Elementary Earth and Space Science Methods

Elementary Earth and Space Science Methods

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Introduction

Introduction: Diffendoofer Day

Dear Future Science Teachers,

We created this book to help you as both a college student and a future teacher. Dr. Ted Neal asked us to help him create this resource from the perspective of students who have taken Science Methods II–what would we want in a textbook for this course? With this in mind, we have gathered and created resources to help you better understand science and feel confident in your abilities as a future teacher.

This book is divided into five parts which align with the Science Methods II course:

- Physics
- Space Science
- Earth Science
- Climate Science
- Course Materials and Pedagogy

Within each part, the material is broken down into smaller chapters. Here you will find written explanations, video links, glossary terms, key takeaways, and practice quizzes to help you understand the material. This book is designed to be a flexible resource; use it as much or as little as you need throughout the course.

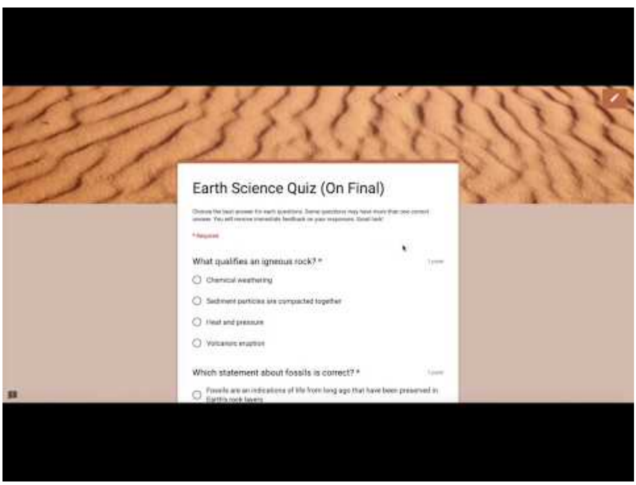
K-6 Next Generation Science Standards (NGSS)

Look for the blue text boxes throughout the book to find the relevant standards in each section.

As Ted likes to say, science is everywhere and it is everything. We hope this book can help you on your journey as a learner and teacher of science.

Cheers,

Rachel Dunn, Jenny Haley, Ella McDonald, Ben Smith



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PART I

PHYSICS

Welcome to Physics. This part is divided into four chapters:

1. Pendulums
2. Magnetism
3. Electricity
4. Forces

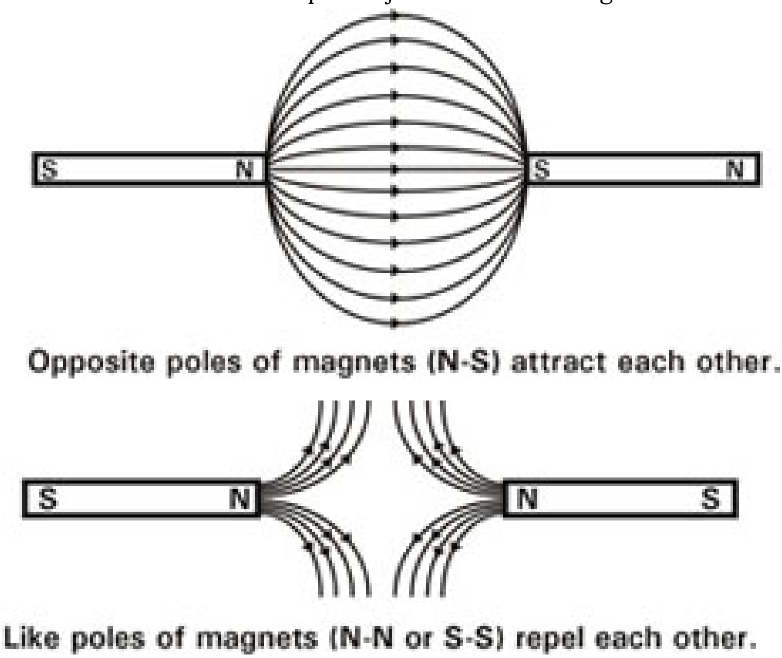
Additionally, there is a practice quiz at the end that covers the entire unit.

1. Magnetism

Formative Assessment: Magnets

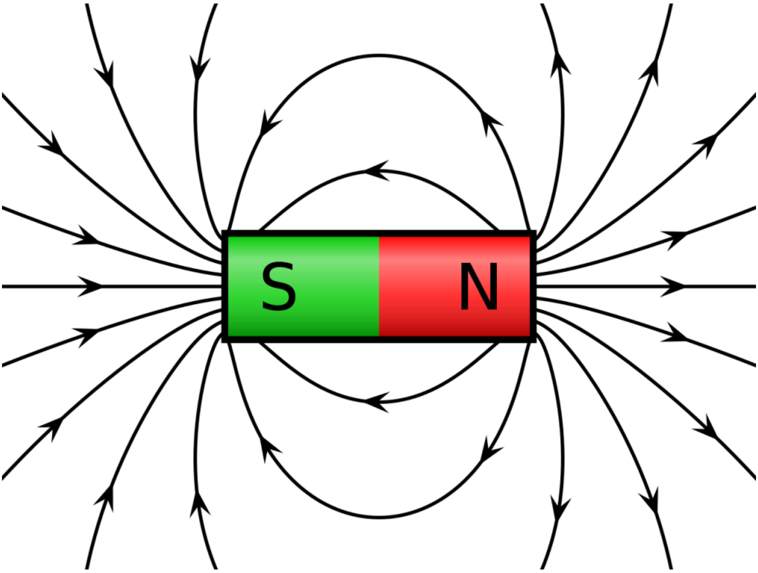
What is Magnetism?

A magnet is an object or material that produces its own magnetic field. Magnets are dipoles meaning they have two poles: a north and a south. Opposite poles (north and south) attract while similar poles (north and north, south and south) repel each other. Magnetism is the force that attracts or repels objects within the magnetic field.

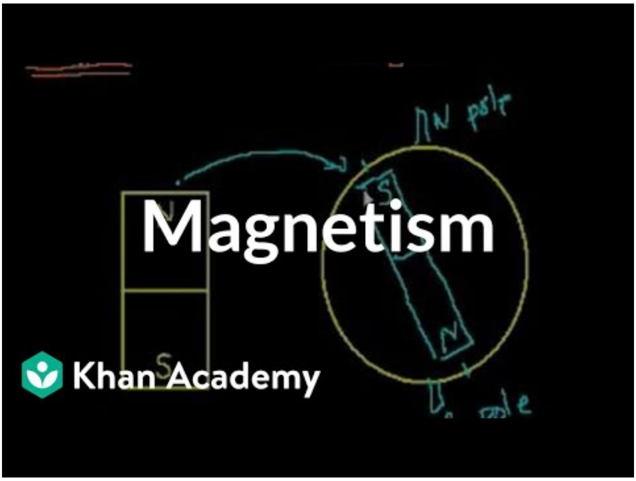


"Magnets" by National Energy Education Development Project is public domain

A magnetic field is the area around a magnet that has magnetic force. The image, below, shows the two poles of a bar magnet and the magnetic field it generates.



For further explanation of magnetism, watch the following video:



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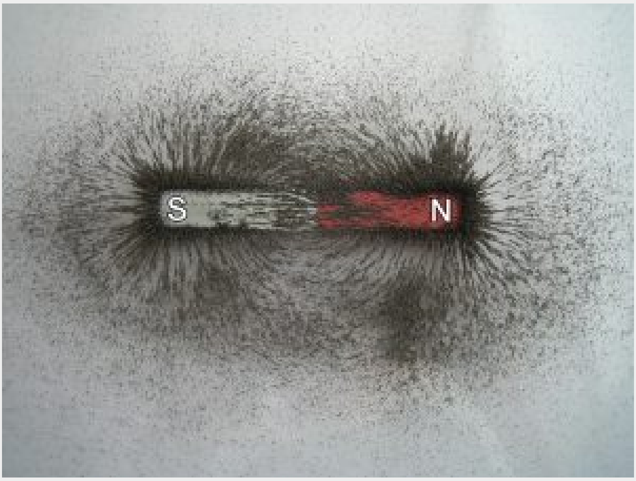
Video credit: "Introduction to Magnetism" by Khan Academy is licensed under CC BY-NC-SA 3.0. Note: All Khan Academy content is available for free at khanacademy.org.

It is a common misconception that all metals are magnetic–only certain metals become magnetized when exposed to a magnetic field. These include iron, nickel, and cobalt.

All matter is made up of atoms. Electrons, negatively charged particles, move around the nucleus of an atom. The movement of electrons generates a **magnetic field**. In most atoms, electron pairs move in opposite directions so they cancel each other out. Metals like iron, however, have unpaired electrons. When exposed to a strong magnet, these electrons in the iron line up and act like tiny bar magnets. Thus, the iron is magnetized.

The image, below, shows a bar magnet surrounded by iron filings. The electrons in the iron atoms line up and the iron becomes magnetized when it is exposed to the bar magnet so we can see the shape of the magnetic field.



"Iron Filings" by Dayna Mason is licensed under CC BY-NC-SA 2.0

If you have a stainless steel refrigerator, you may have noticed that magnets do not stick to the front. Although steel is made from iron (a magnetic metal), the stainless steel in refrigerators is usually mixed with other metals to make it more durable. This changes the structure of the metals so the stainless steel is not magnetic.

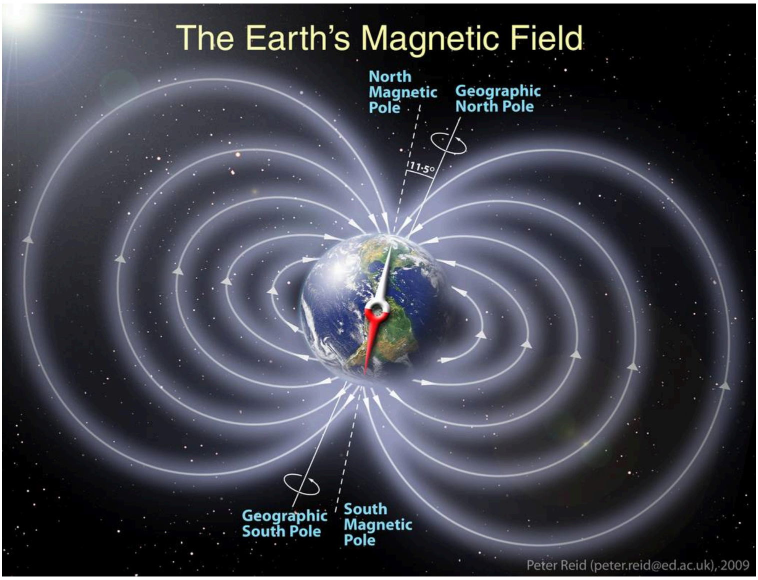
Key Takeaways

All metals are NOT magnetic. Metals that can become magnetized are

- Iron
- Cobalt
- Nickel

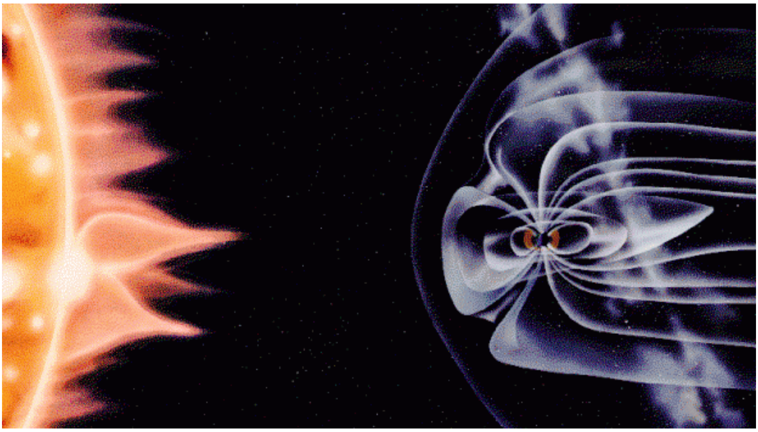
Earth's Magnetic Field

Earth is surrounded by a giant **magnetic field** called the magnetosphere. Earth has a solid iron core surrounded by liquid iron. As the liquid metal moves around, it generates an electric **current** which creates a magnetic field around the planet between the **geomagnetic poles**. As seen in the image, below, the Earth's geomagnetic poles are tilted from the North and South poles.



"*Earth's Magnetic Field*" *by* NASA *is public domain*

Earth's magnetic field is critical to life on Earth because it protects the planet from the Sun. The Sun produces solar wind which moves extremely quickly through space. As seen in the image, below, the solar wind is strong enough to shape Earth's magnetic field; it is flatter on the front and cone shaped on the backside of the planet. Still, the magnetosphere protects Earth from the strongest effects of the solar wind.


"*Earth's Magnetosphere*" *by* NOAA *is public domain*

Compasses

Compasses are used to navigate because their needle points to the magnetic north pole. Historians believe that ancient Chinese civilizations used magnetic compasses in the 11th or 12th century. Later, European explorers used compasses to navigate around the world.

The design of early compasses was simple. First, a needle was rubbed along a magnet to magnetize it. Then, the needle was placed on a piece of cork which floated in a bowl of water. This allowed the needle to spin freely and orient to magnetic north.

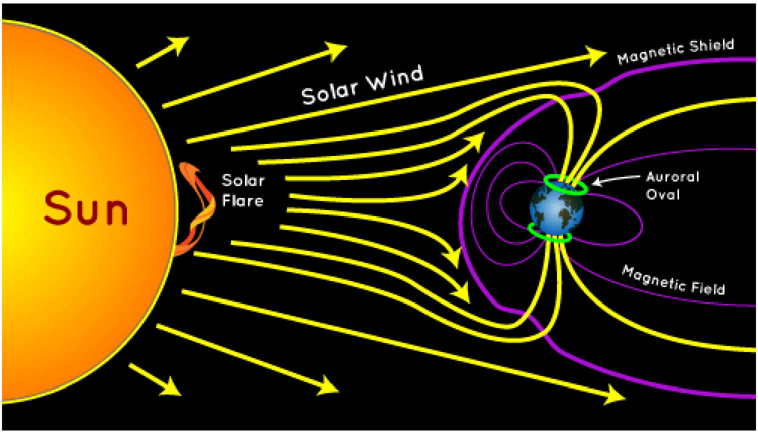
It isn't well understood, but scientists also believe that certain animals like whales, turtles, and bees use Earth's magnetic field to navigate. This is how they are able to travel long distances without getting lost.

Auroras

Auroras are displays of light in the sky. In the Northern Hemisphere this is known as the aurora borealis; in the Southern Hemisphere is is called the aurora australis. The auroras can be seen in far north and far south locations close to the poles.

"*Northern Lights over Alaska*" *by* NASA*/Terry Zaperach is public domain*

During a solar storm, the Sun sends out a huge cloud of electrified gas which is carried through space by solar wind. Some of these particles get past Earth's magnetic field and enter the atmosphere at the North and South poles where the atmosphere is thinner. The solar gases interact with the gases in Earth's atmosphere which causes the light displays. Oxygen causes the lights to show up as green while nitrogen produces a blue or purple aurora.



"[Aurora](#)" by [NASA Space Place](#) is public domain

For more explanation of the magnetosphere and auroras, watch the following video:

A YouTube element has been excluded from this version of the *text. You can view it online here: https://pressbooks.uiowa.edu/methodsii/?p=1175*

Video credit: "What is an Aurora?" by Michael Molina/TED-Ed is licensed under CC BY-NC-ND 4.0

Performance Expectations:

K-PS2-1.	Planning and Carrying Out InvestigationsPlanning and carrying out investigations to answer questions or test solutions to problems in K–2 builds on prior experiences and progresses to simple investigations, based on fair tests, which provide data to support explanations or design solutions.With guidance, plan and conduct an investigation in collaboration with peers.">Plan and conduct an investigation to compare Cause and EffectSimple tests can be designed to gather evidence to support or refute student ideas about causes.">the effects of PS2.A: Forces and MotionPushes and pulls can have different strengths and directions.When objects touch or collide, they push on one another and can change motion.PS2.B: Types and InteractionsWhen objects touch or collide, they push on one another and can change motion.PS3.C: Relationship Between Energy and ForcesA bigger push or pull makes things speed up or slow down more quickly.">different strengths or different directions of pushes and pulls on the motion of an object. [Clarification Statement: Examples of pushes or pulls could include a string attached to an object being pulled, a person pushing an object, a person stopping a rolling ball, and two objects colliding and pushing on each other.] [*Assessment Boundary: Assessment is limited to different relative strengths or different directions, but not both at the same time. Assessment does not include non-contact pushes or pulls such as those produced by magnets.*]

K-PS2-2.	Analyzing and Interpreting DataAnalyzing data in K–2 builds on prior experiences and progresses to collecting, recording, and sharing observations.Analyze data from tests of an object or tool to determine if it works as intended.">Analyze data to determine if ETS1.A: Defining Engineering ProblemsA situation that people want to change or create can be approached as a problem to be solved through engineering. Such problems may have many acceptable solutions.">a design solution works as intended Cause and EffectSimple tests can be designed to gather evidence to support or refute student ideas about causes.">to change PS2.A: Forces and MotionPushes and pulls can have different strengths and directions.Pushing or pulling on an object can change the speed or direction of its motion and can start or stop it.">the speed or direction of an object with a push or a pull.* [Clarification Statement: Examples of problems requiring a solution could include having a marble or other object move a certain distance, follow a particular path, and knock down other objects. Examples of solutions could include tools such as a ramp to increase the speed of the object and a structure that would cause an object such as a marble or ball to turn.] [*Assessment Boundary: Assessment does not include friction as a mechanism for change in speed.*]

3-PS2-3.	Asking Questions and Defining ProblemsAsking questions and defining problems in grades 3–5 builds on grades K–2 experiences and progresses to specifying qualitative relationships.Ask questions that can be investigated based on patterns such as cause and effect relationships.">Ask questions to determine Cause and EffectCause and effect relationships are routinely identified, tested, and used to explain change.">cause and effect relationships PS2.B: Types of InteractionsElectric, and magnetic forces between a pair of objects do not require that the objects be in contact. The sizes of the forces in each situation depend on the properties of the objects and their distances apart and, for forces between two magnets, on their orientation relative to each other.">of electric or magnetic interactions between two objects not in contact with each other. [Clarification Statement: Examples of an electric force could include the force on hair from an electrically charged balloon and the electrical forces between a charged rod and pieces of paper; examples of a magnetic force could include the force between two permanent magnets, the force between an electromagnet and steel paperclips, and the force exerted by one magnet versus the force exerted by two magnets. Examples of cause and effect relationships could include how the distance between objects affects strength of the force and how the orientation of magnets affects the direction of the magnetic force.] [*Assessment Boundary: Assessment is limited to forces produced by objects that can be manipulated by students, and electrical interactions are limited to static electricity.*]

3-PS2-4.	Asking Questions and Defining ProblemsAsking questions and defining problems in grades 3–5 builds on grades K–2 experiences and progresses to specifying qualitative relationships.Define a simple problem that can be solved through the development of a new or improved object or tool.">Define a simple design problem Interdependence of Science, Engineering, and TechnologyScientific discoveries about the natural world can often lead to new and improved technologies, which are developed through the engineering design process.">that can be solved by applying scientific ideas PS2.B: Types of InteractionsElectric, and magnetic forces between a pair of objects do not require that the objects be in contact. The sizes of the forces in each situation depend on the properties of the objects and their distances apart and, for forces between two magnets, on their orientation relative to each other.">about magnets.* [Clarification Statement: Examples of problems could include constructing a latch to keep a door shut and creating a device to keep two moving objects from touching each other.]

MS-PS2-3.	Asking Questions and Defining ProblemsAsking questions and defining problems in grades 6–8 builds from grades K–5 experiences and progresses to specifying relationships between variables, and clarifying arguments and models.Ask questions that can be investigated within the scope of the classroom, outdoor environment, and museums and other public facilities with available resources and, when appropriate, frame a hypothesis based on observations and scientific principles.">Ask questions about data to determine PS2.B: Types of InteractionsElectric and magnetic (electromagnetic) forces can be attractive or repulsive, and their sizes depend on the magnitudes of the charges, currents, or magnetic strengths involved and on the distances between the interacting objects.">the factors Cause and EffectCause and effect relationships may be used to predict phenomena in natural or designed systems.">that affect PS2.B: Types of InteractionsElectric and magnetic (electromagnetic) forces can be attractive or repulsive, and their sizes depend on the magnitudes of the charges, currents, or magnetic strengths involved and on the distances between the interacting objects.">the strength of electric and magnetic forces. [Clarification Statement: Examples of devices that use electric and magnetic forces could include electromagnets, electric motors, or generators. Examples of data could include the effect of the number of turns of wire on the strength of an electromagnet, or the effect of increasing the number or strength of magnets on the speed of an electric motor.] [*Assessment Boundary: Assessment about questions that require quantitative answers is limited to proportional reasoning and algebraic thinking.*]

MS-PS2-5.	Planning and Carrying Out InvestigationsPlanning and carrying out investigations to answer questions or test solutions to problems in 6–8 builds on K–5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or design solutions.Conduct an investigation and evaluate the experimental design to produce data to serve as the basis for evidence that can meet the goals of the investigation.">Conduct an investigation and evaluate the experimental design to provide evidence that PS2.B: Types of InteractionsForces that act at a distance (electric, magnetic, and gravitational) can be explained by fields that extend through space and can be mapped by their effect on a test object (a charged object, or a ball, respectively).">fields exist between objects Cause and EffectCause and effect relationships may be used to predict phenomena in natural or designed systems.">exerting forces on each other PS2.B: Types of InteractionsForces that act at a distance (electric, magnetic, and gravitational) can be explained by fields that extend through space and can be mapped by their effect on a test object (a charged object, or a ball, respectively).">even though the objects are not in contact. [Clarification Statement: Examples of this phenomenon could include the interactions of magnets, electrically-charged strips of tape, and electrically-charged pith balls. Examples of investigations could include first-hand experiences or simulations.] [*Assessment Boundary: Assessment is limited to electric and magnetic fields, and limited to qualitative evidence for the existence of fields.*]

DCI:

Kindergarten

PS2.A: Forces and Motion

- Pushes and pulls can have different strengths and directions.
- Pushing or pulling on an object can change the speed or direction of its motion and can start or stop it.

PS2.B: Types of Interactions

- When objects touch or collide, they push on one another and can change motion.

PS3.C: Relationship Between Energy and Forces

- A bigger push or pull makes things speed up or slow down more quickly. *(secondary)*

Third Grade

PS2.B: Types of Interactions

- Objects in contact exert forces on each other. (3-PS2-1)
- Electric, and magnetic forces between a pair of objects do not require that the objects be in contact. The sizes of the forces in each situation depend on the properties of the objects and their distances apart and, for forces between two magnets, on their orientation relative to each other. (3-PS2-3),(3-PS2-4)

Middle School

PS2.B: Types of Interactions

- Electric and magnetic (electromagnetic) forces can be attractive or repulsive, and their sizes depend on the magnitudes of the charges, currents, or magnetic strengths involved and on the distances between the interacting objects.

PS2.B: Types of Interactions

- Forces that act at a distance (electric, magnetic, and gravitational) can be explained by fields that extend through space and can be mapped by their effect on a test object (a charged object, or a ball, respectively).

Crosscutting:

Cause and Effect

- Simple tests can be designed to gather evidence to support or refute student ideas about causes.

Lesson Ideas:

Have children explore different objects with magnets. Can they make a statement about what things stick to magnets? Predict what will or won't stick and try it out. Try going for a magnet hunt around the classroom with magnet to find objects that stick to magnets.

Can you make magnets move objects at a distance? How far can you get?

2. Pendulums

Formative Assessment: Pendulum

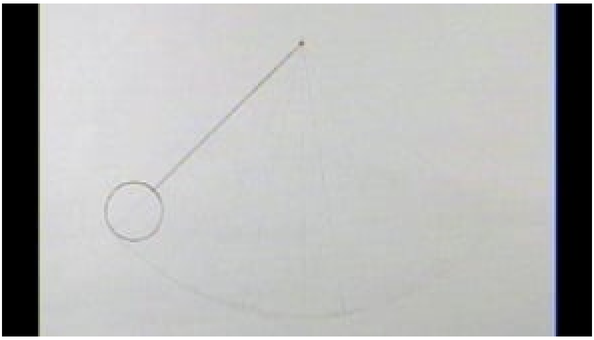
What is a Pendulum?

A pendulum is a weight suspended from a fixed point that can swing freely. Pendulums swing back and forth in a regular motion.

What are some pendulums in real life?

- Swings
- Wrecking ball
- Grandfather clocks

A period is the time it takes a pendulum to swing across and back to its original starting point. One period is shown in the video, below.



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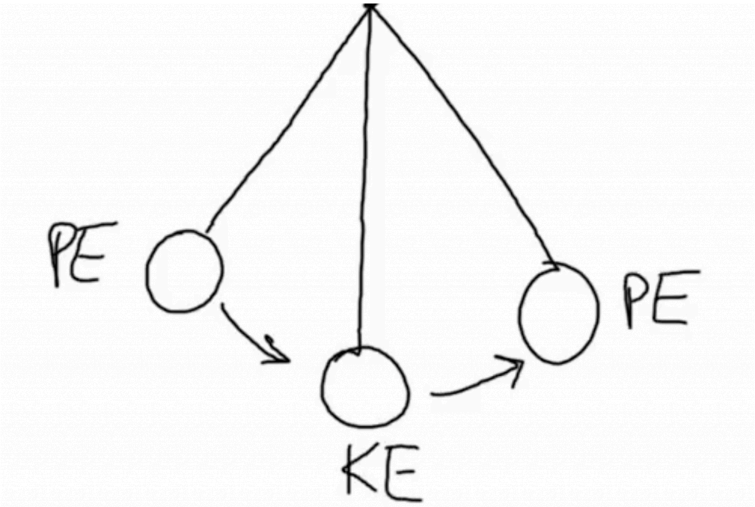
Video credit: "2D Animation-Pendulum" by Melissa Gableman is licensed under CC BY-NC-SA 3.0

Why does a pendulum continue to swing for some time after you let it go? It all has to do with it's energy.

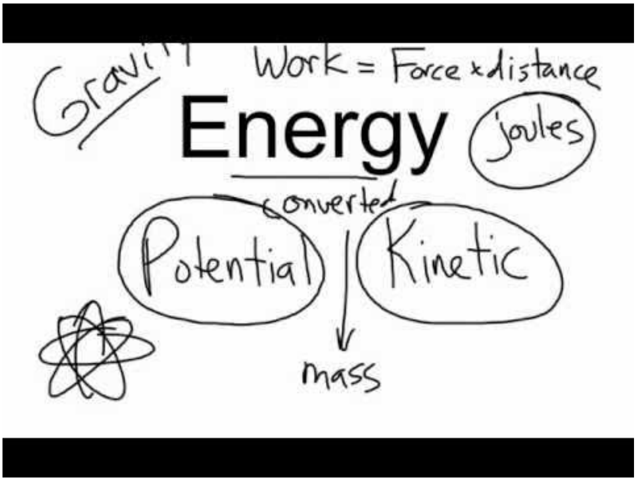
As seen in the image, below, a pendulum has potential energy (PE) and kinetic energy (KE):



"Potential and Kinetic Energy" (screenshot) by Bozeman Science is licensed under CC BY 3.0

- At the starting point of its swing, the pendulum has **potential energy**.
- As the pendulum swings downward, its potential energy is converted into **kinetic energy**.
- As the pendulum swings upward, its kinetic energy is converted back into potential energy.
- Newton's First Law says that objects in motion tend to stay in motion, and objects at rest tend to stay at rest, unless acted upon by an outside force. Therefore, this energy conversion will allow the pendulum to continue swinging back and forth. Eventually, its energy will be lost to forces like friction and the pendulum will come to a stop.

For more explanation of potential and kinetic energy, watch the first few minutes of the video, below.



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Video credit: "Potential and Kinetic Energy" by Bozeman Science is licensed under CC BY 3.0

If a wrecking ball was knocking down a building, where in its swing would you want the ball to connect to the building? Where in its swing does it have the most destructive power? Why?

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here:
https://pressbooks.uiowa.edu/methodsii/?p=1172

Wrecking ball in action by Stefan Kühn is licensed under CC BY-SA 3.0

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https://pressbooks.uiowa.edu/methodsii/?p=1172

Watch the video below to see a wrecking ball in action.

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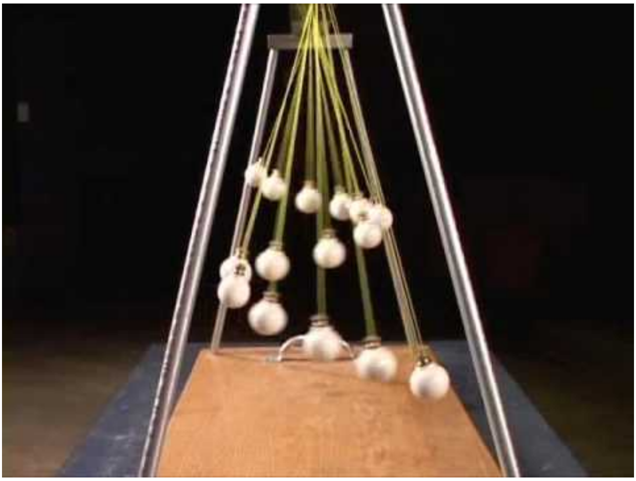
The wrecking ball connects to the building **at the bottom of its swing**.

The video, below, shows 15 pendulums swinging from the same bar. Although the pendulums are released at the same time, they swing at different speeds. This creates the visual effect of a wave. If you focus on one pendulum at a time, you can see that each pendulum is in fact swinging back and forth in a consistent motion.



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Video credit: "Pendulum Waves" by Harvard Natural Sciences Lecture Demonstrations is used with permission

In the pendulum lab, we create a simple pendulum from a string with a weight attached at the end. We want to answer the question: **Is the period of a pendulum affected by the mass of the weight, the angle of release, and/or the length of the string?** To do this, test each variable independently while counting the number of swings the pendulum makes in 10 seconds.

You can repeat the lab with this online PhET simulation here.

An interactive or media element has been excluded from this version of the text. You can view it online here: https://pressbooks.uiowa.edu/methodsii/?p=1172

Here are the results of the testing:

1. Mass of the weight: Does not affect the period
2. Angle of release: Does not affect the period
3. Length of the string: Does affect the period

Watch the [pendulum waves](#) video, above, again and notice each variable.

- Each pendulum's weight has the same mass.
- Each pendulum is released at the same angle.
- Each pendulum has a different length of string which causes them to swing at different speeds. Focus on the shortest pendulum and you can see that it swings fastest. Focus on the longest pendulum and you can see that it swings slowest.

Key Takeaway

The speed of a pendulum's swing is affected by the length of the string.

- Longer string=slower swing, fewer **periods** in 10 seconds

- Shorter string=faster swing, more periods in 10 seconds

Why are pendulums important in science?

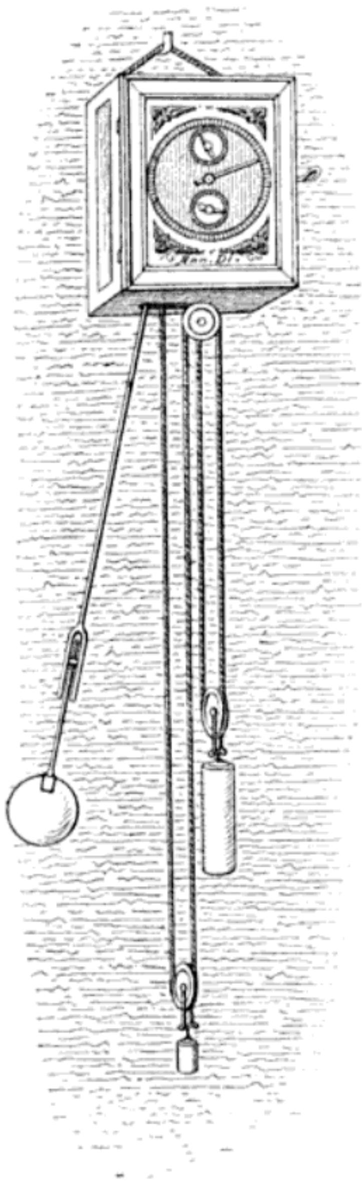
Galileo and Clocks

In the early 1600s, Galileo noticed the swinging motion of a chandelier in the Cathedral of Pisa. By watching the chandelier and timing its swings, Galileo found that each swing of the pendulum took the same amount of time, even as the angle of the swings changed.

Why do you think pendulums made such good clocks?


"Galileo Fresco" by Sailko is licensed under CC BY-SA 3.0

In 1657, Christiaan Huygens, a Dutch scientist, used Galileo's discoveries to patent the first pendulum clock. Before this, clocks were only accurate within a range of 15 minutes, but Huygens' pendulum clock was accurate within 15 seconds.

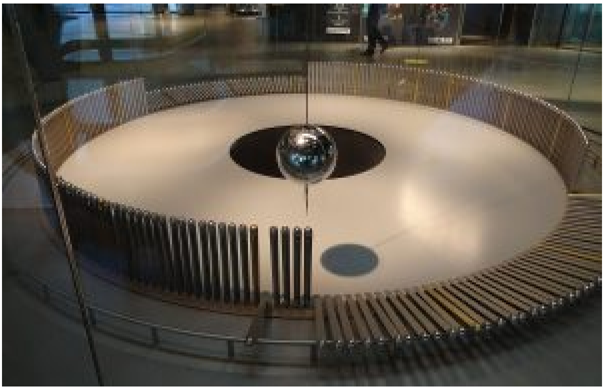


“[Pendulum Clock]” *is public domain*

Focault's Pendulum

In 1851, a Frenchman named Léon Focault used a pendulum to demonstrate that Earth rotated on its axis, a disputed scientific fact at the time. To do this, a Focault pendulum has a heavy metal weight suspended from a high ceiling. It is surrounded by a circle of pins which are knocked down by the pendulum's swings. Over time, the pendulum's path swing changes due to the influence of Earth's rotation and pins fall all around the circle.

As seen in the image, below, Focault pendulums are a familiar sight in science museums around the world today.



"Barcelona Cosmocaixa Focault Pendulum" by Ad Meskens is licensed under CC BY-SA 4.0

Pendulums in Real Life

Wrecking ball

As seen in the image, below, a wrecking ball is a large pendulum suspended from a construction crane.

“Wrecking Ball” by Stefan Kuhn is licensed under CC BY-SA 3.0

Tire swing vs. playground swing

Swings are an easy way to see pendulums in real life.

- In the image on the left, a tire swing is an example of a simple pendulum.
- In the image on the right, the playground swings are suspended from two chains. As shown in the pendulum lab, the length of a pendulum’s string affects the amount of time each period takes. Therefore, both chains on the swing must be exactly the same length or the two sides of the swing will move at different speeds in a jerky motion.

"*Tire Swing*" *is public domain*

"*Swings*" *is public domain*

NGSS Standards

Performance Expectations

3-PS2-2.	Planning and Carrying Out InvestigationsPlanning and carrying out investigations to answer questions or test solutions to problems in 3–5 builds on K–2 experiences and progresses to include investigations that control variables and provide evidence to support explanations or design solutions.Make observations and/or measurements to produce data to serve as the basis for evidence for an explanation of a phenomenon or test a design solution.">Make observations and/or measurements PS2.A: Forces and MotionThe patterns of an object's motion in various situations can be observed and measured; when that past motion exhibits a regular pattern, future motion can be predicted from it. (Boundary: Technical terms, such as magnitude, velocity, momentum, and vector quantity, are not introduced at this level, but the concept that some quantities need both size and direction to be described is developed.)">of an object's motion Planning and Carrying Out InvestigationsPlanning and carrying out investigations to answer questions or test solutions to problems in 3–5 builds on K–2 experiences and progresses to include investigations that control variables and provide evidence to support explanations or design solutions.Make observations and/or measurements to produce data to serve as the basis for evidence for an explanation of a phenomenon or test a design solution.">to provide evidence PatternsPatterns of change can be used to make predictions.">that a pattern can be used to predict PS2.A: Forces and MotionThe patterns of an object's motion in various situations can be observed and measured; when that past motion exhibits a regular pattern, future motion can be predicted from it. (Boundary: Technical terms, such as magnitude, velocity, momentum, and vector quantity, are not introduced at this level, but the concept that some quantities need both size and direction to be described is developed.)">future motion.

MS-PS3-1.	Analyzing and Interpreting DataAnalyzing data in 6–8 builds on K–5 and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis.Construct and interpret graphical displays of data to identify linear and nonlinear relationships.">Construct and interpret graphical displays of data to describe Scale, Proportion, and QuantityProportional relationships (e.g. speed as the ratio of distance traveled to time taken) among different types of quantities provide information about the magnitude of properties and processes.">the relationships of PS3.A: Definitions of EnergyMotion energy is properly called kinetic energy; it is proportional to the mass of the moving object and grows with the square of its speed." aria-describedby="popover200594">kinetic energy to the mass of an object and to the speed of an object.

MS-PS3-2.	Developing and Using ModelsModeling in 6–8 builds on K–5 and progresses t more abstract phenomena and design systems.Develop a model to describe u ModelsModels can be used to represent systems and their interactions – suc within systems.">to describe that when PS3.A: Definitions of EnergyA system their relative positions.PS3.C: Relationship Between Energy and ForcesWhen energy to be transferred to or from the object.">the arrangement of objects i are stored in the system.

Disciplinary Core Ideas

Third grade:

PS2.A: Forces and Motion

- The patterns of an object's motion in various situations can be observed and measured; when that past motion exhibits a regular pattern, future motion can be predicted from it

Middle School:

PS3.A: Definitions of Energy

- Motion energy is properly called kinetic energy; it is proportional to the mass of the moving object and grows with the square of its speed. (MS-PS3-1)
- A system of objects may also contain stored (potential) energy, depending on their relative positions. (MS-PS3-2)

PS3.B: Conservation of Energy and Energy Transfer

- When the motion energy of an object changes, there is inevitably some other change in energy at the same time. (MS-PS3-5)

Crosscutting Concepts

Scale, Proportion, and Quantity

- Proportional relationships (e.g. speed as the ratio of distance traveled to time taken) among different types of quantities provide information about the magnitude of properties and processes. (MS-PS3-1),(MS-PS3-4)

Systems and System Models

- Models can be used to represent systems and their interactions – such as inputs, processes, and outputs – and energy and matter flows within systems. (MS-PS3-2)

Energy and Matter

- Energy may take different forms (e.g. energy in fields, thermal energy, energy of motion). (MS-PS3-5)
- The transfer of energy can be tracked as energy flows through a designed or natural system. (MS-PS3-3)

Lesson Ideas:

Build a block wall. Can the children make the pendulum smash the wall down?

Have children experiment with mass, length of string, how high they raise the pendulum, etc to see what variables affect period. You can have them set up two pendulums at a time to compare the period.

On the playground, have the children experiment with swings. How do you make an empty swing go higher? Faster? How about with a friend?

3. Electricity

Formative Assessment: Electricity

What is Electricity?

Electricity is the movement of electrons (negatively charged particles) from one atom to another. This flow of electrical charge is called a current.

What is a Circuit?

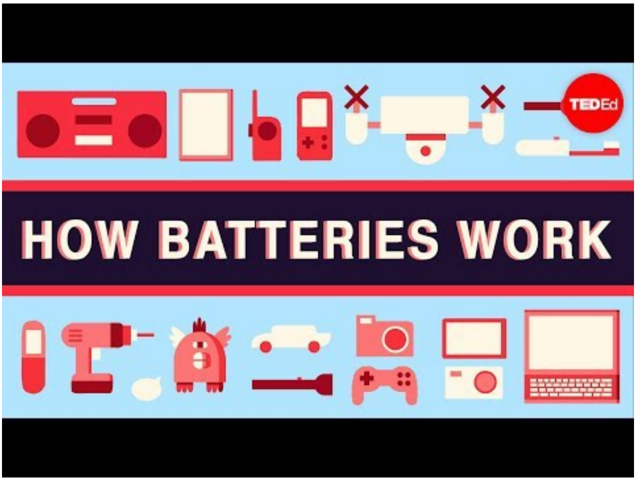
A circuit is a path through which **electricity** can flow. The word “circuit” has the same root as the word “circle”, meaning to go around.

- Closed circuit: The circle is closed, so energy is flowing.
- Open circuit: The circle is open, so energy cannot flow.

To make a simple circuit, you need three things:

- **Battery**: source of **potential energy** in the form of electricity

Watch the video, below, to see how batteries work:

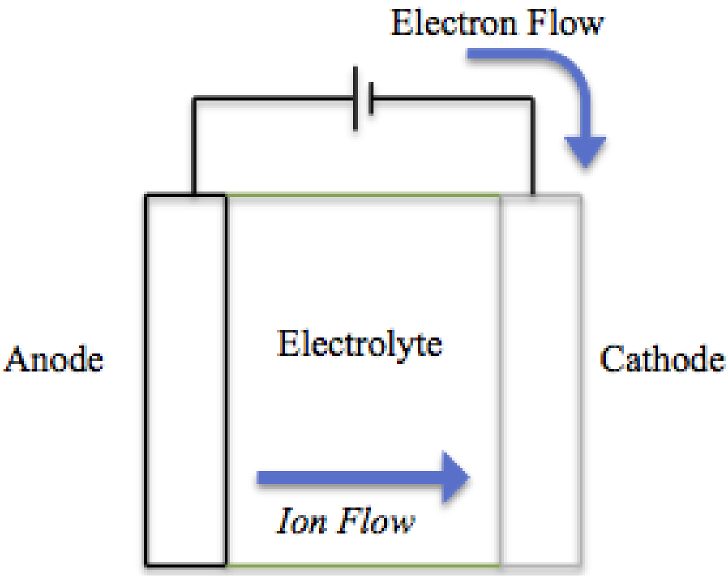


A YouTube element has been excluded from this version of the text. You can view it online here: https://pressbooks.uiowa.edu/methodsii/?p=1177

Video credit: "How Batteries Work" by Adam Jacobson/TED-Ed is licensed under CC BY-NC-ND 4.0

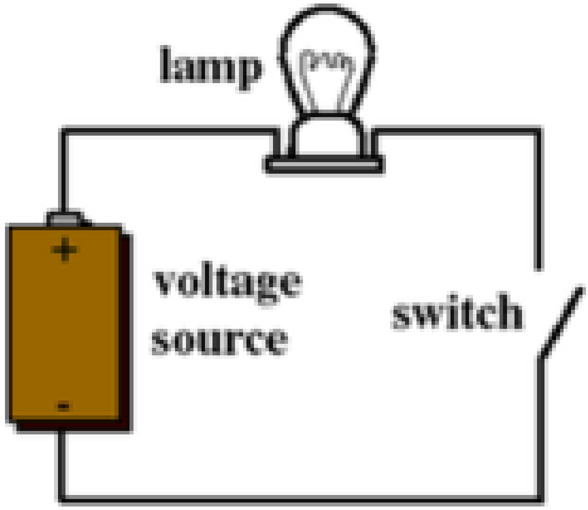
- **Copper wire**: path for the electricity to flow in through the circuit. Copper is a good conductor of electricity so it is often used for wires.
- **Light bulb**: uses electricity from the circuit to light up

Chemical reactions inside the battery cause electrons to build up at the anode (the negative side). They want to get to the cathode (the positive side), but a separator blocks them from traveling within the battery. As seen in the image, below, a copper wire is needed to connect the two sides and provide a path for the electrons.



