ACAP
Alabama Comprehensive Assessment Program

SUMMATIVE

Grade 4
Science

Alabama Educator Instructional Supports

Alabama Course of Study Standards

DATA RECOGNITION DRC CORPORATION

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Introduction

The *Alabama Instructional Supports: Science* is a companion to the 2015 *Alabama Course of Study: Science*. Instructional supports are foundational tools that educators may use to help students become independent learners as they build toward mastery of the *Alabama Course of Study* content standards. **Instructional supports are designed to help educators engage their students in exploring, explaining, and expanding their understanding of the content standards.**

The content standards contained within the course of study may be accessed on the Alabama State Department of Education (ALSDE) website: https://www.alabamaachieves.org/.

When examining these instructional supports, educators are reminded that content standards indicate minimum content—what all students should know and be able to do by the end of each grade level or course. Local school systems may have additional instructional or achievement expectations and may provide instructional guidelines that address content sequence, review, and remediation.

The instructional supports are organized by standard. Each standard's instructional support includes a statement of the content standard, guiding questions with connections to three-dimensional learning, key academic terms, and additional resources.

Content Standards

The content standards are the statements from the 2015 *Alabama Course of Study: Science* that define what all students should know and be able to do at the conclusion of a given grade level or course. Content standards contain minimum required content and complete the phrase "Students will ______."

Guiding Questions with Connections to the Three Dimensions

Guiding questions are designed to create a framework for the given standards and to engage students in exploring, explaining, and expanding their understanding of the content standards provided in the 2015 *Alabama Course of Study: Science*. Therefore, each guiding question is written to help educators convey important concepts within the standard. By utilizing guiding questions, educators are engaging students in investigating, analyzing, and demonstrating knowledge of the underlying concepts reflected in the standard.

An emphasis is placed on the integration of the Three Dimensions of learning as described in the 2012 National Research Council publication *A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*.

Each content standard in the 2015 *Alabama Course of Study: Science* blends knowledge and skills linked to science and engineering that all students should know and be able to do by the end of high school.

The Three Dimensions are the same for all grade levels and are described below.

1. Scientific and Engineering Practices are skills and tools used by students to investigate phenomena, develop and use models, design and build systems, and construct arguments based on evidence to solve problems in the world in which they live.
2. Crosscutting Concepts are unifying conceptual threads that encourage students to connect scientific and engineering ideas across the domains of science.
3. Disciplinary Core Ideas in the four domains of Physical Science, Life Science, Earth and Space Sciences, and Engineering Technology include relevant content that provides students with foundational scientific knowledge.

Each guiding question includes a representative set of sample activities and examples that can be used in the classroom. Due to natural overlaps in content, some activities apply to more than one standard. The set of activities and examples is not intended to include all the activities and examples that would be relevant to the standard.

Key Academic Terms

These academic terms are derived from the standards and are to be incorporated into instruction by the teacher and used by the students.

Additional Resources

Additional resources are included that are aligned to the standard and may provide additional instructional support to help students build toward mastery of the designated standard. Please note that while every effort has been made to ensure all hyperlinks are working at the time of publication, web-based resources are impermanent and may be deleted, moved, or archived by the information owners at any time and without notice. Registration is not required to access the materials aligned to the specified standard. Some resources offer access to additional materials by asking educators to complete a registration. While the resources are publicly available, some websites may be blocked due to Internet restrictions put in place by a facility. Each facility's technology coordinator can assist educators in accessing any blocked content. Sites that use Adobe Flash may be difficult to access after December 31, 2020, unless users download additional programs that allow them to open SWF files outside their browsers.

Printing This Document

It is possible to use this entire document without printing it. However, if you would like to print this document, you do not have to print every page. First, identify the page ranges of the standards or domains that you would like to print. Then, in the print pop-up command screen, indicate which pages you would like to print.

4.PS.1

Grade 4
Energy
4.PS.1 Use evidence to explain the relationship of the speed of an object to the energy of that object.

Connections to *A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*:

Focus for Scientific and Engineering Practice(s):

- Constructing Explanations and Designing Solutions

Focus for Crosscutting Concept(s):

- Patterns
- Cause and Effect
- Energy and Matter

Focus for Disciplinary Core Idea(s):

- Definitions of Energy
- Relationship between Energy and Forces

Guiding Questions

- What is speed (fast vs. slow) and what tools can be used to determine the speed of an object? (p. 7)
- What information is needed to describe speed and a change in speed? (p. 9)
- What evidence is required to show a relationship between speed and energy? (p. 11)
- What patterns can be observed during an investigation when the speed of an object is changed and what energy transfers occur when two objects collide? (p. 11)

Key Academic Terms:

energy, speed, acceleration, motion (movement), frame of reference, speed equation (speed=distance/time), relationship, evidence, variable

Safety Considerations

Please refer to the Alabama K–12 Science Safety Guidelines.

What is speed (fast vs. slow) and what tools can be used to determine the speed of an object?

Background

The motion (movement) of an object is apparent compared to an established frame of reference. Using the environment, humans can determine what is and is not moving.

Speed is a measurement of motion (movement) that is calculated by taking the distance an object moves and dividing it by the amount of time it takes to move across that distance.

$$speed = \frac{distance}{time}$$

Students typically work with units of meters per second when measuring the speeds of common classroom objects like classmates, playground balls, marbles, or bicycles and kilometers per hour when observing larger objects like cars, motorcycles, or planes.

Speed and energy are closely related to each other. Faster moving objects have more energy than slower moving objects.

Activities and Considerations

Activity 1

Place students in small groups and have each group calculate the speed of a marble (or toy car) and collect data using a stopwatch and meterstick. Each group should use the stopwatch to record the time while a marble rolls across a set distance (60 cm suggested below). Students should adjust the speed of the marble by rolling it down ramps that are set at different heights. The table below offers a suggested format for data collection.

Height of Ramp	Time (seconds)	Speed
High		60 cm per ____ seconds
Medium		60 cm per ____ seconds
Low		60 cm per ____ seconds

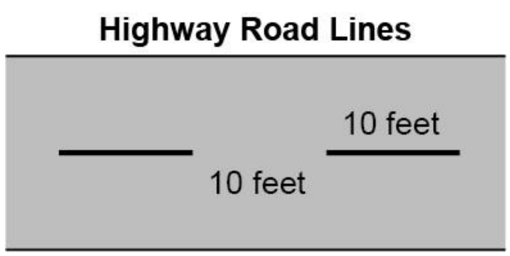
After students collect data, the instructor should lead a discussion about experimental design and variable control. Height is subjective, and the speeds of the marbles may vary from group to group. To demonstrate, the instructor should use two different ramp setups to compare the effects of adjusting the speed of the marble.

Activity 2

This activity allows for a discussion opportunity around speed and frame of reference.

A frame of reference can distort the perception of speed. Start by asking students to estimate the length of the dashed lines on a road or highway. Play a short clip of a car driving down a road in which the lines on the road are clearly visible. Show 30 seconds or one minute of the video to make the calculations easier. Have students count the number of lines while the video is playing. Next, have them estimate what they think the speed of the car was during the video. An example of a video is provided in the Resources section below.

Provide the information shown in the graphic below.



Have students calculate the total distance the car traveled by multiplying the number of lines and spaces by 10 feet.

- 100 lines x 10 feet = 1,000 feet
- 100 spaces x 10 feet = 1,000 feet
- 1,000 feet + 1,000 feet = 2,000 total feet traveled in one minute
- 2,000 feet traveled x 60 minutes = 120,000 feet per hour

Considerations

Extension: The total distance can then be divided by 5,280 feet (1 mile) to calculate the distance in miles per hour (120,000 ÷ 5,280 = 22.7 mph).

Resources

- Scenic Drive—YouTube video that can be used for activity 2

What information is needed to describe speed and a change in speed?

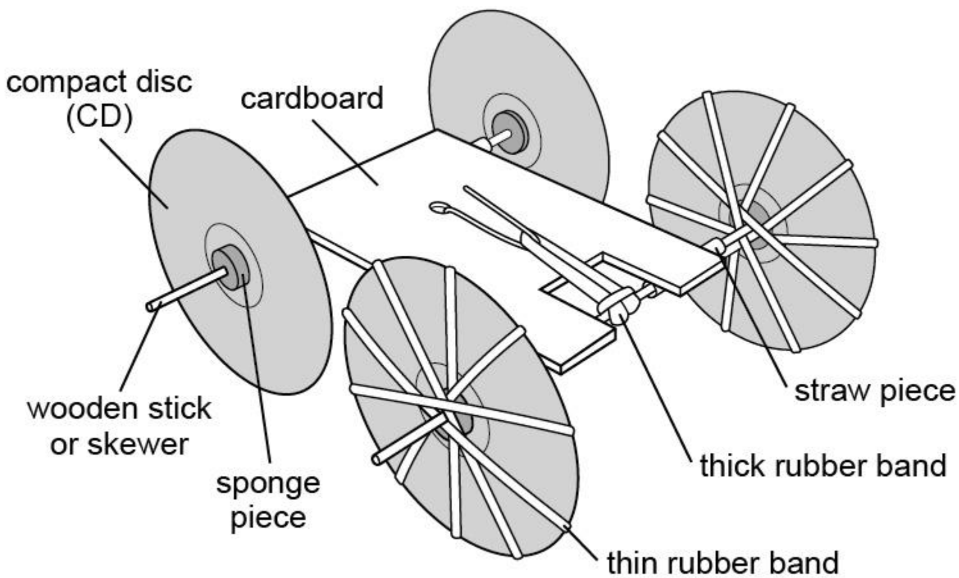
Background

Objects in motion commonly change speed. This is called acceleration and can be detected by using a frame of reference or a stationary object. If an object is not accelerating, then its speed is constant.

Activity

Use a pull-back toy car to demonstrate acceleration. Pull back on the toy car to three different distances to vary the amount of stored energy built up in the car. Students should observe differences in speed and travel distance.

Rubber Band–Powered Car



After the investigation, the following sentence frames could be used:

1. The toy car moved fastest when ________________________________.
2. The toy car went farthest when ________________________________.
3. The toy car had the most energy when ___________________________.
4. Pulling the toy car back a greater distance resulted in ____________________.

Resources

- PBS Moon Rover—PBS web page with detailed information about how to construct a rubber band–powered car
- Rubber Band–Powered Car—*Scientific American* web page with directions for building the rubber band–powered car shown on the previous page

What evidence is required to show a relationship between speed and energy?

What patterns can be observed during an investigation when the speed of an object is changed and what energy transfers occur when two objects collide?

Background

Newton’s first two laws of motion can assist in pattern identification. Newton’s laws are out of scope for this grade level; however, they can be simplified.

The concept of inertia explains that objects at rest stay at rest and that objects in motion maintain their velocity unless acted upon by an outside force. An instructor can also define inertia by focusing on energy. To put it simply, energy must be used to make things move, speed up, or stop.

A change in speed requires a change in energy. This change should be observable or easy to infer. Evidence that can be gathered could include the following:

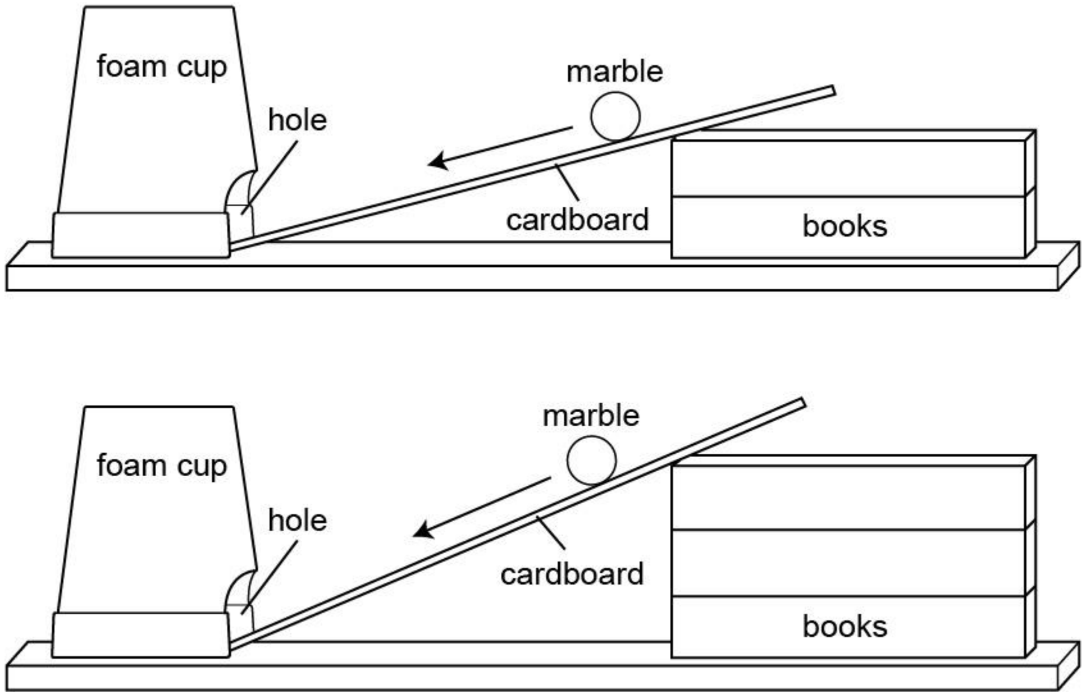
- increase or decrease in temperature
- loud or soft sound of impact
- distance traveled after a collision

Activities and Considerations

Activity 1

A ramp can be used to show the effects of the speed of an object as it collides with another object. The setups shown below can be made from basic materials. The height of the ramp can be changed easily. A marble will roll down the ramp at each height and collide with an object. Students should observe and measure the distance the foam cup moves after the collision with the marble. Observations by the students should show that the foam cup moves a greater distance when the marble rolls down a steeper ramp. (This activity is also used with standard 4.PS.3.)

Marble Investigation



Considerations

Kinetic energy (energy of movement), heat, and sound are involved in energy transfer when objects collide. Instructors may also choose to discuss the transfer of energy to light and the conservation of momentum based on their comfort level with this content.

