planet such as Jupiter is necessary for life. Some scientists argue that Jupiter has protected life on Earth by attracting debris such as asteroids and comets that could have crashed into Earth destroying life. However, other scientists argue that although this is true of our system, other systems may not need a "vacuum cleaner" like Jupiter, because they may not have as many asteroids and comets. In fact, it is possible that if it weren't for Jupiter, that our asteroid belt might have formed into another planet thus greatly reducing the number of asteroids in our Solar System. Therefore, in Astro-Venture, we only focus on the necessity for any large Jupiter-size planets to be in a circular orbit far from any habitable planets.

Note to Teacher: After each lesson, consider posting the main concept of the lesson some place in your classroom. As you move through the unit, you and the students can refer to the 'conceptual flow' and reflect on the progression of the learning. This may be logistically difficult, but it is a powerful tool for building understanding.

Disrupting Earth's Orbit Activity

If Jupiter's orbit were elliptical at 1 AU (the distance of Earth from the Sun), it would have the potential to disrupt Earth's orbit. There are some possible outcomes of that disruption. For the assigned possible outcomes you must:

1. Illustrate and explain how the disruption occurred (show how Jupiter could disrupt Earth's orbit).
2. Illustrate and explain what could happen to Earth (be sure to indicate that it is one of many possibilities).
3. Explain what happens to water on Earth.
4. Explain what happens to the Earth's ability to support human life.

Projects

Option A: Series of Illustrations

Create a series of 4 to 8 illustrations with captions that meet the above requirements. You should also include a separate write-up to cover requirements 3 and 4.

Option B: Animation

Create a short animation to meet the above requirements. You should include a separate write-up to cover the written explanation requirements.

Materials:

- Jupiter's Orbits Diagram
- Digital Camera
- Animation Program for the computer
- Cardboard (to build a frame to support the Jupiter's Orbits Diagram
- Cut out Jupiter and Earth
- Tape or weak glue (the kind used in post-it notes).

Procedure:

- Make cut-out of Jupiter and Earth

- Label Jupiter's Orbits Diagram. Be sure to include information about scale (i.e. which parts are to scale and which parts are not).

- Plan the Animation
  - Decide the length of the animation (5 to 10 seconds)
  - Decide the frame rate (5 frames per second or 10 frames per second)
  - Plan the movement of the planets

- Mount the Jupiter's Orbits Diagram onto the cardboard so that it can stand up on its own.

- Position the camera so that you can see the Jupiter's Orbits Diagram (and only that) in the viewfinder of the camera.

- Use the tape or weak glue to put the planets in their starting positions.

- Shoot a frame. (Take a picture.)

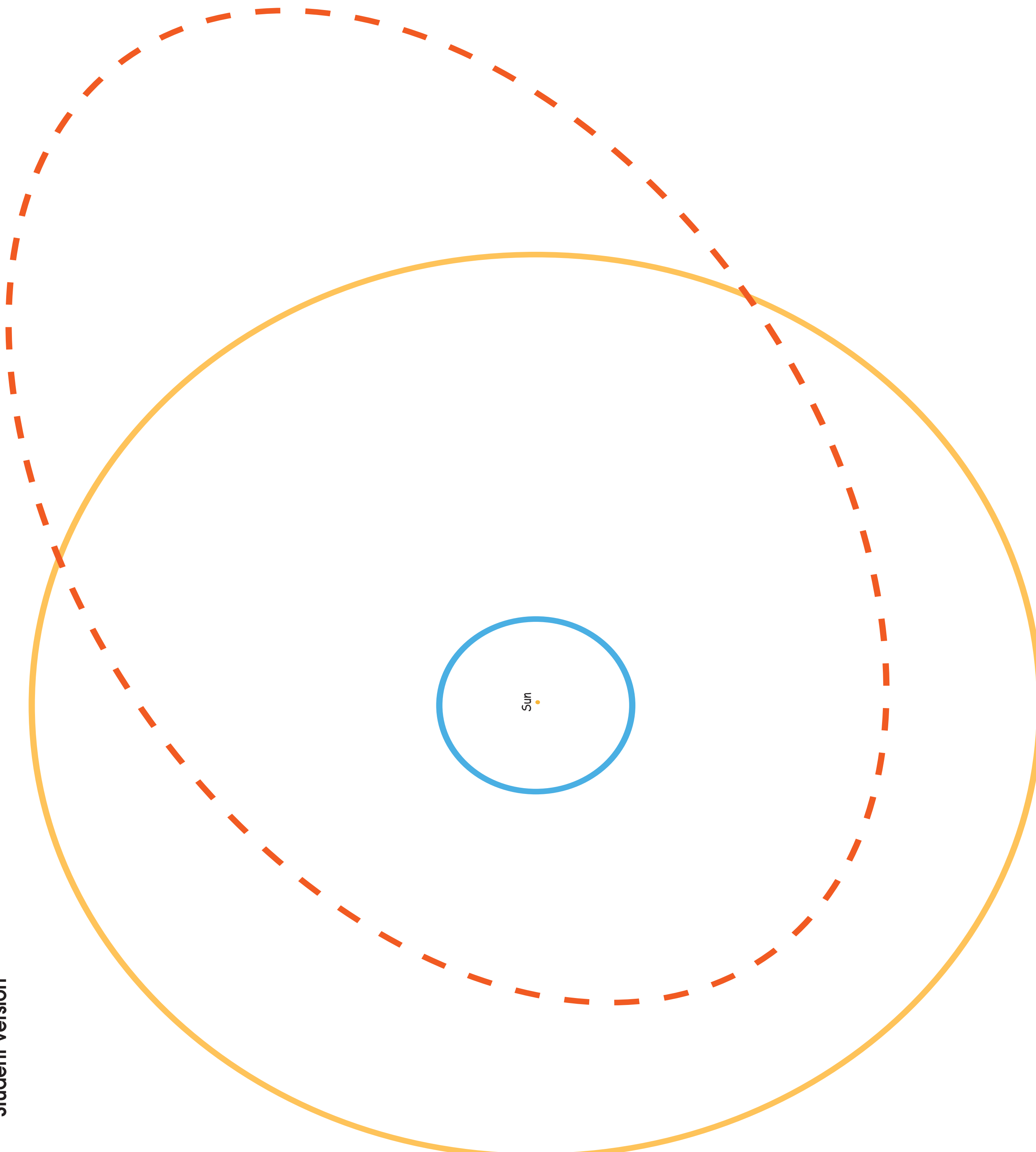
- Move the planets to their next positions. Shoot another frame.
- Repeat the process until all frames have been shot.
- Transfer the pictures to a folder or directory on a computer.
- Follow the instructions for bringing the pictures into the animation program and creating the animation.
  - Most programs will use one of two methods. Either each picture will need to be added to animation one by one, or the program will require you to open the first picture in the sequence and will then import the rest in order.
  - Set the frame rate to the one you decided upon.

