

6TH GRADE SCIENCE



FOR UTAH SEED STANDARDS

6th Grade

for Utah SEEd Standards

Revised 2025

Utah State Board of Education OER

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We especially wish to thank the amazing Utah science teachers whose collaborative efforts made the book possible. Thank you for your commitment to science education and Utah students!

Students as Scientists

What does science look and feel like?

If you're reading this book, either as a student or a teacher, you're going to be digging into the "practice" of science. Probably, someone, somewhere, has made you think about this before, and so you've probably already had a chance to imagine the possibilities. Who do you picture doing science? What do they look like? What are they doing?

Often when we ask people to imagine this, they draw or describe people with lab coats, people with crazy hair, beakers and flasks of weird looking liquids that are bubbling and frothing. Maybe there's even an explosion. Let's be honest: Some scientists do look like this, or they look like other stereotypes: people readied with their pocket protectors and calculators, figuring out how to launch a rocket into orbit. Or maybe what comes to mind is a list of steps that you might have to check off for your science fair project to be judged; or, maybe a graph or data table with lots of numbers comes to mind.

So let's start over. When you imagine graphs and tables, lab coats and calculators, is that what you love? If this describes you, that's great. But if it doesn't, and that's probably true for many of us, then go ahead and dump that image of science. It's useless because it isn't you. Instead, picture yourself as a maker and doer of science. The fact is, we need scientists and citizens like you, whoever you are, because we need all of the ideas, perspectives, and creative thinkers. This includes you.

Scientists wander in the woods. They dig in the dirt and chip at rocks. They peer through microscopes. They read. They play with tubes and pipes in the aisles of a hardware store to see what kinds of sounds they can make with them. They daydream and imagine. They count and measure and predict. They stare at the rock faces in the mountains and imagine how those came to be. They dance. They draw and write and write and write some more.

Scientists — and this includes all of us who do, use, apply, or think about science — don't fit a certain stereotype. What really sets us apart as humans is not just that we know and do things, but that we wonder and make sense of our world. We do this in many ways, through painting, religion, music, culture, poetry, and, most especially, science. Science isn't just a method or a collection of things we know. It's a uniquely human practice of wondering about and creating explanations for the natural world around us. This ranges from the most fundamental building blocks of all matter to the widest expanse of space that contains it all. If you've ever wondered "When did time start?", or "What is the

smallest thing?”, or even just “What is color?”, or so many other endless questions then you’re already thinking with a scientific mind. Of course you are; you’re human, after all.

But here is where we really have to be clear. Science isn’t just questions and explanations. Science is about a sense of wondering and the sense-making itself. We have to wonder and then really dig into the details of our surroundings. We have to get our hands dirty. Here’s a good example: two young scientists under the presence of the Courthouse Towers in Arches National Park. We can be sure that they spent some amount of time in awe of the giant sandstone walls, but here in this photo they’re enthralled with the sand that’s just been re-washed by recent rain. There’s this giant formation of sandstone looming above these kids in the desert, and they’re happily playing in the sand. This is ridiculous. Or is it?



How did that sand get there? Where did it come from? Did the sand come from the rock or does the rock come from sand? And how would you know? How do you tell this story?

Look. There's a puddle. How often is there a puddle in the desert? The sand is wet and fine; and it makes swirling, layered patterns on the solid stone. There are pits and pockets in the rock, like the one that these two scientists are sitting in, and the gritty sand and the cold water accumulate there. And then you might start to wonder: Does the sand fill in the hole to form more rock, or is the hole worn away because it became sand? And then you might wonder more about the giant formation in the background: It has the same colors as the sand, so has this been built up or is it being worn down? And if it's being built up by sand, how does it all get put together; and if it's being worn away then why does it make the patterns that we see in the rock? Why? How long? What next?

Just as there is science to be found in a puddle or a pit or a simple rock formation, there's science in a soap bubble, in a worm, in the spin of a dancer and in the structure of a bridge. But this thing we call "science" is only there if you're paying attention, asking questions, and imagining possibilities. You have to make the science by being the person who gathers information and evidence, who organizes and reasons with this, and who communicates it to others. Most of all, you get to wonder. Throughout all of the rest of this book and all of the rest of the science that you will ever do, wonder should be at the heart of it all. Whether you're a student or a teacher, this wonder is what will bring the sense-making of science to life and make it your own.

Adam Johnston
Weber State University

Science and Engineering Practices

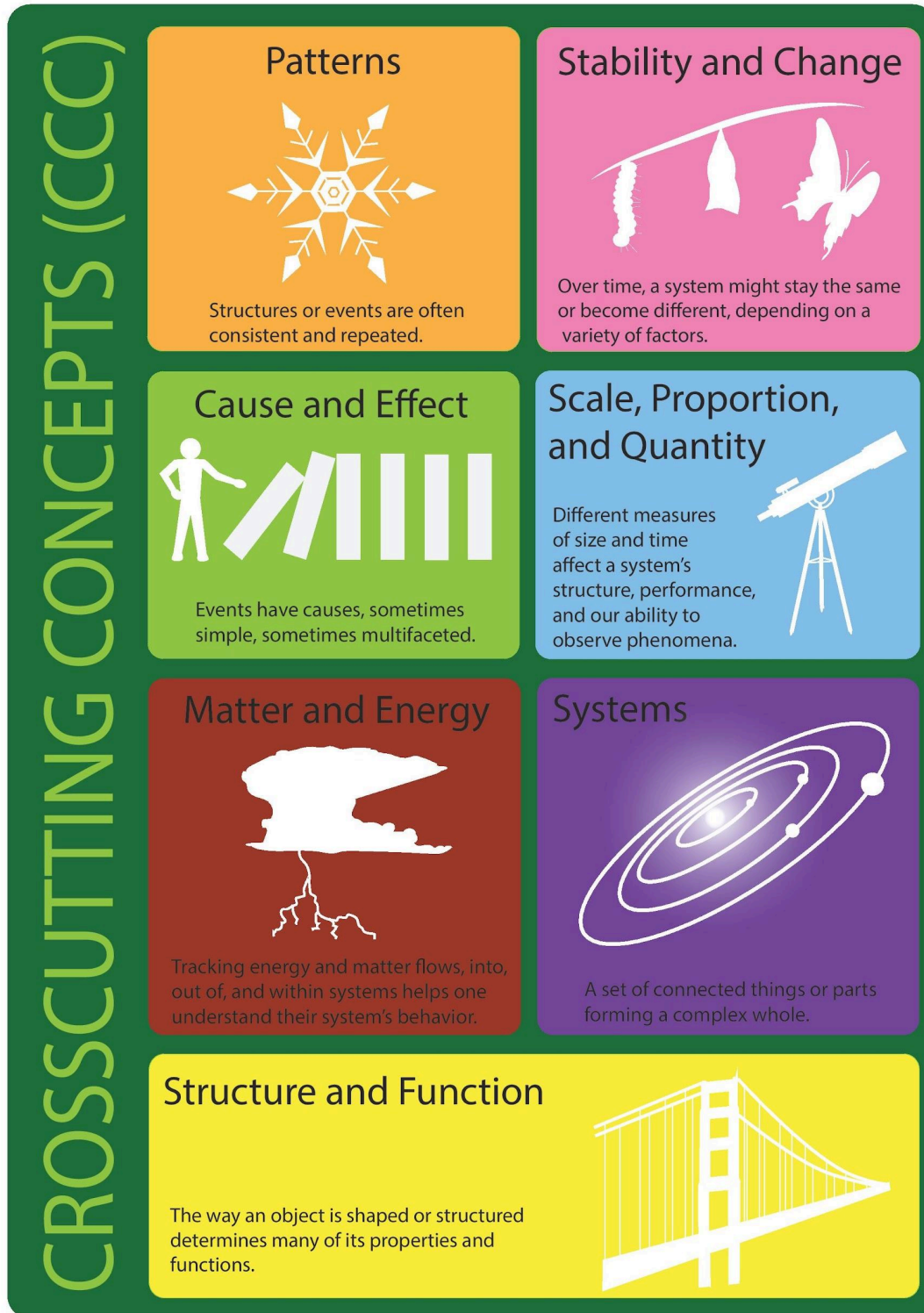
Science and Engineering Practices are what scientists do to investigate and explore natural phenomena.



Created by Susan Larson

Crosscutting Concepts

Crosscutting Concepts are the tools that scientists use to make sense of natural phenomena.



Created by Susan Larson

What is involved in Engineering Design?

Engineering is a creative process where each new version of a design is tested and then modified, based on what has been learned up to that point. This process includes a number of components:

1. Identifying the problem and defining criteria and constraints.
2. Generating ideas for how to solve the problem. Engineers use research, brainstorming, and collaboration with others to come up with ideas for solutions and designs.
3. Use criteria and constraints to evaluate possible design solutions to identify the one(s) that best address these parameters for the problem in context
4. Build and test the prototypes. Using data collected, the engineer analyzes how well prototypes meet the given criteria and constraints.
5. Suggest or make improvements to prototypes to optimize the design.

In the Science with Engineering Education (SEEd) Standards, specific engineering standards generally involve two types of tasks:

1. If the standard includes the idea of designing, then the design process will contain components of defining the problem (along with identifying the criteria and constraints), developing many possible solutions, and optimizing a solution (e.g., determining a best solution for the situation based on the criteria and constraints, testing the solution, refining the solution).
2. If the standard includes the idea of evaluating, then the design process will contain components of defining the problem (along with identifying the criteria and constraints) and optimizing a solution. The idea of developing many possible solutions is not included because various solutions will be provided. The idea of evaluating then means determining a best solution from the provided solutions for the situation based on meeting the criteria and constraints requirements.

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Strand 1 : Structure and Motion within the Solar System

Chapter Outline

- 1.1 Earth, Moon, and Sun System (6.1.1)
- 1.2 Gravity and Inertia (6.1.2)
- 1.3 Scale of the Solar System (6.1.3)



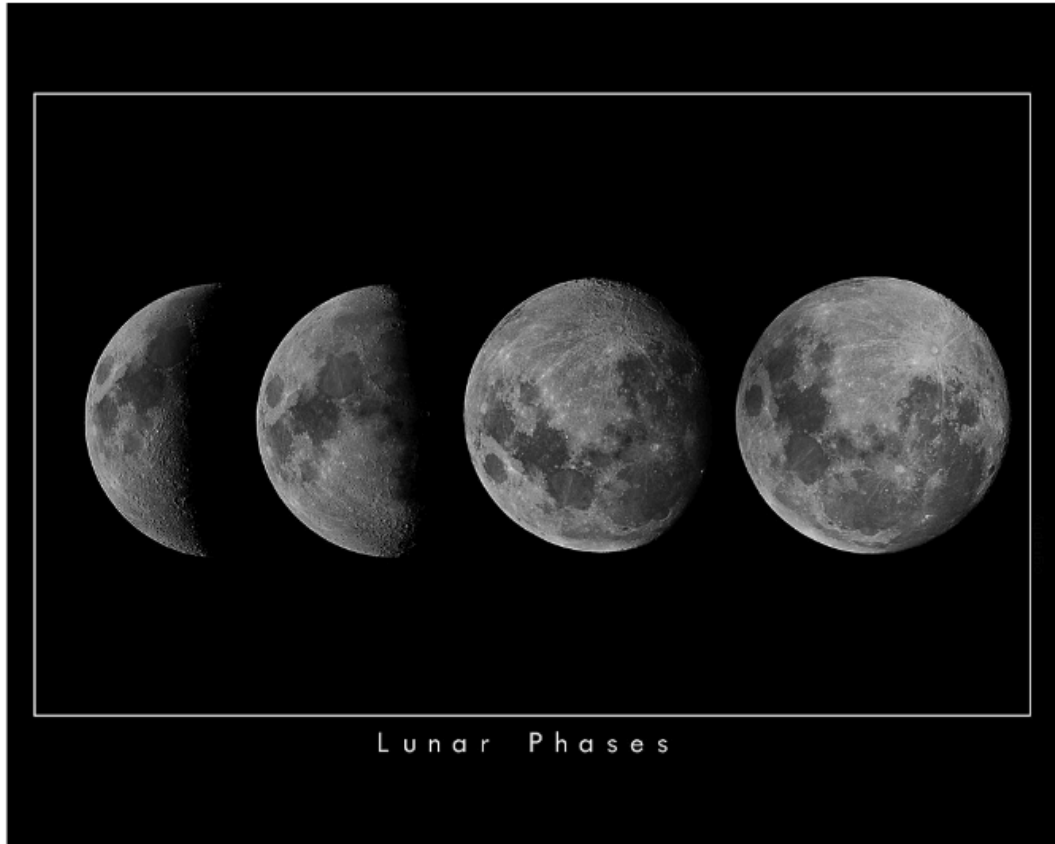
Image by qimono, pixabay.com, CC0

The solar system consists of the Sun, planets, and other objects. Gravity is the force of attraction between masses. The Sun-Earth-Moon system provides an opportunity to study objects in the solar system that influence phenomena we see from Earth. Scientists use data from many sources to determine the scale and properties of objects in our solar system.

6.1.1 Earth, Moon, and Sun System

Phenomenon #1

You look at the sky every night when it gets dark. You notice that the shape of the moon changes over time.



Four Stages Of The Lunar Cycle (Crescent, quarter, gibbous, full) by David Warrington; CC-BY-2.0

Observations & Wonderings

What are you observing about this phenomenon?

What are you wondering about this phenomenon?

6.1.1 Phases of the Moon

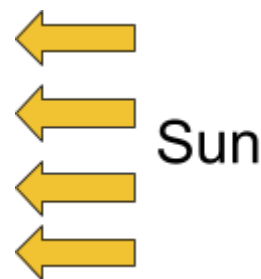
Develop and use a model of the Sun-Earth-Moon system to describe the cyclic patterns of lunar phases, eclipses of the Sun and Moon, and seasons. Examples of models could be physical, graphical, or conceptual. (ESS1.A, ESS1.B)



In this section, focus on visible patterns created by the positions of the Earth, Moon, and Sun.

Phases of the Moon

As the Moon orbits or circles around Earth, different parts of it appear to be illuminated by the Sun. The Moon does not produce any light of its own. It only reflects light from the Sun. The Moon sometimes appears fully illuminated and sometimes appears completely dark. Although it changes in appearance, the Moon is always half illuminated by the Sun. From our perspective on Earth, we see all, a portion, or none of the illuminated part of the Moon. What is seen on Earth, is determined by the position of the Earth, Moon, and Sun on that given night. These predictable patterns in the appearance of the Moon are referred to as phases of the Moon.



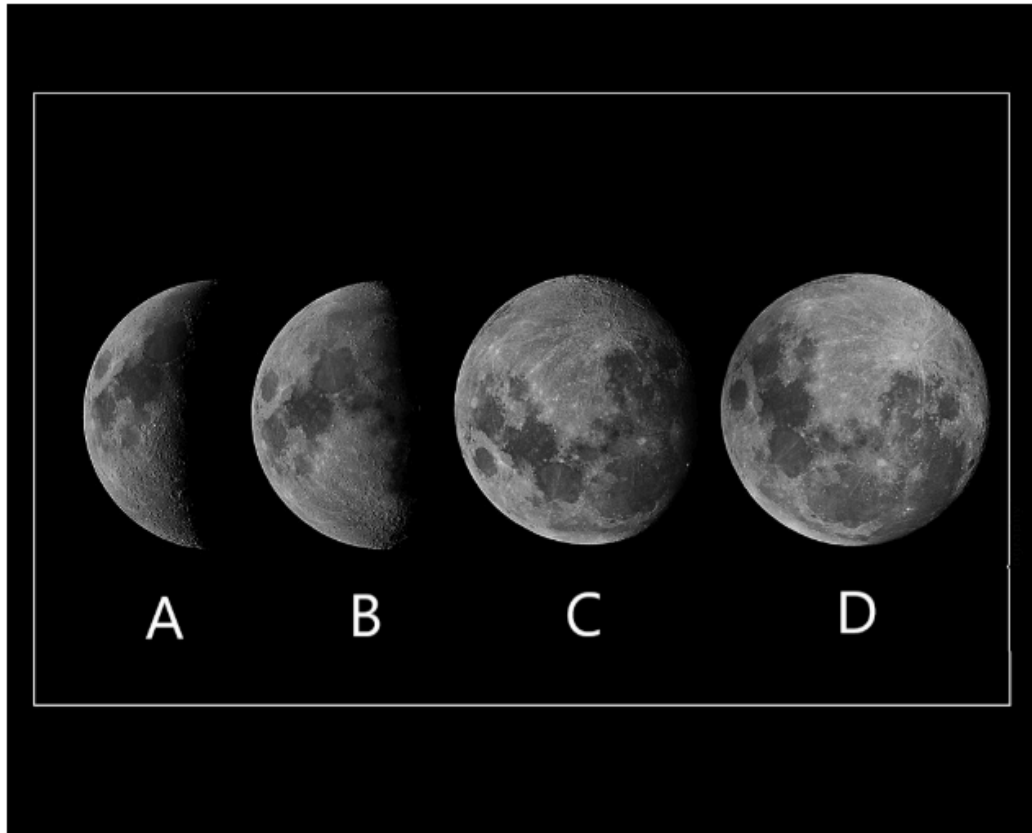
By Bill Dunford, NASA;
<https://solarsystem.nasa.gov/resources/676/phases-of-the-moon/>; public domain

The Full Moon occurs when the Moon appears to be fully illuminated or lit up from our perspective on Earth. This happens when Earth is between the Moon and the Sun. As the Moon continues orbiting around Earth, the illuminated part that is visible from Earth decreases until the Moon appears to be completely dark. This phase is referred to as the New Moon. As the cycle continues, the illuminated part of the Moon will appear to increase until it is fully illuminated again as a Full Moon. This predictable pattern takes about 28 days.

We always see the same side of the Moon, because as the Moon revolves around the Earth, the Moon rotates so that the same side is always facing the Earth. This chart shows why this happens. The center ring shows the Moon as it revolves around the Earth, as seen from above the North Pole. This predictable pattern occurs about every 28 days.

6.1.1 Phases of the Moon

Putting It Together



Adapted from Four Stages Of The Lunar Cycle (Crescent, quarter, gibbous, full) by DavidWarrington; CC-BY-2.0

A month later, you walk outside and see the moon in the shape of a circle.

Writing Performance Task:

In the following tasks, you will identify patterns to complete the Sun-Earth-Moon model and explain why the moon's appearance changes over time.

Gather:

Using the diagram below and the information you've learned in the chapter, shade in what the moon will look like when viewed from Earth throughout the month. Note: Your shaded part represents the dark part of the moon. Anything left blank represents the visible part of the moon.

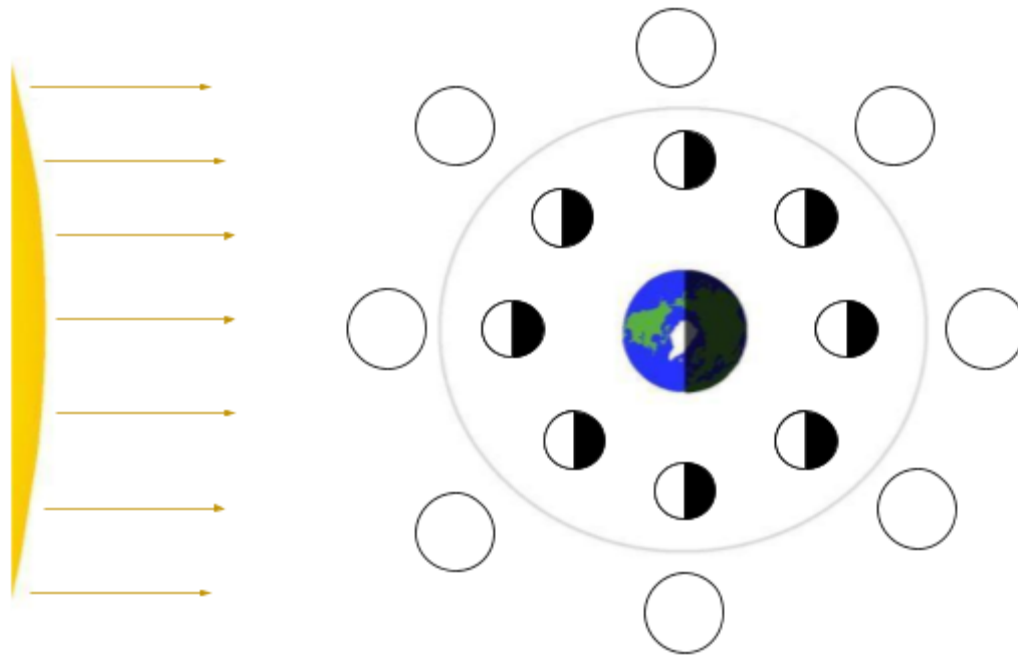
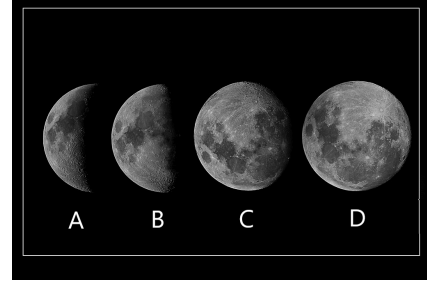


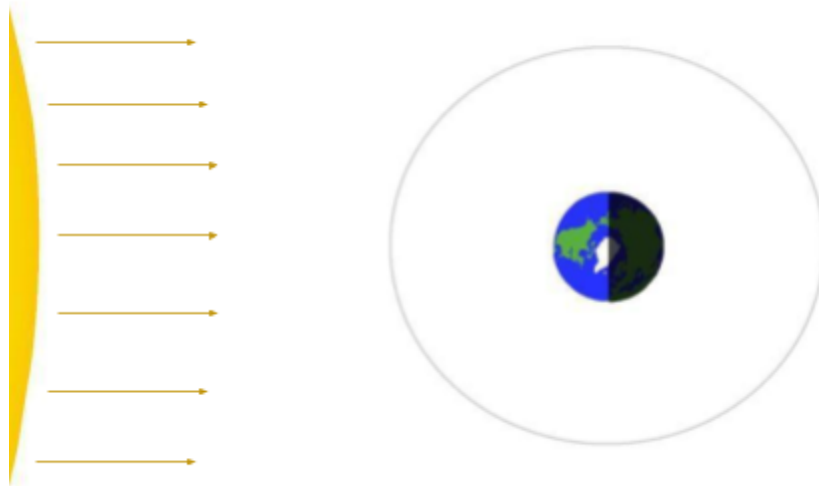
Figure 2. The inner circles represent the moon's position as it orbits Earth. This view is from above, looking down at the North Pole (top view). The outer circles are left blank for you to shade in the moon's apparent shape as it orbits the Earth.

Reason:

Looking back at the phenomenon from the beginning of the chapter, where would the pictures of the Moon be found on the model below?



Place the letter for each view of the moon on the orbit below to show where that phase would be seen from Earth.



Communicate:

A student goes camping and notices that the moon was never visible during the day or night. There are no clouds in the sky and a few days earlier, they were able to see the moon. Their friend is claiming that the moon goes away.

- A. Do you agree with the friend?

- B. Construct an explanation about where the Moon is to support your answer to question A (to show your thinking, your explanation can include words, pictures, and/or labels).

Expected criteria:

- ___ Includes position of Moon in its orbit
- ___ Includes position of Sun
- ___ Includes position of Earth
- ___ Describes the shaded part of the moon
- ___ Describes the visible part of the moon
- ___ Explains why the moon was not visible for the students

6.1.1 Eclipses

Phenomenon #2 - Eclipses

Total solar eclipses are rare. You are lucky to be in the path of totality during an eclipse of the Sun. Below is an image of what you saw over a period of time.

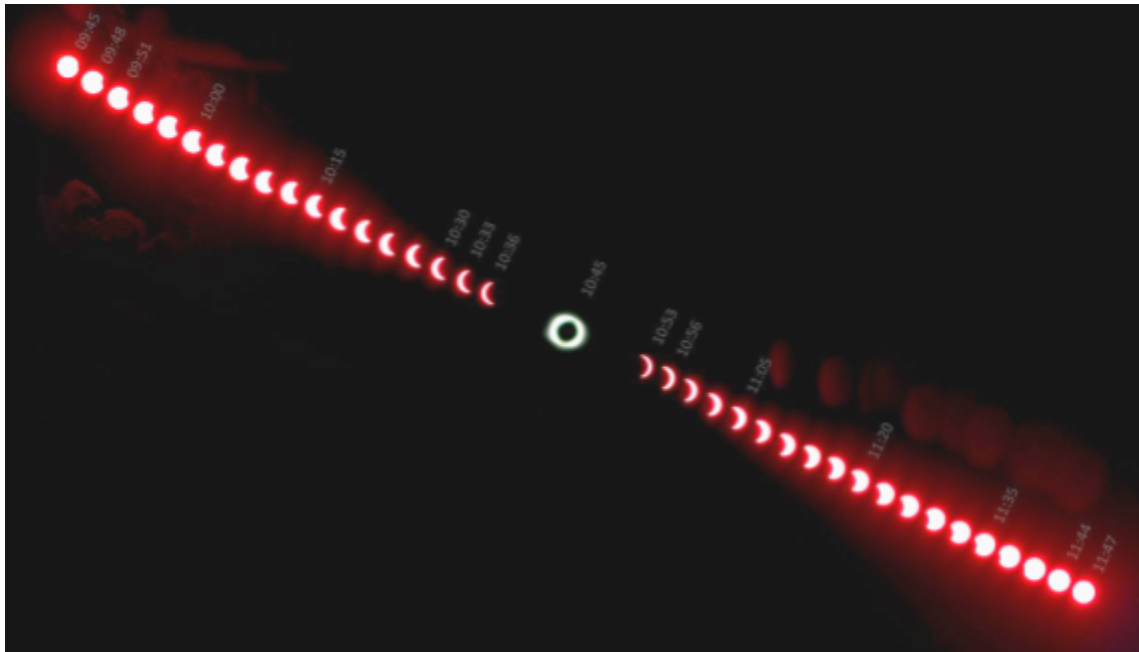


Image by user: kalan;

https://commons.wikimedia.org/wiki/File:2008-08-01_Solar_eclipse_progression_with_timestamps.jpg; CC BY 3.0

Observations & Wonderings

What are you observing about this phenomenon?

What are you wondering about this phenomenon?

Solar Eclipses

When a new moon passes directly between the Earth and the Sun, it causes a solar eclipse. The Moon casts a shadow on the Earth and blocks our view of the Sun. This only happens if all three are lined up and in the same plane. This plane is called the ecliptic. The ecliptic is the plane of Earth's orbit around the Sun.

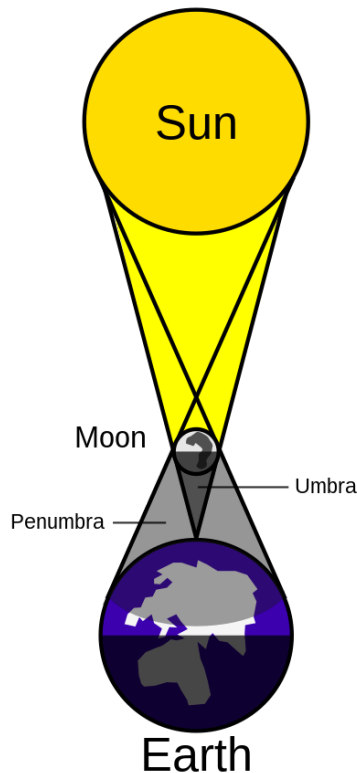


Image by fastfission; https://commons.wikimedia.org/wiki/File:Solar_eclipse.svg; CC0

The Moon's shadow has two distinct parts. The umbra is the inner, cone-shaped part of the shadow. It is the part in which all of the light has been blocked. The penumbra is the outer part of the Moon's shadow. It is where the light is only partially blocked.

When the Moon's shadow completely blocks the Sun, it is a total solar eclipse. If only part of the Sun is out of view, it is a partial solar eclipse.

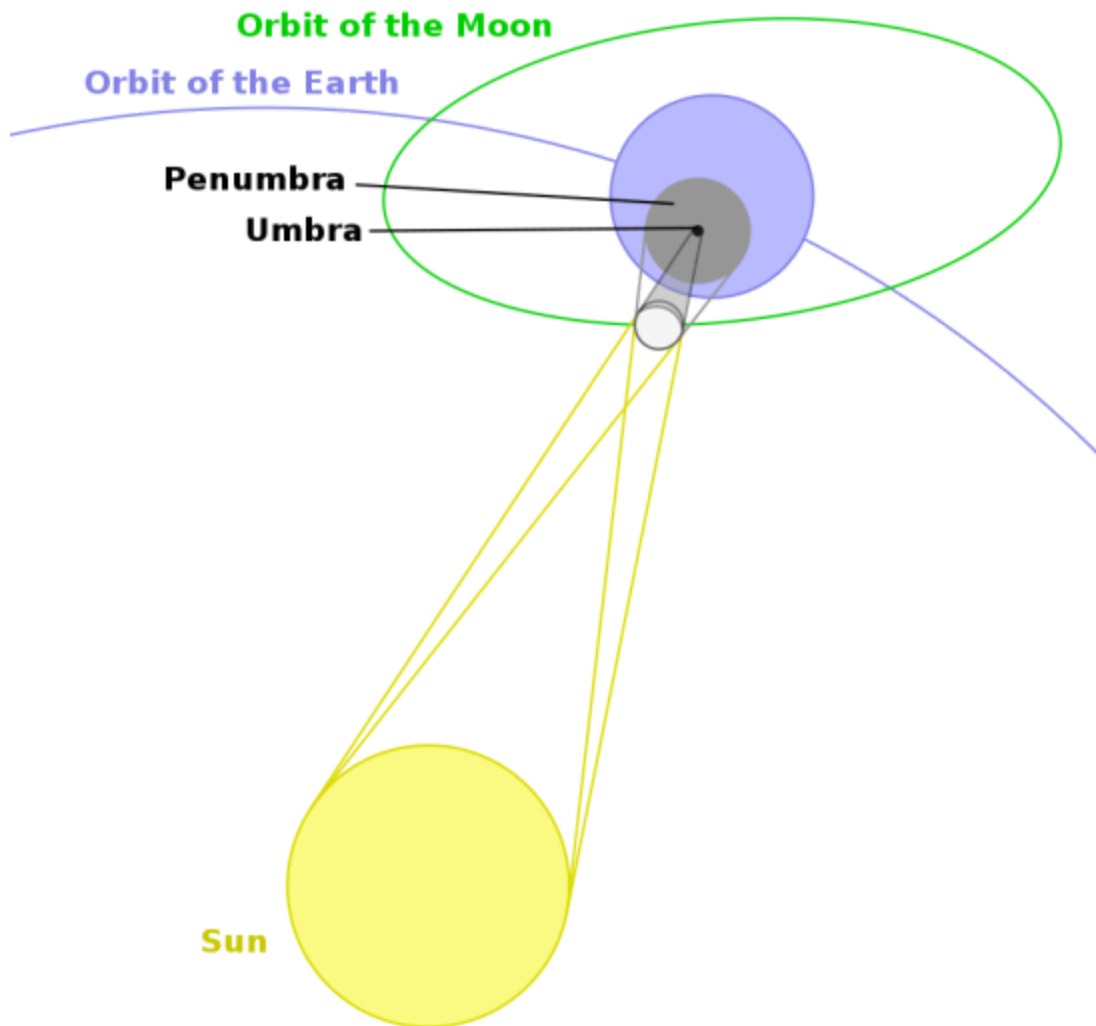
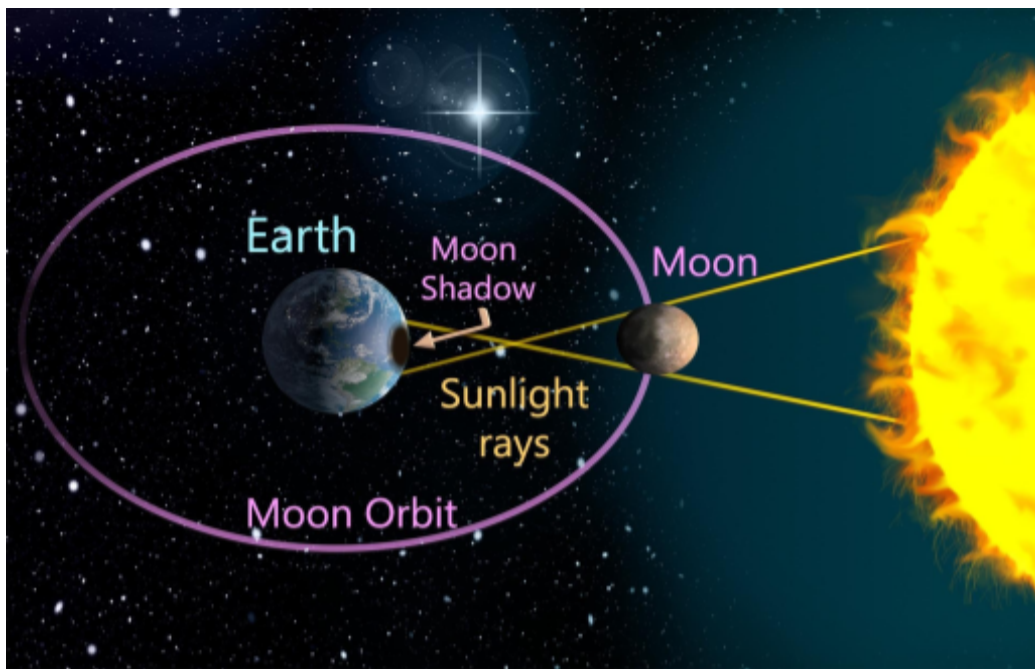


Image by Sagredo;
https://commons.wikimedia.org/wiki/File:Geometry_of_a_Total_Solar_Eclipse.svg; CC0

Solar eclipses are rare events. They usually only last a few minutes. That is because the Moon's shadow only covers a very small area on Earth, and Earth is turning very rapidly.