Activity 2

The game “Red Light, Green Light” can be used to help students recognize several patterns:

- energy is needed to start and stop
- to move faster, more energy is needed
- it is harder to stop faster moving objects than slower moving objects

This game can be played outside or inside and can include a “yellow light” variation.

Rules:

1. The caller stands opposite of the players at an agreed upon distance.
2. Players must all stand at the same starting distance.
3. When the caller says “green light” players can move towards the caller at any speed.
4. When the caller says “red light” players must stop moving. If the caller detects movement by the players, they can be sent back to the starting line.
5. When a player successfully reaches the caller, the game is over.
6. After the first game, engage students in a discussion about their experiences. Question them about why it might be hard to stop quickly if they are moving fast instead of slow. Ask if anyone has a strategy for moving and stopping quickly.

Considerations

This concept is being simplified to exclude the terminology of momentum, kinetic energy, and potential energy.

All the energy in a system is conserved, which is why these other forms of energy are important to discuss. Students may believe that energy is created or destroyed in some of these examples, but it is important to help them understand that it is just transferred into another form.

Resources

- Red Light, Green Light—game rules and description from website
- PhET States of Matter Simulation—allows for the investigation of two elements and two compounds to see the relationships between particle motion, temperature, and state of matter
- Physics Classroom—explains how kinetic energy is related to temperature and goes into detail about the construction and accuracy of thermometers and the creation of thermal units
- Newton's Cradle—The "clacking" shows that sound is produced as a transfer of energy. The demonstration shows a transfer in complementary directions when the demonstrator grabs a sphere from either side. This would be a good place to pause and ask students to predict what they think will happen.

4.PS.2

Grade 4
Energy
4.PS.2 Plan and carry out investigations that explain transference of energy from place to place by sound, light, heat, and electric currents. a. Provide evidence that heat can be produced in many ways (e.g., rubbing hands together, burning leaves) and can move from one object to another by conduction. b. Demonstrate that different objects can absorb, reflect, and/or conduct energy. c. Demonstrate that electric circuits require a complete loop through which an electric current can pass.

Connections to *A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*:

Focus for Scientific and Engineering Practice(s):

- Developing and Using Models
- Planning and Carrying Out Investigations
- Constructing Explanations and Designing Solutions

Focus for Crosscutting Concept(s):

- Patterns
- Cause and Effect
- Energy and Matter

Focus for Disciplinary Core Idea(s):

- Structure and Properties of Matter
- Chemical Reactions

Guiding Questions

- What is energy and how is matter affected by energy? (p. 17)
- How is energy transferred between objects, systems, and places? (p. 18)
- What are the energy inputs, energy outputs, and flows or transfers of energy in systems involving sound, light, heat, and electric currents? (p. 21)
- What patterns can be observed during an energy transfer and how can cause-and-effect relationships be recognized? (p. 21)
- How can students recognize evidence that light or sound can travel from one place to another? (p. 26)
- What materials are required to build a working circuit? (p. 28)
- How can a student plan and carry out an investigation to explain energy transfer using a working circuit, and what is an open circuit? (p. 30)

Key Academic Terms:

investigate, explanation, evidence, energy, transfer/transference, sound, light, heat, electricity, electric current, absorb, reflect, conduct, conduction, circuit, collision, motion, thermal energy, open circuit, closed circuit, closed loop, open loop, system

Safety Considerations

Please refer to the Alabama K–12 Science Safety Guidelines.

What is energy and how is matter affected by energy?

Background

In science, energy is defined as a measurable value that is transferred to an object and gives it the ability to perform work or change temperature. It is important to keep in mind the scientific definition of work, which is the magnitude of a force acting on an object.

There are many forms of energy and each has a unique way of being measured.

Type of Energy	Unit of Measurement
Heat	Joule (J) Base SI unit
Food (chemical)	Calorie (kilojoule, kcal per 100 g) The amount of energy required to heat 1 kilogram of water by 1°C
Electricity	Watt (W) The rate of energy transfer from 1 Joule per second
Temperature	Celsius (°C) The degree of hotness or coldness of an object or substance with reference to a standard value

Matter is constantly affected by energy from its surroundings. It is easy to think of movement when relating energy and matter. If energy is added to matter, then objects move faster. If energy is removed, then objects move slower.

Energy can cause physical and chemical changes to occur as well. If energy is removed from water, it freezes into ice. As energy is placed back into the ice, it melts into a liquid and eventually vaporizes into a gas.

Because matter is unique, different types of matter will respond differently to different types of energy input.

Considerations

The finer details of energy and matter are out of scope for this grade level. It is important to recognize that most units used are derived from a central measurement. It is important that students recognize that energy can change forms, transfer between objects and places, and that it is never created or destroyed.

How is energy transferred between objects, systems, and places?

Background

Energy is constantly moving and changing. Sometimes, the observer can perceive this change and other times, the observer can't perceive it.

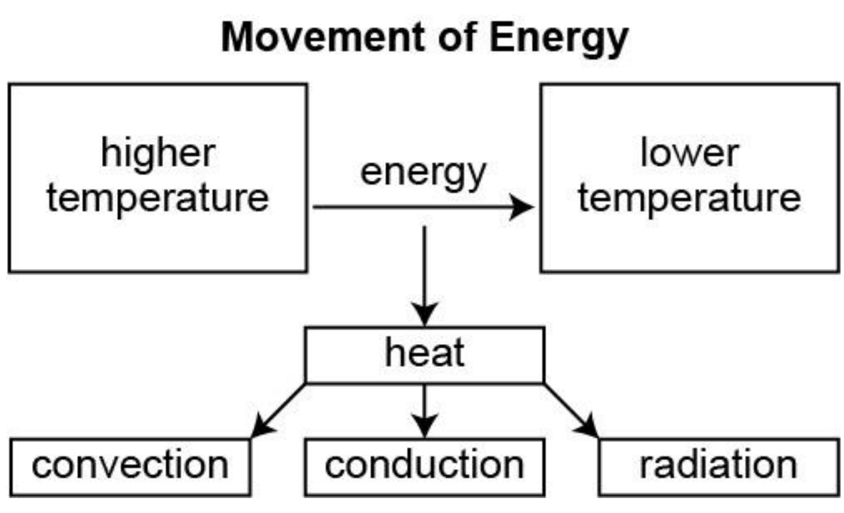
Heat transfer can be broken down into three basic ideas:

- Conduction—transfer of energy due to physical contact between objects
- Convection—transfer of energy due to an imbalance in temperature
- Radiation—transfer of energy in the form of electromagnetic waves

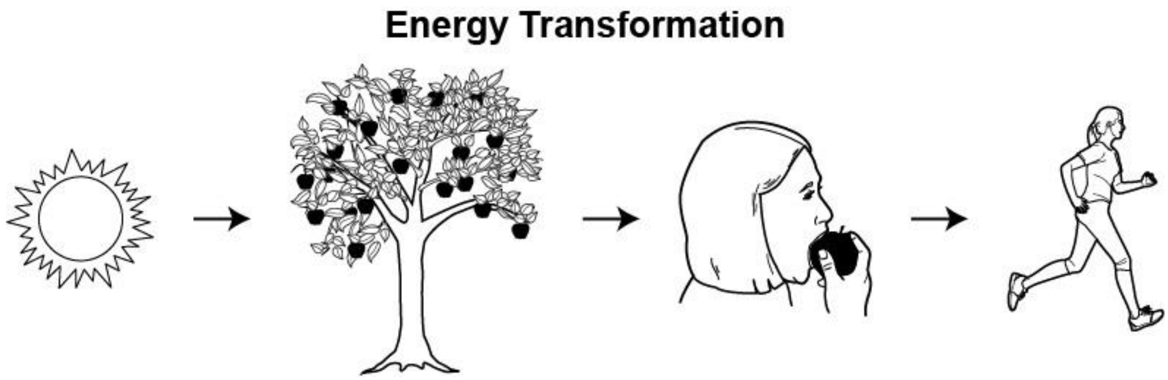
Conduction functions as heat is transferred from warmer objects to cooler objects. For example, sweat on the human body absorbs heat from the skin to evaporate into the air and cool the skin.

Convection occurs in the air and in fluids. Warm objects rise and transfer their energy to other objects or the environment. As they cool, they sink back down. This explains why the top bunk of a bunk bed will be a warmer spot for someone to sleep and how if someone dives down deep in a pond or lake, the water is colder than at the surface.

Radiation causes the atoms in matter to become excited and move rapidly. This often causes the temperature of objects to increase. Standing near a fire or a strong light, an observer can feel the "warmth," which is radiation from the source.



The transfer of energy can be modeled to show how energy can be stored before being used. For example, radiation from the Sun helps plants grow. Plants make sugars with the solar energy (stored chemical energy). Animals that eat the plants gain chemical energy that can be used (movement) or stored (muscle/fat).



Transfer of electrical energy occurs because of a difference in electric potential. Electricity is the movement of electrons across a medium. A battery is stored chemical energy that allows electrons to move and generate an electrical current when a wire is attached. The electrical difference in a battery can be seen easily by examining the nodes on either end. This same principal applies to natural systems.

Certain environments or situations may be referred to as open systems or closed systems. An open system allows for higher rates of energy transfer, while a closed system closely regulates the rate of transfer. For example, an ice cube on a table at room temperature will eventually melt and become the temperature of the room because it is an open system. An ice cube in a freezer will remain a solid because the freezer is a closed system. Transfers of heat are still occurring in both situations but at very different rates.

Activity and Considerations

Activity

This game is a variation of Rock, Paper, Scissors Tag and is meant to help students rationalize a transfer of energy. The rules can be adapted for different environments and situations, but these main constraints should be held constant:

- Students with the most energy move quickly.
- Students with little to no energy should be stationary or move in slow motion.
- The student who wins a match of Rock, Paper, Scissors, **gains** energy and must move faster. The student who lost the match **transferred** energy and now must move slower.

A quick match can be played with the following steps:

1. All students can spread out across the play area. Everyone will start with high energy-jogging or running.
2. When the instructor signals the start, all students will try to move to tag someone.
3. When someone is tagged, a match of Rock, Paper, Scissors begins.
4. Up to three matches may be played if a tie occurs. After three, they must find someone else to tag.
5. The winner must now move faster, and the loser must now move slower.
6. Play is ended when the instructor provides students with a signal.

Considerations

If students are asking questions that cannot yet be answered or if a student is unsatisfied with an answer, the technique of a classroom parking lot might be a helpful approach. This technique allows students to nonverbally express their thoughts and ideas without derailing the pacing of the lesson. Information about this technique and how to use it is found in the Resources section below.

Resources

- Rock, Paper, Scissor Tag—directions to the game in the first activity
- Parking lot—teaching technique to nonverbally collect ideas and questions
- Crash Course: Heat Transfer—YouTube video explaining the basics of heat transfer. Stop at 2:03 if showing to students; the remainder is out of scope but may be of interest to the instructor
- How Refrigerators Work—YouTube video for an instructor to view in order to provide an explanation for curious students
- The Function of Batteries—a well-written article for instructor priming that digs into the science and principles of batteries
- Energy in a Roller Coaster Ride—PBS interactive demonstration that compares the kinetic energy and potential energy of moving roller coaster cars
- PhET Circuits Simulation—interactive demonstration that allows students to build a closed circuit

What are the energy inputs, energy outputs, and flows or transfers of energy in systems involving sound, light, heat, and electric currents?

What patterns can be observed during an energy transfer and how can cause-and-effect relationships be recognized?

Background

Sound requires an input of energy to start a vibration. The vibration needs to pass through a medium (solid, liquid, or gas), which is its pathway. The output is the energy that it transfers as it moves through the medium. Sound can be reflected and/or absorbed along its pathway.

Visible light is part of the electromagnetic spectrum. Light waves can be reflected, refracted, transmitted, and/or absorbed. Waves of different lengths are perceived differently by the human eye, which is why humans see different colors.

Heat can follow different pathways as it moves from warm to cool temperatures. From the source, heat can be transferred through direct contact (conduction), through a moving current of fluid or air due to an imbalance in temperature (convection), or through radiation. As heat moves through materials and surroundings, it may come into contact with insulators and conductors. An insulator limits the amount of heat transfer, while a conductor allows the transfer of heat.

A gain in energy results in faster moving particles and a loss in energy results in slower moving particles. Faster moving particles in objects typically result in a lower density, which causes them to rise. Slower moving particles become denser, which causes them to sink. More heat energy from light is absorbed by the color black than white. Black absorbs all wavelengths of light, while white reflects them. As energy increases in a sound wave, the amplitude (volume) of the wave increases.

Activities

Activity 1

A string phone can be used by students to demonstrate the transfer of sound energy. Speaking into a cup creates sound waves, which are converted into vibrations that travel down a string from one cup to the other.

Materials:

- Two plastic cups
- Sharp pencil or needle to poke holes in cups
- String or fishing line

Directions:

1. Cut a long piece of string, about 20 meters.
2. Use the sharp pencil or needle to poke a small hole in the bottom of each cup.
3. Secure the string to both cups by threading it through and tying a knot.
4. Have two students move into position, standing apart from each other so the string is taut.
5. One student talks into the cup while another student puts the second cup to one ear and listens.

Activity 2

Heat transfer can be demonstrated using different materials.

