

HOW TO BUILD A PLANET

An Original Taylor Planetarium Production

EDUCATOR GUIDE

MUSEUM^{OF} THE ROCKIES

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Dear Educator,

Thank you for choosing to bring your students to the Taylor Planetarium at the Museum of the Rockies (MOR), where our mission is to inspire visitors to explore the rich natural and cultural history of America's Northern Rocky Mountains. A planetarium show is a great way to help your students visualize concepts and spark their curiosity about a new topic.

Studies have shown that learning in museums is not limited to the time spent within their walls, but is heavily influenced by prior knowledge and experiences and continues long after the visit has ended. For these reasons, preparing your students for their planetarium visit and then extending their experience afterward will enhance the educational aspect of the field trip experience.

To aid you in linking this planetarium show to your curriculum, the Museum of the Rockies' Education Department has created this guide. Inside, you will find details on the *How to Build a Planet* planetarium show, including vocabulary and state science standards addressed. We have also assembled complementary classroom activities for various grade levels. We hope that these resources will help you prepare pre- and post-visit activities for your students that tie into your curriculum.

MOR is committed to providing the richest possible learning experience for your students and welcomes your questions and feedback. We look forward to seeing you at the Taylor Planetarium at the Museum of the Rockies soon!

Sincerely,

Claire Thoma
Astronomy Education Intern
Museum of the Rockies

Angie Hewitt
Education Director, Early & Elementary Programs
Museum of the Rockies

OVERVIEW

Grades: 6th–12th

Length: 45 minutes

Show Brief: This planetarium show complements the permanent exhibit, *Landforms/Lifeforms*. In this program, the audience explores the forces that have shaped the earth. Earth as a planet is compared to neighboring planets Venus and Mars to discover what factors allowed for the emergence of life on this planet.

Themes: Big Bang, formation of the solar system, solar fusion, formation of heavy elements, stellar lifecycles, formation of the earth, plate tectonics, emergence and evolution of life

Program Description:

This content-packed planetarium show begins with the age-old question “How did the earth come to be?” A storyteller recounts the ways in which various cultures have answered that question and then the narrator explains that modern scientists continue to try to answer that same question. The narrator goes on to lay out the current understanding of the formation of the universe, the solar system, and the planet with instructive visuals. Topics covered include solar fusion, the creation of heavy elements during the lifecycles of different types of stars, and the formation of the planets. The formation of the earth’s interior into a core, mantle, and crust is described by the “Planetary Chef,” and the forces that led to plate tectonics and mountain building are described. The narrator then relates the wondrous emergence and evolution of life on earth and the changes to the planet that the early life forms made.

After describing the formation of the planet and the evolution of life on earth, the narrator turns our attention towards Venus and Mars to discover why they evolved to be so different from the Earth. Life evolved on earth because the conditions here were just right, but is that common? The narrator explains that other planets have been found to be orbiting other stars and leaves the audience pondering whether there might be other intelligent life somewhere else in the universe and if we might one day be able to venture off of our home planet and out into space to build a new home for ourselves around another star.

Vocabulary:

Big Bang	supernova	crust	vertebrate
Universe	helium	magnetic field	Pangea
neutrons	electrons	atmosphere	plate tectonics
hydrogen	core	continent	greenhouse effect
Milky Way galaxy	mantle	cyanobacteria	ozone layer

OBJECTIVES

Students will:

1. Explain the formation of the solar system and the earth from heavy materials created by stars.
2. Identify at least three conditions that made the earth habitable for life.
3. Explain the reasons for differences in habitability between Earth, Mars, and Venus.

MONTANA SCIENCE STANDARDS ADDRESSED

End of Grade 8

- 2.2 Examine, describe, compare and classify objects and substances based on common physical properties and simple chemical properties.
- 2.4 Model and explain that the states of matter are dependent upon the quantity of energy present in the system and describe what will change and what will remain unchanged at the particulate level when matter experiences an external force or energy change.
- 4.1 Model and explain the internal structure of the earth and describe the formation and composition of Earth's external features in terms of the rock cycle and plate tectonics and constructive and destructive forces.
- 4.6 Describe the earth, moon, planets, and other objects in space in terms of size, force of gravity, structure, and movement in relation to the sun.
- 4.7 Identify scientific theories about the origin and evolution of the earth and solar system.
- 6.2 Identify major milestones in science that have impacted science, technology, and society.
- 6.3 Describe and explain science as a human endeavor and an ongoing process.