(pixabay, CC0)

Solar eclipses are amazing to experience. The light disappears so that it's like night, only strange. Birds may sing as they do at dusk. Stars become visible in the sky. It gets colder outside. Unlike at night, though, the Sun is out. So during a solar eclipse, it's easy to see the Sun's corona and solar prominences.



Images by NASA, public domain

To see totality is rare and usually only lasts a few minutes because the Moon casts only a small shadow on the Earth. You would have to find yourself in the Umbra of the Moon's shadow. Though totality is short, a solar eclipse event lasts several hours as the moon moves across the sky and casts its shadow on the Earth slowly blocking out all or part of the Sun.

Lunar Eclipse

A lunar eclipse occurs when the full moon moves through Earth's shadow, which only happens when Earth is between the Moon and the Sun and all three are lined up in the same plane, called the ecliptic. In an eclipse, Earth's shadow has two distinct parts: the umbra and the penumbra. The umbra is the inner, cone-shaped part of the shadow, in which all of the light has been blocked. The penumbra is the outer part of Earth's shadow where only part of the light is blocked. In the penumbra, the light is dimmed but not totally absent.

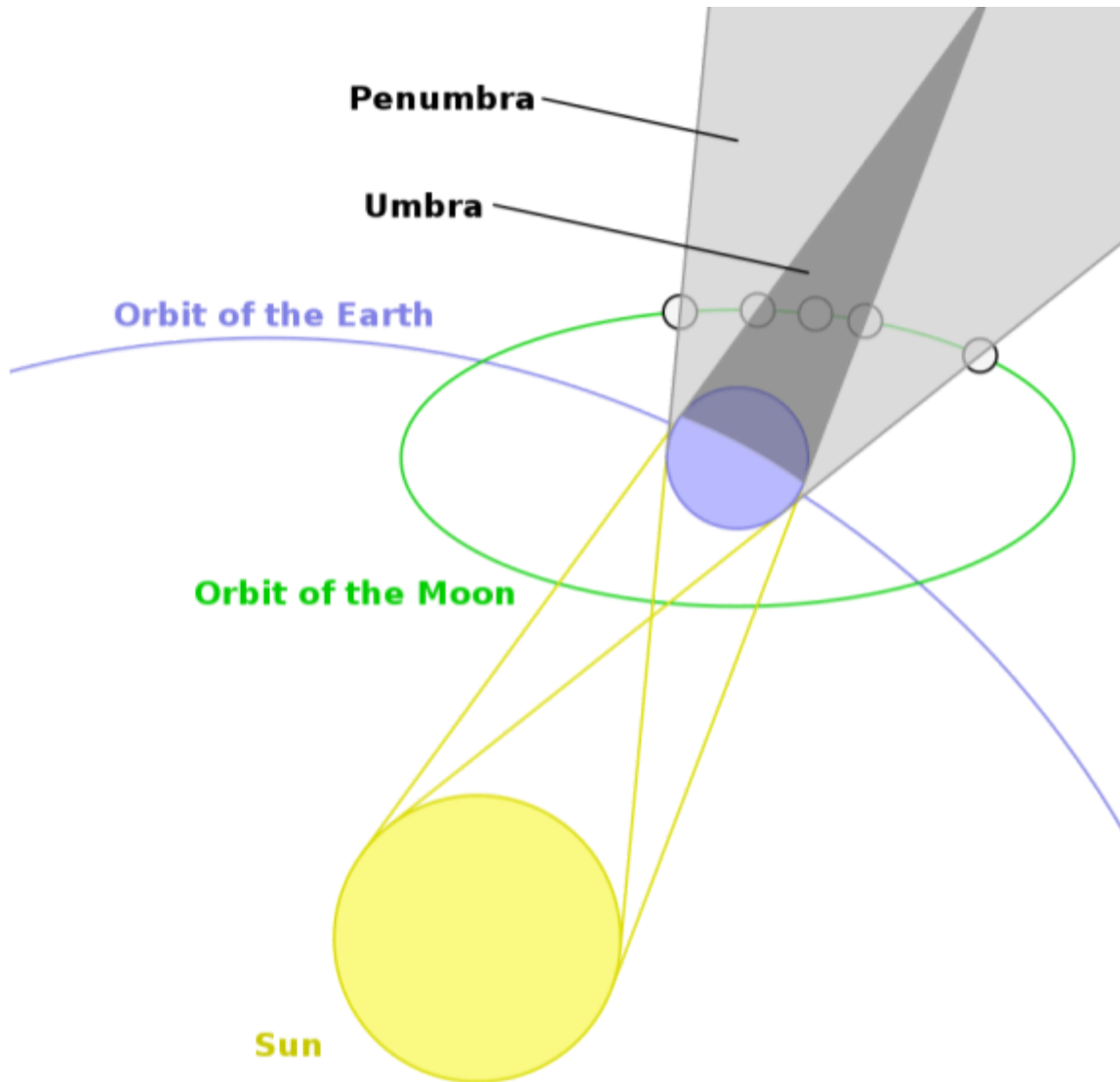


Image by Sagredo; https://commons.wikimedia.org/wiki/File:Geometry_of_a_Lunar_Eclipse.svg; CC0

A total lunar eclipse occurs when the Moon travels completely in Earth's umbra. During a partial lunar eclipse, only a portion of the Moon enters Earth's umbra. Earth's shadow is large enough that a lunar eclipse lasts for hours and can be seen by any part of Earth with a view of the Moon at the time of the eclipse. A lunar eclipse does not occur every month because the Moon's orbit is inclined 5-degrees to Earth's orbit, so the two bodies are not in the same plane every month.

Putting It Together

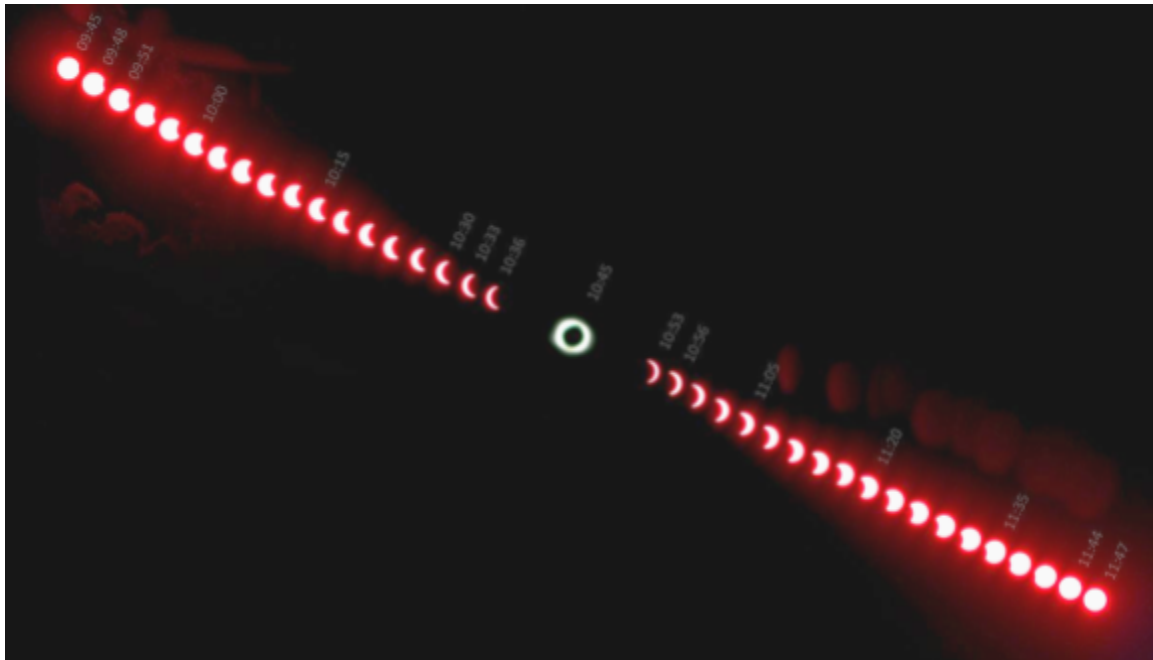


Image by user: kalan;

https://commons.wikimedia.org/wiki/File:2008-08-01_Solar_eclipse_progression_with_timestamps.jpg; CC BY 3.0

Total solar eclipses are rare. You are lucky to be in the path of totality during an eclipse of the Sun. Below is an image of what you saw over a period of time.

Writing Performance Task:

Phenomenon #3 - Seasons

Below is a chart with the sunrise and sunset times during different times of the year. You notice that there are different amounts of light depending on the day.

Date	Sunrise	Sunset	Amount of light
3/21	7:31 am	7:40 pm	12 hours 9 minutes
6/21	5:56 am	9:02 pm	15 hours 6 minutes
9/21	7:13 am	7:28 pm	12 hours 15 minutes
12/21	7:48 am	5:03 pm	9 hours 15 minutes

Data from <https://gml.noaa.gov/grad/solcalc/>

Observations & Wonderings

What are you observing about this phenomenon?

What are you wondering about this phenomenon?

Seasons

The days are getting warmer. Flowers begin to bloom. The sun appears higher in the sky, and daylight lasts longer. Spring seems like a fresh, new beginning. What causes these welcome changes?

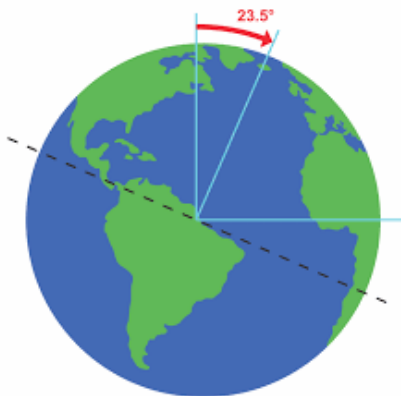
Some people think that Earth is closer to the Sun in the summer and farther away from the Sun in the winter, but that's not true! Why can't that be true? Because when it's summer in one hemisphere, it's winter in the other.

The Earth revolves in an orbit, or the path a planet takes around an object. Initially believed to have a circular orbit, the Earth's orbit is actually slightly elliptical. As Earth moves throughout the year to new positions around the sun, the movement results in our four seasons: summer, autumn, winter, and spring.

From a view above the Northern Hemisphere, Earth appears to orbit the sun in a counterclockwise direction. This takes 365 days or one year and is called a revolution. Because of this, the seasons also follow a cyclical pattern that is the same from year to year.

The distance from the sun doesn't have much effect on the heating and cooling of Earth. In fact, the Northern Hemisphere is closest to the Sun during winter. So, why do we, in the Northern Hemisphere, feel colder when we are closest to the Sun?

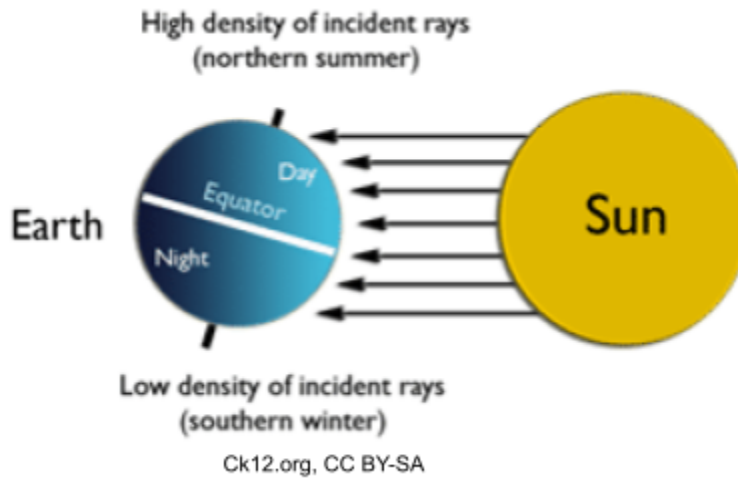
Earth's axis of rotation is tilted at a 23.5 degree angle. Because of this tilt, one of the hemispheres is angled toward the Sun. This causes that hemisphere that is angled toward the Sun to receive more of the Sun's direct energy.



As Earth revolves around the Sun, the axis of rotation maintains its tilt. The axis always points in the same direction, which is toward the North Star (Polaris). The combination of the Earth's revolution around the Sun and Earth's 23.5 degree angle tilt are the reasons we have seasons.

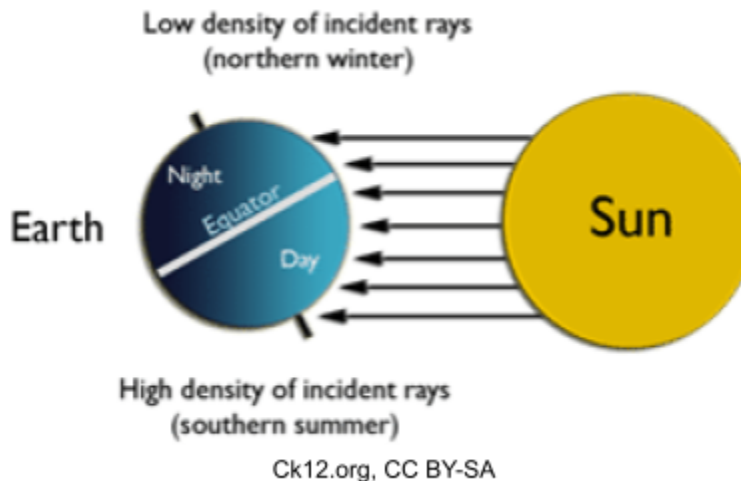
Image by CK-12 Foundation; CC BY-NC 3.0

Northern Hemisphere Summer



During summer in the Northern Hemisphere, the North Pole is tilted towards the Sun. The Sun's rays strike the Northern Hemisphere more directly. The region gets a lot of sunlight. At this time, the Northern Hemisphere experiences summer, while the Southern Hemisphere experiences winter.

Northern Hemisphere Winter



During winter in the Northern Hemisphere, light from the Sun is spread out over a larger area. This indirect light is the same amount of light energy spread over a larger area on the Earth's surface. Therefore, the surface of the Earth does not get as warm. Additionally, with fewer daylight hours in winter,

there is less time for the Sun to warm the Earth's surface.

During winter in the Northern Hemisphere, it is summer in the Southern Hemisphere. In contrast, when it is winter in the Southern Hemisphere it is summer in the Northern Hemisphere. The hemisphere that is experiencing summer, experiences more hours of daylight. The hemisphere that is experiencing winter has less hours of daylight. This is caused by the tilt of the Earth.

Summer occurs in the hemisphere that is tilted toward the Sun. This is when the Sun appears high in the sky and its energy strikes Earth more directly and for longer periods of time. The hemisphere that is tilted away from the Sun experiences winter and the Sun appears lower in the sky. The Earth receives less direct energy from the Sun for shorter periods of time.

Solstice

The North Pole is tilted towards the Sun and the Sun's rays strike the Northern Hemisphere more directly in summer. At the summer solstice, June 21 or 22, the Sun's rays hit the Earth most directly along the Tropic of Cancer (23.5°N); that is, the angle of incidence of the Sun's rays there is zero (the angle of incidence is the deviation in the angle of an incoming ray from straight on). When it is summer solstice in the Northern Hemisphere, it is winter solstice in the Southern Hemisphere.

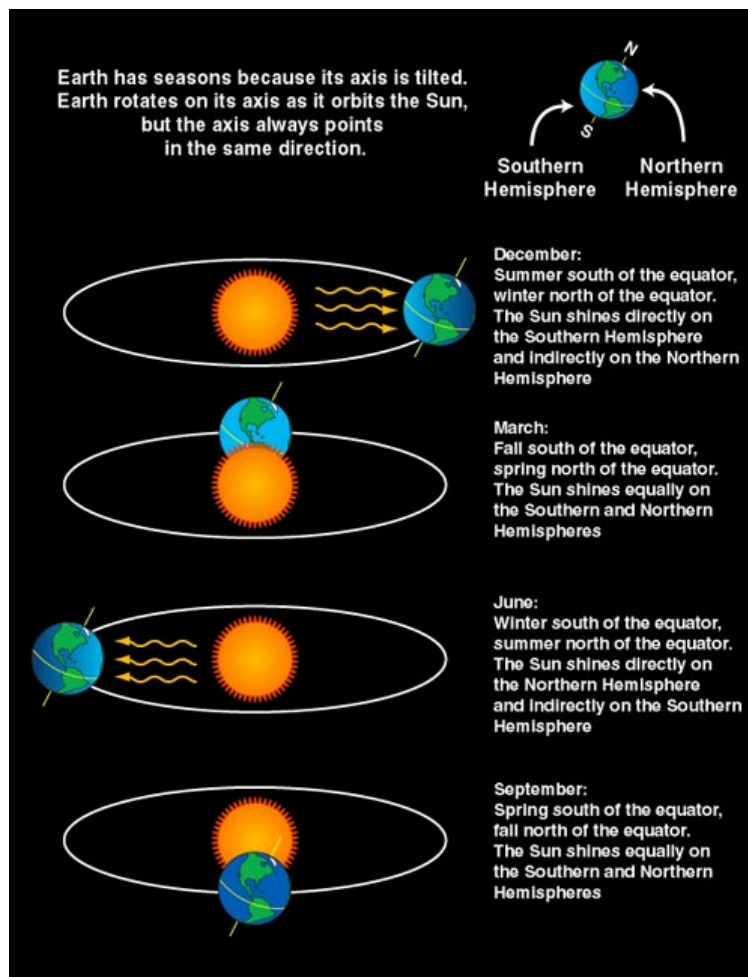


Image by NASA; <https://spaceplace.nasa.gov/seasons/en/seasons.en.jpg>; public domain

Winter solstice for the Northern Hemisphere happens on December 21 or 22. The tilt of Earth's axis points away from the Sun. Light from the Sun is spread out

over a larger area, so that area isn't heated as much. With fewer daylight hours in winter, there is also less time for the Sun to warm the area. When it is winter in the Northern Hemisphere, it is summer in the Southern Hemisphere.

Equinox

Equinox comes halfway between the two solstices. At equinoxes, the Sun's rays shine most directly at the equator. The daylight and nighttime hours are exactly equal on an equinox. The autumnal, or fall, equinox happens on September 22 or 23. The vernal, or spring, equinox happens March 21 or 22 in the Northern Hemisphere.

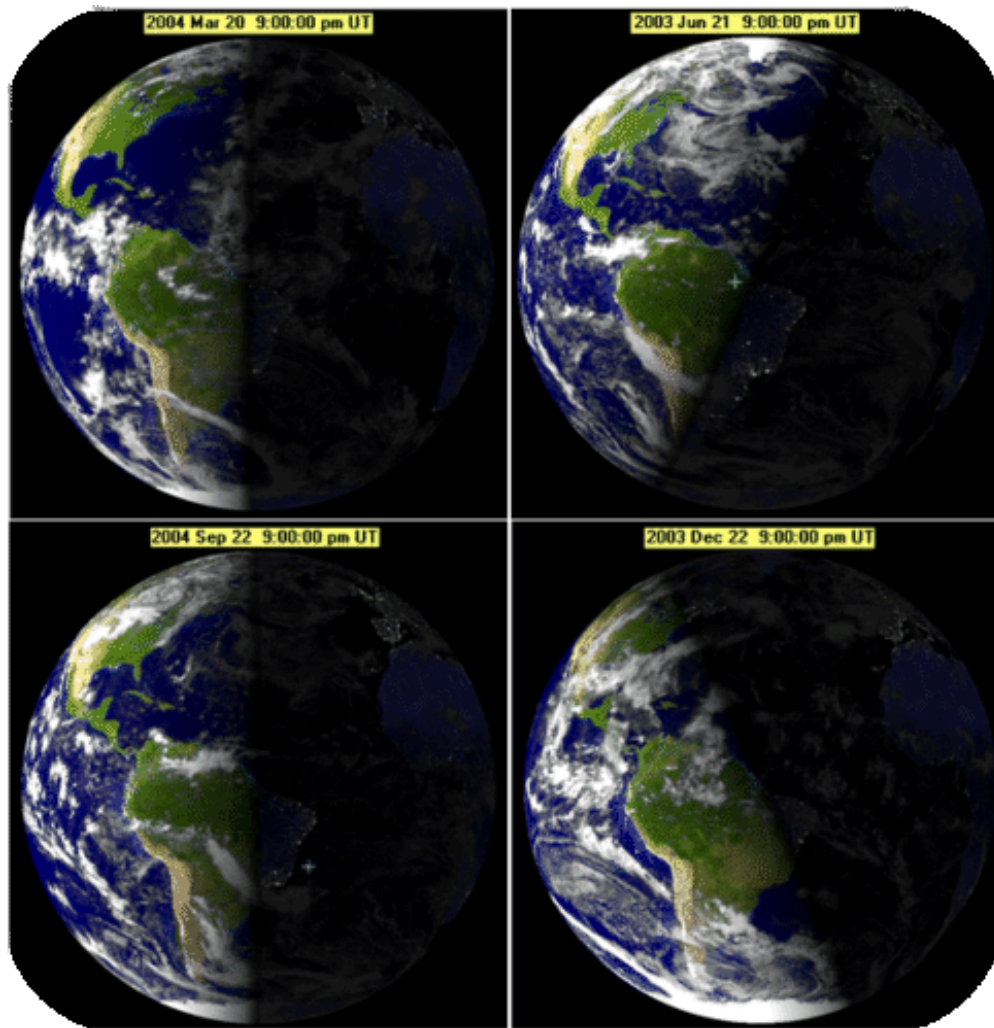


Image by Tom Ruen, Full Sky Observatory; Public Domain

6.1.1 Eclipses

Putting it Together

Below is a chart with the sunrise and sunset times during different times of the year in the state of Utah. You notice that there are different amounts of light depending on the day.

Date	Sunrise	Sunset	Amount of light
3/21	7:31 am	7:40 pm	12 hours 9 minutes
6/21	5:56 am	9:02 pm	15 hours 6 minutes
9/22	7:13 am	7:28 pm	12 hours 15 minutes
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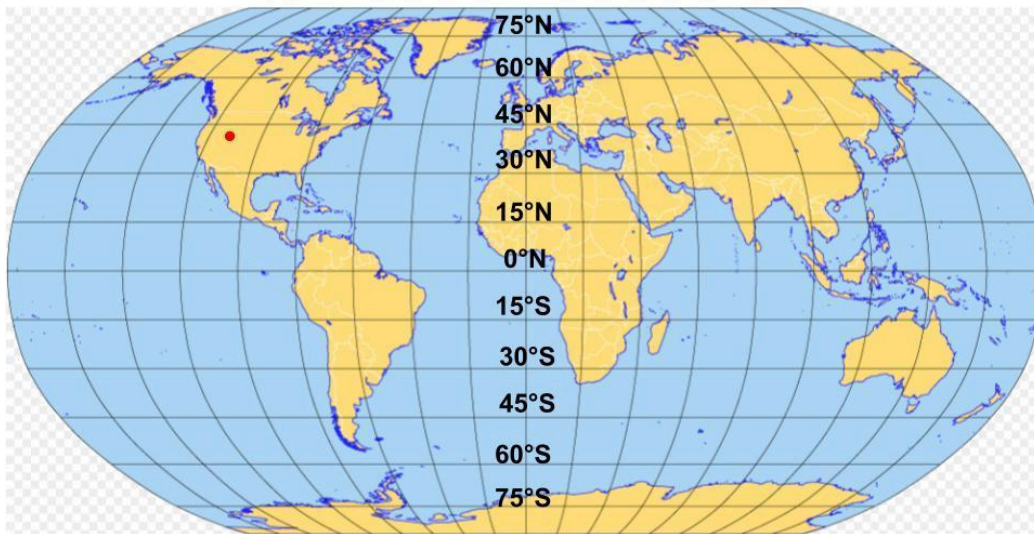
Data from <https://gml.noaa.gov/grad/solcalc/>

Writing Performance Task:

In the tasks that follow, you will use patterns to analyze data, develop a model, and construct an explanation in order to predict the approximate sunrise and sunset in the Rio Negro Province of Argentina on December 21.

Gather:

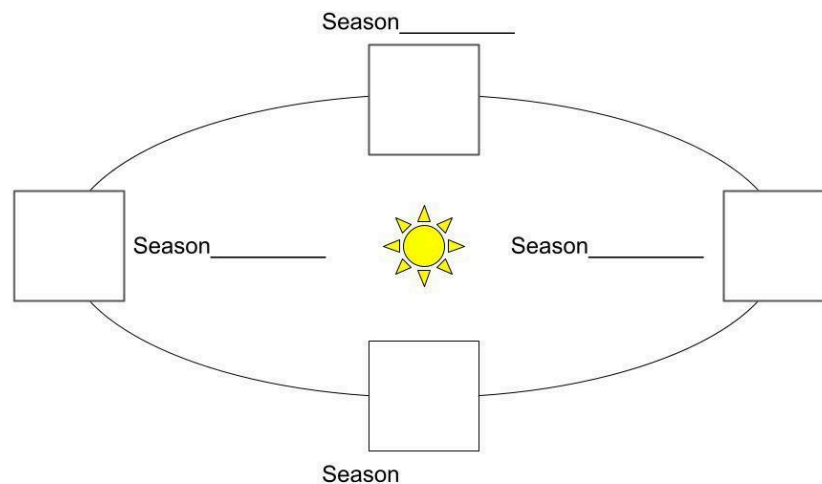
The location of Utah is marked on the map below by the red dot.



What is the approximate latitude of this phenomenon's location?

Reason:

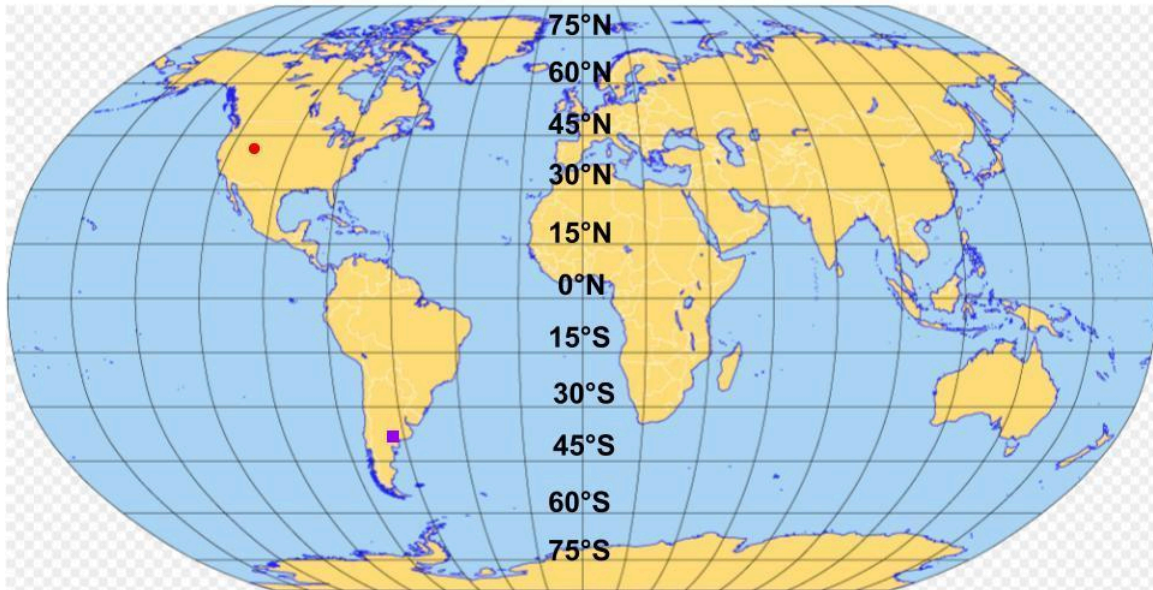
- A. Using the diagram provided, develop a model of the sun, Earth, and phenomenon location by drawing a globe with the appropriate tilt and the location of Utah identified for each of the four dates. The boxes represent each of the four dates from the phenomenon data.



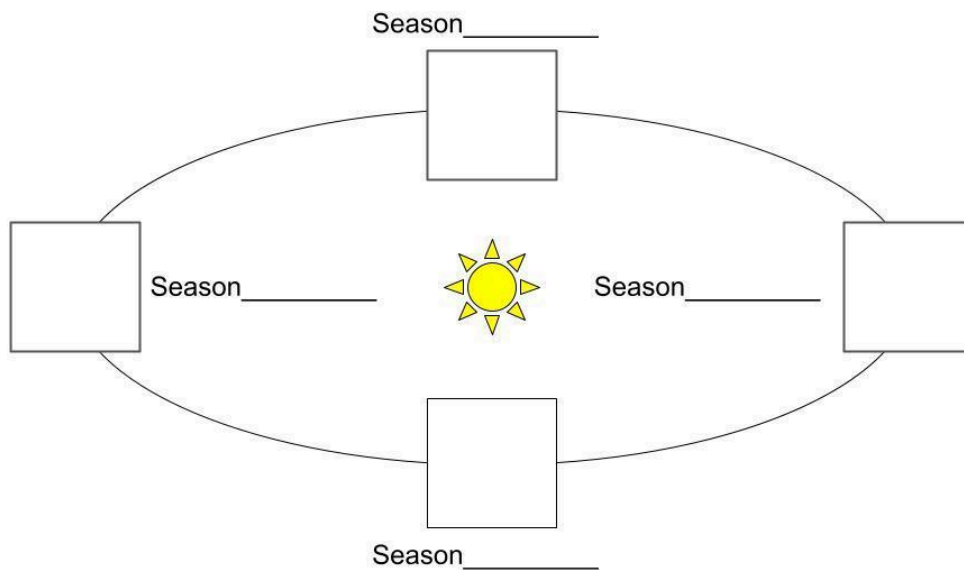
- B. Identify 2 limitations of your model.