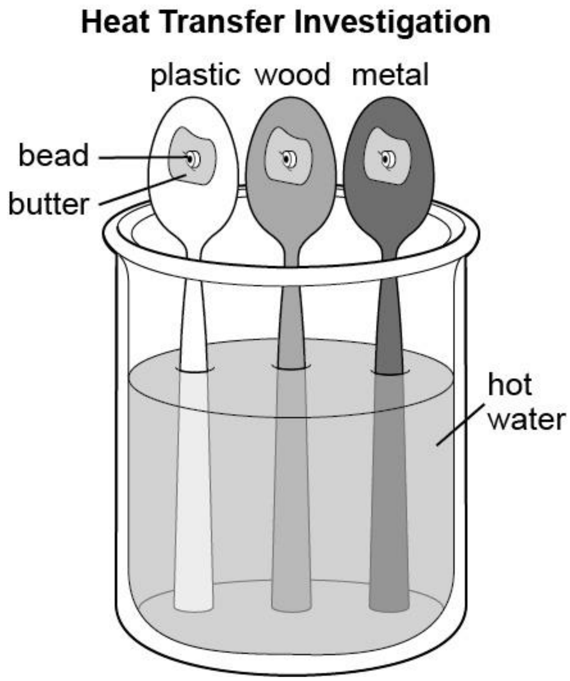
Materials:

- Small glass bowl or beaker
- 3 spoons (1 plastic, 1 wood, 1 metal)
- Butter or peanut butter
- 3 identical beads
- Hot water

Directions:

1. Place the 3 spoons in the glass beaker.
2. Add some butter to each spoon. Make sure that the same amount of butter is used on each spoon.
3. Place a bead in the butter on each spoon.
4. Carefully pour the hot water into the bottom of the beaker.
5. Observe what happens to the beads for 5–10 minutes and record observations. Have students record the time it takes for each bead to fall off its spoon.

Suggestion: larger spoons work best (serving spoons). A foam square can be used to hold the spoons in place.

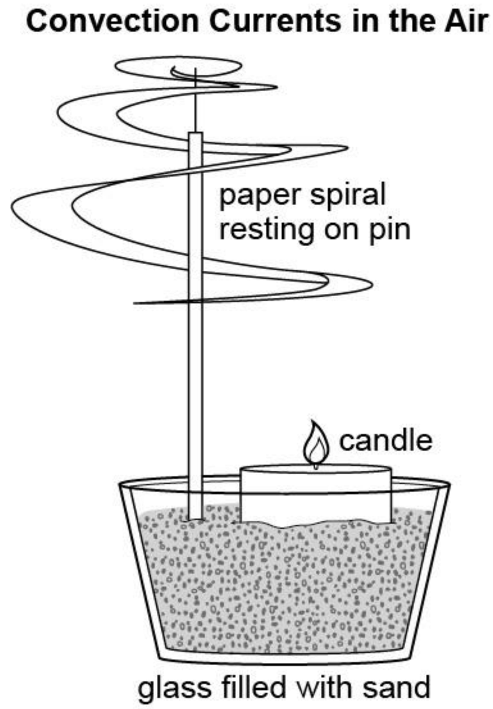


Following the investigation, discuss the students' observations. Highlight the difference in the spoon materials and how this may have affected the time the butter took to melt. Which material was a better insulator? Which material was a better conductor? What process transferred the heat energy from the water to the butter at the top of the spoon?

Activity 3

The following activity can be performed as a demonstration or as an investigation. The setup can be modified to meet safety standards and can include powerful light bulbs instead of candles.

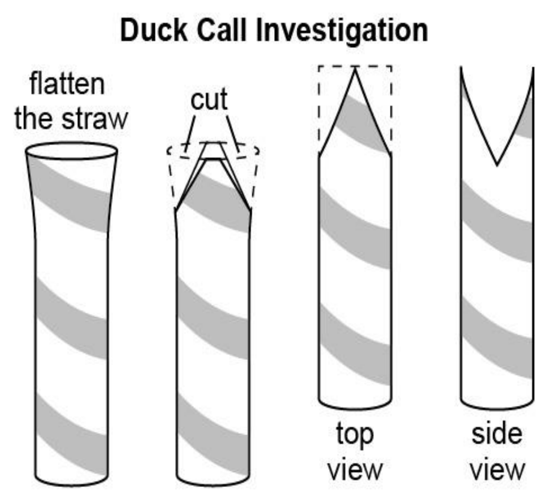
1. Draw a spiral on paper and then cut it out. (see spinning snake resource)
2. Place a pin into the end of a skewer or bamboo stick and place the setup into a cup of sand.
3. Gently place the spiral on the head of the pin so that it hangs freely.
4. Below the spiral, place a tea candle. The spiral should be trimmed so that it does not come into contact with the flame of the candle.
5. Light the candle and observe how the spiral moves on its own due to the rising warm air.



Activity 4

In this investigation, students create a duck call using a plastic drinking straw. As the length of the straw is changed, the pitch also changes. If the setting allows, students could go outside to try to call actual ducks and see if they can get a response back from them.

Energy must transfer to the cut portions of the straw, which causes it to vibrate. The vibrations affect the movement of air and result in the duck noise being produced. Too little energy and no noise will be heard. The more energy put into the vibrations, the louder the call will be.



Resources

- Misconceptions about Temperature (Newer)—Veritasium videos from YouTube
- Misconceptions about Heat (Original)—Veritasium videos from YouTube
- cK-12 Flexbook—primer on sound and energy
- String Phone—directions for making a string phone
- Conducting Heat—heat transfer demonstration
- Spinning Snake—link to materials, directions, and explanation
- Straw Duck Call—directions for activity 4

How can students recognize evidence that light or sound can travel from one place to another?

Background

Light travels in a straight line and sound does too, but sound moves in a straight line in all directions, which means it can travel at many different angles. It is easy to provide evidence like "I see it" or "I hear it" as a source of evidence for movement, but it is important to show the variety of ways in which evidence can be gathered. It is also important to keep in mind that not all students have the ability to see or hear. Gathering evidence using a variety of sources and senses encourages curiosity and inclusiveness.

Activity and Considerations

Activity

In this activity, students use a metal coat hanger, string, and their ears. This activity allows for variable manipulation such as the type of string used, the type of material attached to the string, the shape of the material, and the strength of the collision. It is recommended that metal coat hangers are used, but this can be done with metal spoons as an alternative.

This activity helps students understand that sound moves from one place to another. The student wraps the string around their fingers and then places their fingers in their ears. The coat hanger collides with another object and the student describes whether they hear a sound.

Coat Hanger Acoustics

Considerations

The topic of colorblindness will most likely be brought up by students. Instructors should investigate this topic to answer student questions and address the different types of technology available that assist those who are colorblind.

Resources

- Light Experiment—PBS video that demonstrates how light travels in a straight line
- Hearing Sound with Fingers in Your Ears—directions for Activity
- Swedish Fishing—activity focusing on light refraction

What materials are required to build a working circuit?

Background

A circuit must have a power source, such as a battery or generator, to provide electric current. The power source must have conductive material, typically an insulated wire, that creates a closed loop. Items can be added to the loop, like lights or switches, which can cause an increase in resistance or a break in the circuit. If the circuit is broken, the current cannot pass from one side to the other.

Circuits can be modified for efficiency by having components and loops created in parallel. This provides multiple pathways for the current to travel rather than the current relying on a single pathway with many obstacles.

Insulating material such as wood or plastic will not easily allow current to pass through and can be used to break circuits or obstruct pathways.

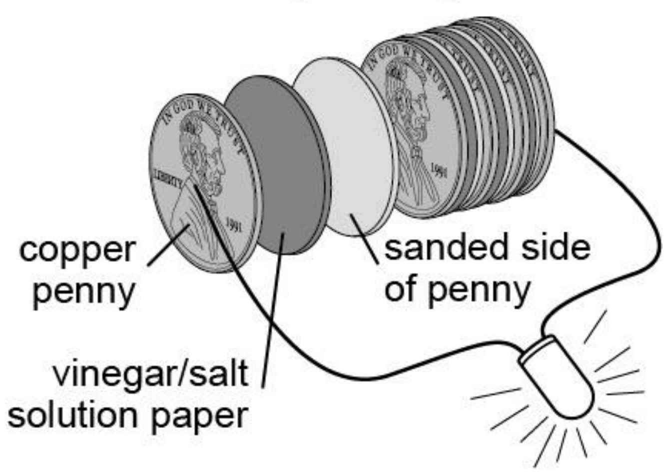
In a more realistic and complex sense, a circuit can be formed with any difference in electrical potential and a conductive pathway.

Activity

In this investigation, students can create a basic electric cell. The materials required are minimal and only include a salt solution, pennies (new ones work best), paper, sandpaper, and a red LED. Pennies should have one side sanded down to expose the zinc metal under the copper plating. Paper should then be soaked in the salt solution and placed between alternating layers of pennies.

After five pennies have been stacked, the LED legs can be placed on either side of the stack and should light up. This activity would work best when paired with discussions about electricity and conductors.

Penny Battery



Resources

- Penny Battery—link to materials list, directions, and explanation
- TEDEd, Batteries—This video explains how batteries function. Images can be understood by students, but the overall content is out of scope. It may be beneficial to use this video only for instruction priming
- Lemon Battery—explains how citrus fruit can be used to create a voltaic cell from *Scientific American*

How can a student plan and carry out an investigation to explain energy transfer using a working circuit, and what is an open circuit?

Background

In a series circuit, the current is the same in all components, but the voltage drops with every new addition. This means that if several lights are added in series, their current would be identical, but they would all appear dim due to the decrease in voltage. If more lights are added to the chain, all lights would become dimmer. As lights are removed from the chain, all remaining lights would become brighter. If the pathway is opened at any point, the entire circuit will become nonfunctional.

In a parallel circuit, the current and the voltage are divided equally among each available path. If multiple lights are set up in parallel, they will not dim as more are added to the circuit. If there is a break in one of the pathways, the remaining closed circuit will continue to function.

Variables that can be explored in circuit construction include the following:

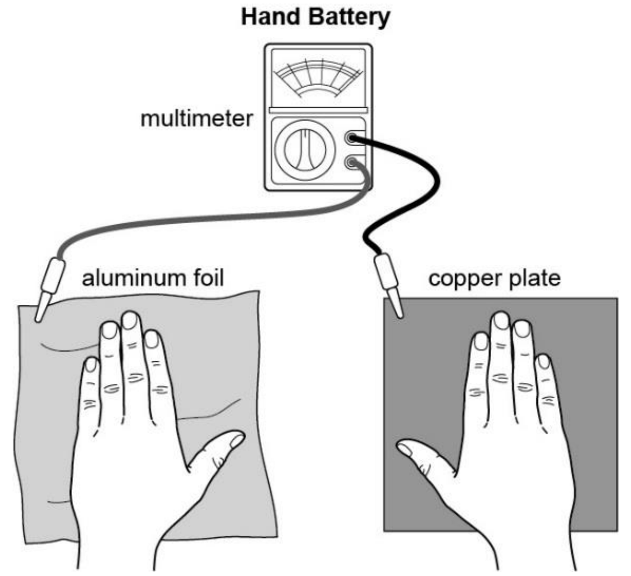
- Setting up multiple LEDs in series and then in parallel
- Setting up a motor and LED in series and in parallel
- Repeating the first two constructions but using incandescent bulbs
- Adding resistors of different values to a circuit and observing their effect

Activities

Activity 1

This activity can show students that a difference in electric potential and conductive material is enough to create a circuit.

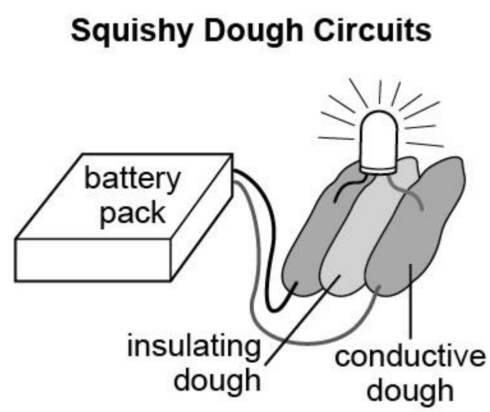
It also introduces students to the tools used to measure current and can introduce the concept of a resistor as well.



Activity 2

The concept of a squishy circuit allows for a tactical and creative experience for students. It removes the barrier of fine motor skills required by other products and methods.

Instructors can save money by making their own dough and can purchase materials from the source or look for alternative methods of providing power, LEDs, and motors.



Resources

- Hand Battery—link to instructions, materials, and explanation
- Squishy Circuit Dough Recipes—link to instructions and materials
- Chibitronics—This kit would serve as a good primer for an instructor on paper circuit construction. If this method of circuit creation seems like something that is worth pursuing, LEDs and copper tape can be purchased in bulk quantities for student use rather than individual kits.

4.PS.3

Grade 4
Energy
4.PS.3 Investigate to determine changes in energy resulting from increases or decreases in speed that occur when objects collide.

Connections to *A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*:

Focus for Scientific and Engineering Practice(s):

- Planning and Carrying Out Investigations
- Asking Questions and Defining Problems
- Obtaining, Evaluating, and Communicating Information

Focus for Crosscutting Concept(s):

- Energy and Matter
- Patterns
- Cause and Effect
- Scale, Proportion, and Quantity

Focus for Disciplinary Core Idea(s):

- Definitions of Energy
- Relationship between Energy and Forces

Guiding Questions

- What is the law of conservation of energy? (p. 34)
- What materials are needed to investigate changes in speed during collisions? (p. 37)
- Which investigative tools are necessary to determine how energy is affected when the speeds of objects change after they collide? (p. 37)
- How can colliding objects be modeled? (p. 39)

- How can the relationship between speed and energy be described? (p. 39)
- What is the relationship between patterns of motion and the transformation of energy? (p. 39)
- How is energy distributed between two objects after a collision? (p. 41)
- How is energy transferred during a collision between two objects? (p. 41)
- What does a change in shape or temperature after a collision indicate? (p. 41)
- What evidence indicates a transfer of energy to the surrounding air after a collision? (p. 41)
- How are sound and heat related to the collision of two objects? (p. 41)

Key Academic Terms:

investigation, energy, evidence, speed, motion, thermal (heat) energy, sound energy, collision, law of conservation of energy, energy transfer, chemical energy, mechanical (motion) energy

Safety Considerations

Please refer to the Alabama K–12 Science Safety Guidelines.

What is the law of conservation of energy?