Your project will be evaluated using the following rubric. Please note that some elements of the rubric may not apply to both illustrations and animations.

4	• The disruption and its effects on Earth, water, and human life are accurately, creatively and elegantly portrayed in the illustration and explained concisely and effectively in the captions. • Elements on the illustration or in the animation are spaced appropriately and design elements (color, lines, shapes, and content illustrations) make it exceptionally clear and easy to understand. The animation flows consistently well.
3	• The disruption and its effects on Earth, water, and human life are clearly and accurately portrayed in the illustration or animation and explained in the captions. • Elements on the illustration or in the animation are spaced appropriately, and design elements (color, lines, shapes, and content illustrations) make it easy to read and understand. The animation flows well.
2	• The disruption and its effects on Earth, water, and human life are not completely clear or completely accurate. • Elements on the illustration or in the animation could be better spaced and design elements (color, lines, shapes, and content illustrations) make it a little difficult to read and understand. The animation is jerky and skips parts.
1	• The disruption and its effects on Earth, water, and human life are unclear or inaccurate in the illustration, animation, or caption. • Elements on the poster are either squashed together or large spaces are empty, and design elements (color, lines, shapes, and content illustrations) make the poster difficult to read. The animation shows little or no flowing movement.

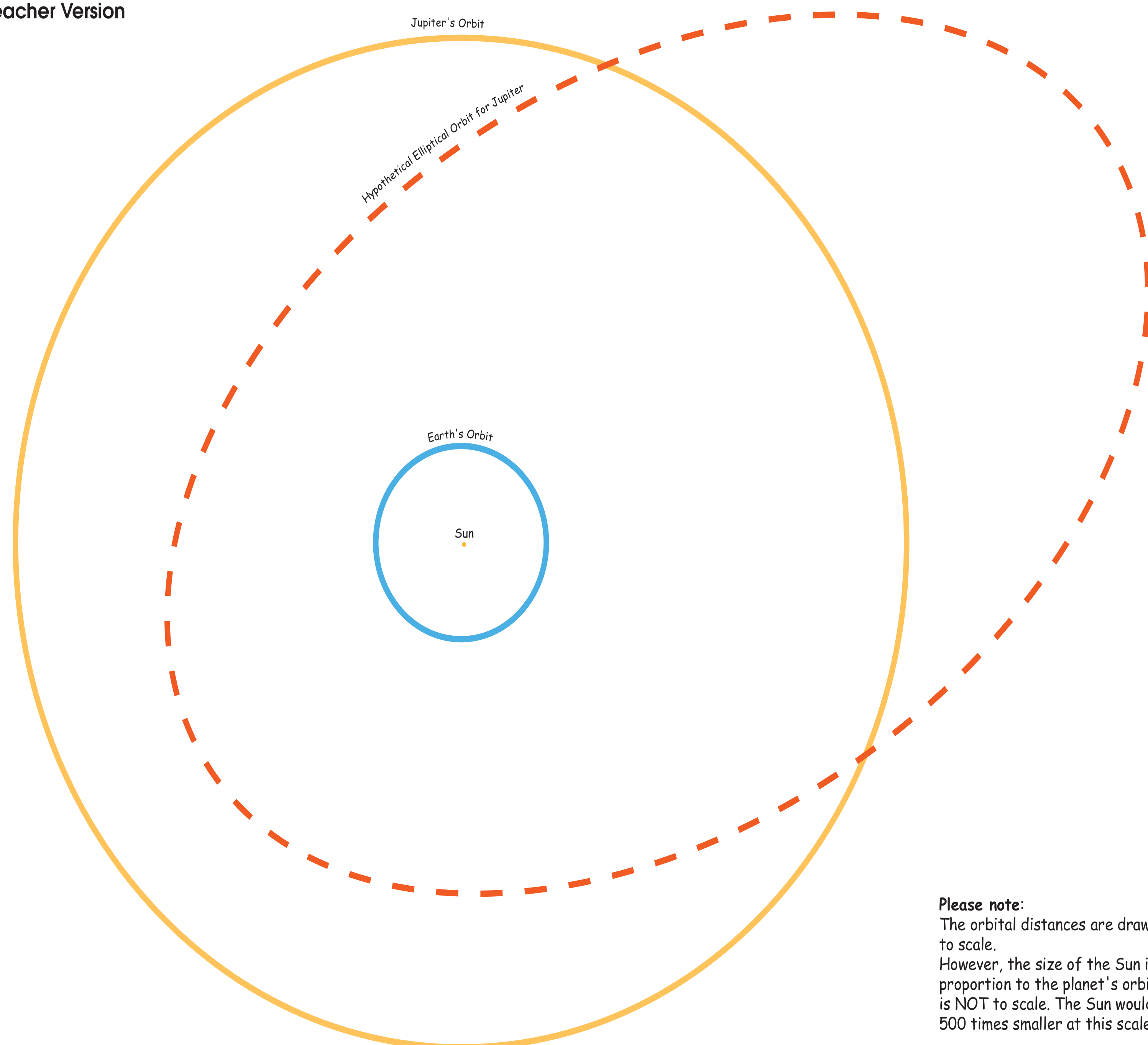
Jupiter's Orbit Diagram

Student Version



Jupiter's Orbit Diagram

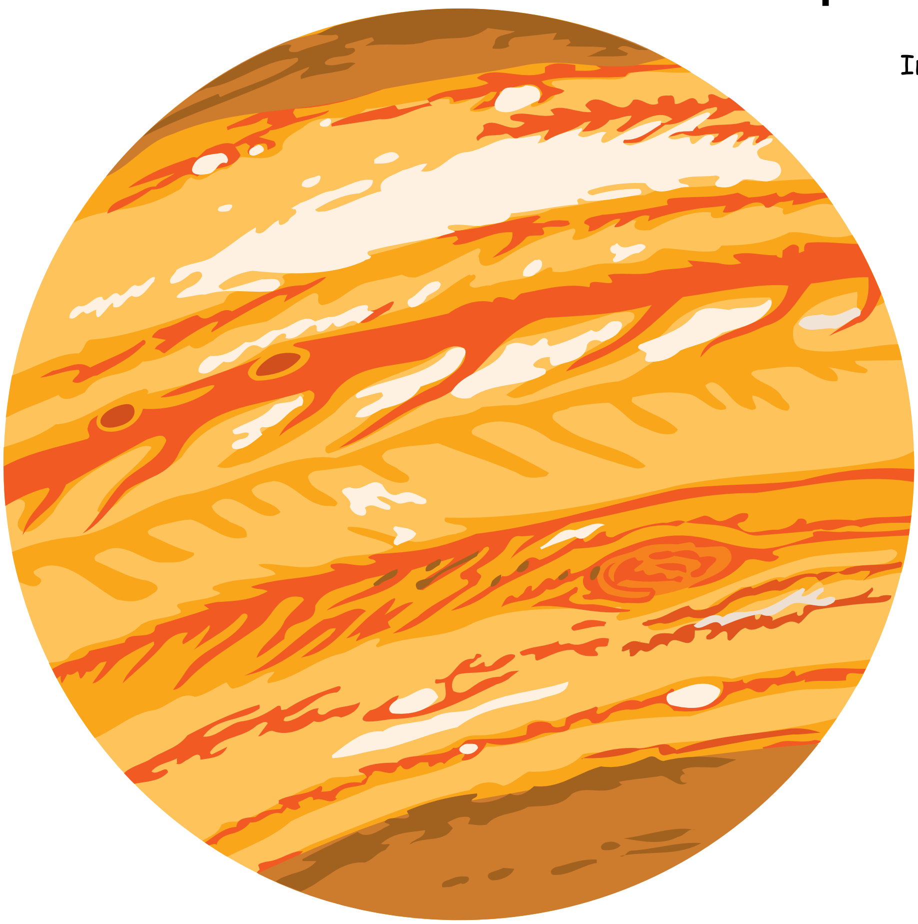
Teacher Version

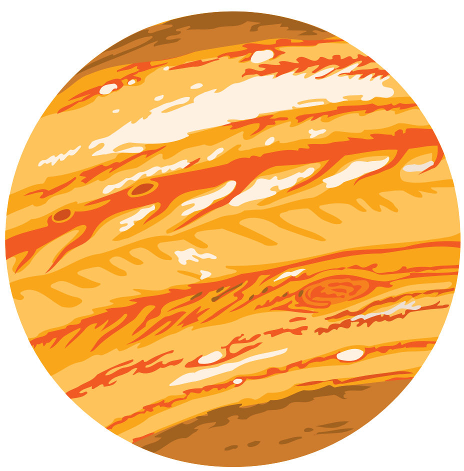


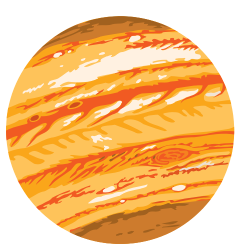
Please note:
The orbital distances are drawn to scale.
However, the size of the Sun in proportion to the planet's orbits is NOT to scale. The Sun would be 500 times smaller at this scale!

Jupiter and Earth cut-outs 1

In this example Jupiter and Earth are NOT proportional or to scale.