Communicate:

The location for the Rio Negro Province of Argentina is marked on the map below by the purple square.



- A. Using the diagram provided, develop a model of the sun and Earth for the location of Rio Negro Province of Argentina by drawing a globe with the appropriate tilt and the location identified for each of the four dates identified in the phenomenon.



- B. Using the patterns in the data and models above, predict the approximate sunrise and sunset times in the Rio Negro Province of Argentina on December 21.
- C. Construct an explanation for the times you selected.

6.1.2 Gravity and Inertia

Phenomenon

The International Space Station has been orbiting the Earth since 1998. The Space Station never goes further into space or falls back to Earth.



Image by NASA; public domain

Observations & Wonderings

What are you observing about this phenomenon?

What are you wondering about this phenomenon?

6.1.2 Gravity and Inertia

Develop and use a model to describe the role of gravity and inertia in the orbital motions of objects in our solar system. (ESS1.B)



As you read, examine the relationships of objects in the solar system to understand the role of gravity and inertia.

The Role of Gravity and Inertia

Most of the objects that are part of our solar system are constantly orbiting the Sun, the star in our solar system. Mass is a measure of the amount of matter in an object. Everything that has mass also has gravity. Gravity is the attraction of one particle or body to another. You have gravity. Your pencil has gravity.

Larger masses have a stronger gravitational force, or the measurement of the pull of gravity, than smaller masses. The greater the mass of an object, the greater the gravitational pull it has on other objects.

The Sun is the most massive object in our solar system and so it exerts the greatest force of gravity on all the planets. Since the Sun is the largest mass in our solar system, its gravitational force holds Earth and other planets in orbit around it. This force of gravity makes all the planets move in an orbital motion around the Sun instead of moving in a straight line.

The distance between the Sun and each of its planets is very large. The greater the distance between objects, the smaller the force of attraction. The force of gravity is dependent upon the mass of objects and the distance between the two objects. Gravity keeps each planet orbiting the Sun because, despite the large distances, the star and its planets have very large masses. We wouldn't be here without gravity.

As you can see in this NASA picture, Earth is tiny compared with the massive sun. Gravity pulls Earth toward the Sun,

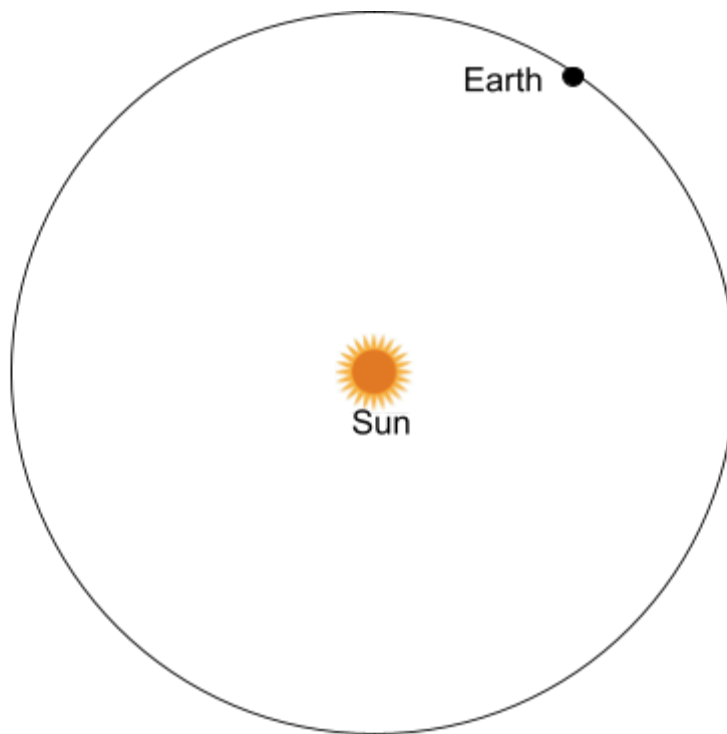


but Earth never falls into the Sun. Instead, it constantly revolves around the Sun, making one complete revolution every 365.25 days, or one year.

The reason the Earth revolves around the Sun instead of falling into it is because of inertia. Inertia is the tendency of an object to resist a change in its motion. All objects have inertia and the inertia of an object depends on its mass. Objects with greater mass also have greater inertia. The Earth's inertia keeps it moving forward at the same time that it is pulled by the Sun's gravitational force. Working together, inertia and gravity cause Earth to orbit the Sun.

Orbital Motion

Earth and many other bodies including asteroids, comets, and the other planets move around the Sun in curved paths called orbits. Generally, the orbits are elliptical, or oval, in shape. You can see the shape of Earth's orbit in the next figure. Because of the Sun's strong gravity, Earth and the other bodies constantly fall toward the Sun, but their forward movement causes them to fall around the Sun instead of into it. As a result, they keep orbiting the Sun and never crash to its surface. The motion of Earth and the other bodies around the Sun is called orbital motion. Orbital motion occurs whenever an object is moving forward and at the same time is pulled by gravity toward another object.



Earth does not orbit the sun in a perfect circle. It has an elliptical orbit, different from a circle by 1.67%. (*size and distance not to scale*)

M Huddleston, CC0

Orbital Motion of the Moon

Just as Earth orbits the Sun, moons also orbit planets. The Moon is affected by Earth's gravity more than it is by the Sun's gravitational pull because the Moon is much closer to Earth. The Earth's gravity pulls the Moon toward Earth. At the same time, the Moon has forward movement, or inertia, that partly counters the force of Earth's gravity. This inertia causes the Moon to orbit Earth instead of falling toward the surface of the planet.

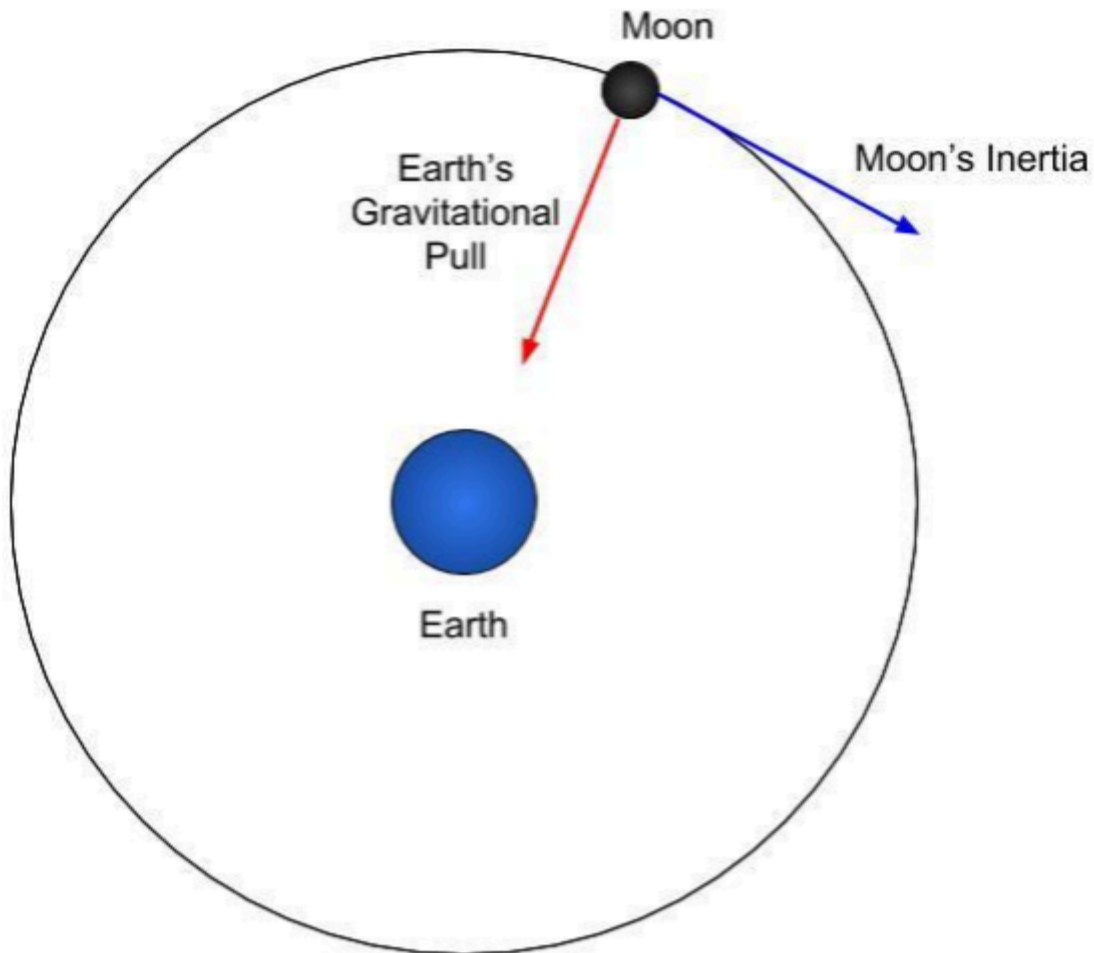


Image by: T. Poulsen, CC0

6.1.2 Gravity and Inertia

Putting It Together

Using what you have learned about gravity in the solar system, explain how the International Space Station is able to stay orbiting in the Earth's orbit.



Image by NASA; public domain

Writing Performance Task:

In the tasks that follow, you will develop a model of the International Space Station (ISS) orbiting Earth, and explain why the ISS doesn't fall to Earth or drift away.

Gather:

Identify the components of Moon-Earth System

- A. What are the factors that influence the Moon's orbit around Earth? Fill in the blanks.

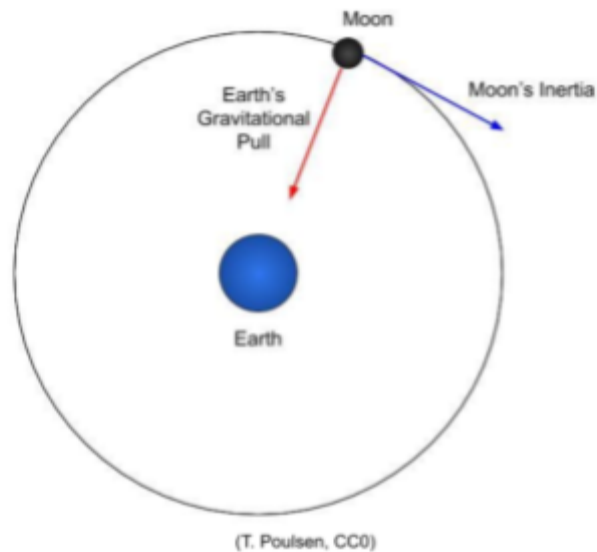


Figure 1. A Model of the Earth-Moon System.

Word bank: Earth, gravitational, orbit, inertia

1. The _____ is at the center of the Earth-Moon system.
2. Moon is held in orbit by the Earth's _____ pull.
3. The path that the Moon follows around the Earth is called an _____.
4. _____ is the force that keeps the moon from being pulled towards Earth.

Reason:

Figure 2. shows an incomplete model of the Earth-ISS system.

A. Based on what you know about gravity and inertia, with the information related to the ISS, complete the model below.

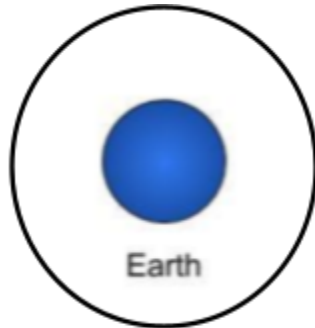


Figure 2. Incomplete Model of the Earth-ISS System

Expected criteria:

- ☐ Draw the ISS
- ☐ Includes a labeled arrow for Earth's gravitational pull
- ☐ Includes a labeled arrow for ISS' inertia force

B. Compare and contrast the similarities and differences between the model of the Moon orbiting Earth and your model of the ISS orbiting Earth.

Similarities between systems	Differences between systems

C. Choose **two** factors that would make the biggest impact on maintaining the ISS in its stable orbit for the model you developed.

1. the mass of ISS
2. the mass of Sun
3. the distance between Earth and the ISS
4. the distance between Moon and the ISS
5. the distance between Moon and Sun

Communicate:

Use your model to construct an explanation of why the International Space Station (ISS) doesn't crash into Earth or drift away into space. What would happen if neither the mass or distance changed? Make sure to use **all** the words from the word bank in your explanation.

Word Bank

___ Inertia

___ Gravity

___ Mass

___ Distance

___ Orbit

6.1.3 Scale of the Solar System

Phenomenon

It takes the Earth 365.25 days to fully rotate around the Sun. This is one year on Earth. Look at the table below at the length of a year on each planet. Use the data below to compare objects in the solar system.

Planet	Distance from Sun (AU)	Length of Year (In Earth Years)
Mercury	0.39 AU	0.24 years
Venus	0.72 AU	0.62 years
Earth	1.00 AU	1.00 years
Mars	1.52 AU	1.88 years
Jupiter	5.20 AU	11.86 years
Saturn	9.54 AU	29.46 years
Uranus	19.22 AU	84.01 years
Neptune	30.06 AU	164.8 years

Observations & Wonderings

What are you observing about this phenomenon?

What are you wondering about this phenomenon?

6.1.3 Scale of the Solar System

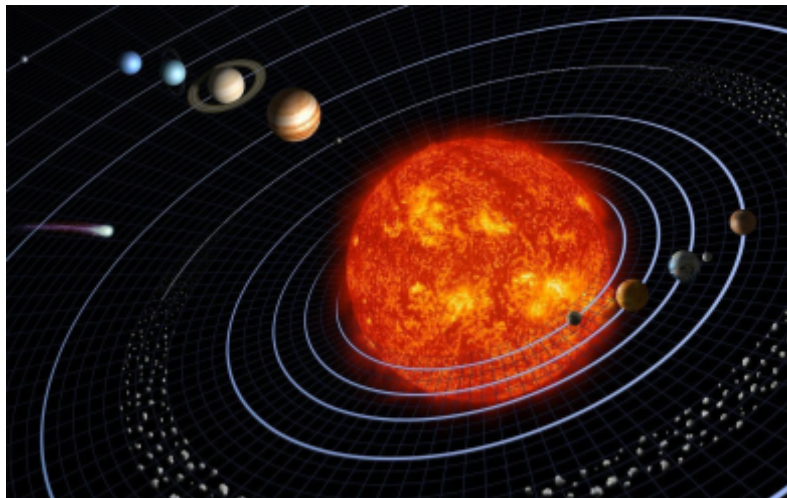
Use computational thinking to analyze data and determine the scale and properties of objects in the solar system. Examples of scale could include size and distance. Examples of properties could include layers, temperature, surface features, and orbital radius. Data sources could include Earth and space-based instruments such as telescopes and satellites. Types of data could include graphs, data tables, drawings, photographs, and models. (ESS1.A, ESS1.B)



Objects in our solar system vary greatly in scale and properties. Analyze different data related to scale and how the size of objects and distance between objects affects our solar system's structure and performance.

Scale and Properties of Objects in the Solar System

The solar system is made up of eight planets and their moons, asteroids, comets, and many smaller objects that orbit the Sun. The Sun is the star at the center of our solar system. It sustains life on Earth because it is a source of heat, light, and energy.



(pixabay, CC0)

A planet is a celestial body that revolves around a star. It does not give off its own light. It is also larger than asteroids or comets. The planets of our solar system, in order from the Sun, are Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, and Neptune.

Measuring Distances

Since stars and galaxies are so far away from each other, measuring distances in miles or kilometers is difficult because the numbers are so large. Let's begin with the Earth's distance from the Sun. Earth is about 93,000,000 miles or 150,000,000 kilometers from the Sun. This distance is called an Astronomical Unit and is the average distance between the Earth and the Sun.

Scientists and astronomers sometimes use a light-year, the distance light travels in one year, to measure these distances. A beam of light from the Sun takes 8.3 minutes or about 500 seconds to reach the Earth. Speed of light, the time it takes light to travel, is about 186,000 miles per second (300,000 kilometers per second). The speed of light is much faster than rockets can travel today.

Light-Year Calculation

- 60 seconds per minute ($\times$) 60 minutes per hour = 3,600 seconds per hour.
- 3,600 seconds per hour ($\times$) 24 hours per day = 86,400 seconds per day.
- 86,400 seconds per day ($\times$) 365 days a year = 31,536,000 seconds per year.
- 31,536,000 seconds per year ($\times$) 186,000 miles per second = 5,865,696,000,000 miles per year = 1 light-year in miles.

Or

- 31,536,000 seconds per year ($\times$) 300,000 kilometers per second = 9,469,800,000,000 kilometers per year = 1 light-year in kilometers.

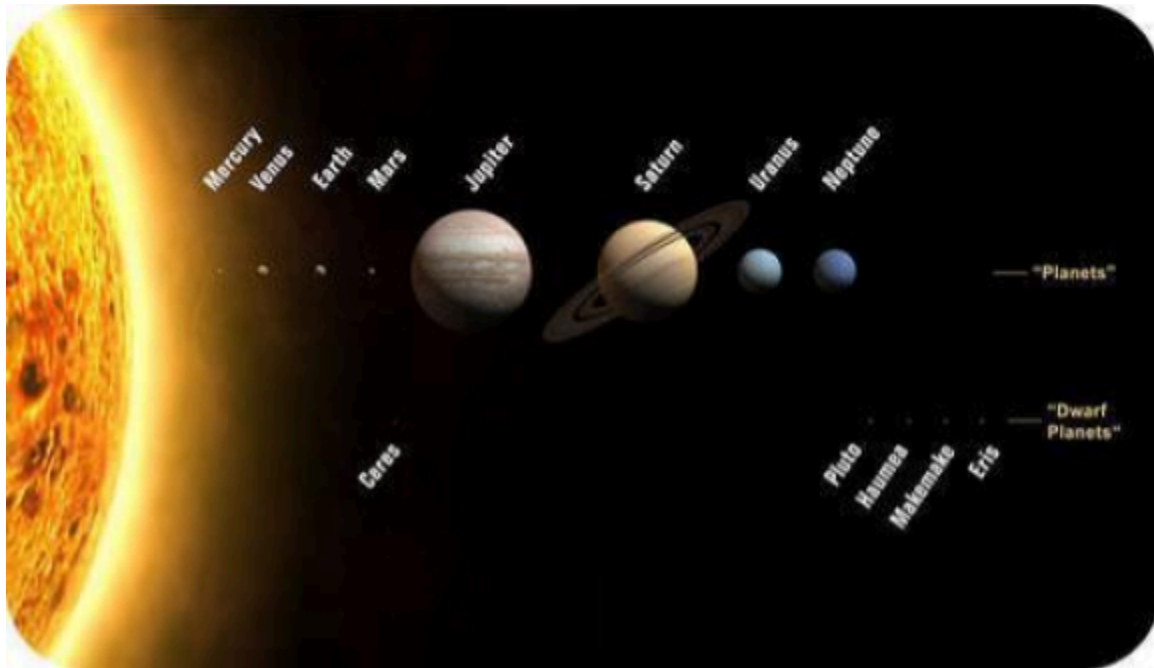
The table below shows the distances between the Sun and the planets using light years, miles, kilometers and astronomical units.

Distance of Planets from the Sun

Planet	Light-Years	Miles (mi)	Kilometers (km)	Astronomical Units (AU)
Mercury	0.000006 (3.2 light minutes)	36,000,000	58,000,000	0.39
Venus	0.000011 (6 light minutes)	67,000,000	108,000,000	0.72
Earth	0.000016 (8.3 light minutes)	93,000,000	150,000,000	1.00
Mars	0.000024 (12.7 light minutes)	141,000,000	228,000,000	1.52
Jupiter	0.000082 (43.3 light minutes)	484,000,000	778,000,000	5.20
Saturn	0.000151 (79.5 light minutes)	888,000,000	1,429,000,000	9.54
Uranus	0.000304 (2.7 light hours)	1,786,000,000	2,875,000,000	19.22
Neptune	0.000476 (4.2 light hours)	2,799,000,000	4,504,000,000	30.06

Measuring Size

The Sun is an average size star. But, it is the largest object in the solar system. The Sun makes up 99.8 percent of the mass of the Solar System.



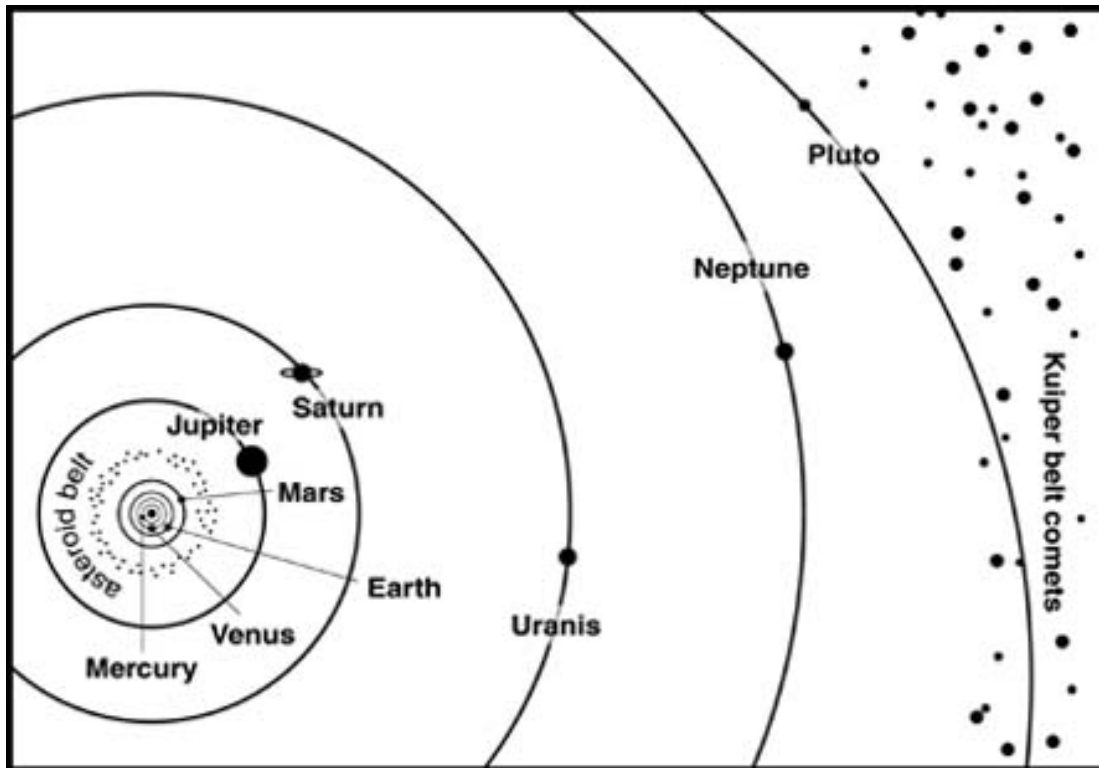
Relative sizes of the Sun, planets, and dwarf planets are to scale. The relative distances are not to scale.
(NASA, public domain)

The next table provides data to compare the sizes of the Sun and the planets. The table also shows how long it takes each planet to spin on its axis (the length of a day) and how long it takes each planet to complete an orbit (the length of a year); in particular, notice how slowly Venus rotates relative to Earth.

Mass, Diameter, Rotation, and Revolution of Planets and Sun as Compared to Earth

Object	Mass (Relative to Earth)	Diameter of Planet (Relative to Earth)	Length of Day (Earth Days)	Length of Years (Earth Years)
Sun	333,000 x Earth's Mass	109.2 x Earth's diameter	---	---
Mercury	0.06	0.39	56.84 Earth days	0.24 Earth years
Venus	0.82	0.95	243.02	0.62
Earth	1.00	1.00	1.00	1.00
Mars	0.11	0.53	1.03	1.88
Jupiter	317.8	11.21	0.41	11.86
Saturn	95.2	9.41	0.43	29.46
Uranus	14.6	3.98	0.72	84.01
Neptune	17.2	3.81	0.67	164.8

The next figure shows the relative sizes of the orbits of the planets, asteroid belt, and Kuiper belt. In general, the farther away from the Sun, the greater the distance from one planet's orbit to the next. The orbits of the planets are not circular but slightly elliptical.

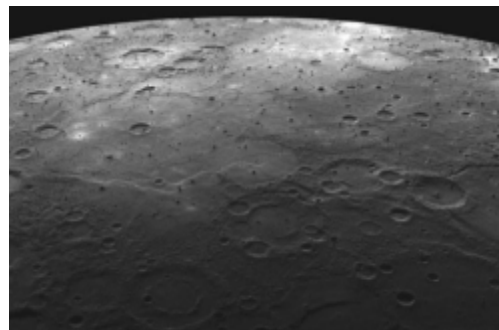


Planets

Planets are bodies that orbit a star. In our solar system there are eight planets. The following facts can be used to compare the planets:

Mercury

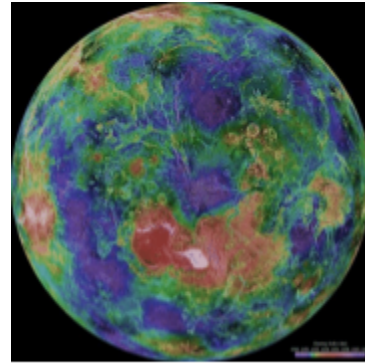
- It is the nearest planet to the Sun.
- Earth's Moon and Mercury's surface look similar.
- It has a very thin atmosphere.
- It has no moons.
- It has the greatest range of temperature, 662°F (day) to -274°F (night) = 936°.
- Rotation: 58.7 Earth days.
- Revolution: 88 Earth days.
- Distance from Sun: 0.39 AU's.



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Venus

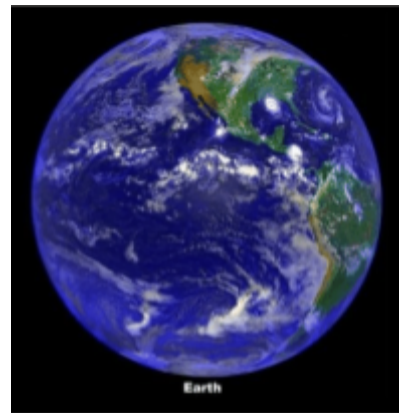
- It is the second planet from the Sun.
- It spins slowly backwards as it orbits the Sun.
- Its atmosphere is mostly made up of carbon dioxide.
- The atmosphere traps heat making Venus the hottest planet (860°F).
- Its surface is one dominated largely by volcanic activity.
- There are very few craters on Venus.
- It has no moons.
- Rotation: 243 Earth days.
- Revolution: 224.7 Earth days.
- Distance from Sun: 0.72 AU's.



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Earth

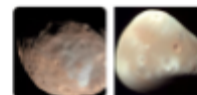
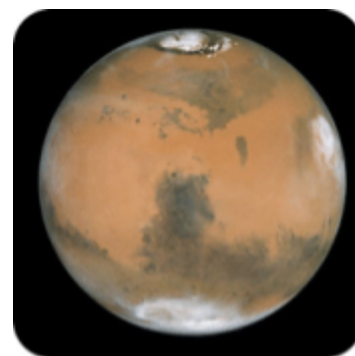
- It is the third planet from the Sun.
- It is covered by about 70% water and 30% land.
- It has 1 large moon.
- It has conditions necessary to support life.
- It has volcanoes, mountains, earthquakes and a few craters.
- Rotation: 24 hours.
- Revolution: 365.25 days.
- Distance from Sun: 1 AU.



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Mars

- It is the fourth planet from the sun.
- Iron oxides (rust) cause its surface to be reddish in color.
- It has polar ice caps made of frozen carbon dioxide and water ice.
- It has 2 small moons (Phobos and Deimos).
- It has a thin atmosphere that is less than 1% of Earth's.
- Huge dust storms sometimes cover the surface.
- Rotation: 24.6 hours.
- Revolution: 687 Earth days.
- Distance from Sun: 1.52 AU's.



Mars and its moons
(Phobos and Deimos)
Public Domain

Jupiter

- It is the fifth planet from the sun.
- Its atmosphere is made mostly of hydrogen, helium and methane.
- Its Great Red Spot is a storm, which has lasted for at least 400 years.
- It has a very small and faint ring system.
- It has 4 large and 63 small moons for a total of 67 moons.
- It is the largest planet in our solar system.
- Jupiter has very faint rings discovered by Pioneer 10.
- Ganymede is the largest moon in the Solar System. It is larger than Mercury.
- Four largest moons (Io, Europa, Callisto, and Ganymede) were discovered by Galileo in 1610
- Rotation: 9.9 hours.
- Revolution: 11.9 Earth years.
- Distance from Sun: 5.2 AU's.



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Saturn

- It is the sixth planet from the Sun.
- It is the second largest planet.
- It has an atmosphere of hydrogen, helium, and methane.
- It has 82 moons, the most of any planet..
- The largest moon, Titan, is larger than Mercury.
- It is not very dense, so if it were set upon Earth's oceans, it would float.
- It has a large ring system. Saturn and rings would fit between the Earth and the Moon.
- Rotation: 10.7 hours.
- Revolution: 29.4 Earth years.
- Distance from Sun: 9.58 AU's.

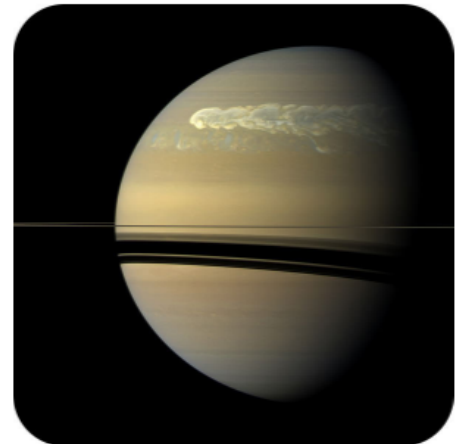


Image by NASA; public domain

Uranus

- It is the seventh planet from the Sun.
- It is the third largest planet in our solar system.
- It has a small faint ring system.
- Its axis points toward the Sun, so it rotates on its side.
- It has 27 moons.
- It has an atmosphere of hydrogen, helium, and methane.
- Methane causes Uranus to appear blue in color.
- Rotation: 17.2 hours.
- Revolution: 83.7 Earth years.
- Distance from Sun: 19.20 AU's.