"Battery" by Halie1758 is licensed under CC BY-SA 4.0

The diagram, below, shows a simple circuit. The **current** flows from the negative side of the battery, through the copper wire to the light bulb, and then through the copper wire to the positive side of the battery. Additionally, a switch can be used to turn the flow of electricity on (closed circuit) and off (open circuit).

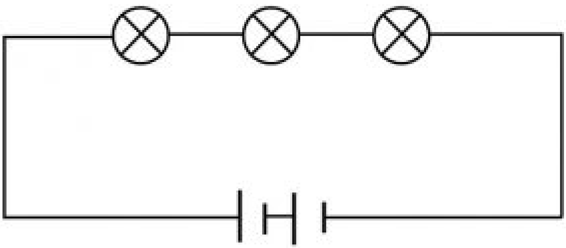


"*Simple electric circuit*" *by* *Kvr.lohith* *is licensed under* CC BY-SA 4.0

Types of Circuits

- **Series circuit**: Electricity flows through one continuous loop

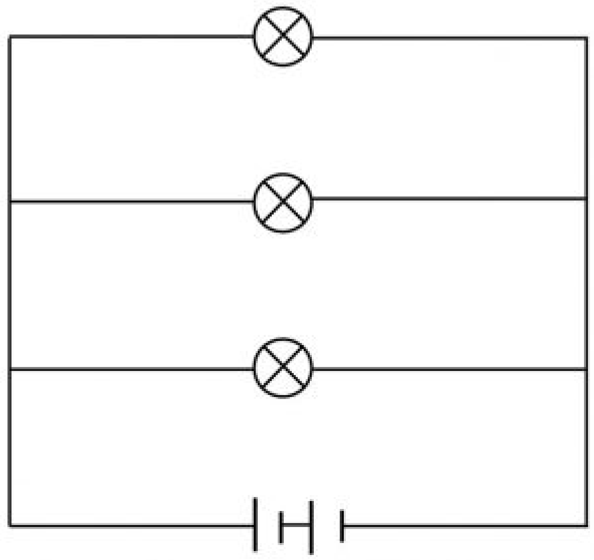
In the image, below, electricity flows to each light bulb (represented by a circle with an X) through one continuous path.



"*Series Circuit*" *by brightyellowjeans is licensed under* CC BY-SA 4.0

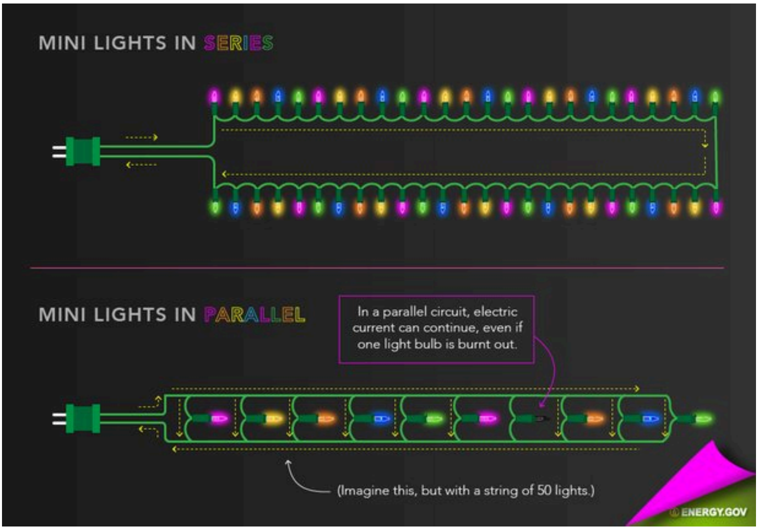
- **Parallel circuit**: Electricity flows through multiple loops in the same circuit

As seen in the image, below, electricity flows to each light bulb (represented by a circle with an X) through a different path within the same circuit.



"Parallel Circuit" by brightyellowjeans is licensed under CC BY-SA 4.0

To understand **series** and **parallel** circuits, it is helpful to use the example of holiday lights.

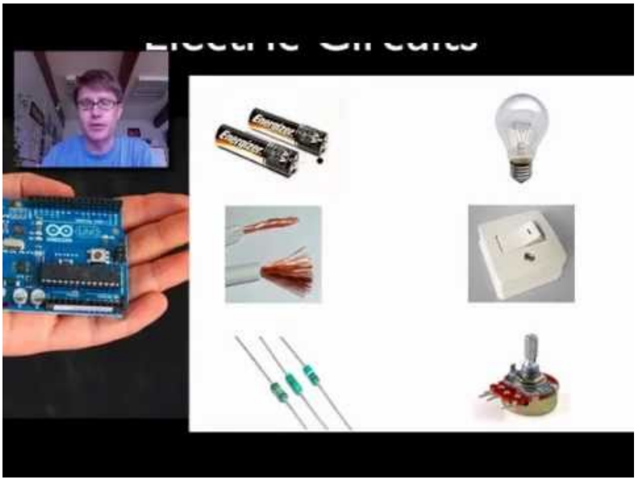


"Mini Lights" by Energy.gov is public domain

As seen in the image, above, holiday lights can be wired in a series or a parallel circuit.

- In a series circuit, each light is wired through the same continuous path. So if one light burns out, the flow of energy through the circuit is interrupted and the entire string of lights will not work.
- In a parallel circuit, each light is connected to the circuit by a separate pathway. Thus, if one light burns out, all of the other lights will continue to function.

For more information about electricity and circuits, watch the video below:



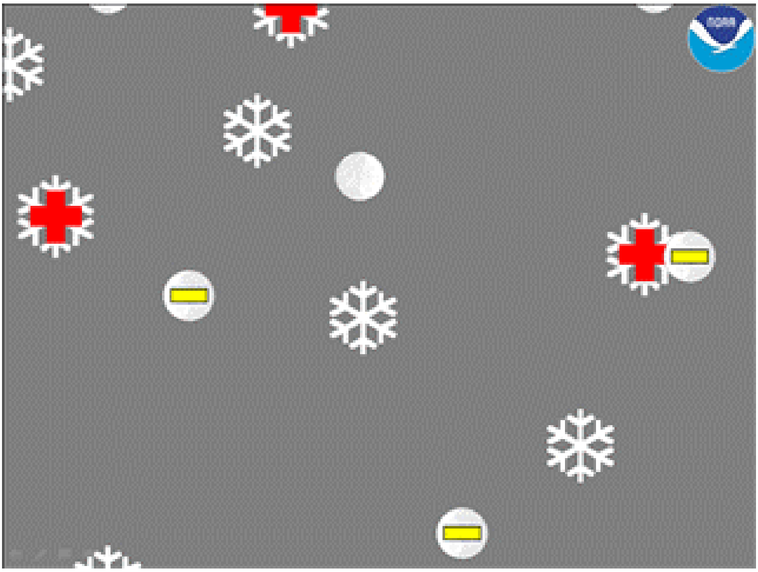
A YouTube element has been excluded from this version of the text. You can view it online here: https://pressbooks.uiowa.edu/methodsii/?p=1177

Video credit: "Electricity and Electric Circuits" by Bozeman Science is licensed under CC BY 3.0

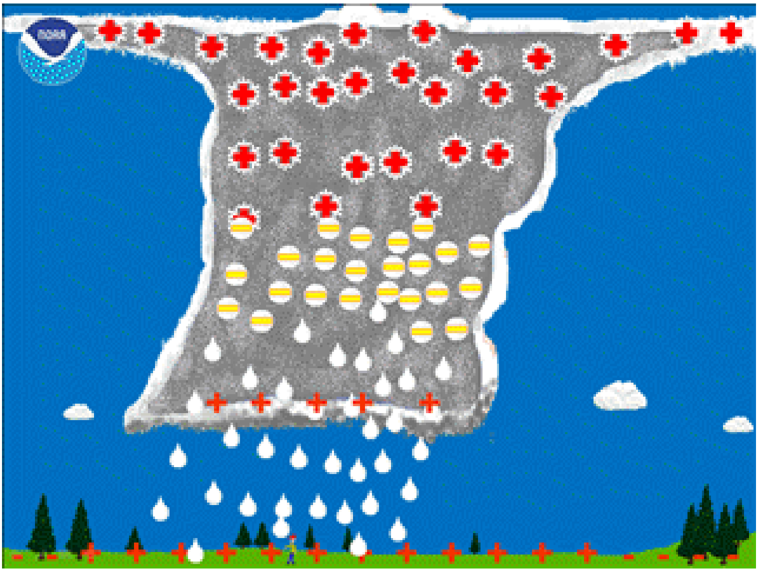
Electricity in Nature

Humans use electricity as a power source, but it occurs everywhere. Lightning is the most obvious example of electricity in nature. The animations, below, illustrate how lightning occurs.

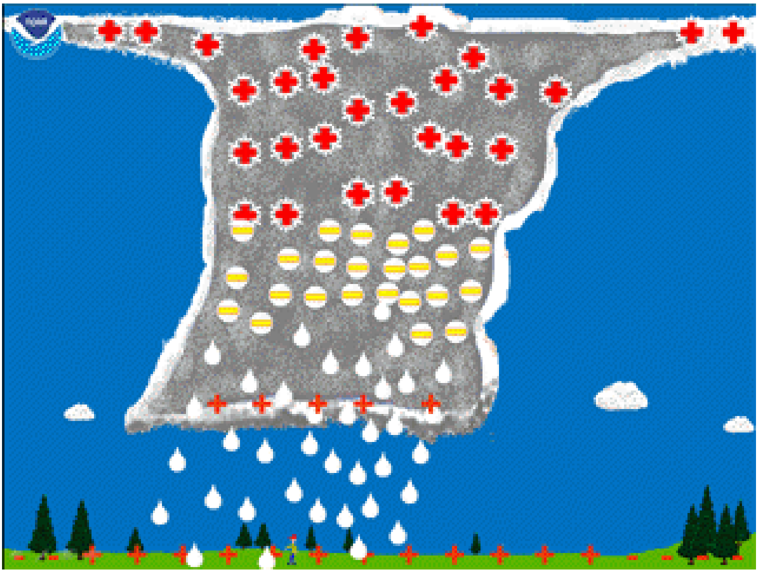
1. During a thunderstorm, particles inside clouds (mostly ice crystals) begin to move rapidly due to the energy of the storm. As these particles collide, they become positively or negatively charged.



2. Positive and negative charges build up within clouds and the atmosphere. Smaller particles lose electrons so they become positively charged and move into the upper part of the cloud. Larger particles gain these electrons so they become negatively charged and move into the lower part of the cloud.



3. When separated charges build up enough, they are discharged in the form of lightning. Lightning can occur between clouds or between clouds and the ground.

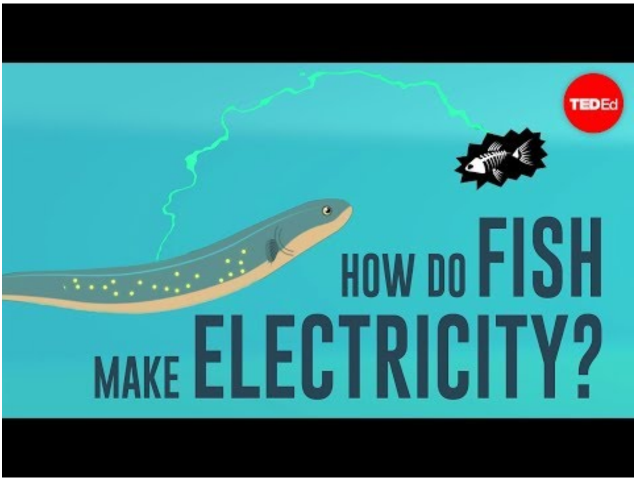


“Lightning animations” by NOAA are public domain

Interestingly, lightning does not only happen during thunderstorms. Scientists have observed lightning in space on Jupiter and Saturn. It can also happen during volcanic eruptions, as seen in the image, below. Before an eruption, ash particles are densely packed within the volcano. When a volcano erupts, the ash particles rapidly move and collide which causes them to become positively and negatively charged. Like in a storm cloud, the charged particles separate and lightning occurs.

"Galunggung, Indonesia" by R. Hadian/U.S. Geological Survey is public domain

Electricity is also found in living things. For example, neurons in the human brain use electricity to send messages between cells. Some fish, such as electric eels, also produce their own electricity to locate and stun prey. Watch the video, below, to learn how this works.



A YouTube element has been excluded from this version of the text. You can view it online here: https://pressbooks.uiowa.edu/methodsii/?p=1177

Video credit: "How Do Fish Make Electricity?" by Eleanor Nelsen/TED-Ed is licensed under CC BY-NC-ND 4.0

NGSS
Performance Standards:

3-PS2-3.	Asking Questions and Defining ProblemsAsking questions and defining problems in grades 3–5 builds on grades K–2 experiences and progresses to specifying qualitative relationships.Ask questions that can be investigated based on patterns such as cause and effect relationships.">Ask questions to determine Cause and EffectCause and effect relationships are routinely identified, tested, and used to explain change.">cause and effect relationships PS2.B: Types of InteractionsElectric, and magnetic forces between a pair of objects do not require that the objects be in contact. The sizes of the forces in each situation depend on the properties of the objects and their distances apart and, for forces between two magnets, on their orientation relative to each other.">of electric or magnetic interactions between two objects not in contact with each other. [Clarification Statement: Examples of an electric force could include the force on hair from an electrically charged balloon and the electrical forces between a charged rod and pieces of paper; examples of a magnetic force could include the force between two permanent magnets, the force between an electromagnet and steel paperclips, and the force exerted by one magnet versus the force exerted by two magnets. Examples of cause and effect relationships could include how the distance between objects affects strength of the force and how the orientation of magnets affects the direction of the magnetic force.] [*Assessment Boundary: Assessment is limited to forces produced by objects that can be manipulated by students, and electrical interactions are limited to static electricity.*]

4-PS3-2.	Planning and Carrying Out InvestigationsPlanning and carrying out investigations to answer questions or test solutions to problems in 3–5 builds on K–2 experiences and progresses to include investigations that control variables and provide evidence to support explanations or design solutions.Make observations to produce data to serve as the basis for evidence for an explanation of a phenomenon or test a design solution.">Make observations to provide evidence that Energy and MatterEnergy can be transferred in various ways and between objects.">energy can be transferred PS3.A: Definitions of EnergyEnergy can be moved from place to place by moving objects or through sound, light, or electric currents. PS3.B: Conservation of Energy and Energy TransferEnergy is present whenever there are moving objects, sound, light, or heat. When objects collide, energy can be transferred from one object to another, thereby changing their motion. In such collisions, some energy is typically also transferred to the surrounding air; as a result, the air gets heated and sound is produced.Light also transfers energy from place to place.Energy can also be transferred from place to place by electric currents, which can then be used locally to produce motion, sound, heat, or light. The currents may have been produced to begin with by transforming the energy of motion into electrical energy.">from place to place by sound, light, heat, and electric currents. [*Assessment Boundary: Assessment does not include quantitative measurements of energy.*]

4-PS3-4.	Constructing Explanations and Designing SolutionsConstructing explanations and designing solutions in 3–5 builds on K–2 experiences and progresses to the use of evidence in constructing explanations that specify variables that describe and predict phenomena and in designing multiple solutions to design problems.Apply scientific ideas to solve design problems.">Apply scientific ideas to design, test, ETS1.A: Defining Engineering ProblemsPossible solutions to a problem are limited by available materials and resources (constraints). The success of a designed solution is determined by considering the desired features of a solution (criteria). Different proposals for solutions can be compared on the basis of how well each one meets the specified criteria for success or how well each takes the constraints into account.">and refine a device PS3.B: Conservation of Energy and Energy TransferEnergy can also be transferred from place to place by electric currents, which can then be used locally to produce motion, sound, heat, or light. The currents may have been produced to begin with by transforming the energy of motion into electrical energy.PS3.D: Energy in Chemical Processes and Everyday LifeThe expression “produce energy” typically refers to the conversion of stored energy into a desired form for practical use.">that converts energy Energy and MatterEnergy can be transferred in various ways and between objects.Influence of Science, Engineering and Technology on Society and the Natural WorldEngineers improve existing technologies or develop new ones.">from one form to another.* [Clarification Statement: Examples of devices could include electric circuits that convert electrical energy into motion energy of a vehicle, light, or sound; and, a passive solar heater that converts light into heat. Examples of constraints could include the materials, cost, or time to design the device.] [*Assessment Boundary: Devices should be limited to those that convert motion energy to electric energy or use stored energy to cause motion or produce light or sound.*]

4-ESS3-1.	Obtaining, Evaluating, and Communicating InformationObtaining, evaluating, and communicating information in 3–5 builds on K–2 experiences and progresses to evaluate the merit and accuracy of ideas and methods.Obtain and combine information from books and other reliable media to explain phenomena.">Obtain and combine information to describe that ESS3.A: Natural ResourcesEnergy and fuels that humans use are derived from natural sources, and their use affects the environment in multiple ways. Some resources are renewable over time, and others are not.">energy and fuels are derived from natural resources Cause and EffectCause and effect relationships are routinely identified and used to explain change.Interdependence of Science, Engineering, and TechnologyKnowledge of relevant scientific concepts and research findings is important in engineering.Influence of Science, Engineering and Technology on Society and the Natural WorldOver time, people's needs and wants change, as do their demands for new and improved technologies.">and their uses affect the environment. [Clarification Statement: Examples of renewable energy resources could include wind energy, water behind dams, and sunlight; non-renewable energy resources are fossil fuels and fissile materials. Examples of environmental effects could include loss of habitat due to dams, loss of habitat due to surface mining, and air pollution from burning of fossil fuels.]

MS-PS2-3.	Asking Questions and Defining ProblemsAsking questions and defining problems in grades 6–8 builds from grades K–5 experiences and progresses to specifying relationships between variables, and clarifying arguments and models.Ask questions that can be investigated within the scope of the classroom, outdoor environment, and museums and other public facilities with available resources and, when appropriate, frame a hypothesis based on observations and scientific principles.">Ask questions about data to determine PS2.B: Types of InteractionsElectric and magnetic (electromagnetic) forces can be attractive or repulsive, and their sizes depend on the magnitudes of the charges, currents, or magnetic strengths involved and on the distances between the interacting objects.">the factors Cause and EffectCause and effect relationships may be used to predict phenomena in natural or designed systems.">that affect PS2.B: Types of InteractionsElectric and magnetic (electromagnetic) forces can be attractive or repulsive, and their sizes depend on the magnitudes of the charges, currents, or magnetic strengths involved and on the distances between the interacting objects.">the strength of electric and magnetic forces. [Clarification Statement: Examples of devices that use electric and magnetic forces could include electromagnets, electric motors, or generators. Examples of data could include the effect of the number of turns of wire on the strength of an electromagnet, or the effect of increasing the number or strength of magnets on the speed of an electric motor.] [*Assessment Boundary: Assessment about questions that require quantitative answers is limited to proportional reasoning and algebraic thinking.*]

MS-PS2-5.	Planning and Carrying Out InvestigationsPlanning and carrying out investigations to answer questions or test solutions to problems in 6–8 builds on K–5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or design solutions.Conduct an investigation and evaluate the experimental design to produce data to serve as the basis for evidence that can meet the goals of the investigation.">Conduct an investigation and evaluate the experimental design to provide evidence that PS2.B: Types of InteractionsForces that act at a distance (electric, magnetic, and gravitational) can be explained by fields that extend through space and can be mapped by their effect on a test object (a charged object, or a ball, respectively).">fields exist between objects Cause and EffectCause and effect relationships may be used to predict phenomena in natural or designed systems.">exerting forces on each other PS2.B: Types of InteractionsForces that act at a distance (electric, magnetic, and gravitational) can be explained by fields that extend through space and can be mapped by their effect on a test object (a charged object, or a ball, respectively).">even though the objects are not in contact. [Clarification Statement: Examples of this phenomenon could include the interactions of magnets, electrically-charged strips of tape, and electrically-charged pith balls. Examples of investigations could include first-hand experiences or simulations.] [*Assessment Boundary: Assessment is limited to electric and magnetic fields, and limited to qualitative evidence for the existence of fields.*]

DCI

3rd grade

PS2.B: Types of Interactions

- Objects in contact exert forces on each other. (3-PS2-1)
- Electric, and magnetic forces between a pair of objects do not require that the objects be in contact. The sizes of the forces in each situation depend on the properties of the objects and their distances apart and, for forces between two magnets, on their orientation relative to each other. (3-PS2-3),(3-PS2-4)

4th Grade

PS3.A: Definitions of Energy

- Energy can be moved from place to place by moving objects or through sound, light, or electric currents. (4-PS3-2),(4-PS3-3)

PS3.B: Conservation of Energy and EnergyTransfer

- Energy can also be transferred from place to place by electric currents, which can then be used locally to produce motion, sound, heat, or light. The currents may have been produced to begin with by transforming the energy of motion into electrical energy. (4-PS3-2),(4-PS3-4)

PS3.D: Energy in Chemical Processes and Everyday Life

- The expression "produce energy" typically refers to the conversion of stored energy into a desired form for practical use. (4-PS3-4)

ESS3.A: Natural Resources

- Energy and fuels that humans use are derived from natural sources, and their use affects the environment in multiple ways. Some resources are renewable over time, and others are not. (4-ESS3-1)

Middle School

PS2.B: Types of Interactions

- Electric and magnetic (electromagnetic) forces can be attractive or repulsive, and their sizes depend on the magnitudes of the charges, currents, or magnetic strengths involved and on the distances between the interacting objects. (MS-PS2-3)
- Gravitational forces are always attractive. There is a gravitational force between any two masses, but it is very small except when one or both of the objects have large mass—e.g., Earth and the sun. (MS-PS2-4)
- Forces that act at a distance (electric, magnetic, and gravitational) can be explained by fields that extend through space and can be mapped by their effect on a test object (a charged object, a magnet, or a ball, respectively). (MS-PS2-5)

Crosscutting

Cause and Effect

- Cause and effect relationships are routinely identified. (3-PS2-1)
- Cause and effect relationships are routinely identified, tested, and used to explain change. (3-PS2-3)

Energy and Matter

- Energy can be transferred in various ways and between objects. (4-PS3-1),(4-PS3-2),(4-PS3-3),(4-PS3-4)

Cause and Effect

- Cause and effect relationships are routinely identified and used to explain change. (4-ESS3-1)

Lesson Ideas:

Ted had some really great ideas for prompts for challenges to do with electricity. Kids would do well with them. (get prompts)

4. Wind Turbines

Formative Assessment: Wind Turbines

What are Wind Turbines?

Wind energy is an important and growing source of renewable energy. The process of generating energy by harnessing the power of the wind is a simple idea of energy conversion. There are many different methods to produce energy from wind. The most common method is through the use of wind turbines. Wind turbines convert kinetic energy from the wind to mechanical energy through the rotational movement of the blades. An electric generator then converts the mechanical energy from the spinning blades into electric energy that can be used to power many sources.

A YouTube element has been excluded from this version of the text. You can view it online here: https://pressbooks.uiowa.edu/methodsii/?p=1458

Video credit: "Energy 101: Wind Power" by Lee Patrick Sullivan is licensed under CC BY-SA 4.0

Key Takeaways

Type your key takeaways here.

- Wind energy is a form of kinetic energy
- Rotation of the blades (turbine) and gear box is a form of mechanical energy
- The generator has a spinning rotor causing a rotating magnetic flux inside stator of coils to create current as a form of electrical energy (induction)

Wind turbines have a significant history dating back to 250 BC or even earlier with vertical structures being used in the Middle East, India, and China to pump water or crush grain [13]. Leading up to today's application, we can see them in use all over the world as a source of renewable energy.

History of Windmills:

- **3,500 BC:** Egyptians invented the first sailboats.
- **2,000 BC:** Windmills were used to pump water in China
- **500 to 900 AD:** Persians innovated windmills that were used to crush grains and pump water
- **1300's AD:** The Dutch built windmills with a horizontal axis, a technological advancement, that allowed them to drain fields along with improvements in grain grinding.
- **Early 1800s:** Westward migration brought windmills to the plains for pumping water, a technology still used in rural areas today.
- **1887:** Professor James Blyth, from Glasgow, Scotland, built the first windmill to generate electrical energy.
- **By the 1920's:** Windmills across the United States were producing significant quantities of electricity for commercial sale.
- **The 1950's:** A negative turning point for wind generated energy in the United States as a turn was made toward cheap coal to power homes.

- **1990s:** Concerns for the environment, particularly Climate Change, lead a renewed expansion of green energy sources, including tax incentives
- **2000's:** Iowa is a leading state in the realm of wind energy. Currently Iowa leads the nation in per capita generation of Energy and is second, only to Texas, in overall energy produced.

NGSS

Performance Standards:

3-PS2-3.	Asking Questions and Defining ProblemsAsking questions and defining problems in grades 3–5 builds on grades K–2 experiences and progresses to specifying qualitative relationships.Ask questions that can be investigated based on patterns such as cause and effect relationships.">Ask questions to determine Cause and EffectCause and effect relationships are routinely identified, tested, and used to explain change.">cause and effect relationships PS2.B: Types of InteractionsElectric, and magnetic forces between a pair of objects do not require that the objects be in contact. The sizes of the forces in each situation depend on the properties of the objects and their distances apart and, for forces between two magnets, on their orientation relative to each other.">of electric or magnetic interactions between two objects not in contact with each other. [Clarification Statement: Examples of an electric force could include the force on hair from an electrically charged balloon and the electrical forces between a charged rod and pieces of paper; examples of a magnetic force could include the force between two permanent magnets, the force between an electromagnet and steel paperclips, and the force exerted by one magnet versus the force exerted by two magnets. Examples of cause and effect relationships could include how the distance between objects affects strength of the force and how the orientation of magnets affects the direction of the magnetic force.] [*Assessment Boundary: Assessment is limited to forces produced by objects that can be manipulated by students, and electrical interactions are limited to static electricity.*]

4-PS3-2.	Planning and Carrying Out InvestigationsPlanning and carrying out investigations to answer questions or test solutions to problems in 3–5 builds on K–2 experiences and progresses to include investigations that control variables and provide evidence to support explanations or design solutions.Make observations to produce data to serve as the basis for evidence for an explanation of a phenomenon or test a design solution.">Make observations to provide evidence that Energy and MatterEnergy can be transferred in various ways and between objects.">energy can be transferred PS3.A: Definitions of EnergyEnergy can be moved from place to place by moving objects or through sound, light, or electric currents. PS3.B: Conservation of Energy and Energy TransferEnergy is present whenever there are moving objects, sound, light, or heat. When objects collide, energy can be transferred from one object to another, thereby changing their motion. In such collisions, some energy is typically also transferred to the surrounding air; as a result, the air gets heated and sound is produced.Light also transfers energy from place to place.Energy can also be transferred from place to place by electric currents, which can then be used locally to produce motion, sound, heat, or light. The currents may have been produced to begin with by transforming the energy of motion into electrical energy.">from place to place by sound, light, heat, and electric currents. [*Assessment Boundary: Assessment does not include quantitative measurements of energy.*]

4-PS3-4.	Constructing Explanations and Designing SolutionsConstructing explanations and designing solutions in 3–5 builds on K–2 experiences and progresses to the use of evidence in constructing explanations that specify variables that describe and predict phenomena and in designing multiple solutions to design problems.Apply scientific ideas to solve design problems.">Apply scientific ideas to design, test, ETS1.A: Defining Engineering ProblemsPossible solutions to a problem are limited by available materials and resources (constraints). The success of a designed solution is determined by considering the desired features of a solution (criteria). Different proposals for solutions can be compared on the basis of how well each one meets the specified criteria for success or how well each takes the constraints into account.">and refine a device PS3.B: Conservation of Energy and Energy TransferEnergy can also be transferred from place to place by electric currents, which can then be used locally to produce motion, sound, heat, or light. The currents may have been produced to begin with by transforming the energy of motion into electrical energy.PS3.D: Energy in Chemical Processes and Everyday LifeThe expression "produce energy" typically refers to the conversion of stored energy into a desired form for practical use.">that converts energy Energy and MatterEnergy can be transferred in various ways and between objects.Influence of Science, Engineering and Technology on Society and the Natural WorldEngineers improve existing technologies or develop new ones.">from one form to another.* [Clarification Statement: Examples of devices could include electric circuits that convert electrical energy into motion energy of a vehicle, light, or sound; and, a passive solar heater that converts light into heat. Examples of constraints could include the materials, cost, or time to design the device.] [*Assessment Boundary: Devices should be limited to those that convert motion energy to electric energy or use stored energy to cause motion or produce light or sound.*]

4-ESS3-1.	Obtaining, Evaluating, and Communicating InformationObtaining, evaluating, and communicating information in 3–5 builds on K–2 experiences and progresses to evaluate the merit and accuracy of ideas and methods.Obtain and combine information from books and other reliable media to explain phenomena.">Obtain and combine information to describe that ESS3.A: Natural ResourcesEnergy and fuels that humans use are derived from natural sources, and their use affects the environment in multiple ways. Some resources are renewable over time, and others are not.">energy and fuels are derived from natural resources Cause and EffectCause and effect relationships are routinely identified and used to explain change.Interdependence of Science, Engineering, and TechnologyKnowledge of relevant scientific concepts and research findings is important in engineering.Influence of Science, Engineering and Technology on Society and the Natural WorldOver time, people's needs and wants change, as do their demands for new and improved technologies.">and their uses affect the environment. [Clarification Statement: Examples of renewable energy resources could include wind energy, water behind dams, and sunlight; non-renewable energy resources are fossil fuels and fissile materials. Examples of environmental effects could include loss of habitat due to dams, loss of habitat due to surface mining, and air pollution from burning of fossil fuels.]

MS-PS2-3.	Asking Questions and Defining ProblemsAsking questions and defining problems in grades 6–8 builds from grades K–5 experiences and progresses to specifying relationships between variables, and clarifying arguments and models.Ask questions that can be investigated within the scope of the classroom, outdoor environment, and museums and other public facilities with available resources and, when appropriate, frame a hypothesis based on observations and scientific principles.">Ask questions about data to determine PS2.B: Types of InteractionsElectric and magnetic (electromagnetic) forces can be attractive or repulsive, and their sizes depend on the magnitudes of the charges, currents, or magnetic strengths involved and on the distances between the interacting objects.">the factors Cause and EffectCause and effect relationships may be used to predict phenomena in natural or designed systems.">that affect PS2.B: Types of InteractionsElectric and magnetic (electromagnetic) forces can be attractive or repulsive, and their sizes depend on the magnitudes of the charges, currents, or magnetic strengths involved and on the distances between the interacting objects.">the strength of electric and magnetic forces. [Clarification Statement: Examples of devices that use electric and magnetic forces could include electromagnets, electric motors, or generators. Examples of data could include the effect of the number of turns of wire on the strength of an electromagnet, or the effect of increasing the number or strength of magnets on the speed of an electric motor.] [*Assessment Boundary: Assessment about questions that require quantitative answers is limited to proportional reasoning and algebraic thinking.*]

MS-PS2-5.	Planning and Carrying Out InvestigationsPlanning and carrying out investigations to answer questions or test solutions to problems in 6–8 builds on K–5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or design solutions.Conduct an investigation and evaluate the experimental design to produce data to serve as the basis for evidence that can meet the goals of the investigation.">Conduct an investigation and evaluate the experimental design to provide evidence that PS2.B: Types of InteractionsForces that act at a distance (electric, magnetic, and gravitational) can be explained by fields that extend through space and can be mapped by their effect on a test object (a charged object, or a ball, respectively).">fields exist between objects Cause and EffectCause and effect relationships may be used to predict phenomena in natural or designed systems.">exerting forces on each other PS2.B: Types of InteractionsForces that act at a distance (electric, magnetic, and gravitational) can be explained by fields that extend through space and can be mapped by their effect on a test object (a charged object, or a ball, respectively).">even though the objects are not in contact. [Clarification Statement: Examples of this phenomenon could include the interactions of magnets, electrically-charged strips of tape, and electrically-charged pith balls. Examples of investigations could include first-hand experiences or simulations.] [*Assessment Boundary: Assessment is limited to electric and magnetic fields, and limited to qualitative evidence for the existence of fields.*]

DCI

3rd grade

PS2.B: Types of Interactions

- Objects in contact exert forces on each other. (3-PS2-1)
- Electric, and magnetic forces between a pair of objects do not require that the objects be in contact. The sizes of the forces in each situation depend on the properties of the objects and their distances apart and, for forces between two magnets, on their orientation relative to each other. (3-PS2-3),(3-PS2-4)

PS3.A: Definitions of Energy

- Energy can be moved from place to place by moving objects or through sound, light, or electric currents. (4-PS3-2),(4-PS3-3)

PS3.B: Conservation of Energy and EnergyTransfer

- Energy can also be transferred from place to place by electric currents, which can then be used locally to produce motion, sound, heat, or light. The currents may have been produced to begin with by transforming the energy of motion into electrical energy. (4-PS3-2),(4-PS3-4)

PS3.D: Energy in Chemical Processes and Everyday Life

- The expression "produce energy" typically refers to the conversion of stored energy into a desired form for practical use. (4-PS3-4)

ESS3.A: Natural Resources

- Energy and fuels that humans use are derived from natural sources, and their use affects the environment in multiple ways. Some resources are renewable over time, and others are not. (4-ESS3-1)

Middle School

PS2.B: Types of Interactions

- Electric and magnetic (electromagnetic) forces can be attractive or repulsive, and their sizes depend on the magnitudes of the charges, currents, or magnetic strengths involved and on the distances between the interacting objects. (MS-PS2-3)
- Gravitational forces are always attractive. There is a gravitational force between any two masses, but it is very small except when one or both of the objects have large mass—e.g., Earth and the sun. (MS-PS2-4)
- Forces that act at a distance (electric, magnetic, and gravitational) can be explained by fields that extend through space and can be mapped by their effect on a test object (a charged object, a magnet, or a ball, respectively). (MS-PS2-5)

Crosscutting

Cause and Effect

- Cause and effect relationships are routinely identified. (3-PS2-1)
- Cause and effect relationships are routinely identified, tested, and used to explain change. (3-PS2-3)

Energy and Matter

- Energy can be transferred in various ways and between objects. (4-PS3-1),(4-PS3-2),(4-PS3-3),(4-PS3-4)

Cause and Effect

- Cause and effect relationships are routinely identified and used to explain change. (4-ESS3-1)

Lesson Ideas:

Ted had some really great ideas for prompts for challenges to do with electricity. Kids would do well with them. (get prompts)

5. Practice Quiz

Follow this link to take the physics practice quiz. You will get immediate feedback on your answers.

"[Focus photo of bulb](#)" is licensed under [CC0 1.0 Universal](#)

6.

Forces formative assessment: https://forms.gle/oFdHLf4GKQbA9tX69

What is a force?

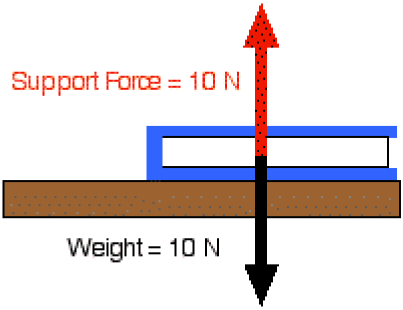
How can we make an object move? We can push, pull, spin, bounce, throw, kick, and drop it, for example. Is it possible to make something move without these actions? No! These actions are all **forces.** A force needs to act on an object that is not moving in order to make it move.

A force is a push or a pull.

Newton's First Law

Why do things not move?

We may not be aware of it, but every object, every motion, even things that are not moving are all acted on by forces at all times. Consider a book on a table. It may seem to not have any forces, but when you hold it book in the palm of your hand, you feel the force of the weight of the book pushing down on your hand. In order to hold the book up, your hand pushes up on the book. If you put the book back on the table, the book pushes down while the table pushes up.



(note: N stands for Newtons, or the unit of force)

The table pushes up on the book with the same amount of force as the book pushing down on the table, which leads us to a more sophisticated definition of force:

> A force is a push or pull upon an object resulting from the object's interaction with another object.

A force does not just magically appear by itself on an object; there needs to be another object acting on it in some way.

Why do things move?

So what will make something move? In order to make our book move, we need to apply another force to it that is strong enough to make it move. Experiment with the simulation, "net force," or the tug or war, below. What do you notice?

An interactive or media element has been excluded from this version of the text. You can view it online here:
https://pressbooks.uiowa.edu/methodsii/?p=1179

If you have equal forces applied to both ends of the rope, it does not move! The forces are balanced. In order to move, one side must have a bigger pull, or force, than the other. The forces must be unbalanced. When the forces on an object are unbalanced, things move. In other words, objects at rest remain at rest, while objects in motion stay in motion unless acted on by an unbalanced external force. This is Newton's First Law:

Newton's First Law

Objects at rest remain at rest, while objects in motion stay in motion unless acted on by an unbalanced external force

Or

Every object persists in its state of rest or uniform motion in a straight line unless it is compelled to change that state by forces impressed on it.

Car crashes vividly illustrate Newton's first law. Watch the video below. Why do we need to wear our seat belts in cars?

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In a car crash, the car stops suddenly but we keep going since we are an object in motion, staying in motion. We need the seat belt to stop us so we do not go flying through the windshield.

Why do things stop moving?

If objects in motion stay in motion, why do they stop eventually? Why will a block eventually stop sliding after you give it a hard push?

As the block slides, the floor rubs against it, creating a force that acts against the direction of the block's movement. This force is called **friction.**

Friction is:
A force that holds back the motion of a sliding object
Or
Resistance to motion of one object moving relative to another

Try the friction part of the simulation. Notice what happens when you increase the friction slider bar.

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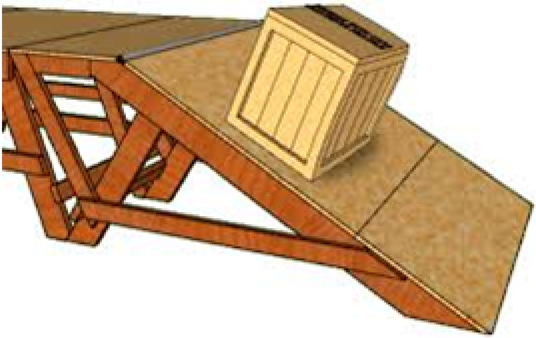
https://pressbooks.uiowa.edu/methodsii/?p=1179



Do objects have to be moving in order for there to be friction? No! You can have

kinetic friction, which is generated when things are moving, or **static friction,** which is present even when objects are staying still. For example, a box on a ramp may not slide because static friction is preventing it from sliding down the ramp.

What affects *how* objects move? Inertia!

Try playing around with the motion part of the simulation. What do you notice?

> *An interactive or media element has been excluded from this version of the text. You can view it online here:*
> *https://pressbooks.uiowa.edu/methodsii/?p=1179*

You probably noticed that heavier objects require a bigger push, or force, to move. Heavier objects have more **inertia.** Objects with greater inertia require more force to change their motion: to start moving, stop moving, or change direction. For example, think of the Titanic trying to avoid crashing into an iceberg; it had too much inertia to change direction quickly enough and hit the iceberg, thus sinking.

We also see inertia and Newton's first law in action when we perform a magic trick: pulling a tablecloth off a table that has dishes on it, and not breaking the dishes. Can you figure out why the dishes stay on the table?

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Notice that the video offered a few tips to make the trick work. It suggested that you weigh down any light objects, thus increasing their inertia. It also suggests pulling the tablecloth quickly and straight down. Why do you need to pull quickly and down?

Newton's Second Law

What factors affect force and how objects move?

We already see that **mass** affects how things move. Force has two other factors we need to be aware of: **speed** and **direction**. In the tablecloth trick, we had to pull the tablecloth quickly and down. We had to apply a fast force in a certain direction. If we moved the tablecloth slowly, the dishes would just come along with it. However, when we moved it quickly, the tablecloth accelerated, or sped up very quickly, and the dishes just couldn't keep up. This leads us to Newton's Second Law.

Newton's Second Law

The greater the mass of an object, the more force it will take to accelerate the object.

or

Force is equal to the change in momentum (mV) per change in time. For a constant mass, force equals mass times acceleration.

$F = ma$

For example, if we apply the same amount of force to a shopping cart loaded with groceries versus a empty cart, the loaded cart will move more slowly than the empty cart. If we want the two carts to move at the same speed, we need to use more force to move the loaded cart.

Newton's Third Law

So far, we have been thinking of forces as single forces acting on an object. However, is that entirely accurate?When a book rests on a table, you have two forces: the force of the book on the table and the force of the table on the book.

Consider a woman throwing a ball. What forces are present?

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https://pressbooks.uiowa.edu/methodsii/?p=1179

As the soccer player's hand pushes against the ball, the ball pushes back against her hand equally as hard. The two forces are equal. Forces come in pairs: an action and a reaction force. This is Newton's third law.

Newton's Third Law

For every action there is an equal and opposite reaction.

For example, when a diver jumps off a diving board, she pushes down on the board with her feet. The board pushes upwards against her feet just as hard and she is launched into the air.

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Rockets are launched into space with Newton's Third Law. Watch the following video (you can scroll ahead to 1:20 for the actual launch). What is the action and its equal and opposite reaction that launches the rocket into space?

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As the rocket fuel burns, it is pushed down out of the rocket as gas, which produces its opposite force that pushes upwards on the rocket, sending it into space.

Can you make an object move without touching it?

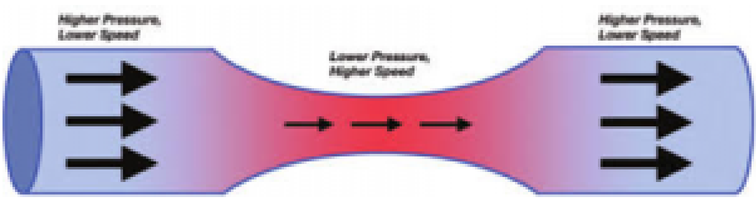
Yes you can!