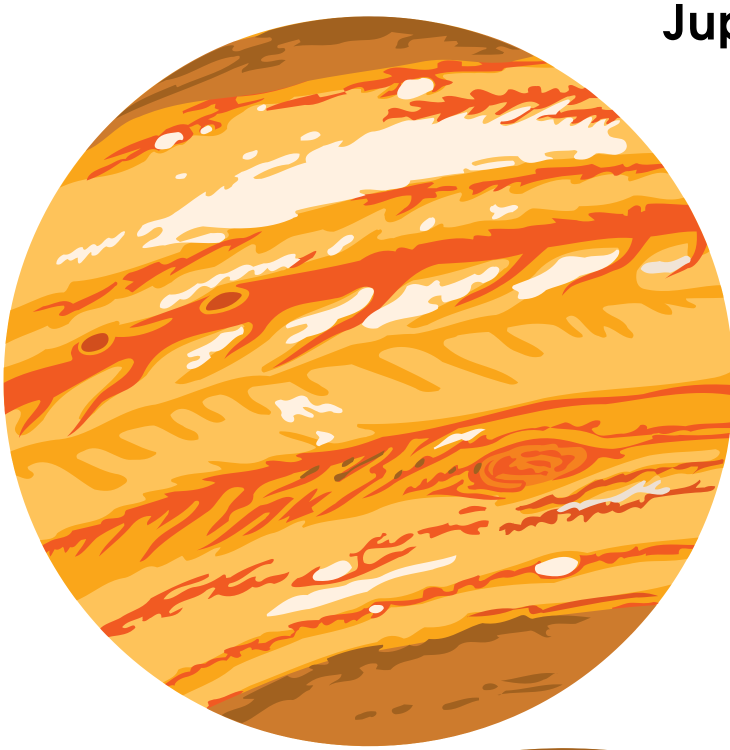


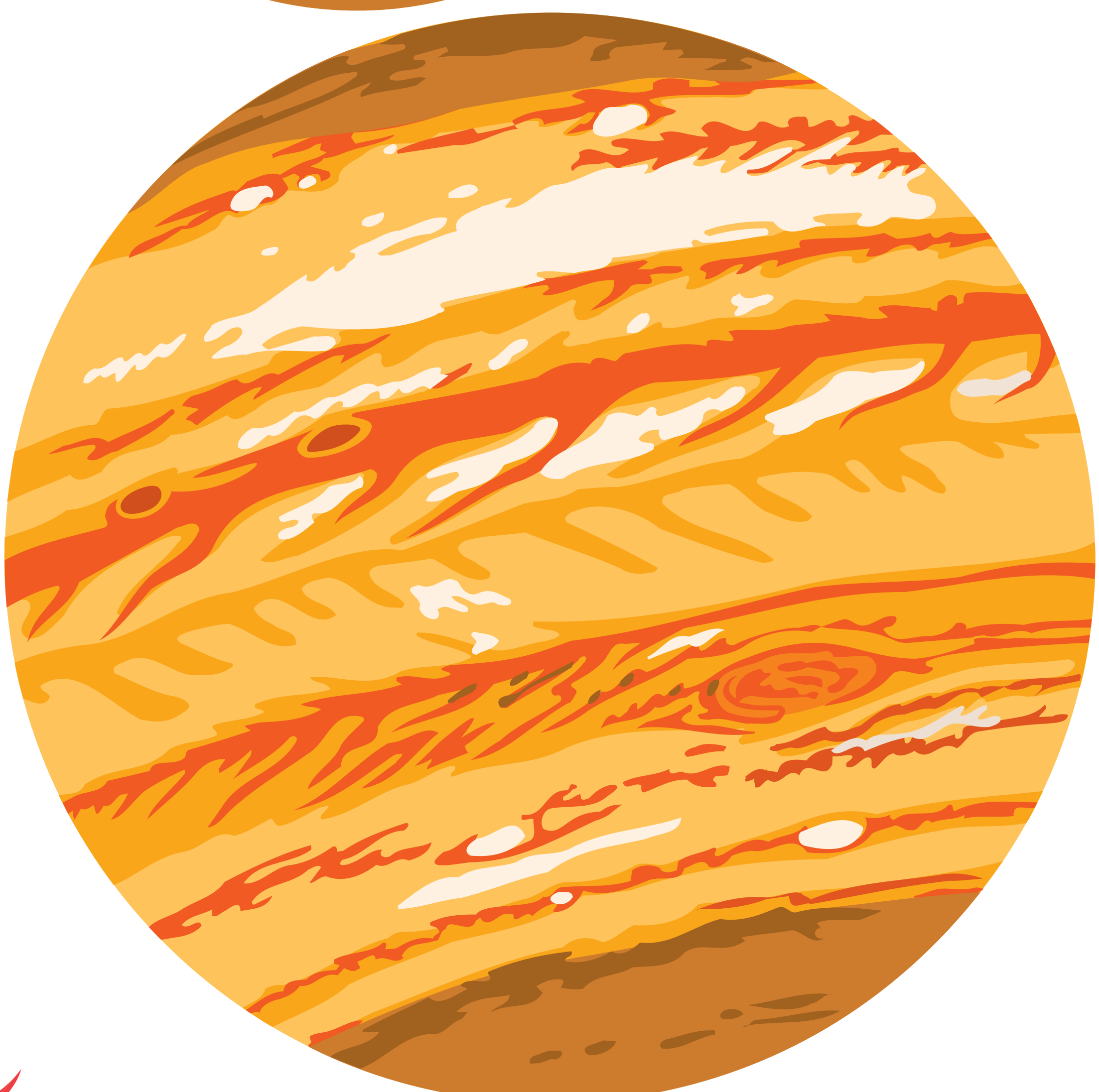




Jupiter and Earth cut-outs 2

In this example Jupiter and Earth are
PROPORTIONAL to each other but **not** to scale.