Background

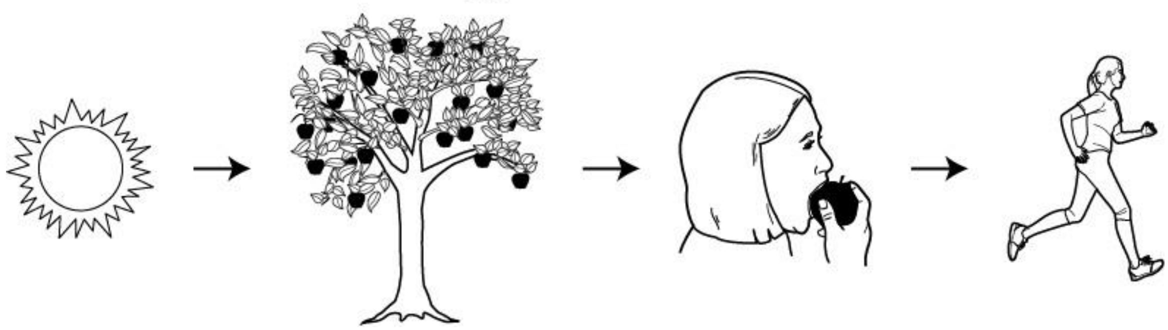
The law of conservation of energy states that energy is never created or destroyed; it is transformed from one form to another. The different forms of energy include but are not limited to the following:

- Light
- Heat
- Sound
- Chemical
- Movement

During transformations, a lot of energy is lost to the environment in the form of heat.

This image shows how chemical energy from the Sun transforms into light energy, which is used by plants to grow. The plant stores chemical energy in the apple (shown on the tree below), which is eaten by a human who then transforms the chemical energy into mechanical energy in order to move. During the movement, the human will sweat, and some energy will be transformed into heat.

Energy Transformation



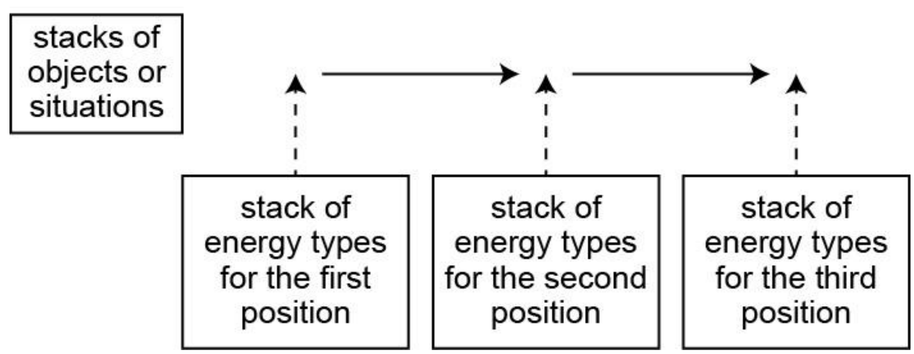
Activities and Considerations

Activity 1

Have students brainstorm ways in which they experience energy transformations in their daily lives. Examples could include the following:

- Chemical energy from a meal to food energy
- Chemical energy from fuel in a vehicle to movement energy
- Mechanical energy from movement to heat energy
- Mechanical energy from movement to sound energy

Activity 2

Have students do a card sort to show different energy transformations. Use a main set of cards that contains objects or situations (4–6 total items) and have students pick one of these object cards. Use another stack of cards that contains the energy transformations to show how energy moves.	**Card Sort** 

Considerations

The activities can be performed at a variety of scales depending on the environment. The depth at which energy transformation and applied vocabulary are taught is dependent on instructor discretion.

Resources

- Law of Conservation—PBS media video explaining the law of conservation through an engineering perspective
- Energy Transfer for Kids—YouTube video that shows energy transfers. The vocabulary is more specific but is transferrable to the vocabulary described in the background section
- Card Sort Template—Google Document with directions for template usage for activity 2

What materials are needed to investigate changes in speed during collisions?

Which investigative tools are necessary to determine how energy is affected when the speeds of objects change after they collide?

Background

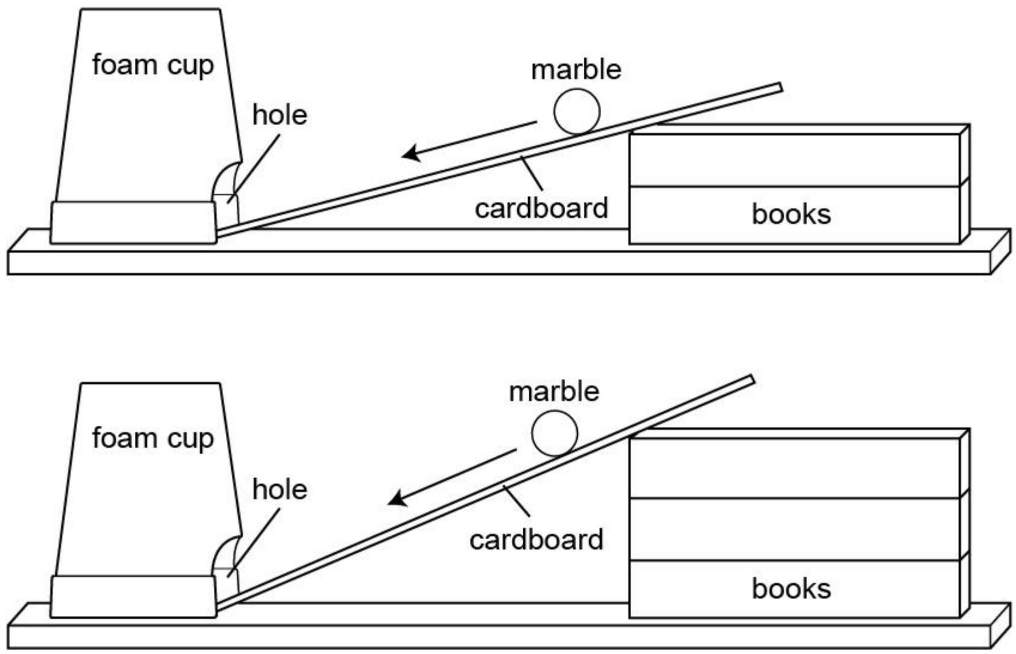
Changes in speed can be measured quantitatively by calculating speed or qualitatively through observations. Cubes and spheres are good objects to use for collision investigations because their simple shape allows for reliable outcomes.

Activity and Considerations

Activity

A ramp can be used to show the effects of the speed of an object as it collides with another object. The setups shown below can be made from basic materials. The height of the ramp can be changed easily. A marble will roll down the ramp at each height and collide with an object. Students should observe and measure the distance the foam cup moves after the collision with the ball. Observations by the students should show that the foam cup moves a greater distance when the marble rolls down a steeper ramp. Discuss the role speed has on the energy of the marble and the resulting effects on the movement of the foam cup. (This activity is also used with standard 4.PS.1).

Marble Investigation



Considerations

When performing investigations, it is important to be mindful of the masses of the objects being used. Make sure that materials are clearly labeled to help with data collection. Modeling an investigation procedure may help students feel more confident before they attempt the lab independently.

Big box hardware stores typically have a scrap pile of wood in their lumber yards. This can help bring down material cost for instructors and may even result in donated materials for the classroom.

How can colliding objects be modeled?

How can the relationship between speed and energy be described?

What is the relationship between patterns of motion and the transformation of energy?

Background

Models can include such things as images, lab experiences, and graphic organizers. When creating a visual model, labels should be included to help students better understand and identify variables.

As energy increases in an object, the speed of the object also increases. This is true for all types of matter, from atoms to cars. The energy can come in various forms, like electromagnetic radiation, but the most common in the classroom will be heat or motion.

As motion increases, heat energy will increase. When objects move faster, they transform more energy into heat.

If a moving object collides with a stationary object of the same mass, the direction of motion will stay the same, but the transfer of energy will cause one object to rest while the other object moves. If a light object collides with a stationary, heavier object, the heavier object will move slowly in the original direction of motion. The lighter object will move backwards after the collision due to Newton's third law. If a heavy object collides with a stationary, lighter object, both will move in the original direction of motion of the heavier object. The lighter object will be moving at a faster rate than the heavier object.

Activity and Considerations

Activity

Students can use a dime and a quarter to demonstrate the results of objects of different masses colliding. The quarter should be stationary on a table. One student slides the dime so it collides with the quarter. Observe the resulting motion of both coins. Repeat with the dime as the stationary coin.

Considerations

Collisions of objects of different masses, collisions in opposing directions, collisions in the same direction at different speeds, and inelastic collisions are likely out of scope for this grade level. Students will naturally ask about these variations, and it is up to the discretion of the instructor to decide the depth at which they wish to pursue them. Topics like the conservation of momentum may or may not be covered during these investigations.

Resources

- Crashes and Collisions—a middle school collision lesson that could be simplified for younger grade levels
- Collision of Equal Mass—shows the result of a collision between a moving object and a stationary object
- Collision of Unequal Mass (Normal speed, Slow Motion)—shows the result of a collision between a more massive moving sphere and less massive stationary sphere
- Collision of Unequal Mass—shows the result of a collision between a less massive moving sphere and a more massive stationary sphere (reverse of the previous link)
- Collision Simulation—simulation replicates a billiards table with variables that can be manipulated by the user.
- PhET Simulation— This is a Java executable file that must be downloaded and run locally. This is a good demonstration of energy if the ramp has no angle and the energy graph is magnified.
- PhET Lesson—Questions from the lesson can be used for class discussion.

How is energy distributed between two objects after a collision?

How is energy transferred during a collision between two objects?

What does a change in shape or temperature after a collision indicate?

What evidence indicates a transfer of energy to the surrounding air after a collision?

How are sound and heat related to the collision of two objects?

Background

Energy is conserved during a collision. The amount of energy put into the system is the same as the amount of energy that leaves the system. During the collision, energy is transformed into other forms, which follows the criteria for the conservation of energy.

Common forms of energy transformation during a collision occur between the following:

- Heat
- Sound
- Movement

The presence of sound during a collision is an indicator of a transformation of energy. The volume of sound produced during a collision is an indicator of the strength of the collision. Louder sounds mean that more energy was transferred.

If a collision is strong enough, a deformation of shape may occur. The change of shape indicates that energy was transferred to the object even if the object does not move or does not move as predicted. This is evidence for an inelastic collision and might include something like a sphere colliding with sand or modeling clay. As objects change shape, heat is produced as a product of the change. Depending on the material, the amount of heat produced can vary. Metal objects would produce larger amounts of heat than nonmetal objects because more energy is required to deform them.

Activity and Considerations

Activity

Students can drop marbles from different heights into a pie tin filled with sand, flour, or powdered sugar. The displacement of the material is an indicator of the strength of the impact. A variation of this can be performed using soft modeling clay and heavier spheres like ball bearings. The medium of the impact should be reshaped after each trial so that differences can be accurately observed and measured if needed.

Considerations

Heat is a very difficult energy transfer to quantify in a classroom setting. It is important to remind students that even if they cannot observe the transfer, it is still occurring.

Resources

- Car Sliding on Ice—a short video that provides a discussion opportunity about energy transfer

4.PS.4

Grade 4
Energy
4.PS.4 Design, construct, and test a device that changes energy from one form to another (e.g., electric circuits converting electrical energy into motion, light, or sound energy; a passive solar heater converting light energy into heat energy).

Connections to *A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*:

Focus for Scientific and Engineering Practice(s):

- Constructing Explanations and Designing Solutions

Focus for Crosscutting Concept(s):

- Energy and Matter
- Systems and System Models

Focus for Disciplinary Core Idea(s):

- Conservation of Energy and Energy Transfer
- Energy in Chemical Processes and Everyday Life
- Defining and Delimiting Engineering Problems

Guiding Questions

- What is meant by transforming energy? (p. 45)
- How can energy be changed from one form to another? (p. 45)
- What is solar energy? (p. 47)
- What is electrical energy? (p. 48)
- What forms of energy can electrical energy be converted to? (p. 48)
- How can a device change one form of energy to another? (p. 49)

Key Academic Terms:

design process, energy, transformation, conversion, electrical energy, chemical energy, heat energy, light energy, sound energy, motion energy, device, design, criteria, constraint, solar, convert

Safety Considerations

Please refer to the Alabama K–12 Science Safety Guidelines.

What is meant by transforming energy?

How can energy be changed from one form to another?

Background

Energy is the ability to do work. In other words, energy makes things happen. Energy can occur in many different forms, and when it changes from one form to another, that is referred to as a transformation.

Energy transformations occur naturally and are manipulated by humans for many reasons. As technology progresses, energy transformations become more complicated and efficient.

Activities and Considerations

Activity 1

The instructor can demonstrate various types of electrical and battery-powered devices for the students. One example that includes many transformations is a hair dryer. Plug in a hair dryer and turn it on. Ask students to develop a list of all the energy transformations they observe. Students can take turns holding the hair dryer as they make their observations. Ask students the following questions.

1. What is the source of energy for the hair dryer?

   Answer: electricity

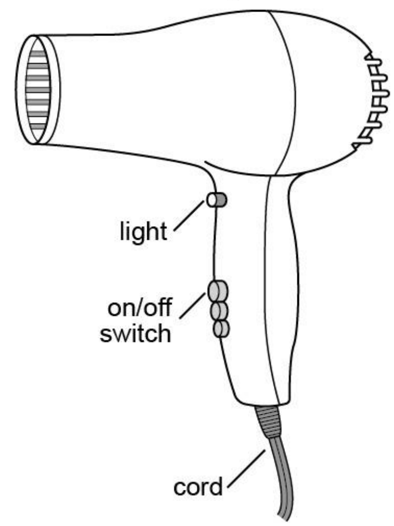
2. What energy transformations are taking place?

   Answer: electrical → mechanical, heat, sound, and light

3. Which energy transformations are not needed to dry one’s hair? In other words, which forms of energy are byproducts of this device?

   Answer: sound and light

Hair Dryer



Activity 2

Additionally, the instructor can model the use of a windup or shake flashlight to demonstrate the transformation of mechanical energy into electrical, light, and heat energy. An emergency radio can also be used to show how mechanical energy can be used to generate electrical and sound energy.