End of Grade 12

- 2.1 Describe the structure of atoms, including knowledge of (a) subatomic particles and their relative masses, charges, and locations within the atom, (b) the electrical and nuclear forces that hold the atom together, (c) fission and fusion, and (d) radioactive decay.
- 4.1 Understand the theory of plate tectonics and how it explains the interrelationship between earthquakes, volcanoes, and sea floor spreading.
- 4.5 Explain the impact of terrestrial, solar, oceanic, and atmospheric conditions on global climate patterns.
- 4.6 Describe the origin, location, and evolution of stars and their planetary systems in respect to the solar system, the Milky Way, the local galactic group, and the universe.
- 4.7 Relate how evidence from advanced technology applied to scientific investigations (e.g., large telescopes and space-borne observatories), has dramatically impacted our understanding of the origin, size, and evolution of the universe.
- 5.2 Give examples of scientific innovation challenging commonly held perceptions.
- 5.3 Evaluate the ongoing, collaborative scientific process by gathering and critiquing information.
- 6.2 Trace developments that demonstrate scientific knowledge is subject to change as new evidence becomes available.
- 6.3 Describe, explain, and analyze science as a human endeavor and an ongoing process.

SOLAR SYSTEM FORMATION DANCE & PLATE TECTONIC BUBBLES

Grades 6 - 12

STANDARDS ADDRESSED:

6th Grade

ESL.2.1 Using inquiry processes students explore convection currents in the mantle and explain how it results in plate tectonics resulting in mountain building and trenches.

8th Grade

ESP.3.3 Students explain theories of the origin and evolution of the Earth and Solar System.

High School

EI.1.0 Students explore the climate and seasons on the Earth and other planets in the Solar System.

ES1.2 Students explain the ideas of isostasy, crustal uplift, and study earth's asthenosphere, mantle, and crust.

RESOURCES AND MATERIALS:

- Ball representing the Sun
 - 1 nametag for each student
 - Large open space with distances from the Sun marked with tape, string, etc.
- For each group (Activity 2):
- 1 pie tin
 - 1 tea light candle
 - Matches or lighter
 - 4 film canisters
 - 3 colors of food coloring with droppers
 - 2-3 cups of water
 - 2-3 tablespoons liquid hand soap for a pearly appearance
 - Pocket-sized mirror
 - 1 copy of Convection in a Pan handout for each student

PURPOSE:

Students will gain an understanding of the formation of the Solar System and earth and the geologic processes that result in mountain building by acting out these processes.

OBJECTIVES:

1. Students will be able to explain the formation of the Solar System.
2. Students will be able to explain the process of convection within the earth.

ACTIVITY 1 - Solar System Formation:

Create nametags for students to wear with the following labels: *(There are 13 total elements. Make sure each element is present and then double up on elements as needed. The number refers to the element's atomic number and should be written on the nametag.)*

- Hydrogen-1
- Helium-2
- Lithium-3
- Carbon-6
- Nitrogen-7
- Oxygen-8
- Neon-10
- Magnesium-12
- Silicon-14
- Sulfur-16
- Iron-26
- Nickel-28
- Gold-79

This activity requires a large amount of open space. It will work in a classroom that has been cleared of desks, a gymnasium, or outside.

Place a ball representing the Sun in the middle of the room. You may want to mark out circles at regular distances from the Sun to help students remain far enough away as they orbit. Pass out nametags to students. Have students stand randomly around the Sun.

Read the following script and have your students act it out:

“Five billion years ago, before any member of our solar system formed, there was a big cloud of gas and dust that held many different types of elements. The particles of gas and dust inside the cloud slowly started to condense as the tiny particles were gravitationally attracted.” (Students move about randomly.)

“Eventually, the center of the cloud, where the gas was thickest, collapsed inward and formed a protostar. As the cloud collapsed inward, it began to spin and formed a disc of material around the protostar called a *protoplanetary disc*.” (Students begin to walk in a circle counter-clockwise around the Sun.)

“As the protoplanetary disc spins, the heavier elements are drawn closer to the protostar by its gravity while the lighter elements drift farther from the star.” (Students wearing nametags with heavier elements (larger numbers) migrate inward to the Sun while orbiting but should still be at slightly different distances. Students representing lighter elements drift farther away but stagger themselves at slightly different distances from the Sun. Numbers 13+ stand 1-8 feet from Sun, numbers 6-12 stand 5-12 feet from Sun, and numbers 5 and under stand 12 or more feet from Sun.)