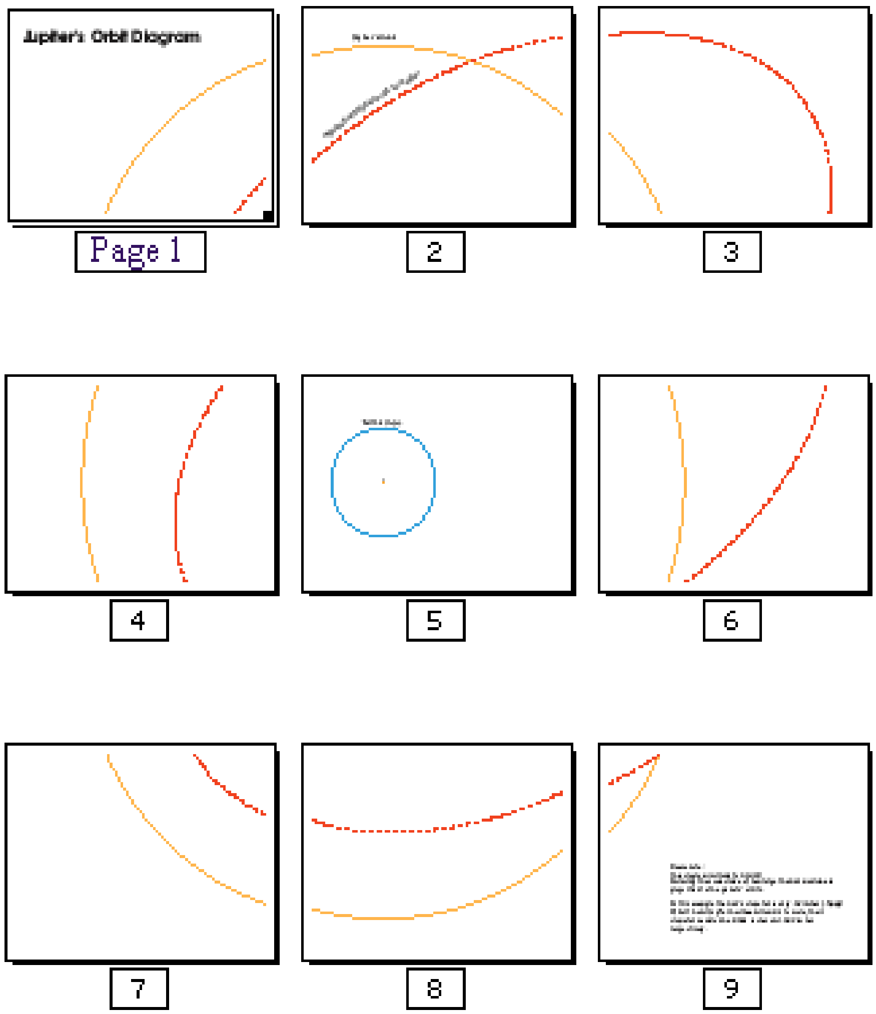




Jupiter Orbits Diagram to Scale

Starting on page 194, we have included a nine-page classroom-size diagram of the Sun, Earth's orbit, Jupiter's orbit and a hypothetical elliptical orbit for Jupiter. Once all nine pages are printed and taped together you will have a model that is to SCALE. Students will be able to see