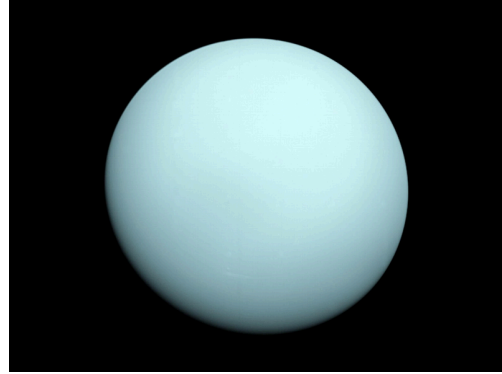
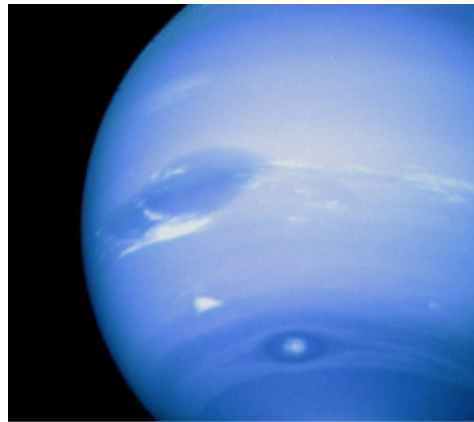


Image by NASA; public domain

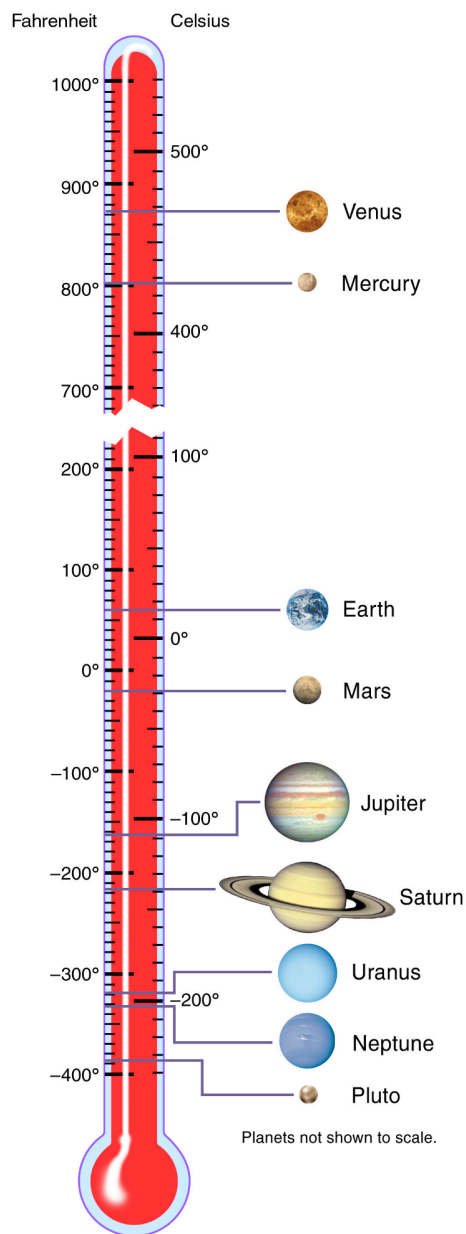
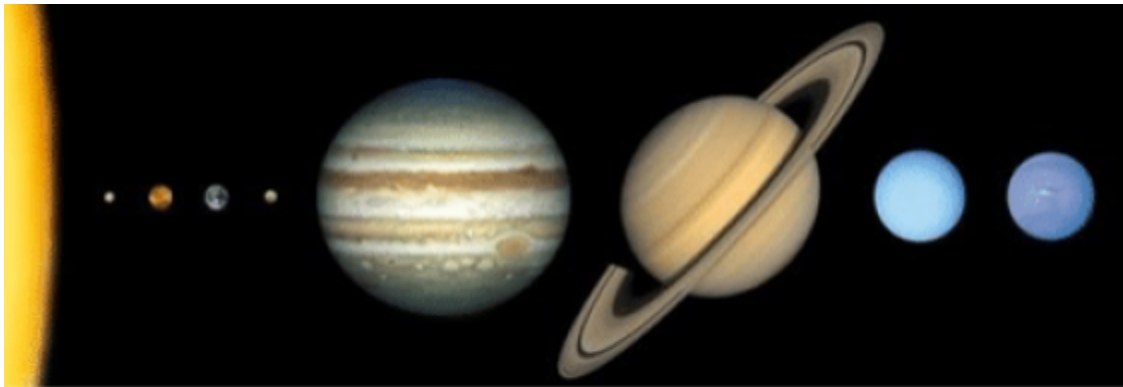
Neptune

- It is the eighth planet from the Sun.
- It sometimes has a Great Dark Spot that is a huge storm system as large as Earth.
- It has the fastest winds in the solar system.
- Its atmosphere is made of hydrogen, helium, and methane.
- Methane causes Neptune to appear blue in color.
- It has 14 moons.
- Its moon, Triton, has an atmosphere.
- It has a small, faint ring system.
- Rotation: 16.1 hours.
- Revolution: 163.7 Earth years.
- Distance from Sun: 30.05 AU's.



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Comparing the Eight Planets



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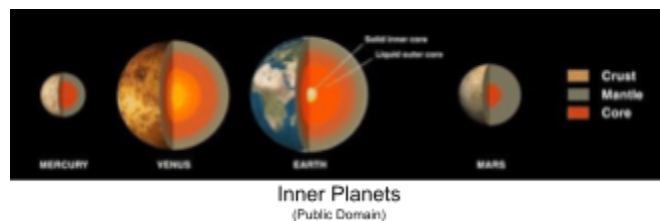
The sizes of the planets in this picture are shown to scale and allow us to compare sizes. The distances between the planets are not to scale.

Here is an image showing the average temperatures of the planets. Mercury is the closest to the Sun, but Venus is actually hotter than Mercury.

The Inner Planets

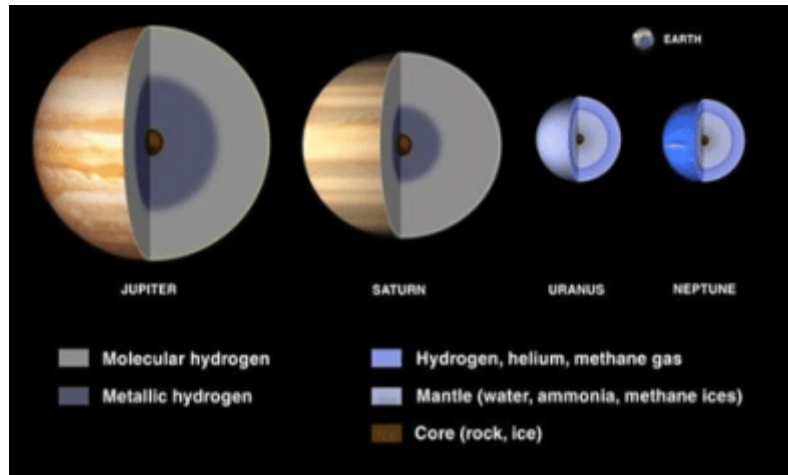
Look at the picture of the solar system again. The four planets closest to the Sun, Mercury, Venus, Earth, and Mars, are called the inner planets. They all are made of rock; some of them have a thin layer of gas around them called an atmosphere.

The next image shows us what the cores of each of the rocky planets may look like. The core is the inner part of the planet, and it is made up of different layers.



The Outer Planets

The four outer planets are gas giants. These planets are very far from the Sun. They don't have a hard surface that a spacecraft can land on. Instead, they are giant balls of very cold gases. Astronomers think that these planets have hot, solid cores, deep beneath their atmospheres.



Outer Planets (Public Domain)

Dwarf Planets

The dwarf planets of our solar system are exciting proof of how much we are learning about our solar system. With the discovery of many new objects in our solar system, astronomers refined the definition of a planet in 2006. Pluto did not fit the criteria for a planet, so it was placed in a new category of dwarf planets with other similar celestial bodies.

According to the International Astronomical Union (IAU), a dwarf planet must:

- Orbit a star
- Have enough mass to be nearly spherical
- Not have cleared the area around its orbit of smaller objects
- Not be a moon



Pluto and its moon, Charon, are actually two objects.
(Public Domain)

Dwarf planets are like planets except they have not cleared their orbits of smaller objects, such as rocks and dust. They do not have enough gravity to pull the rocks and dust into the composition of the planet.

There are many dwarf planets. Here are five that have been recognized by the IAU: Pluto, Ceres, Haumea, Makemake, and Eris.

Dwarf Planet	Diameter	# of Moons	Location
Pluto	2,400 km	3	Kuiper Belt, sometimes passes inside Neptune's orbit
Ceres	950 km	0	Asteroid belt
Haumea	1,916x1,518*	2	Kuiper Belt
Makemake	Between 1,360 and 1,480**	0	Kuiper Belt
Eris	2,326 km	1	Kuiper Belt

**diameter of the dwarf planet along its longest axis.*

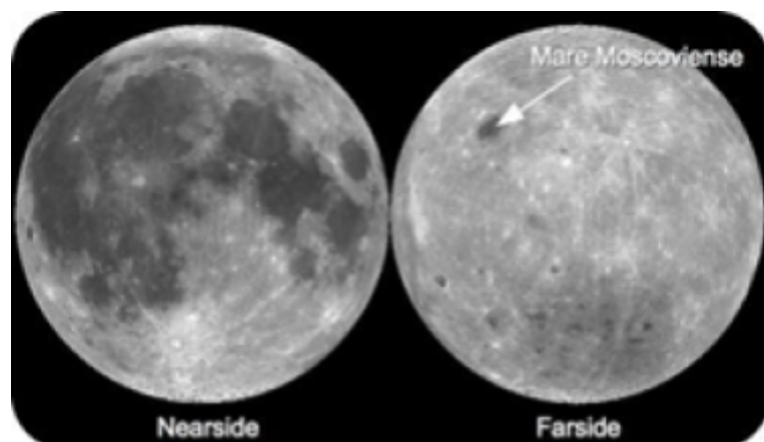
***estimate based on current data*

Astronomers know there may be other dwarf planets far out in the solar system. Look for Quaoar, Varuna, and Orcus to possibly be added to the list of dwarf planets in the future. We still have a lot to discover and explore!

Earth's Moon

A moon is a celestial body that orbits around a planet.

The surface of Earth's Moon is covered with craters that are made by space rocks that hit the Moon at high speeds. The rocks may be as small as grains of sand or as big as a house. They travel so fast that they explode when they hit the Moon, and they make a round hole. The Moon has a pale gray surface. You can also see dark gray marks on it.



(Public Domain)

The first astronauts to walk on the Moon stepped into fine, powdery dust. They collected rock samples to bring back to Earth. The footprints from the astronauts who first walked on the Moon are still there! There is no wind on the Moon to blow them away. Those footprints will be on the moon in many thousands of years.

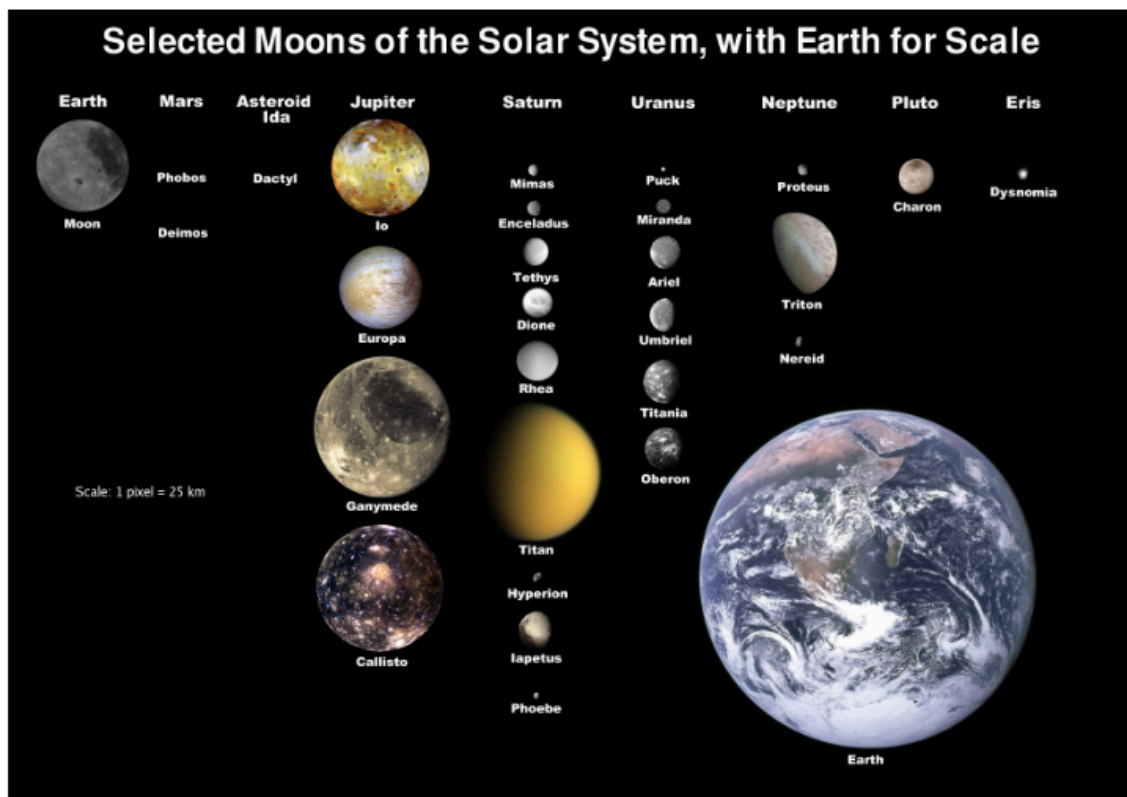


(Public Domain)

The light-colored areas are craters, highlands, and mountains. The darker areas are plains. Some of these plains were made when huge space rocks hit the Moon. They later filled with lava. Because the Moon has no air, no wind, and no water, there is no erosion. That is the reason why the craters on the Moon change very little after they are made.

Moons of Other Planets

Other planets have moons too. The next image shows some of the moons in our solar system. Not all of them are shown here. They are at the correct size scale so they can be compared to Earth and our Moon.



Public Domain, NASA

6.1.2 Scale of the Solar System

Putting It Together

It takes the Earth 365.25 days to fully rotate around the Sun. This is one year on Earth. Look at the table below at the length of a year on each planet. Use the data below to compare objects in the solar system.

Planet	Distance from Sun (AU)	Length of Year (In Earth Years)
Mercury	0.39 AU	0.24 years
Venus	0.72 AU	0.62 years
Earth	1.00 AU	1.00 years
Mars	1.52 AU	1.88 years
Jupiter	5.20 AU	11.86 years
Saturn	9.54 AU	29.46 years
Uranus	19.22 AU	84.01 years
Neptune	30.06 AU	164.8 years

Writing Performance Task:

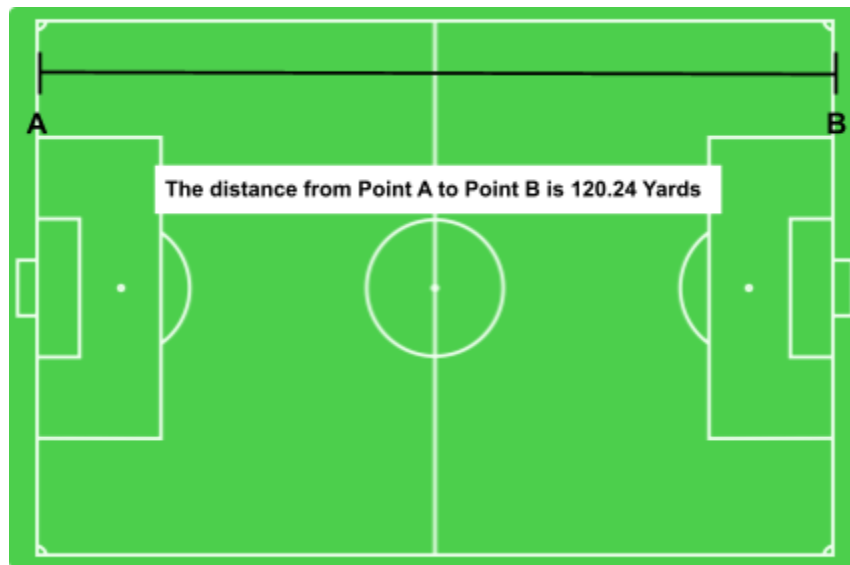
In the tasks that follow, you will use computational thinking to analyze data and determine the scale and properties of objects in the solar system.

Gather:

There are eight planets in our solar system. At the center of our solar system lies the sun. The planets orbit the sun at different rates and distances.

Your science class is building a scale model of the distances between the planets and the sun. The class has to measure and decide where to put each “planet” in your model.

Your teacher explains that all the planets rarely form one straight line in their orbits. However for this model, the planets will all be placed in a straight line from the sun. He also indicates that the soccer field outside is 120.24 yards from one end to the other.

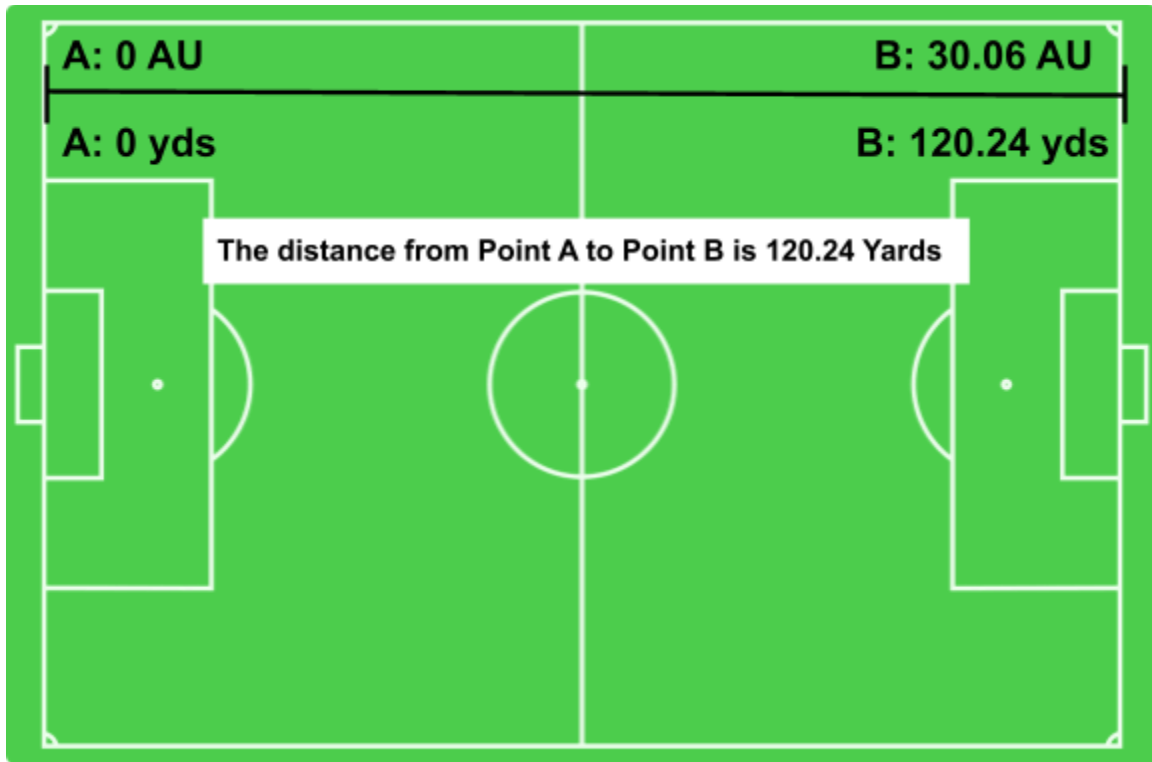


Point A in the image above represents the start of your model and Point B represents the furthest point in your model. You have 9 objects to represent each planet and the sun.

1. What is the correct order of the planets?

Reason:

Your teacher explains that when creating a scale model we must maintain accurate proportions. He states that our field is 120.24 yards long, and therefore, our model with all the planets must fit into that space. He places the sun at 0 yds and Neptune at 120.24 yds. He specifies that the sun's place represents 0 AU and Neptune's place represents 30.06 AU in our model.



Object	Distance (AU)	Model Distance (yards)
Sun	0.00	0
Neptune	30.06	120.24

- A. Using the soccer field model and table above, fill in the blanks below. Do not worry about the scale factor on this step.

$$\frac{\text{Actual distance from the Sun to Neptune (AU)}}{\text{Scale Factor}} = \frac{\text{Distance from the Sun to Neptune on the soccer field (yards)}}{?}$$

- B. Using the equation above, you will be finding how much Neptune's actual distance was scaled up by (increased by). To do this, you will be dividing, using the equation below. Fill in the first two blanks and then use a calculator to find the scale factor.

$$\frac{\text{Distance from the Sun to Neptune on the soccer field (yards)}}{\text{Actual distance from the Sun to Neptune (AU)}} = \text{Scale Factor}$$

Communicate:

Using a calculator and the scale factor from above, calculate each planet's distance in yards. Write your answer in column three in the table below. Hint: your scale factor should be the same for each object.

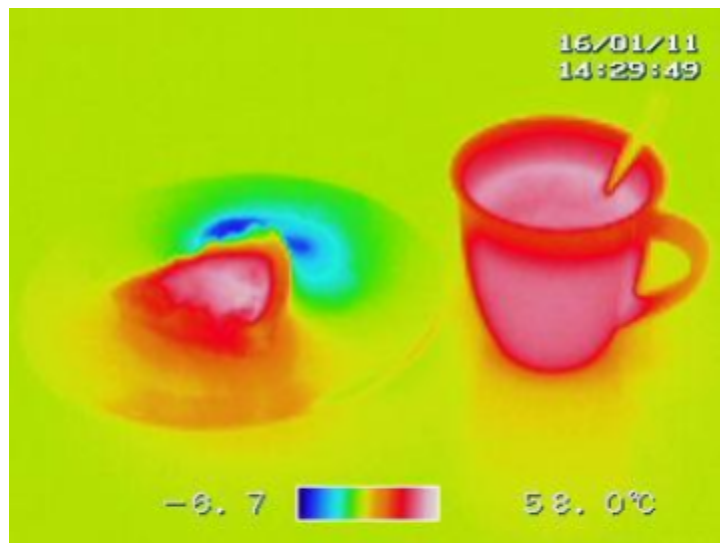
Object	Distance (AU)	Scale factor	Model Distance (yards)
Sun	0.00	x _____	0
Mercury	0.39	x _____	= _____
Venus	0.72	x _____	= _____
Earth	1.00	x _____	= _____
Mars	1.52	x _____	= _____
Jupiter	5.20	x _____	= _____
Saturn	9.54	x _____	= _____
Uranus	19.22	x _____	= _____
Neptune	30.06	x _____	120.24

Strand 2: Energy and Matter

Chapter Outline

- 2.1 Atoms and Molecules (6.2.1)
- 2.2 States of Matter (6.2.2)
- 2.3 Heat Energy and Particle Motion (6.2.3)
- 2.4 Engineering Design (6.2.4)

Matter and energy are fundamental components of the universe. The amount of matter and energy in the universe is never lost or destroyed but can be changed into other forms. Matter is anything that has mass and takes up space. Transfer of energy creates change in matter. Changes between general states of matter can occur through the transfer of energy. Density describes how closely matter is packed together. Substances with a higher density have more matter in a given space than substances with a lower density. Changes in heat energy can alter the density of a material. Insulators resist the transfer of heat energy, while conductors easily transfer heat energy. These differences in energy flow can be used to design products to meet the needs of society.



Cup of coffee and slice of apple pie with ice cream on it through an infrared camera
wikimedia, Public Domain

6.2.1 Atoms and Molecules

Phenomenon



Pixabay.com, CC0

Salt and sugar look and feel similar. However, they do not taste similar.

Observations & Wonderings

What are you observing about this phenomenon?

What are you wondering about this phenomenon?

6.2.1 Atoms and Molecules

Develop models to show that molecules are made of different kinds, proportions and quantities of atoms. Emphasize understanding that there are differences between atoms and molecules, and that certain combinations of atoms form specific molecules. Examples of simple molecules could include water (H_2O), atmospheric oxygen (O_2), and carbon dioxide (CO_2). (PS1.A)



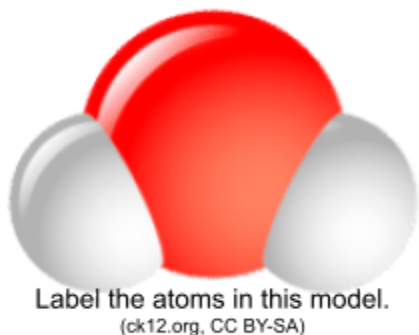
Develop models that show how different proportions and quantities of atoms form different molecules.

Atoms and Molecules

Everything you can see, touch, smell, feel, and taste is made of atoms. Atoms are the basic building-blocks of all matter (including you and me, and everyone else you'll ever meet). If we want to know about what something is made of, then you have to know a few things about these incredibly small particles.

Smallest Building Blocks

Everyday experiences should convince you that matter is found in many forms, yet all matter you have ever seen is made of atoms. These atoms combine to form molecules, which can be made up of the same or different types of atoms.



Molecules are formed when two or more atoms link up. For instance, a molecule of oxygen that we breathe is made of two atoms of oxygen (O_2). A molecule of water is made of two atoms of hydrogen (H_2) and one atom of oxygen (O). All water molecules have the same ratio: two hydrogen to one oxygen (H_2O). This figure shows a water molecule that has two hydrogen atoms (shown in gray) bonded to one oxygen atom (shown in red).

To help develop your model of atoms and molecules, think of interlocking building blocks. Each block is individual with its own color, shape, and size like an atom.

You can combine these blocks together to form a simple structure like a molecule.

Two things are important to know about molecules:

- A molecule always has the same type of atoms in the same proportions. For example, carbon dioxide always has two atoms of oxygen for each atom of carbon, and water always has two atoms of hydrogen for each atom of oxygen.
- A pure substance always has the same composition throughout. For example, all the water in a cup of water has the same type and proportion of atoms.

Properties of Molecules

The properties of a molecule are different from the properties of the atoms that form them. That's because atoms in a molecule combine and become an entirely different substance with its own unique properties.

Do you put salt on your food? Table salt is the molecule sodium chloride. A molecule of table salt contains an atom of sodium and an atom of chlorine. As shown in the figure below, sodium is a solid that reacts explosively with water, and chlorine is a poisonous gas. But together in table salt, sodium and chlorine form a harmless unreactive compound that you can safely eat.

Sodium + Chlorine → Sodium chloride



(ck12.org, CC BY-SA)

6.2.1 Atoms and Molecules

Putting It Together



Pixabay.com, CC0

Salt and sugar look and feel similar. However, they do not taste similar.

Focus Questions

1. How would a model of an atom and molecule be different?
2. How would you model a carbon dioxide molecule that has one atom of carbon and two atoms of oxygen (CO_2)?
3. How would you model an atom of Chlorine?

6.2.2 States of Matter

Phenomenon



Image by authors; CC0

Hold chocolate chips in your hand for a few minutes. The chips have gone soft and squishy.

Observations & Wonderings

What are you observing about this phenomenon?

What are you wondering about this phenomenon?

6.2.2 States of Matter

Develop a model to predict the effect of heat energy on states of matter and density. Emphasize the arrangement of particles in states of matter (solid, liquid, or gas) and during phase changes (melting, freezing, condensing, and evaporating). (PS1.A, PS3.A)



Adding and removing energy causes phase changes and affects density.

States of Matter

There are three major states in which any given type of matter can exist. The three states are gas, liquid, and solid.



Gas



Liquid



Solid

(ck12.org, CC BY-SA)

Solids are defined by the following characteristics:

- Definite shape (will hold its shape)
- Definite volume
- Particles vibrate in place

Liquids have the following characteristics:

- No definite shape (takes the shape of its container)
- Has definite volume

- Particles are free to move over each other, but are still attracted to each other

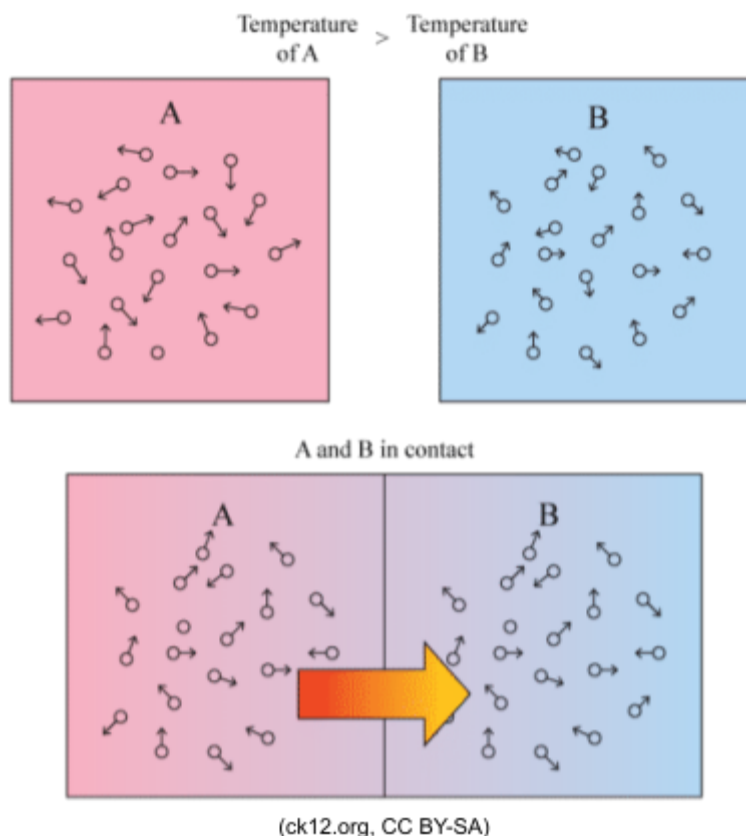
Gases have the following characteristics:

- No definite shape (takes the shape of its container)
- No definite volume (takes the volume of its container)
- Particles move in random motion with little or no attraction to each other

How tightly atoms and molecules are packed together is referred to as density. Solids are denser than liquids. Liquids are denser than gases.

What Is Heat?

Heat is the transfer of thermal energy between substances. Thermal energy is the energy causing the particles of matter to move. Temperature is the average measure of that energy. Thermal energy always moves from matter with greater thermal energy to matter with less thermal energy, so it moves from warmer to cooler substances. You can see this in the next figure.



Faster-moving particles of the warmer substance bump into and transfer some of their energy to slower-moving particles of the cooler substance. Thermal energy is transferred in this way until both substances have the same average thermal energy and temperature.

As thermal energy is transferred, materials expand and the temperature increases. As temperatures decrease materials tend to contract. The density of a substance is temperature dependent and usually decreases as temperature increases. Density is an important physical property of matter. It reflects how closely packed the particles are along with the arrangement of the particles in matter.

For instance, a golf ball and a table tennis ball are about the same size. However, the golf ball is much heavier than the table tennis ball. Now imagine a similar size ball made out of lead. That would be very heavy indeed! What are we comparing? By comparing the mass of an object relative to its size, we are studying a property called density. Matter with less density will rise and matter with greater density will sink.



(Tumbler of Cola with Ice by Simon Cousins, CC-BY)

How do you cool down a glass of room-temperature cola? You probably add ice cubes to it, as in this picture. You might think that the ice cools down the cola, but in fact, it works the other way around. The warm cola heats up the ice. Thermal energy from the warm cola is transferred to the much colder ice, causing it to melt. The cola loses thermal energy in the process, so its temperature falls.

Changes in States of Matter

A change of state occurs whenever matter changes from one form to another, for example a solid changing to a liquid. This change is an effect of energy being transferred from one substance to another. Changes of state are physical changes, meaning they do not change how molecules are combined. For example, when fog changes to water vapor, it is still water (H_2O) and can change back to liquid water again. Matter may change back and forth between these states.

As energy in a substance is transferred, it may cause a change in its state. In the previous example, ice was added to a cola. The energy was transferred from the warmer cola to the cooler ice. This caused the ice to melt and change from a solid to a liquid.

Types of Phase Changes

Melting occurs when particles of a solid absorb enough energy to partly overcome the force of attraction holding them together. This allows them to move out of their fixed positions and slip over one another. The solid becomes a liquid.