Considerations

Students should have received previous guidance on energy transformation from 4.PS.3.

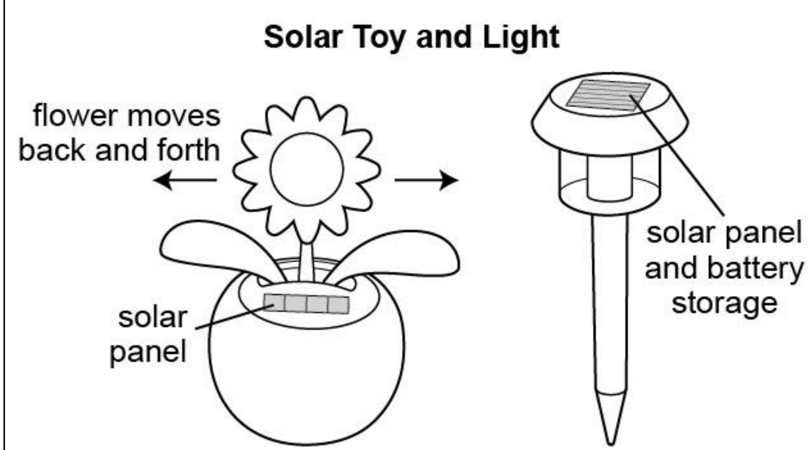
What is solar energy?

Background

Solar energy is the process of capturing electromagnetic energy from the Sun and converting it to electrical energy or stored chemical energy in a battery. A solar panel contains several components that allow for this process to occur. The element silicon is crucial for solar panel construction due to silicon’s ability to lose and gain electrons. The movement of electrons from one side of a cell to another is what generates the electrical current that can be used or stored.

Activity and Considerations

Activity

Students can be shown a solar toy or light that can be purchased from a dollar store. The instructor can then engage students in a discussion about the transformation of energy from solar to electrical energy. A solar toy converts the electrical current into motion energy and does not passively store energy in most cases. A solar light stores the energy gained and then releases it when it is no longer stimulated. When the reservoir of stored electrical energy is depleted, the light can no longer be sustained.	

Considerations

Discussions about the trade-offs of solar energy should be reserved for discussions around engineering principles. The focus should be on the conversion aspect of a solar panel.

Resources

- How Solar Panels Work —This TEDEd video explains the inner workings of a solar panel. The first half of the video may only benefit the instructor.

What is electrical energy?

What forms of energy can electrical energy be converted to?

Background

Electrical energy is the movement of electrons across a medium. An electrical circuit helps guide the movement of electrons so that the movement can be converted into another form of energy.

Electrical energy can be converted into many forms, including the following forms:

- mechanical (motion) in motors
- heat and light via a burner on a stove
- electromagnetic waves in cell phones, radios, and other transmission devices

Activity and Considerations

Activity

Instructors could explain or demonstrate how electricity has benefitted humans in numerous situations. An example could be comparing candlelight and gaslight to electric light.

Considerations

It is important to note that electrical energy does not simply appear and is instead the result of other forms of energy transforming in ways that allow it to function. Students should have received guidance on energy transfer from 4.PS.2: convection currents in the air and squishy dough circuits.

Students may wonder how something like a wireless charger functions without the use of the wires in a traditional circuit. This transfer of energy is known as induction and functions due to the electric field that is produced as electrons move. The field can excite other materials into motion and thus produce a current in an object without being in physical contact.

Resources

- Wireless Charging—This YouTube video explains the function of an induction charger. In the middle of the video, the efficiency of wireless charging is discussed, which can be useful to revisit in the next set of guiding questions. If showing to students, you may want to skip over part of the video or remove it entirely. **This reference is intended only for instructors.**

How can a device change one form of energy to another?

Background

Many devices are designed to transform one type of energy into another. Devices cannot transform all the energy, however. Some of the energy is lost to the environment as heat. Some of the energy intended for the completion of a goal will always be lost due to other transformations because of the lack of a perfectly controlled system. Efficiency can always be improved but never perfected.

Activities

Activity 1

Engage students in a discussion about the most efficient way to boil water in their homes. Possible answers may include a stove (gas or electric), microwave, or electric kettle.

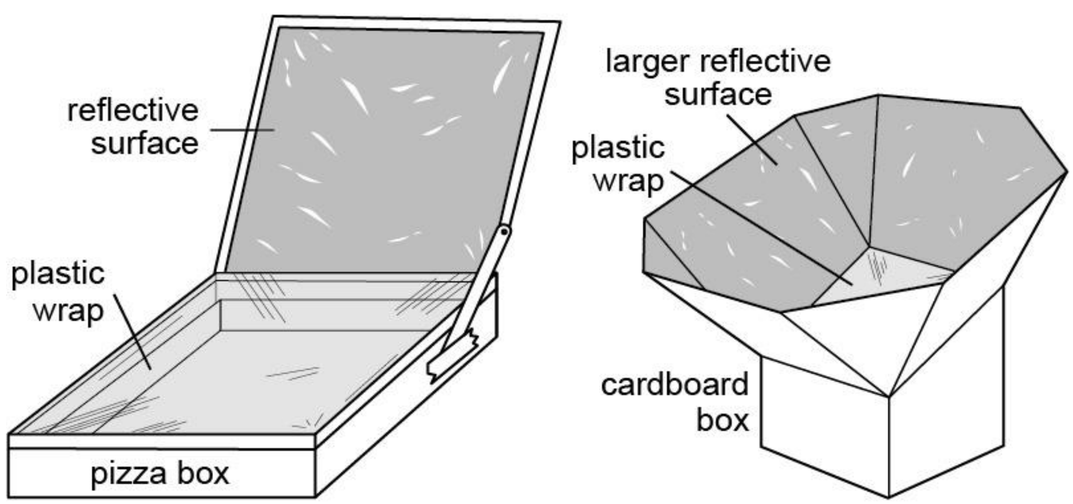
Discussion can center around which would boil the water fastest, which method uses the least amount of energy, and which method wastes less heat energy.

Activity 2

Have students design and build solar ovens to cook marshmallows. Reflective materials like aluminum foil can be used to direct energy from the Sun toward the marshmallows in order to melt or cook them.

Different designs will yield different results, and discussion can be had around the efficiency of each design. The ambient temperature can be used to test the efficiency of the designs.

Solar Cookers



Design 1 Design 2

Resources

- Pulley Activity—web resource for an engineering investigation
- How Solar Panels Work—This video was referenced previously, but this link contains a time stamp to the portion that focuses on the efficiency aspect and physical limitations of solar panels.
- Boiling Water—The Guardian had a discussion on this topic, and the various replies can be used as conversation points in class discussion.
- Cooking Cookies—PBS Learning Media resource on the efficiency of a solar oven
- Solar Oven—detailed information on solar oven efficiency

4.PS.5

Grade 4
Energy
4.PS.5 Compile information to describe how the use of energy derived from natural renewable and nonrenewable resources affects the environment (e.g., constructing dams to harness energy from water, a renewable resource, while causing a loss of animal habitats; burning of fossil fuels, a nonrenewable resource, while causing an increase in air pollution; installing solar panels to harness energy from the sun, a renewable resource, while requiring specialized materials that necessitate mining).

Connections to *A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*:

Focus for Scientific and Engineering Practice(s):

- Obtaining, Evaluating, and Communicating Information

Focus for Crosscutting Concept(s):

- Energy and Matter
- Cause and Effect

Focus for Disciplinary Core Idea(s):

- Natural Resources

Guiding Questions

- How do food and fuel provide energy? (p. 53)
- What is chemical energy? (p. 55)
- What is renewable energy? (p. 57)
- What is nonrenewable energy? (p. 57)
- What are some examples of renewable and nonrenewable resources on Earth? (p. 57)

- How would a concept map be constructed to show the differences and similarities between renewable and nonrenewable resources? (p. 57)
- How is energy derived from natural resources (renewable and nonrenewable)? (p. 59)
- What are the advantages and disadvantages of using specific types of renewable and nonrenewable resources for energy? (p. 61)
- How is the environment affected by the use of common renewable and nonrenewable energy sources? (p. 61)

Key Academic Terms:

natural resource, renewable natural resource, nonrenewable natural resource, energy transformation, pollution, conservation of energy, fossil fuel, solar energy, solar panel, wind energy, wind turbine, hydroelectric power plant, nuclear energy, geothermal energy, environment, habitat, harness

Safety Considerations

Please refer to the Alabama K–12 Science Safety Guidelines.

How do food and fuel provide energy?

Background

Food provides many different types of nutrients to give humans and animals the energy they need. Having a well-balanced diet is important for the general fitness of any living organism. Proteins, carbohydrates, fats, vitamins, and minerals can all be obtained in the food humans consume daily. The benefits of these nutrients are described below.

- Proteins: Proteins help cells grow and build muscle and are commonly obtained through the digestion of meat, eggs, beans, peas, nuts, and dairy.
- Carbohydrates: Sugars are carbohydrates and are identified as being simple or complex. Simple sugars are converted into energy quickly and complex sugars are broken down slowly to provide a more consistent source of energy. Carbohydrates are obtained through the consumption of grains, fruits, and vegetables.
- Fats: Fats provide long term energy storage and insulation from the environment. Fat can also absorb certain vitamins that are important for bodily functions. Fats are obtained through the consumption of many types of food, but some of the best sources are fish, nuts, oils, and eggs.
- Vitamins and minerals: These nutrients are important for growth and body function. The body requires only small portions of these nutrients to maintain a healthy balance. All food groups provide these nutrients in varying amounts. Common minerals required include calcium, potassium, sodium, and iron.

Fuel includes a wide range of materials. The Sun, steam, electricity, and fossil fuels fall into this category. Fuel can be used for a variety of purposes such as transportation, light, heating, and cooling.

Activity

Activity 1

Have students keep a journal of the food they eat for three days. Each day, they can organize how much of each type of food group they consume and better understand their diets and how diet relates to health and physical activity.

	Breakfast	Lunch	Dinner
Day 1			
Day 2 Day 3			

Proteins	Carbohydrates	Fats

Considerations

There might be opportunity for some cross-curricular cooperation with the health/physical education department for this guiding question.

Extension: Compare the diet of an Olympian to that of a fourth grader and discuss how the diets are designed to meet the energy output needs of the person.

Resources

- Child Nutrition—recommended caloric diet from the Mayo Clinic
- CK-12—nutrition unit

What is chemical energy?

Background

Technically, everything except heat and gravity are forms of chemical energy. Chemical energy is stored in the atoms of matter. Chemical reactions excite that energy to the point that it is released and transforms into another form of energy. It would be appropriate to narrow the scope of chemical energy to include the following categories:

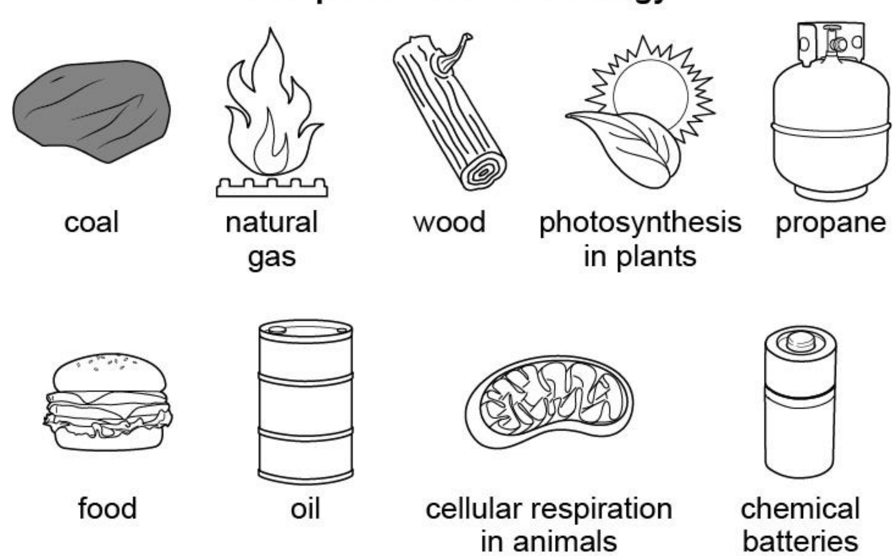
- Food
- Fossil fuels
- Electricity and batteries

Activities and Considerations

Activity 1

Show students the following diagram and have them identify the items that contain chemical energy. After a list of items has been created, have students share with each other to discuss any similarities and differences.

Examples of Chemical Energy



Have students share their results with the class. Discuss the possibilities of each item in the list. Provide students with the following information.

Item	Source of Chemical Energy?	Description
Coal	Yes	Combustion converts chemical energy into light and heat.
Natural gas	Yes	Combustion converts chemical energy into light and heat.
Wood	Yes	Combustion converts chemical energy into light and heat.
Photosynthesis in plants	Yes	Solar energy is converted into chemical energy in the form of sugars.
Propane	Yes	Combustion converts chemical energy into light and heat.
Food	Yes	Chemical energy is converted into food energy through digestion.
Oil (petroleum)	Yes	Combustion converts chemical energy into light and heat.
Cellular respiration in animals	Yes	Chemical energy in sugars is converted into food energy.
Chemical batteries	Yes	Stored chemical energy is converted into electricity.

Considerations

Use discretion on the items included. You want to expose students to items that they may not have considered.

What is renewable energy?

What is nonrenewable energy?

What are some examples of renewable and nonrenewable resources on Earth?

How would a concept map be constructed to show the differences and similarities between renewable and nonrenewable resources?

Background

Renewable energy sources are readily available and are replenished naturally over short periods of time. Nonrenewable energy sources are in limited supply and are replenished over very long periods of time.

Renewable energy examples include the following:

- Solar
- Wind
- Geothermal
- Hydroelectric
- Nuclear energy

Nonrenewable energy examples include the following:

- Oil
- Coal
- Natural gas
- Nuclear energy

Activities and Considerations

Activity 1

Concept maps could take the form of mind maps, Venn diagrams, or T-charts. Many types of energy are used to produce electricity, heat, and motion. These three categories can be further deconstructed to include things like motion and light. They can be broken down on an individual level after a higher order has been established.