Gravity, magnets, and **electrostatic forces (static electricity)** can all make things move without touching the object itself.

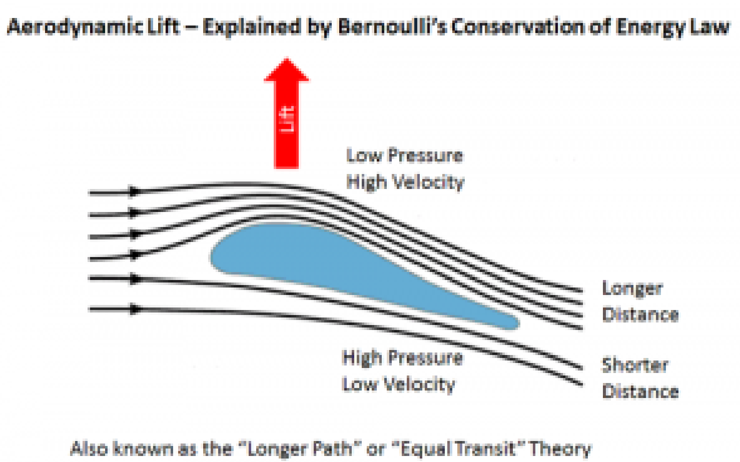
Bernoulli's Principle

How do airplanes fly? What forces allow a huge heavy plane to fly?

Bernoulli's Principle states that as the speed of a moving gas or liquid increases, **pressure** decreases and vice versa; as the speed decreases, pressure increases.



Airplane wings are curved to take advantage of this. As air flows over the top curved part of the wing, it has to travel at a faster speed because it needs to travel a longer distance than the air going under the wing. This creates a difference in pressure between the top of the wing and the bottom. The top of the wing has low pressure and the bottom of the wing has high pressure. This higher pressure generates lift and the airplane flies.



NGSS

Performance Expectations

K-PS2-1.	Planning and Carrying Out InvestigationsPlanning and carrying out investigations to answer questions or test solutions to problems in K–2 builds on prior experiences and progresses to simple investigations, based on fair tests, which provide data to support explanations or design solutions.With guidance, plan and conduct an investigation in collaboration with peers.">Plan and conduct an investigation to compare Cause and EffectSimple tests can be designed to gather evidence to support or refute student ideas about causes.">the effects of PS2.A: Forces and MotionPushes and pulls can have different strengths and directions.When objects touch or collide, they push on one another and can change motion.PS2.B: Types and InteractionsWhen objects touch or collide, they push on one another and can change motion.PS3.C: Relationship Between Energy and ForcesA bigger push or pull makes things speed up or slow down more quickly.">different strengths or different directions of pushes and pulls on the motion of an object. [Clarification Statement: Examples of pushes or pulls could include a string attached to an object being pulled, a person pushing an object, a person stopping a rolling ball, and two objects colliding and pushing on each other.] [*Assessment Boundary: Assessment is limited to different relative strengths or different directions, but not both at the same time. Assessment does not include non-contact pushes or pulls such as those produced by magnets.*]

K-PS2-2.	Analyzing and Interpreting DataAnalyzing data in K–2 builds on prior experiences and progresses to collecting, recording, and sharing observations.Analyze data from tests of an object or tool to determine if it works as intended.">Analyze data to determine if ETS1.A: Defining Engineering ProblemsA situation that people want to change or create can be approached as a problem to be solved through engineering. Such problems may have many acceptable solutions.">a design solution works as intended Cause and EffectSimple tests can be designed to gather evidence to support or refute student ideas about causes.">to change PS2.A: Forces and MotionPushes and pulls can have different strengths and directions.Pushing or pulling on an object can change the speed or direction of its motion and can start or stop it.">the speed or direction of an object with a push or a pull.* [Clarification Statement: Examples of problems requiring a solution could include having a marble or other object move a certain distance, follow a particular path, and knock down other objects. Examples of solutions could include tools such as a ramp to increase the speed of the object and a structure that would cause an object such as a marble or ball to turn.] [*Assessment Boundary: Assessment does not include friction as a mechanism for change in speed.*]

3-PS2-1.	Planning and Carrying Out InvestigationsPlanning and carrying out investigations to answer questions or test solutions to problems in 3–5 builds on K–2 experiences and progresses to include investigations that control variables and provide evidence to support explanations or design solutions.Plan and conduct an investigation collaboratively to produce data to serve as the basis for evidence, using fair tests in which variables are controlled and the number of trials considered.">Plan and conduct an investigation to provide evidence Cause and EffectCause and effect relationships are routinely identified.">of the effects of PS2.A: Forces and MotionEach force acts on one particular object and has both strength and a direction. An object at rest typically has multiple forces acting on it, but they add to give zero net force on the object. Forces that do not sum to zero can cause changes in the object's speed or direction of motion. (Boundary: Qualitative and conceptual, but not quantitative addition of forces are used at this level.) PS2.B: Types of InteractionsObjects in contact exert forces on each other.">balanced and unbalanced forces on the motion of an object. [Clarification Statement: Examples could include an unbalanced force on one side of a ball can make it start moving; and, balanced forces pushing on a box from both sides will not produce any motion at all.] [*Assessment Boundary: Assessment is limited to one variable at a time: number, size, or direction of forces. Assessment does not include quantitative force size, only qualitative and relative. Assessment is limited to gravity being addressed as a force that pulls objects down.*]

3-PS2-2.	Planning and Carrying Out InvestigationsPlanning and carrying out investigations to answer questions or test solutions to problems in 3–5 builds on K–2 experiences and progresses to include investigations that control variables and provide evidence to support explanations or design solutions.Make observations and/or measurements to produce data to serve as the basis for evidence for an explanation of a phenomenon or test a design solution.">Make observations and/or measurements PS2.A: Forces and MotionThe patterns of an object's motion in various situations can be observed and measured; when that past motion exhibits a regular pattern, future motion can be predicted from it. (Boundary: Technical terms, such as magnitude, velocity, momentum, and vector quantity, are not introduced at this level, but the concept that some quantities need both size and direction to be described is developed.)">of an object's motion Planning and Carrying Out InvestigationsPlanning and carrying out investigations to answer questions or test solutions to problems in 3–5 builds on K–2 experiences and progresses to include investigations that control variables and provide evidence to support explanations or design solutions.Make observations and/or measurements to produce data to serve as the basis for evidence for an explanation of a phenomenon or test a design solution.">to provide evidence PatternsPatterns of change can be used to make predictions.">that a pattern can be used to predict PS2.A: Forces and MotionThe patterns of an object's motion in various situations can be observed and measured; when that past motion exhibits a regular pattern, future motion can be predicted from it. (Boundary: Technical terms, such as magnitude, velocity, momentum, and vector quantity, are not introduced at this level, but the concept that some quantities need both size and direction to be described is developed.)">future motion. [Clarification Statement: Examples of motion with a predictable pattern could include a child swinging in a swing, a ball rolling back and forth in a bowl, and two children on a see-saw.] [*Assessment Boundary: Assessment does not include technical terms such as period and frequency.*]

MS-PS2-1.	Constructing Explanations and Designing SolutionsConstructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific ideas, principles, and theories.Apply scientific ideas or principles to design an object, tool, process or system.">Apply PS2.A: Forces and MotionFor any pair of interacting objects, the force exerted by the first object on the second object is equal in strength to the force that the second object exerts on the first, but in the opposite direction (Newton's third law).">Newton's Third Law Constructing Explanations and Designing SolutionsConstructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific ideas, principles, and theories.Apply scientific ideas or principles to design an object, tool, process or system.">to design a solution to a problem PS2.A: Forces and MotionFor any pair of interacting objects, the force exerted by the first object on the second object is equal in strength to the force that the second object exerts on the first, but in the opposite direction (Newton's third law).">involving the motion of Systems and System ModelsModels can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy and matter flows within systems.Influence of Science, Engineering, and Technology on Society and the Natural WorldThe uses of technologies and any limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions.">two colliding objects.* [Clarification Statement: Examples of practical problems could include the impact of collisions between two cars, between a car and stationary objects, and between a meteor and a space vehicle.] [*Assessment Boundary: Assessment is limited to vertical or horizontal interactions in one dimension.*]

MS-PS2-2.	Planning and Carrying Out InvestigationsPlanning and carrying out investigations to answer questions or test solutions to problems in 6–8 builds on K–5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or design solutions.Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim.">Plan an investigation to provide evidence that Stability and ChangeExplanations of stability and change in natural or designed systems can be constructed by examining the changes over time and forces at different scales.">the change in PS2.A: Forces and MotionThe motion of an object is determined by the sum of the forces acting on it; if the total force on the object is not zero, its motion will change. The greater the mass of the object, the greater the force needed to achieve the same change in motion. For any given object, a larger force causes a larger change in motion.All positions of objects and the directions of forces and motions must be described in an arbitrarily chosen reference frame and arbitrarily chosen units of size. In order to share information with other people, these choices must also be shared.">an object's motion depends on the sum of the forces on the object and the mass of the object. [Clarification Statement: Emphasis is on balanced (Newton's First Law) and unbalanced forces in a system, qualitative comparisons of forces, mass and changes in motion (Newton's Second Law), frame of reference, and specification of units.] [*Assessment Boundary: Assessment is limited to forces and changes in motion in one-dimension in an inertial reference frame and to change in one variable at a time. Assessment does not include the use of trigonometry.*]

DCI

Kindergarten

PS2.A: Forces and Motion

- Pushes and pulls can have different strengths and directions. (K-PS2-1),(K-PS2-2)
- Pushing or pulling on an object can change the speed or direction of its motion and can start or stop it. (K-PS2-1),(K-

PS2-2)

PS2.B: Types of Interactions

- When objects touch or collide, they push on one another and can change motion. (K-PS2-1)

PS3.C: Relationship Between Energy and Forces

- A bigger push or pull makes things speed up or slow down more quickly. *(secondary to K-PS2-1)*

ETS1.A: Defining Engineering Problems

- A situation that people want to change or create can be approached as a problem to be solved through engineering. Such problems may have many acceptable solutions. *(secondary to K-PS2-2)*

Third Grade

PS2.A: Forces and Motion

- Each force acts on one particular object and has both strength and a direction. An object at rest typically has multiple forces acting on it, but they add to give zero net force on the object. Forces that do not sum to zero can cause changes in the object's speed or direction of motion. (Boundary: Qualitative and conceptual, but not quantitative addition of forces are used at this level.) (3-PS2-1)

- The patterns of an object's motion in various situations can be observed and measured; when that past motion exhibits a regular pattern, future motion can be predicted from it. (Boundary: Technical terms, such as magnitude, velocity, momentum, and vector quantity, are not introduced at this level, but the concept that some quantities need both size and direction to be described is developed.) (3-PS2-2)

Middle School

PS2.A: Forces and Motion

- For any pair of interacting objects, the force exerted by the first object on the second object is equal in strength to the force that the second object exerts on the first, but in the opposite direction (Newton's third law). (MS-PS2-1)
- The motion of an object is determined by the sum of the forces acting on it; if the total force on the object is not zero, its motion will change. The greater the mass of the object, the greater the force needed to achieve the same change in motion. For any given object, a larger force causes a larger change in motion. (MS-PS2-2)
- All positions of objects and the directions of forces and motions must be described in an arbitrarily chosen reference frame and arbitrarily chosen units of size. In order to share information with other people, these choices must also be shared. (MS-PS2-2)

PS2.B: Types of Interactions

- Objects in contact exert forces on each other. (3-PS2-1)

Crosscutting Concepts

Cause and Effect

- Simple tests can be designed to gather evidence to support or refute student ideas about causes. (K-PS2-1),(K-PS2-2)

Patterns

- Patterns of change can be used to make predictions. (3-PS2-2)

Cause and Effect

- Cause and effect relationships are routinely identified. (3-PS2-1)
- Cause and effect relationships are routinely identified, tested, and used to explain change. (3-PS2-3)

Cause and Effect

- Cause and effect relationships may be used to predict phenomena in natural or designed systems. (MS-PS2-3),(MS-PS2-5)

Systems and System Models

- Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy and matter flows within systems. (MS-PS2-1),(MS-PS2-4)

Stability and Change

- Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and forces at different scales. (MS-PS2-2)

Lesson Ideas:

Too many to list: anything to do with motion: ramps, cars,

PART II

SPACE SCIENCE

Welcome to Space Science. This part is divided into four chapters:

1. Earth
2. The Moon
3. Our Solar System
4. Origins and the Universe

Additionally, there is a practice quiz at the end that covers the entire unit.

7. Earth

Formative Assessment: Sun, Earth and the Moon

Heliocentrism vs Geocentrism

In early times, humans believed in geocentrism–the theory that Earth is at the center of the solar system, and the Sun and other planets revolve around it. During the Renaissance in the 1500s, Copernicus popularized the concept of heliocentrism–the theory that the Sun is at the center of the universe and Earth orbits the Sun.

Throughout Copernicus' lifetime, the scientific community widely denied the theory of heliocentrism. A generation later, the Sun-centered theory became more commonly accepted when Galileo invented the telescope in 1609, making it easier to observe space. Additionally, Galileo made a variety of discoveries about our solar system that disproved the geocentric model of the universe. Despite these new discoveries, however, there was still significant pushback against heliocentrism, particularly from the Catholic Church.

At the time, the Church defended its stance on geocentrism because it believed Galileo's discoveries left too many questions unanswered and did not explicitly prove heliocentrism. During this period, a case could still *technically* be made for geocentrism until technology advanced enough for scientists to discover more evidence supporting heliocentrism.

Additionally, the Church had certain clergy who interpreted parts of the Bible very literally, as if it were a science textbook rather than a theological work. Galileo's claims were scandalous in their eyes because heliocentrism directly conflicted with certain biblical passages. For these reasons, the Church put Galileo on trial, convicted him of heresy, and sentenced him to house arrest for the remainder of his life. In 1822, the Church eventually accepted the theory of heliocentrism once there was enough scientific evidence to claim it as truth.

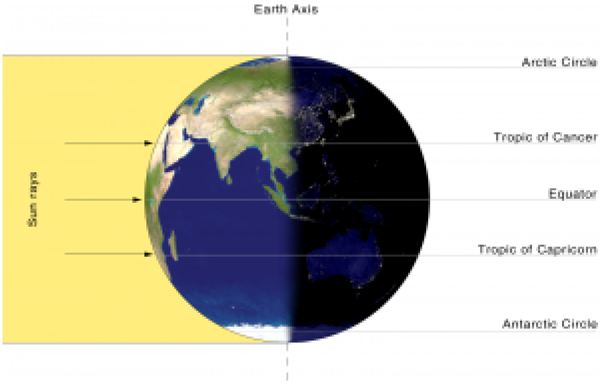
Key Takeaway

To remember the theories of **heliocentrism** and **geocentrism**, break down the names and look at the etymology.

- The root *geo*– means "earth", and *centr*– means "center". So, *geocentrism* is the theory in which Earth is at the center of the solar system.
- The root *helio*– means "sun", and *centr*– means "center". So, heliocentrism is the theory in which the Sun is at the center of the solar system.

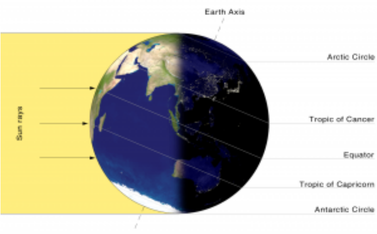
Equinox & Solstice

There are 2 equinoxes and 2 solstices per year – Spring Equinox, Autumn Equinox, Winter Solstice, and Summer Solstice. **Equinoxes** (which sounds like the word equal) mark the day in which all of Earth receives an equal amount of sunlight–12 hours. This equal amount of sunlight occurs when the Equator is directly in line with the Sun. The Spring Equinox happens around March 20th and the Autumn Equinox happens around September 23rd each year.

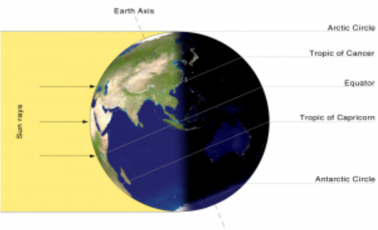


Equinox
"*Illumination of Earth by Sun on the day of equinox*" *by Przemyslaw "Blueshade" Idzkiewicz is licensed under CC BY SA-2.0*

Solstices mark the days of the year in which a hemisphere receives the least amount of sunlight (aka the shortest day of the year) and the most amount of sunlight (aka the longest day of the year). These days occur when one of the tropic lines are directly in line with the Sun. In the Northern Hemisphere, the **Winter Solstice** (the day with the least sunlight, usually around December 21) occurs when the Tropic of Capricorn (the southern tropic line) is in line with the Sun. The **Summer Solstice** (the day with the most sunlight, usually around June 21) occurs when the Tropic of Cancer (the northern tropic line) is in line with the Sun.



Winter Solstice
"Illumination of Earth by Sun on the day of summer solstice in the northern hemisphere" by Przemyslaw "Blueshade" Idzkiewicz is licensed under CC BY SA-2.0



Summer Solstice
"Illumination of Earth by Sun on the day of summer solstice in the northern hemisphere" by Przemyslaw "Blueshade" Idzkiewicz is licensed under CC BY SA-2.0

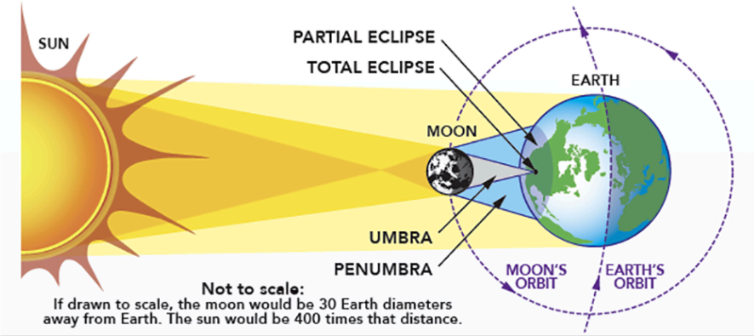
Eclipses

Eclipses happen when light is blocked. There are two types of eclipse that we can see on Earth: solar eclipses and lunar eclipses.

To understand each type of eclipse, you must determine whether the Sun or Moon is being blocked.

Solar Eclipse

- In a solar eclipse the Sun is being blocked–this happens when the Moon perfectly crosses between Earth and the Sun. A solar eclipse always occurs during a new moon.



Solar Eclipse
Image credit: "[Total Solar Eclipse](#)" by NASA

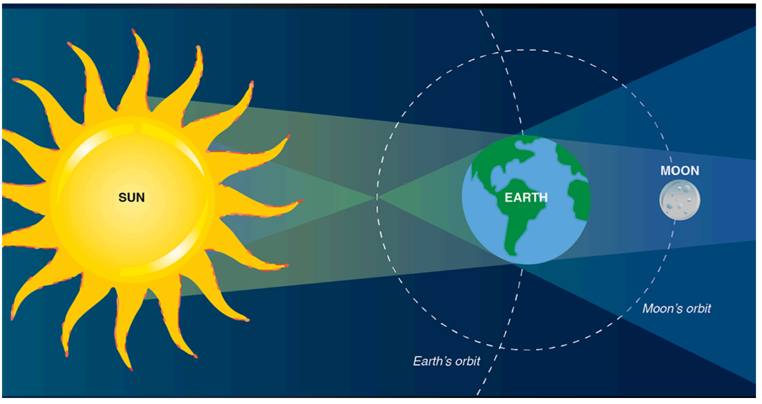
For more explanation of solar eclipses, watch the video below:

A YouTube element has been excluded from this version of the text. You can view it online here: https://pressbooks.uiowa.edu/methodsii/?p=36

Video credit: "What Creates a Total Solar Eclipse?" by Andy Cohen/TED-Ed is licensed under CC BY-NC-ND 4.0

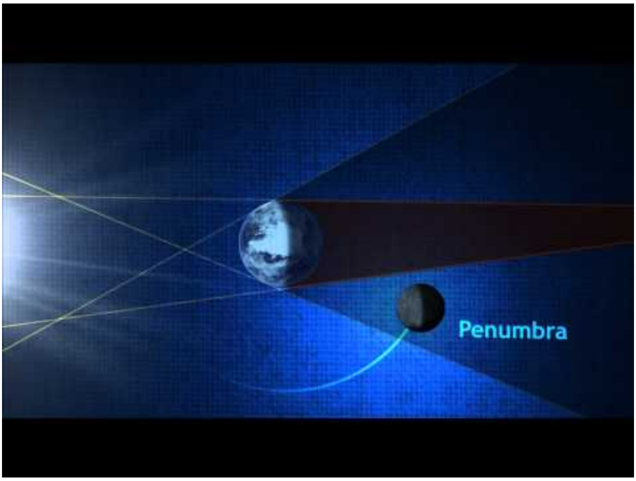
Lunar Eclipse

- In a lunar eclipse, the Moon is blocked when it passes through Earth's shadow. When the Moon is in this position, the Sun's light cannot reach it. A lunar eclipse always occurs during a full moon.



Lunar Eclipse
"Lunar Eclipse" by NASA's Marshall Space Flight Center is licensed under CC BY-NC 2.0

For more explanation of lunar eclipses, watch the video below:



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Video credit: "Lunar Eclipse Essentials" by NASA is public domain

Seasons

Earth orbits in the same plane as the other planets in our solar system: the **Plane of the Ecliptic**. However, Earth's is also tilted on it axis. This tilt never changes in relation to space, so different areas of Earth are tilted toward the Sun at different times of year. This is why we have seasons.

- If a hemisphere is tilted towards the Sun it gets more sunlight and it warms up–aka summer.
- If a hemisphere is tilted away from the Sun it gets less sunlight and it cools down–aka winter.

Additionally, the Northern and Southern Hemispheres have opposite seasons due to the tilt of Earth's axis. When the Northern Hemisphere is tilted towards the Sun it is summer (this is winter in the Southern Hemisphere). When the Southern Hemisphere is tilted towards the Sun it is summer (this is winter in the Northern Hemisphere).

Earth's seasons are explained in the image below.

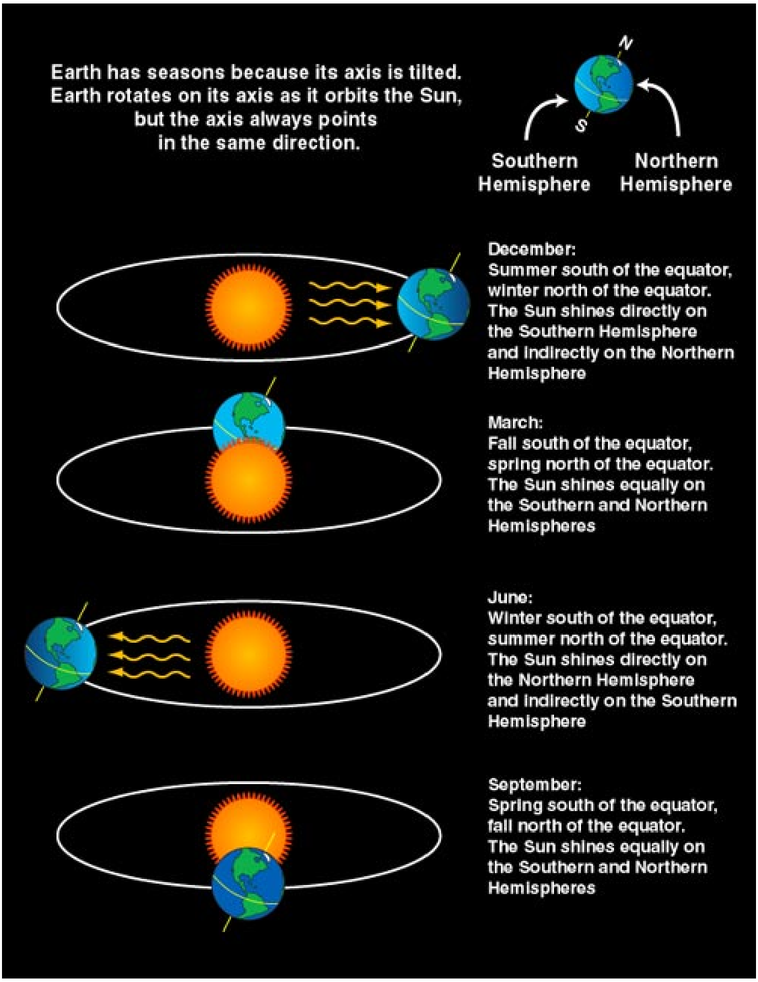


Image credit: Seasons by NASA Space Place is public domain

Key Takeaways

- As Earth orbits around the Sun, different areas receive direct or indirect sunlight due to the tilt of Earth on its axis. This is what causes seasons.
- Earth's distance away from the Sun does not cause the seasons.

K-6 Standards

K-PS3-1. Make observations to determine the effect of sunlight on Earth's surface.

1-ESS1-2. Make observations at different times of year to relate the amount of daylight to the time of year.

5-ESS1-2. Represent data in graphical displays to reveal patterns of daily changes in length and direction of shadows, day and night, and the seasonal appearance of some stars in the night sky.

Shadows

Watch the video, below, to learn more about the tropic lines and Earth's shadows. The following practice questions will be explained in the video:

1. It is the **Summer Solstice** in the Southern Hemisphere and you are standing on the Tropic of Capricorn. It is noon, so the Sun is directly above you. Which direction does your shadow point?
2. If you are in Iowa, what will happen to the length of your shadow as we approach the Spring **Equinox**?

A YouTube element has been excluded from this

version of the text. You can view it online here:
https://pressbooks.uiowa.edu/methodsii/?p=36

NGSS
Performance Expectations

1-ESS1-2.	Planning and Carrying Out InvestigationsPlanning and carrying out investigations to answer questions or test solutions to problems in K–2 builds on prior experiences and progresses to simple investigations, based on fair tests, which provide data to support explanations or design solutions.Make observations (firsthand or from media) to collect data that can be used to make comparisons.">Make observations ESS1.B: Earth and the Solar SystemSeasonal patterns of sunrise and sunset can be observed, described, and predicted.">at different times of year PatternsPatterns in the natural world can be observed, used to describe phenomena, and used as evidence.">to relate ESS1.B: Earth and the Solar SystemSeasonal patterns of sunrise and sunset can be observed, described, and predicted.">the amount of daylight to the time of year. [Clarification Statement: Emphasis is on relative comparisons of the amount of daylight in the winter to the amount in the spring or fall.] [*Assessment Boundary: Assessment is limited to relative amounts of daylight, not quantifying the hours or time of daylight.*]

5-ESS1-2.	Analyzing and Interpreting DataAnalyzing data in 3–5 builds on K–2 experiences and progresses to introducing quantitative approaches to collecting data and conducting multiple trials of qualitative observations. When possible and feasible, digital tools should be used.Represent data in graphical displays (bar graphs, pictographs and/or pie charts) to reveal patterns that indicate relationships.">Represent data in graphical displays to reveal PatternsSimilarities and differences in patterns can be used to sort, classify, communicate and analyze simple rates of change for natural phenomena.">patterns of ESS1.B: Earth and the Solar SystemThe orbits of Earth around the sun and of the moon around Earth, together with the rotation of Earth about an axis between its North and South poles, cause observable patterns. These include day and night; daily changes in the length and direction of shadows; and different positions of the sun, moon, and stars at different times of the day, month, and year. (5-ESS1-2)">daily changes in length and direction of shadows, day and night, and the seasonal appearance of some stars in the night sky. [Clarification Statement: Examples of patterns could include the position and motion of Earth with respect to the sun and selected stars that are visible only in particular months.] [*Assessment Boundary: Assessment does not include causes of seasons.*]

MS-ESS1-1.	Developing and Using ModelsModeling in 6–8 builds on K–5 experiences and progresses to developing, using, and revising models to describe, test, and predict more abstract phenomena and design systems.Develop and use a model to describe phenomena.">Develop and use a model ESS1.A: The Universe and Its StarsPatterns of the apparent motion of the sun, the moon, and stars in the sky can be observed, described, predicted, and explained with models.ESS1.B: Earth and the Solar SystemThis model of the solar system can explain eclipses of the sun and the moon. Earth's spin axis is fixed in direction over the short-term but tilted relative to its orbit around the sun. The seasons are a result of that tilt and are caused by the differential intensity of sunlight on different areas of Earth across the year.">of the Earth-sun-moon system Developing and Using ModelsModeling in 6–8 builds on K–5 experiences and progresses to developing, using, and revising models to describe, test, and predict more abstract phenomena and design systems.Develop and use a model to describe phenomena.">to describe Patterns Patterns can be used to identify cause-and-effect relationships.">the cyclic patterns of ESS1.A: The Universe and Its StarsPatterns of the apparent motion of the sun, the moon, and stars in the sky can be observed, described, predicted, and explained with models.ESS1.B: Earth and the Solar SystemThis model of the solar system can explain eclipses of the sun and the moon. Earth's spin axis is fixed in direction over the short-term but tilted relative to its orbit around the sun. The seasons are a result of that tilt and are caused by the differential intensity of sunlight on different areas of Earth across the year.">lunar phases, eclipses of the sun and moon, and seasons. [Clarification Statement: Examples of models can be physical, graphical, or conceptual.]

DCI

First grade

ESS1.B: Earth and the Solar System

- Seasonal patterns of sunrise and sunset can be observed, described, and predicted. (1-ESS1-2)

Fifth grade

ESS1.B: Earth and the Solar System

- The orbits of Earth around the sun and of the moon around Earth, together with the rotation of Earth about an axis between its North and South poles, cause observable patterns. These include day and night; daily changes in the length and direction of shadows; and different positions of the sun, moon, and stars at different times of the day, month, and year. (5-ESS1-2)

Middle School

This model of the solar system can explain eclipses of the sun and the moon. Earth's spin axis is fixed in direction over the short-term but tilted relative to its orbit around the sun. The seasons are a result of that tilt and are caused by the differential intensity of sunlight on different areas of Earth across the year. (MS-ESS1-1)

Crosscutting Concepts

First grade

Patterns

- Patterns in the natural world can be observed, used to describe phenomena, and used as evidence. (1-ESS1-1),(1-ESS1-2)

– –

Connections to Nature of Science

Scientific Knowledge Assumes an Order and Consistency in Natural Systems

- Science assumes natural events happen today as they happened in the past. (1-ESS1-1)
- Many events are repeated. (1-ESS1-1)

5th Grade

Patterns

- Similarities and differences in patterns can be used to sort, classify, communicate and analyze simple rates of change for natural phenomena. (5-ESS1-2)

Cause and Effect

- Cause and effect relationships are routinely identified and used to explain change. (5-PS2-1)

Systems and System Models

- Models can be used to represent systems and their interactions. (MS-ESS1-2)

Lesson ideas:

Create a daily journal of sky observations: where the Sun is, what time sun rise and sun set, Moon position. Can be part of daily calendaring. Compare to seasons.

Play with shadows outside and inside: shadow tag, tracing shadows with sidewalk chalk and seeing how they move throughout the day; compare shadows to where the Sun is. Play with shadows inside: shine flashlights on sticks indoors, have kids move the flashlight up and down to see how the lenght of shadow moves. Draw the shadow and write where the flashlight was.

Experiment with Sun/Moon/Earth system as we did in class to understand equinoxes, solistices, eclipses, seasons, etc.

8. The Moon

Formative Assessment: The Moon & Stars Phases of the Moon

The Moon orbits around Earth once every 28 days, or about once a month. Depending on where the Moon is in its orbit, it appears different from Earth. However, everyone on Earth sees the same phase of the Moon on the same day.

The phases of the moon are:

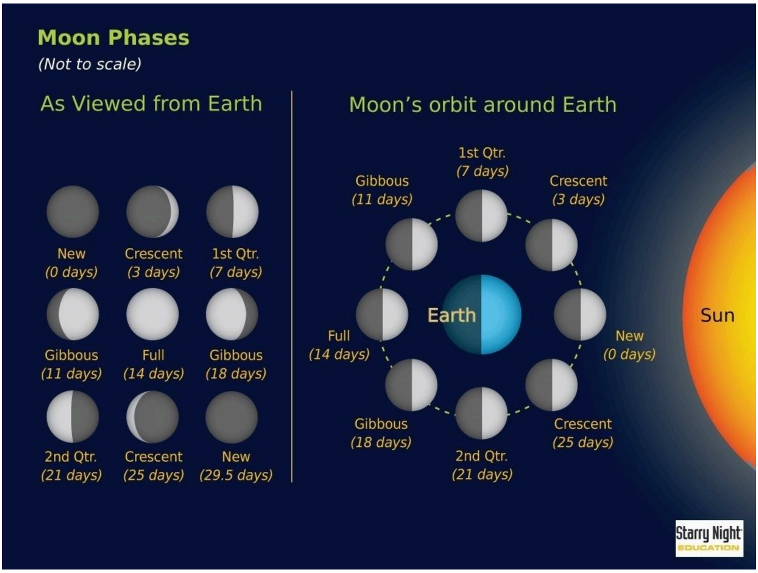
- **New:** The Moon's face is not visible from Earth
- **Crescent:** Between a new moon and a quarter moon
- **Quarter**: From Earth, we can see half of the moon's face which is a quarter of the entire moon
- **Gibbous**: Between a quarter moon and a full moon
- **Full**: All of the Moon's face is visible from Earth

For the first half of this cycle, the visible part of the Moon waxes or grows larger. After reaching a full moon, the Moon wanes or grows smaller for the second of the cycle.

The image, below, shows the Moon's phases.

K-6 Standards

1-ESS1-1. Use observations of the sun, moon, and stars to describe patterns that can be predicted.



"[Moon Phases from Earth](#)" by [pmonaghan](#) is licensed under [CC-By-NC-ND 2.0](#)

Where are the Moon, Sun, and Earth in relation to each other for the different Moon phases?

For further explanation of the Moon's phases, watch the following video.

A YouTube element has been excluded from this version of the text. You can view it online here: https://pressbooks.uiowa.edu/methodsii/?p=38

Characteristics of the Moon

- **Distance from Earth**: 239,000 miles
- **Size**: As seen in the image, below, the Moon is about 1/4 the size of Earth.

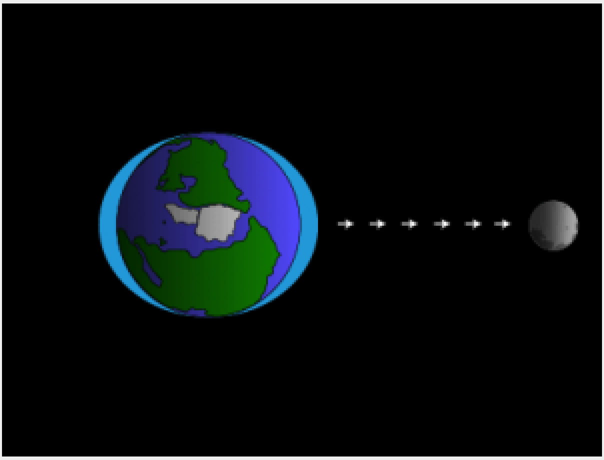
"*The Earth and the moon with their size at the exact same scale*" *by* *Lsmpascal*–
Own work is licensed under CC BY-SA 3.0.

- **Composition**:
  - Very similar to Earth
  - Has an iron **core**, **mantle**, and **crust**
- **Surface**: The Moon's rocky surface is covered in dormant volcanoes and **craters** which are the results of impacts from **meteorites** and **asteroids** over billions of years. The Moon is covered with craters for two reasons:

  1. It does not have an atmosphere to protect

it from the impact of objects such as asteroids in space.
2. There is no wind on the Moon to **erode** existing craters.

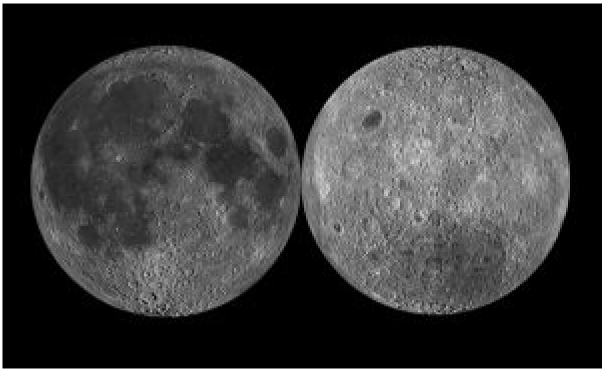
- **Climate**: The Moon has no atmosphere, wind, or weather. Thus, the temperature can range from extremely hot to extremely cold since there is no atmosphere to protect it from the Sun's heat or insulate the surface.
- **Gravity**: Remember, more mass=more gravity and less mass=less gravity. As such, the Moon has 1/6 of the gravity of Earth. This means if you weigh 60 lbs on Earth, you would weigh 10 lbs on the Moon.
    - The Moon's gravity, although weaker than Earth's gravity, has enough pull to move water. This is what causes tides on Earth. As Earth rotates on its axis, the area on the near side of the Moon feels its gravity. As seen in the image below, this causes the water on that side–as well as the opposite side of Earth–to bulge out and create a high tide. As Earth continues to rotate, the gravitational pull weakens and the water recedes, creating a low tide. Since Earth completes one full rotation on its axis each day, most areas have two high tides and two low tides per day.



"*Tidal Force*" *by NOAA SciJinks is public domain*

Sides of the Moon

There are two sides of the moon: the near side (the side we can see from Earth) and the far side (also known as the dark side). The Moon does not create its own light; it gets light from the Sun. As such, the dark side is not actually dark–it is just called the dark side because we cannot see it from Earth.



The near side of the Moon (left) vs. the far side of the Moon (right). Image credit: Near and far side of the moon by NASA

Since Earth has a larger mass, it exerts a stronger gravitational pull on the Moon. Earth's pull controls the Moon's orbit so that the Moon rotates once on its axis in the same amount of time it takes to orbit Earth. Therefore, the same side of the Moon is always facing Earth and we have a near side and a dark side. This effect is called tidal locking.

Click this link to see an animation of how tidal locking works as the Moon orbits Earth.

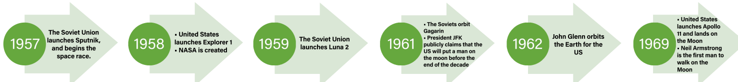
Nearside of the Moon	Farside of the Moon
• The side we can see from Earth	• Not visible from Earth
• Thinner crust: The Moon was in a molten state when it was first created. This side of the Moon is closer to Earth, so it received more heat and cooled off more slowly.	• Thicker crust: This side of the Moon is farther from Earth, so it received less heat and cooled more quickly.
• Large dark spots called **maria** (singular is "mare") were formed from ancient volcanic eruptions. The leftover basalt rock spread out and cooled forming the maria. Early astronomers thought these dark spots were actual seas and thus used the word mare which is Latin for sea.	• Rugged and marked with many small craters as a result of impacts from space debris.

Sputnik and the Space Race

On October 4th, 1957 the Soviet Union successfully launched Sputnik, the world's first artificial satellite, into Earth's orbit. This successful launch of Sputnik sparked the Space Race between the Soviet Union and the United States. These two countries competed to get the first human to land on the Moon.

On January 31, 1958, the United States launched Explorer 1, a satellite that discovered the magnetic radiation belts around Earth. That same year, the United States created the National Aeronautics and Space Administration (NASA). In 1959, the Soviet Union launched Luna 2, the first spacecraft to land on the Moon. In April 1961, the Soviet astronaut Yuri Gagarin became the first person in space when he orbited Earth. Shortly after, astronaut Alan Shepard became the first American in space in May 1961.

The Space Race heated up and President John F. Kennedy claimed that the United States would put a man on the Moon before the end of the decade. In 1962, American astronaut John Glenn successfully orbited the Earth. In 1968, American mission Apollo 8 orbited the Moon. Finally, in 1969, the American mission Apollo 11 successfully landed the first two people on the Moon: astronauts Neil Armstrong and Buzz Aldrin.



Interesting Fact

Dr. James Van Allen from the University of Iowa created the radiation detector that launched on the Explorer 1 satellite. This led to the discovery of magnetic radiation belts around Earth which are known as Van Allen radiation belts in his honor. Van Allen Hall on Iowa's campus is also named after him.

Women and Space

Traditionally, the story of the Space Race features male scientists and astronauts. However, women have played a key role in the history of American space exploration. NASA mathematicians Katherine Johnson and Dorothy Vaughan along with engineer Mary Jackson were key members of the team that launched John Glenn into space in 1962. In addition to this mission, these women had long careers at NASA. Their stories have recently been popularized in the movie *Hidden Figures*.

[Katherine Johnson](#) by [NASA](#)

[Mary Jackson](#) by [NASA](#)

Dorothy Vaughan by NASA

Initially, women were seen to have a physical advantage as astronauts; they tend to be lighter, shorter, and consume less food. In 1960, astronaut Jerrie Cobb had logged twice as many flying hours as John Glenn. But NASA made a requirement that astronauts had to be military pilots, a job only men could have. A group of 13 female astronauts, including Cobb, was gathered and subjected to the same tests as the male astronauts. The women passed all of the tests, and in many cases, performed better than the men. Still, NASA refused to support the female astronauts. In 1983, Sally Ride became the first female astronaut in space.

Sally Ride by NASA

Jerrie Cobb by SDASM Archives

NGSS

Performance Expectations

1-ESS1-1.	Analyzing and Interpreting DataAnalyzing data in K–2 builds on prior experiences and progresses to collecting, recording, and sharing observations.Use observations (firsthand or from media) to describe patterns in the natural world in order to answer scientific questions.">Use observations ESS1.A: The Universe and its StarsPatterns of the motion of the sun, moon, and stars in the sky can be observed, described, and predicted.">of the sun, moon, and stars PatternsPatterns in the natural world can be observed, used to describe phenomena, and used as evidence.">to describe patterns ESS1.A: The Universe and its StarsPatterns of the motion of the sun, moon, and stars in the sky can be observed, described, and predicted.">that can be predicted. [Clarification Statement: Examples of patterns could include that the sun and moon appear to rise in one part of the sky, move across the sky, and set; and stars other than our sun are visible at night but not during the day.] [*Assessment Boundary: Assessment of star patterns is limited to stars being seen at night and not during the day.*]

MS-ESS1-1.	Developing and Using ModelsModeling in 6–8 builds on K–5 experiences and progresses to developing, using, and revising models to describe, test, and predict more abstract phenomena and design systems.Develop and use a model to describe phenomena.">Develop and use a model ESS1.A: The Universe and Its StarsPatterns of the apparent motion of the sun, the moon, and stars in the sky can be observed, described, predicted, and explained with models.ESS1.B: Earth and the Solar SystemThis model of the solar system can explain eclipses of the sun and the moon. Earth's spin axis is fixed in direction over the short-term but tilted relative to its orbit around the sun. The seasons are a result of that tilt and are caused by the differential intensity of sunlight on different areas of Earth across the year.">of the Earth-sun-moon system Developing and Using ModelsModeling in 6–8 builds on K–5 experiences and progresses to developing, using, and revising models to describe, test, and predict more abstract phenomena and design systems.Develop and use a model to describe phenomena.">to describe Patterns Patterns can be used to identify cause-and-effect relationships.">the cyclic patterns of ESS1.A: The Universe and Its StarsPatterns of the apparent motion of the sun, the moon, and stars in the sky can be observed, described, predicted, and explained with models.ESS1.B: Earth and the Solar SystemThis model of the solar system can explain eclipses of the sun and the moon. Earth's spin axis is fixed in direction over the short-term but tilted relative to its orbit around the sun. The seasons are a result of that tilt and are caused by the differential intensity of sunlight on different areas of Earth across the year.">lunar phases, eclipses of the sun and moon, and seasons. [Clarification Statement: Examples of models can be physical, graphical, or conceptual.]