The process in which water or any other liquid changes to a solid is called freezing. Freezing occurs when a liquid cools to a point at which its particles no longer have enough energy to overcome the force of attraction between them. Instead, the particles remain in fixed positions, crowded closely together.

When air cools, it can hold less water vapor, so some of the water vapor in the air changes to liquid water. The process in which water vapor—or another gas—changes to a liquid is called condensation. Another common example of condensation is pictured in the next figure.



This picture shows the contrail (condensation trail) left behind by a jet. Water vapor in its exhaust gases condense on dust particles in the air.

By Stiopa - Own work, CC BY-SA 3.0,

Evaporation is the process in which a liquid changes to a gas. It occurs when individual liquid particles at the exposed surface of the liquid absorb just enough energy to overcome the force of attraction with other liquid particles. If the surface particles are moving in the right direction, they will pull away from the liquid and move into the air becoming a gas.

6.2.2 States of Matter

Putting It Together



(CC0)

Hold chocolate chips in your hand for a few minutes. The chips have gone soft and squishy.

Writing Performance Task:

In the tasks that follow, you will be developing and using a model to explain what causes the chocolate chips to change over time.

Gather:

A student wants to model the phenomenon above. The student takes the temperature of their hand, the chocolate chips, and the air of the room before placing the chocolate chips on their hand. The approximate starting temperature of the student's hand was 90° F, the air in the room was approximately 70° F and the chocolate chips were 70° F.

After placing the chocolate chips on the student's palm, and a few minutes have passed, the student takes the ending temperature of their hand, the chocolate chips, and the air in the room. The approximate ending temperature of the student's hand was 90° F, the air in the room was approximately 70° F and the chocolate chips were 85° F.

A. Heat is the transfer of thermal energy from one object to another. Label temperatures in the model below to show how thermal energy is changed within the hand-chip-room system.

Hand-chip-room system model	
Perspective: from the side of the person holding the chocolate chips	
Air above the hand Air temp. _____ ° F	Chocolate Chips Starting temp. _____ ° F Ending temp. _____ ° F
	
Student's hand Starting temp. _____ ° F Ending temp. _____ ° F	
Air below the hand	

B. Using the table below circle phrases that describe the particles in each state of matter.

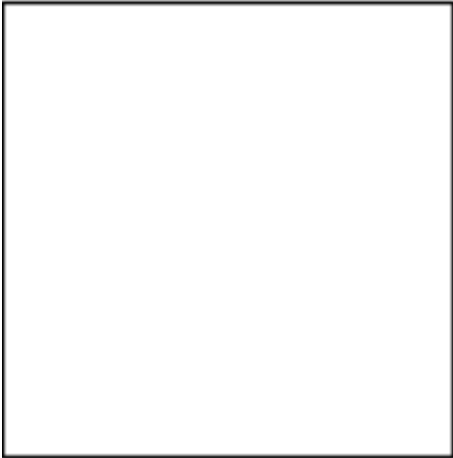
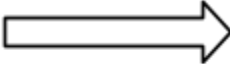
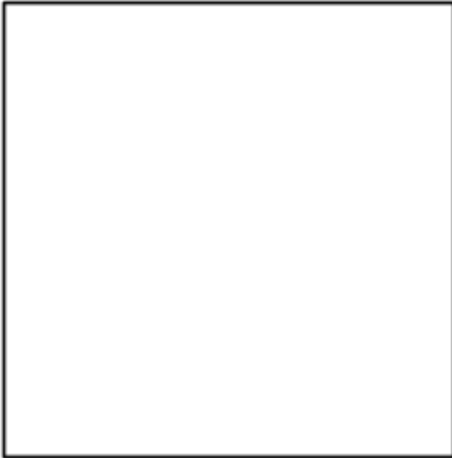
	Solid	Liquid	Gas
Density (circle one phrase)	Packed tightly Packed loosely Spread apart	Packed tightly Packed loosely Spread apart	Packed tightly Packed loosely Spread apart
Motion (circle one phrase)	Vibrate in place Move slowly past each other Move freely	Vibrate in place Move slowly past each other Move freely	Vibrate in place Move slowly past each other Move freely
Structure (circle one phrase)	Has no specific shape Holds shape	Has no specific shape Holds shape	Has no specific shape Holds shape

Reason:

Return to your model above and add arrows that show how thermal energy is being transferred within the hand-chip-room system.

Communicate:

A. Draw a model of the chocolate chip particles before and after the student held them. Use circles to represent the chocolate chip particles.

0 minutes		5 minutes
		
Starting phase: _____		Ending phase: _____

B. Develop an explanation for what caused the chocolate chips to melt over time. Include at least 1 piece of evidence from this task (can use sections above) that supports your explanation.

The chocolate chips changed after being placed on the hand because

_____.

Expected criteria:

- ___ Models the motion of the chocolate chip particles before and after
- ___ Models the correct density of the chocolate chip particles before and after
- ___ Identifies the correct starting and ending phase
- ___ Explains how energy transfer affected the chocolate chips
- ___ Explains how particle motion changes in the chocolate chips
- ___ Includes one piece of applicable evidence in their explanation.

6.2.3 Heat Energy and Particle Motion

Phenomenon



(Emerald Bay, Lake Tahoe, USA by Michael
https://commons.wikimedia.org/wiki/File:Emerald_Bay.jpg#/media/File:Emerald_Bay.jpg, CC-BY)



Pixabay.com, CC0

The first photo shows a large lake, and the second shows a small pond. The two different bodies of water are close in geographic location and experience the same weather and temperature changes.

Observations & Wonderings

What are you observing about this phenomenon?

What are you wondering about this phenomenon?

6.2.3 Heat Energy and Particle Motion

Plan and carry out an investigation to determine the relationship between temperature, the amount of heat transferred, and the change of average particle motion in various types or amounts of matter. Emphasize recording and evaluating data, and communicating the results of the investigation. (PS3.A)



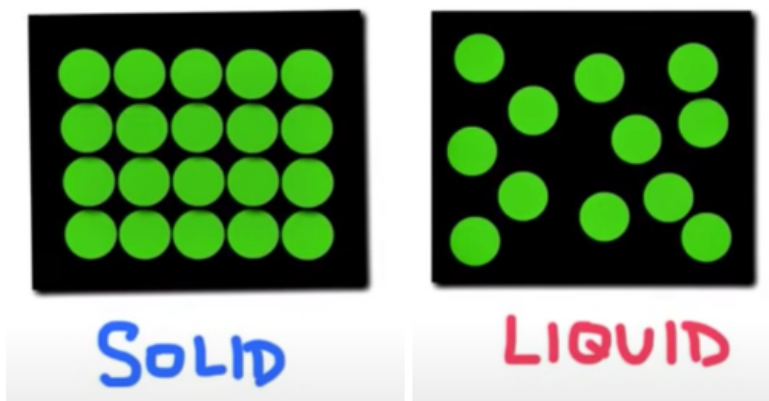
The transfer of energy drives the motion and/or cycling of matter. It can take many forms and be tracked through a system.

Heat Energy and Particle Motion

The energy from the motion of moving particles is called kinetic energy. Kinetic energy has four forms, thermal energy is one form of kinetic energy that makes particles move. As you learned in section 6.2.2, heat is the way thermal energy moves from one substance to another. Everything around you that has mass is made of particles that are always moving. However, different objects can have different amounts of kinetic energy based on their temperature and what they are made of.

Density

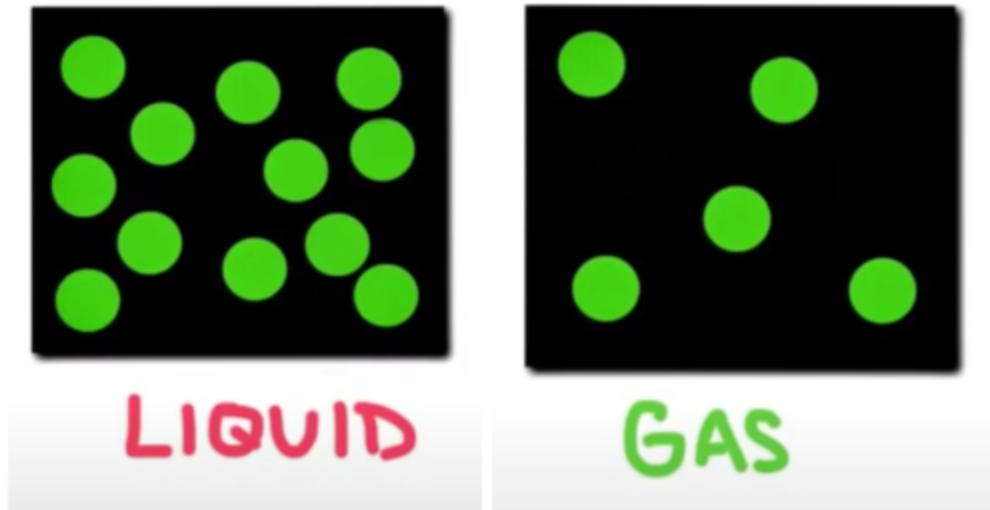
Density describes how closely particles are packed together. Substances with a higher density have more matter in a given space than one with a lower density. This means that solid objects have less kinetic energy than liquids of the same amount because the particles are closer together and cannot move very much.



[ck 12.org](http://ck12.org)

[ck 12.org](http://ck12.org)

For the same reason, liquids have less kinetic energy than gases whose particles move about very quickly.



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Mass

Large objects have more total kinetic energy than small objects of the same matter and temperature because there are more particles in total. So the iceberg has more kinetic energy than the ice cubes.



pixabay

Temperature

Hot objects have more kinetic energy than cold objects of the same matter because the molecules are moving faster. For example, if you put a drop of food coloring into hot water and a drop into cold water, the faster moving molecules distribute the color faster than the slow, cold molecules.



When you freeze the water, the molecules move so slowly and the kinetic energy is so low, that the water becomes a solid.



Images by J. Sumsion; CC-BY

Heat Transfer

Temperature is a measure of the kinetic energy of the particles of matter. The word heat is often used to mean temperature but heat really refers to energy that is being transferred between two objects that are at different temperatures. One of the ways this transfer occurs is called conduction.

The term conduction refers to the transfer of energy as it passes between objects. The transfer of thermal energy is called heat. Particles of matter are in constant motion. Sometimes they collide with other particles. When they do, they transfer some of their energy. The energy is transferred from particle to particle. It is sort of like a row of dominoes falling over. In this process, thermal energy moves through a substance. It can even move into other nearby substances. When heat flows into an object, its thermal energy increases and so does its temperature.

For example, the particles in this cup are very warm and when the spoon is placed inside, the energy is transferred up the spoon causing the particles inside the spoon to move faster. This is what makes the spoon warm!



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Thermal Energy and Temperature

Thermal energy and temperature are closely related. Both reflect the amount of moving particles of matter as energy. However, temperature is the average measure of that energy, whereas thermal energy is the total energy within a system. The amount of temperature increase depends on three things: 1) how much heat was added, 2) the size of the object, and 3) the material of which the object is made.

Does this mean that matter with a lower temperature has less thermal energy than matter with a higher temperature? Not necessarily because you have to add in the other factor which is the mass of the objects.



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Boiling Soup
100°C (212°F)
Greater temperature

Warm Water
38°C (100°F)
Greater thermal energy

Although the water in the tub has a much lower temperature, it has greater thermal energy. This is because temperature is a measure of the average energy of the particles, rather than a measure of the total energy. The particles of soup have a greater average thermal energy than the particles of water in the tub; the soup has a higher temperature. However, the mass of the water in the tub is much greater than the mass of the soup in the pot. This means that there are many more particles of water in the tub than particles in the soup. All these moving particles give the water in the tub greater total energy, even though their average energy is less. Therefore, the water in the tub has greater thermal energy than the soup.

6.2.3 Heat Energy and Particle Motion

Putting It Together



(Emerald Bay, Lake Tahoe, USA by Michael
https://commons.wikimedia.org/wiki/File:Emerald_Bay.jpg#/media/File:Emerald_Bay.jpg, CC-BY)



Pixabay.com, CC0

The first photo shows a large lake, and the second shows a small pond. The two different bodies of water are close in geographic location and experience the same weather and temperature changes.

Writing Performance Task:

In the tasks that follow, you will be **planning an investigation** and analyzing the results to explain the transfer of energy by using a model for the phenomenon.

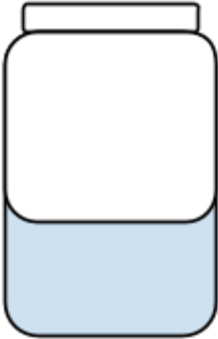
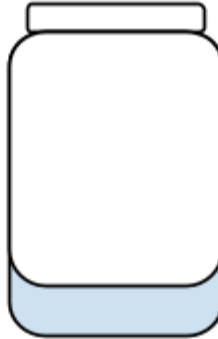
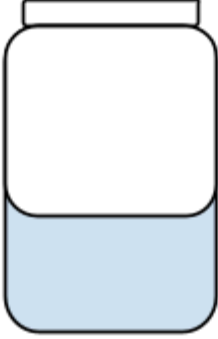
Gather:

- A. Looking on pages 82-83 in your textbook, what three things could affect the amount of energy in a sample of matter?

1. _____
2. _____
3. _____

Reasoning:

A class wants to use a model to investigate the lake and pond phenomenon. The student gets two jars of equal size and material and fills them with different amounts of bottled water. They then place the jars on a shelf in their freezer. They check on the jars of water every 15 minutes. Once the water in each jar is completely frozen, they record the time it took for the water to freeze in the results box.

Starting setup		Result	
Jar 1	Jar 2	Jar 1	Jar 2
			
Amount: 200 mL	Amount: 100 mL	Amount: 200 mL	Amount: 100 mL
Liquid: bottled water	Liquid: bottled water	Liquid: bottled water	Liquid: bottled water
Jar material: plastic	Jar material: plastic	Jar material: plastic	Jar material: plastic
Temperature of water: 72° F	Temperature of water: 72° F	Temperature of water: 32° F	Temperature of water: 32° F
Location: freezer shelf	Location: freezer shelf	Location: freezer shelf	Location: freezer shelf
Time to freeze: not applicable	Time to freeze: not applicable	Time to freeze: 2 hours	Time to freeze: 1 hour
Density: 1 g/mL	Density: 1 g/mL	Density: 1 g/mL	Density: 1 g/mL

A. Identify the variables for the student's jar investigation. There should be one x per row.

	Independent	Dependent	Control
Amount of water			
Liquid			
Jar material			
Temperature			
Location			
Time to freeze			
Density			

B. Based on the class's jar investigation, which jar represents the lake and which represents the pond? (circle 1 for each jar)

Jar 1 (circle one): Pond or Lake

Jar 2 (circle one): Pond or Lake

Communicate:

Based on the jar investigation above, support a claim and give reasoning about which body of water from the phenomenon would freeze first.

A. Circle a claim you agree with:

Claim 1: The lake will freeze before the pond.

Claim 2: The pond will freeze before the lake.

B. Give 2 pieces of evidence from the jar investigation that would support your claim.

1.

2.

C. Using at least one concept from the reading and your evidence above, give scientific reasoning about why the claim you chose above makes sense.

Expected criteria:

- ☐ Circles correct claim
- ☐ Gives two pieces of evidence from the jar investigation that justifies the claim
- ☐ Discusses total particle motion in explanation
- ☐ Includes at least one piece of applicable evidence
- ☐ Includes at least one applicable concept from the reading
- ☐ Explains why one body of water freezes before the other

6.2.4 Energy Transfer

Authentic Situation

Have you ever noticed that when you walk on a tile floor it feels colder than when you walk on carpet? This student moved into an apartment that only has one small area of carpet and the rest of the floor is white tile. Her feet are always cold because she is not allowed to wear shoes inside.



CC0

Observations and Wonderings

What is the problem in this situation?

What are the possible criteria (positive outcomes) to this situation?

What are the constraints (limitations) with this situation?

6.2.4 Energy Transfer

Design an object, tool, or process that minimizes or maximizes heat energy transfer. *Identify criteria and constraints, develop a prototype for iterative testing, analyze data from testing, and propose modifications for optimizing the design solution.* Emphasize demonstrating how the structure of differing materials allows them to function as either conductors or insulators. (PS3.A, PS3.B, ETS1.A, ETS1.B, ETS1.C)



Engineering uses scientific knowledge to solve human needs and wants. In this section focus on how the structure of different materials helps them function as conductors or insulators.

Engineering Design

The process of designing a new technology includes much more than just coming up with a good idea. Possible problems that can limit success must be considered. These might include factors such as the cost or safety of the new product or process. Making and testing a model of the design are also important. These steps ensure that the design actually works to solve the problem. This process also gives the designer a chance to find problems and modify the design if necessary. No solution is perfect, but testing and refining a design assures that the technology will provide a workable solution to the problem it is intended to solve.

Engineering design can be accomplished in many different ways. Some of the steps have to be repeated, and the steps may not always be done in the same sequence, but there are some basic steps to solving an engineering problem. First, an engineer defines the problem that needs to be solved, and researches what criteria (success outcomes) and constraints (limitations) they need to consider. Next, engineers brainstorm to come up with many possible ideas for solutions. Finally, engineers select the solution that best meets the criteria and constraints for the situation. They design, build, test, and revise their solution. This is called optimizing the solution.

Consider the problem of developing a solar-powered car. Many questions would have to be researched in the design process. For example, what is the best shape for gathering the sun's rays? How will sunlight be converted to usable energy to run the car? Will a backup energy source be needed? After

researching the answers, possible designs are developed. This generally takes imagination as well as sound reasoning. Then a model must be designed and tested. This allows any problems with the design to be worked out before a final design is selected and produced.

Heat Energy Transfer: Thermal Conductors

Conduction is the transfer of thermal energy between particles of matter that are touching.

Thermal conduction occurs when particles of warmer matter bump into particles of cooler matter and transfer some of their thermal energy to the cooler particles. Conduction is usually faster in certain solids and liquids than in gasses. Materials that are good conductors of thermal energy are called thermal conductors.



Ck12.org, CC BY-SA

When hot water flows through the coils of the radiator, the metal quickly heats up by conduction and then radiates thermal energy into the surrounding air.

Besides the heating element inside a toaster, another example of a thermal conductor is an element on the top of a stove or hot plate, like the one pictured.



Image by congerdesign; pixabay.com, CC0

Thermal Insulators

One way to retain your own thermal energy on a cold day is to wear clothes that trap air. That's because air, like other gases, is a poor conductor of thermal energy. The particles of gases are relatively far apart, so they don't bump into each other or into other things as often as the more closely spaced particles of liquids or solids. Therefore, particles of gases have fewer opportunities to transfer thermal energy. Materials that are poor thermal conductors are called thermal insulators. Down-filled snowsuits, like those in the next picture, are good thermal insulators because their feather filling traps a lot of air.



(ck12.org, CC-BY-SA)

Another example of a thermal insulator is pictured below. This picture shows fluffy pink insulation inside the attic of a home. Like the down filling in a snowsuit, the insulation traps a lot of air.

The insulation helps to prevent the transfer of thermal energy into the house on hot days and out of the house on cold days. Other materials that are thermal insulators include plastic and wood. That's why pot handles and cooking utensils are often made of these materials. This helps to prevent the transfer of energy that can cause burns.



(ck12.org)

6.2.4 Energy Transfer

Putting It Together



CC0

Have you ever noticed that when you walk on a tile floor it feels colder than when you walk on carpet? This student moved into an apartment that only has one small area of carpet and the rest of the floor is white tile. Her feet are always cold because she is not allowed to wear shoes inside.

Engineering Design Task:

In the tasks that follow, you will be constructing explanations and designing solutions to solve a problem about the transfer of energy.

Gather:

A. This chapter talked about thermal insulators:

Can you think of examples of everyday items that use insulation to help retain heat?

B. Looking back at the phenomenon, what role does insulation play in keeping your feet warm? How can insulation reduce heat loss?

C. Why is it important to set criteria and constraints when designing a product or process?

Reason:

Scenario:

You and a team of engineers are tasked with designing a new type of slipper that keeps feet warm and comfortable on cold surfaces like tile floors. Your goal is to create slippers that minimize heat loss from the feet to the floor, while also being comfortable and durable.

Material	Benefits	Considerations
Felt	soft, warm, good insulation	Not very durable
Foam	Lightweight and flexible	Limited insulation, can flatten over time
Socks (cotton)	Breathable and comfortable	Not sturdy enough to be used as the bottom of a shoe
Cardboard	Easy to shape	Not durable
Fleece	very warm and soft	Bulky, can breakdown (pill) over time

A. What outcomes (criteria) do you need to consider it a successful slipper?

1. _____

2. _____

3. _____

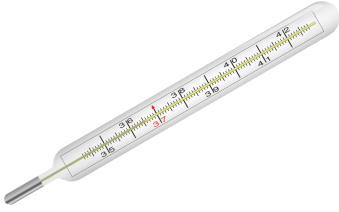
B. What is conduction, and how does it relate to the way heat moves between your feet and the floor? *(You can draw a model to answer this question)*

--

C. How do different materials affect the rate of heat conduction? (Choose 2 materials and compare them)

Material 1:	Material 2:

D. Pick a testing method to test how much heat transfers from the slippers:

	Temperature Measurement Test	Heat Source Test	Heat Transfer Rate Test
Testing Method			
How it works	Place a thermometer under the slipper on a cold surface and measure the temperature after standing for a set time. Compare the temperature readings of different slipper designs.	Use a heating pad or warm water bottle inside the slipper and measure how long it takes for the temperature to drop to a certain level when exposed to room temperature or a cold surface.	Use a heat-sensitive camera or infrared thermometer to measure the surface temperature of the slipper and the heat loss over time when placed on a cold surface.

Why did you choose this method? Explain your reason.

Communicate:

Material	Comfort Rating (1-5)	Insulation Rating (1-5)	Durability Rating (1-5)	Cost
Felt	3	1	3	\$3 per sheet
Foam	2	5	4	\$5 per sheet
Socks (cotton)	4	3	5	\$4 per sheet
Cardboard	1	2	1	\$1 per sheet
Fleece	5	4	2	\$2 per sheet

Ratings: 1- poor, 2- fair, 3- average, 4- above, 5- excellent

Engineers have to make trade-offs because they have limited resources (constraints). Based on the new data above choose 2 materials to use in a slipper and explain how they best fit the criteria.

A. Materials:

1. _____

2. _____

How do they best fit the criteria?

Extension:

What materials, other than the ones in the table, would you use on a slipper and why?

Material: _____

Why it would be a good option:

Strand 3: Earth's Weather Patterns and Climate

Chapter Outline

- 3.1 Water Cycle (6.3.1)
- 3.2 Pressure and Air Masses (6.3.2)
- 3.3 Climate (6.3.3)
- 3.4 The Greenhouse Effect (6.3.4)



Image by NOAA; <https://www.noaa.gov/education/resource-collections/weather-atmosphere/hurricanes>; public domain

Water continually cycles among land, ocean, and atmosphere through evaporation, condensation, crystallization, and precipitation. This cycle is known as the water cycle. The Sun is the driving force behind this cycling. Thermal energy (heat) is transferred from the Sun by radiation. The Earth is heated unevenly and because of this, ocean currents and atmospheric density is affected creating convection currents in the ocean and atmosphere. These currents influence regional and global climates.

6.3.1 Water Cycle

Phenomenon



Image by Antranas; pixabay.com; CC0

After a rainstorm you notice a puddle of water outside. If you continue to observe the water from time to time, you will find that eventually the puddle is gone.

Observations & Wonderings

What are you observing about this phenomenon?

What are you wondering about this phenomenon?

6.3.1 Water Cycle

Develop a model to describe how the cycling of water through Earth's systems is driven by energy from the Sun, gravitational forces, and density. (ESS2.C)



In this section, focus on energy. Think about how the transfer of energy drives the motion and cycling of water throughout the water cycle.

The Water Cycle

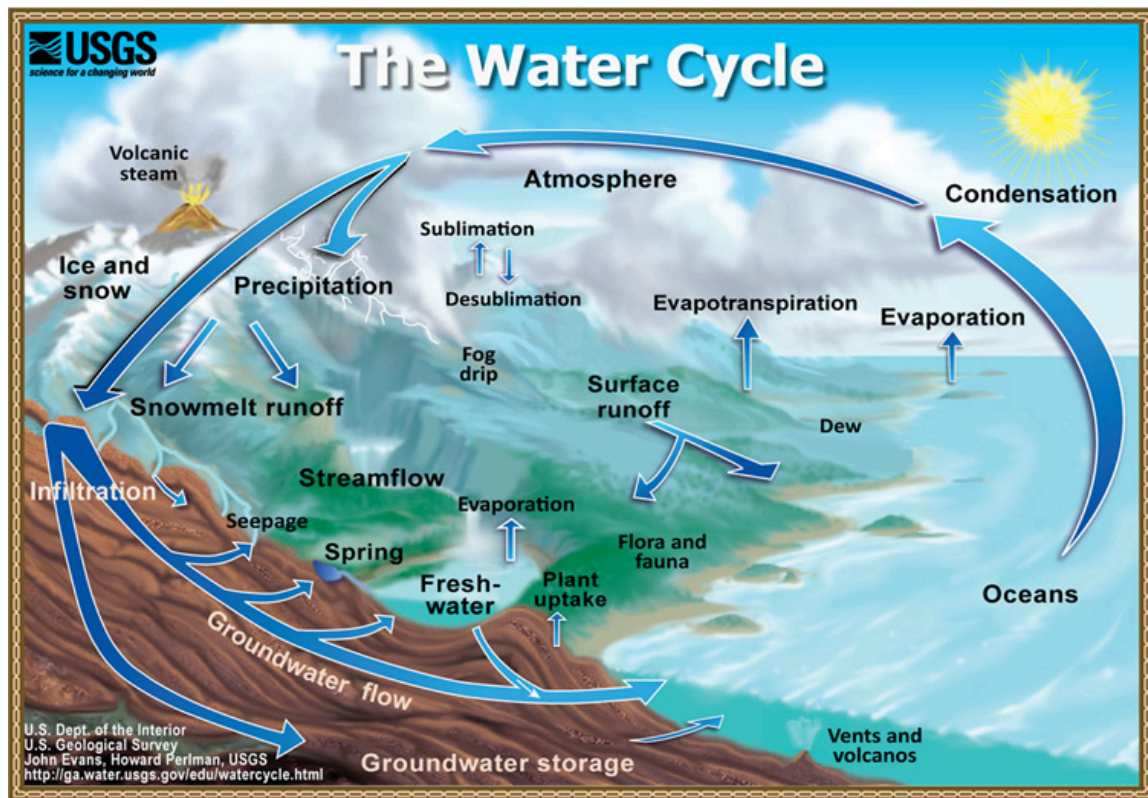
The water molecules found in your glass of water could have erupted from a volcano early in Earth's history. The molecules probably spent time in a glacier. They may have been far below the ground. They could have been in the belly of a dinosaur. Because of the properties of water, water molecules can cycle through almost anywhere on Earth. Where will those water molecules go next?

Water constantly moves between living organisms, such as plants. It moves between non-living things, such as clouds, rivers, and oceans. The water cycle does not have a starting or ending point. It is a nonstop recycling process. It involves oceans, lakes and other bodies of water. It also involves the land surfaces and the atmosphere. One possible pathway water could follow is:

- Water molecules on the ocean's surface get energy from the Sun. The molecules change from a liquid to gas. This process is called evaporation. Evaporated water molecules mix with the air molecules above the ocean surface.
- The air with these gaseous water molecules is heated by the Sun. This heated air rises high in the atmosphere.
- Temperature decreases with altitude. High in the atmosphere the temperature is cold enough for water molecules in the air to lose energy and become denser. This causes them to change from a gas into many tiny droplets of liquid water, a process called condensation. These tiny water droplets form a cloud. This cloud is pushed by winds which carry it over land.
- As the water droplets in the cloud increase in size, they become heavier and eventually fall back to Earth's surface. This is called precipitation.
- When the liquid water molecules reach the surface, they can move into the ground or flow along the surface. If these water molecules flow along the surface into a stream or river, they can eventually move back into the ocean where this cycle can begin again.

Most precipitation that occurs over land is not absorbed by the soil. This water remains on the surface and is called runoff. Runoff collects in streams and rivers and eventually flows back into the ocean.

Water moves through living organisms. Plants soak up water through their roots. The water moves up the plant. It will evaporate from the leaves. This process is called transpiration. Another name for transpiration is evapotranspiration. Transpiration, like evaporation, returns water back into the atmosphere.



Forces that Drive the Water Cycle

Solar Energy

The Sun provides the energy that drives the water cycle. For water to evaporate it requires energy. The Sun directly supplies energy needed for evaporation. Water can also evaporate when it absorbs energy from objects it touches. Most of the energy that is on Earth's surface comes either directly or indirectly from the Sun.

Density and Gravity

When a parcel of air containing gaseous water molecules is heated by the Sun, it will expand. This decreases the density of this particular parcel of air, so that it

weighs less. It will then be pushed upward by colder, denser air that is pulled downward and underneath it by gravity.

Energy lost by water molecules in condensation is acquired by the surrounding air molecules, increasing their motion. This causes the air around the water droplets to expand, decreasing its density. This heated air within the cloud rises (this upward movement of air is called an updraft). These rising air molecules exert an upward force on the liquid water drops and ice crystals in the cloud and keep them aloft even though they are denser than the air.

As cloud droplets collide they merge to form larger drops. If the drops become large enough, the force from the rising air is no longer strong enough and the drops will fall to the ground as rain, snow or hail.

Some of the water falling on land will seep into the ground. This is a process called infiltration. Water which doesn't seep into the ground moves across the surface from a higher to lower elevation. This is caused by gravity. It will eventually flow into streams and rivers and then into lakes or the ocean.

Earth's Water Reservoirs

Water can be found in many different locations on the Earth. It can be found in oceans, clouds, puddles or living things. Each of these locations is called a reservoir.

Oceans

Most of Earth's water is stored in the oceans. In fact, 97% of the Earth's water is in this reservoir.

Atmosphere

When water absorbs energy it will change from a liquid to a gas (water vapor). The Sun's energy can evaporate water from the ocean surface or from lakes, streams, or puddles on land. Water vapor remains in the atmosphere as a gas until it condenses to become tiny droplets of liquid. If it is cold enough, the water molecules can freeze and form ice crystals. The droplets (or ice crystals) make up clouds, which are blown about the globe by wind. As water droplets in the clouds collide and grow, they fall from the sky as precipitation. Precipitation can be rain, sleet, hail, or snow. Sometimes precipitation falls back into the ocean and sometimes it falls onto the land surface.

Streams and Lakes

When water falls from the sky as rain it may enter streams and rivers that flow downward to lakes and oceans. Water that falls as snow may sit on a mountain for several months. Snow may become ice in a glacier, where it will remain for

hundreds or thousands of years. Snow and ice slowly melt over time to become liquid water, which provides a steady flow of fresh water to streams, rivers, and lakes.

Soil

A significant amount of water seeps into the ground. Soil moisture is an important reservoir for water. Water trapped in soil is important for plants to grow.

Groundwater

Water may seep through dirt and rock below the soil and then through pores infiltrating the ground. The water goes into Earth's groundwater system. Groundwater enters aquifers (which are porous layers of rock that can hold water) that may store fresh water for centuries. The water may come to the surface through springs. It may find its way back to the oceans. Water can remain in this reservoir for hundreds or even thousands of years.