Activity 2

Have each student create a graphic organizer for a specific energy source. Students can then meet in small groups and try to find ways to combine their organizers into a single graphical representation. Then, post the group organizers around the room and have students perform a gallery walk and leave comments with sticky notes.

Considerations

Scientists tend to disagree on whether nuclear energy is renewable or nonrenewable. The material (uranium) is found in a finite amount in Earth's interior, but the amount of energy that can be generated and the low emissions are taken into consideration. Some scientists think that the necessary use of nonrenewable materials to build and operate nuclear power plants makes it a nonrenewable energy source. This can be incorporated into a discussion.

Resources

- The Great Nuclear Energy Debate—resource that highlights opposing views on the categorization of nuclear energy
- Graphic Organizers—templates that can provide inspiration or be printed
- Gallery Walk—teaching strategy that allows for student voice representation and input
- CK12—4th grade energy section on renewable and nonrenewable energy

How is energy derived from natural resources (renewable and nonrenewable)?

Background

Renewable resources come from many different sources. Some of them are listed below.

- Solar energy comes from the Sun and can be captured by solar panels, which absorb energy, or can be directed to specific locations using reflective surfaces.
- Wind energy can be captured using turbines or mills.
- Geothermal energy is heat naturally released from the inner layers of Earth.
- Hydroelectric energy is captured using a difference in gravitational potential via a dam or through heating water to create steam.

Nonrenewable resources come from organic material that has been changed over millions of years or minerals that require invasive methods to obtain (mining).

Oil, coal, and natural gas are created when organic material is buried deep within Earth and exposed to high amounts of pressure. Metals like iron, gold, and silver are the result of deep Earth systems pushing material closer to the crust.

Activity and Considerations

Activity

Students can create paper windmills and use them to lift various objects in a paper cup. Extension activities might include design variations or brainstorming how the same task could be accomplished using a nonrenewable resource and what the trade-offs might be when compared to using a renewable resource.	

Considerations

Depending on time and materials available to instructors, various engineering projects or challenges can be presented to students.

Resource

- Windmill Engineering—PBS media link to engineering activity

What are the advantages and disadvantages of using specific types of renewable and nonrenewable resources for energy?

How is the environment affected by the use of common renewable and nonrenewable energy sources?

Background

The technology required to capture the energy from renewable sources involves using nonrenewable materials, like metal. The idea of trade-offs, especially on a large time scale, is important to keep in mind. While things like wind turbines, solar panels, and dams may help in generating cleaner electricity, they might also directly impact the environment in which they operate. These pieces of technology are manufactured with rare Earth minerals that are acquired through mining, and that mining does impact the environment.

Nonrenewable energy is affordable but causes pollution. While the use of nonrenewable energy benefits humans in the short term, it may cause devastating effects worldwide over a longer scale of time.

Activity and Considerations

Activity

Find grade-appropriate literature that highlights the topics of environmental trade-offs and energy sources. A jigsaw approach could be used to have students research and share their learning.

Considerations

Global warming is a topic that is likely to come up or be asked about by students. Use instructor discretion related to the depth at which to cover this topic. It is important to make students aware of the issue without causing distress or anxiety to students. Finding a balance between information, urgency, and importance is necessary.

Resources

- Powering a City—free lesson funded by American Association for the Advancement of Science
- Jigsaw—teaching technique that encourages cooperation, collaboration, and presentation
- Newsela—resource for providing grade-appropriate descriptions of current events
- CK12—4th grade energy section on renewable and nonrenewable energy
- Epic—grade-level-appropriate books
- ReadWorks—grade-level-appropriate books
- TeachingBooks—grade-level-appropriate books

4.PS.6

Grade 4
Waves and Their Applications in Technologies for Information Transfer
4.PS.6 Develop a model of waves to describe patterns in terms of amplitude and wavelength, and including that waves can cause objects to move.

Connections to *A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*:

Focus for Scientific and Engineering Practice(s):

- Developing and Using Models
- Analyzing and Interpreting Data

Focus for Crosscutting Concept(s):

- Patterns
- Systems and System Models
- Cause and Effect
- Energy and Matter

Focus for Disciplinary Core Idea(s):

- Wave Properties

Guiding Questions

- What is a wave? (p. 65)
- How is a wave produced? (p. 65)
- What is the relationship between waves and energy? (p. 65)
- What are properties of waves (amplitude and wavelength)? (p. 67)
- How can a wave model depict and describe wave characteristics such as wavelength and amplitude? (p. 67)
- How does changing a wave property affect other wave properties? (p. 69)

- What is the relationship between the motion of an object carried by a water wave and the net motion of that water wave? (p. 69)

Key Academic Terms:

wave, wave property, wavelength, amplitude, net motion, evidence, model, pattern

Safety Considerations

Please refer to the Alabama K–12 Science Safety Guidelines.

What is a wave?

How is a wave produced?

What is the relationship between waves and energy?

Background

A wave is a movement that carries energy from one point to another. If a wave moves through matter, it is referred to as a mechanical wave. Common types of mechanical waves are sound and water waves.

If a wave is not a mechanical wave, then it is referred to as an electromagnetic wave. Common forms of electromagnetic waves are visible light, radio waves, microwaves, and x-rays.

A mechanical wave requires matter to be present for its formation. An energy source must initiate movement in the form of an oscillation. An oscillation is consistent movement in a vertical or horizontal direction.

Fundamentally, waves are created due to vibrations. This is true for electromagnetic waves, but the vibrations occur due to differences in magnetic and electric fields rather than with particles of matter.

The amount of energy determines the frequency and amplitude of a wave. There is a direct relationship between energy, frequency, and amplitude which means that as energy increases, the frequency and/or amplitude also increase.

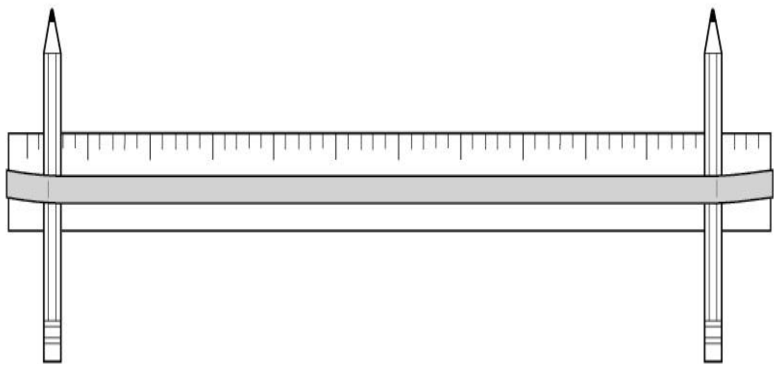
Activity and Consideration

Activity

Students can make a simple guitar using a rubber band, a ruler, and two pencils. As one pencil is moved up and down the ruler, the tone of the note being played changes.

Students can discuss which note they believe requires the most energy to produce. Qualitative and quantitative data can be gathered from this investigation to support their ideas.

Rubber Band Guitar



Consideration

Finer details of waves are covered in the upcoming guiding questions. This can serve as an introduction or an inquiry activity.

Resources

- Rubber Band Guitar—instructions to build a rubber band guitar by *Scientific American*

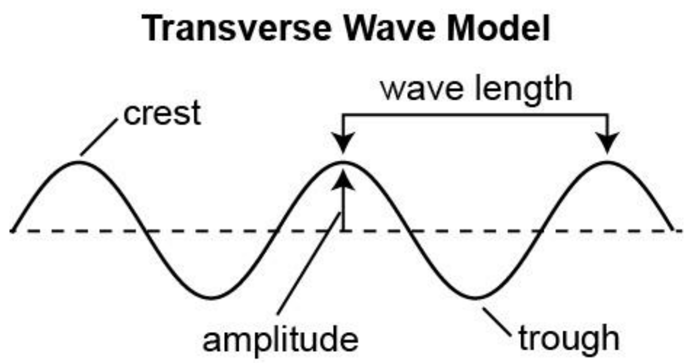
What are properties of waves (amplitude and wavelength)?

How can a wave model depict and describe wave characteristics such as wavelength and amplitude?

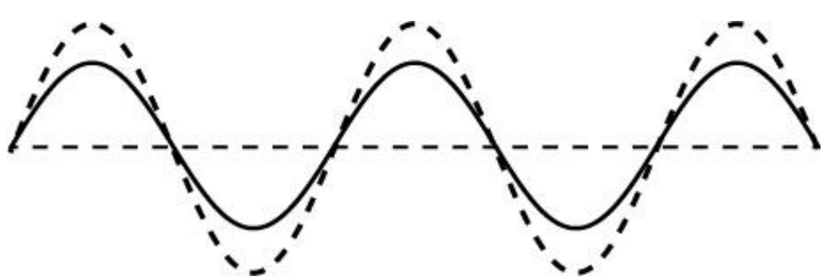
Background

Amplitude refers to the height of a wave, and wavelength is a measurement of the distance between the crests of a wave.

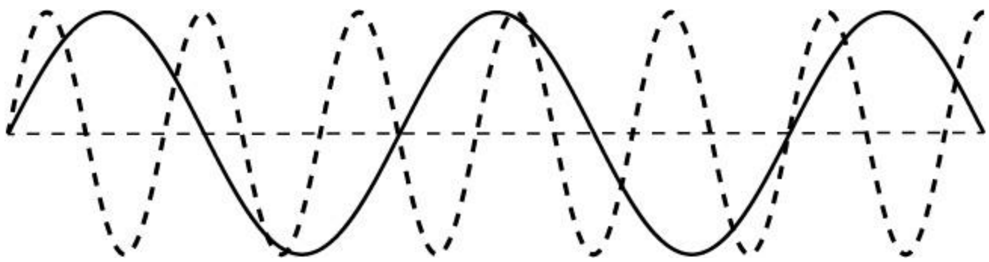
Most wave models depict a transverse wave. These models are helpful in identifying the various parts of a wave and are easy to manipulate.



Different types of waves will have different amplitudes and wavelengths. If two waves have the same wavelength but different amplitudes, there is a difference in energy present. The wave shown below with a dashed line has more energy than the wave with the solid line, because it has a larger amplitude. Their wavelengths are identical.



The wave shown below with the dotted line has a smaller wavelength than the wave with the solid line. Shorter wavelengths mean there is more energy. Their amplitudes are the same.



Activity and Considerations

Activity

Students can create waves using a long piece of rope or a jump rope. One partner will need to hold the rope in a fixed position while the other moves their end up and down in a consistent motion. Students can observe how the wave changes as energy is used to move the rope.

Considerations

There are also waves known as longitudinal waves. These types of waves are how actual sound waves function, but it is not necessary to introduce at this grade level. An instructor could offer these types of waves as an extension piece for more advanced students.

Resources

- Wave Simulation—free cross-platform simulation offered by PhET

How does changing a wave property affect other wave properties?

What is the relationship between the motion of an object carried by a water wave and the net motion of that water wave?

Background

Changing the amplitude of a wave has no effect on the wavelength.

If the frequency, the number of oscillations in a set amount of time, of a wave changes, then the wavelength will change. Faster oscillations result in smaller distances between crests (shorter wavelengths).

In sound waves, if the amplitude changes, the volume of the sound will increase or decrease. If the wavelength changes, the pitch of the noise will be higher or lower.

In light waves, the range of colors is produced by different wavelengths. The amplitude of light wave affects the brightness of the color observed.

Waves move through matter, but matter moves perpendicular to the direction of the wave. If a wave moves from the left to the right, matter will move up and down. Matter will not move in the same direction as the wave.

Activity

Engage students to do “the wave” while seated in a circle. This helps them see that energy moves around the circle, but the individual components (students) move only up and down. Make sure to point out that when standing with arms extended, students are at the crest of the wave. When students are seated with their hands down, they are modeling the trough of the wave.

Resources

- Cause of Ocean Waves—resource from NOAA

4.PS.7

Grade 4
Waves and Their Applications in Technologies for Information Transfer
4.PS.7 Develop and use models to show multiple solutions in which patterns are used to transfer information (e.g., using a grid of 1s and 0s representing black and white to send information about a picture, using drums to send coded information through sound waves, using Morse code to send a message).

Connections to *A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*:

Focus for Scientific and Engineering Practice(s):

- Developing and Using Models

Focus for Crosscutting Concept(s):

- Patterns

Focus for Disciplinary Core Idea(s):

- Wave Properties
- Information Technologies and Instrumentation
- Optimizing the Design Solution

Guiding Questions

- How are patterns used to transfer information? (p. 72)
- What is needed for a code to be used as communication? (p. 72)
- How can a model illustrate how patterns are used to transfer information? (p. 72)
- How are pictures coded (digitized)? (p. 74)
- How can a grid be used to describe the transfer of information? (p. 74)
- How can sound waves be used to communicate over long distances? (p. 76)
- How can light waves be used to communicate over long distances? (p. 76)

Key Academic Terms:

signal, transmit, coding, transfer, detect, digitized image, grid, sound waves, Morse code, light waves, pattern

Safety Considerations

Please refer to the Alabama K–12 Science Safety Guidelines.

How are patterns used to transfer information?

What is needed for a code to be used as communication?

How can a model illustrate how patterns are used to transfer information?

Background

Humans are skilled at pattern recognition and using patterns to make decisions. These patterns might help humans decide whether an area is safe or whether someone is communicating with them.

For a pattern to send a discrete message, there must be a method of transportation and someone that understands how to interpret the pattern. This is true for things like smoke signals, drumbeats, or complex computer algorithms.