(Students continue orbiting the Sun, always remaining the same distance from the Sun as they represent the disc of material that surrounded the Sun during its formation.)

“As the material in the disc travels around the young star, some elements travel faster than others. Particles start to collide, and when they do, they stick together. As the particles grow in size and mass, they sweep up even more particles. Soon, there are clumps of material called planetesimals orbiting the new star.” (Students hold their arms out to represent the “bubble” of influence surrounding their particle. When one student comes within another student’s “bubble,” the two particles are gravitationally attracted and stick together. As students stick together, they should hold hands and form a circle. As their circles become larger, they will collect even more students. After 2-3 “planetesimals” have formed, have students freeze and discuss: What types of elements make up the planet closest to the Sun? Farthest from the Sun?)

(There should be a few students remaining just out of reach of the planets.) “Some material was far enough from the planets that it did not become part of the planet, but it was captured by the planet’s gravity and formed a moon.” (Students who are out of reach of the planets demonstrate orbiting the planets as the planets orbit the Sun.)

As the planets continued to condense, the heavier elements settled inward, forming cores, while the lighter elements remained closer to the surface. (Students representing heavier elements (within each planet) move inward to make a core while the others remain in an outer circle and the student-moons continue to orbit.)

“This is the way in which solar systems and planets, including our own, formed. Where do you think the asteroids came from?” (They were left over bits of rock that never formed a planet because they are constantly being tugged in opposite directions by the gravity of the

Sun and the gravity of Jupiter. The Kuiper belt, Pluto and other dwarf planets that are very distant from the Sun, are also left over from the formation of the solar system.)

EXTENSION:

Ask your students to write creative short stories, draw pictures, or create comic strips illustrating/explaining the formation of the solar system. A possible idea is to tell the story from the perspective of a single particle.

ACTIVITY 2 - Convection in a Pan:

Adapted from a lesson created by Irene, Archway School, Berkley, CA.

This activity includes materials, other background information, and assessments accessible at

<http://www.mysciencebox.org/convection/lesson>

This lesson is part of an online Box on Plate tectonics that includes 5 lessons and can be found at

<http://www.mysciencebox.org/platetectonics>.

Tell students that they are going to watch what happens when a candle is placed under a pan of soapy water. Get the students into groups and assign each a work area to assemble around.

Have one member of each group get a pie pan and the other needed materials.

Spread out the 4 film canisters on the table. Place the pie pan on top. It should look like a circular table on peg legs.

Go around to each group and fill each pan a little more than half full with soapy water. Tell the students what is in the water to make it pearly. Ask them not to touch the surface so that the liquid can settle and fluid motion can cease.

Pass out the handouts. Tell students that they are going to light the candle and put it under the pan. Something will happen to the liquid. Explain that their job is to carefully watch the liquid and draw arrows on the diagrams in the handout to show how the liquid is moving in different places.

When the water in the pans is still, have students light the candle and slip it underneath the pan, right in the center.

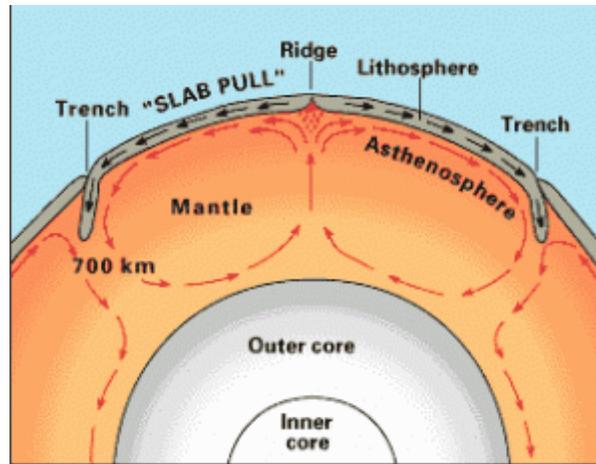
Have students watch what happens. The food coloring is a tool that can help them figure out what is going on by placing a drop in different places around the pan and watching how the coloring moves away from that spot.

Let the students experiment, discuss and draw for up to 10 minutes then blow out the candles. After 10 minutes or so, the water in the pan will begin to get too hot and the pearlescent molecules (glycol stearate) will begin to break down.

Give students a little more time to finish their drawings.