DCI

First Grade

ESS1.A: The Universe and its Stars

- Patterns of the motion of the sun, moon, and stars in the sky can be observed, described, and predicted. (1-ESS1-1)

Fifth Grade

ESS1.B: Earth and the Solar System

- The orbits of Earth around the sun and of the moon around Earth, together with the rotation of Earth about an axis between its North and South poles, cause observable patterns. These include day and night; daily changes in the length and direction of shadows; and different positions of the sun, moon, and stars at different times of the day, month, and year. (5-ESS1-2)

Middle School

ESS1.A: The Universe and Its Stars

- Patterns of the apparent motion of the sun, the moon, and stars in the sky can be observed, described, predicted, and explained with models. (MS-ESS1-1)

ESS1.B: Earth and the Solar System

- The solar system consists of the sun and a collection of objects, including planets, their moons, and asteroids that are held in orbit around the sun by its gravitational pull on them. (MS-ESS1-2),(MS-ESS1-3)
- This model of the solar system can explain eclipses of the sun and the moon. Earth's spin axis is fixed in direction over the short-term but tilted relative to its orbit around the sun. The seasons are a result of that tilt and are caused by the differential intensity of sunlight on different areas of Earth across the year. (MS-ESS1-1)

Crosscutting Concepts

Patterns

- Patterns in the natural world can be observed, used to describe phenomena, and used as evidence. (1-ESS1-1),(1-ESS1-2)

– –

Connections to Nature of Science

Scientific Knowledge Assumes an Order and Consistency in Natural Systems

- Science assumes natural events happen today as they happened in the past. (1-ESS1-1)
- Many events are repeated. (1-ESS1-1)

Lesson ideas:

Take children outside to see the Moon in the daytime. Show them how to observe the Moon, and keep a Moon journal, and encoruage them to look for the Moon day and night. Look at your Moon journal to see what the patterns are.

Try to recreate what they see outside with the Earth Sun Moon system.

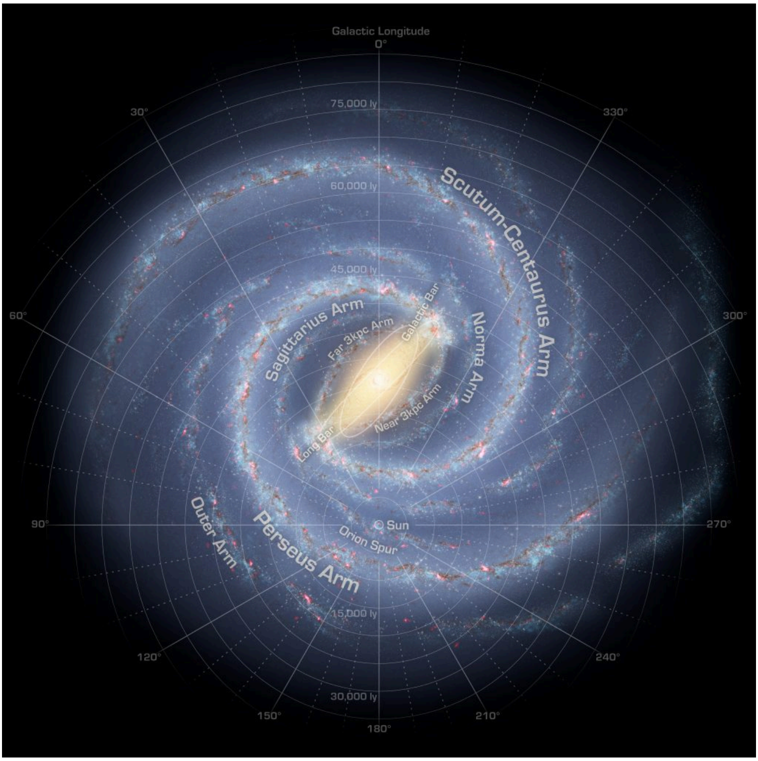
9. Our Solar System

The Milky Way

A **galaxy** is a collection of billions of stars, gas, and dust held together by gravity in space. Our **solar system** is located in the Milky Way Galaxy. As seen in the image, below, it got its name because it appears as a milky band of light in the sky.

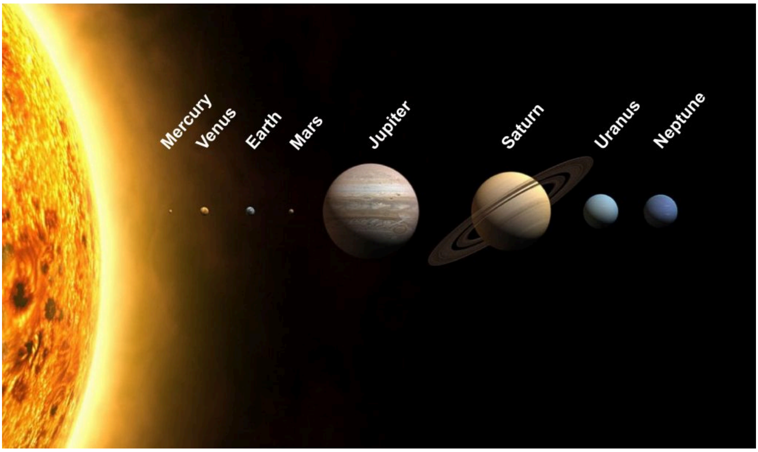
Image of the Milky Way Galaxy taken in Chile

As seen in the image, below, the Milky Way is a large spiral-shaped galaxy which contains hundreds of billions of stars. At the center of the Milky Way is a supermassive black hole named Sagittarius A which has a mass of 4 million suns. Our Sun, Earth, and all the planets are located halfway between the center and the outer edge on a small partial arm called the Orion Spur.



Spiral shape of the Milky Way Galaxy. Our solar system is located on the Orion Spur. "The Milky Way Galaxy" by NASA/JPL-Caltech/R. Hurt

Planets



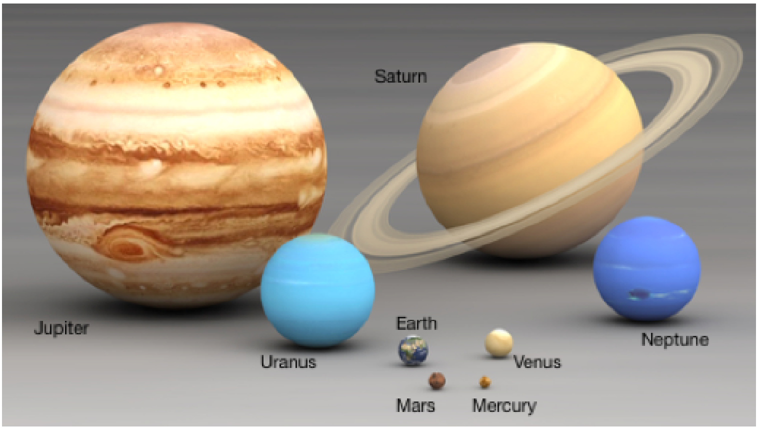
Planets in the Solar System "[A representative image of the solar system with sizes, but not distances, to scale](#)" by WP is licensed under [CC BY-SA 3.0](#)

There are 8 planets in our solar system: Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, and Neptune. To remember the order of the planets (closest to farthest from the sun), use the acronym "My Very Educated Mother Just Served Us Nutella."

The four inner planets–Mercury, Venus, Earth, and Mars–are rocky planets because they have a solid surface. The four outer planets–Jupiter, Saturn, Uranus, and Neptune–are gaseous planets because they are composed of gases, mainly hydrogen and helium. Notice that the rocky planets are much smaller in size and the gaseous planets are larger. One theory for this is that when the Sun turned on and became a star, it caused the gas clouds of the four inner planets to blow away. The rocky planets were left with a smaller, solid planet. The gaseous planets are farther from the sun, so they retained their composition. As they increased in mass, their gravity increased which allowed them to attract more and more material from space and grow larger in size.

Sizes and Distances of Planets

The image below shows the huge variance in size between planets in our solar system. Notice the differences in size between the inner, rocky planets and the outer, gaseous planets.



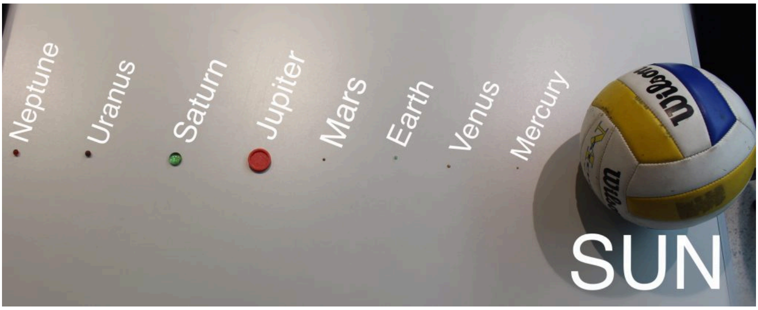
"Size planets comparison" by Lsmpascal-Own work is licensed under CC BY-SA 3.0/labels added from original

Measurements of Our Solar System

Element	Diameter (km)	Distance from the Sun ($x10^6$) (km)
Sun	1,392,000	————————
Mercury	4,897	57.9
Venus	12,104	108.2
Earth	12,756	149.6
Mars	6,794	227.9
Jupiter	142,980	778.6
Saturn	120,540	1433.5
Uranus	51,120	2872.5
Neptune	49,530	4495.1

Watch the following video to see a size comparison of the planets across Iowa's campus.

A YouTube element has been excluded from this version of the text. You can view it online here: https://pressbooks.uiowa.edu/methodsii/?p=40



Size comparison of the planets

K-6 Standards

5-ESS1-1. Support an argument that differences in the apparent brightness of the sun
compared to other stars is due to their relative distances from Earth.

Why is Pluto Not a Planet?

Pluto was the ninth planet in our solar system until a controversial 2006 decision when it was reclassified as a dwarf planet. Pluto meets two requirements to be a planet: it orbits around the sun and its gravity formed the planet into a round shape. However, it does not meet the third requirement of "clearing the neighborhood." Planets must have gravitational dominance and clear the neighborhood around their orbit; this means that large planets (more mass=more gravity) either attract or eject other, smaller bodies from that region of space. Several other dwarf planets and similarly-sized space objects were discovered in the solar system near Pluto's orbit in the Kuiper Belt. Therefore, Pluto has not cleared the neighborhood and so it cannot be considered a planet.

Asteroids

During the early life of our solar system, dust and rocks in space were pulled together by gravity to form the planets. Not all the dust and rocks were made into planets; smaller, rocky remnants called **asteroids** remain and orbit the Sun in our solar system. Between Mars and Jupiter, you can find the Main Asteroid Belt which is where most of the known asteroids orbit.

Other Objects in the Solar System

- *Comet*: A frozen ball of gas, rock, and dust that orbit the Sun. When a comet gets close to the Sun, it heats up and the gas and dust form a tail.
- *Meteoroid*: A small rock in space that orbits around the Sun. Most meteors have broken off of larger objects such as asteroids or comets. They can be as small as a grain of sand or as large as a pickup truck.
- *Meteor*: The streak of light that is caused when a meteoroid enters Earth's atmosphere and burns up due to friction. Also known as a shooting star.
- *Meteorite*: A meteoroid that survives its trip through the atmosphere and lands somewhere on Earth. The impact of a meteorite can cause a crater on the surface of a planet.

Image of Halley's Comet by NASA is public domain

Meteorite found in the Nubian Desert in northern Sudan by NASA

NGSS

Performance Expectations

5-ESS1-1.	Engaging in Argument from Evidence Engaging in argument from evidence in 3–5 builds on K–2 experiences and progresses to critiquing the scientific explanations or solutions proposed by peers by citing relevant evidence about the natural and designed world(s).Support an argument with evidence, data, or a model.">Support an argument that ESS1.A: The Universe and its StarsThe sun is a star that appears larger and brighter than other stars because it is closer. Stars range greatly in their distance from Earth.">differences in the apparent brightness of the sun compared to other stars is due to Scale, Proportion, and QuantityNatural objects exist from the very small to the immensely large.">their relative distances ESS1.A: The Universe and its StarsThe sun is a star that appears larger and brighter than other stars because it is closer. Stars range greatly in their distance from Earth.">from the Earth. [*Assessment Boundary: Assessment is limited to relative distances, not sizes, of stars. Assessment does not include other factors that affect apparent brightness (such as stellar masses, age, stage).*]

5-PS2-1.	Engaging in Argument from Evidence Engaging in argument from evidence in 3–5 builds on K–2 experiences and progresses to critiquing the scientific explanations or solutions proposed by peers by citing relevant evidence about the natural and designed world(s).Support an argument with evidence, data, or a model.">Support an argument that PS2.B: Types of InteractionsThe gravitational force of Earth acting on an object near Earth's surface pulls that object toward the planet's center.">the gravitational force Cause and EffectCause and effect relationships are routinely identified and used to explain change.">exerted by Earth on objects PS2.B: Types of InteractionsThe gravitational force of Earth acting on an object near Earth's surface pulls that object toward the planet's center.">is directed down. [Clarification Statement: "Down" is a local description of the direction that points toward the center of the spherical Earth.] [*Assessment Boundary: Assessment does not include mathematical representation of gravitational force.*]

MS-ESS1-2.	Developing and Using ModelsModeling in 6–8 builds on K–5 experiences and progresses to developing, using, and revising models to describe, test, and predict more abstract phenomena and design systems.Develop and use a model to describe phenomena.">Develop and use a model to describe ESS1.A: The Universe and Its StarsPatterns of the apparent motion of the sun, the moon, and stars in the sky can be observed, described, predicted, and explained with models.ESS1.B: Earth and the Solar System.The solar system consists of the sun and a collection of objects, including planets, their moons, and asteroids that are held in orbit around the sun by its gravitational pull on them.The solar system appears to have formed from a disk of dust and gas, drawn together by gravity.">the role of gravity in the motions within galaxies and the Systems and System ModelsModels can be used to represent systems and their interactions. ">solar system. [Clarification Statement: Emphasis for the model is on gravity as the force that holds together the solar system and Milky Way galaxy and controls orbital motions within them. Examples of models can be physical (such as the analogy of distance along a football field or computer visualizations of elliptical orbits) or conceptual (such as mathematical proportions relative to the size of familiar objects such as students' school or state).] [*Assessment Boundary: Assessment does not include Kepler's Laws of orbital motion or the apparent retrograde motion of the planets as viewed from Earth.*]
MS-ESS1-3.	Analyzing and Interpreting DataAnalyzing data in 6–8 builds on K–5 experiences and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis.Analyze and interpret data to determine similarities and differences in findings. ">Analyze and interpret data to determine Scale, Proportion, and QuantityTime, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small.">scale properties ESS1.B: Earth and the Solar SystemThe solar system consists of the sun and a collection of objects, including planets, their moons, and asteroids that are held in orbit around the sun by its gravitational pull on them. ">of objects in the solar system. [Clarification Statement: Emphasis is on the analysis of data from Earth-based instruments, space-based telescopes, and spacecraft to determine similarities and differences among solar system objects. Examples of scale properties include the sizes of an object's layers (such as crust and atmosphere), surface features (such as volcanoes), and orbital radius. Examples of data include statistical information, drawings and photographs, and models.] [*Assessment Boundary: Assessment does not include recalling facts about properties of the planets and other solar system bodies.*]

DCI

5th Grade

PS2.B: Types of Interactions

- The gravitational force of Earth acting on an object near Earth's surface pulls that object toward the planet's center. (5-PS2-1)

ESS1.A: The Universe and its Stars

- The sun is a star that appears larger and brighter than other stars because it is closer. Stars range greatly in their distance from Earth. (5-ESS1-1)

middle School

ESS1.B: Earth and the Solar System

- The solar system consists of the sun and a collection of objects, including planets, their moons, and asteroids that are held in orbit around the sun by its gravitational pull on them. (MS-ESS1-2),(MS-ESS1-3)
-
    - The solar system appears to have formed from a disk of dust and gas, drawn together by gravity. (MS-ESS1-2)

Crosscutting Concepts

Patterns

- Similarities and differences in patterns can be used to sort, classify, communicate and analyze simple rates of change for natural phenomena. (5-ESS1-2)

Cause and Effect

- Cause and effect relationships are routinely identified and used to explain change. (5-PS2-1)

Scale, Proportion, and Quantity

- Natural objects exist from the very small to the immensely large. (5-ESS1-1)

Patterns

- Patterns can be used to identify cause-and-effect relationships. (MS-ESS1-1)

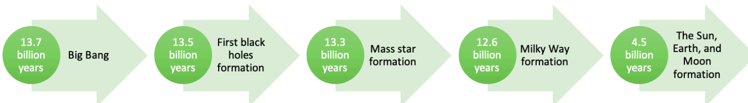
Scale, Proportion, and Quantity

- Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small. (MS-ESS1-3)

Systems and System Models

- Models can be used to represent systems and their interactions. (MS-ESS1-2)

10. Origins and the Universe



This timeline shows the key events in the formation of the universe. Each event is explained in more detail in this chapter.

The Big Bang

The Big Bang is the best-supported scientific theory for how the universe was created. 13.7 billion years ago there was nothing and nowhere. Everything that ever existed was contained in a subatomic particle that was billions of times smaller than an atom. Within a fraction of a second, this amazingly tiny particle stretched and inflated to an unimaginably huge size. Space, time, and the fundamental particles of the universe were created in this instant.

Key Takeaway

Although the word "bang" is part of the name, the **Big Bang** was an **expansion** or an inflation rather than an explosion.

Although there are alternate theories, the Big Bang theory is supported by multiple sources of scientific evidence.

1. Edwin Hubble discovered that the universe is still expanding

today. If it is constantly expanding and growing now, that means it was smaller before–and likely the size of an unimaginably small particle at the beginning.

2. Scientists detected Cosmic Microwave Background, a type of radiation that is present everywhere in the universe. Evidence suggests that this is leftover radiation from the energy of the Big Bang.

For more explanation of the Big Bang theory, watch the following video.

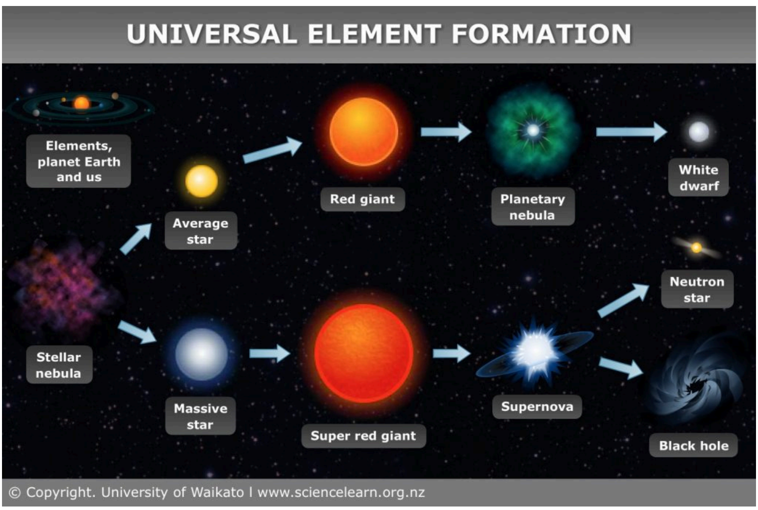
A YouTube element has been excluded from this version of the text. You can view it online here: https://pressbooks.uiowa.edu/methodsii/?p=42

Video credit: "Big Bang Introduction" by Khan Academy is licensed under CC BY-NC-SA 3.0. Note: All Khan Academy content is available for free at khanacademy.org.

The Life Cycle of Stars

All stars begin their lives as clouds of gas and dust which are called **nebulae**. The particles in a nebula start to attract, so their combined mass increases. Therefore, they have more gravity which pulls in even more particles. Eventually, there will be enough particles under intense heat and pressure in the center core and **nuclear fusion** can occur. The star ignites and becomes a fully functioning star.

The image, below, shows the life cycles of different types of stars.



Life Cycle of Stars "Universal Element Formation" by Science Learning Hub-Pokapū Akoranga Pūtaiao, University of Waikato

Depending on the amount of material in the nebula, an average star (like the Sun) or a supermassive star is formed. As the star burns through its fuel, it loses mass; therefore, it has less gravity and its size increases. An average star turns into a **red giant**. As it continues burning fuel, the red giant becomes very large. Then, the outer layers are blown off creating a planetary nebula and the inner core of the star remains, called a white dwarf star.

A supermassive star turns into a super red giant. These stars have more mass so they burn through their fuel more quickly, therefore losing gravity and becoming extremely large. Eventually, the super red giant will run out of fuel, collapse in on itself, and create a giant explosion called a **supernova**. From there, the star can either form a **black hole** or an extremely compact neutron star.

Interesting Fact: We Are Made of Stardust

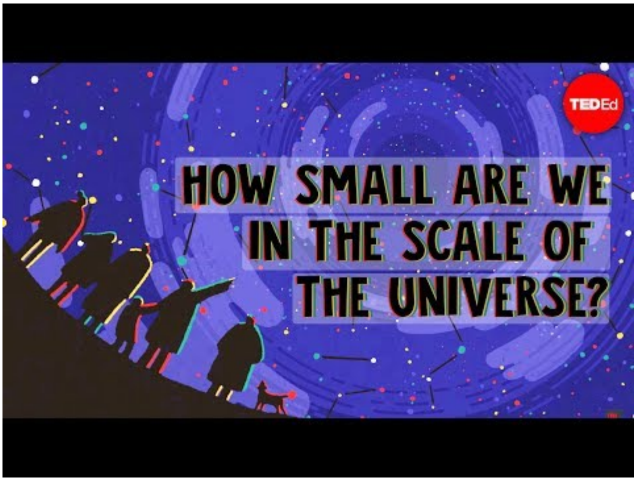
- Nuclear fusion in stars begins with hydrogen atoms which fuse together to make helium. Eventually, the reactions increase and atoms continue fusing into different elements; stars can fuse all of the elements up to iron on the periodic table.
- When the dust and debris from a star is blown away in a planetary nebula or supernova, all of these elements scatter into space where they will become the basis for all new stars and matter in the universe. Therefore, we are made of stardust.

Galaxies

A **galaxy** is a collection of billions of stars, gas, and dust held together by gravity in space. Using the Hubble Space Telescope, scientists can take images of space. In one small area, called the eXtreme Deep Field or XDF (image below) each of the bright spots is an entire galaxy–there are 5,550 galaxies within the image. There are probably 100 hundred billion galaxies in the entire universe.

"Hubble eXtreme Deep Field" by NASA is public domain

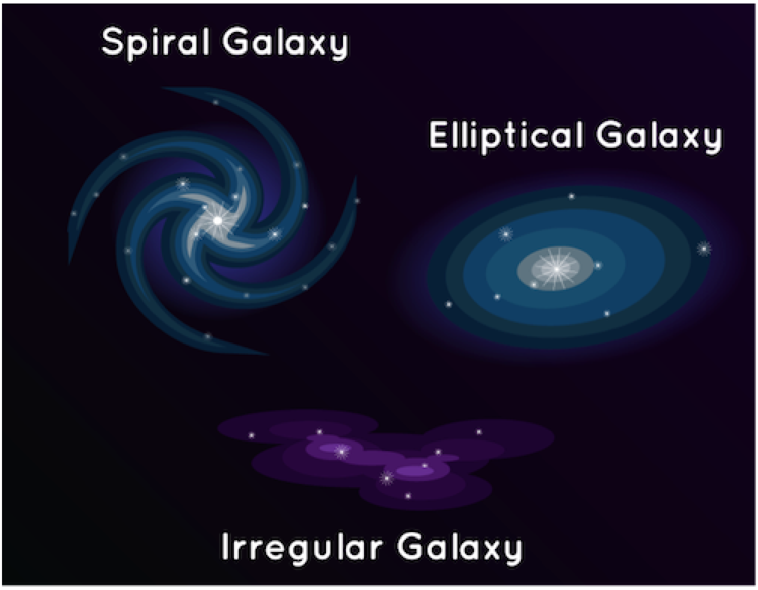
To understand the scale of the Hubble eXtreme Deep Field, watch the video below:



A YouTube element has been excluded from this version of the text. You can view it online here: https://pressbooks.uiowa.edu/methodsii/?p=42

Video credit: "How Small are We in the Scale of the Universe?" by Alex Hofeldt/TED-Ed is licensed under CC BY-NC-ND 4.0

As seen in the image, below, there are 3 shapes of galaxies: spiral, elliptical, and irregular. Our galaxy, the Milky Way, is a spiral galaxy. Most galaxies have a supermassive **black hole** at the center which has an extremely strong gravitational pull that holds the entire galaxy together.

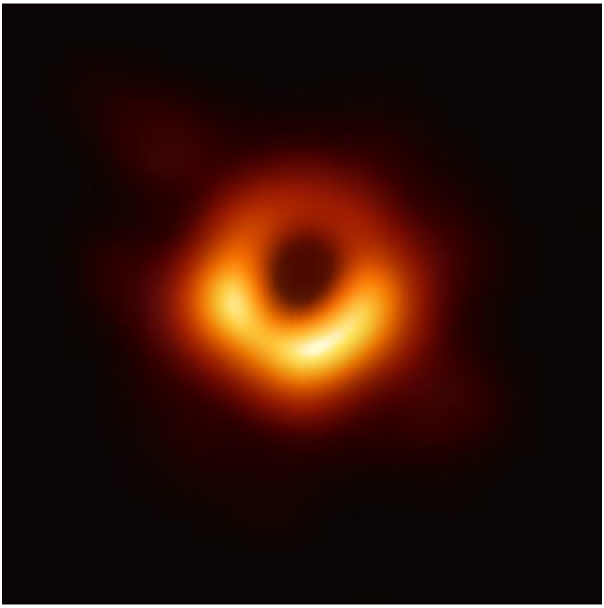


"Galaxies" by NASA is public domain

Black Holes

A **black hole** is an area in space with extremely strong gravity from which no light can escape. Thus, the area appears black. At the end of its lifecycle, a supermassive star collapses in on itself which causes a huge explosion called a **supernova**; this results in the formation of a black hole.

Seen below, scientists captured the first image of a black hole in 2019 using powerful telescopes.



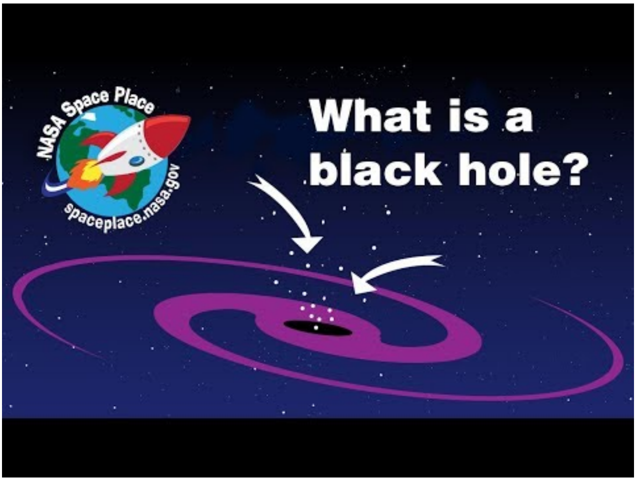
“Black Hole” by Event Horizon Telescope is licensed under CC BY 4.0

Since black holes trap all light inside, the dark spot in the center of the image is the black hole’s shadow surrounded by a ring of glowing gas in space. Based on this image, scientists were able to determine that the this black hole’s mass is 6.5 billion times larger than the mass of our Sun.

Interesting Fact

Katie Bouman, a female graduate student at MIT, led the creation of the computer algorithm that made it possible to get this first image of a black hole.

For more explanation of black holes, watch the following video.

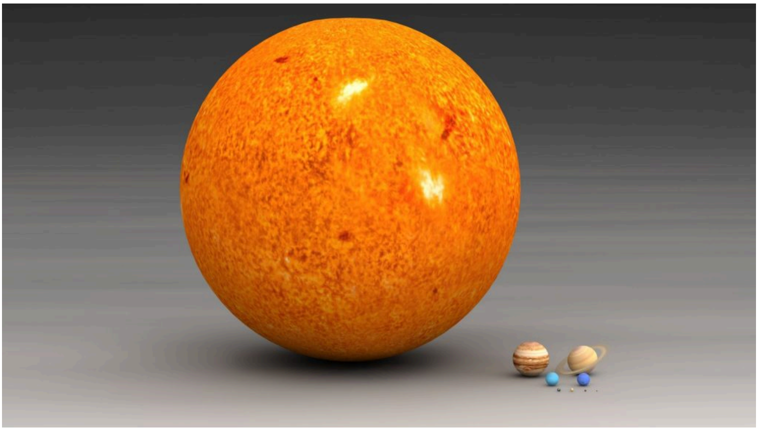


A YouTube element has been excluded from this version of the text. You can view it online here: https://pressbooks.uiowa.edu/methodsii/?p=42

Video credit: "What is a Black Hole?" by NASA Space Place is public domain

Origins of the Sun, Earth, and Moon

Our solar system was most likely formed from a giant rotating **nebula** after a former star underwent a **supernova**. 4.65 billion years ago, this rotation and intense gravity caused the nebula to collapse on itself. This caused it to spin faster and flatten into a disk shape, the **Plane of the Ecliptic**. Much of this material was pulled toward the center of the disk and a star was formed: the Sun. The Sun contains 99.8% of the mass in our solar system.



Scale image of the Sun compared to the planets in our solar system "Planets and sun size comparison" by Lsmpascal-Own work is licensed under CC BY-SA 3.0

Although it is enormous compared to the size of Earth, the Sun is an average-sized star. It is mostly made of hydrogen and helium. Currently, it is halfway through its fuel supply. In around 5-6 billion years, the Sun will burn all of its fuel and become a white dwarf star.

After the **Plane of the Ecliptic** was formed, the planets formed from the leftover gas and dust orbiting around the Sun. One theory says that when the Sun turned on and became a star, the force of its energy blew off the gas clouds around the four inner planets which is why they are rocky and the outer planets are gaseous. Earth, a rocky planet, is about 4.65 billion years old. Scientists believe that life on Earth appeared approximately 3.5 billion years ago, based on evidence found in fossils.

For more detail of how space dust turns into planets, watch the video below:

A YouTube element has been excluded from this version of the text. You can view it online here: https://pressbooks.uiowa.edu/methodsii/?p=42

Video credit: "The Dust Bunnies That Build Our Planet" by Lorin Swint Matthews/TED-Ed is licensed under CC BY-NC-ND 4.0

Key Takeaway

Earth was NOT formed during the Big Bang.

- The Big Bang occurred 13.7 billion years ago.
- Earth was formed 4.65 billion years ago.
- This means there is a lapse of 9 *billion years* between the Big Bang and the formation of Earth.

The Moon was formed when a Mars-sized object named Theia collided with the Earth. Early in its creation, Earth was molten. When it collided with Theia, chunks of Earth's crust were ejected into space. Gravity bounded these pieces together and the Moon was formed, eventually cooling and hardening into its current rocky state. Evidence which supports this theory include that the Moon and Earth have very similar composition including an iron core, mantle, and crust, although the Moon is less dense since it was formed from lighter elements in Earth's crust. The Moon is held to Earth by gravity and it is Earth's only natural satellite object, although the distance between them is increasing by about 1.6 inches per year.

NGSS

Performance Expectations

5-ESS1-1.	Engaging in Argument from Evidence Engaging in argument from evidence in 3–5 builds on K–2 experiences and progresses to critiquing the scientific explanations or solutions proposed by peers by citing relevant evidence about the natural and designed world(s).Support an argument with evidence, data, or a model.">Support an argument that ESS1.A: The Universe and its StarsThe sun is a star that appears larger and brighter than other stars because it is closer. Stars range greatly in their distance from Earth.">differences in the apparent brightness of the sun compared to other stars is due to Scale, Proportion, and QuantityNatural objects exist from the very small to the immensely large.">their relative distances ESS1.A: The Universe and its StarsThe sun is a star that appears larger and brighter than other stars because it is closer. Stars range greatly in their distance from Earth.">from the Earth. [*Assessment Boundary: Assessment is limited to relative distances, not sizes, of stars. Assessment does not include other factors that affect apparent brightness (such as stellar masses, age, stage).*]

MS-ESS1-2.	Developing and Using ModelsModeling in 6–8 builds on K–5 experiences and progresses to developing, using, and revising models to describe, test, and predict more abstract phenomena and design systems.Develop and use a model to describe phenomena.">Develop and use a model to describe ESS1.A: The Universe and Its StarsPatterns of the apparent motion of the sun, the moon, and stars in the sky can be observed, described, predicted, and explained with models.ESS1.B: Earth and the Solar System.The solar system consists of the sun and a collection of objects, including planets, their moons, and asteroids that are held in orbit around the sun by its gravitational pull on them.The solar system appears to have formed from a disk of dust and gas, drawn together by gravity.">the role of gravity in the motions within galaxies and the Systems and System ModelsModels can be used to represent systems and their interactions. ">solar system. [Clarification Statement: Emphasis for the model is on gravity as the force that holds together the solar system and Milky Way galaxy and controls orbital motions within them. Examples of models can be physical (such as the analogy of distance along a football field or computer visualizations of elliptical orbits) or conceptual (such as mathematical proportions relative to the size of familiar objects such as students' school or state).] [*Assessment Boundary: Assessment does not include Kepler's Laws of orbital motion or the apparent retrograde motion of the planets as viewed from Earth.*]

MS-ESS1-3.	Analyzing and Interpreting DataAnalyzing data in 6–8 builds on K–5 experiences and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis.Analyze and interpret data to determine similarities and differences in findings. ">Analyze and interpret data to determine Scale, Proportion, and QuantityTime, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small.">scale properties ESS1.B: Earth and the Solar SystemThe solar system consists of the sun and a collection of objects, including planets, their moons, and asteroids that are held in orbit around the sun by its gravitational pull on them. ">of objects in the solar system. [Clarification Statement: Emphasis is on the analysis of data from Earth-based instruments, space-based telescopes, and spacecraft to determine similarities and differences among solar system objects. Examples of scale properties include the sizes of an object's layers (such as crust and atmosphere), surface features (such as volcanoes), and orbital radius. Examples of data include statistical information, drawings and photographs, and models.] [*Assessment Boundary: Assessment does not include recalling facts about properties of the planets and other solar system bodies.*]

DCI

fifth grade

ESS1.A: The Universe and its Stars

- The sun is a star that appears larger and brighter than other stars because it is closer. Stars range greatly in their distance from Earth. (5-ESS1-1)

middle school

ESS1.A: The Universe and Its Stars

- Patterns of the apparent motion of the sun, the moon, and stars in the sky can be observed, described, predicted, and explained with models. (MS-ESS1-1)

- Earth and its solar system are part of the Milky Way galaxy, which is one of many galaxies in the universe. (MS-ESS1-2)

ESS1.B: Earth and the Solar System

- The solar system consists of the sun and a collection of objects, including planets, their moons, and asteroids that are held in orbit around the sun by its gravitational pull on them. (MS-ESS1-2),(MS-ESS1-3)
- The solar system appears to have formed from a disk of dust and gas, drawn together by gravity. (MS-ESS1-2)

Crosscutting Concepts

Scale, Proportion, and Quantity

- Natural objects exist from the very small to the immensely large. (5-ESS1-1)

Patterns

- Patterns can be used to identify cause-and-effect relationships. (MS-ESS1-1)

Scale, Proportion, and Quantity

- Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small. (MS-ESS1-3)

middle school

Systems and System Models

- Models can be used to represent systems and their interactions. (MS-ESS1-2)

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11. Space Science Practice Quiz

Follow this link to take the space science practice quiz. You will get immediate feedback on your answers.

"*Hubble eXtreme Deep Field*" *by* NASA

PART III

EARTH SCIENCE

Welcome to Earth Science. This part is divided into three chapters:

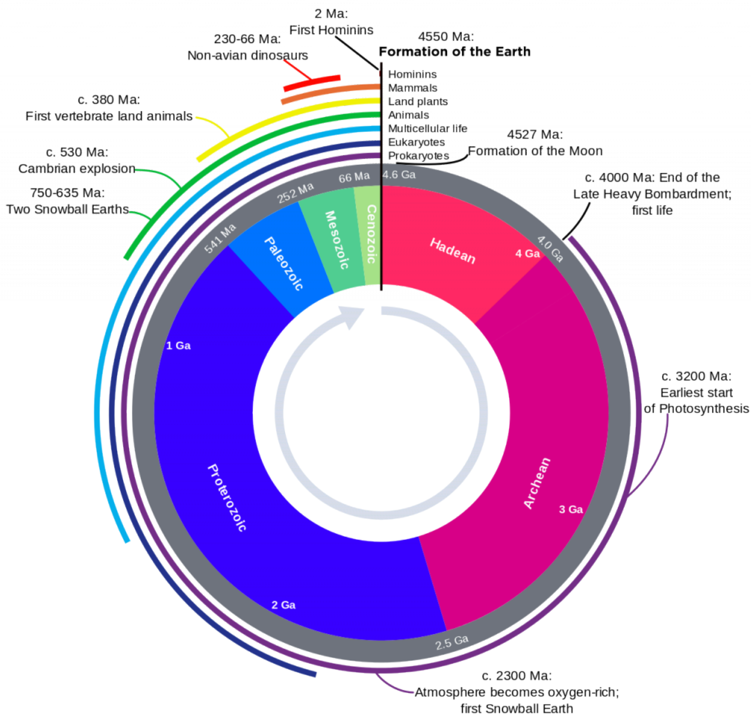
1. History of Earth
2. Earth's Structure: At the Surface and Underground
3. Rocks and the Rock Cycle

There are two practice quizzes for Earth Science.

12. History of Earth

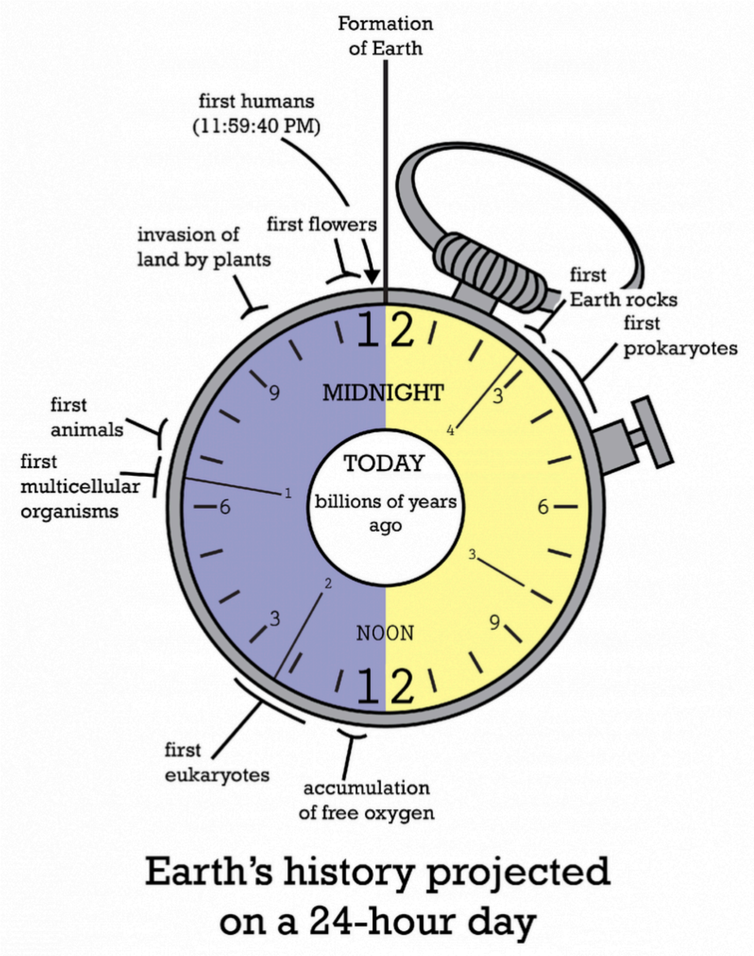
Geologic Time

Earth was formed about 4.65 billion years ago. Scientists use the geologic time scale to describe events that have happened throughout Earth's history.



In this image, Ma is an abbreviation for millions of years and Ga is an abbreviation for billions of years. "[Geologic Clock]" by [Woudlouper] is public domain

If the entirety of Earth's history was represented on a clock, humans would appear at 11:59:40 PM.

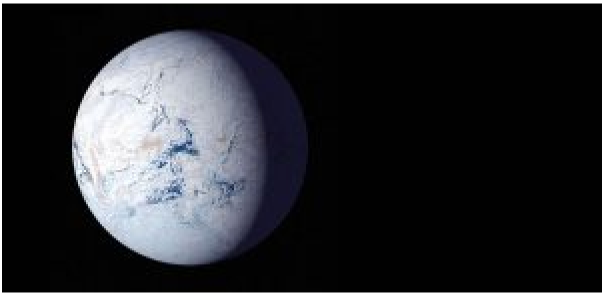


Origins of Life on Earth: Bacteria, Plants, and Animals

- 4.65 billion years ago: Earth is formed
- 4 billion years ago: The first life on Earth was simple, prokaryotic bacteria.
- 600 million years ago: Aquatic plants and animals evolved. It is likely that life originated in water because it offered early organisms more temperature stability compared to land, currents provided early movement, and they didn't have to fight gravity.
- 500 million years ago: Huge period of evolution and diversification of life known as the Cambrian Period.
- 400 million years ago: Terrestrial plants and animals evolved.
- 65-250 million years ago: Dinosaurs lived during the Mesozoic Era.
- 200,00-300,000 years ago: Homo sapiens, early ancestors of humans, evolved.