how small the Sun is in proportion to the orbits of Earth and Jupiter--quite an eye-opener!

To assemble the nine-page diagram, tape them in sequence in "landscape" orientation. See the picture below.



Build your own Solar System to scale!

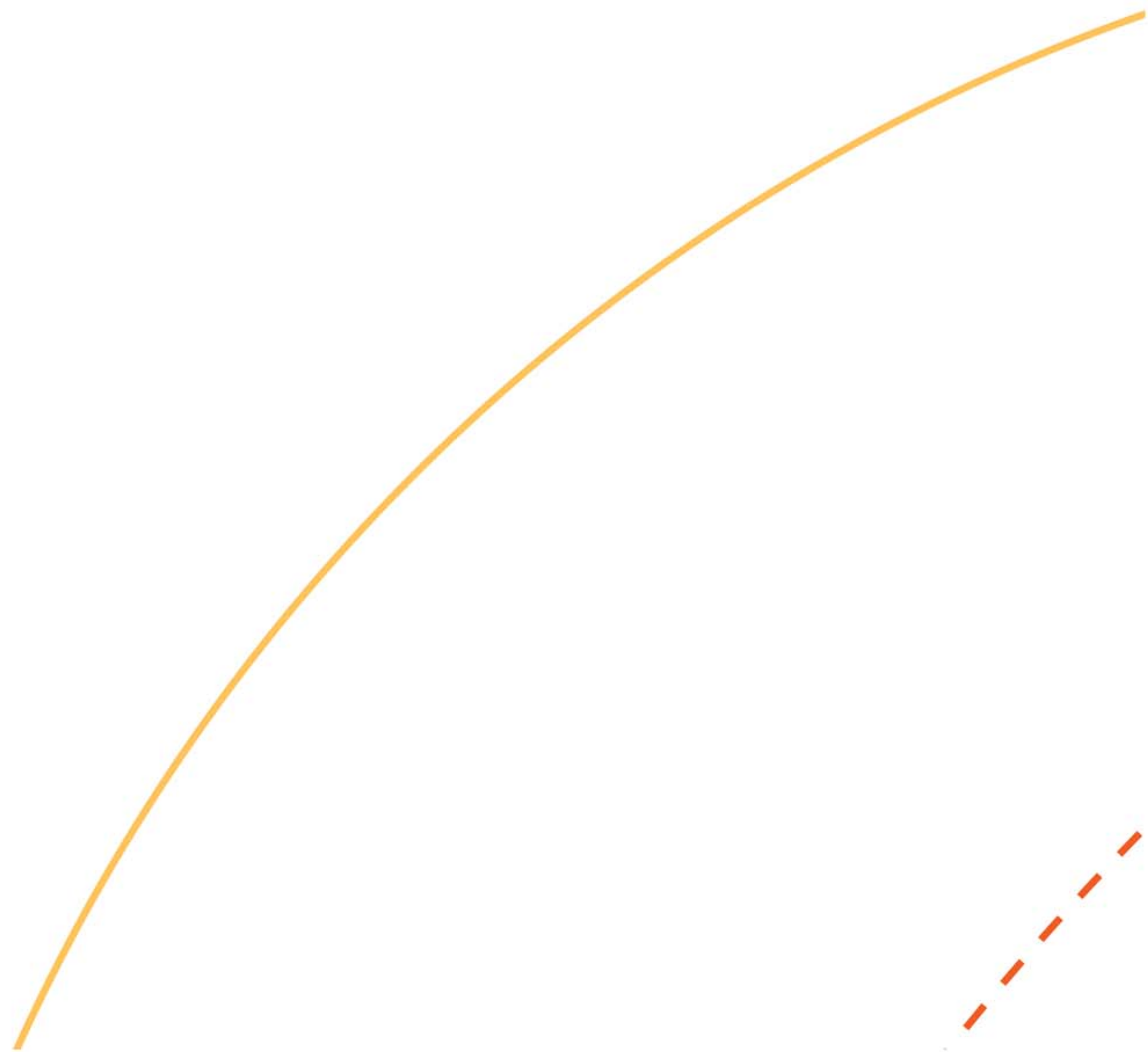
Make a scale model of the Solar System and learn the REAL definition of "space."