Clean up and dispose of the soap solution down the sink (or save it for the next class).

Discuss the students' observations of convection currents together as a class. Together, draw 3 different views of the fluid motion on the board (top view, bottom view, and side view).



Mantle Convection: Figure 32 from "This Dynamic Earth". Image courtesy of the USGS.

Hot air rises. How does that relate to what is going on in the pie pan? Students may find it helpful to label the side view drawing of the pie pan convection cells with words describing what is happening at every place. (For example, label the water right above the candle in the center "Water near candle flame gets hot." Label an arrow rising from the candle to the surface "Hot water rises." Etc.)

Discuss what is going on in the mantle of the Earth. On the board, draw a cross section through the Earth like the diagram shown. Relate this picture to the convection cells observed in the pie pan. Show how the super-hot core of the Earth is like the candle heating the mantle above it until the hot mantle rises towards the surface of the Earth.

Optional: Discuss other examples of convection in the Earth's atmosphere and oceans.

PLANETARY CHEF

Grades: 6 – 12

Adapted from activities found in Janice VanCleave's Astronomy for Every Kid: 101 Easy Experiments That Really Work, 1991.

**BOZEMAN SCIENCE
CURRICULUM STANDARDS
ADDRESSED:**
7th Grade

PFE.2.1 Students recognize that energy is conserved but can change forms such as light to heat, electricity to light, motion to heat (friction).

High School

LS.4.0 Students examine whether life exists elsewhere in the solar system and universe even though extreme environments prevail.

ES.2.1 Students investigate the topography of other worlds and compare them to Earth.

EI.3.2 Students will discuss the greenhouse effect on Venus and relate the possibility of the greenhouse effect occurring on Earth.

RESOURCES AND MATERIALS:

- 2 thermometers
- 1 glass jar
- 2 aluminum cans
- 1 desk lamp
- Black and white construction paper
- Tape
- 1 meter stick
- Direct sunlight
- Planetary Chef worksheets

PURPOSE:

These lessons will help students understand how factors such as distance from the sun, atmosphere, and albedo affect a planet's habitability.

OBJECTIVES:

1. Students will perform a series of experiments to understand various factors that affect planetary habitability.
2. Students will be able to explain how various factors affect planetary habitability.

ACTIVITY 1: Too Close for Comfort

Explain to your students that they are going to perform a set of experiments as a class to learn about factors that affect the temperature of planets. After learning about these factors, the students will invent their own planets using what they learned. Hand out one Planetary Chef worksheet (available at the end of this guide) to each student.

Ask students to predict whether a thermometer placed close to an energy source will register a higher, lower, or the same temperature as a thermometer placed farther away from the energy source.

Place one thermometer 10cm away from the desk lamp. Place the second thermometer 100cm away from the desk lamp. Turn on the lamp (both thermometers should be positioned so that they receive light from the lamp). Wait 10 minutes and then have your students record the temperatures on both thermometers on their Planetary Chef worksheet (experiment 1). Lead a discussion about the results and why the thermometer at 10cm got hotter than the thermometer at 100cm. Relate these results back to the planets in our solar system; ask students to explain which planets should be hottest and which coldest if the only factor determining temperature were distance from the sun.

ACTIVITY 2: Albedo

Explain to your students that *albedo* is another factor that affects planetary temperature. Define albedo as a number that represents how much light a surface reflects. Have students brainstorm the main factors that affect albedo: color and texture. (Lighter colors reflect more light and so have a higher albedo than darker colors. Smoother surfaces reflect more light and so have a higher albedo than rough surfaces. Therefore, planets covered in ice, which is white and smooth, have the highest albedos in our solar system.)

To demonstrate the effect of albedo on temperature, remove the lids from two aluminum cans. Wrap one in white paper and the other in black paper. Place a thermometer in each can, and place both cans at the same distance from a desk lamp. Position the lamp so that it is shining at the sides of the cans rather than down into the cans. Turn the desk lamp on, and have your students record the temperatures on both thermometers after 10 minutes on their Planetary Chef worksheet (experiment 2).

Lead the students in a discussion about the results, and relate them back to the planets in our solar system. If albedo were the only factor affecting planetary temperature, which planets would be hottest, and which would be coldest? Based on the results, would you expect the moon to be hotter or colder than the earth?