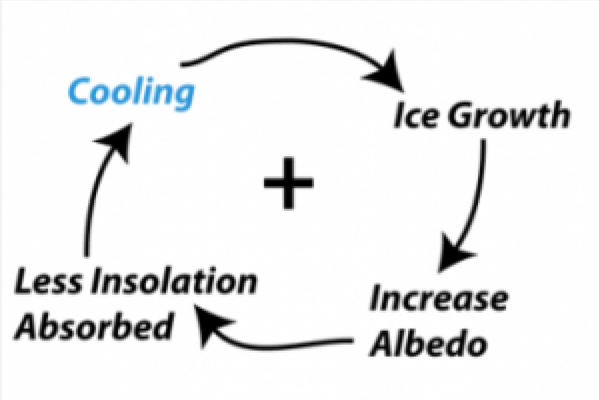
Snowball Earth

At least three times in Earth's history, the planet was engulfed almost entirely in ice–an event called **Snowball Earth**. These events happened between 580 and 750 million years ago. Evidence for Snowball Earth comes from sedimentary rocks. In a normal ice age, the types of rock deposited by glaciers would be found mostly near Earth's poles. However, geologists found glacial rocks of similar ages around the world, at both the poles and equatorial regions. This led to the Snowball Earth theory.



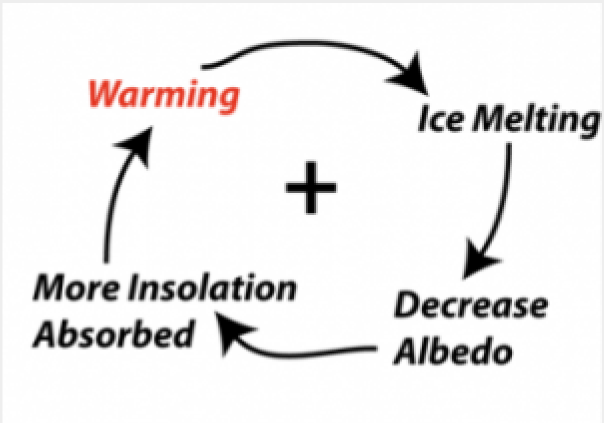
"Snowball Earth" by NASA is public domain.

Snowball Earth was caused by a chain of events called a **positive feedback loop**. Ice has a high **albedo** and is very insulating, so it is not heated up efficiently by sunlight. As ice accumulated on the planet, it increasingly reflected more sunlight and cooled Earth even further. Thus, this created a cycle of ice formation, increased albedo, and cooling of Earth which continued until the entire planet was covered in ice.



"*Positive Feedback Mechanism*" *by David Bice/Penn State College of Earth and Mineral Sciences is licensed under* CC BY-NC-SA 4.0

Why is Earth not covered in ice now if the positive feedback loop continues forever? The leading theory is that **volcanoes** continued erupting during Snowball Earth, emitting high levels of carbon dioxide, which was trapped under the ice. Eventually, the carbon dioxide built up enough to start melting the ice. Ice turned to water, which has a lower **albedo** and thus absorbed more of the Sun's energy. This led to a new positive feedback loop that resulted in warming of the planet and the end of Snowball Earth. Additionally, it is believed that bacterial life on Earth survived the harsh conditions during Snowball Earth events by living near the heat sources from volcanoes.



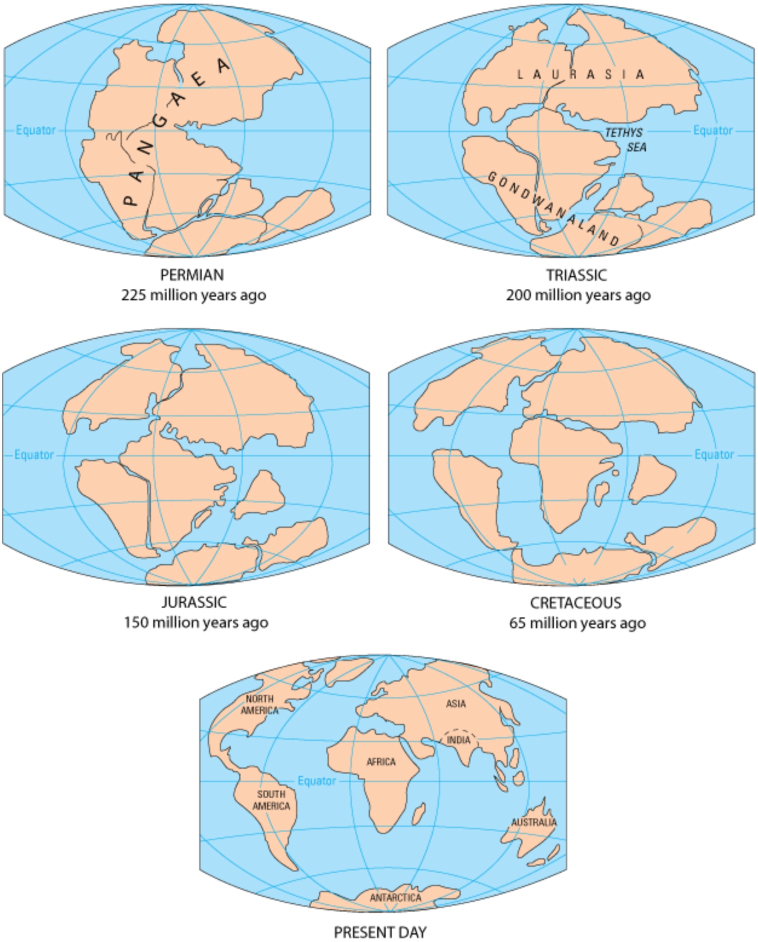
"Positive Feedback Mechanism" by David Bice/Penn State College of Earth and Mineral Sciences is licensed under CC BY-NC-SA 4.0

K-6 Standards

2-ESS2-3. Obtain information to identify where water is found on Earth and that it can be solid or liquid.

Pangaea

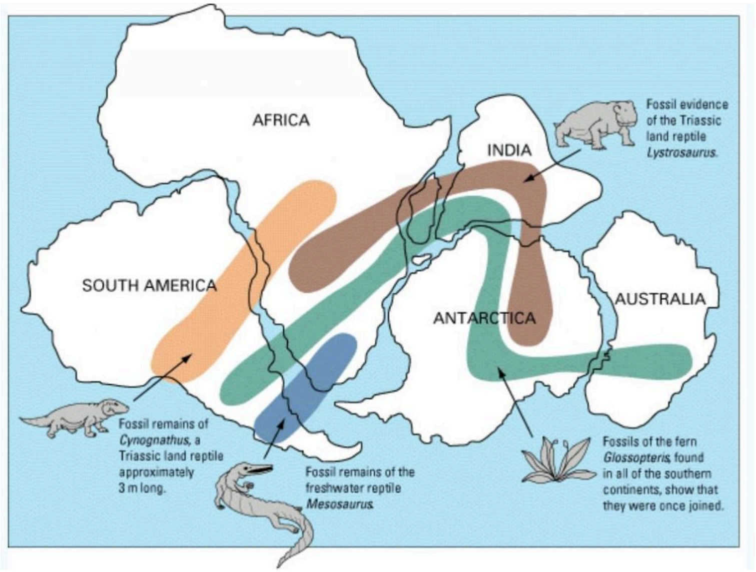
Due to **plate tectonics**, Earth's land is constantly shifting and changing over time. 250 million years ago, all of Earth's landmass was united in a single supercontinent called **Pangaea**. About 200 million years ago, this supercontinent began to break up into pieces as the plates moved away from each other. Smaller landmasses were formed until, eventually, the continents we recognize today were shaped. It is easy to see how certain continents, like South America and Africa, once fit together. Even today, the location of the continents continues to fluctuate. Scientists theorize that a new supercontinent, called Pangaea Proxima, could form 250 million years in the future.



"*Pangaea to Present*" *by* USGS *is public domain.*

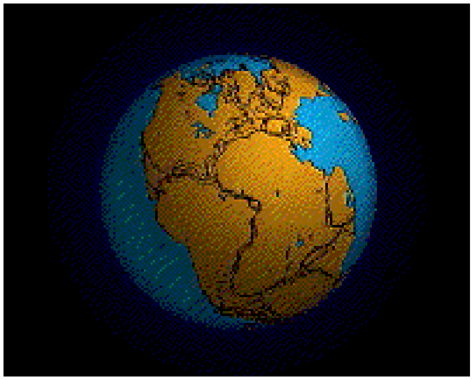
Continental Drift

Proposed by scientist Alfred Wegener, the theory of **continental drift** was one of the earliest ways to explain why continents moved over time. Wegener noticed that the shape of Earth's continents, such as South America and Africa, could fit together like a jigsaw puzzle. He also studied fossils from different continents that showed the remains of identical plants and animals spread throughout the world. For example, dinosaurs lived during the Triassic, Jurassic, and Cretaceous periods. As Pangaea broke into different pieces, fossils show that dinosaurs spread to different continents and evolved into different species over time. Based on this evidence, Wegener theorized that all of Earth's continents were originally united in the supercontinent Pangaea. Over time, they drifted apart to their current positions.



"Continental Drift" *by* USGS *is public domain*

While parts of this theory were correct, Wegener's ideas had some flaws. For example, Wegener was unable to explain how the continents had separated over time. Consequently, this theory was replaced by the **plate tectonics** theory which is discussed in the next chapter, "Earth's Structure: At the Surface and Underground".



Animation of continental drift "[Pangaea Animation](#)" by [USGS](#) is public domain

Key Takeaways

Timeline of Earth's History:

NGSS

Performance Expectations

2-ESS1-1.	Constructing Explanations and Designing SolutionsConstructing explanations and designing solutions in K–2 builds on prior experiences and progresses to the use of evidence and ideas in constructing evidence-based accounts of natural phenomena and designing solutions. Make observations from several sources to construct an evidence-based account for natural phenomena.">Use information from several sources to provide evidence that ESS1.C: The History of Planet EarthSome events happen very quickly; others occur very slowly, over a time period much longer than one can observe.">Earth events Stability and ChangeThings may change slowly or rapidly.">can occur quickly or slowly. [Clarification Statement: Examples of events and timescales could include volcanic explosions and earthquakes, which happen quickly and erosion of rocks, which occurs slowly.] [*Assessment Boundary: Assessment does not include quantitative measurements of timescales.*]

2-ESS2-2.	Developing and Using ModelsModeling in K–2 builds on prior experiences and progresses to include using and developing models (i.e., diagram, drawing, physical replica, diorama, dramatization, or storyboard) that represent concrete events or design solutions.Develop a model to represent patterns in the natural world.">Develop a model to represent ESS2.B: Plate Tectonics and Large-Scale System InteractionsMaps show where things are located. One can map the shapes and kinds of land and water in any area.">the shapes and kinds of land and bodies of water PatternsPatterns in the natural world can be observed.">in an area. [*Assessment Boundary: Assessment does not include quantitative scaling in models.*]

2-ESS2-3.	Obtaining, Evaluating, and Communicating InformationObtaining, evaluating, and communicating information in K–2 builds on prior experiences and uses observations and texts to communicate new information.Obtain information using various texts, text features (e.g., headings, tables of contents, glossaries, electronic menus, icons), and other media that will be useful in answering a scientific question.">Obtain information to identify PatternsPatterns in the natural world can be observed.">where water is found on Earth ESS2.C: The Roles of Water in Earth's Surface ProcessesWater is found in the ocean, rivers, lakes, and ponds. Water exists as solid ice and in liquid form.">and that it can be solid or liquid.

4-ESS2-2.	Analyze and Interpret DataAnalyzing data in 3–5 builds on K–2 experiences and progresses to introducing quantitative approaches to collecting data and conducting multiple trials of qualitative observations. When possible and feasible, digital tools should be used.Analyze and interpret data to make sense of phenomena using logical reasoning. (4-ESS2-2).">Analyze and interpret data ESS2.B: Plate Tectonics and Large-Scale System InteractionsThe locations of mountain ranges, deep ocean trenches, ocean floor structures, earthquakes, and volcanoes occur in patterns. Most earthquakes and volcanoes occur in bands that are often along the boundaries between continents and oceans. Major mountain chains form inside continents or near their edges. Maps can help locate the different land and water features areas of Earth.">from maps to describe PatternsPatterns can be used as evidence to support an explanation.">patterns of ESS2.B: Plate Tectonics and Large-Scale System InteractionsThe locations of mountain ranges, deep ocean trenches, ocean floor structures, earthquakes, and volcanoes occur in patterns. Most earthquakes and volcanoes occur in bands that are often along the boundaries between continents and oceans. Major mountain chains form inside continents or near their edges. Maps can help locate the different land and water features areas of Earth.">Earth's features. [Clarification Statement: Maps can include topographic maps of Earth's land and ocean floor, as well as maps of the locations of mountains, continental boundaries, volcanoes, and earthquakes.]

5-ESS2-1.	Developing and Using ModelsModeling in 3–5 builds on K–2 experiences and progresses to building and revising simple models and using models to represent events and design solutions.Develop a model using an example to describe a scientific principle.">Develop a model using an example to describe ESS2.A: Earth Materials and SystemsEarth's major systems are the geosphere (solid and molten rock, soil, and sediments), the hydrosphere (water and ice), the atmosphere (air), and the biosphere (living things, including humans). These systems interact in multiple ways to affect Earth's surface materials and processes. The ocean supports a variety of ecosystems and organisms, shapes landforms, and influences climate. Winds and clouds in the atmosphere interact with the landforms to determine patterns of weather.">ways the geosphere, biosphere, hydrosphere, and/or atmosphere Systems and System ModelsA system can be described in terms of its components and their interactions. ">interact. [Clarification Statement: Examples could include the influence of the ocean on ecosystems, landform shape, and climate; the influence of the atmosphere on landforms and ecosystems through weather and climate; and the influence of mountain ranges on winds and clouds in the atmosphere. The geosphere, hydrosphere, atmosphere, and biosphere are each a system.] [*Assessment Boundary: Assessment is limited to the interactions of two systems at a time.*]

5-ESS2-2.	Using Mathematics and Computational ThinkingMathematical and computational thinking in 3–5 builds on K–2 experiences and progresses to extending quantitative measurements to a variety of physical properties and using computation and mathematics to analyze data and compare alternative design solutions.Describe and graph quantities such as area and volume to address scientific questions.">Describe and graph Scale, Proportion, and QuantityStandard units are used to measure and describe physical quantities such as weight and volume.">the amounts ESS2.C: The Roles of Water in Earth's Surface ProcessesNearly all of Earth's available water is in the ocean. Most fresh water is in glaciers or underground; only a tiny fraction is in streams, lakes, wetlands, and the atmosphere.">of salt water and fresh water in various reservoirs Using Mathematics and Computational ThinkingMathematical and computational thinking in 3–5 builds on K–2 experiences and progresses to extending quantitative measurements to a variety of physical properties and using computation and mathematics to analyze data and compare alternative design solutions.Describe and graph quantities such as area and volume to address scientific questions.">to provide evidence about ESS2.C: The Roles of Water in Earth's Surface ProcessesNearly all of Earth's available water is in the ocean. Most fresh water is in glaciers or underground; only a tiny fraction is in streams, lakes, wetlands, and the atmosphere.">the distribution of water on Earth. [*Assessment Boundary: Assessment is limited to oceans, lakes, rivers, glaciers, ground water, and polar ice caps, and does not include the atmosphere.*]

MS-ESS2-2.	Constructing Explanations and Designing SolutionsConstructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific ideas, principles, and theories.Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students' own experiments) and the assumption that theories and laws that describe nature operate today as they did in the past and will continue to do so in the future.">Construct an explanation based on evidence for how ESS2.A: Earth Materials and SystemsThe planet's systems interact over scales that range from microscopic to global in size, and they operate over fractions of a second to billions of years. These interactions have shaped Earth's history and will determine its future.ESS2.C: The Roles of Water in Earth's Surface ProcessesWater's movements—both on the land and underground—cause weathering and erosion, which change the land's surface features and create underground formations.">geoscience processes have changed Earth's surface Scale, Proportion, and QuantityTime, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small.">at varying time and spatial scales. [Clarification Statement: Emphasis is on how processes change Earth's surface at time and spatial scales that can be large (such as slow plate motions or the uplift of large mountain ranges) or small (such as rapid landslides or microscopic geochemical reactions), and how many geoscience processes (such as earthquakes, volcanoes, and meteor impacts) usually behave gradually but are punctuated by catastrophic events. Examples of geoscience processes include surface weathering and deposition by the movements of water, ice, and wind. Emphasis is on geoscience processes that shape local geographic features, where appropriate.]

MS-ESS2-3.	Analyzing and Interpreting DataAnalyzing data in 6–8 builds on K–5 experiences and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis.Analyze and interpret data to provide evidence for phenomena.">Analyze and interpret data PatternsPatterns in rates of change and other numerical relationships can provide information about natural systems.">on the distribution ESS2.B: Plate Tectonics and Large-Scale System InteractionsMaps of ancient land and water patterns, based on investigations of rocks and fossils, make clear how Earth's plates have moved great distances, collided, and spread apart.">of fossils and rocks, continental shapes, and seafloor structures to provide evidence of the past plate motions. [Clarification Statement: Examples of data include similarities of rock and fossil types on different continents, the shapes of the continents (including continental shelves), and the locations of ocean structures (such as ridges, fracture zones, and trenches).] [*Assessment Boundary*: *Paleomagnetic anomalies in oceanic and continental crust are not assessed.*]

DCI

Second grade

ESS1.C: The History of Planet Earth

- Some events happen very quickly; others occur very slowly, over a time period much longer than one can observe. (2-ESS1-1)

ESS2.B: Plate Tectonics and Large-Scale System Interactions

- Maps show where things are located. One can map the shapes and kinds of land and water in any area. (2-ESS2-2)

ESS2.C: The Roles of Water in Earth's Surface Processes

- Water is found in the ocean, rivers, lakes, and ponds. Water exists as solid ice and in liquid form. (2-ESS2-3)

Fifth Grade

ESS2.A: Earth Materials and Systems

- Earth's major systems are the geosphere (solid and molten rock, soil, and sediments), the hydrosphere (water and ice), the atmosphere (air), and the biosphere (living things, including humans). These systems interact in multiple ways to affect Earth's surface materials and processes. The ocean supports a variety of ecosystems and organisms, shapes landforms, and influences climate. Winds and clouds in the atmosphere interact with the landforms to determine patterns of weather. (5-ESS2-1)

ESS2.C: The Roles of Water in Earth's Surface Processes

- Nearly all of Earth's available water is in the ocean. Most fresh water is in glaciers or underground; only a tiny fraction is in streams, lakes, wetlands, and the atmosphere. (5-ESS2-2)

Middle School

ESS2.A: Earth's Materials and Systems

- The planet's systems interact over scales that range from microscopic to global in size, and they operate over fractions of a second to billions of years. These interactions have shaped Earth's history and will determine its future. (MS-ESS2-2)

ESS2.B: PLate Tectonics and Large-Scale System Interactions

- Maps of ancient land and water patterns, based on investigations of rocks and fossils, make clear how Earth's plates have moved great distances, collided, and spread apart. (MS-ESS2-3)

ESS2.C: The Roles of Water in Earth's Surface Processes

- Water's movements—both on the land and underground—cause weathering and erosion, which change the land's surface features and create underground formations. (MS-ESS2-2)

Crosscutting Concepts

Patterns

- Patterns in the natural world can be observed.

(2-ESS2-2),(2-ESS2-3)

Stability and Change

- Things may change slowly or rapidly. (2-ESS2-1)

fifth grade

Scale, Proportion, and Quantity

- Standard units are used to measure and describe physical quantities such as weight and volume. (5-ESS2-2)

Systems and System Models

- A system can be described in terms of its components and their interactions. (5-ESS2-1),(5-ESS3-1)

middle school

Patterns

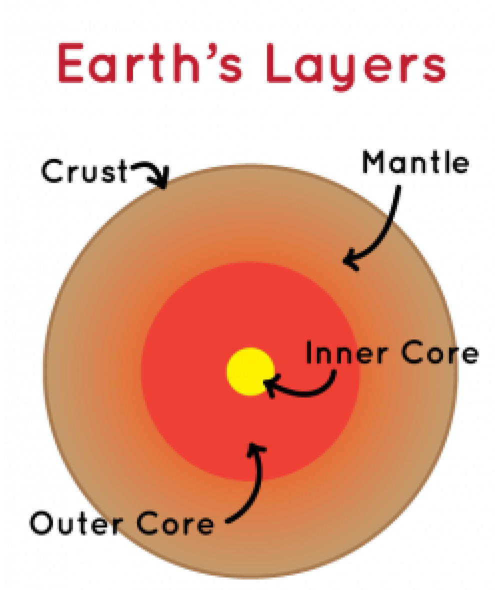
- Patterns in rates of change and other numerical relationships can provide information about natural systems. (MS-ESS2-3)

Scale Proportion and Quantity

- Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small. (MS-ESS1-4),(MS-ESS2-2)

13. Earth's Structure: At the Surface and Underground

Layers of Earth

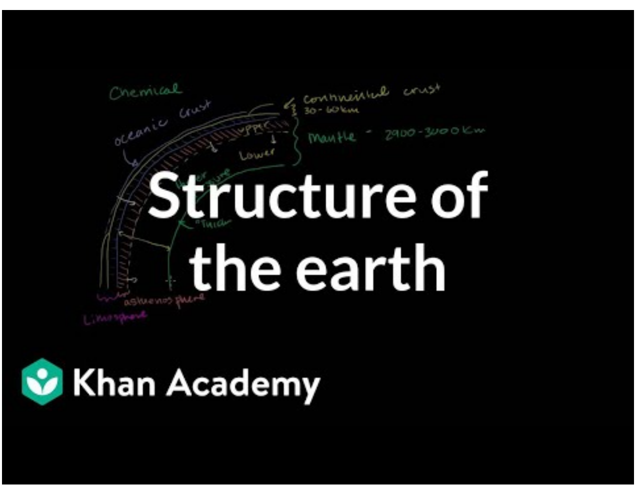


"*Earth's Layers*" *by* *NASA Space Place*

Earth is made up of four layers. The outermost layer is called the **crust**. The crust is made up rocks such as basalt and granite and it is very thin in comparison to the other layers. The crust is broken into many pieces called plates. There are two types of plates: **continental plates** and **oceanic plates**. Continental plates are much thicker than oceanic plates. Picture the depth of the ocean floor compared to the land; the ocean floor is much far below the land and, therefore, oceanic plates are thinner than continental plates.

The next layer is the **mantle** which is between the crust and core. This is the largest and thickest layer of Earth. The upper part of the mantle is made of magma; the tectonic plates float on this layer which is how they move.

Finally, Earth's **core** is made of two layers: the outer and inner core. The liquid outer core is mostly made of iron and nickel. It is incredibly hot, so the metals remain in a liquid state. The flow of the liquid metals creates Earth's magnetic field which is why compasses always point north. Additionally, the magnetic field protects the planet from extreme weather and radiation in space. The solid inner core is also made of iron and nickel. However, this layer is solid because the materials are under intense pressure at the center of Earth. Scientists know that the inner core is solid because of how seismic waves from earthquakes travel through the interior of Earth. The waves are unable to travel straight through the layers; instead they are refracted or bent by the dense inner core, so scientists believe this layer is solid.



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Video credit: "Structure of the earth" by Khan Academy is licensed under CC BY-NC-SA 3.0. Note: All Khan Academy content is available for free at khanacademy.org.

Plate Tectonics

Plate tectonics explains how Earth's plates move. Earth's **crust** is divided into many plates which float on the molten upper layer of the **mantle**. This area is called the **lithosphere**. The movement of the plates is driven by convection currents in the mantle. Heat rises from the mantle and cools as it gets closer to the surface; from there, it sinks down where it is reheated and the cycle repeats. This creates a current that moves the plates. Although they are constantly moving, each plate moves very slowly–about 3 to 5 centimeters (1 to 2 inches) per year.

K-6 Standards

2-ESS1-1. Use information from several sources to provide evidence that Earth events can occur quickly or slowly.

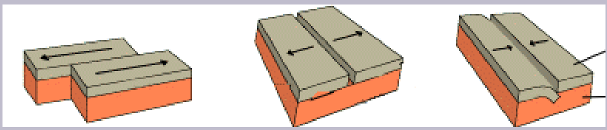
MS-ESS2-2. Construct an explanation based on evidence for how geoscience processes have changed Earth's surface at varying time and spatial scales.

MS-ESS2-3. Analyze and interpret data on the distribution of fossils and rocks, continental shapes, and seafloor structures to provide evidence of the past plate motions.

Tectonic Plate Boundaries

There are three types of tectonic plate boundaries:

1. Transform boundary: plates sideswipe each other
2. Divergent boundary: plates pull apart from each other
3. Convergent boundary: plates push into each other



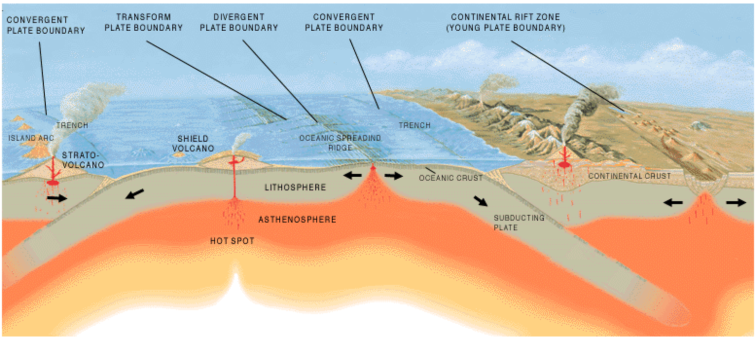
Transform, divergent, and convergent plate boundaries. "Plate tectonics" by USGS is public domain.

Depending on the type of tectonic plate and the type of plate boundary, different landforms can occur along plate boundaries.

- **Convergent** plates:
  - When **two continental plates converge**, the land is pushed

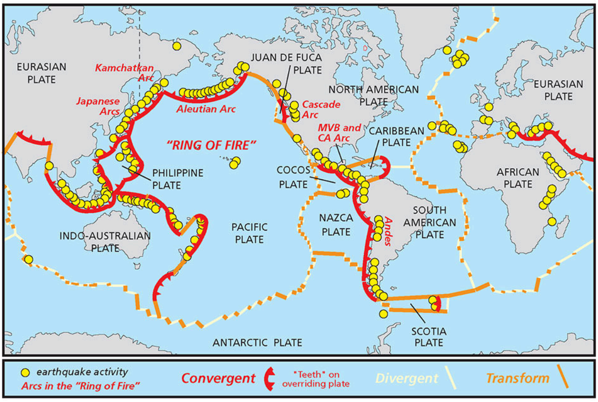
into each other and upward forming a mountain.

  - When **two oceanic plates converge**, one plate is **subducted** under the other. In this situation, a **trench** or an **island arc** is formed.
  - When a **continental plate converges with an oceanic plate,** the denser oceanic plate is subducted under the continental plate. As the oceanic plate is forced deeper underground, it reaches very high temperatures and melts into magma. Then, magma can rise up into the space and form **volcanoes**. This can also form a mountain range; for examples, the Andes mountains were formed in this way.
- **Divergent** plates
  - In the ocean, magma rises up to fill the space between plates and a volcano is formed. When the material from the volcanic eruptions builds up over time, it forms a **mid-ocean ridge**.
  - On land, a rift valley, or large crack is formed.



"Tectonic Plate Boundaries" by Jose F. Vigil/USGS is public domain

As seen in the map below, the **Ring of Fire** is an area in the Pacific Ocean bounded by several tectonic plates. Most of Earth's earthquakes and volcanoes occur in this area due to the shifting of tectonic plates along these boundaries.



"[Map of Tectonic Plates]" by [NOAA] is *public domain*

Volcanoes

A **volcano** is a vent that allows magma, rock fragments, ash, and gases to escape to the surface of a planet or moon. Volcanoes have created more than 80% of Earth's surface. Volcanoes are found on every continent and on the sea floor in Earth's oceans, as well as on several planets and moons in space.

When the material (magma, ash, and gases) from a volcano comes to Earth's surface, it is called an eruption. There are two different types of volcanic eruptions: explosive and effusive. Explosive eruptions are when the magma is fiercely fragmented and rapidly expelled from a volcano. Effusive eruptions are when lava steadily flows out a volcano onto the ground.

Effusive Eruptions

- lava steadily flows out a volcano onto the ground
- occurs when magmas reaches the surface
- builds up gentle sloping shield volcanoes

“*Effusive eruption*” *by* *Michael Ryan/USGS* *is* *public domain*

Explosive Eruptions

- the magma is fiercely fragmented and rapidly expelled
- occurs where cooler magmas reaches the surface
- builds up steep sloping composite volcanoes

"*Explosive eruption*" *by* *Mike Doukas/ USGS* *is* *public domain*

How Volcanoes are Formed

Volcanoes form when magma from deep within Earth rises to the surface. Volcanoes can be formed in 3 ways: converging tectonic plates, diverging tectonic plates, or over a hot spot.

- Convergent plates

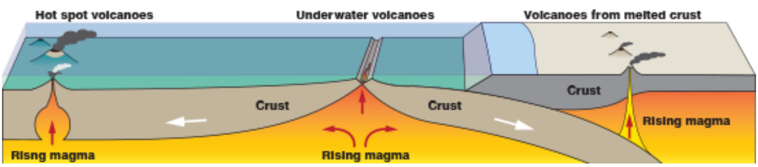
When an oceanic plate converges with a continental plate, the oceanic plate **subducts** under the continental plate forming a **subduction zone**. At this zone, the denser plate is pushed under the other and the rock melts under intense heat and pressure as it is pushed further into Earth. Thus, the melted rock turns to **magma** and is able to rise to Earth's surface as a volcano.

- Divergent plates

When two plates diverge, magma rises up to fill the space in between and an underwater volcano forms.

- Hot spots

A hot spot is an extremely hot area in the mantle where magma can rise up to the surface and create volcanic activity. The heat comes from deep within Earth, melting rock at the crust and forming magma. More typically, volcanoes occur along plate boundaries, but hot spots are located in the middle of tectonic plates. Yellowstone National Park in Wyoming is a supervolcano located over a hot spot. It hasn't erupted for 174,000 years and is not expected to erupt soon. However, features in the park such as the geyser Old Faithful are fueled by volcanic activity over the hot spot.



"*Volcano formation*" *by* *NASA Space Place*

The Hawaiian Islands, an **island arc**, were also formed by hot spot volcanoes on the Pacific Plate. The Pacific Plate is slowly moving northwest over time while the hot spot stays in the same place. As such, different areas of the plate are located over the hot spot at different times. Material from underwater volcanic eruptions at the hot spot builds up until it eventually reaches the surface, forming an island.

Based on the ages of rocks found on the islands, scientists can determine that the westernmost island, Kauai, is the oldest. 5 million years ago, Kauai was located over the hot spot. As the Pacific Plate shifted west, new islands in the chain were formed. Therefore, the easternmost island, the Big Island, is the youngest island and it is currently located over the hot spot. Eventually, new islands will continue to form in Hawaii. Scientists have detected a the beginnings of a new island, named Loihi, located southwest of the Big Island. Although it is currently located far below the ocean surface, volcanic eruptions have started to form Loihi and it will reach the surface in tens of thousands of years.

A YouTube element has been excluded from this version of the text. You can view it online here: https://pressbooks.uiowa.edu/methodsii/?p=359

Video credit: "Hawaiian Islands Formation" by Khan Academy is licensed under CC BY-NC-SA 3.0. Note: All Khan Academy content is available for free at khanacademy.org.

Earthquakes

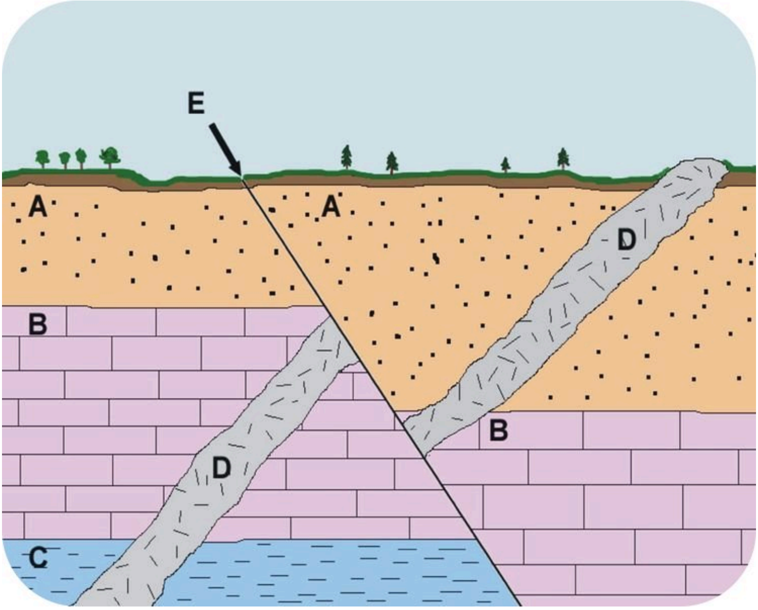
Tectonic plates float on the **mantle**, the layer below the crust.

Breaks in the rock of the plates are called **faults**; these can occur in the form of plate boundaries as well as smaller cracks on the interior of plates. The rock moves along these fault lines at **transform boundaries**. Sometimes, however, they are unable to easily pass. The plates continue to push into or slide past each other which causes intense stress to build up. Eventually, the rocks will snap and the pressure will be released in the form of powerful seismic waves. This causes the ground to shake–an earthquake.

Law of Superposition

The **Law of Superposition** states that deeper layers of rock are older; deeper layers of rock were formed before layers that are closer to the surface. The **Law of Original Horizontality** states that successive layers of rock are formed in flat, horizontal layers; this is because gravity pulls down on the rock when it forms. Using these laws, geologists and archaeologists can determine the relative age the layers of rocks.

Sometimes, however, layers of rock do not match up horizontally. Due to the movement of Earth's plates, the layers constantly shift and may become skewed or tilted. Additionally, surface level factors such as erosion and weathering can affect the top layer of earth by washing parts of it away. Finally, intrusions of **magma** (which forms igneous rock) can disrupt the horizontal layers beneath the surface. All of these factors provide clues for scientists to understand what occurred and when it happened at different times on Earth.



"*Laws of Superposition and Original Horizontality*" *by* *CK-12* *is licensed under* *CC BY-NC 3.0*

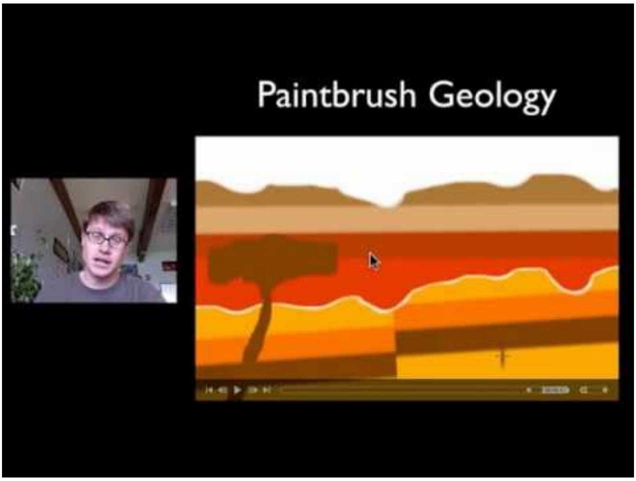
In the image, above, the layers of rock oldest to youngest are C, B, A, D.

- C is the oldest because it is the deepest layer.
- Next, B was formed on top of C.
- Then, A was formed on top of B.
- D is an intrusion of magma. We can tell it happened after A, B, and C were formed because it intrudes through all three layers and reaches the surface of Earth.
- Finally, a shift occurred in the layers due to plate tectonics, represented by the line, E. We can tell this happened last because every layer of rock and the intrusion have been disrupted and they are skewed horizontally.

K-6 Standards

4-ESS1-1. Identify evidence from patterns in rock formations and fossils in rock layers to support an explanation for changes in a landscape over time.

To learn more about the Law of Superposition, the following video is highly-recommended viewing:



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Fossils

Fossils are the remains of plants or animals that have been preserved in rock. Fossils form when the remains of a plant or animal are quickly buried after they die. Over time, the remains are replaced by minerals and compacted between layers of sediment to form fossils in sedimentary rock. Fossils are very fragile so they can only be found in sedimentary rocks; the extreme heat and pressure needed to form igneous and metamorphic rocks would destroy the fossil.

Fossils can also tell a story. Using the Laws of **Superposition** and **Original Horizontality**, geologists can figure out the relative age of a certain layer of rock. Sometimes, a specific type of fossil is found widely throughout one of these horizontal layers. Scientists can infer, then, that the organism lived during the same geologic time; this is called an index fossil. If the same type of fossil is found in other areas of rock, scientists can figure out that certain layers of rock were formed at the same time as well. In this way, fossils are a record of geologic time that tell a story to the people who find them.

K-6 Standards

3-LS4-1. Analyze and interpret data from fossils to provide evidence of the organisms and the environments in which they lived long ago.

NGSS

5-ESS2-1.	Developing and Using ModelsModeling in 3–5 builds on K–2 experiences and progresses to building and revising simple models and using models to represent events and design solutions.Develop a model using an example to describe a scientific principle.">Develop a model using an example to describe ESS2.A: Earth Materials and SystemsEarth's major systems are the geosphere (solid and molten rock, soil, and sediments), the hydrosphere (water and ice), the atmosphere (air), and the biosphere (living things, including humans). These systems interact in multiple ways to affect Earth's surface materials and processes. The ocean supports a variety of ecosystems and organisms, shapes landforms, and influences climate. Winds and clouds in the atmosphere interact with the landforms to determine patterns of weather.">ways the geosphere, biosphere, hydrosphere, and/or atmosphere Systems and System ModelsA system can be described in terms of its components and their interactions. ">interact. [Clarification Statement: Examples could include the influence of the ocean on ecosystems, landform shape, and climate; the influence of the atmosphere on landforms and ecosystems through weather and climate; and the influence of mountain ranges on winds and clouds in the atmosphere. The geosphere, hydrosphere, atmosphere, and biosphere are each a system.] [*Assessment Boundary: Assessment is limited to the interactions of two systems at a time.*]

MS-ESS2-1.	Developing and Using ModelsModeling in 6–8 builds on K–5 experiences and progresses to developing, using, and revising models to describe, test, and predict more abstract phenomena and design systems.Develop and use a model to describe phenomena.">Develop a model to describe Stability and ChangeExplanations of stability and change in natural or designed systems can be constructed by examining the changes over time and processes at different scales, including the atomic scale.">the cycling of ESS2.A: Earth Materials and SystemsAll Earth processes are the result of energy flowing and matter cycling within and among the planet's systems. This energy is derived from the sun and Earth's hot interior. The energy that flows and matter that cycles produce chemical and physical changes in Earth's materials and living organisms.">Earth's materials and the flow of energy that drives this process. [Clarification Statement: Emphasis is on the processes of melting, crystallization, weathering, deformation, and sedimentation, which act together to form minerals and rocks through the cycling of Earth's materials.] [*Assessment Boundary: Assessment does not include the identification and naming of minerals.*]

MS-ESS1-4.	Constructing Explanations and Designing SolutionsConstructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific ideas, principles, and theories.Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students' own experiments) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.">Construct a scientific explanation based on evidence ESS1.C: The History of Planet EarthThe geologic time scale interpreted from rock strata provides a way to organize Earth's history. Analyses of rock strata and the fossil record provide only relative dates, not an absolute scale. ">from rock strata for how the geologic Scale, Proportion, and QuantityTime, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small.">time scale is used ESS1.C: The History of Planet EarthThe geologic time scale interpreted from rock strata provides a way to organize Earth's history. Analyses of rock strata and the fossil record provide only relative dates, not an absolute scale. ">to organize Earth's 4.6-billion-year-old history. [Clarification Statement: Emphasis is on how analyses of rock formations and the fossils they contain are used to establish relative ages of major events in Earth's history. Examples of Earth's major events could range from being very recent (such as the last Ice Age or the earliest fossils of homo sapiens) to very old (such as the formation of Earth or the earliest evidence of life). Examples can include the formation of mountain chains and ocean basins, the evolution or extinction of particular living organisms, or significant volcanic eruptions.] [*Assessment Boundary: Assessment does not include recalling the names of specific periods or epochs and events within them.*]

MS-ESS2-2.	Constructing Explanations and Designing SolutionsConstructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific ideas, principles, and theories.Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students' own experiments) and the assumption that theories and laws that describe nature operate today as they did in the past and will continue to do so in the future.">Construct an explanation based on evidence for how ESS2.A: Earth Materials and SystemsThe planet's systems interact over scales that range from microscopic to global in size, and they operate over fractions of a second to billions of years. These interactions have shaped Earth's history and will determine its future.ESS2.C: The Roles of Water in Earth's Surface ProcessesWater's movements—both on the land and underground—cause weathering and erosion, which change the land's surface features and create underground formations.">geoscience processes have changed Earth's surface Scale, Proportion, and QuantityTime, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small.">at varying time and spatial scales. [Clarification Statement: Emphasis is on how processes change Earth's surface at time and spatial scales that can be large (such as slow plate motions or the uplift of large mountain ranges) or small (such as rapid landslides or microscopic geochemical reactions), and how many geoscience processes (such as earthquakes, volcanoes, and meteor impacts) usually behave gradually but are punctuated by catastrophic events. Examples of geoscience processes include surface weathering and deposition by the movements of water, ice, and wind. Emphasis is on geoscience processes that shape local geographic features, where appropriate.]