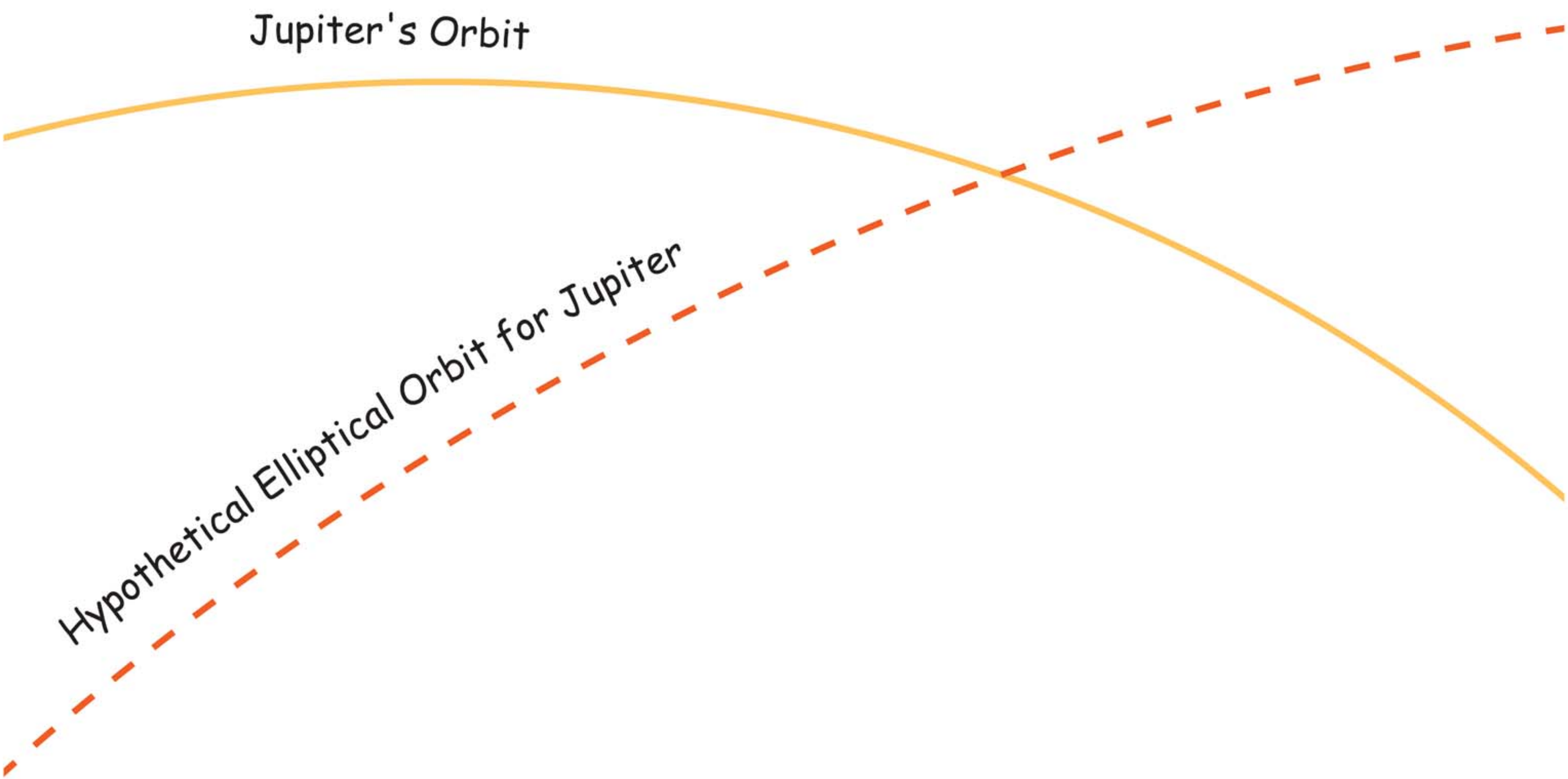
http://www.exploratorium.edu/ronh/solar_system/