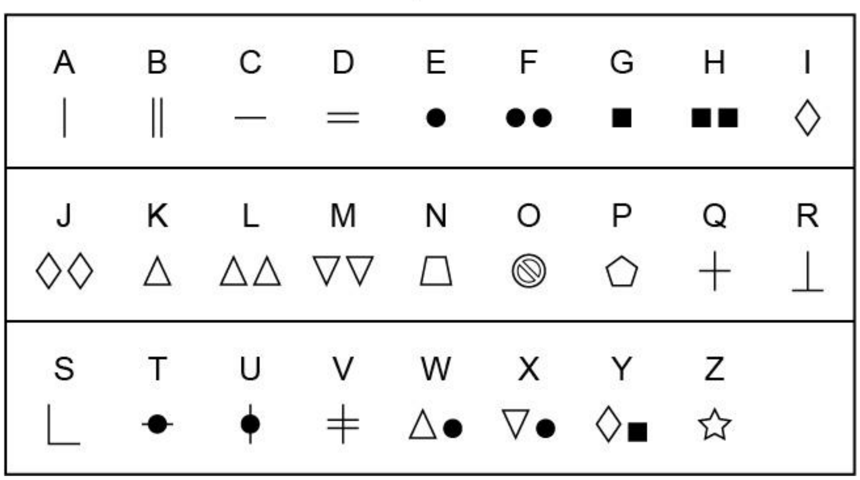
Changes in sound can serve as a model to transfer information. This can be simple like the pattern in Morse code or complex like the Yoruba talking drum.

Pictures and written language can serve as a model for the transfer of information through patterns as well.

Activity and Considerations

Activity

Cipher



Introduce students to the idea of a cipher and have them create their own code to send to friends. Start by having them write out the letters of the alphabet and place a simple symbol below each letter. Students can trade ciphers and have partners decode messages.

Considerations

There is opportunity here for cross-curricular integration when examining different cultures and their forms of communication.

Resources

- Yoruba Talking Drum—Wikipedia page detailing the purpose and function of the talking drum
- Crypto Club—This website introduces the idea of coded messages. Some are Flash based and will no longer work after 2020 in most web browsers.

How are pictures coded (digitized)?

How can a grid be used to describe the transfer of information?

Background

When images are converted to a digital format, a numerical value is assigned for every color. Computers use a red, green, and blue color palette with numerical values in a range from 0–255. They form an array of values that translate to the different colors shown on computers, phones, and tablets.

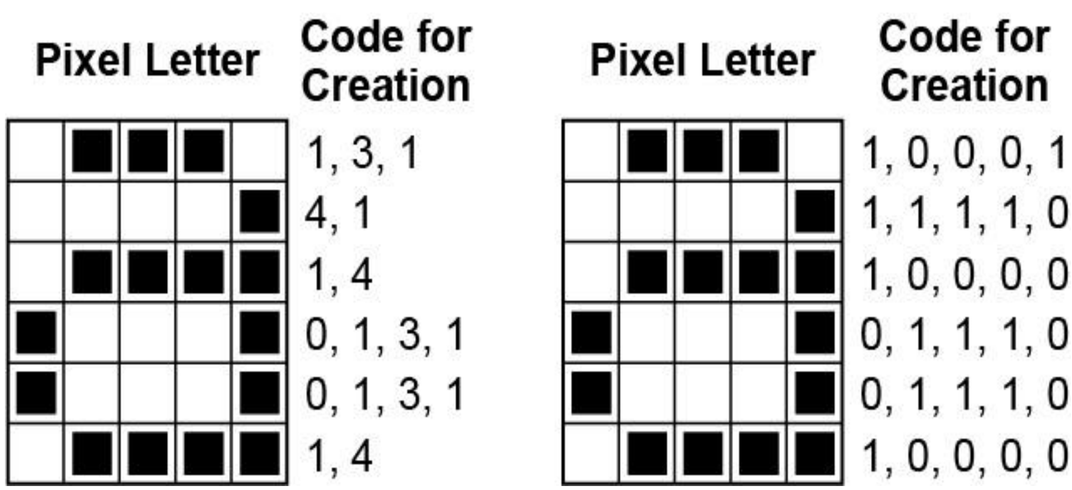
Each space that contains color is called a pixel. Pixels are arranged in a grid that provides the viewing resolution of devices. Larger grids allow for more detailed images and the possibility of greater pixel density. The use of the grid is also necessary for arranging the image so that it can display properly.

Activity and Considerations

Activity

Create 5 x 6 grids and pass them out to students. Ask students to color in boxes to create a letter. After every student has made a letter, show them a premade letter *a* with the code next to it.

Have students discuss how this code translates to the creation of the letter. Both images are created the same way, but the image on the left uses a simplified pattern, while the image on the right displays the value of each pixel. Have students try to write out the code for the letter they created.



Considerations

Color schemes can be mentioned, but it may be more appropriate to take a binary approach (0, 1) and work with only black and white. Another simplification would be a classic "color by number" activity in which colors are assigned logical numerical values rather than an array of numbers.

Resources

- Creation of Digital Images—BBC bitesize series that offers an explanation
- Computer Science Activities—collection of free learning activities that teach computer science
- RGB Color Picker—website that lets you manipulate the values in an RGB array to see the resulting colors

How can sound waves be used to communicate over long distances?

How can light waves be used to communicate over long distances?

Background

Sound and light can be used in both analog and digital communication. Simply shouting or flashing a light can allow for simple communication over a short distance. Converting these forms of communication into a digital format increases the range at which they can be reliably sent and received.

Sound waves are commonly converted into radio waves or microwaves and are sent around the world using cell towers, satellites, and radio transmitters. The physical movement of a microphone is encoded into a digital signal and then sent out as a wave. Once that wave is received, the digital signal is translated back into the physical movements of the speaker, which recreate the source sound.

Light is used in fiber optic communication. A similar chain of conversion is used by which a data source is translated into pulses of light that are sent through cables of glass. The light pulses are then converted back into digital signals that replicate their source material.

Activity and Considerations

Activity

As a class, generate a list that shows all the different ways humans communicate with light and sound. Light might be more difficult for students to generate, so start them with simple things like a traffic light or turn signal. Other examples include but are not limited to open/closed signs, crosswalk audio sounds, fire alarms with flashing lights, school bells, and the lights and sounds of rescue vehicles.

Considerations

The finer details of the communication methods are out of scope for this grade level. Students may have a deep curiosity and if instructors feel comfortable, they may choose to go more in-depth on this topic.

Resources

- The Secret Sounds of Fish—YouTube video from BBC Earth that can be used to discuss conversion of analog signals to digital signals
- CBS Saturday Morning—YouTube video about transatlantic communication via telegraph and now fiber optics
- Whale Songs—TEDEd video that shows the use of patterns for song creation and distance that songs travel through the ocean

4.PS.8

Grade 4
Waves and Their Applications in Technologies for Information Transfer
4.PS.8 Construct a model to explain that an object can be seen when light reflected from its surface enters the eyes.

Connections to *A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*:

Focus for Scientific and Engineering Practice(s):

- Developing and Using Models
- Constructing Explanations

Focus for Crosscutting Concept(s):

- Cause and Effect
- Structure and Function

Focus for Disciplinary Core Idea(s):

- Electromagnetic Radiation

Guiding Questions

- How do waves enable us to see objects? (p. 80)
- How can a model be used to show how objects are seen by the eye? (p. 80)
- How can a model be used to explain how light travels and how it is reflected or absorbed? (p. 82)
- How can the relationship between color, light reflection, and light absorption be described and modeled? (p. 82)
- How does a mirror affect the movement of light? (p. 82)

- How does the path of light change when light interacts with different surfaces or objects (transparent, translucent, opaque)? (p. 82)
- How can the function and structure of a prism be described and modeled? (p. 85)

Key Academic Terms:

light energy, reflect, absorb, transparent, translucent, opaque, wave model, light properties, refract

Safety Considerations

Please refer to the Alabama K–12 Science Safety Guidelines.

How do waves enable us to see objects?

How can a model be used to show how objects are seen by the eye?

Background

Light waves across the electromagnetic spectrum behave in similar ways. When light waves encounter an object, they are either transmitted through the object, reflected off the object, or absorbed by the object.

The only reason we can see the things around us is because light, either from the Sun or from devices like lamps or flashlights, reflects off them into our eyes. If the light source is removed, light does not reach our eyes and those objects seem to disappear. The objects do still exist, but we can no longer see them.

Activities and Considerations

Activity

Materials:

- 4 playing cards or small pieces of opaque construction paper
- Modeling clay or binder clips
- Laser pointer or small flashlight

Procedure:

Hold three of the cards together and punch a hole through the middle of all three. The fourth card should not have a hole. Add a small amount of clay to the bottom of each card (or use binder clips) and line the cards up so that they are standing vertically and placed in a straight line. The card without the hole should be placed on the end.

Before turning on the light source, ask students the following questions:

1. What do you think will happen to the light if it is shone through the hole in the first card?
2. Will the light pass through the holes? If so, at what point will the light stop?

Shine the light through the first card with a hole and have the students record observations. Discuss what would happen if the holes in the cards were not lined up and whether light would still travel through the holes.

Considerations

Topics like eye color are out of scope for this standard.

Resources

- Optical Illusions—website of illusions to help with discussions about how the brain translates light stimulation
- How Light Travels—video demonstrating how light travels in a straight line

How can a model be used to explain how light travels and how it is reflected or absorbed?

How can the relationship between color, light reflection, and light absorption be described and modeled?

How does a mirror affect the movement of light?

How does the path of light change when light interacts with different surfaces or objects (transparent, translucent, opaque)?

Background

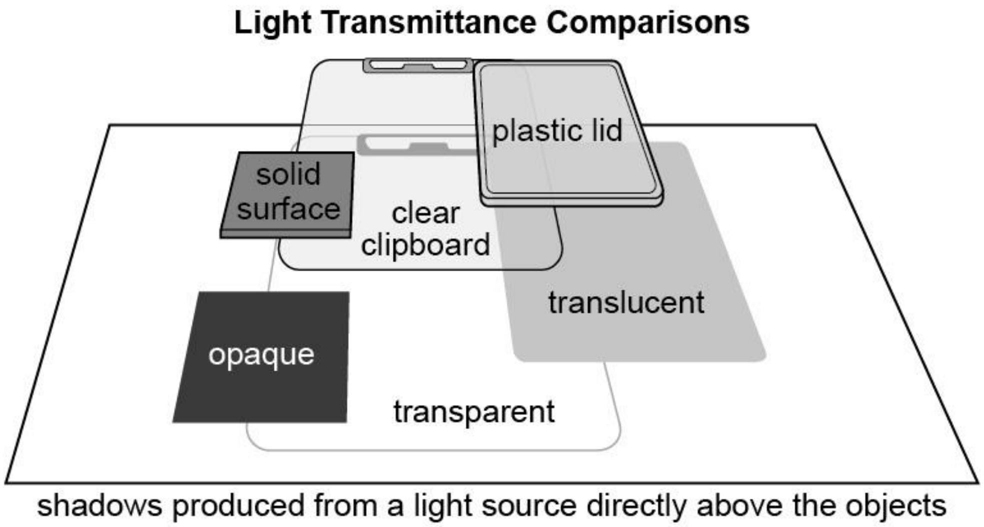
Light travels in a straight line in all directions until it meets an object. When light strikes an object, it can be reflected, absorbed, refracted, or transmitted. When modeling light, it is useful to use a straight line with an arrow to show the direction that it is travelling.

When light is absorbed by an object, the arrow can be removed from the model. When light reflects off an object, the lines that leave the surface should be close to the same angle at which they impacted the object.

When light strikes an object, some of the energy will be absorbed and some will be reflected. The reflected light from the object is perceived as color.

A mirror will reflect light at a reliable, measurable angle in one direction.

If light strikes a transparent object, it reflects very little light because most of the light moves directly through it. Glass and water can be considered transparent because objects can be clearly seen through them when a light source is provided. Translucent materials allow some light to pass through but also reflect some light away. Opaque objects do not allow any light to pass through them and only absorb and reflect light. The model below shows the different shadows produced by a solid surface, a clear clipboard, and a plastic lid.



Activities and Considerations

Activity 1

Have students use a flashlight to see what common objects they can classify as transparent, translucent, and opaque.

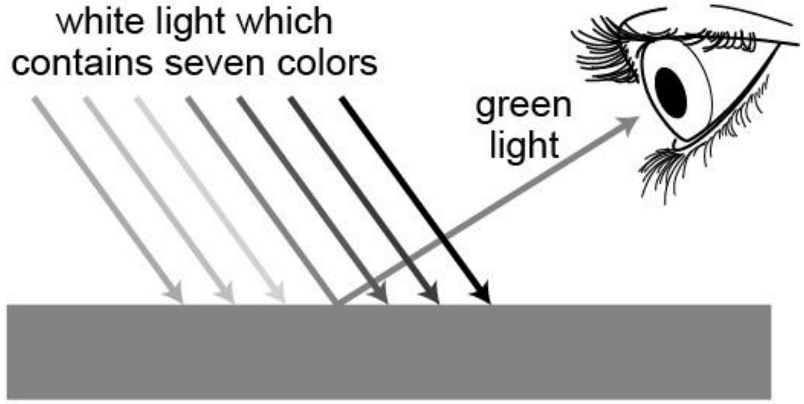
Suggestions:

- opaque: tinfoil
- transparent: plastic food wrap (cling wrap)
- translucent: wax paper

For each object, they can record their observations in a notebook or on a piece of paper.

Activity 2

Students can use colored pencils, crayons, or markers to model how light reflects off opaque objects. As students become more comfortable with the concept, different variables can be manipulated, such as the color of the light, to increase the rigor of the activity.



Resources

- Light and Shadows for Kids—Kids Academy video explaining some characteristic of light
- PhET Color Simulation—cross-platform simulation that allows the manipulation of many different variables

How can the function and structure of a prism be described and modeled?