MS-ESS2-3.	Analyzing and Interpreting DataAnalyzing data in 6–8 builds on K–5 experiences and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis.Analyze and interpret data to provide evidence for phenomena.">Analyze and interpret data PatternsPatterns in rates of change and other numerical relationships can provide information about natural systems.">on the distribution ESS2.B: Plate Tectonics and Large-Scale System InteractionsMaps of ancient land and water patterns, based on investigations of rocks and fossils, make clear how Earth's plates have moved great distances, collided, and spread apart.">of fossils and rocks, continental shapes, and seafloor structures to provide evidence of the past plate motions. [Clarification Statement: Examples of data include similarities of rock and fossil types on different continents, the shapes of the continents (including continental shelves), and the locations of ocean structures (such as ridges, fracture zones, and trenches).] [*Assessment Boundary*: *Paleomagnetic anomalies in oceanic and continental crust are not assessed.*]

DCI

2nd Grade

ESS1.C: The History of Planet Earth

- Some events happen very quickly; others occur very slowly, over a time period much longer than one can observe. (2-ESS1-1)

ESS2.B: Plate Tectonics and Large-Scale System Interactions

- Maps show where things are located. One can map the shapes and kinds of land and water in any area. (2-ESS2-2) fourth grade

ESS1.C: The History of Planet Earth

- Local, regional, and global patterns of rock formations reveal changes over time due to earth forces, such as earthquakes. The presence and location of certain fossil types indicate the order in which rock layers were formed. (4-ESS1-1)

ESS2.B: Plate Tectonics and Large-Scale System Interactions

- The locations of mountain ranges, deep ocean trenches, ocean floor structures, earthquakes, and volcanoes occur in patterns. Most earthquakes and volcanoes occur in bands that are often along the boundaries between continents and oceans. Major mountain chains form inside continents or near their edges. Maps can help locate the different land and water features areas of Earth. (4-ESS2-2)

fifth grade

ESS2.A: Earth Materials and Systems

- Earth's major systems are the geosphere (solid and molten rock, soil, and sediments), the hydrosphere (water and ice), the atmosphere (air), and the biosphere (living things, including humans). These systems interact in multiple ways to affect

Earth's surface materials and processes. The ocean supports a variety of ecosystems and organisms, shapes landforms, and influences climate. Winds and clouds in the atmosphere interact with the landforms to determine patterns of weather. (5-ESS2-1)

Middle school

ESS1.C: The History of Planet Earth

- The geologic time scale interpreted from rock strata provides a way to organize Earth's history. Analyses of rock strata and the fossil record provide only relative dates, not an absolute scale. (MS-ESS1-4)

ESS2.A: Earth's Materials and Systems

- The planet's systems interact over scales that range from microscopic to global in size, and they operate over fractions of a second to billions of years. These interactions have shaped Earth's history and will determine its future. (MS-ESS2-2)

ESS2.B: PLate Tectonics and Large-Scale System Interactions

- Maps of ancient land and water patterns, based on investigations of rocks and fossils, make clear how Earth's plates have moved great distances, collided, and spread apart. (MS-ESS2-3)

Crosscutting Concepts
Second grade

Patterns

- Patterns in the natural world can be observed. (2-ESS2-2),(2-ESS2-3)

Stability and Change

- Things may change slowly or rapidly. (2-ESS2-1)

fourth grade

Patterns

- Patterns can be used as evidence to support an explanation. (4-ESS1-1),(4-ESS2-2)

Cause and Effect

- Cause and effect relationships are routinely identified, tested, and used to explain change. (4- ESS2-1),(4-ESS3-2)

Fifth grade

Scale, Proportion, and Quantity

- Standard units are used to measure and describe physical quantities such as weight and volume. (5-ESS2-2)

Systems and System Models

- A system can be described in terms of its components and their interactions. (5-ESS2-1),(5-ESS3-1)

14. Practice Quiz 1

Follow this link to take the earth science practice quiz. You will get immediate feedback on your answers.

"Hawaii Volcano Eruption" by USGS is public domain

15. Rocks and the Rock Cycle

Types of Rocks

Rocks are classified as three types: Igneous, Sedimentary, and Metamorphic.

Igneous	**Sedimentary**	**Metamorphic**
• formed when magma cools	• formed when many small particles called sediments are compacted together over time	• formed when existing rocks undergo extreme heat and pressure
• The early Earth was made of liquid magma that then cooled to form solid rocks, so this was the first type of rock.	• Fossils are always found in sedimentary rocks.	• The word metamorphic means to transform or change shape; you may have heard the term metamorphosis–the process in which a caterpillar transforms into a butterfly.

Intrusive Igneous Rocks	Extrusive Igneous Rocks
When magma cools underground, it cools more slowly. Since it is inside Earth, it is well protected and forms larger crystals. This is called an intrusive rock.	When magma cools in water or on the surface of Earth, like after a volcano erupts, it cools more quickly and forms smaller crystals. This is called an extrusive rock.

Rock Cycle

The key processes in the rock cycle are heat & pressure and **weathering** & **erosion**. Each type of rock can undergo different changes that affect its form and the type of rock it is.

Igneous rocks:

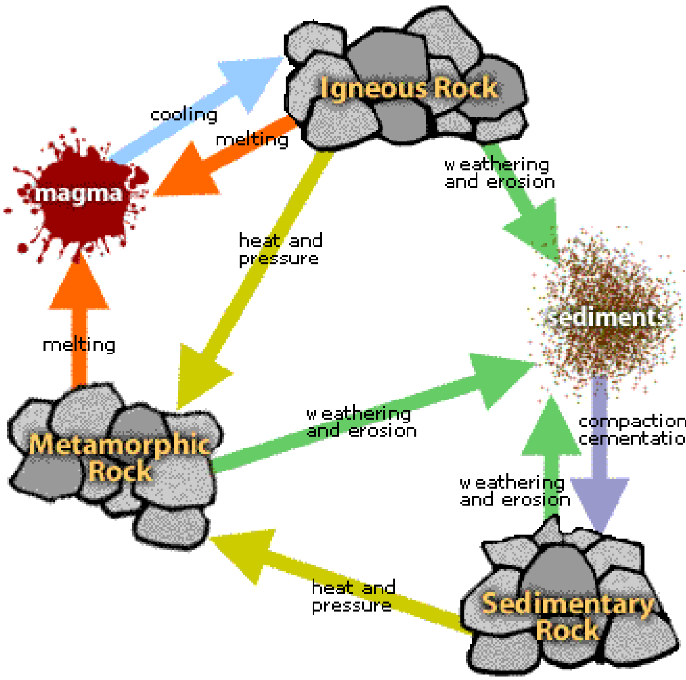
- Can undergo heat and pressure to become a metamorphic rock
- Can undergo weathering and erosion to become a sedimentary rock
- Can melt and become magma again. Then, it will cool and re-form as an igneous rock.

Sedimentary rocks:

- Can undergo heat and pressure to become a metamorphic rock
- Can undergo weathering and erosion, thereby breaking apart into sediments. Then, these sediments can be compacted again into sedimentary rocks.
- Can melt and become magma or igneous rock

Metamorphic rocks:

- Can undergo heat and pressure to transform into another metamorphic rock
- Can undergo weathering and erosion to become a sedimentary rock
- Can melt and become magma and igneous rock



"*The Rock Cycle*"

Geodes

A **geode** forms when a cavity forms in a rock, which can occur in different ways. One way a cavity can form occurs when a bubble of carbon dioxide and water vapor forms in flowing lava. As the molten rock cools and the gas dissolves, an empty space is left behind. Another possibility in which a cavity can form occurs when lava solidifies under water. Sometimes the outside of the melted rock cools before the inside, which becomes brittle and breaks a little bit due to the weight of the liquid inside.

However, cavities can also form in sedimentary rocks, such as limestone and sandstone, which produce the geodes we find in Iowa. In these particular rocks, the leading theory is that after deposition there was a period of erosion. In this time, the believe is that a more dense object carved out the cavity from the inside, like a shell moving around and gouging out the hollow space. Then, a period of deposition occurred where mineral infused water penetrated the permeable surface and began filling the geode with quartz. In other cases, organic material, like a piece of wood, gets buried in the sediment and eventually weathers over time, leaving behind empty space. Once these rocks are hollow, or at least semi-hollow, various minerals are able to seep in through the rock's microscopic pores, creating crystalline structures over long periods of time. Different minerals form different types and colors of crystals inside the geodes.

Archimedes' Principle

Archimedes' principle says that the weight of the displaced liquid is equal to the weight of the object. In class, we apply Archimedes' Principle to figure out how dense a geode is. A geode that is less dense will have more crystals inside, which is usually the kind of geode you see cut open.

Watch the video, below, for an explanation of Archimedes' Principle.

A YouTube element has been excluded from this version of the text. You can view it online here: https://pressbooks.uiowa.edu/methodsii/?p=361

Video credit: "How taking a bath led to Archimedes' Principle" by Mark Salata/TED-Ed is licensed under CC BY-NC-ND 4.0

Like the Archimedes' crown, a geode is an irregular shape so it is hard to measure the volume. We can use Archimedes' principle to figure out whether a geode is solid or hollow. To do this, calculate the specific gravity of the geode.

Specific gravity

- Formula for specific gravity: W(air) / (W(air)-W(water))
    - Weight of displaced liquid = weight of the object
- The specific gravity for a geode is .27.
    - If the formula equals .27, it is likely the geode is solid quartz.
    - If the formula equals less than .27, the geode will be more hollow and have more crystals inside.

Weathering, Erosion, and Deposition

Weathering is the breakdown of rocks on Earth's surface. There are two types of weathering:

1. Mechanical: also known as physical weathering, rock is broken down into smaller fragments due to water, wind, or other conditions such as temperature and pressure changes
2. Chemical: chemical reactions change the molecular structure of the rock

After the rocks are broken down through weathering, erosion can occur. Erosion is the process by which the small bits of rock are transported to a new location. Finally, deposition occurs when the particles are added to or deposited at a new location. These three processes act as a cycle, continually breaking down and building up different parts of Earth's landscape.

Key Takeaway

Weathering is the making the mess and **Erosion** is cleaning it up.

K-6 Standards

2-ESS2-1. Compare multiple solutions designed to slow or prevent wind or water from changing the shape of the land.

4-ESS2-1. Make observations and/or measurements to provide evidence of the effects of weathering or the rate of erosion by water, ice, wind, or vegetation.

Sand

Sand is any rocky material that is bigger in size than silt and smaller than gravel. Sand is created when rocks are **weathered**, or broken down, in one of two ways: by water or by wind. When wind or water continually passes over a rock, it breaks it down into smaller and smaller pieces and sand is formed. Sand that was formed from weathering by wind tends to be pitted and frosted in appearance because other grains of sand have constantly been pelted against the rock. Sand that was formed from weathering by water tends to be smooth and polished because the water has continually passed over the rock.

Where did this sand come from?

Type of Sand	**Location**	**Characteristics**
Weathering by wind	Dunes in the desert	Scratched or frosted, pitted, uniform in size
Weathering by water	Rocks near water	Rounded, polished, smooth

Like fossils, sand can also tell a story. Based on where it is found in the world, sand is composed of different materials. Thus, it can also come in a variety of colors such as black, white, green, red and pink. Black sand, for example, is made from lava that has cooled to form an igneous rock; one place it can be found is near volcanoes in Hawaii.

"*Hawaii Black Sand Beach*" *by* *Ryan Keene* *is licensed under* CC BY-NC-ND 2.0

NGSS

5-ESS2-1.	Developing and Using ModelsModeling in 3–5 builds on K–2 experiences and progresses to building and revising simple models and using models to represent events and design solutions.Develop a model using an example to describe a scientific principle.">Develop a model using an example to describe ESS2.A: Earth Materials and SystemsEarth's major systems are the geosphere (solid and molten rock, soil, and sediments), the hydrosphere (water and ice), the atmosphere (air), and the biosphere (living things, including humans). These systems interact in multiple ways to affect Earth's surface materials and processes. The ocean supports a variety of ecosystems and organisms, shapes landforms, and influences climate. Winds and clouds in the atmosphere interact with the landforms to determine patterns of weather.">ways the geosphere, biosphere, hydrosphere, and/or atmosphere Systems and System ModelsA system can be described in terms of its components and their interactions. ">interact. [Clarification Statement: Examples could include the influence of the ocean on ecosystems, landform shape, and climate; the influence of the atmosphere on landforms and ecosystems through weather and climate; and the influence of mountain ranges on winds and clouds in the atmosphere. The geosphere, hydrosphere, atmosphere, and biosphere are each a system.] [*Assessment Boundary: Assessment is limited to the interactions of two systems at a time.*]

MS-ESS2-1.	Developing and Using ModelsModeling in 6–8 builds on K–5 experiences and progresses to developing, using, and revising models to describe, test, and predict more abstract phenomena and design systems.Develop and use a model to describe phenomena.">Develop a model to describe Stability and ChangeExplanations of stability and change in natural or designed systems can be constructed by examining the changes over time and processes at different scales, including the atomic scale.">the cycling of ESS2.A: Earth Materials and SystemsAll Earth processes are the result of energy flowing and matter cycling within and among the planet's systems. This energy is derived from the sun and Earth's hot interior. The energy that flows and matter that cycles produce chemical and physical changes in Earth's materials and living organisms.">Earth's materials and the flow of energy that drives this process. [Clarification Statement: Emphasis is on the processes of melting, crystallization, weathering, deformation, and sedimentation, which act together to form minerals and rocks through the cycling of Earth's materials.] [*Assessment Boundary: Assessment does not include the identification and naming of minerals.*]

DCI

Second grade

ESS2.A: Earth Materials and Systems

- Wind and water can change the shape of the land. (2-ESS2-1)

fifth grade

ESS2.A: Earth Materials and Systems

- Earth's major systems are the geosphere (solid and molten rock, soil, and sediments), the hydrosphere (water and ice), the atmosphere (air), and the biosphere (living things, including humans). These systems interact in multiple ways to affect Earth's surface materials and processes. The ocean supports a variety of ecosystems and organisms, shapes landforms, and influences climate. Winds and clouds in the atmosphere interact with the landforms to determine patterns of weather. (5-ESS2-1)

middle school

ESS2.A: Earth's Materials and Systems

- All Earth processes are the result of energy flowing and matter cycling within and among the planet's systems. This energy is derived from the sun and Earth's hot interior. The energy that flows and matter that cycles produce chemical and physical changes in Earth's materials and living organisms. (MS-ESS2-1)

crosscutting
middle school

Cause and Effect

- Cause and effect relationships may be used to predict phenomena in natural or designed systems. (MS-ESS3-1)

Energy and Matter

- Within a natural or designed system, the transfer of energy drives the motion and/or cycling of matter. (MS-ESS2-4)

Stability and Change

- Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and processes at different scales, including the atomic scale. (MS-ESS2-1)

16. Practice Quiz 2

Follow this link to take the earth science practice quiz. You will get immediate feedback on your answers.

"*Sand Under a Microscope*"

PART IV
CLIMATE SCIENCE

Welcome to Climate Science. This part is divided into five chapters:

1. Climate vs. Weather
2. Climate: Background Information
3. Global Climate Change
4. Local Climate Change
5. Weather

Additionally, there is an optional watching guide for *Before the Flood* and a practice quiz that covers the entire unit.

17. Climate vs. Weather

Weather vs. Climate

Weather is the short-term atmospheric conditions in an area like, "It's raining" or "It's sunny today". As such, weather can change day to day.

Climate is the usual weather activity that can be expected for an area and time of year such as, "Minnesota is so snowy during the winter" or "Florida is sunny in the summer". Climate is measured in 30-year intervals, so the term **climate change** refers to the continual change of the climate over time from what is typically expected to happen.

Some people confuse weather and climate. For example, you may hear something like, "This snowstorm is crazy…we need global warming!" However, this statement confuses weather and climate. A snowstorm that lasts for a few days is a weather event; global warming is part of climate change which is measured over decades. Earth could have its hottest day on record–a weather event–but we cannot call that climate change unless a trend indicating a change in temperature can be measured over a 30-year period.

K-6 Standards

3-ESS2-2. Obtain and combine information to describe climates in different regions of the world.

Key Takeaways

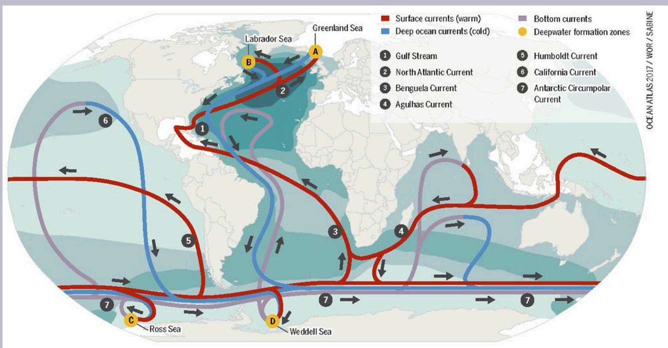
- **Weather:** what is happening NOW
- **Climate**: what happens USUALLY

What factors determine whether an area has a hot or cold climate?

L.O.W.E.R. Near Water

- **L**: **Latitude**
  - Latitudes near the Equator have warmer temperatures.
  - Latitudes near the North and South poles have colder temperatures.
- **O**: Ocean currents
  - The temperature of an ocean current affects the temperature of the air that passes over it.
  - Example: The California Current brings

cooler air from north to south; therefore, California's coastal cities tend to have a cooler climate. Conversely, the Gulf Stream carries warmer air from tropical areas to the southeastern United States; therefore, this region tends to have a warmer climate.

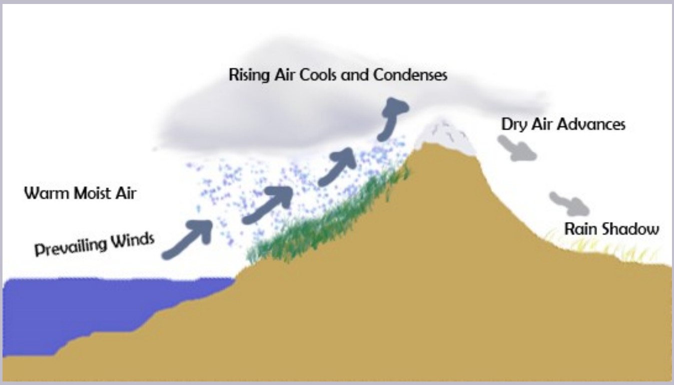


On this map, you can see the cold California Current (#6) that carries cold air to the west coast and the warm Gulf Stream (#1) that carries warm air to the east coast. "Global Conveyer Belt" by Heinrich-Böll-Stiftung is licensed under CC BY 2.0

- **W**: Wind and **air masses**
  - Air masses take on the climatic conditions of the area where they are formed. When wind moves these air masses to a new area, they bring the climatic conditions with them which can affect the weather and climate of the new location.
  - Example: If the wind or air mass is coming from the Arctic, it will bring colder air to an

area. If the wind or air mass is coming from the tropics, it will bring warmer air to an area.

- **E**: Elevation
    - Higher altitudes tend to be cooler, while lower altitudes tend to be warmer. This is because there is less pressure at higher altitudes, so the air expands and cools.
- **R**: Relief (aka **topography**)
    - When an air mass rises to pass over topography such as a mountain, it expands and cools. This causes precipitation on that side of the mountain. A **rain shadow** is created because the precipitation cannot pass over the mountain to the other side.



"Rain Shadow" by NPS is public domain

    - Example: The Sierra Nevada mountain range in California is a topographical feature that affects climate. West of the mountains, moist air comes off the Pacific Ocean. As this air rises to go up the mountains, precipitation occurs; San Francisco, a city west of the Sierra Nevada, is known for having a cool and wet climate. On the other side of the mountain, precipitation is blocked and the area becomes a desert known as a rain shadow; Death Valley, one of the hottest and driest places in the world is located east of the Sierra Nevada.

- **Near Water**:
    - In the summer, water acts like an air conditioner to keep the air temperatures cool. In the winter, water acts like a heater to keep the temperatures from getting too cool.
    - Continental climate=far from water; maritime climate=near water.
    - Example: As seen in the map below, Ontario, Canada–an inland province–has a moderate climate due to its proximity to the Great Lakes. Ontario is cooler in the summer and warmer in the winter than other areas at the same **latitude** due to the effects of the Great Lakes.

"[Map of Canada]" *by E Pluribus Anthony is public domain*

NGSS

K-PS3-1.	Panning and Carrying Out InvestigationsPlanning and carrying out investigations to answer questions or test solutions to problems in K–2 builds on prior experiences and progresses to simple investigations, based on fair tests, which provide data to support explanations or design solutions.Make observations (firsthand or from media) to collect data that can be used to make comparisons.">Make observations to determine Cause and EffectEvents have causes that generate observable patterns.">the effect of PS3.B: Conservation of Energy and Energy TransferSunlight warms Earth's surface.">sunlight on Earth's surface. [Clarification Statement: Examples of Earth's surface could include sand, soil, rocks, and water.] [*Assessment Boundary: Assessment of temperature is limited to relative measures such as warmer/cooler.*]

K-ESS2-1.	Analyzing and Interpreting DataAnalyzing data in K–2 builds on prior experiences and progresses to collecting, recording, and sharing observations.Use observations (firsthand or from media) to describe patterns in the natural world in order to answer scientific questions.">Use and share observations of ESS2.D: Weather and ClimateWeather is the combination of sunlight, wind, snow or rain, and temperature in a particular region at a particular time. People measure these conditions to describe and record the weather and to notice patterns over time.">local weather conditions PatternsPatterns in the natural world can be observed, used to describe phenomena, and used as evidence.">to describe patterns ESS2.D: Weather and ClimateWeather is the combination of sunlight, wind, snow or rain, and temperature in a particular region at a particular time. People measure these conditions to describe and record the weather and to notice patterns over time.">over time. [Clarification Statement: Examples of qualitative observations could include descriptions of the weather (such as sunny, cloudy, rainy, and warm); examples of quantitative observations could include numbers of sunny, windy, and rainy days in a month. Examples of patterns could include that it is usually cooler in the morning than in the afternoon and the number of sunny days versus cloudy days in different months.] [*Assessment Boundary: Assessment of quantitative observations limited to whole numbers and relative measures such as warmer/cooler.*]

K-ESS3-2.	Asking Questions and Defining ProblemsAsking questions and defining problems in grades K–2 builds on prior experiences and progresses to simple descriptive questions that can be tested.Ask questions based on observations to find more information about the designed world.Obtaining, Evaluating, and Communicating InformationObtaining, evaluating, and communicating information in K–2 builds on prior experiences and uses observations and texts to communicate new information.Read grade-appropriate texts and/or use media to obtain scientific information to describe patterns in the natural world.">Ask questions to obtain information about ESS3.B: Natural HazardsSome kinds of severe weather are more likely than others in a given region. Weather scientists forecast severe weather so that the communities can prepare for and respond to these events.ETS1.A: Defining and Delimiting an Engineering ProblemAsking questions, making observations, and gathering information are helpful in thinking about problems.">the purpose of weather forecasting to prepare for, Cause and EffectEvents have causes that generate observable patterns.Interdependence of Science, Engineering, and TechnologyPeople encounter questions about the natural world every day.Influence of Engineering, Technology, and Science on Society and the Natural WorldPeople depend on various technologies in their lives; human life would be very different without technology.">and respond to, ESS3.B: Natural HazardsSome kinds of severe weather are more likely than others in a given region. Weather scientists forecast severe weather so that the communities can prepare for and respond to these events.">severe weather.* [Clarification Statement: Emphasis is on local forms of severe weather.]

3-ESS2-1.	Analyzing and Interpreting DataAnalyzing data in 3–5 builds on K–2 experiences and progresses to introducing quantitative approaches to collecting data and conducting multiple trials of qualitative observations. When possible and feasible, digital tools should be used.Represent data in tables and various graphical displays (bar graphs and pictographs) to reveal patterns that indicate relationships.">Represent data in tables and graphical displays to describe ESS2.D: Weather and ClimateScientists record patterns of the weather across different times and areas so that they can make predictions about what kind of weather might happen next. ">typical weather conditions PatternsSimilarities and differences in patterns can be used to sort, classify, and analyze simple rates of change for natural phenomena and designed products.">expected during a particular season. [Clarification Statement: Examples of data could include average temperature, precipitation, and wind direction.] [*Assessment Boundary: Assessment of graphical displays is limited to pictographs and bar graphs. Assessment does not include climate change.*]

3-ESS3-1.	Engaging in Argument from EvidenceEngaging in argument from evidence in 3–5 builds on K–2 experiences and progresses to critiquing the scientific explanations or solutions proposed by peers by citing relevant evidence about the natural and designed world(s).Make a claim about the merit of a solution to a problem by citing relevant evidence about how it meets the criteria and constraints of the problem.">Make a claim about the merit of a design solution Cause and EffectCause and effect relationships are routinely identified, tested, and used to explain change.Connections to Engineering, Technology, and Applications of ScienceEngineers improve existing technologies or develop new ones to increase their benefits (e.g., better artificial limbs), decrease known risks (e.g., seatbelts in cars), and meet societal demands (e.g., cell phones).">that reduces the impacts of ESS3.B: Natural HazardsA variety of natural hazards result from natural processes. Humans cannot eliminate natural hazards but can take steps to reduce their impacts.">a weather-related hazard.* [Clarification Statement: Examples of design solutions to weather-related hazards could include barriers to prevent flooding, wind resistant roofs, and lightning rods.]

MS-ESS2-5.	Planning and Carrying Out InvestigationsPlanning and carrying out investigations in 6-8 builds on K-5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or solutions.Collect data to produce data to serve as the basis for evidence to answer scientific questions or test design solutions under a range of conditions.">Collect data to provide evidence for how ESS2.C: The Roles of Water in Earth's Surface Processes*The complex patterns of the changes and the movement of water in the atmosphere, determined by winds, landforms, and ocean temperatures and currents, are major determinants of local weather patterns.ESS2.D: Weather and ClimateBecause these patterns are so complex, weather can only be predicted probabilistically.">the motions and complex interactions of air masses* Cause and EffectCause and effect relationships may be used to predict phenomena in natural or designed systems.">result in changes ESS2.C: The Roles of Water in Earth's Surface ProcessesThe complex patterns of the changes and the movement of water in the atmosphere, determined by winds, landforms, and ocean temperatures and currents, are major determinants of local weather patterns.ESS2.D: Weather and ClimateBecause these patterns are so complex, weather can only be predicted probabilistically.">in weather conditions. [Clarification Statement: Emphasis is on how air masses flow from regions of high pressure to low pressure, causing weather (defined by temperature, pressure, humidity, precipitation, and wind) at a fixed location to change over time, and how sudden changes in weather can result when different air masses collide. Emphasis is on how weather can be predicted within probabilistic ranges. Examples of data can be provided to students (such as weather maps, diagrams, and visualizations) or obtained through laboratory experiments (such as with condensation).] [*Assessment Boundary: Assessment does not include recalling the names of cloud types or weather symbols used on weather maps or the reported diagrams from weather stations.*]

MS-ESS2-6.	Developing and Using ModelsModeling in 6–8 builds on K–5 experiences and progresses to developing, using, and revising models to describe, test, and predict more abstract phenomena and design systems.Develop and use a model to describe phenomena.">Develop and use a model to describe how ESS2.C: The Roles of Water in Earth's Surface ProcessesVariations in density due to variations in temperature and salinity drive a global pattern of interconnected ocean currents. ESS2.D: Weather and ClimateWeather and climate are influenced by interactions involving sunlight, the ocean, the atmosphere, ice, landforms, and living things. These interactions vary with latitude, altitude, and local and regional geography, all of which can affect oceanic and atmospheric flow patterns.The ocean exerts a major influence on weather and climate by absorbing energy from the sun, releasing it over time, and globally redistributing it through ocean currents.">unequal heating and rotation of the Earth cause patterns of Systems and System ModelsModels can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems.">atmospheric and oceanic circulation that determine ESS2.C: The Roles of Water in Earth's Surface ProcessesVariations in density due to variations in temperature and salinity drive a global pattern of interconnected ocean currents. ESS2.D: Weather and ClimateWeather and climate are influenced by interactions involving sunlight, the ocean, the atmosphere, ice, landforms, and living things. These interactions vary with latitude, altitude, and local and regional geography, all of which can affect oceanic and atmospheric flow patterns.The ocean exerts a major influence on weather and climate by absorbing energy from the sun, releasing it over time, and globally redistributing it through ocean currents.">regional climates. [Clarification Statement: Emphasis is on how patterns vary by latitude, altitude, and geographic land distribution. Emphasis of atmospheric circulation is on the sunlight-driven latitudinal banding, the Coriolis effect, and resulting prevailing winds; emphasis of ocean circulation is on the transfer of heat by the global ocean convection cycle, which is constrained by the Coriolis effect and the outlines of continents. Examples of models can be diagrams, maps and globes, or digital representations.] [*Assessment Boundary: Assessment does not include the dynamics of the Coriolis effect.*]

DCI

Kindergarten

PS3.B: Conservation of Energy and Energy Transfer

- Sunlight warms Earth's surface. (K-PS3-1),(K-PS3-2)

ESS2.D: Weather and Climate

- Weather is the combination of sunlight, wind, snow or rain, and temperature in a particular region at a particular time. People measure these conditions to describe and record the weather and to notice patterns over time. (K-ESS2-1)

Third Grade

ESS2.D: Weather and Climate

- Scientists record patterns of the weather across different times and areas so that they can make predictions about what kind of weather might happen next. (3-ESS2-1)
- Climate describes a range of an area's typical weather conditions and the extent to which those conditions vary over years. (3-ESS2-2)

ESS3.B: Natural Hazards

- A variety of natural hazards result from natural processes. Humans cannot eliminate natural hazards but can take steps to reduce their impacts. (3-ESS3-1) *(Note: This Disciplinary Core*

Idea is also addressed by 4-ESS3-2.)

Middle School

ESS2.C: The Roles of Water in Earth's Surface Processes

- The complex patterns of the changes and the movement of water in the atmosphere, determined by winds, landforms, and ocean temperatures and currents, are major determinants of local weather patterns. (MS-ESS2-5)
- Variations in density due to variations in temperature and salinity drive a global pattern of interconnected ocean currents. (MS-ESS2-6)

ESS2.D: Weather and Climate

- Weather and climate are influenced by interactions involving sunlight, the ocean, the atmosphere, ice, landforms, and living things. These interactions vary with latitude, altitude, and local and regional geography, all of which can affect oceanic and atmospheric flow patterns. (MS-ESS2-6)
- Because these patterns are so complex, weather can only be predicted probabilistically. (MS-ESS2-5)
- The ocean exerts a major influence on weather and climate by absorbing energy from the sun, releasing it over time, and globally redistributing it through ocean currents. (MS-ESS2-6)

Crosscutting concepts

Patterns

- Patterns of change can be used to make predictions. (3-ESS2-1),(3-ESS2-2)

Cause and Effect

- Cause and effect relationships are routinely identified, tested, and used to explain change. (3-ESS3-1)

middle school

Cause and Effect

- Cause and effect relationships may be used to predict phenomena in natural or designed systems. (MS-ESS2-5)

Systems and System Models

- Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems. (MS-ESS2-6)

Stability and Change

- Stability might be disturbed either by sudden events or gradual changes that accumulate over time. (MS-ESS3-5)

18. Climate: Background Information

Climate is what happens USUALLY

Earth's Atmosphere

Earth's atmosphere is a layer of gases, mainly nitrogen and oxygen, between Earth's surface and space. From space, the atmosphere can be seen as a thin blue line around Earth's circumference in the image below.

"The Atmosphere" by NASA is public domain

The atmosphere is relatively thin, 60 miles wide, but it plays an important role for the planet. It lets in heat from the Sun so Earth has a livable temperature, while also acting a shield to block much of the Sun's harmful radiation. When Earth's systems are in balance, the atmosphere is a key part of regulating temperature, weather, and climate.

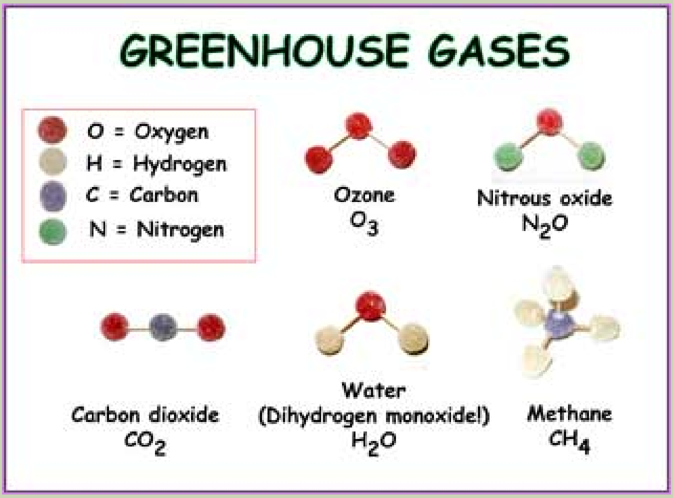
What is a greenhouse gas?

Certain gases in Earth's atmosphere are called greenhouse gases. Like a greenhouse, they let sunlight through to reach the surface of Earth and then trap its heat in the atmosphere. The most abundant greenhouse gases are:

- **Carbon dioxide (CO_2)**-Carbon dioxide is naturally released from decaying organisms and volcanic eruptions. However, humans are the main cause of excess carbon dioxide in the atmosphere from burning fossil fuels.
- **Nitrous oxide (N_2O)**-Bacteria naturally produce nitrous oxide, but humans create more from industrial activities such as factory waste and agricultural products such as fertilizer.
- **Methane (CH_4)**-Methane is naturally created in wetlands and oceans, but humans also contribute to excess methane through agriculture; cows release a significant amount of methane by burping when they

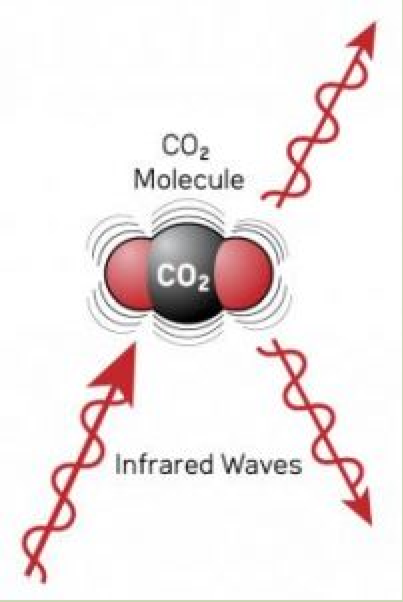
digest their food.

- **Water Vapor (H_2O)**-From the effects of climate change, there is more energy in Earth's systems and the global water cycle. As the temperature increases, this causes more water to evaporate and enter the atmosphere as water vapor, a heat-trapping molecule.
- **Ozone (O_3)**-High in the atmosphere, the ozone layer (naturally occurring ozone) blocks the Sun's radiation and helps regulate Earth's temperature. Lower in the atmosphere, however, human activities such as vehicle emissions create additional ozone. This ozone is bad because it traps heat in the atmosphere and creates smog.



"Greenhouse Gases" *by* NASA Space Place *is public domain*

Greenhouse gases are complex molecules made of three or more atoms bonded together. Gases move quickly and collide with other molecules in the atmosphere. This causes greenhouse gas molecules to vibrate and have an asymmetrical shape.

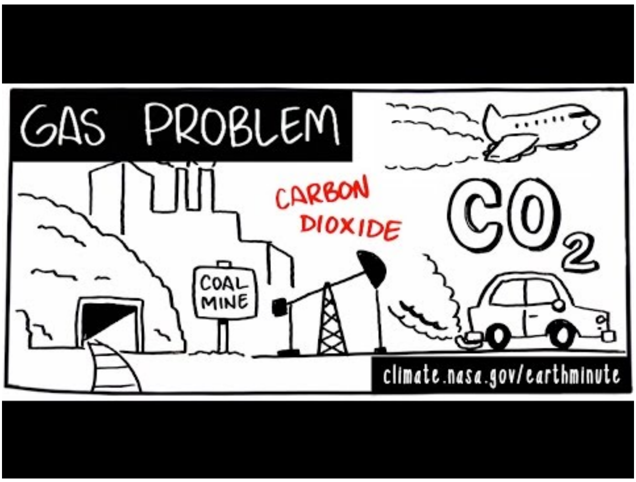


"Vibrating CO_2 Molecules" by Skeptical Science is licensed under CC BY 3.0

Because of this asymmetrical shape, they can absorb infrared radiation from the Sun. Then, the radiation is released back into the atmosphere which helps keep the planet warm enough to support life. Other gases in Earth's atmosphere such as nitrogen and oxygen are more abundant, but they do not absorb infrared radiation because their molecular structure stays symmetrical.

The Greenhouse Effect

Watch the following video for a short explanation of carbon dioxide and the greenhouse effect.



A YouTube element has been excluded from this version of the text. You can view it online here: https://pressbooks.uiowa.edu/methodsii/?p=613

Video Credit: "Earth's Gas Problem" by NASA Global Climate Change is public domain

What is the greenhouse effect?

The greenhouse effect describes how greenhouse gases in Earth's atmosphere trap heat.

When infrared radiation from the Sun reaches Earth:

- Some radiation is reflected back into space by the atmosphere and surfaces with a high **albedo** such as ice.
- Other radiation is absorbed by greenhouse gases and surfaces with a low albedo such as land and water.
    - Absorbed radiation is later released as heat which increases Earth's temperature.

Watch the animation, below, to see the greenhouse effect in action.

"The Greenhouse Effect" by NASA is public domain

The greenhouse effect is a key part of Earth's natural processes. Without heat from the Sun's radiation and the atmosphere's protection, Earth's temperature would not be regulated to support life. However, the greenhouse effect can go too far when Earth's systems are out of balance.

Earth's atmosphere can be compared to a blanket that is wrapped around the planet; the planet needs this blanket to survive in outer space. But when there are too many greenhouse gases in the atmosphere (from burning **fossil fuels**, for example), they radiate more heat than normal. This causes Earth's blanket to get thicker and thicker and global temperature increases. Unfortunately, Earth cannot simply take the blanket off in order to cool down. Over time, this leads to our current situation: global **climate change** with wide-reaching and serious consequences.

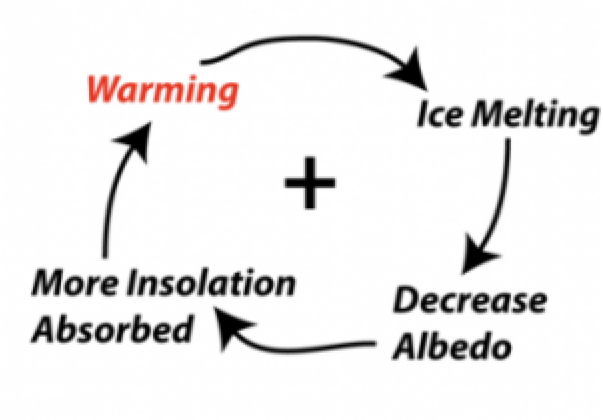
Albedo Effect

Albedo is the amount of energy reflected by a surface. Light surfaces tend to have a high albedo because they reflect more energy. Dark surfaces tend to have a low albedo because they absorb more energy.

As seen in the image, below, the Sun's rays project solar radiation to Earth's surface. Lighter-colored surfaces such as ice reflect the radiation. Darker-colored surfaces such as land and water absorb the Sun's heat.

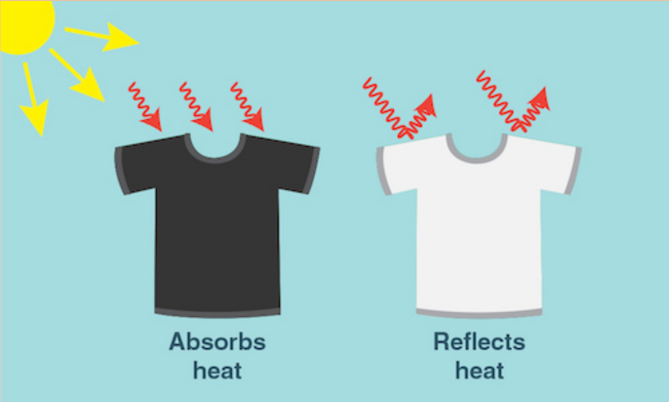
"Albedo" by NASA is public domain

Currently, Earth's albedo is decreasing as a result of climate change. As ice melts at the poles and glaciers, it is replaced by land and water. Because of their darker colors, land and water have low albedo–they absorb radiation which increases Earth's temperature and leads to increased ice melt. This relationship, a **positive feedback loop**, is shown in the image below.



Key Takeaways

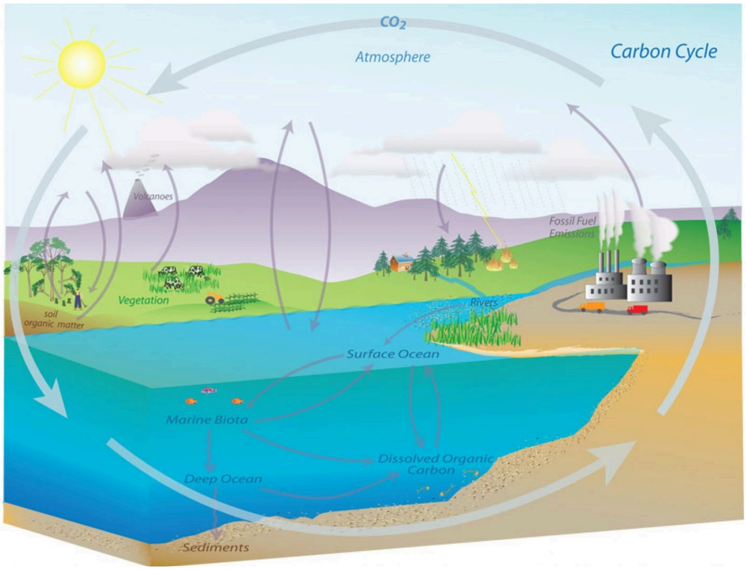
- Darker materials absorb heat–low albedo
- Lighter materials reflect heat–high albedo



"Albedo" by NASA is public domain

The Carbon Cycle

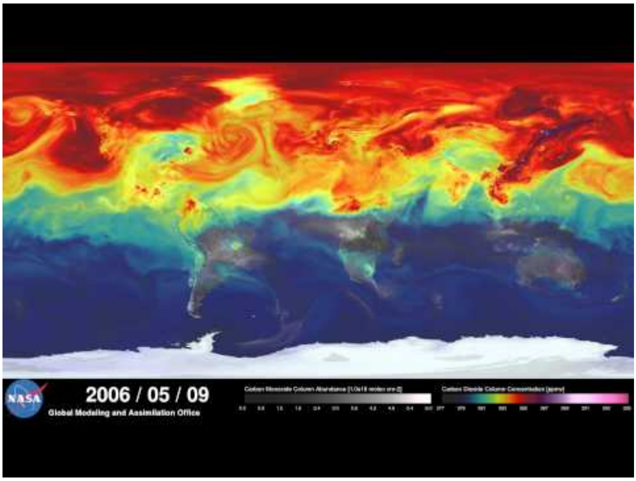
Carbon is an abundant element that is critical for life on Earth. As seen in the image, below, carbon naturally moves between the atmosphere, land, and water in the carbon cycle. Most of Earth's carbon is stored in rocks and sediments, but also in the oceans and in the atmosphere.



"Carbon Cycle" by NOAA is public domain

Carbon dioxide, a greenhouse gas, is important for life on Earth. For example, it traps heat to regulate Earth's temperature and is a key component of photosynthesis, the process by which plants create their own food. Due to human activities, however, carbon dioxide is increasing to abnormally high levels in the atmosphere and causing Earth's temperature to heat up.

The following video shows the global carbon cycle, how carbon dioxide in Earth's atmosphere fluctuates and moves around the globe over the course of a year.