ACTIVITY 3: Greenhouse Effect

Explain to your students that there is one more major factor affecting planetary temperature. It is the presence and composition of a planet's atmosphere. Place one thermometer inside a glass jar and close the lid. Place the jar in direct sunlight. Place the other thermometer next to the jar so that it is also in direct sunlight. (This can be done outside or next to a window, as long as the sunlight is direct.) Explain that these two thermometers are both receiving the same amount of energy from the sun. After 20 minutes, have your students record the temperature of both thermometers on their Planetary Chef worksheet (experiment 3).

Lead a discussion about why the thermometer that was in the jar had a higher recorded temperature than the thermometer not in a jar. Help students understand that the radiation from the sunlight (heat) could dissipate from the uncovered thermometer but was trapped inside the glass jar, making the temperature inside the jar rise. This result actually illustrates two effects observed in nature. First, the jar can represent a planet with an atmosphere and demonstrate how the atmosphere makes the planet warmer than a planet that does not have an atmosphere or that has a much thinner atmosphere (the Earth and Mars are an example of this observation). The experiment also models two planets with atmospheres. In this case, the jar represents an atmosphere that contains many more greenhouse gases than the other. The difference between the temperature on Venus and Earth is one such example. Venus' super-hot temperature is primarily due to a runaway greenhouse effect in which its atmosphere traps most of the heat radiation from the sun and heats the surface to such high temperatures that rocks glow red. Have students imagine that all of the planets were lined up so that they were all the same distance from the sun and predict which planets would be hottest and which coldest based on their atmospheres.

ACTIVITY 4: Planetary Chef

Now that students have observed and considered how distance from the sun, albedo, and atmosphere affect planetary temperature separately, have them begin to consider them in combination. Lead a short discussion asking students to try to explain how these factors can explain the planetary temperatures observed in our solar system.

Mercury: up 450°C in day and -186°C at night

Venus: 460°C

Earth: average 7.2°C but ranges from 70°C to -89°C

Moon: -153°C to 107°C

Mars: ranges from 20°C to -120°C

Jupiter: deep in the planet but not yet in the core, the temperature is 21°C. At the top of the clouds, it is -145°C

Io (large, volcanic moon of Jupiter): -143°C

Saturn: Tops of the clouds are -175°C, but the temperature rises as you near the core.

Enceladus (small, icy moon of Saturn): -201°C

Uranus: -224°C
Neptune: -218°C
Pluto: -229°C

Have students synthesize the results of these three experiments by inventing their own planets with the goal of the planet having a habitable average temperature. Assign students to invent a planet that orbits a star that is either hotter or cooler than the sun. The students should present their invented planets to the class. Students should find that there are many ways to achieve the goal of a habitable planet. For example, if the star is smaller than the sun, one student may place the planet closer to the star while another student has a planet farther away but with a thicker atmosphere or lower albedo.

TYING IT ALL TOGETHER:

As discussed in How to Build a Planet, several factors including distance from the sun, albedo, and atmosphere resulted in major differences in temperature and habitability on the planets of Venus, Earth, and Mars.

SORTING THE SOLAR SYSTEM

Grades 6–12

BOZEMAN SCIENCE CURRICULUM STANDARDS ADDRESSED:

8th Grade

ESP.3.2 Students describe the Earth, Moon, planets and other objects in space in terms of relative size, composition, location and movement.

HT.1.3 Students simulate collaborative problem solving and give examples of how scientific knowledge and technology are shared with other scientists and the public.

High School

PM.2.0 Students describe and classify planets, stars, and other celestial bodies based on their chemical and physical properties.

RESOURCES AND MATERIALS:

Email MOR

(visitmor@montana.edu) to obtain a complete list of materials

- Set of 44 solar system cards for each group of 4 students

PURPOSE:

This lesson will help students gain an understanding of how the objects in the solar system are categorized.

OBJECTIVE:

Students will be able to identify objects that fall into each of the different categories of objects in the solar system.

ACTIVITY

Email MOR (visitmor@montana.edu) to obtain a copy of this lesson that teaches students about the current classification system for objects in the solar system by first allowing them to make up their own grouping for those objects. This activity is especially helpful for students who are confused about why Pluto is no longer considered a planet. (Like Ceres, the largest of the asteroids, which was considered a planet until the other asteroids were discovered, Pluto has been found to be only one member of a “belt” of objects beyond Neptune known as the Kuiper Belt.) This is also a lesson in the changing nature of science and the way in which new discoveries can change human understanding of nature.