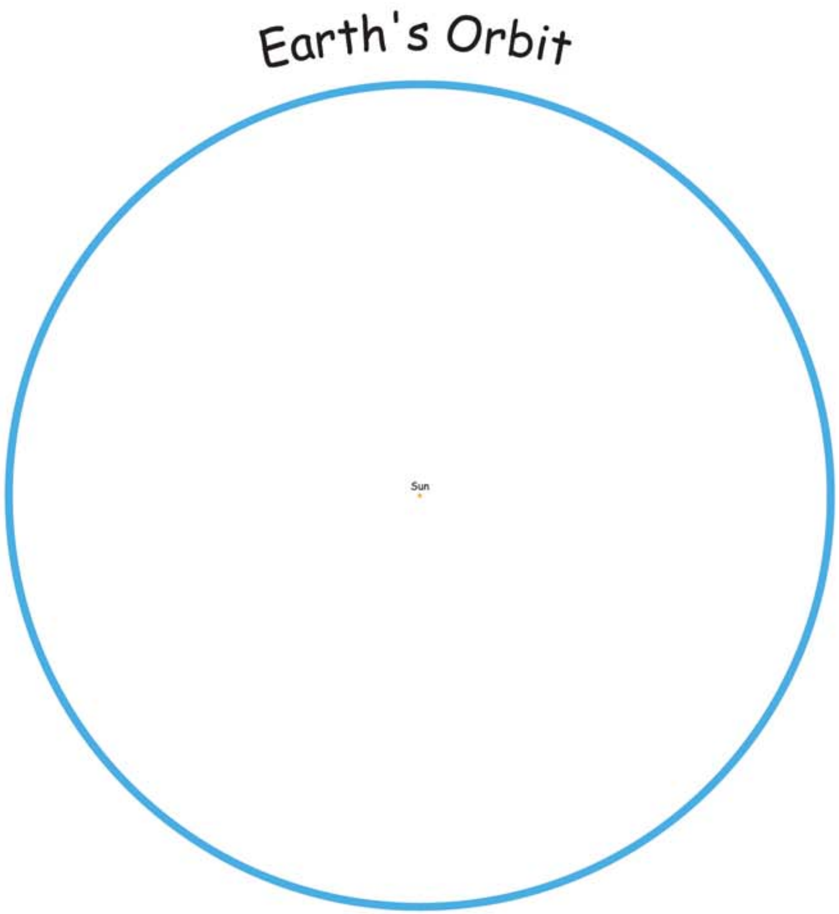
- Fill in the diameter of the Sun (in inches or millimeters) by which you want your model to be scaled.
- Click the "Calculate" button.

The proportional sizes of the planets will automatically fill in, along with a scaled orbit radius (in feet and inches or meters). Also provided are some other interesting scale comparisons at the bottom of the chart.

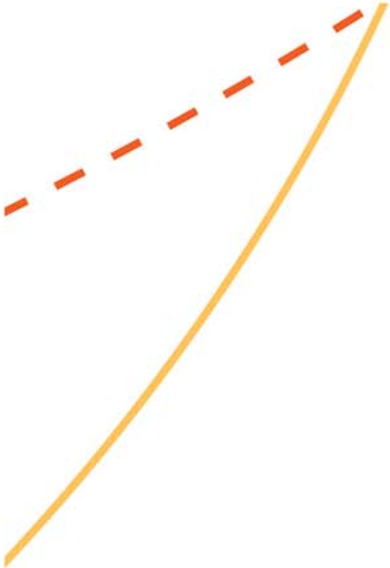
Jupiter's Orbit Diagram




Jupiter's Orbit
Hypothetical Elliptical Orbit for Jupiter



Earth's Orbit
Sun



Please note:
This diagram is drawn to SCALE!
Including the scaled size of how large the Sun would be in proportion to the planets' orbits.

In this example the Sun's diameter is only .02 inches (.5mm)!
If Earth and Jupiter had been drawn in to scale, their diameter would on be .0001 inches and .002 inches respectively.

Astro Journal

Embarking on an Astronomy Astro-Venture!

By:______________________________ (your name)

Astro Journal

Scientific Question:

Hypothesis/Prediction: What do you predict and why?

Materials: What materials will you use to investigate?

Procedure: List the steps you will take to investigate.

Step 1:

Step 2:

Step 3:

Step 4:

Step 5:

Name:

Data Collection: Record and display your data in a chart, table, picture or graph.

Results: Summarize what your data mean.

Conclusions: Compare and contrast your hypothesis and results. How did testing your hypothesis/prediction change your original ideas?

Scientific Inquiry Evaluation Rubric For Evaluating Astro Journal Entries

Component	Expectations
Hypothesis/ Prediction	• Clearly stated • Specific enough to be testable/observable and give a meaningful result • Has basis in solid information or observations and a logical reasoning process
Materials, Procedures, and Data	• Clearly stated • Complete • Accurate and tied directly to hypothesis and scientific question
Results	• Clearly stated • Refers directly to Scientific Question and data • Draws a reasonable conclusion from that data
Conclusions	• Clearly stated • States how hypothesis/prediction was confirmed and/or altered • Refers directly to findings, observations, and/or data to explain why thoughts were changed.

Scores:
4: Expectations Exceeded
3: Expectations Met
2: Expectations Not Quite Met
1: Expectations Not Met