Biosphere

Plants and animals depend on water to live. Plants and animals are another place where water is stored. Plants take up water from the soil and release large amounts of water vapor into the air through their leaves in transpiration.

6.3.1 Water Cycle

Putting It Together



Image by Antranas; pixabay.com; CC0

After a rainstorm you notice a puddle of water outside. If you continue to observe the water from time to time, you will find that eventually the puddle is gone.

Focus Questions

1. How does energy from the Sun affect the movement of water through the water cycle?
2. How does water change states as it moves through the water cycle?
3. What roles do density and gravity play in the water cycle?

6.3.2 Pressure and Air Masses

Phenomenon

Yesterday, it was warm and sunny. Today it is windy, cloudy, and cold with rain.



*Storm Front by Nicholas D.,
<https://flic.kr/p/9VFSdS>, CC BY-NC*

Observations & Wonderings

What are you observing about this phenomenon?

What are you wondering about this phenomenon?

What type of weather is associated with clouds that look like this?

6.3.2 Air Pressure

Investigate the interactions between air masses that cause changes in weather conditions. Collect and analyze weather data to provide evidence for how air masses flow from regions of high pressure to low pressure causing a change in weather. Examples of data collection could include field observations, laboratory experiments, weather maps, or diagrams. (ESS2.C, ESS2.D)



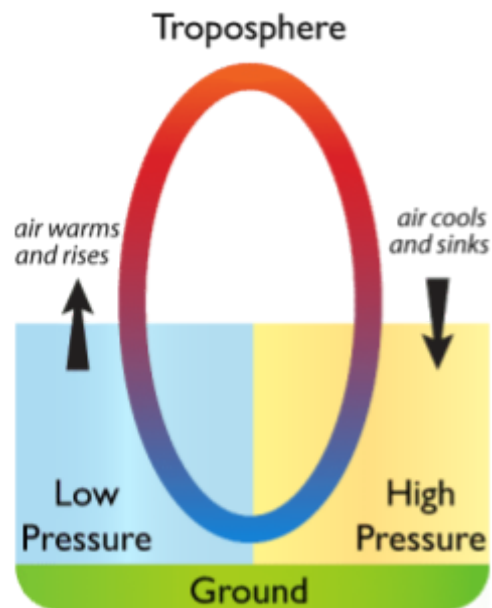
Analyzing cause and effect relationships help us to predict and understand changes in weather.

Air Pressure

Pressure in the atmosphere is created by the weight of the atmosphere pushing down on the surface. Air heated at the surface rises, creating a low pressure zone. Air from the surrounding area rushes into the space left by the rising air. As air cools it sinks back to the surface. When the air reaches the ground, it creates a high pressure zone. Air flowing from areas of high pressure to low pressure creates winds. The greater the pressure difference between the pressure zones, the stronger the wind blows.

Warm air can hold more moisture than cool air. When warm air rises and cools in a low pressure zone, it may not be able to hold all the water it contains as vapor. Some water vapor may condense to form clouds and precipitation. When cool air descends, it warms and can then hold more moisture.

Gases at sea level are also compressed by the weight of the atmosphere above them. The force of the air weighing down over a unit of area is known as its atmospheric pressure, or air pressure. Why are we not crushed? The molecules inside our bodies are pushing outward to compensate. Air pressure is felt from all directions, not just from above.



Warm air rises, creating a low pressure zone; cool air sinks, creating a high pressure zone
(ck12.org, CC BY-SA)



This bottle was closed at an altitude of 3,000 meters where air pressure is lower. When it was brought down to sea level, the higher air pressure caused the bottle to collapse.

(Ck12.org, CC BY-SA)

At higher altitudes the atmospheric pressure is lower and the air is less dense than at lower altitudes. That's what makes your ears pop when you change altitude. Gas molecules are found inside and outside your ears. When you change altitude quickly, like when an airplane is descending, your inner ear keeps the density of molecules at the original altitude. Eventually the air molecules inside your ear suddenly move through a small tube in your ear to equalize the pressure. This sudden rush of air is felt as a popping sensation.

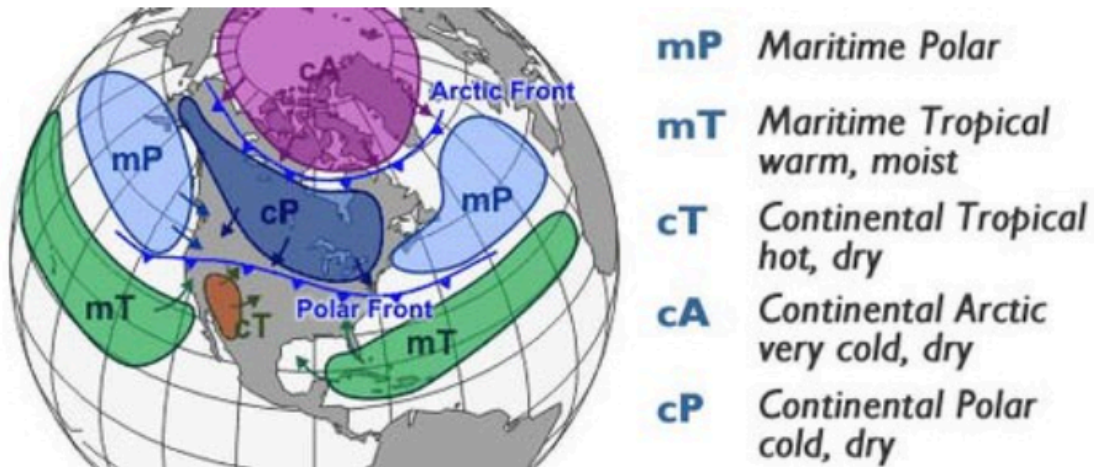
Air Masses

An air mass is a large body of air that has about the same conditions throughout. It has nearly the same temperature and humidity. For example, an air mass might have cold dry air. Another air mass might have warm moist air. The characteristics of an air mass depend on where the air mass formed. The air must stay over that location long enough to pick up those characteristics. When the air mass sits over a region for several days or longer, it picks up the distinct temperature and humidity characteristics of that region.

Formation of Air Masses

Most air masses form over polar or tropical regions. They may form over continents or oceans. Air masses are moist if they form over oceans. They are dry if they form over continents. Air masses that form over oceans are called maritime air masses. Those that form over continents are called continental air masses. The image below shows air masses that form over or near North America (Figure [below](#)). Temperate zones are ordinarily too unstable for air

masses to form. Instead, air masses move across temperate zones, so these areas are prone to having more varied weather.

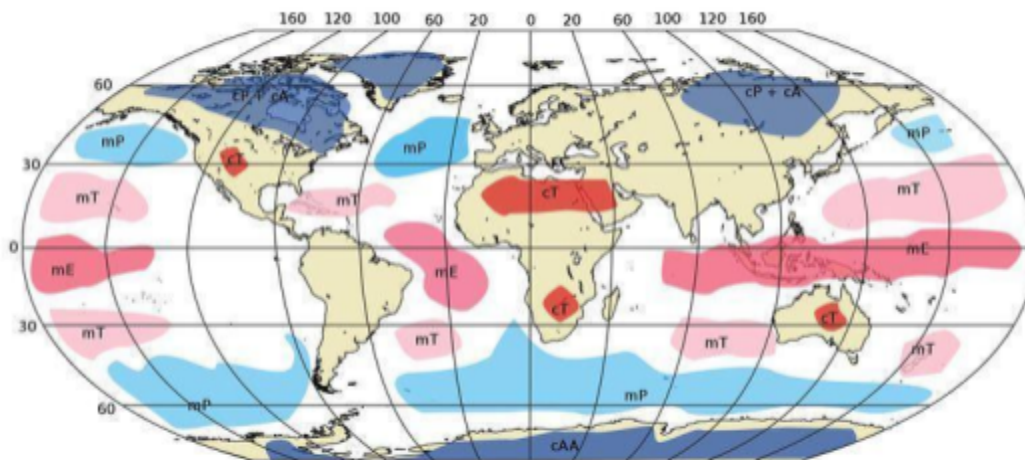


[Figure 2]

North American air masses.

Image courtesy of National Oceanic and Atmospheric Administration; labels added by CK-12 Foundation; <http://commons.wikimedia.org/wiki/File:Airmassesorigin.gif>; Public Domain

An air mass takes on the conditions of the area where it forms. For example, a continental polar air mass has cold dry air. A maritime polar air mass has cold moist air.



This picture shows where different types of air masses form. Some form over land and some form over water. They are also named for the area over which they form.
(Public Domain)

Movement of Air Masses

When a new air mass moves over a region it brings its characteristics to the region. This may change the area's temperature and humidity. Moving air masses cause the weather to change when they contact different conditions. For example, a warm air mass moving over cold ground may cause an inversion.

Why do air masses move? Winds and jet streams push them along. Cold air masses tend to move toward the equator. Warm air masses tend to move toward the poles. The Coriolis effect causes them to move on a diagonal. Many air masses move toward the northeast over the U.S. This is the same direction that global winds blow.

Air masses are slowly pushed along by high-level winds. When an air mass moves over a new region, it shares its temperature and humidity with that region. So the temperature and humidity of a particular location depends partly on the characteristics of the air mass that sits over it.

Fronts

Two air masses meet at a front. At a front, the two air masses have different characteristics and do not easily mix. One air mass is lifted above the other, creating a low pressure zone. If the lifted air is moist, there will be condensation and precipitation. Winds are common at a front. The greater the temperature difference between the two air masses, the stronger the winds will be. Fronts are the main cause of stormy weather.

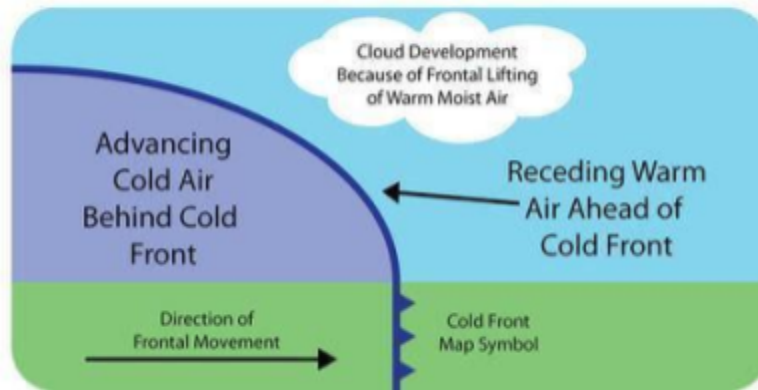
There are four types of fronts, three moving and one stationary. With cold fronts and warm fronts, the air mass at the leading edge of the front gives the front its name. In other words, a cold front is right at the leading edge of moving cold air and a warm front marks the leading edge of moving warm air.

Cold Fronts

When a cold air mass takes the place of a warm air mass, there is a cold front (next figure).



The map symbol for a cold front is blue triangles that point in the direction the front is moving.



The cold air mass slides beneath the warm air mass and pushes it up.

ck12.org, CC BY-SA

Imagine that you are standing in one spot as a cold front approaches. Along the cold front the cold air pushes up the warm air, causing the air pressure to decrease (Figure above). If the humidity is high enough clouds will develop. High in the atmosphere, winds blow ice crystals from the tops of these clouds. At the front, there will be a line of rain showers, snow showers, or thunderstorms with blustery winds. Behind the front is the cold air mass. This mass is drier, so precipitation stops. The weather may be cold and clear or only partly cloudy. Winds may continue to blow into the low pressure zone at the front.



A developing thunderstorm

Image: CC0

The weather at a cold front varies with the season.

- Spring and summer: the air is unstable so thunderstorms or tornadoes may form.
- Spring: if the temperature variation is high, strong winds blow.
- Autumn: strong rains fall over a large area.
- Winter: the cold air mass is likely to have formed in the frigid arctic, so there are frigid temperatures and heavy snows.

Warm Fronts

At a warm front, a warm air mass slides over a cold air mass (next figure). When warm air moves over the colder air the atmosphere is relatively stable.

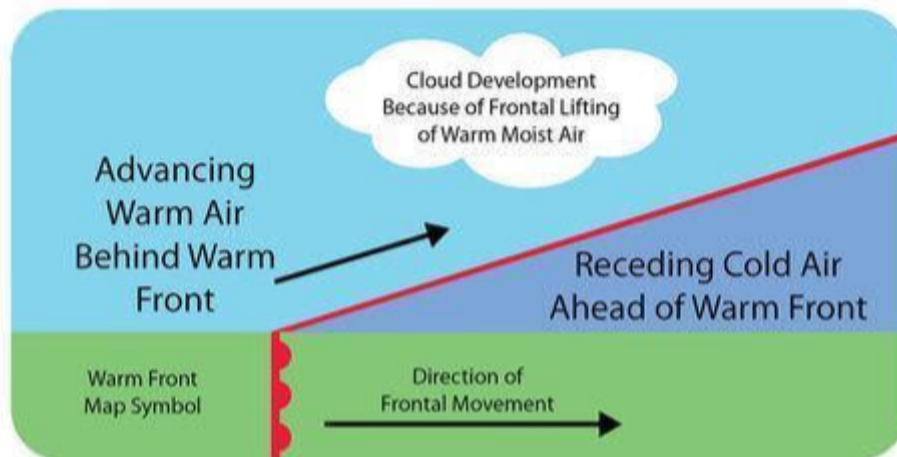
Imagine that you are on the ground in the wintertime under a cold winter air mass with a warm front approaching. The transition from cold air to warm air takes place over a long distance. The first signs of changing weather appear long before the front is

actually over you. Initially, the air is cold: the cold air mass is above you and the warm air mass is above it. High clouds mark the transition from one air mass to the other.

Over time, the clouds become thicker. As the front approaches, clouds appear and the sky turns gray. Since it is winter precipitation falls as snow. Winds grow stronger as the low pressure approaches. As the front gets closer, the cold air mass is just above you but the warm air mass is not too far above that. The weather worsens. As the warm air mass approaches, temperatures rise and snow turns to sleet and freezing rain. Warm and cold air mix at the front, leading to the formation of clouds and fog.



The map symbol for a warm front is red half-circles that point in the direction the front is moving.



Warm air moves forward to take over the position of colder air.

ck12.org, CC BY-SA

Stationary Fronts

At a stationary front the air masses do not move (next figure). A front may become stationary if an air mass is stopped by a barrier, such as a mountain range. A stationary front may bring days of rain, drizzle, and fog. Winds usually blow parallel to the front, but in opposite directions. After several days, the front will likely break apart.



The map symbol for a stationary front has red domes for the warm air mass and blue triangles for the cold air mass.

Occluded Fronts

An occluded front usually forms around a low pressure system (next figure). The occlusion starts when a cold front catches up to a warm front. The air masses, in order from front to back, are cold, warm, and then cold again.



The map symbol for an occluded front is mixed cold front triangles and warm front domes.

The weather at an occluded front is especially fierce right at the occlusion. Precipitation and shifting winds are typical. The Pacific Coast has frequent occluded fronts.

6.3.2 Air Pressure

Putting It Together

Yesterday, it was warm and sunny. Today it is windy, cloudy, and cold with rain.



*Storm Front by Nicholas D.,
<https://flic.kr/p/9VFSdS>, CC BY-NC*

Focus Questions

1. What causes different types of air masses to move?
2. What is the effect of air masses moving?
3. What type of front is related to the picture above?

6.3.3 Climate

Phenomenon

Every winter Salt Lake City experiences inversion. When an inversion occurs if you were to be in the valley, it would seem like clouds or fog when you looked in the sky. If you were to drive up the canyon to go skiing, the sky is clear and you can look down onto the inversion.



Image by Paweł Kuźniar; CC BY-SA

Observations & Wonderings

What are you observing about this phenomenon?

What are you wondering about this phenomenon?

6.3.3 Climate

Develop and use a model to show how unequal heating of Earth's systems cause patterns of atmospheric and oceanic circulation that determine regional climates. Emphasize how warm water and air move from the equator toward the poles. Examples of models could include Utah regional patterns such as lake-effect and wintertime temperature inversions. (ESS2.C, ESS2.D)



As you read this section, think about both the atmosphere and the ocean as systems as you learn about how thermal energy (heat) is distributed around Earth by these systems.

Overall Movement of Air and Water

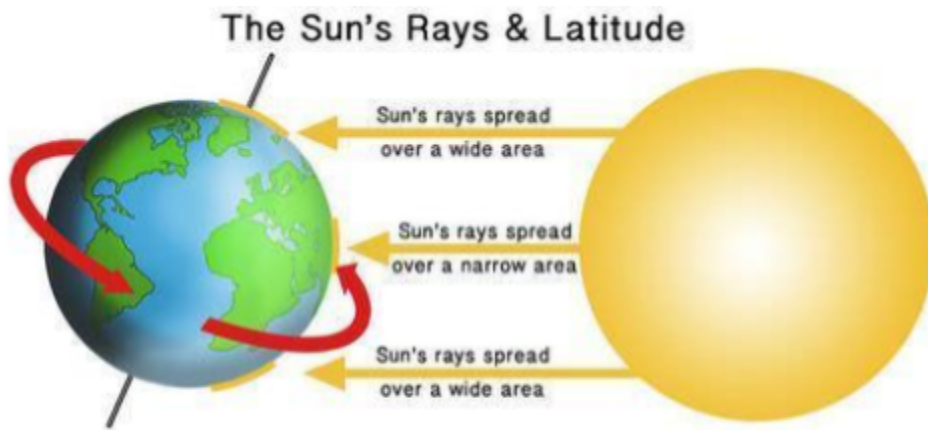
The atmosphere and hydrosphere make a system that together moves incoming heat from the sun from the equator out across the planet. In this system, we are talking about all of the air above ground that makes up the atmosphere. We are also talking about the water within the oceans of the planet. As the sun warms the air, it begins to rise and move. It forms a series of convection cells. When the movement of air is averaged out, you get three main air cells in the northern hemisphere. You also get three in the southern hemisphere. The overall motion is movement of air from the equator to the poles and back again. This air movement pushes on the ocean water. Through friction, it causes surface currents to form. These surface currents also move water that has absorbed energy at the equator. It moves to the poles, spreading out the total energy.

This is the global conveyor belt. The water freezes at the poles. It becomes salty and dense. The water sinks and slowly makes its way back to the equator. This transfer of energy, along with other geographical factors, cause areas with common weather to occur. The 30 year average of these areas is called climate. The following sections provide more information about atmospheric and oceanic circulation. This determines climate.

Energy and Latitude

Different parts of Earth's surface receive different amounts of sunlight (next figure). The Sun's rays strike Earth's surface most directly at the Equator. Near the poles, the Sun's rays strike the surface less directly. This spreads the rays

over a wide area. The more focused the rays are, the more energy an area receives, and the warmer it is.



In the summer the lowest latitudes get the most energy from the Sun. The highest latitudes get the least. (ck12.org, CC BY-SA)

Latitude is the distance north or south of the equator. It's measured in degrees, from 0° to 90°. Several climate factors vary with latitude. The difference in solar energy received at different latitudes causes unequal heating of Earth's surface. Places that get more solar energy will be warmer. Places that get less solar energy will be cooler. Warm air rises and cool air sinks. This principle means that air moves around the planet. The Earth's atmosphere carries heat, therefore the heat moves around the globe in ways that affect weather patterns. Temperature changes with latitude.

- At the equator, the sun's rays are most direct. Temperatures are highest.
- At higher latitudes, the sun's rays are less direct. The farther an area is from the equator, the lower is its temperature.
- At the poles, the sun's rays are least direct. Much of the area is covered with ice and snow, which reflect a lot of sunlight. Temperatures are lowest here.

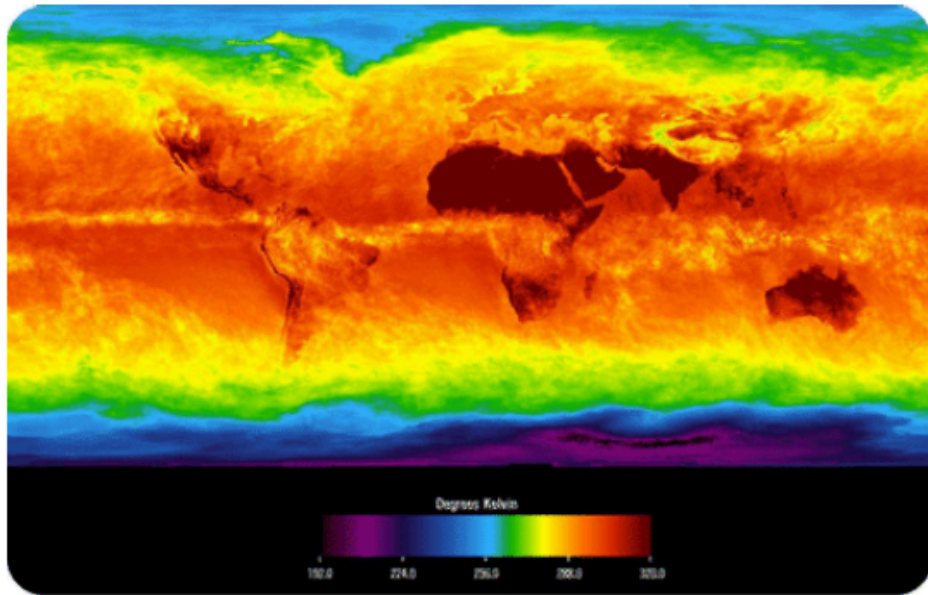


Image courtesy of NASA/JPL; Public Domain

Circulation of the Atmosphere and the Ocean

Global Air Currents

It may not look like it, but various processes work to moderate Earth's temperature across the globe. Atmospheric circulation brings warm air towards the poles and cold polar air towards the Equator. If the Earth's atmosphere didn't move the temperature differences would be much greater. In general, cold air masses tend to flow toward the Equator and warm air masses tend to flow toward the poles. This brings heat to cold areas and cools down areas that are warm. It is one of the many processes that act to balance out the planet's temperatures.

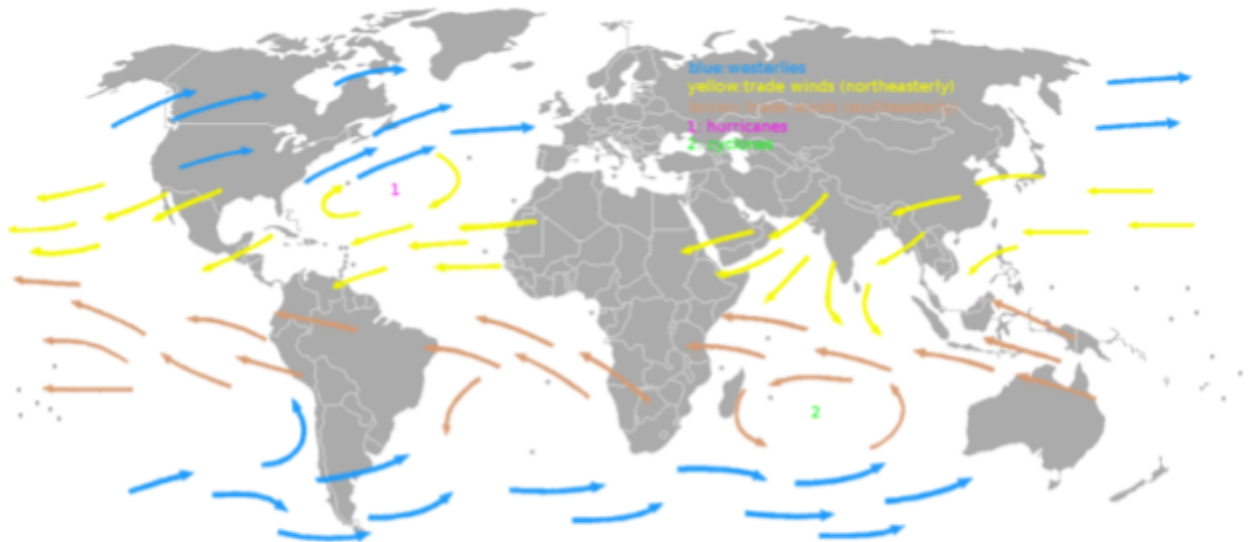
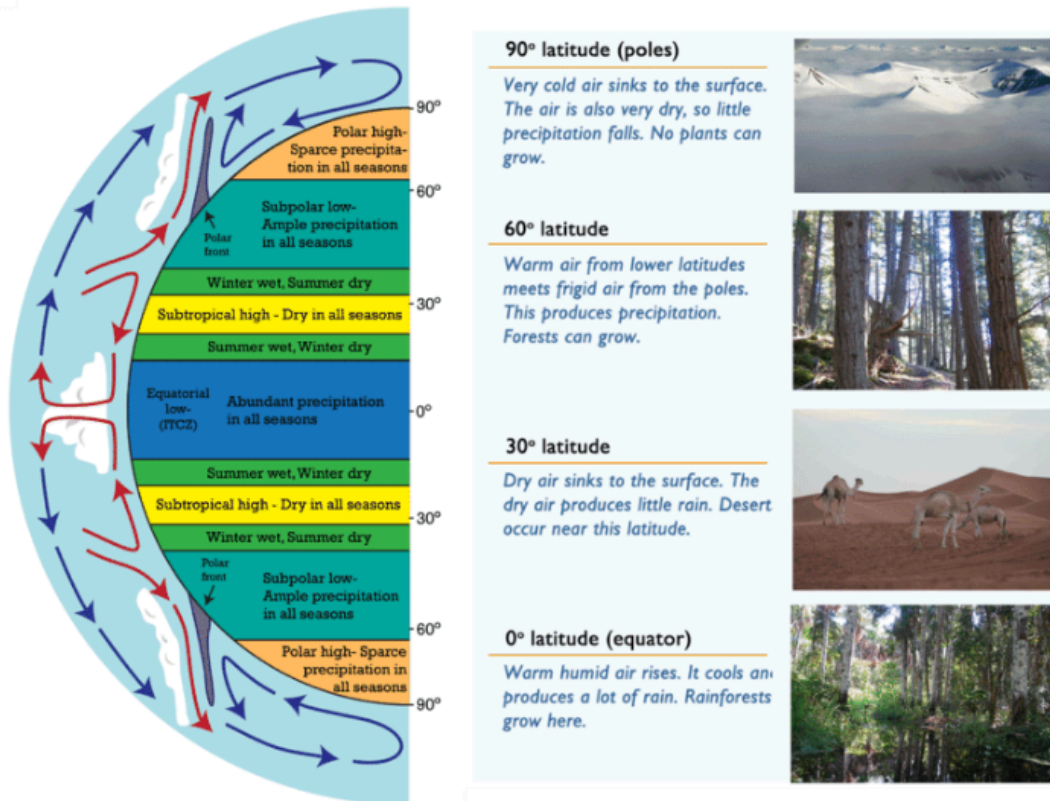


Diagram of global atmospheric circulation patterns.
Image: Public Domain

Ocean water moves in predictable ways along the ocean surface. Surface currents can flow for thousands of kilometers. They can reach depths of hundreds of meters. Surface currents do not depend on the weather. They remain unchanged even in large storms because they depend on factors that do not change. They are created by global wind patterns and the rotation of the Earth. They are important because they distribute heat around the planet and are a major factor influencing climate around the globe.

Global Air Currents and Climate

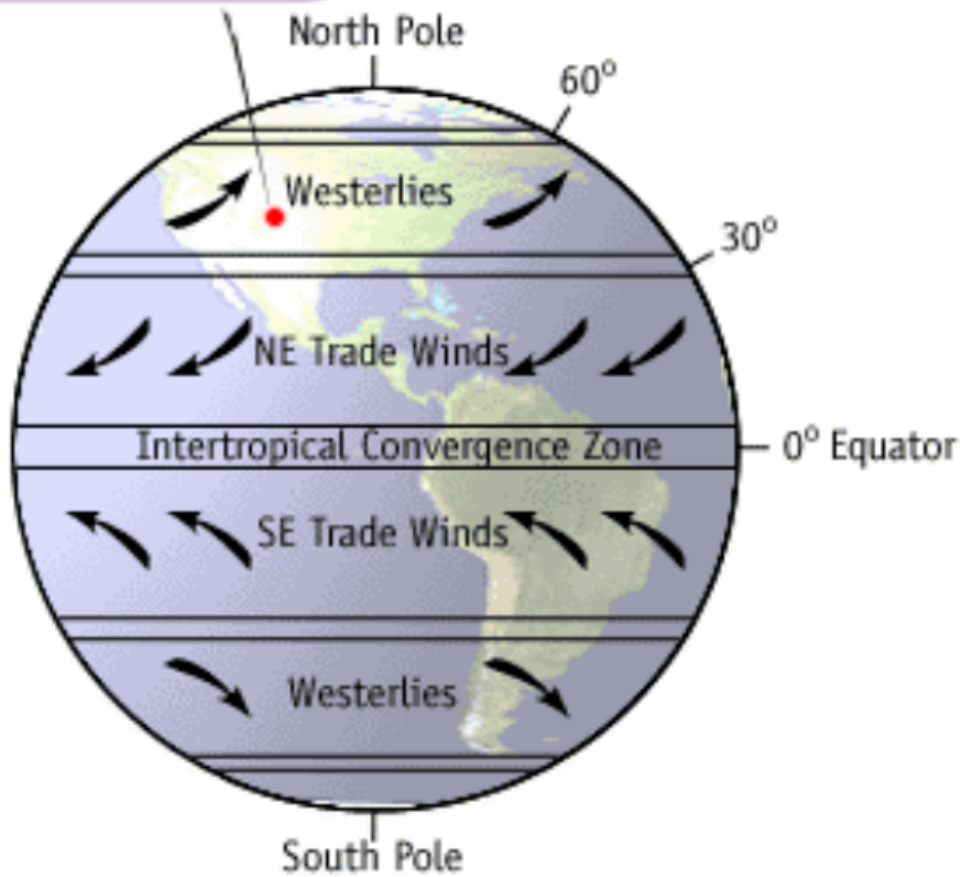


Credit: Global Circulation Diagram: CK-12 Foundation - Christopher AuYeung; Snow: Kitty Terwolbeck; Forest: Thomas Quine (Flickr:quinet); Desert: John Yavuz Can; Rainforest: Ivan Mlinaric
 Source: Snow: <http://www.flickr.com/photos/kittysfotos/7902668768/>; Forest: <http://www.flickr.com/photos/quinet/7406208974/>; Desert: <http://www.flickr.com/photos/yavuzcan/8177337117/>; Rainforest: <http://www.flickr.com/photos/eye1/3187012243/>
 License: Global circulation diagram: CC BY-NC 3.0; Remaining images: CC BY 2.0

Winds on Earth are either global or local. Global winds blow in the same direction all the time. They are connected to the unequal heating of Earth by the Sun and the rotation of the Earth. These predictable wind patterns allowed early sailing ships to travel around the globe. Ocean currents created by these wind patterns move ocean water around the planet. Normally warm water at the Equator will be pushed to the polar areas and colder water will be pushed to the equator. The next figure below shows the direction that these winds blow. Global winds are the prevailing, or usual, winds at a given latitude. The winds move air masses, which causes weather.