A YouTube element has been excluded from this version of the text. You can view it online here: https://pressbooks.uiowa.edu/methodsii/?p=613

Video Credit: "A Year in the Life of Earth's CO_2" by NASA is public domain

What is ppm?

Carbon dioxide in the atmosphere is measured in parts per million (ppm).

So, if the CO_2 concentration is 400 ppm, that means 400 molecules out of every one million gas molecules in the atmosphere are carbon dioxide.

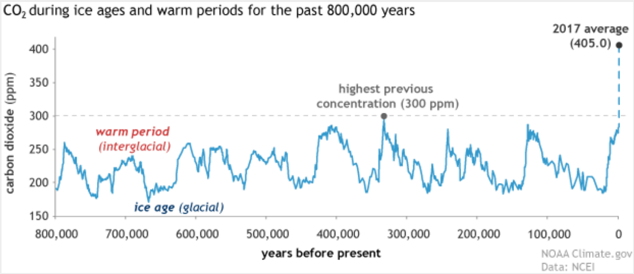
Ice Cores

Scientists use ice cores, samples of ice drilled from ice sheets and glaciers, to gather data about carbon dioxide levels over time. The **Law of Superposition** and the **Law of Original Horizontality** can be applied to ice cores as well: Older layers of ice are compacted and trapped beneath newer layers over time. Within each layer, bubbles of carbon dioxide are trapped; this provides scientists with a record of atmospheric levels of carbon dioxide going back hundreds of thousands of years. Scientists can also use this data to create climate models which help predict future climate change.

"Ice Core" by Ludovic Brucker/NASA Goddard Space Flight Center is public domain

The graph, below, was created using ice core data. As shown in the graph, carbon dioxide levels on Earth have naturally fluctuated for hundreds of thousands of years. Still, CO_2 levels were relatively stable within a certain range and never exceeded 300 **ppm**.

At the far right side of the graph, there is a sharp uptick in CO_2 levels, indicating the rise of fossil fuel use. By 2017, the average was 405 ppm. NASA's most recent data from July 2019 measured 411 ppm of CO_2 in the atmosphere. All of this data indicates that Earth's systems are out of balance from typical patterns that have been established over millennia.



"CO2 Graph" by NOAA Climate.gov is public domain

NGSS

K-PS3-1.	Panning and Carrying Out InvestigationsPlanning and carrying out investigations to answer questions or test solutions to problems in K–2 builds on prior experiences and progresses to simple investigations, based on fair tests, which provide data to support explanations or design solutions.Make observations (firsthand or from media) to collect data that can be used to make comparisons.">Make observations to determine Cause and EffectEvents have causes that generate observable patterns.">the effect of PS3.B: Conservation of Energy and Energy TransferSunlight warms Earth's surface.">sunlight on Earth's surface. [Clarification Statement: Examples of Earth's surface could include sand, soil, rocks, and water.] [*Assessment Boundary: Assessment of temperature is limited to relative measures such as warmer/cooler.*]

K-PS3-2.	Constructing Explanations and Designing SolutionsConstructing explanations and designing solutions in K–2 builds on prior experiences and progresses to the use of evidence and ideas in constructing evidence-based accounts of natural phenomena and designing solutions.Use tools and materials provided to design and build a device that solves a specific problem or a solution to a specific problem.">Use tools and materials to design and build a structure Cause and EffectEvents have causes that generate observable patterns.">that will reduce PS3.B: Conservation of Energy and Energy TransferSunlight warms Earth's surface.">the warming effect of sunlight on an area.* [Clarification Statement: Examples of structures could include umbrellas, canopies, and tents that minimize the warming effect of the sun.]

5-ESS2-1.	Developing and Using ModelsModeling in 3–5 builds on K–2 experiences and progresses to building and revising simple models and using models to represent events and design solutions.Develop a model using an example to describe a scientific principle.">Develop a model using an example to describe ESS2.A: Earth Materials and SystemsEarth's major systems are the geosphere (solid and molten rock, soil, and sediments), the hydrosphere (water and ice), the atmosphere (air), and the biosphere (living things, including humans). These systems interact in multiple ways to affect Earth's surface materials and processes. The ocean supports a variety of ecosystems and organisms, shapes landforms, and influences climate. Winds and clouds in the atmosphere interact with the landforms to determine patterns of weather.">ways the geosphere, biosphere, hydrosphere, and/or atmosphere Systems and System ModelsA system can be described in terms of its components and their interactions. ">interact. [Clarification Statement: Examples could include the influence of the ocean on ecosystems, landform shape, and climate; the influence of the atmosphere on landforms and ecosystems through weather and climate; and the influence of mountain ranges on winds and clouds in the atmosphere. The geosphere, hydrosphere, atmosphere, and biosphere are each a system.] [*Assessment Boundary: Assessment is limited to the interactions of two systems at a time.*]

MS-ESS2-5.	Planning and Carrying Out InvestigationsPlanning and carrying out investigations in 6-8 builds on K-5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or solutions.Collect data to produce data to serve as the basis for evidence to answer scientific questions or test design solutions under a range of conditions.">Collect data to provide evidence for how ESS2.C: The Roles of Water in Earth's Surface Processes*The complex patterns of the changes and the movement of water in the atmosphere, determined by winds, landforms, and ocean temperatures and currents, are major determinants of local weather patterns.*ESS2.D: *Weather and ClimateBecause these patterns are so complex, weather can only be predicted probabilistically.">the motions and complex interactions of air masses* Cause and EffectCause and effect relationships may be used to predict phenomena in natural or designed systems.">result in changes ESS2.C: The Roles of Water in Earth's Surface ProcessesThe complex patterns of the changes and the movement of water in the atmosphere, determined by winds, landforms, and ocean temperatures and currents, are major determinants of local weather patterns.ESS2.D: Weather and ClimateBecause these patterns are so complex, weather can only be predicted probabilistically.">in weather conditions. [Clarification Statement: Emphasis is on how air masses flow from regions of high pressure to low pressure, causing weather (defined by temperature, pressure, humidity, precipitation, and wind) at a fixed location to change over time, and how sudden changes in weather can result when different air masses collide. Emphasis is on how weather can be predicted within probabilistic ranges. Examples of data can be provided to students (such as weather maps, diagrams, and visualizations) or obtained through laboratory experiments (such as with condensation).] [*Assessment Boundary: Assessment does not include recalling the names of cloud types or weather symbols used on weather maps or the reported diagrams from weather stations.*]

MS-ESS3-5.	Asking Questions and Defining ProblemsAsking questions and defining problems in grades 6–8 builds on grades K–5 experiences and progresses to specifying relationships between variables, and clarifying arguments and models.Apply scientific knowledge and evidence to explain real-world phenomena, examples, or events.Ask questions to identify and clarify evidence of an argument.">Ask questions to clarify evidence ESS3.D: Global Climate ChangeHuman activities, such as the release of greenhouse gases from burning fossil fuels, are major factors in the current rise in Earth's mean surface temperature (global warming). Reducing the level of climate change and reducing human vulnerability to whatever climate changes do occur depend on the understanding of climate science, engineering capabilities, and other kinds of knowledge, such as understanding of human behavior and on applying that knowledge wisely in decisions and activities.">of the factors Stability and ChangeStability might be disturbed either by sudden events or gradual changes that accumulate over time.">that have caused the rise in ESS3.D: Global Climate ChangeHuman activities, such as the release of greenhouse gases from burning fossil fuels, are major factors in the current rise in Earth's mean surface temperature (global warming). Reducing the level of climate change and reducing human vulnerability to whatever climate changes do occur depend on the understanding of climate science, engineering capabilities, and other kinds of knowledge, such as understanding of human behavior and on applying that knowledge wisely in decisions and activities.">global temperatures over the past century. [Clarification Statement: Examples of factors include human activities (such as fossil fuel combustion, cement production, and agricultural activity) and natural processes (such as changes in incoming solar radiation or volcanic activity). Examples of evidence can include tables, graphs, and maps of global and regional temperatures, atmospheric levels of gases such as carbon dioxide and methane, and the rates of human activities. Emphasis is on the major role that human activities play in causing the rise in global temperatures.]

DCI

Kindergarten

PS3.B: Conservation of Energy and Energy

Transfer

- Sunlight warms Earth's surface. (K-PS3-1),(K-PS3-2)

Fifth Grade

ESS2.A: Earth Materials and Systems

- Earth's major systems are the geosphere (solid and molten rock, soil, and sediments), the hydrosphere (water and ice), the atmosphere (air), and the biosphere (living things, including humans). These systems interact in multiple ways to affect Earth's surface materials and processes. The ocean supports a variety of ecosystems and organisms, shapes landforms, and influences climate. Winds and clouds in the atmosphere interact with the landforms to determine patterns of weather. (5-ESS2-1)

middle school

ESS2.D: Weather and Climate

- Weather and climate are influenced by interactions involving sunlight, the ocean, the atmosphere, ice, landforms, and living things. These interactions vary with latitude, altitude, and local and regional geography, all of which can affect oceanic and atmospheric flow patterns. (MS-ESS2-6)

ESS3.D: Global Climate Change

- Human activities, such as the release of greenhouse gases from burning fossil fuels, are major factors in the current rise in Earth's mean surface temperature (global warming). Reducing the level of climate change and reducing human vulnerability to whatever climate changes do occur depend on the understanding of climate science, engineering capabilities, and other kinds of knowledge, such as understanding of human behavior and on applying that knowledge wisely in decisions and activities. (MS-ESS3-5)

Crossscutting
middle school

Systems and System Models

- Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems. (MS-ESS2-6)

19. Global Climate Change

Climate Change

According to a recent headline from the National Oceanic and Atmospheric Administration (NOAA),

"July 2019 was hottest month on record for the planet"

Click here to read the full report.

NOAA. (2019). *July 2019 was the hottest month on record for the planet. Retrieved from https://www.noaa.gov/news/july-2019-was-hottest-month-on-record-for-planet*

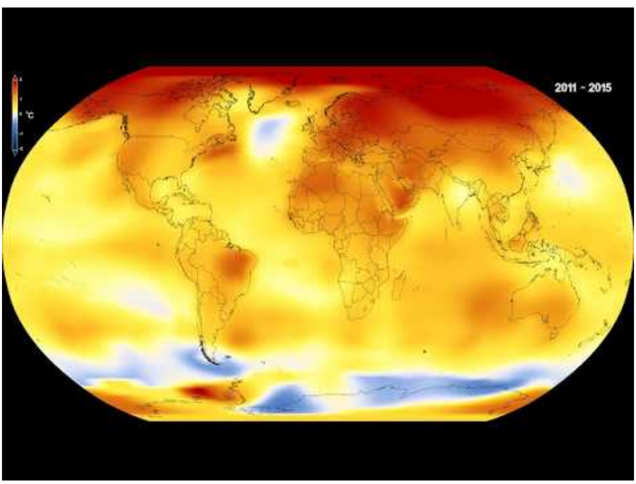
Fast Facts:

- Since record keeping began in 1880, July 2019 was the hottest month on record.
- Year-to-date, January to July 2019 was the second-hottest time period on record with temperatures 1.71 degrees F higher than average globally.
- Arctic and Antarctic sea ice levels were both at record lows for the month of July.

At the most basic level, climate change is a significant change over a 30-year period from the typical or expected weather patterns of an area. Earth's climate has always fluctuated; the difference now is that Earth is experiencing significant climate change in a much shorter time period–decades rather than millions of years.

Climate change is human-caused. Since the rise of industrialization in the 19th century, humans have relied more and more on **fossil fuels** for energy. However, fossil fuels release a significant amount of **greenhouse gases**, especially carbon dioxide, into the air when they are burned. This has led to a rapid rise in global temperature as well as many other changes to Earth's natural balance.

The video, below, shows Earth's temperature increase between 1880 and 2017.



A YouTube element has been excluded from this version of the text. You can view it online here: https://pressbooks.uiowa.edu/methodsii/?p=794

Video Credit: "Global Temperature" by NASA Climate Change is public domain

Tipping Points: The Point of No Return

Human caused climate change is not a new idea.

- In 1861, scientist John Tyndall explained how greenhouse gases like carbon dioxide and water vapor absorb heat in the atmosphere.
- In 1896, scientist Svante Arrhenius built upon Tyndall's work and predicted global warming.
- In 1956, an article published in the New York Times discussed the role of carbon dioxide in human-caused climate change (Click here to access the article).
- In 2006, Al Gore's popular documentary *An Inconvenient Truth* warned the general public of imminent and serious consequences of climate change.

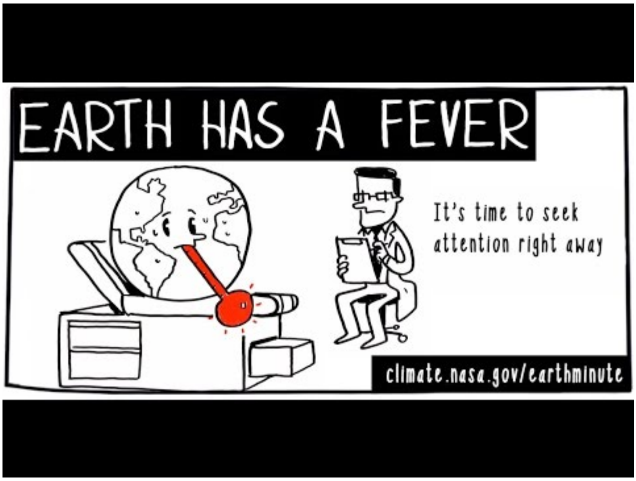
Despite decades of warnings and scientific data, human-caused climate change has severely escalated. Atmospheric carbon dioxide has massively increased leading to higher global temperatures and a multitude of other serious consequences for the planet.

Recently, scientists have warned that we are near to reaching a tipping point, a place of irreversible damage where abnormal and extreme climate change conditions become the norm. Some climate models predict that Earth could reach a tipping point by 2060 if significant action is not taken to reduce greenhouse gas emissions and other human factors that accelerate climate change.

Global Impact of Climate Change

Due to climate change, Earth's systems are out of balance. Global systems have more energy than normal and climate change events are often amplified by each other. This creates a **positive feedback loop** which has wide-ranging effects. including more extreme temperatures, more extreme weather events, melting sea ice, glacier retreat, sea level rise, and ecosystem disruption.

Watch the video, below, for a quick overview of the impacts of climate change.



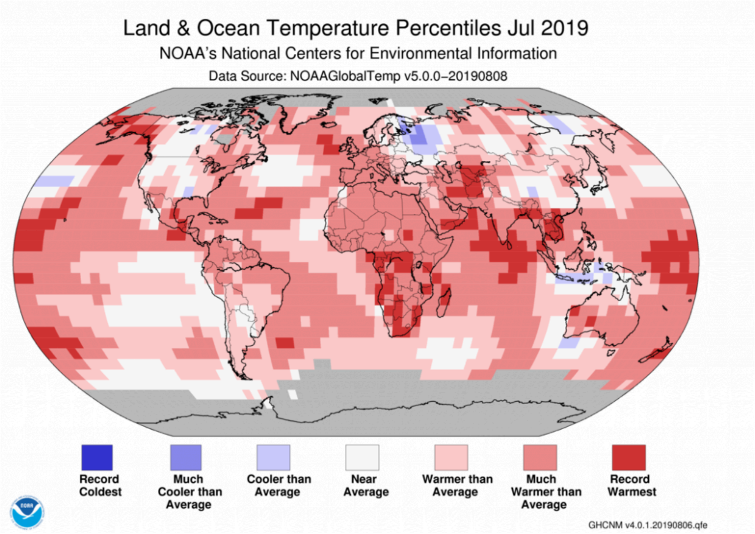
A YouTube element has been excluded from this version of the text. You can view it online here: https://pressbooks.uiowa.edu/methodsii/?p=794

Video Credit: "Earth Has a Fever" by NASA Global Climate Change is public domain

More Extreme Temperatures

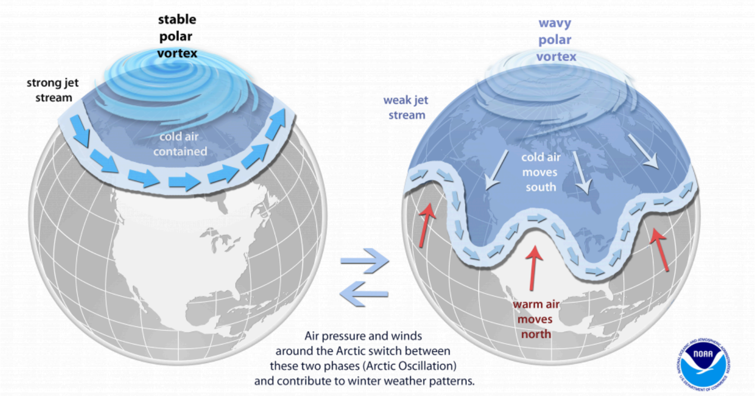
Climate change is not just global warming. Although Earth's climate is heating up overall, climate change leads to increased frequency and intensity of temperature–a **weather** event–at both the high and low range of the spectrum.

For example, July 2019 was the hottest month on record globally. On the map, below, the pink and red shading indicates areas that had warmer than average temperatures (essentially the entire planet).



"*Temperature Map*" *by* NOAA *is public domain*

On the other hand, climate change can also cause extreme and abnormally cold temperatures. As seen in the images below, the polar vortex–a system of freezing wind and air–split from its normal position over the Arctic in January 2019. The vortex, now unstable, caused the **jet stream** to warp from its normal pattern. This pushed extremely cold Arctic air down to the midwestern United States while areas of Alaska experienced warm weather. While the polar vortex is an example of **weather**, not **climate**, it is likely that the planet will experience more frequent and unexpected temperature extremes such as this due to the effects of climate change.



"Polar Vortex" by NOAA is public domain

More Extreme Weather Events

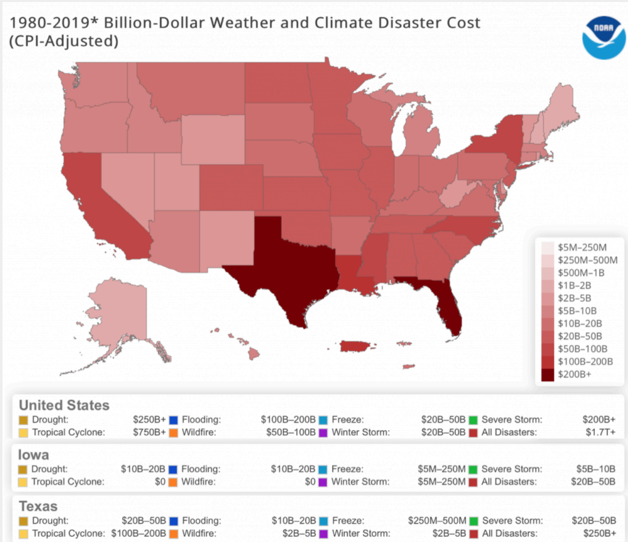
An increase in the frequency and intensity of extreme weather events is one way many people can observe and recognize climate change. The image, below, shows weather events that typically increase due to climate change. From left to right they are: heat waves, drought, hurricanes, wildfires, and melting sea ice.

"Photo Collage" by NOAA is public domain

The map, below, shows the cost per state in weather disasters causing $1 billion or more in damages between 1980 and 2019. In total, these disasters costed the U.S. more than $1.7 trillion, although different states were affected by different types of weather.

- Iowa (shaded a medium red color on the map) has experienced the most impact from drought and flood-related damages, each costing between $10-20 billion.
- Texas (shaded a dark red color on the map) has suffered the most from tropical cyclones–including Hurricanes Rita, Ike, and Harvey–with a total cost of $100-200 billion.

Click here to access the interactive map and see data for other states.



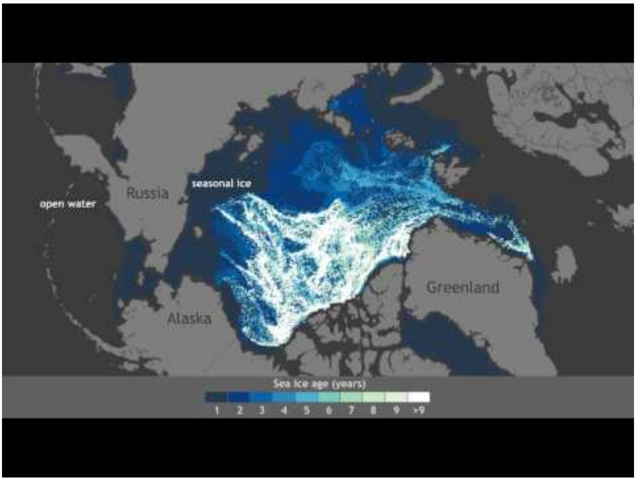
"*Billion-Dollar Weather Events*" *by NOAA National Centers for Environmental Information is public domain*

K-6 Standards

MS-ESS3-2. Analyze and interpret data on natural hazards to forecast future catastrophic events and inform the development of technologies to mitigate their effects.

Melting Sea Ice

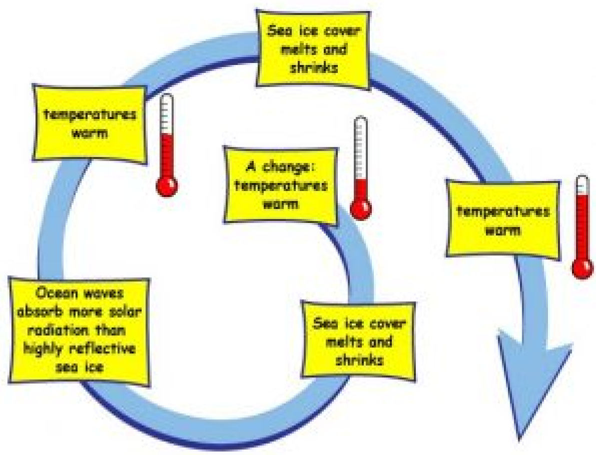
Melting sea ice affects the entire planet, not just the Arctic. Arctic sea ice acts as Earth's air conditioner. **Air masses** and ocean currents carry the ice's cooling effect to other parts of the planet. As shown in the animation, below, Arctic sea ice has been steadily shrinking for decades.



A YouTube element has been excluded from this version of the text. You can view it online here: https://pressbooks.uiowa.edu/methodsii/?p=794

Video credit: "Arctic sea ice growing younger, thinner" by NOAAClimate is public domain

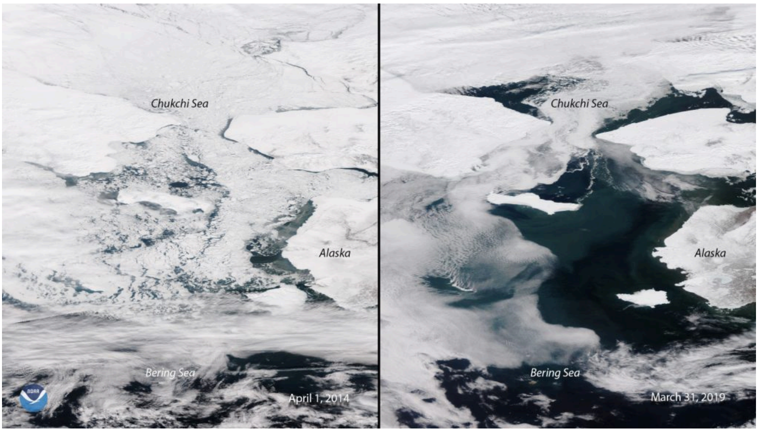
Temperatures at the North and South Poles are rising at twice the rate of the rest of the world due to melting ice and the **albedo** effect. This is an example of a **positive feedback loop**: As temperatures warm, more sea ice melts into water which absorbs solar radiation and causes temperatures to warm even further. The image, below, illustrates this positive feedback loop.



"Positive Feedback Loop" by NASA Climate Kids is public domain

As the darker-colored seawater absorbs the Sun's radiation, the oceans heat up. Higher ocean temperatures negatively affect plants and living creatures in aquatic ecosystems which affects marine-based economic industries, such as fishing, in turn.

The photos, below, show the Bering and Chukchi Seas which are located in the northern Pacific Ocean between Alaska and Russia. These seas typically have maximum ice cover in late March and early April; as seen in the image on the left, most of the sea is covered in ice. Just five years later, the image on the right shows significantly less ice on the sea. In fact, 2019 had the lowest levels of ice on record for this region.



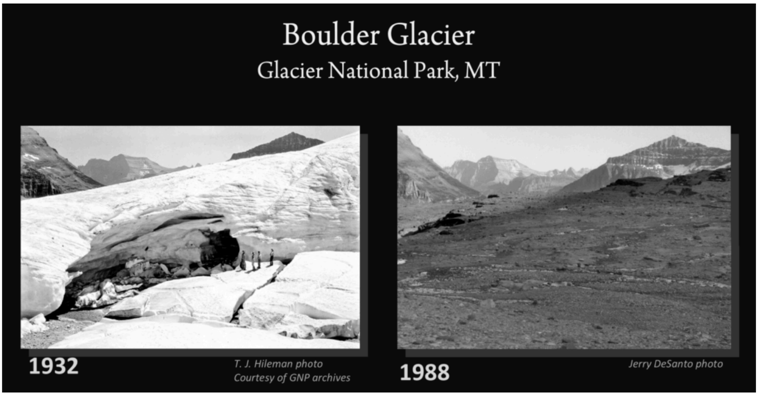
"Sea Ice" by NOAA is public domain

Glacier Retreat

Glaciers are large bodies of snow and ice that move slowly across land. Glaciers naturally fluctuate in size with the seasons, but climate change has led to warmer temperatures overall. This means that glaciers melt at a faster rate than snow falls to rebuild the glacier's mass, a phenomenon called glacier retreat.

Melting glaciers affects the ecosystem of an area because different plants and animals will not be able to survive in a changing landscape. Additionally, humans rely on typical ice melt from glaciers as a critical water source which dwindles when glaciers retreat.

For example, when Montana's Glacier National Park was created in 1910, it had 150 glaciers. Today, only 26 remain and they are all significantly smaller than their original size. The image, below, shows the significant retreat of the Boulder Glacier. Today, the glacier is so small it is considered inactive. Click here to see more images of **glacier retreat**.



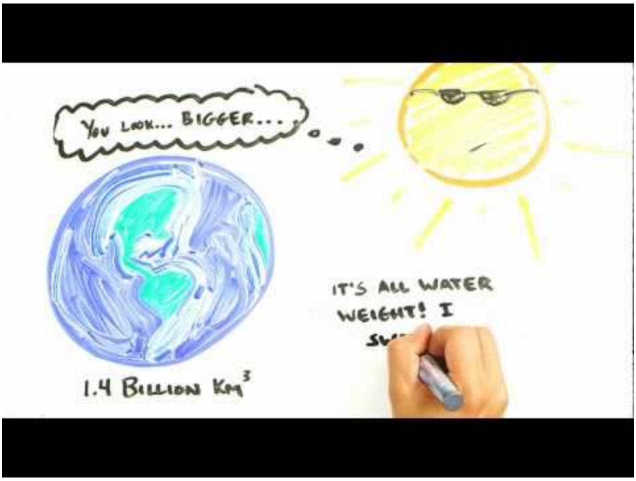
"Retreat of Boulder Glacier". Left photo by George Grant. Right photo by Jerry DeSanto. Images courtesy of NOROCK are public domain.

Sea Level Rise

The main cause of sea level rise is **thermal expansion**. When water is heated, its volume increases. Picture a pot of water boiling on the stove: When the liquid water heats, it expands and turns to steam which has a larger volume.

The same thing happens with water in the ocean. As Earth's temperature increases due to climate change, the oceans are absorbing 90% of the increased heat. As the temperature of the ocean increases, its volume increases so sea level rises.

Watch the following video for more explanation of thermal expansion.



A YouTube element has been excluded from this version of the text. You can view it online here: https://pressbooks.uiowa.edu/methodsii/?p=794

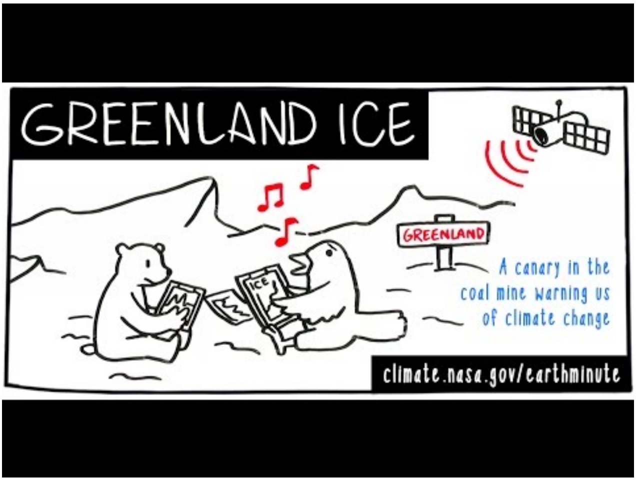
Video Credit: "The Secret to Rising Sea Levels–Thermal Expansion" by ASAP Science, video used with permission

The second cause of sea level rise is ice melt from land. As global temperatures rise, ice sheets and **glaciers** are melting at increasingly fast rates. However, it is important to note that only ice melt from Antarctica and other land masses contributes to sea level rise.

- Antarctica is a continent so it has land underneath the ice. When the ice melts, it runs off into the ocean. Thus, there is more water in the ocean and sea level rises.
- Ice at the North Pole floats in the ocean; it does not have land underneath. Therefore, the volume of water in the ocean stays

the same and sea level does not change when Arctic ice melts.

Like Antarctica, ice melting off of Greenland contributes to sea level rise because Greenland is an island (there is land underneath the ice). Watch the following short video for further explanation.



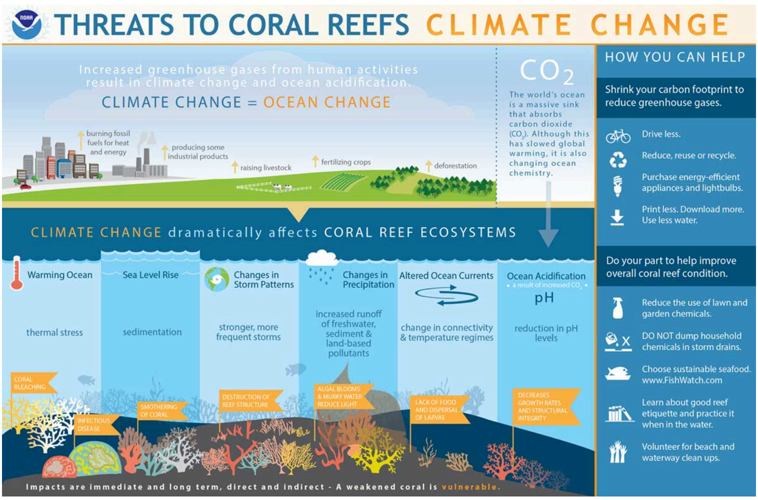
A YouTube element has been excluded from this version of the text. You can view it online here: https://pressbooks.uiowa.edu/methodsii/?p=794

Video Credit: "Greenland Ice" by NASA Global Climate Change is public domain

Ecosystem Disruption

As the climate changes, the delicate balance of many **ecosystems** is disrupted or even destroyed. One example is coral reefs. Coral reefs play a critical role in the ocean ecosystem–they provide shelter for thousands of marine species, they regulate carbon dioxide levels in the ocean, they protect the shoreline from rough waters and storms, and they generate billions of dollars in revenue from fishing and tourism.

Coral reefs are severely impacted by climate change. Scientists estimate that more than a quarter of coral reefs have died worldwide in the last three decades. Read the infographic below to learn more about coral reefs and climate change.



"[Threats to Coral Reefs](#)" *by* [NOAA National Ocean Service](#) *is public domain*

K-6 Standards

K-ESS2-2. Construct an argument supported by evidence for how plants and animals (including humans) can change the environment to meet their needs.

What is Being Done?

A Short Timeline of Events

- **December 2015**-Paris Climate Accord: 195 countries agree to reduce greenhouse gas emissions in order to keep the global temperature increase below 1.5-2°C.
- **June 2017**-President Trump announced that the U.S. would be pulling out of the Paris Climate Accord.
- **October 2018**-A special report from the Intergovernmental Panel on Climate Change (IPCC) states that Earth could reach the 1.5°C **tipping point** by 2040. The world is not on track to meet this goal without huge and immediate changes.
- **July 2019**-The hottest month on record globally according to a report by NOAA,.
- **September 2019**-Global Climate Strike: Led by young people and 16-year-old activist Greta Thunberg, millions of people gather around the world to demand action on climate change.
- **October 4, 2019**-Greta Thunberg visits Iowa City (!) in support of local student-led climate strikers. More than 3,000 people attended the climate strike in downtown Iowa City.

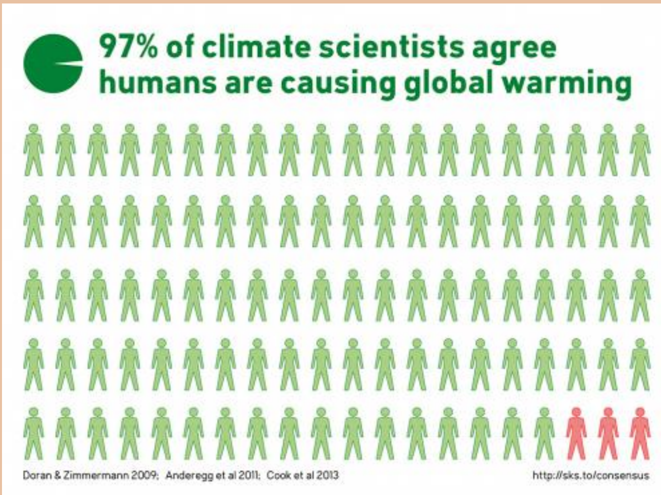
"Greta Thunberg" by Anders Hellberg is licensed under CC BY-SA 4.0

Climate change is in the news nearly every day. One way to keep up with current events is to subscribe to Climate Fwd, a weekly newsletter from the New York Times. You can find information in the Helpful Links chapter of this book.

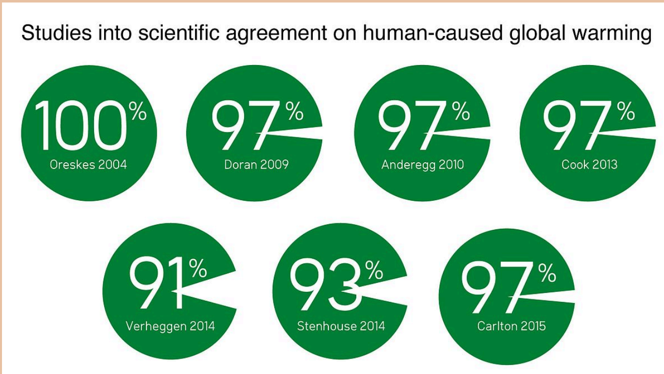
Misinformation and Doubt

Key Takeaway

As shown in the graphic, below, **97% of scientists agree that climate change is human-caused**. This data comes from a study of 11,944 peer-reviewed scientific articles by Cook, et al. (2013).



As shown in the graphic, below, this conclusion has been corroborated by a number of other studies. Among scientists, there is near-consensus that climate change is human-caused.



"Scientific Consensus" by Skeptical Science is licensed under CC BY 3.0

Despite the scientific data, there is still widespread misinformation and doubt spread to the public. Large corporations and wealthy individuals have significant economic and political through which they influence climate change policies and information. **These climate deniers are economically driven; by donating to causes that deny climate change, climate deniers make more money.** As such, conservative billionaires and mega corporations spend billions of dollars funding climate denial initiatives each year. As a result, misinformation and incomplete information about climate change is disseminated to the public causing confusion and doubt.

Click here to "Meet the Money Behind the Climate Denial Movement".

Prominent climate deniers include:

- **ExxonMobil**: One of the largest oil companies in the world.
- **Koch family foundations**: Related to Koch Industries, a multi-billion dollar conglomerate of companies in the oil, gas, paper,

and chemical industries.

- **The Bradley Foundation, Searle Freedom Trust, Coors affiliated foundations, Scaife affiliated foundations, and the DeVos Foundation**: Wealthy conservative family foundations that have contributed to climate change denial.
- **Donors Trust and Donors Capital Fund**: Two related organizations that pool the funds of large donors to give to conservative causes. Known donors include, again, the Bradley Foundation, Searle Freedom Trust, Coors affiliated foundations, the DeVos family, and the Koch family.

"[Attack the Consensus](#)" by [Skeptical Science](#) is licensed under [CC BY 3.0](#)

Climate change information on the Environmental Protection Agency's (EPA) website has been significantly altered during the Trump administration.

- Starting in 2017, several pages about climate change were removed or "being updated" for a year and a half. If you visit the EPA's website, climate change is not one of the suggested environmental topics nor does it appear anywhere on the homepage.
- In October 2018, the EPA stopped updating many of its climate pages. The image, below, shows what happens if you navigate to epa.gov/climatechange, the former climate change homepage.

Screenshot of epa.gov/climatechange

In a 2019 report, the Environmental Data and Governance Initiative analyzed 5,300 government webpages. They found that "over half of all pages where 'climate change' was completely removed from public access (73/136) were U.S. Environmental Protection Agency (EPA) pages" (Nost et al., 2019). All of these changes limit and confound the public's access to credible scientific information.

We need to be clear on the science behind climate change. Although the majority of science teachers cover climate change in their curriculum, one survey found that 30% of teachers "tell students that the current warming 'is likely due to natural causes'" (Mooney, 2016). As teachers, it is up to us to help our students access accurate scientific information and prevent misconceptions.

To find more credible sources of information about all things science, check out the Helpful Links chapter of this book.

"Earth from Space" by NASA/Reto Stöckli, Nazmi El Saleous, and Marit Jentoft-Nilsen is public domain

Sources:

Mooney, C. (2016). How teachers are getting it wrong on climate change. *The Washington Post*. Retrieved from https://www.washingtonpost.com/news/energy-environment/wp/2016/02/11/how-teachers-are-getting-it-wrong-on-climate-change/

Nost, E., Gehrke, G., Lemelin, A., Beck, M., Braun, S., Malival, G., and EDGI. (2019). New report analyzes changes to climate topics across thousands of US federal agency websites. Retrieved from https://envirodatagov.org/new-report-analyzes-changes-to-climate-topics-across-thousands-of-us-federal-agency-websites/

NGSS

5-ESS3-1.	Obtaining, Evaluating, and Communicating InformationObtaining, evaluating, and communicating information in 3–5 builds on K–2 experiences and progresses to evaluating the merit and accuracy of ideas and methods.Obtain and combine information from books and/or other reliable media to explain phenomena or solutions to a design problem.">Obtain and combine information about ESS3.C: Human Impacts on Earth SystemsHuman activities in agriculture, industry, and everyday life have had major effects on the land, vegetation, streams, ocean, air, and even outer space. But individuals and communities are doing things to help protect Earth's resources and environments.">ways individual communities use science ideas to protect the Earth's Systems and System Models A system can be described in terms of its components and their interactions">resources and environment.

MS-ESS3-5.	Asking Questions and Defining ProblemsAsking questions and defining problems in grades 6–8 builds on grades K–5 experiences and progresses to specifying relationships between variables, and clarifying arguments and models.Apply scientific knowledge and evidence to explain real-world phenomena, examples, or events.Ask questions to identify and clarify evidence of an argument.">Ask questions to clarify evidence ESS3.D: Global Climate ChangeHuman activities, such as the release of greenhouse gases from burning fossil fuels, are major factors in the current rise in Earth's mean surface temperature (global warming). Reducing the level of climate change and reducing human vulnerability to whatever climate changes do occur depend on the understanding of climate science, engineering capabilities, and other kinds of knowledge, such as understanding of human behavior and on applying that knowledge wisely in decisions and activities.">of the factors Stability and ChangeStability might be disturbed either by sudden events or gradual changes that accumulate over time.">that have caused the rise in ESS3.D: Global Climate ChangeHuman activities, such as the release of greenhouse gases from burning fossil fuels, are major factors in the current rise in Earth's mean surface temperature (global warming). Reducing the level of climate change and reducing human vulnerability to whatever climate changes do occur depend on the understanding of climate science, engineering capabilities, and other kinds of knowledge, such as understanding of human behavior and on applying that knowledge wisely in decisions and activities.">global temperatures over the past century. [Clarification Statement: Examples of factors include human activities (such as fossil fuel combustion, cement production, and agricultural activity) and natural processes (such as changes in incoming solar radiation or volcanic activity). Examples of evidence can include tables, graphs, and maps of global and regional temperatures, atmospheric levels of gases such as carbon dioxide and methane, and the rates of human activities. Emphasis is on the major role that human activities play in causing the rise in global temperatures.]

MS-ESS3-4.	Engaging in Argument from EvidenceEngaging in argument from evidence in 6–8 builds on K–5 experiences and progresses to constructing a convincing argument that supports or refutes claims for either explanations or solutions about the natural and designed world(s).Construct an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem.">Construct an argument supported by evidence for how ESS3.C: Human Impacts on Earth SystemsTypically as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise.">increases in human population and per-capita consumption of natural resources Cause and EffectCause and effect relationships may be used to predict phenomena in natural or designed systems.">impact Earth's systems. [Clarification Statement: Examples of evidence include grade-appropriate databases on human populations and the rates of consumption of food and natural resources (such as freshwater, mineral, and energy). Examples of impacts can include changes to the appearance, composition, and structure of Earth's systems as well as the rates at which they change. The consequences of increases in human populations and consumption of natural resources are described by science, but science does not make the decisions for the actions society takes.]

DCI

Fifth GRade

ESS3.C: Human Impacts on Earth Systems

- Human activities in agriculture, industry, and everyday life have had major effects on the land, vegetation, streams, ocean, air, and even outer space. But individuals and communities are doing things to help protect Earth's resources and environments. (5-ESS3-1)

middle school

ESS3.D: Global Climate Change

- Human activities, such as the release of greenhouse gases from burning fossil fuels, are major factors in the current rise in Earth's mean surface temperature (global warming). Reducing the level of climate change and reducing human vulnerability to whatever climate changes do occur depend on the understanding of climate science, engineering capabilities, and other kinds of knowledge, such as understanding of human behavior and on applying that knowledge wisely in decisions and activities. (MS-ESS3-5)

ESS3.C: Human Impacts on Earth Systems

Typically as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise. (MS-ESS3-3),(MS-ESS3-4)

20. Local Climate Change

Why Should You Care About Climate Change?

Popular news stories often focus on climate change at a global level–think rising carbon dioxide in the atmosphere or polar bears and melting sea ice. At a national level, wildfires in California or hurricanes on the Atlantic coast are well-covered in the news.