TYING IT ALL TOGETHER:

As discussed in *How to Build a Planet*, human understanding of the solar system, its formation, and its current constituents has evolved and continues to evolve with new discoveries.

FEEDBACK

Please contact the Education Department with any questions, comments or suggestions regarding this curriculum.

MUSEUM OF THE ROCKIES

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HANDOUTS

NAME: _____

CLASS: _____

Convection in a Pan

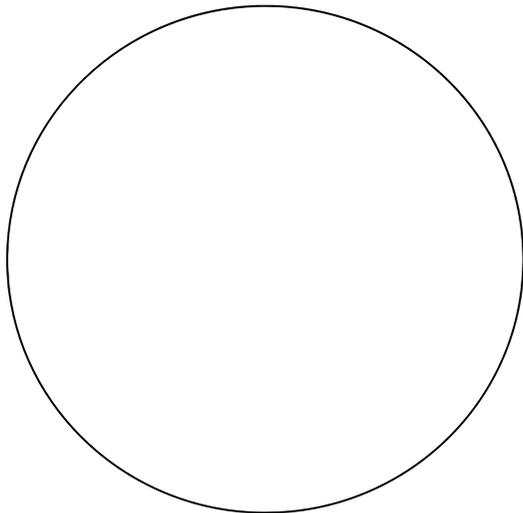
After you light the candle under the pie pan in front of you, wait 3 minutes and carefully observe the surface of the soapy water.

With your group, try these things to help you figure out what is happening:

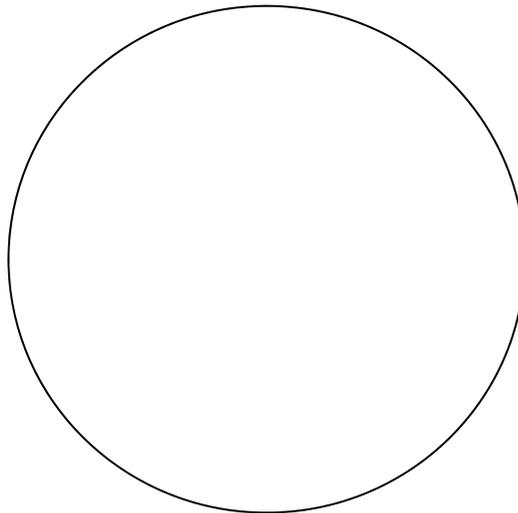
1. Add one drop of food coloring to the center of the liquid, directly above the candle flame.
2. Add one drop of food coloring of a different color to the liquid between the center and the rim of the pan.
3. Add one drop of food coloring of a different color to the edge of the liquid, near the rim of the pan.

When you think you know how the liquid is moving, use arrows to show the direction of motion of the liquid from these 3 different views:

What do you see looking down onto the surface of the liquid?



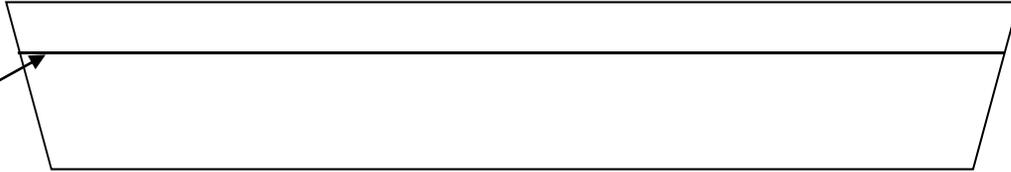
If the pan were made of glass and if you could lie down on the table and watch the liquid from below, what would you see?



What would you see if you had x-ray vision and could look through the pan from the side?

Pie pan
edges ↘

Surface
of liquid ↗



NAME: _____

PLANETARY CHEF

Experiment 1

Variable:

Temperature (°C)	
Thermometer 1	Thermometer 2

Conclusion:

Experiment 2

Variable:

Temperature (°C)	
Thermometer 1	Thermometer 2

Conclusion:

Experiment 3

Variable:

Temperature (°C)	
Thermometer 1	Thermometer 2

Conclusion:

Build your own planet!

Your mission is to create a planet that could be hospitable to life. Choose the size of the star your planet is orbiting, distance from the star, albedo, and atmosphere below.

This planet is orbiting a star that is (circle one) bigger than the Sun/smaller than the Sun.

Describe the planet's distance from its star:

Describe the planet's albedo:

Describe the planet's atmosphere:

Draw a picture of the planet, and label all important characteristics.