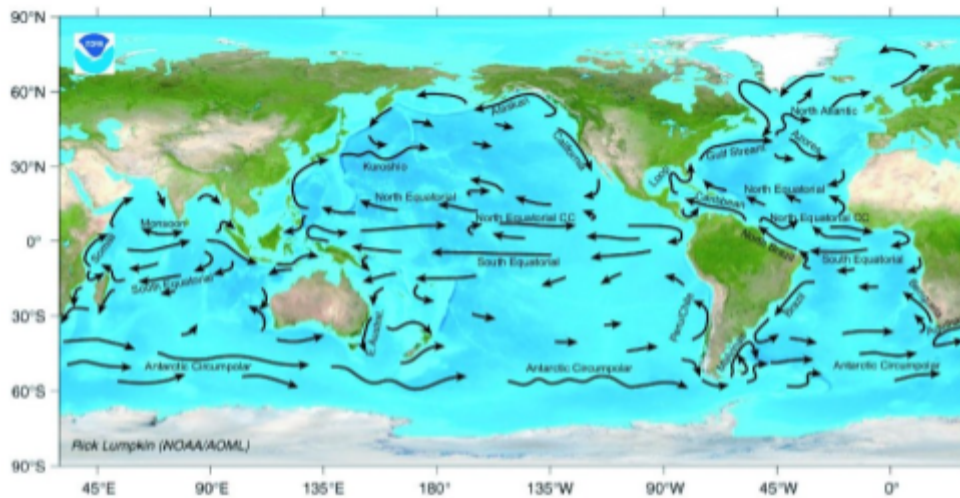
The direction of prevailing winds determines which type of air mass usually moves over an area. For example, a west wind might bring warm moist air from over an ocean. An east wind might bring cold dry air from over a mountain range.

Most of the U.S. has westerly winds.



Credit: Courtesy of National Park Services and Parks as Classroom Public Domain

Surface Currents



Major ocean surface currents

Image: Public Domain

Surface currents play a huge role in Earth's climate. The Equator and poles have very different climates. These regions would have very different climates if ocean currents did not transfer heat from the equatorial regions to higher latitudes.

An example of how ocean currents affect an area's climate is the Gulf Stream. The Gulf Stream is a river of warm water in the Atlantic Ocean. It is about 160 kilometers wide and about a kilometer deep. Water that enters the Gulf Stream is heated as it travels along the Equator. The warm water then flows up the east coast of North America and across the Atlantic Ocean to Europe. The energy the Gulf Stream transfers is more than 100 times the world's energy demand.

The Gulf Stream's warm waters raise temperatures in the North Sea. This raises the air temperatures over land between 3 to 6°C (5 to 11°F). London is about six degrees further south than Quebec. However, London's average January temperature is 3.8°C (38°F). Quebec's is only -12°C (10°F). Because air traveling over the warm water in the Gulf Stream picks up a lot of water, London gets a lot of rain. Quebec is much drier and receives its precipitation as snow. When water reaches high latitudes where the temperatures are cold enough to cause the density to increase, it sinks into the deep ocean basins as demonstrated in the next figure.

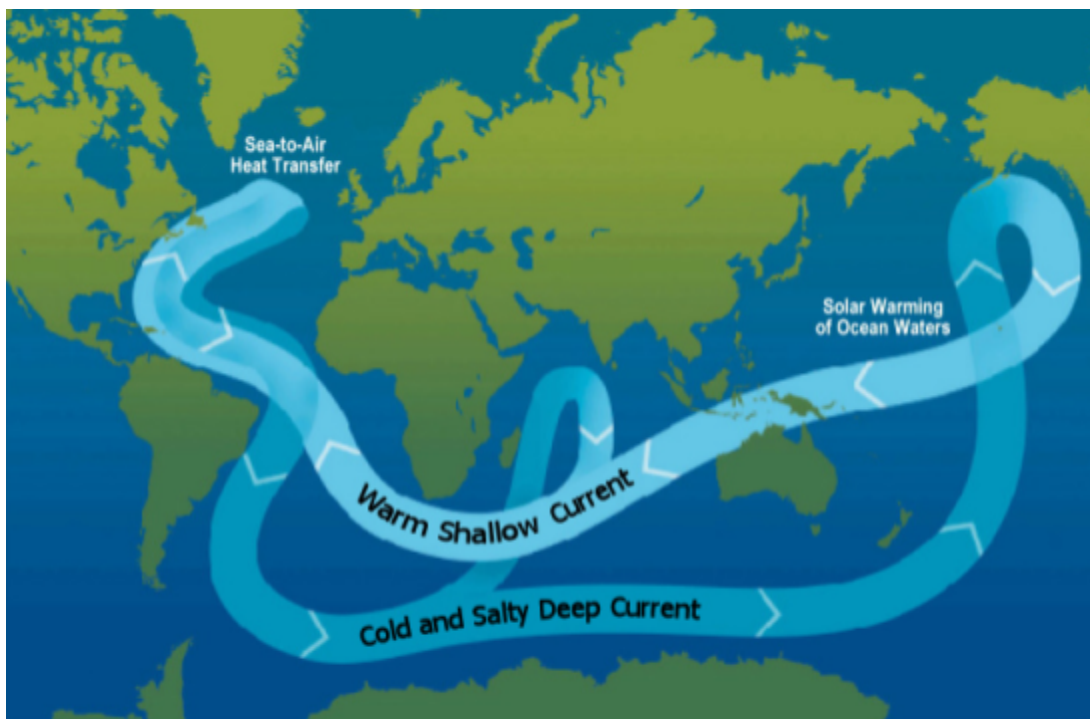


Image: Public Domain

Temperature Inversion

Sometimes there is a temperature inversion, in which air temperature in the troposphere increases with altitude and warm air sits over cold air. Inversions are very stable and may last for several days or even weeks. Inversions form:

- Over land at night or in winter when the ground is cold. The cold ground cools the air that sits above it, making this low layer of air denser than the air above it.
- Near the coast, where cold seawater cools the air above it. When that denser air moves inland, it slides beneath the warmer air over the land.

Since temperature inversions are stable, they often trap pollutants and produce unhealthy air conditions in cities (Figure below).



Image by Ed Dunens; <https://flic.kr/p/k1uuYY>; CC BY 2.0

Smoke makes a temperature inversion visible. The smoke is trapped in cold dense air that lies beneath a cap of warmer air.

At the top of the troposphere is a thin layer in which the temperature does not change with height. This means that the cooler, denser air of the troposphere is trapped beneath the warmer, less dense air of the stratosphere. Air from the troposphere and stratosphere rarely mix.

Mountains and Climate

Did you ever hike or drive up a mountain? Did you notice that it was cooler near the top? Climate is not just different on a mountain. Just having a mountain range nearby can affect the climate.

Altitude and Temperature

Air temperature falls at higher altitudes. You can see this in Figure below. Why does this happen? Since air is less dense at higher altitudes, its molecules are spread farther apart than they are at sea level. These molecules have fewer collisions, so they produce less heat.

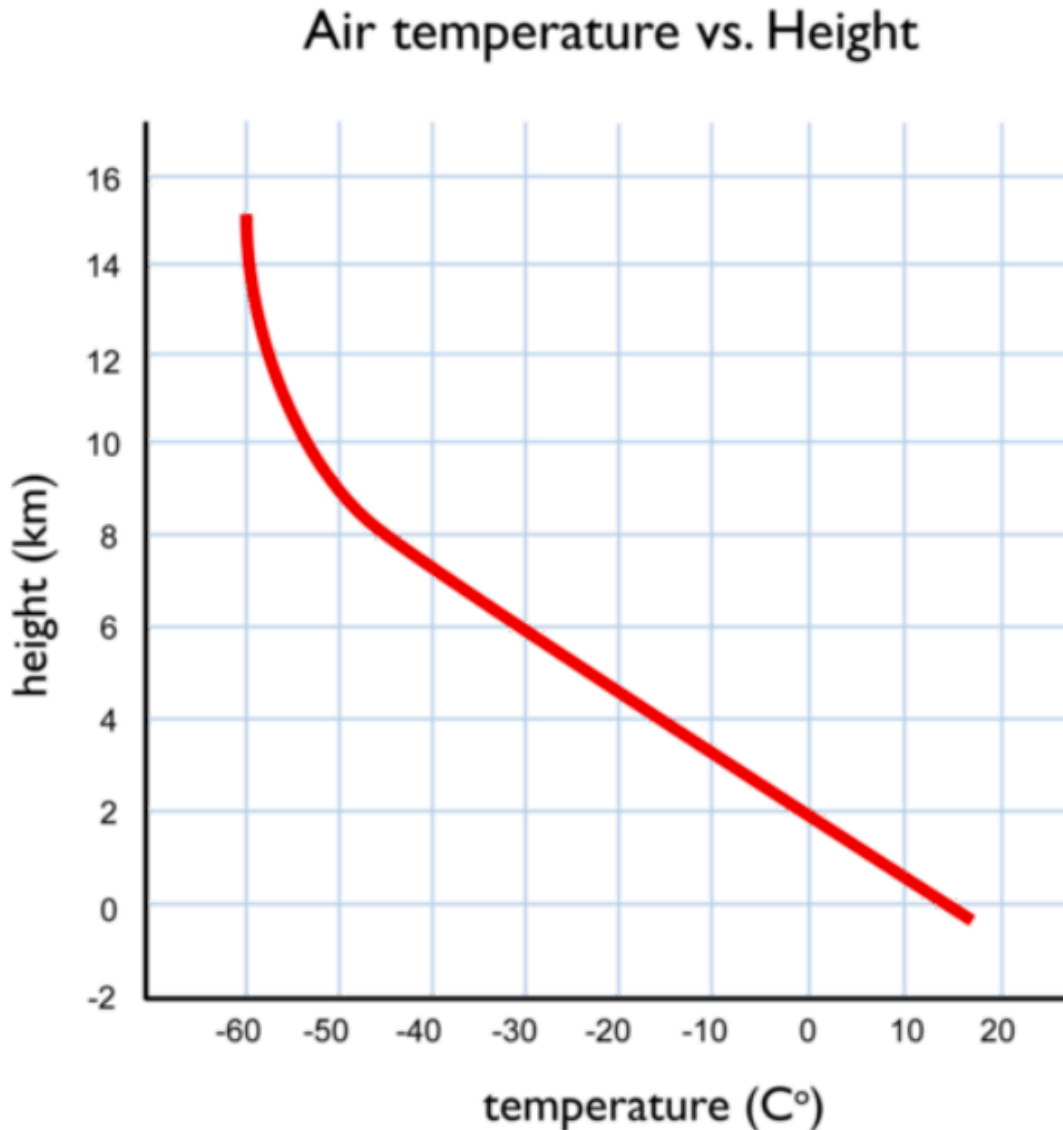


Image by Hana Zavadska; CK-12 Foundation; CC BY-NC 3.0

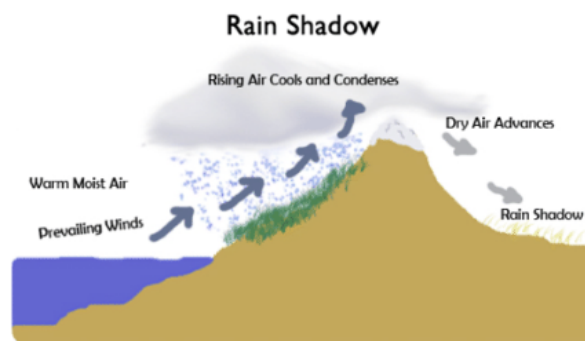
Look at the mountain in Figure below. The peak of Mount Kilimanjaro, Tanzania (Africa, 3° south latitude) is 6 kilometers (4 miles) above sea level. At 3°S it's very close to the equator. At the bottom of the mountain, the temperature is high year round. How can you tell that it's much cooler at the top?



Image by Dan Heap; <https://flic.kr/p/b1ao1a>; CC BY 2.0

Mountains and Precipitation

Mountains can also affect precipitation. Mountains and mountain ranges can cast a rain shadow. As winds rise up a mountain range the air cools and precipitation falls. On the other side of the range the air is dry and it sinks. So there is very little precipitation on the far (leeward) side of a mountain range. The figure below shows how this happens.



[Figure 10]

Image by User:Bariot/Wikimedia Commons; Public Domain

6.3.3 Climate

Putting It Together

Every winter Salt Lake City experiences inversion. When an inversion occurs if you were to be in the valley, it would seem like clouds or fog when you looked in the sky. If you were to drive up the canyon to go skiing the sky is clear and you can look down onto the inversion.



Image by Paweł Kuźniar; CC BY-SA

Focus Questions

1. Why do inversions form?
2. How do they have to relate to the uneven heating of the Earth?

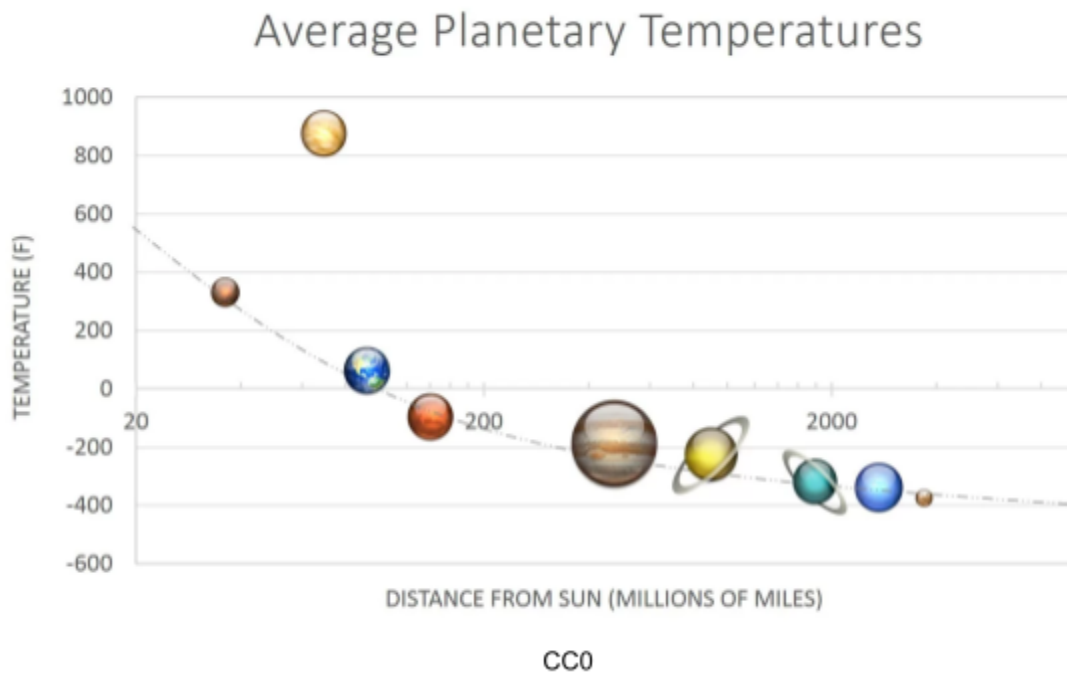
Final Task

Develop a model to show the Earth processes that cause inversions to occur.

6.3.4 The Greenhouse Effect

Phenomenon

Although Mercury is the planet closest to the sun, Venus is the hottest planet in our solar system.



Observations & Wonderings

What are you observing about this phenomenon?

What are you wondering about this phenomenon?

6.3.4 The Greenhouse Effect

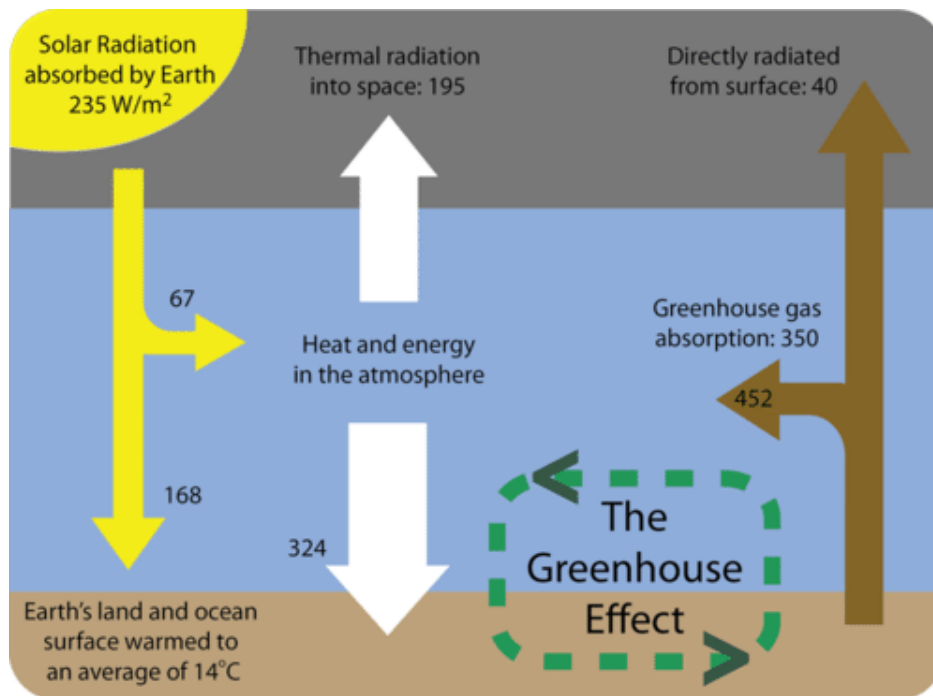
Construct an explanation supported by evidence for the role of the natural greenhouse effect in Earth's energy balance, and how it enables life to exist on Earth. Examples could include comparisons between Earth and other planets such as Venus and Mars. (ESS2.D)



Energy from the Sun interacts with Earth and the atmosphere. The natural greenhouse effect contributes to Earth's energy balance, and allows for life to exist on Earth.

What is the Greenhouse Effect?

Greenhouse gases warm the atmosphere by trapping heat. Some of the heat that radiates out from the ground is trapped by greenhouse gases in the troposphere. Like a blanket on a sleeping person, greenhouse gases act as insulation for the planet. The warming of the atmosphere because of insulation by greenhouse gases is called the greenhouse effect (Figure below). Greenhouse gases are the component of the atmosphere that moderate Earth's temperatures. It keeps Earth warm. The greenhouse effect allows Earth to have temperatures that can support life.



Gases that absorb heat in the atmosphere are called greenhouse gases. They include carbon dioxide and water vapor. Greenhouse gases act as insulation for the planet. The warming of the atmosphere is because heat is absorbed and emitted by greenhouse gases. Greenhouse gases are the components of the atmosphere that moderate Earth's temperatures.

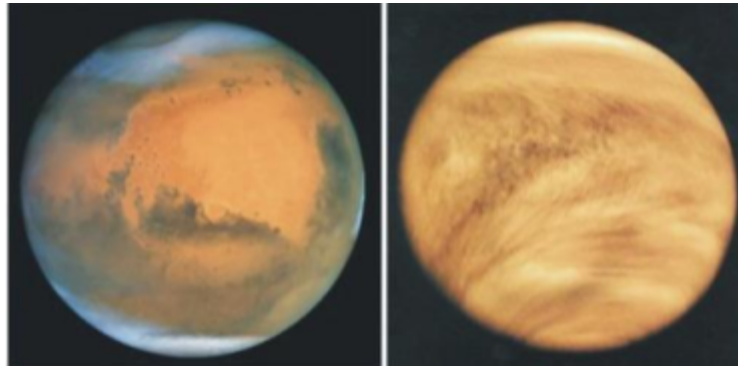
Greenhouse gases include Carbon Dioxide (CO₂), Water (H₂O), methane, O₃, and nitrous oxides (NO and NO₂). All are a normal part of the atmosphere. The greenhouse effect is a natural feature of Earth's atmosphere. Without the greenhouse effect, Earth's surface temperature would average -18°C (0°F). This is too cold to support life as we know it. With the greenhouse effect, Earth's surface temperature averages 15°C (59°F). It is this temperature range to which today's diversity of life has adapted. The table below shows where different gases come from.

Greenhouse Gas	Where It Comes From
Carbon dioxide	Respiration, volcanic eruptions, decomposition of plant material
Methane	Decomposition of plant material under some conditions, biochemical reactions in stomachs
Nitrous oxide	Produced by bacteria
Ozone	Atmospheric processes

The movement of energy due to the greenhouse effect is shown in the figure below. As much as 30% of the solar radiation which reaches the Earth's surface is reflected back into space. About 70% is absorbed as heat. This heat warms the land, waters, and atmosphere. If there were no atmosphere, most of the heat would radiate back out into space. Earth's atmosphere contains molecules of water (H₂O), carbon dioxide (CO₂), methane (CH₄), and ozone (O₃). They absorb some of the infrared radiation. Some of this radiation also warms the atmosphere. Some are radiated down to the Earth's surface or out into space. A balance between the heat which is absorbed and the heat which is radiated out into space results in a balance which maintains a constant average temperature for the Earth.

Different greenhouse gases have different abilities to trap heat. For example, one methane molecule traps 23 times as much heat as one CO₂ molecule.

If we compare Earth's atmosphere to the atmospheres which surround Mars and Venus (next figure) we can understand why the composition of the Earth's atmosphere is important. Mars' atmosphere is very thin. It has less than 1% of the surface pressure of the Earth. The thin atmosphere cannot hold heat. The average surface temperature is -5°C (-67°F) even though that atmosphere is 95% CO_2 and contains a great deal of dust. Daily differences in temperature are extreme. Mars's atmosphere cannot hold heat.



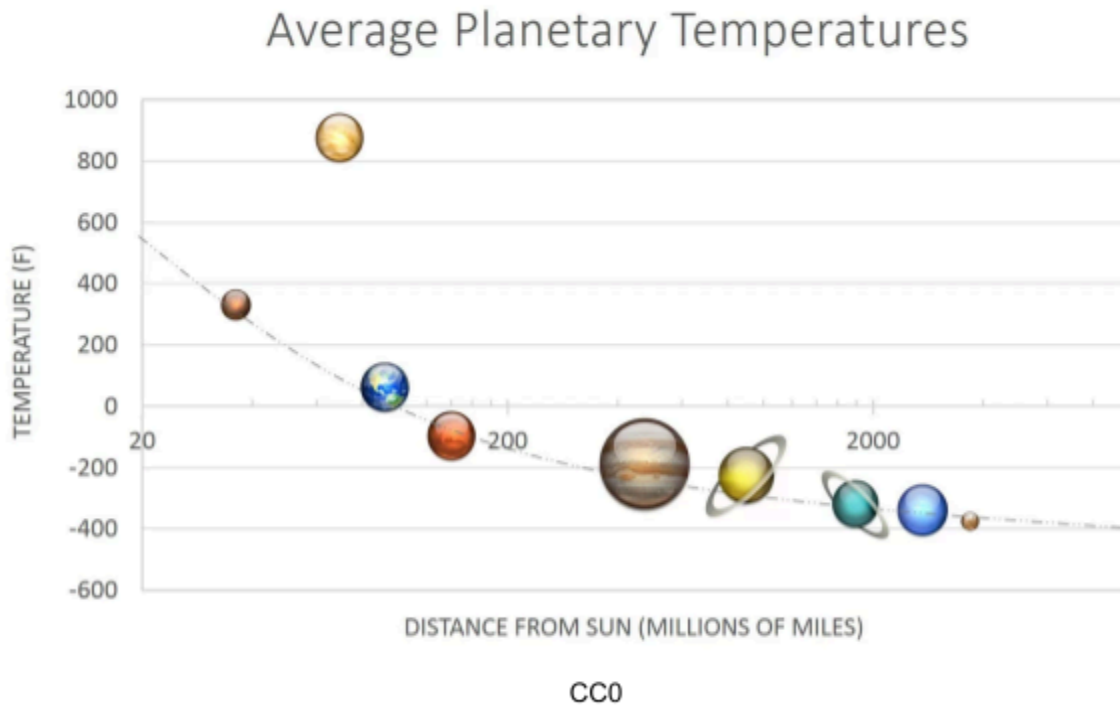
The thickness of a planet's atmosphere strongly influences its temperature through the greenhouse effect. Mars (left) has an extremely thin atmosphere, and an average temperature near -55°C . Venus (right) has a far more dense atmosphere than Earth, and surface temperatures reach 500°C .
(Public Domain)

Venus' atmosphere is much thicker than Earth's. The air pressure is 92 times the surface pressure of Earth. 96% of the atmosphere is CO_2 . This strong greenhouse effect heats the surface temperature of Venus as high as 500°C , the hottest of any planet in our solar system. The thick atmosphere prevents heat from escaping at night. Daily temperature differences are small.

6.3.4 The Greenhouse Effect

Putting It Together

Although Mercury is the planet closest to the sun, Venus is the hottest planet in our solar system.



Focus Questions

1. Explain how the atmosphere enables life to exist on Earth.
2. Why can't Venus and Mars, though near Earth, sustain life?

Final Task

Construct an explanation on how the Earth's temperature would be affected if the greenhouse gases in the atmosphere were different? How would Earth's temperature be affected if the greenhouse gases in the atmosphere increased? What if they decreased?

Strand 4: Ecosystems

Chapter Outline

- 4.1 Ecosystems (6.4.1)
- 4.2 Interactions Among Organisms (6.4.2)
- 4.3 Matter and Energy in Ecosystems (6.4.3)
- 4.4 Stability of Populations in Ecosystems (6.4.4)
- 4.5 Designing Solutions for Preserving Ecosystems (6.4.5)



GreatBlueHeronTampaFL by Chad E.,
<https://commons.wikimedia.org/wiki/File:GreatBlueHeronTampaFL.JPG>
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Ecology is the study of ecosystems. That is, ecology is the study of how living organisms interact with each other and with the nonliving part of their environment. The living organisms, such as plants and animals, interact with each other and the environment around them. Consistent interactions occur within and between species in various ecosystems as organisms obtain

resources, change the environment, and are affected by the environment. This influences the flow of energy through an ecosystem, resulting in system variations. Additionally, ecosystems benefit humans through processes and resources, such as the production of food, water and air purification, and recreation opportunities. Scientists and engineers investigate interactions among organisms and evaluate design solutions to preserve biodiversity and ecosystem resources.

6.4.1 Ecosystems

Phenomenon

Ducks on a pond in Ogden, Utah. July 2023.



Photo by L. Pohahau

Observations & Wonderings

What are you observing about this phenomenon?

What are you wondering about this phenomenon?

6.4.1 Ecosystems

Analyze data to provide evidence for the effects of resource availability on organisms and populations in an ecosystem. **Ask questions** to predict how changes in resource availability affects organisms in those ecosystems. Examples could include water, food, and living space in Utah environments. (LS2.A)



Changes to the living and nonliving parts of an ecosystem might affect the organisms and populations in the ecosystem.

What is an Ecosystem?

An ecosystem consists of all the nonliving factors and living organisms interacting in the same habitat. Living organisms are biotic factors. The biotic factors of an ecosystem include all the populations in a habitat. That includes all the species of plants, animals, and fungi, as well as all the microorganisms. Abiotic factors include sunlight, soil, water, temperature, and air impact the living organisms greatly contribute to the environment.

Utah has four different types of ecosystems. These include the desert, wetland, alpine, and forest ecosystems. Each system contains biotic and abiotic factors that characterize the area. Let's explore each of the ecosystems.

Utah's Desert Ecosystems



By Palacemusic - Prise de vue personnelle, CC BY-SA 3.0,
<https://commons.wikimedia.org/w/index.php?curid=6020905>

Utah is known for its deserts and beautiful rock formations. Most of the southern and western parts of the state are desert. The desert ecosystems do not receive a lot of precipitation. It tends to become hot in the day and gets cold at night. The lack of water results in sandy soil that does not have a lot of nutrients. The soil also does not hold a lot of water, so when it does rain, the area will sometimes have flash floods. Plants and animals in the desert have adapted and do not require a lot of water to survive.



Public Domain,
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By Jim Harper - en-wikipedia, CC BY-SA 2.5,
<https://commons.wikimedia.org/w/index.php?curid=1054130>

For example, the Prickly Pear Cactus (see picture above) stores water in its stems and roots. The roots are shallow so they can absorb more water when it rains. Prickly needles surround the outside of the cactus to protect it from being eaten. The Leopard Lizard is a common animal in the Utah deserts. It has adapted to the hot ground by growing long legs and toes to keep its body up! Another animal found in desert ecosystems is the Jack Rabbit (see picture above). This animal is known for its large ears and feet. They use their ears to keep them cool! Their hind legs are very long so they can run quickly and avoid predators.

Utah's Wetland Ecosystems



*Above: Image by 12019; pixabay.com; CC0
Left: Image by makamuki0; pixabay.com; CC0*

Wetlands are areas located between water and land. The land is covered with water for most of the year, but the water can rise and fall. Utah has two types of wetlands. The Great Salt Lake area has a saltwater ecosystem. Utah Lake has a freshwater wetland ecosystem. The dirt is typically saturated with water. Wetlands also have a seasonal change in temperature and precipitation. Wetlands are beneficial because they provide water sources for plants and animals. The plants in the wetlands do not need long roots. Instead, they have leaves that spread across the water. Some common plants found in wetlands areas of Utah include cattails and duckweed. The Great Salt Lake area is so salty most animals cannot survive. However, tiny brine shrimp do well in the area. They are eaten by many of the birds, such as the Snowy Egret, who use the wetlands as a place to stop during migration.

How do the abiotic factors of the wetlands help the wildlife survive?

Utah's Alpine Ecosystems

The alpine ecosystem is defined as an area that is so high in elevation that regular trees and plants cannot grow. The ground is covered in snow and is frozen almost the entire year. Most of the precipitation comes from snow. Wind often blows and dries out the plants in alpine areas. Plants in alpine ecosystems are short. They commonly grow in clusters and have tough leaves so they don't blow away in the wind. Two examples of plants that grow in the alpine

ecosystems are the Tufted Rockmat and the Woolly Butterweed. The Muscoid Fly is a small animal that survives in the high altitudes by climbing into flowers at night that are shaped like solar reflectors and keep the flies warm!



Plxabay.com, CC0

Why do you think some plants in alpine ecosystems grow in clusters?

Utah's Forest Ecosystems



An aspen forest in the summertime
Image by BldrJanet; pixabay.com; CC0

The forest ecosystem is defined as an area with temperatures that change throughout the year, but it receives enough precipitation to support plants and animals. The forests in Utah usually have four seasons. The soil is very rich because of the plants and animals. Trees, shrubs, flowers, and small plants are common in forest ecosystems. The trees are much larger in the forest than other areas. A common tree in Utah's forests include Quaking Aspen, which can grow up to 50 feet tall. Another common tree is the Cottonwood. They usually grow near water and produce flowers in the spring that look like puffs of cotton. Mule deer (see below), Boreal Chorus Frog (shown below), and the Red Fox, all call the forest home.



Image by MikeGoad; pixabay.com; CC0



By The original uploader was Tnarg 12345 at English Wikipedia. - Transferred from en.wikipedia to Commons., CC BY-SA 3.0, <https://commons.wikimedia.org/w/index.php?curid=2232718>

Think about the difference between trees in the forest and the smaller shrubs found in the Alpine ecosystem. What are some of the abiotic factors that affect tree growth?

Within an ecosystem, organisms will also vary depending on the availability of resources. If an ecosystem changes, it can cause changes to the population of organisms in that ecosystem. For example, if fertilizers from agricultural runoff enter a freshwater pond, it causes more algae to grow. Algae blocks sunlight from reaching the bottom of the pond. The growth of organisms, living on the bottom, which require sunlight is limited. Droughts, many years with significantly less precipitation, can also cause changes to an ecosystem.

What might happen to a forest ecosystem if there was a major drought?

6.4.1 Ecosystems

Putting It Together



Photo by L. Pohahau

Ducks on a pond in Ogden, Utah. July 2023.

Writing Performance Task:

In the tasks that follow, you will analyze data, use cause and effect relationships, and construct an explanation in order to predict how changes in resource availability affects organisms of a pond in UT.

Gather:

Ogden Pond, pictures taken in July, 2023.