However, **climate change is happening now in Iowa and it affects all of us.**

According to Iowa scientists, "Time is running out" (Lynch, 2019). Click here to read about the current state of climate change in Iowa.

Additionally, climate change is a key issue in the 2020 presidential election. Since the Iowa caucus plays a key role in national politics, several candidates have visited Iowa town and farms to learn more about the local impacts of climate change. Click here to read more about "How Climate Change in Iowa is Changing U.S. Politics".

Climate Change in Iowa

The main topics for climate change in Iowa are:

- Hotter temperatures
- More precipitation and drought
- Impact on agriculture
- Habitat changes

Hotter Temperatures

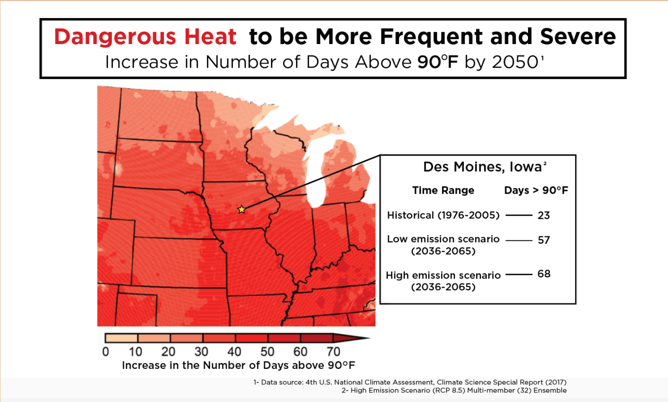
Iowa Climate Statement 2019: "*Dangerous Heat Events Will Be More Frequent and*

Severe"

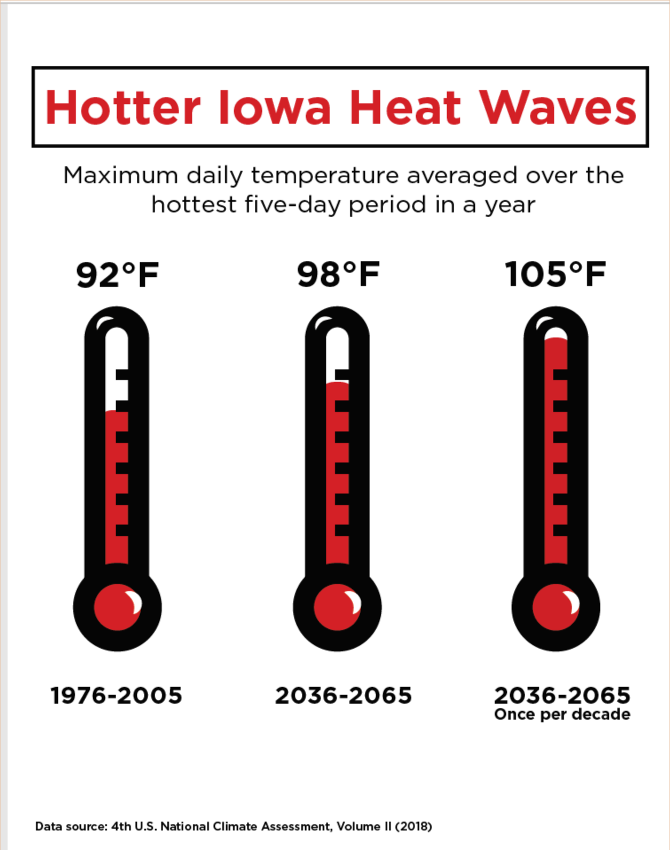
Based on peer-reviewed data, researchers and educators from colleges and universities across Iowa release the Iowa Climate Statement each year. According to the Iowa Climate Statement 2019, "**Dangerous Heat Events Will Be More Frequent and Severe**". Dangerously high temperatures negatively affect the health and safety of the humans and animals who live in Iowa.

Below are three graphics which illustrate the data in the Iowa Climate Statement. Notice that the historical data and projections for temperature are measured in 30 year periods. **Climate** is measured over a 30-year period, so these models indicate **climate change**.

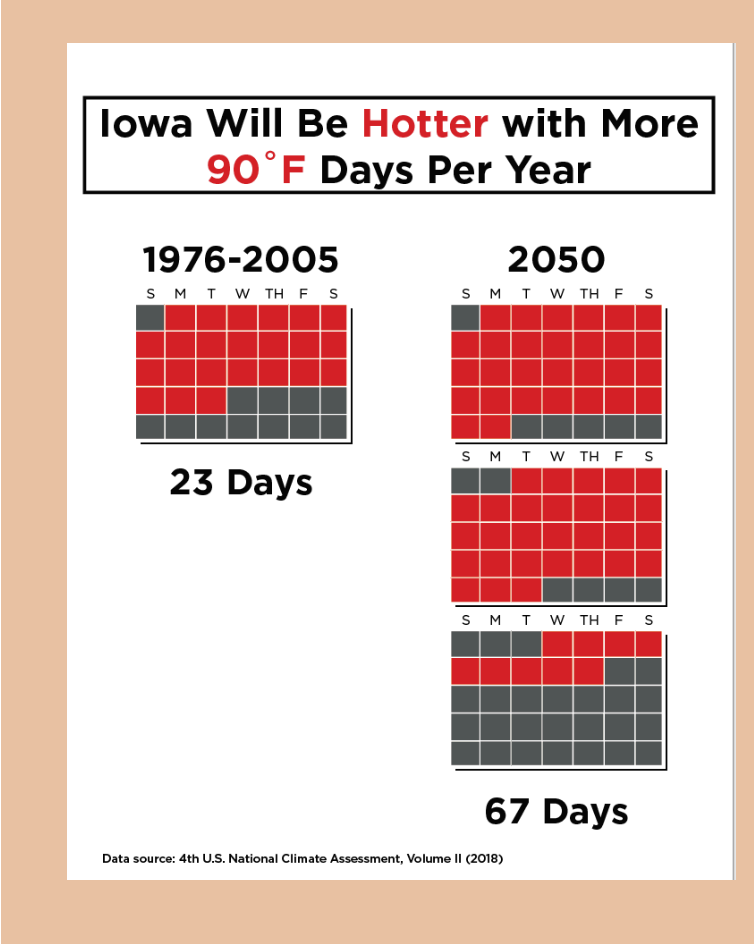
The map, below, shows the projected number of days above 90°F in Des Moines, Iowa. The historical number is 23 days, but it could be between 57 and 68 days by 2050 depending on greenhouse gas emissions.



The image, below, shows trends in Iowa heat waves. Historically, the high temperature averaged at 92°F during heat waves. By mid-century, the average will be 98°F and sometimes reach as high as 105°F.



The image, below, shows the number of days in Iowa that are 90°F or hotter. Historical data measured 23 days; by 2050, it is projected to nearly triple to 67 days.



More Precipitation and Drought

According to the Iowa Climate Statement 2012, "In a warmer climate, wet years get wetter and dry years get dryer" (UI Center for Global and Environmental Research, 2012, p. 1).

As a result of climate change and changing weather patterns, Iowa will have:

- An increase in extreme precipitation leading to more floods
- More periods of drought

"*Iowa Flooding*" *by* *Joe Germuska* *is licensed under* CC BY-NC 2.0

The University of Iowa

At the University of Iowa, we are still rebuilding campus from the damages sustained during the flood of 2008. The extreme flooding was the result of high precipitation and already-saturated ground; the ground could not absorb anymore water so the Coralville Reservoir and Iowa River overflowed and flooded Iowa's campus. The water reached more than 20 university buildings resulting in hundreds of millions of dollars in damages.

Click here to see photos of campus during the flood of 2008.

Since 2008, changes have been made:

- The Iowa Flood Center was established to monitor flood risk and to inform the public.
- Some buildings, like Hancher Auditorium and the Voxman Music Building, had to be completely rebuilt and moved to safer locations. The Stanley Museum of Art is the last campus building to be rebuilt; it will reopen in 2022, more than a decade later.

- Dubuque Street by Mayflower Residence Hall, a main thoroughfare into Iowa City, was raised after being closed for a month during the flood of 2008. Construction finished in 2018.

The old [Hancher Auditorium] by [Phil Roeder] is licensed under [CC BY 2.0]

The new [Hancher Auditorium] by [Steve Shupe] is licensed under [CC BY-NC 2.0]

Still, flood events are somewhat unpredictable and likely to increase due to the effects of climate change. This is a risk that the University of Iowa and the surrounding communities will have to navigate in the future.

Impact on Agriculture

Agriculture and related industries put billions of dollars in Iowa's economy each year. Due to climate change and changing weather patterns, several aspects of agriculture will be affected.

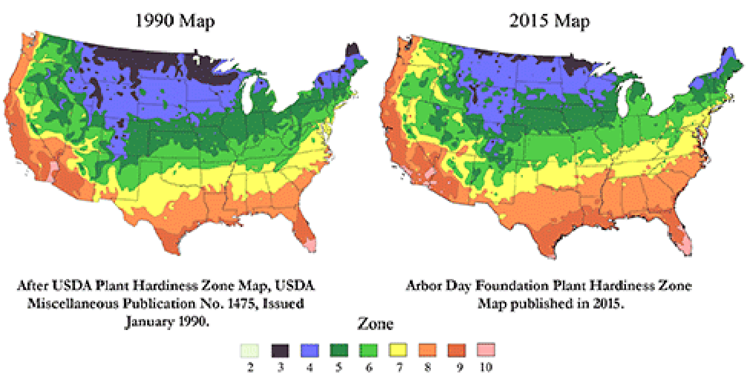
- Higher temperatures may lead to longer growing seasons and higher crop yield. However, this can also lead to an increase in agricultural pests.
- Unpredictable weather patterns like temperature and precipitation affect when, and if, farmers are able to harvest their crops.
- There are about 20 million pigs in Iowa (compared to about 3 million humans). These pigs and other livestock are at increased risk for sickness and death due to dangerously high temperatures.
- Increased precipitation and flooding leads to increased soil erosion and poor soil health.

"Farm in Sherrill, Iowa" is licensed under CC0 1.0

Habitat changes

As temperatures rise and typical weather and climate patterns change, Iowa's habitat is changing too. Hardiness zones are one way of defining which plants will grow best in an area based on the average temperature. As seen in the maps, below, the range of plants in Iowa is shifting north over time.

- In 1990, Iowa was evenly split between zones 4 (blue) and 5 (dark green).
- In 2015, Iowa is entirely in zone 5 (dark green) with zone 6 (light green) starting to appear at the southern edge of the state.



"*Hardiness Zones Map*" *by* *Arbor Day Foundation* *is licensed under* CC BY-ND 2.5

When the plants and trees in Iowa change, it affects all living things–humans, animals, and insects–which must adapt to survive. Notice that the date range (1990-2015) is 25 years. Therefore, the change in **hardiness zones** indicates **climate change** in Iowa. As climate change continues, Iowa's landscape will change in rapid and unpredictable ways.

K-6 Standards

3-LS4-4. Make a claim about the merit of a solution to a problem caused when the environment changes and the types of plants and animals that live there may change.

What Can You Do About Climate Change?

People are sometimes unmotivated to address climate change because it seems like a problem for the future. Or, they may be daunted by the enormity of the problem and unsure of where to begin. The following article discusses "Why People Aren't Motivated to Address Climate Change." Click here to read the article.

If we want to protect Earth and life as we know it, it is critical to take action on climate change immediately. Here are some ways you can get started:

- Calculate your carbon footprint and then take steps to reduce your personal environmental impact.
- Educate yourself about current climate issues–the helpful links chapter in this book has multiple sources about climate science.
- Talk to your politicians about why we need to take action on climate change.

K-6 Standards

K-ESS3-3. Communicate solutions that will reduce the impact of humans on the land, water, air, and/or other living things in the local environment.

5-ESS3-1. Obtain and combine information about ways individual communities use science ideas to protect the Earth's resources and environment.

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21. Weather

Weather is what is happening NOW

Warm and cold fronts

A warm front is the boundary where a warmer **air mass** is moving in to replace a cooler air mass; the air behind a warm front is warmer than the area it is moving into.

A cold front is the boundary where a cooler air mass is moving in to replace a warmer air mass; the air behind a cold front is cooler than the area it is moving into.

Pressure systems

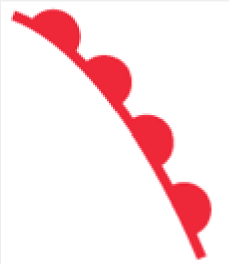
The air pressure on Earth changes throughout the day which affects the weather of an area. A high or low pressure system indicates higher or lower pressure than what is typical for an area. In general, air moves from high pressure areas to low pressure areas.

In a low pressure system, there is less pressure on Earth's surface so air rises. The rising air carries water vapor into the atmosphere which forms clouds and leads to precipitation. As such, a low pressure system is associated with more volatile weather conditions such as clouds, rain, and wind.

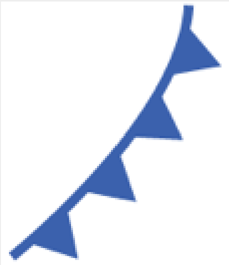
In a high pressure system, there is more pressure on Earth's surface so air descends. Consequently, fewer clouds form. Therefore, the weather is typically sunny and clear in a high pressure system.

How to Read a Weather Map

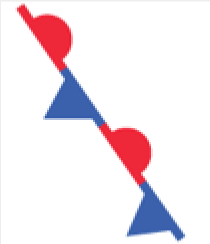
A red line indicates a warm front. The circles point in the direction that the front is moving.



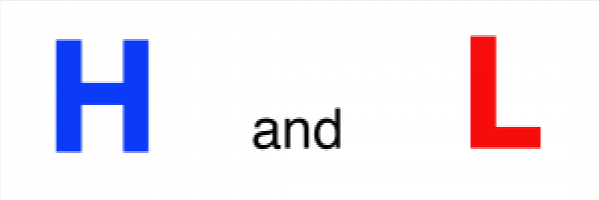
A blue line indicates a cold front. The triangles point in the direction that the front is moving.



A line that alternates blue and red indicates a stationary front–an area where a warm and cold front meet, but neither replaces the other.

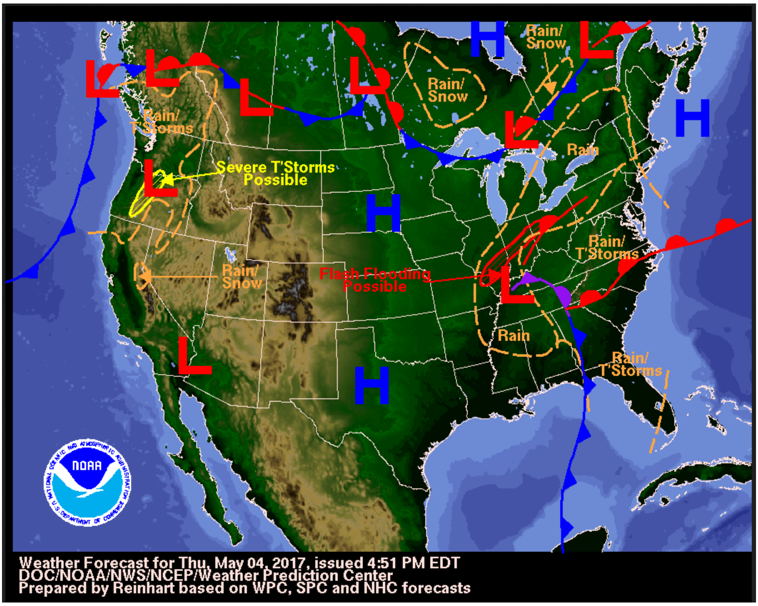


A blue H is used to indicate a high pressure system. A red L is used to indicate a low pressure system.



All weather symbols by NOAA are public domain

On the weather map, below, different symbols are used to indicate weather conditions across the United States.

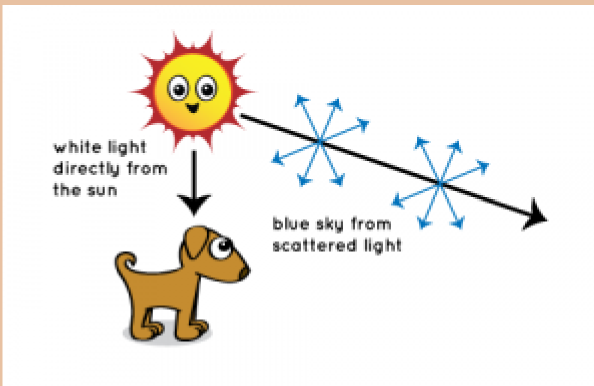


"Weather Map" by NOAA is public domain

"Red sky at night, sailor's delight. Red sky in morning, sailors take warning."

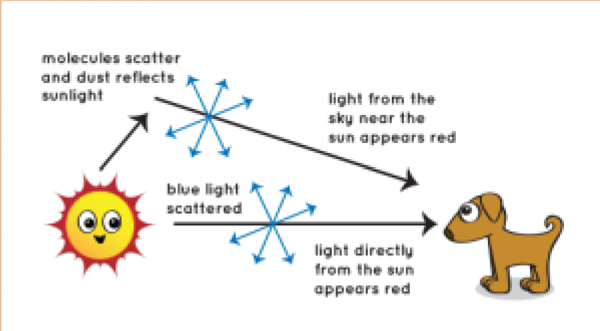
This saying has been used to predict the weather for many years; similar sayings have even been quoted in the Bible and Shakespeare's plays. However, this saying is also scientifically accurate.

Light from the Sun is made of all the colors of the rainbow. Picture the arc of a rainbow: The red wavelengths on the outside are longer and the blue wavelengths on the inside are shorter. On a typical day, the blue light is scattered and reflected by particles in the atmosphere most efficiently because it travels in shorter wavelengths. This is why the sky is blue.



"Blue Sky" by NASA Space Place is public domain

A **high pressure system** is associated with good weather. However, the air is filled with dust and aerosols because the air is pushed down closer to the surface of Earth. These particles scatter long red wavelengths through the atmosphere more efficiently than blue wavelengths which gives the sky a red appearance at sunrise and sunset.



"Red Sky" by NASA Space Place is public domain

"Red sky at night, sailor's delight."

In the middle **latitudes**, between 30 and 60 degrees, weather generally moves from west to east. The Sun sets in the west, so a red sky at night indicates that good weather will be moving toward you the next day.

"Red sky at morning, sailors take warning."

The Sun rises in the east, so a red sky in the morning indicates that the good weather has already passed. Therefore, a **low pressure system**, and bad weather, will likely be moving in next.

K-6 Standards

K-ESS2-1. Use and share observations of local weather conditions to describe patterns over
time.

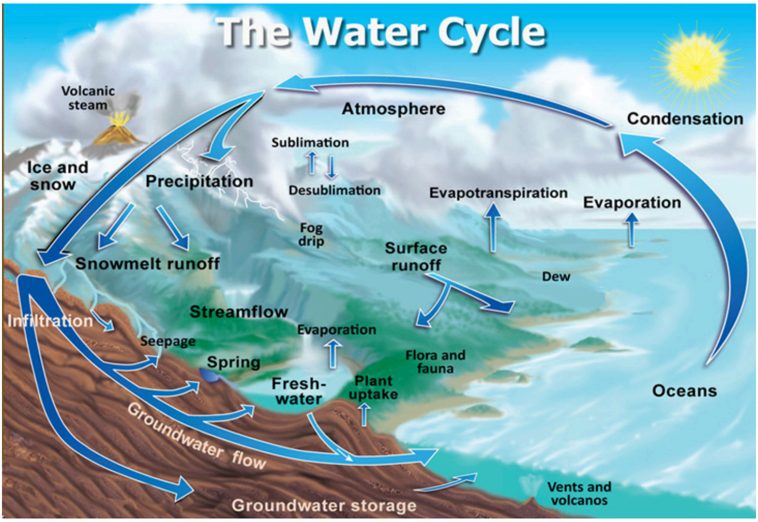
K-ESS3-2. Ask questions to obtain information about the purpose of weather forecasting to
prepare for, and respond to, severe weather.

3-ESS2-1. Represent data in tables and graphical displays to describe typical weather
conditions expected during a particular season.

3-ESS3-1. Make a claim about the merit of a design solution that reduces the impacts of a
weather-related hazard.

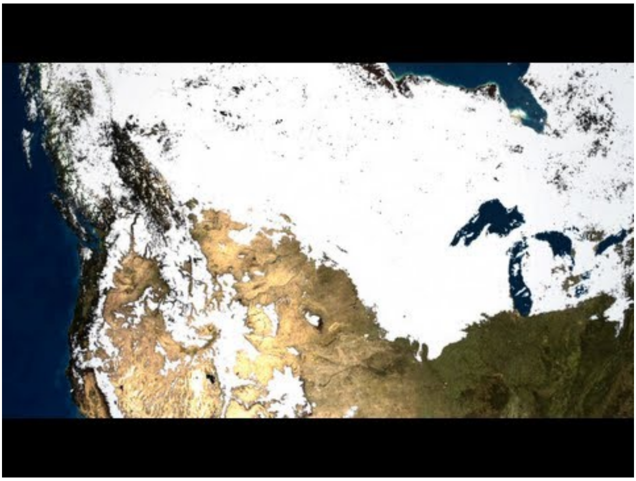
Water Cycle

Although it may seem to change, the amount of water on Earth is actually constant. However, the water's physical state and its location change in a process called the **water cycle**.



"The Water Cycle" by John Evans and Howard Periman/USGS is public domain

Watch the video, below, for a review of the water cycle.



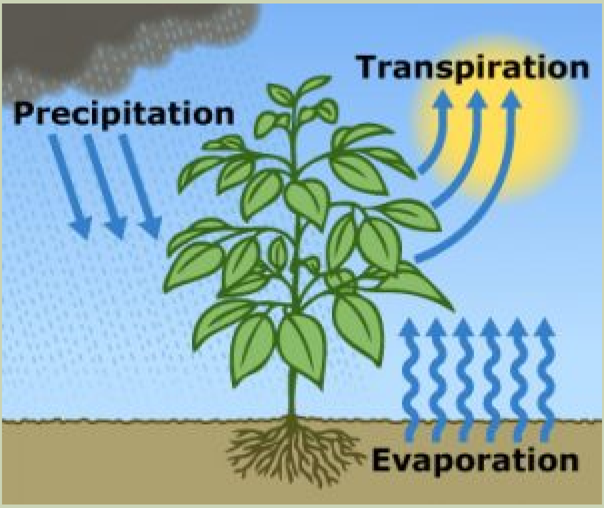
A YouTube element has been excluded from this version of the text. You can view it online here: https://pressbooks.uiowa.edu/methodsii/?p=615

Video credit: "Earth's Water Cycle" by NASA Goddard is public domain

Key Terms in the Water Cycle

- Liquid water **evaporates** from Earth's surface or bodies of water and enters the atmosphere as a gas called water vapor.

- Water vapor **condenses** into tiny liquid water droplets which form clouds.
- The water droplets combine into larger drops and **precipitation** such as rain occurs.
- Sometimes, water in clouds skips the liquid precipitation phase and goes straight from water vapor to solid form. This process, called **desublimation**, results in snow. The opposite of desublimation is **sublimation**, where water changes straight from its solid state to gas. This process is difficult to visualize in the water cycle, but it is the same process that occurs with dry ice–when exposed to air, carbon dioxide from solid dry ice is released in the form of gas through sublimation.
- When precipitation hits the surface of Earth, it becomes surface runoff. The water flows over the land and reenters bodies of water such as lakes, rivers, and oceans. where it will eventually evaporate again, thus continuing the water cycle.
- Some water will **infiltrate** the ground, becoming groundwater that can seep into **aquifers**.
- Precipitation can also evaporate from the surface of the land. Or, plants can absorb water through their roots. The water moves through the plant and is released through the plant's leaves where it can evaporate back into the atmosphere. This process is called **evapotranspiration**.



"*[Evapotranspiration](#)*" *by [Salinity Management Org.](#) is public domain*

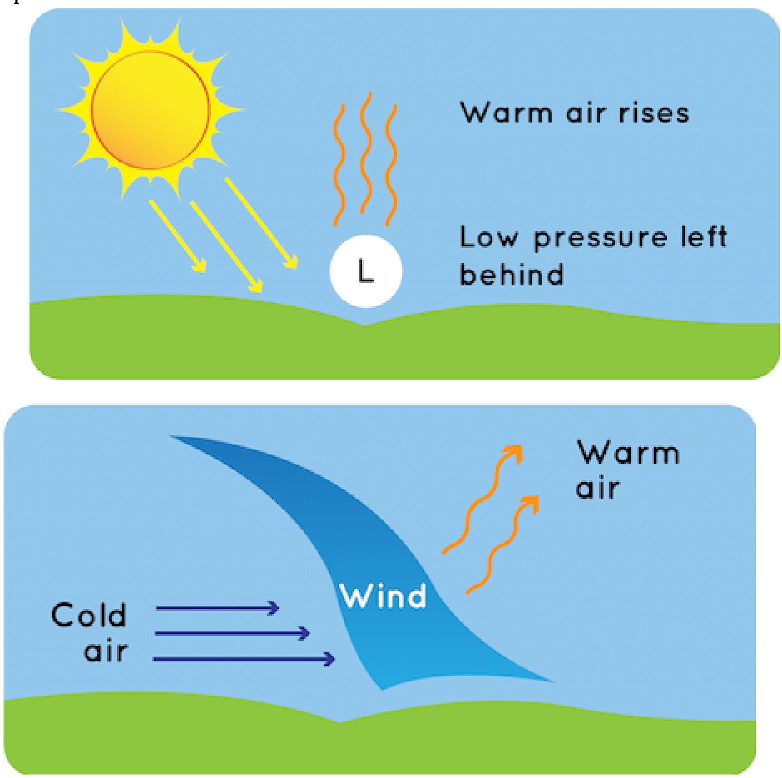
For more explanation of the terms, watch the following video from Khan Academy:

A YouTube element has been excluded from this version of the text. You can view it online here: https://pressbooks.uiowa.edu/methodsii/?p=615

Wind

Wind is caused when Earth's surface is heated unevenly by the Sun. Different types of surfaces on Earth, such as land or water, absorb heat differently. Additionally, darker-colored areas absorb more heat than lighter-colored surfaces. Finally, Earth is tilted on its axis so the Sun hits certain areas of the surface more directly than others which causes temperature differences. All of these factors contribute to the uneven heating of Earth's surface.

Remember that warm air rises and cool air descends. When warm air rises, it leaves a low pressure area behind. In order to maintain balance, air from a cooler, high-pressure area moves in to fill the space and wind occurs.



“[Wind]” by [NOAA] is public domain

K-ESS2-1.	Analyzing and Interpreting DataAnalyzing data in K–2 builds on prior experiences and progresses to collecting, recording, and sharing observations.Use observations (firsthand or from media) to describe patterns in the natural world in order to answer scientific questions.">Use and share observations of ESS2.D: Weather and ClimateWeather is the combination of sunlight, wind, snow or rain, and temperature in a particular region at a particular time. People measure these conditions to describe and record the weather and to notice patterns over time.">local weather conditions PatternsPatterns in the natural world can be observed, used to describe phenomena, and used as evidence.">to describe patterns ESS2.D: Weather and ClimateWeather is the combination of sunlight, wind, snow or rain, and temperature in a particular region at a particular time. People measure these conditions to describe and record the weather and to notice patterns over time.">over time. [Clarification Statement: Examples of qualitative observations could include descriptions of the weather (such as sunny, cloudy, rainy, and warm); examples of quantitative observations could include numbers of sunny, windy, and rainy days in a month. Examples of patterns could include that it is usually cooler in the morning than in the afternoon and the number of sunny days versus cloudy days in different months.] [*Assessment Boundary: Assessment of quantitative observations limited to whole numbers and relative measures such as warmer/cooler.*]

-ESS2-2.	Developing and Using ModelsModeling in K–2 builds on prior experiences and progresses to include using and developing models (i.e., diagram, drawing, physical replica, diorama, dramatization, or storyboard) that represent concrete events or design solutions.Develop a model to represent patterns in the natural world.">Develop a model to represent ESS2.B: Plate Tectonics and Large-Scale System InteractionsMaps show where things are located. One can map the shapes and kinds of land and water in any area.">the shapes and kinds of land and bodies of water PatternsPatterns in the natural world can be observed.">in an area. [*Assessment Boundary: Assessment does not include quantitative scaling in models.*]

kindergarten

ESS2.D: Weather and Climate

- Weather is the combination of sunlight, wind, snow or rain, and temperature in a particular region at a particular time. People measure these conditions to describe and record the weather and to notice patterns over time. (K-ESS2-1)

second grade

ESS2.C: The Roles of Water in Earth's Surface Processes

- Water is found in the ocean, rivers, lakes, and ponds. Water exists as solid ice and in liquid form. (2-ESS2-3)

22. Before the Flood

The link below is a guide to use while watching *Before the Flood* (2016). This is **not required** for class, but can be used as an additional resource.

Click here to access and download the watching guide.

"The Garden of Earthly Delights" by Hieronymus Bosch is public domain

23. Climate Science Practice Quiz

Follow this link to take the climate science practice quiz. You will get immediate feedback on your answers.

"La Fortuna Waterfall Costa Rica" by Boris G is licensed under CC BY-NC-SA 2.0

PART V

COURSE MATERIALS AND PEDAGOGY

In this section, you will find links to all course materials and additional resources to support your learning and pedagogy.

1. **Formative Assessments**: Links to formative assessments for the course
2. **Course Readings and Videos**: Links to course materials
3. **Helpful Links**: Links to additional resources for science education

24. Formative Assessments

Click on the links below to access the formative assessments for this course

[Diffendoofer Day]

- [Pendulums]
- [Magnets]
- [Electricity]
- [Moon]
- [A Private Universe]
- [Stars]
- [Rocks and Sand]
- [Midterm Assessment of the Course]

25. Course Readings and Videos

Click on the links below to access the Science Methods course readings and videos

Five Good Reasons to Use Science Notebooks

Gilbert, J. & Kotelma, M. (2005). Five good reasons to use science notebooks. *Science and Children*, November/December, 28-32.

Activitymania

Moscovici, H., & Nelson, T. (1998). Shifting from Activitymania to Inquiry. *Science and Children*, 35(4), 14-40. Retrieved September 18, 2020, from http://www.jstor.org/stable/43169335

A Private Universe

A Vimeo element has been excluded from this version of the text. You can view it online here: [*https://pressbooks.uiowa.edu/methodsii/?p=715*](https://pressbooks.uiowa.edu/methodsii/?p=715)

Harvard-Smithsonian Center for Astrophysics. (1987). A *private universe* [Video documentary]. Retrieved from https://vimeo.com/113349804

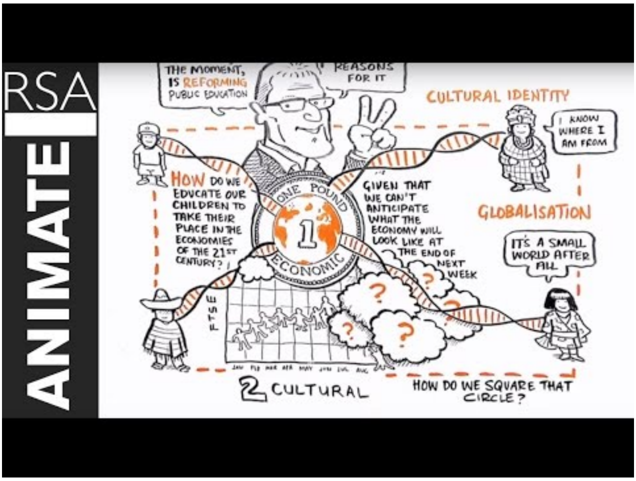
Misconceptions Die Hard

Stepans, J. I., Beiswenger, R. E., & Dyche, S. (1986). Misconceptions die hard. *The Science Teacher*, September, 65-69.

Sweater Article

Watson, B. & Konicek, R. (1990). Teaching for conceptual change: Confronting children's experience. *Phi Delta Kappan*, May, 35-40.

Changing Education Paradigms



A YouTube element has been excluded from this version of the text. You can view it online here: https://pressbooks.uiowa.edu/methodsii/?p=715

Video Credit: "Changing Education Paradigms" by Sir Ken Robinson and RSA Animate. TED Talks are licensed under CC BY-NC-ND 4.0

Introduction to Earth/Space Science

National Research Council (2012). A *framework for k-12 science education: Practices, crosscutting concepts, and core Ideas.* Washington, DC: The National Academies Press. https://doi.org/10.17226/13165.

Space Science Overview

Rutherford, F. J. (1990). The physical setting. In *Science for all Americans online* (Chapter 4). Retrieved from http://www.project2061.org/publications/sfaa/ online/chap4.htm

Environmental Education–School of the Wild

Braus, J.A. & Wood, D. (1993). Environmental education in the schools: Creating a program that works. Peace Corps Information Collection and Exchange. 4-13.

26. Helpful Links

If you want to learn more about **science education**:

Next Generation Science Standards (NGSS)

The Next Generation Science Standards are the current model of standards for science education. They are currently being used by 20 states, while an additional 24 states have developed standards based on the NGSS.

Science Methods 2 YouTube Channel

Videos created by the Science Methods 2 team. You can also find some of our favorite science and education channels on our page.

Science Friday

Weekly radio show/podcast on NPR with science news and interest stories (Rachel from the Science Methods 2 team highly recommends listening if you want to understand more current events and cool things about science).

TED Talks

TED's mission is to "spread ideas". Accessible videos about a wide variety of topics.

- For Science TED Talks, click here.
- For Education TED Talks, click here.

If you want learn more about **space science**:

NASA

News, articles, and amazing images all about space.

NASA Space Place

Quick and simple information about all things space. This website is geared toward kids, but it is helpful for teachers too.

If you want to learn more about **earth science**:

United States Geological Survey (USGS)

Scientific government agency focused on earth.

If you want to learn more about **climate science**:

Climate Fwd Newsletter

Weekly newsletter from the New York Times with news and articles related to climate change. You can read the articles online or sign up to have them sent directly to your email. Note: Iowa City/Coralville residents can get a free NYTimes subscription using their Iowa City Public Library card via this link.

Iowa Climate Statements

Every year, researchers and educators for Iowa release a climate report to inform the public of climate change. Topics have included the impact of climate change on Iowa agriculture, droughts in Iowa, humidity and heat, and calls to politicians to address climate change.

National Oceanic and Atmospheric Administration (NOAA)

Scientific government agency focused on the environment.

"Hubble eXtreme Deep Field" by NASA is public domain

Glossary

Air Mass

A large body of air that takes on the climatic conditions of the area where it is formed.

Albedo

The amount of energy reflected by a surface. Light surfaces tend to have a high albedo because they reflect more energy. Dark surfaces tend to have a low albedo because they absorb more energy.

Aquifer

An underground area of rock that stores groundwater. Humans often pump out groundwater from aquifers or use them as a source for wells.

Asteroid

Rocky celestial bodies left over from the formation of the solar system that are smaller than planets and orbit the Sun.

Big Bang Theory

Scientific theory for how the universe was created.

Black Hole

An area in space with extremely strong gravity from which no light can escape.

Boundary

The border between two tectonic plates.

Buoyancy

the ability or tendency to float in water or air or some other fluid

Circuit

A path through which electricity can flow.

Climate

The typical weather conditions in an area over a 30-year period.

Climate Change

A significant change over a 30-year period from the typical or expected weather patterns of an area. Modern climate change is human-caused.

Comet

A frozen ball of gas, rock, and dust that orbit the Sun. When a comet gets close to the Sun, it heats up and the gas and dust form a tail.

Condensation

Process by which water changes states from water vapor to liquid water.

Continental Drift

Theory that states that all of Earth's land was originally a united supercontinent that drifted apart over time. This theory was eventually replaced by the theory of plate tectonics.

Continental Plates

Less dense tectonic plates that make up the surface of land on Earth.

Convergent Boundary

Tectonic plates push into each other.

Core

The innermost layers of Earth; made of a liquid outer core and a solid inner core.

Crater

Depression formed by an impact.

Crust

The outermost layer of Earth.

Current

A flow of electrical charge

Desublimation

Process by which water vapor (gas) converts straight to solid form, resulting in snow.

Divergent Boundary

Tectonic plates pull apart from each other.

Ecosystem

An interconnected community of all the living organisms and the physical landscape of an area.

Electricity

The movement of electrons from one atom to another creating a flow of electrical charge

Equinox

The day when there is an equal amount of day and night (12 hours each). Occurs when the Sun shines directly on the Equator.

Erosion

Process by which broken down rocks are carried to a new location.

Evaporation

Process by which water changes states from liquid to gaseous water vapor.

Evapotranspiration

Process by which water evaporates from the surface of the land or from plant's leaves.

Fault

Break or crack in the plates on Earth's crust.

Fossil Fuels

Finite sources of energy derived from ancient remains of decomposing organisms. The main fossil fuels are coal, oil, and natural gas.

friction

a force that holds back the motion of a sliding object

Galaxy

A collection of billions of stars, gas, and dust held together by gravity in space.

Geocentrism

The theory that Earth is at the center of our solar system, and the Sun and other planets revolve around it.

Geode

a rock containing a cavity lined with crystals or other mineral matter

Geomagnetic Poles

North and south axes of Earth's magnetic field

Glacier

Large body of snow and ice that moves slowly across land.

Glacier Retreat

When glaciers melt at a faster rate than snow falls to rebuild the glacier's mass.

Greenhouse Gas

An asymmetrical gas in Earth's atmosphere that traps heat. The main greenhouse gases are carbon dioxide, nitrous oxide, methane, and water vapor.

Hardiness Zones

A way of indicating which plants will grow best in an area based on the average temperature.

Heliocentrism

The theory that the Sun is at the center of our solar system.

High Pressure System

Air pressure on Earth is higher than normal, so air descends. A high pressure system is associated with good weather--sunny and clear skies.

Hot Spot

An extremely hot area located in the center of a tectonic plate where magma can rise to the surface. Some volcanoes are located over hot spots, rather than at tectonic plate boundaries.

inertia

An object's tendency to resist changes in motion.

Infiltration

The process by which surface water soaks into the ground.

Island Arc

A chain of islands in the ocean in an arc shape. Formed by two convergent oceanic plates and volcanic eruptions.

Jet Stream

A large current of wind which carries warm and cold air masses to different areas of Earth.

Kinetic Energy

The energy of an object due to motion.

Latitude

A location's distance from the Equator.

Law of Original Horizontality

Due to the pull of gravity, new rock is initially formed in flat, horizontal layers.

Law of Superposition

Deeper layers of rocks are older than layers closer to the surface.

Lithosphere

Part of Earth made of the crust and the upper molten part of the mantle.

Low Pressure System

Air pressure on Earth is lower than normal, so air rises. A low pressure system is associated with bad weather--clouds, rain, and wind.

Magma

Molten rock beneath Earth's surface.

Magnet

An object or material that produces its own magnetic field

Magnetic Field

The area around a magnet that has magnetic force

Magnetism

A force that attracts or repels objects that contain magnetic material

Mantle

The middle layer of Earth between the crust and the core.

Meteor

The streak of light that is caused when a meteoroid enters Earth’s atmosphere and burns up due to friction. Also known as a shooting star.

Meteorite

A meteoroid that survives its trip through the atmosphere and lands somewhere on Earth. The impact of a meteorite can cause a crater on the surface of a planet.

Meteoroid

A small rock in space that orbits around the Sun. Most meteoroids have broken off of larger objects such as asteroids or comets. They can be as small as a grain of sand or as large as a pickup truck.

Mid-Ocean Ridge

An underwater chain of mountains formed at a divergent plate boundary.

Nebula

A cloud of gas and dust in space.

Nuclear Fusion

The process by which stars get their energy. Atoms fuse together creating a nuclear reaction which releases energy in the form of heat and light in the star.

Oceanic Plates

Denser tectonic plates that make up the ocean floor on Earth.

Pangaea

A supercontinent made of all of Earth's landmass that existed 200-250 million years ago.

Parallel Circuit

A circuit where electricity flows through multiple paths

Period

The time it takes a pendulum to swing across and back to its original starting point.

Plane of the Ecliptic

The disk-shaped plane in which everything in our solar system orbits around the Sun.

Plate Tectonics

Theory that Earth's crust is divided into many pieces, called tectonic plates, which move over time due to convection currents in the mantle.

Positive Feedback Loop

A process where one change triggers the next in a continuous cycle that encourages the initial change.

Potential Energy

The energy held by an object that gives it capacity to do work.

ppm

Parts per million; a unit of measurement for carbon dioxide and other gases in the atmosphere.

Precipitation

Heavier water droplets condense and fall from clouds to Earth's surface in the form of rain, snow, or hail.

pressure

force applied over an area

Rain Shadow

A desert area that is created when a mountain blocks precipitation from passing to one side.

Red Giant

Phase in a star's life cycle where it greatly increases in size as it burns fuel through nuclear fusion.

Ring of Fire

An area in the Pacific Ocean bounded by several tectonic plates. Due to tectonic activity along these plates, this area has a high number of earthquakes and volcanic eruptions.

Series Circuit

A circuit where electricity flows through one continuous path

Snowball Earth

A period of extreme glaciation where a positive feedback loop led to Earth being covered almost entirely by ice.

Solar System

Our Sun and all of the planets and other bodies in space (comets, asteroids, meteoroids) that orbit around the Sun in the plane of the ecliptic.

Subduction

When two tectonic plates converge, the denser plate is pushed under the other.

Subduction Zone

The boundary between two convergent tectonic plates where one plate subducts under the other.

Sublimation

Process by which water changes straight from its solid state to gas. This is the same process that occurs with dry ice--when exposed to air, carbon dioxide is released in the form of gas through sublimation.

Summer Solstice

The day with the most sunlight. In the Northern Hemisphere this occurs when the Sun shines directly on the Tropic of Cancer.

Supernova

The giant explosion of a supermassive star at the end of its life cycle.

Thermal Expansion

An increase in the volume of matter when its temperature increases.

As global temperature increases, ocean water heats and expands which contributes to sea level rise.

Tipping Point

A place of irreversible damage where abnormal and extreme climate change conditions become the norm.

Topography

The physical features of an area of land.

Transform Boundary

Tectonic plates sideswipe each other.

Trench

A long depression formed on the ocean floor from the convergence of two oceanic plates. Trenches are some of the deepest place on Earth's surface.

Volcano

A vent that allows magma, rock fragments, ash, and gases to escape to the surface of a planet or moon.

Water Cycle

Process of how water in different states continuously moves on, above, and below Earth's surface.

Weather

The short term atmospheric conditions in an area.

Weathering

The breakdown of rocks on Earth's surface

Winter Solstice

The day with the least of sunlight. In the Northern Hemisphere this occurs when the Sun shines directly on the Tropic of Capricorn.