Photo by L. Pohahau

- A. What types of plants do you see around the pond?
- B. What is the water level like in the pond? Is it high, low, or average?
- C. How clear or murky is the water in the pond?
- D. Are there any animals eating plants or other animals?

Reason:

Scenario:

You are participating in your school science club and studying the Ogden pond ecosystem. Your task is to observe and record data about different organisms living in the pond. Here's what you found:

		Resources		
Organism	Number of Organisms	Average Available Food (grams)	Suitable Water Quality (pH) for species	Ideal Sunlight (hours/day)
Frogs	150	1000	6.5	8
Fish	200	8000	7.0	10
Pond Snails	300	500	6.8	6
Water Lilies	100	150	7.2	9
Dragonflies	50	200	6.5	11

Table 1: Ogden Pond Ecosystem

Note: pH balance is a way to measure how acidic or basic (alkaline) is. The pH scale goes from 0 to 14:

- A pH of 7 is neutral, which means it's neither acidic nor basic.
- Numbers less than 7 mean the substance is acidic (like lemon juice or vinegar).
- Numbers greater than 7 mean the substance is basic (like baking soda).

A. Based on the information above, complete the Abiotic or Biotic table below. Identify if the resource is abiotic or biotic. Explain why it is important to the organisms in the Ogden pond ecosystem. The first one has been done for you.

	Abiotic	Biotic	Why it is important to the organism
Number of organisms	✓		Each organism plays a specific role in the food chain. If there are too few predators, prey populations can grow too large and over consume plants. Conversely, if there are too few prey, predators might starve.
Food			
Water quality			
Sunlight			

Table 2: Abiotic or Biotic

B. In general, why do you think that biotic and abiotic factors are important for the survival of organisms in ecosystems?

C. How might changes in abiotic factors impact biotic factors in an ecosystem?

Communicate:

A. Based on the table 1 Ogden Pond Ecosystem given above, pick an organism and describe what would happen to your organism population if the following resources changed:

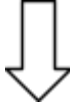
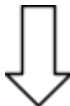
My organism is: _____		
What would happen to the population of your organism if...	The population would go (circle one):	Explain your choice.
The available food was cut in half?	 or 	
Chemical waste is dumped into the pond? (caused the pH level increased drastically)	 or 	
The amount of sunlight increased by 50%?	 or 	
1/3 of the water from the pond is taken and sourced for local neighborhoods?	 or 	

Table 3: All about Resource

Expected criteria: _____ Explains the effect of decreased food _____ Explains the effect of increased pH _____ Explains the effect of increased sunlight _____ Explains the effect of space being taken from the pond
--

6.4.2 Interactions Among Organisms

Phenomenon

Momma bear with a sockeye pink salmon at Kamchatka in Russia and a honeybee on a flower.



Kandukuru Nagarjun from Bangalore, India, CC BY 2.0, via Wikimedia Commons



Image: by Fielding Smith, CC BY 3.0, via Wikimedia Commons

Observations & Wonderings

What are you observing about this phenomenon?

What are you wondering about this phenomenon?

6.4.2 Interactions Among Organisms

Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems. Emphasize consistent interactions in different environments such as competition, predation, and mutualism. (LS2.A)



Analyzing patterns allows us to identify similarities and differences within systems. There are patterns of interactions in all ecosystems.

Interactions among Organisms

All ecosystems have the same general roles that organisms fill. It's just that the organisms that fill those roles are different. For example, every ecosystem must have some organisms that produce food in the form of chemical energy. These organisms are primarily algae in the oceans, plants on land, and bacteria at hydrothermal vents.

Organisms interact with each other in different ways; however, those interactions are the same across every ecosystem. For example, some species compete for the same resources. Other species interact in predator-prey relationships.

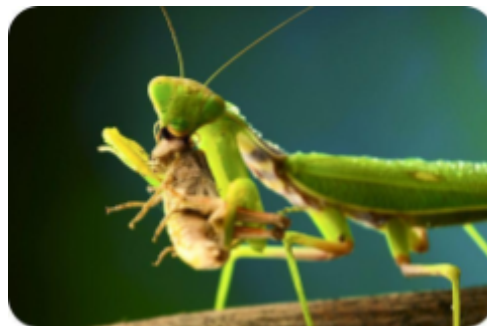
Some interactions are beneficial to both species. These relationships are essential to maintaining the balance of organisms in an ecosystem.

Competition

Competition occurs between species that try to use the same resources. When there is competition, one species may move or adapt so that it uses different resources or obtains the resources in a different way. It may live at the tops of trees and eat leaves that are somewhat higher on bushes, for example. If one species cannot find a way to compete, it will die out.

Predator-Prey

The predator-prey relationship is when a predator organism feeds on another living organism or organisms, known as prey. In some predator-prey relationships the predator hunts, kills, and eats its prey. When you think of an animal hunting for its food, large animals such as lions may come to mind. However, many tiny animals also hunt for their food. For example, the praying



Ck12.org, CC BY-SA

mantis eats grasshoppers. To eat the grasshopper, the praying mantis first has to catch the grasshopper, which is a form of hunting.

Mutualism

Some relationships between species are beneficial to the interacting species. Mutualism describes a relationship between two different species in which both species are helped.

An example of mutualism is between deer and the bacteria that live in their intestines. The bacteria get a place to live. Meanwhile, the bacteria help the deer digest food. Both species benefit, so this is a mutualistic relationship.

The clownfish and the sea anemones also have a mutualistic relationship. The clownfish protects the anemone from anemone-eating fish, and the stinging tentacles of the anemone protect the clownfish from predators.



Ck12.org, CC BY-SA

6.4.2 Interactions Among Organisms

Putting It Together



Momma bear with a sockeye pink salmon at Kamchatka in Russia and a honeybee on a flower.

Writing Performance Task:

In the tasks that follow, you will be analyzing patterns of interactions among organisms across different ecosystems. You will then construct an explanation predicting interactions in another ecosystem.

Gather:

Below you are given information about three different ecosystems: a forest, a coral reef, and a grassland. In each ecosystem, there are examples of interactions between organisms.

Forest Ecosystem	Coral Reef Ecosystem	Grassland Ecosystem
Wolves <u>hunting</u> deer. Trees <u>competing</u> for sunlight. Birds <u>eating</u> insects off deer.	Coral and algae <u>competing</u> for space. Sharks <u>hunting</u> fish. Clownfish <u>living in</u> sea anemones.	Oxpeckers <u>eating</u> ticks off buffalo. Grasses <u>competing</u> for water. Lions <u>hunting</u> zebras.

- A. What patterns do you notice about interactions in the ecosystems? Identify at least two patterns.

- B. Why do these patterns of interactions occur consistently across different environments? Select the best answer:

1. Because all ecosystems have the same species.
2. Because organisms in different ecosystems all need similar resources to survive, such as food, water, and space.
3. Because scientists can only study one environment at a time.
4. Because people influence the interactions between living things and their surroundings.

Reason:

Choose one of the ecosystems from the previous section and complete the table below.

Ecosystem I chose: _____		
Interaction	Description	Example from ecosystem
Competition		
Predator-Prey		
Mutualism		

Description options:

- both organisms benefit from the interaction
- one organism feeds on another organism (i.e. hunting)
- species try to use the same resources

Communicate:

Construct a short explanation predicting what might happen in another ecosystem, like a desert, if similar interactions occur. Use the patterns you've identified to support your prediction. Use the reading from the chapter to help you if needed.

Expected criteria:

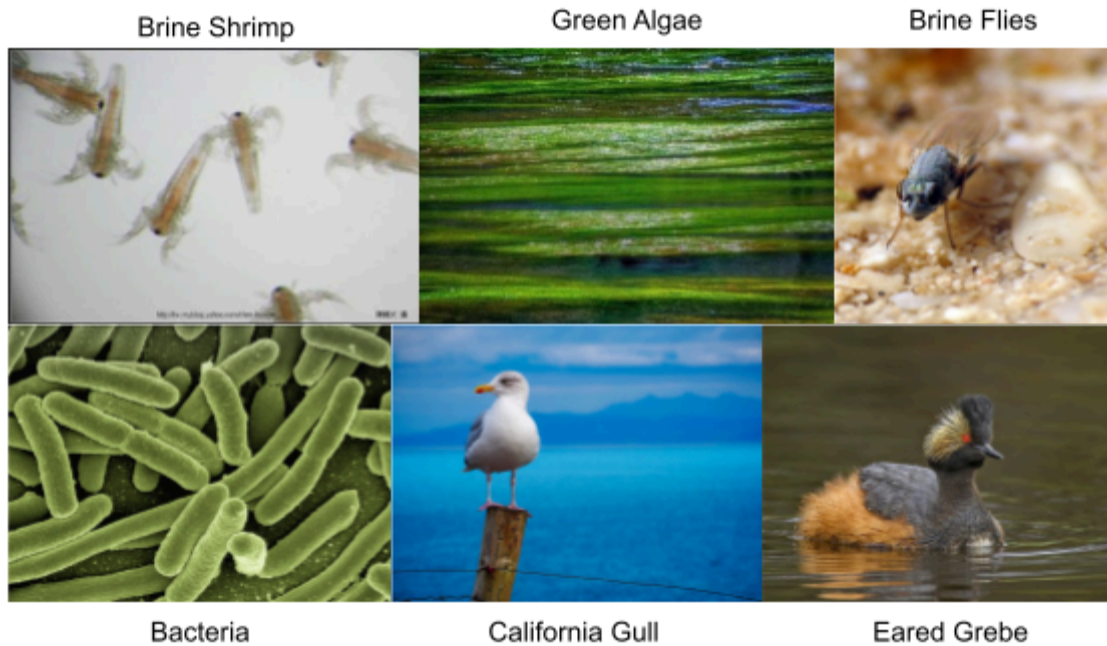
- _____ Identify the ecosystem type (desert or other not already used)
- _____ Discuss an example of competition in the ecosystem
- _____ Discuss an example of predator/prey interaction in the ecosystem
- _____ Discuss an example of mutualism in the ecosystem

[illegible]

6.4.3 Matter and Energy in Ecosystems

Phenomenon

These images show organisms that live in or around the Great Salt Lake.



Brine Shrimp: Ho-Wen Chen; CC BY-NC-ND
Green Algae: Green algae in the Semois by Eric Huybrechts; CC BY-ND
Brine Flies: Image by Katja Schulz; CC BY
Bacteria: by Geralt; pixabay.com; CC0
Seagull by 12019; pixabay.com; CC0
Eared Grebe: by Alan D. Wilson; CC BY-SA

Observations & Wonderings

What are you observing about this phenomenon?

What are you wondering about this phenomenon?

6.4.3 Matter and Energy

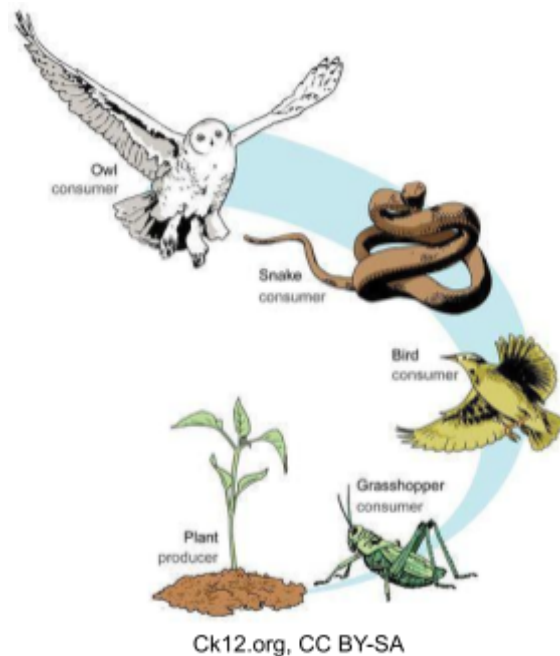
Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem. Emphasize food webs and the role of producers, consumers, and decomposers in various ecosystems. Examples could include Utah ecosystems such as mountains, Great Salt Lake, wetlands, and deserts. (LS2.B)



Energy and matter play an important role in many of Earth's ecosystems. Energy flows from producers to consumers and through decomposers who also play a role in helping to recycle matter in an ecosystem.

Matter and Energy in Ecosystems

Energy must constantly flow through an ecosystem for the system to remain stable. What exactly does this mean? Essentially, it means that organisms must eat other organisms. Food chains (figure below) show the eating patterns in an ecosystem. Food energy flows from one organism to another. Arrows are used to show the feeding relationship between the animals. The arrow points from the organism being eaten to the organism that eats it. For example, an arrow from a plant to a grasshopper shows that the grasshopper eats the leaves. Energy and nutrients are moving from the plant to the grasshopper. Next, a bird might prey on the grasshopper, a snake may eat the bird, and then an owl might eat the snake.



In a wetland ecosystem, one possible food chain might look like this: cattail → grasshopper → frog → hawk. The producers are always at the beginning of the food chain, bringing energy into the ecosystem. Through photosynthesis, the producers not only create their own food, but also create the food for the other organisms in the ecosystem. Next come the consumers. They eat other

organisms in order to obtain energy. In the wetland example, cattails are the producers. They are eaten by grasshoppers, which are then eaten by frogs.

Finally, hawks eat frogs. The grasshoppers, frogs, and hawks are all consumers in this food chain.



Polyporus squamosus Molter by Dan Molter,
https://en.wikipedia.org/wiki/File:Polyporus_squamosus_Molter.jpg, CC BY-SA

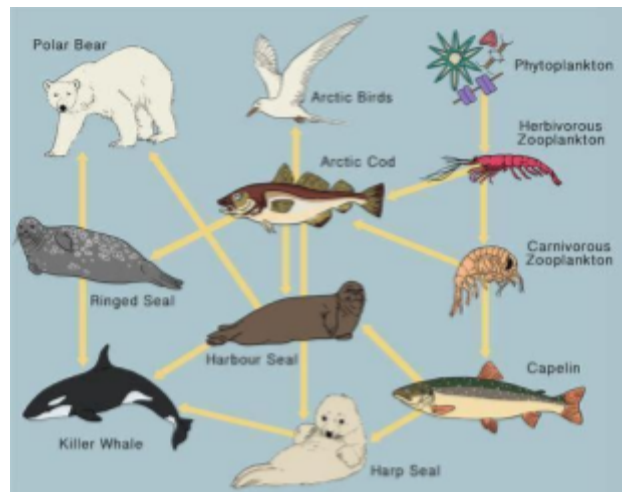
Producers and consumers are not the only roles organisms have in an ecosystem, decomposers also play a very important role in maintaining ecosystem stability.

Decomposers are organisms that obtain nutrients and energy by breaking down dead organisms and animal waste. Decomposers release nutrients back into the environment. These nutrients are recycled back into the ecosystem so that the producers can use them. They are passed to other organisms when the producers are eaten or consumed. Examples of

decomposers are mushrooms on a decaying log, bacteria in the soil, and earthworms.

Imagine what would happen if there were no decomposers. Waste, and the remains of dead organisms, would pile up and the nutrients within the waste and dead organisms would not be released back into the ecosystem. Producers would not have enough nutrients.

Each organism can eat and be eaten by many different types of organisms, so simple food chains are rare in nature. We can combine food chains together to create a more accurate flow of energy within an ecosystem. A food web (next figure) shows the feeding relationships between many organisms in an ecosystem. For example, the arctic cod is eaten by the harbor seal, harp seal, ringed seal, and arctic birds. Even though a food web shows many more arrows, it still shows the cycling of matter and the flow of energy.



Food web in the Arctic Ocean, ck12.org, CC BY-SA.

6.4.3 Matter and Energy

Putting It Together



These images show organisms that live in or around the Great Salt Lake.

Focus Questions

1. Which is a more accurate model to show the flow of energy in an ecosystem, a food chain or food web? Explain your reasoning.
2. How do decomposers play a role in the cycling of matter in an ecosystem?
3. Refer to the food web of the Arctic Ocean. Suppose a pesticide in the water killed all the Zooplankton. Describe two effects this would have on the ecosystem.

Final Task

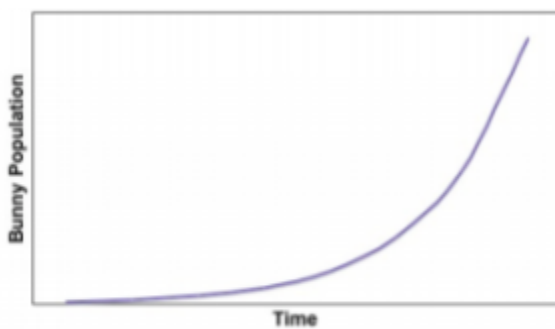
Develop a model to show the cycling of energy in this ecosystem of organisms that live in or around the Great Salt Lake. Make sure to include all 6 organisms.

6.4.4 Stability of Populations in Ecosystems

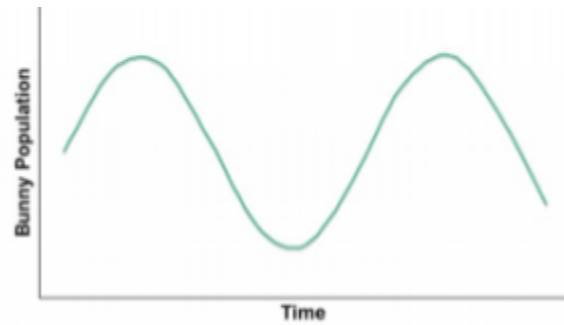
Phenomenon



Public Domain



Bunny population without predators



Bunny population with predators
(CC0)

Observations & Wonderings

What are you observing about this phenomenon?

What are you wondering about this phenomenon?

6.4.4 Stability of Populations

Construct an argument supported by evidence that the stability of populations is affected by changes to an ecosystem. Emphasize how changes to living and nonliving components in an ecosystem affect populations in that ecosystem. Examples could include Utah ecosystems such as mountains, Great Salt Lake, wetlands, and deserts. (LS2.C)



Small changes to one part of an ecosystem can cause a large change to another part of an ecosystem.

Stability of Populations in Ecosystems

In the early 1800s, when people began to settle in the West, the government paid people to seek out wolves and kill them.

By the 1920s, there were no more wolf packs in Yellowstone National Park. Elk populations in the park increased, and the population of aspen trees began to decline. In 1995, the National Park Service reintroduced 31 gray wolves into Yellowstone National Park. Over the years, the wolf population has continued to grow.



Public Domain

Current research by wildlife biologists is helping us to learn the important role wolves play in maintaining biodiversity in their ecosystem. After the reintroduction of the wolves, new aspen trees began to grow because fewer elk were grazing on the young seedlings. Biologists have also discovered that in areas where elk are more vulnerable to wolf attacks, the growth of aspen groves have been increasing dramatically. These are just a few reasons that the reintroduction of the wolves has increased the biodiversity of the whole park. The example of the wolves in Yellowstone National Park is an example of how changes in populations of one organism affect the populations of other organisms.

The stability of populations in an ecosystem is affected by many factors. For a population to be healthy, factors such as food, nutrients, water and space, must be available. Low food supply or a lack of space are limiting factors in an ecosystem. When there are limiting factors in an ecosystem, populations of a

species can decline. This decline could be caused by less offspring being born, increase in death rates, or individuals emigrating to other areas.

Limiting Factors

If there are 12 hamburgers at a lunch table and 24 people sit down at a lunch table, will everyone be able to eat? At first, maybe you will split hamburgers in half, but if more and more people keep coming to sit at the lunch table, you will not be able to feed everyone. The amount of hamburgers limit the number of people at the lunch table.

Similarly, the amount of food limits the number of organisms in an ecosystem.

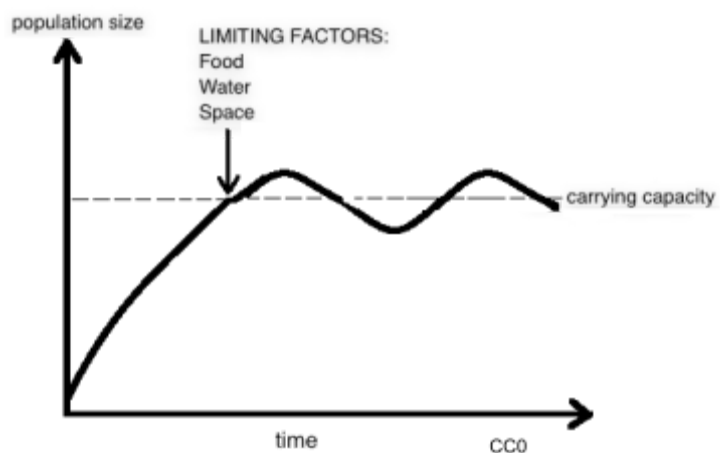
If organisms cannot get food, they will die or find a new place to live. It is possible for any resource to be a limiting factor, however, a resource such as food can have dramatic consequences on a population.

Other limiting factors include light, water, nutrients or minerals, oxygen, the ability of an ecosystem to recycle nutrients and/or waste, disease and/or parasites, temperature, space, and predation.

Weather can also be a limiting factor. Whereas most plants like rain, an individual cactus-like *Agave Americana* plant actually likes to grow when it is dry. Rainfall limits reproduction of this plant which, in turn, limits growth rate. Can you think of some other factors like this?

Human activities can also limit the growth of populations. Such activities include the use of pesticides and herbicides as well as habitat destruction.

When the population size is small, there is usually plenty of food and other resources for each individual. Organisms can easily reproduce, so the birth rate is high. As the population increases, the food supply, or the supply of another necessary resource, may decrease. When necessary resources, such as food, decrease, some individuals will die. Overall, the population cannot reproduce at the same rate, so the birth rates drop. This will cause the population growth rate to decrease.



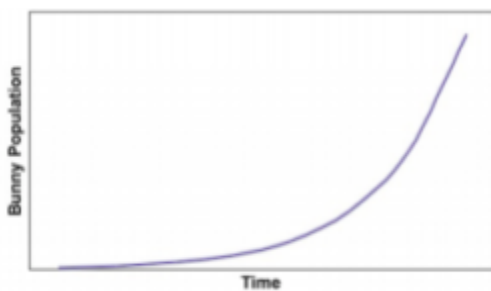
When the population decreases to a certain level where every individual can get enough food and other resources, and the birth and death rates become stable, the population has leveled off at its carrying capacity.

6.4.4 Stability of Populations

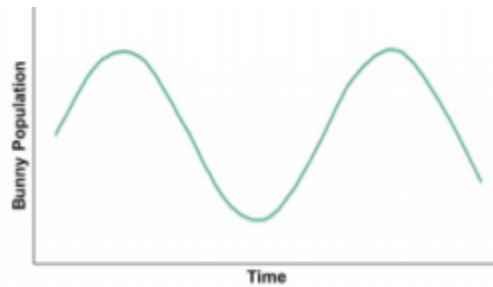
Putting It Together



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Bunny population without predators



Bunny population with predators
(CC0)

Focus Questions

1. Explain why aspen tree populations declined when wolf packs were eliminated in Yellowstone Park.
2. What are three examples of limiting factors?
3. When organisms face limiting factors, what effect will this have on their population?

Final Task

Using evidence from the graphs, construct an argument for the changes in bunny population in the two scenarios.

6.4.5 Stability and Change

Authentic Situation

Nonnative lake trout have been illegally introduced into Yellowstone Lake in Yellowstone National Park. Because of this, native cutthroat populations are in decline.



Image by Diane Renkin (NPS); <https://flic.kr/p/FTdbvM>; public domain

Observations and Wonderings

What is the problem in this situation?

What are the possible criteria (positive outcomes) to this situation?

What are the constraints (limitations) with this situation?

6.4.5 Stability and Change

Evaluate competing design solutions for preserving ecosystem resources and biodiversity based on how well the solutions maintain stability within the ecosystem. Emphasize **obtaining, evaluating and communicating** information of differing design solutions. Examples could include policies affecting ecosystems, responding to invasive species or solutions for the preservation of ecosystem resources specific to Utah, such as air and water quality and prevention of soil erosion. (LS2.C, LS4.D, ETS1.A, ETS1.B, ETS1.C)



In this section, solutions will be designed whose primary function is to conserve Earth's environments and resources.

In this chapter you have learned how changes to the living and nonliving parts of an ecosystem affect the ecosystem.

As you read this section, think about how human activities can also change ecosystems and why maintaining ecosystem stability is important for preserving the services that ecosystems provide to humans.

Invasive Species

Invasive species are well known for the changes they cause in ecosystems. They may not have natural predators. In most habitats, there is a balance. This balance controls the size of groups of animals. Invasive species have an unfair advantage over their rivals. They are able to out-compete the native species for resources. At times, invasive species are very successful. In some areas, they have taken over the habitat. In this case, the native species goes extinct.

Recently, cargo ships have transported new species to the Great Lakes. These include the zebra mussel, spiny water flea, and ruffe (a freshwater fish). These new species are better at hunting for food. They have caused some of the native species to go extinct.

Invasive species can disrupt food chains. They can carry diseases. They may also prey on native species directly. More importantly, they out-compete native species for limited resources, like food. All of these effects can lead to extinction of the native species.

Read the following information to help you learn more about this problem so you

can identify an effective possible solution.

Lake Trout in Yellowstone Lake

Nonnative lake trout have been illegally introduced into Yellowstone Lake. Their presence in the lake poses a serious threat to the native cutthroat trout population because young lake trout compete with cutthroats for food and adult lake trout prey on cutthroats. If lake trout were to deplete the cutthroat population, the number of species dependent on the cutthroat for food (such as bears, eagles, and otters) could decline. This could destroy the excellent cutthroat trout fishing in the lake that people have enjoyed for over a century.

The dilemma is: How do you protect the native Yellowstone cutthroat trout and other species dependent on the native trout?

Design solutions proposed by Yellowstone National Park management-

1. Eliminate the lake trout entirely by destroying all fish life, and then reintroduce the cutthroat. This would cost between \$32 and \$181 million.
2. Gillnet some, not all, the lake trout to reduce costs. (Pictured below)
3. Leave the lake trout alone and see what happens.
4. Recruit thousands of anglers to catch lake trout.



fishes by peacecorpschadsey, <https://flic.kr/p/5zJQRk>, CC-BY-SA

Almost half of the streams and lakes in Yellowstone National Park did not support trout populations prior to the coming of European Americans. Stocking programs initiated by the U.S. Fish Commission in the late 1800s and early 1900s established populations of rainbow, brown, brook, and lake trout, as well as Yellowstone cutthroat trout, in most of the fishless waters.

In some cases, nonnative fishes were introduced into waters where native cutthroat trout flourished. As a consequence, native cutthroat trout were often replaced by the introduced nonnatives, and hybridization between cutthroat trout and rainbow trout was common.

The goal of these introductions was to provide angling opportunities for visitors to the Yellowstone area. In this vein, these stockings were very successful. There was little concern for whether these interactions with native trout were harmful; the main goal was to provide fish for anglers. As nonnative trout expanded in Yellowstone National Park, the range of the native cutthroat trout contracted.

Despite these introductions, Yellowstone cutthroat trout flourished in many parts of their native range within the Park, and until the 1990s, Yellowstone Lake supported the largest genetically pure population of Yellowstone cutthroat trout on earth.

Lake trout (*Salvelinus namaycush*) are native to Canada, Alaska, the Great Lakes, New England, and parts of Montana. The species was first documented in Yellowstone Lake in 1994. Evidence from chemical patterns in lake trout ear bones sampled in the late 1990s indicate that they were introduced illegally from nearby Lewis Lake sometime in the 1980s. Despite major efforts to remove them by gillnetting, the lake trout have had a significant ecological impact on the native Yellowstone cutthroat trout, an important food for other native animals. Lake trout differ from cutthroat trout as potential prey because they can grow larger, occupy deeper areas of the lake, and spawn in the lake instead of in shallow tributaries.

- 1890s: The park stocked fish; lake trout were introduced to Lewis and Shoshone lakes.
- Lake trout were illegally introduced into Yellowstone Lake in the 1980s and 1990s.
- 1980s–1990s: Lake trout illegally introduced into Yellowstone Lake
- 1994: First verified lake trout caught in Yellowstone Lake.
- A mature lake trout can eat ~41 cutthroat trout per year.
- The cutthroat trout population in Yellowstone Lake is ~10% or less of historic highs.
- Many wildlife species, including the grizzly bear, otter, and bald eagle, depend on cutthroat trout for a portion of their diet.
- Most predators can't catch lake trout because the trout live in deep water, spawn in the lake, and are large.

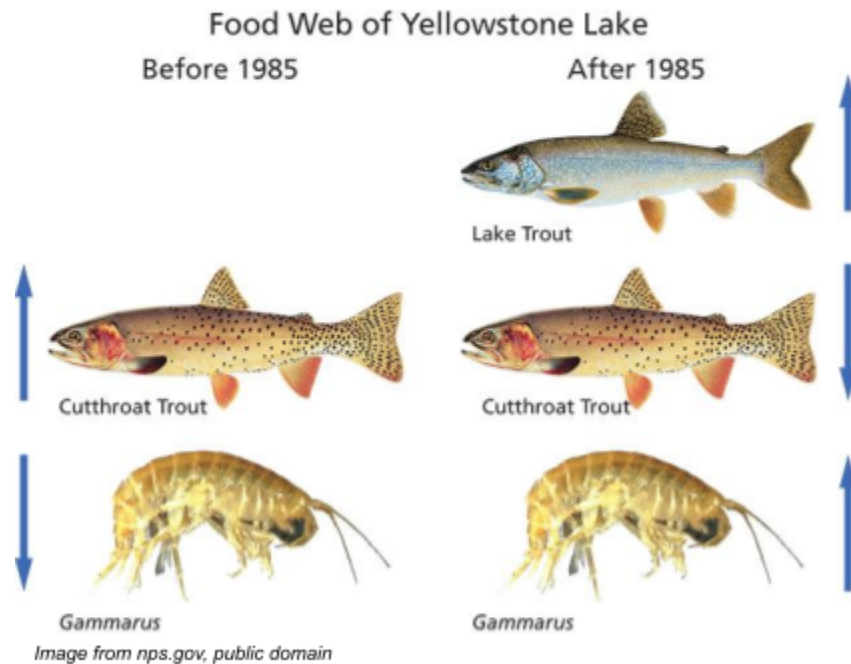
Current Status

- Gillnetting has removed more than 3.14 million lake trout since 1994.
- Anglers catch approximately 20,000 lake trout each year.

- Population models estimate a 70% decline in age 6+ lake trout since 2012.
- Lake trout recruitment remains strong. However, 2018 results indicate that is beginning to decrease as well.

Outlook

With continued aggressive control efforts, fisheries managers expect to reduce lake trout numbers and lessen impacts to cutthroat trout. Recent monitoring indicates Yellowstone cutthroat trout in Yellowstone Lake are starting to rebound and the lake trout population is in decline.



6.4.5 Stability and Change

Putting It Together



Image by Diane Renkin (NPS);public domain

Nonnative lake trout have been illegally introduced into Yellowstone Lake in Yellowstone National Park. Because of this, native cutthroat populations are in decline.

Focus Questions

1. Are there any advantages to keeping an invasive species in the new environment?
2. What can happen in the system if the invasive species is allowed to remain?

Final Task

To help you find the best solution for the invasive species problem that is affecting the Yellowstone cutthroat,

- A. First, write a sentence that clearly describes the problem.
- B. Next, write end goals that will help you know you have successfully solved the problem. These are your criteria for success.
- C. Now, write the limitations or constraints you have to solving the problems such as cost, time, and materials.
- D. Compare each possible solution to your list of criteria and constraints.
- E. Which solution best meets the items in those lists?
- F. How does this design solution balance everyday needs (agriculture, industry, and energy) while conserving Earth's environments and resources?