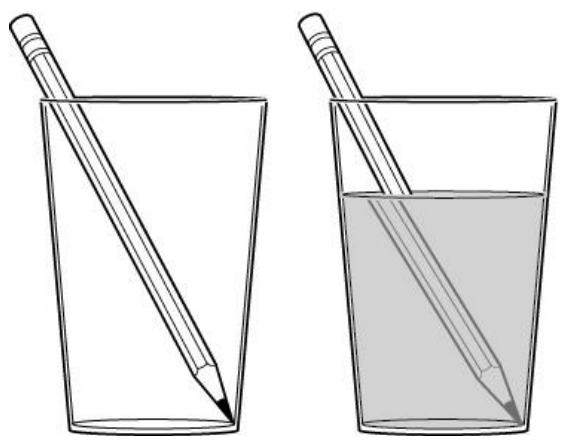
Background

A prism is a transparent material, like glass, plastic, or even a clear liquid, that refracts light. As light enters the material, its speed changes. A change in speed causes light to bend, and the different wavelengths of light bend as they enter and leave the prism. This characteristic is the reason white light displays a rainbow when shown through a prism.

Activity and Considerations

A simple setup involving two clear glasses, pencils, and some water can be used to demonstrate a prism. Viewing the glass from the side, students can observe the pencil appearing to bend. This phenomenon is caused by a change in the speed of the light as it enters the water.

Light Refraction in Water



Additionally, prisms can be purchased cheaply from online retailers. Demonstrate light refraction for students using a prism. An alternate method is using a spray bottle and water to show light refraction.

Resources

- Newton's Prism - demonstrations of light dispersion
- Newton's Light Experiment—short video from the BBC that explains Newton's light spectrum experiments
- Build Your Own Spectroscope—activity that creates a spectroscope out of common household materials

4.LS.9

Grade 4
From Molecules to Organisms: Structures and Processes
4.LS.9 Examine evidence to support an argument that the internal and external structures of plants (e.g., thorns, leaves, stems, roots, colored petals, xylem, phloem) and animals (e.g., heart, stomach, lung, brain, skin) function to support survival, growth, behavior, and reproduction.

Connections to *A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*:

Focus for Scientific and Engineering Practice(s):

- Engaging in Argument from Evidence

Focus for Crosscutting Concept(s):

- Systems and System Models
- Cause and Effect
- Structure and Function

Focus for Disciplinary Core Idea(s):

- Structure and Function

Guiding Questions

- What are the basic internal and external structures of plants and animals? (p. 88)
- How can the internal and external structures of plants be described and recognized? (p. 90)
- What evidence can be used to support the claim that internal and external plant structures support survival, growth, behavior, or reproduction? (p. 90)
- How can the internal and external structures of animals be described and recognized? (p. 92)
- What structures are used for survival, growth, and reproduction in animals? (p. 92)

- What structures are used for obtaining resources (e.g., sunlight, water, gases) that aid in survival, growth, and reproduction in plants? (p. 95)
- Which behaviors help animals survive and reproduce (e.g., migration, hibernation, herding)? (p. 96)

Key Academic Terms:

evidence, argument, growth, internal structure, external structure, thorn, leaf, stem, root, colored petal, xylem, phloem, heart, stomach, lung, brain, skin, survival, reproduction, behavior, function

Safety Considerations

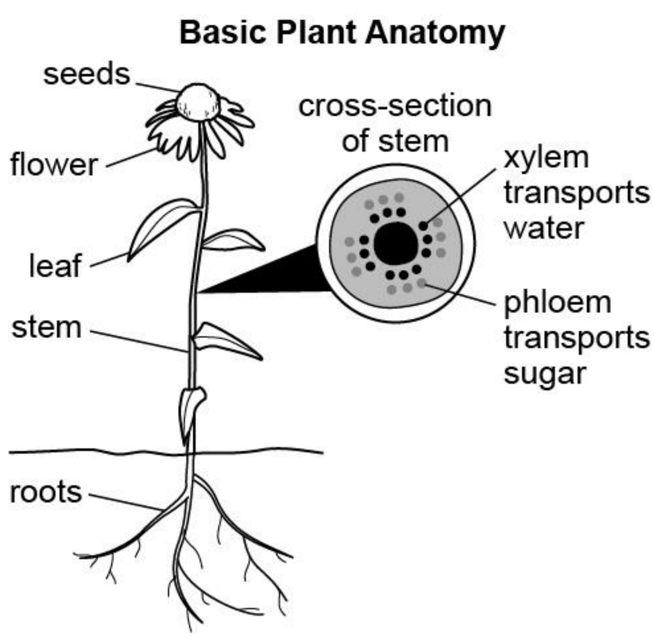
Please refer to the Alabama K–12 Science Safety Guidelines.

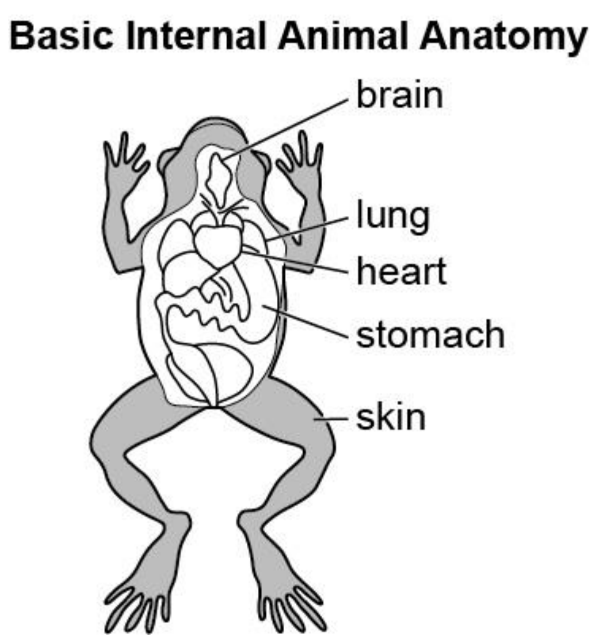
What are the basic internal and external structures of plants and animals?

Background

In general, plants have roots that carry water and nutrients up from the soil into the stem. The stem has two types of tissue, called xylem and phloem, that form layers within it. Xylem is responsible for moving water from the roots upward to the leaves of the plant, while phloem transports sugars and nutrients from the leaves to cells in the stem and roots. Plants have leaves that capture sunlight for use in the photosynthesis process, which produces sugars for the plant. Many plants have defensive structures, like thorns or spines, that impede predators. Colored petals in flowers are held up by rigid stems to attract pollinators. Pollinators may assist in a plant's reproduction cycle.

Animals also have external structures, like skin, that help with growth and survival. Internally, animals have hearts that pump blood throughout the body. Blood moves throughout the body carrying nutrients and oxygen to tissues and organs. Animal stomachs chemically break down food into the smaller molecules that the body uses to perform cellular respiration to produce energy. Lungs exchange carbon dioxide for oxygen. All body systems are controlled by the brain of the animal.





Activity and Considerations

Activity

Compare models of internal and external structures of plants and animals and have students observe similarities and differences between them.

Considerations

When gathering images of animals to show to students, take into consideration that some students may feel uncomfortable if the images are too realistic. Try to find a balance between scientifically accurate images and grade-appropriate images.

Resources

- Generation Genius—video about structure and function for kids in grades 3–5

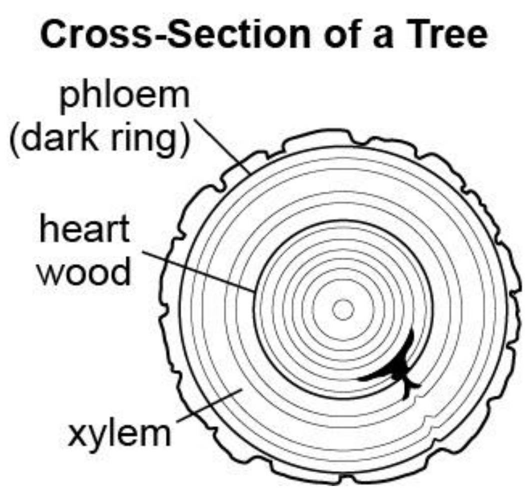
How can the internal and external structures of plants be described and recognized?

What evidence can be used to support the claim that internal and external plant structures support survival, growth, behavior, or reproduction?

Background

The external structures of the plant, such as leaves, stems, and roots, can be easily identified, and their purposes are more obvious than internal structures.

Internal structures can be recognized if observers know what they are looking for. Xylem and phloem are both tube-like structures in plants. They are often located near each other, and the phloem may be a darker layer of tissue due to the sugars that it transports.

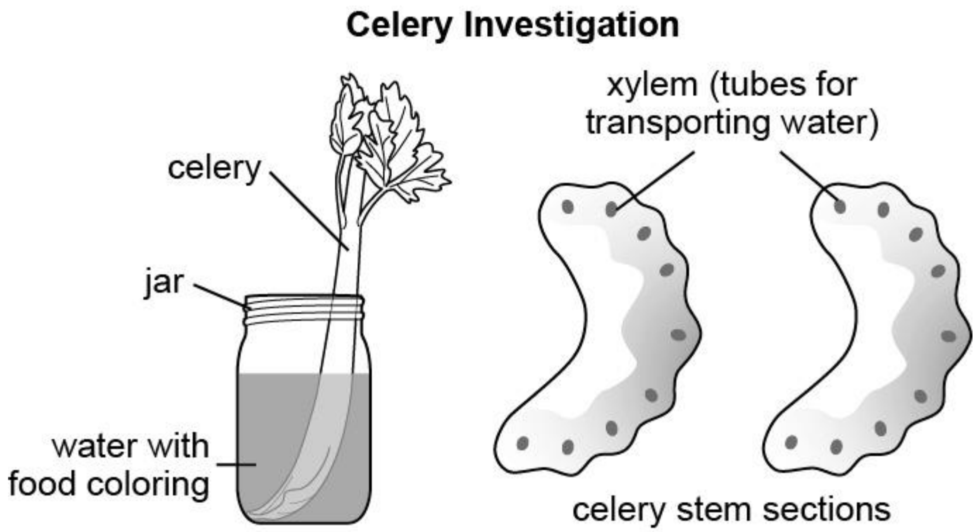


Evidence that these structures are important can be seen simply by the fact that most plants have them. One would expect to see more plants without these structures if they lacked importance.

Activities

Activity 1

Have students place celery into a container of water with food coloring overnight. When they return the next day, the celery should be rigid, and the xylem should be easily observable due to the dyed water passing up through them from the water. Students can dissect the celery and try to remove the xylem to better observe their round shape.



An alternative approach can be to have students dissect celery and attempt to identify structures they believe are xylem and phloem. Then, they can place the celery in water and better understand why the xylem can now be so easily identified.

Activity 2

Investigate phototropism with students to study how well plants grow when sunlight is restricted.

Resources

- Celery Investigation—step-by-step directions for the celery investigation
- Phototropism Experiment – Do plants grow more toward certain colors of light?
- Grow Some Good – how to create a phototropism maze

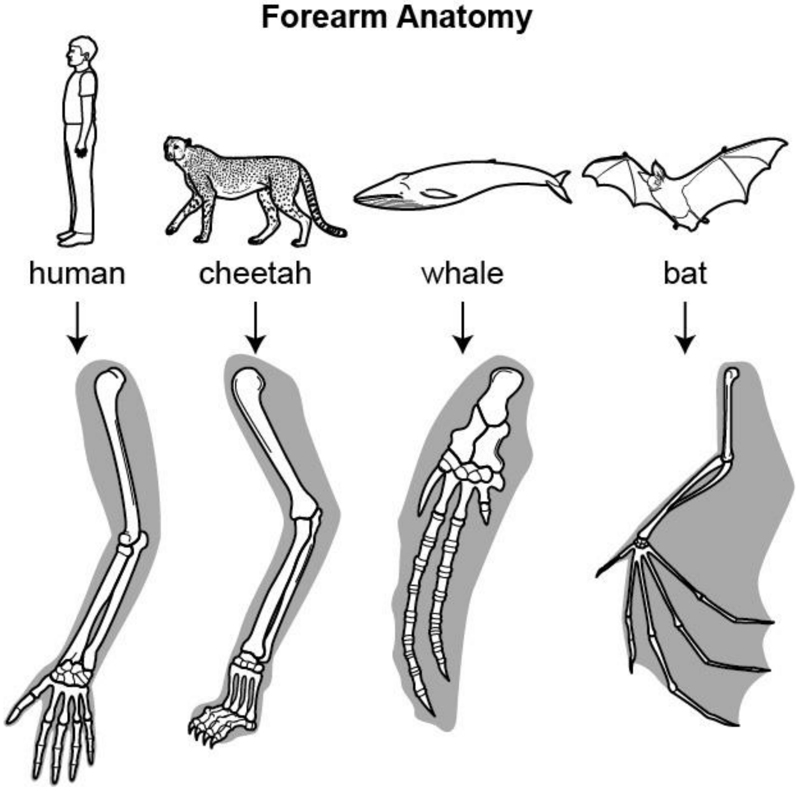
How can the internal and external structures of animals be described and recognized?

What structures are used for survival, growth, and reproduction in animals?

Background

Animal organs may appear different depending on the species of animal, but they perform similar functions. Bones help provide structure, the heart pumps blood, the stomach aids in digestion of nutrients, lungs make respiration possible, and the brain controls all body functions. The differences between animal organs offer explanations for individual species survival and predict growth patterns and reproductive habits.

Forearm Anatomy



The differences between the structure of forearms in different animals show how each structure functions uniquely for the animal’s survival. The organization of the bones and the number of bones in each region are important points of comparison between these animals.

Animals can use physical structures to adapt to environmental conditions. For example, the fur of an arctic fox changes color with the season to help it better blend into its environment. During the warm months of the year, the color of the fox coat is brown and grey, but during the winter, the fox grows white fur. This change helps it survive harsh winters and better blend into its environment.

Arctic Fox

Activities

Activity 1

Identify common animals with external structures that are used for a similar purpose. For example, animals that live in similar places or perform similar activities could be grouped together.

Habitats	Activities
• Cold • Hot • Wet • Dry	• Fly • Swim • Hunt • Migrate

Activity 2

Have students look at a variety of animal images and discuss what common internal organs might be different and why. For example, the heart of an elephant is much larger than the heart of a mouse. It is reasonable to assume that larger animals require larger hearts to pump blood throughout their bodies.

Resources

- Digestive Track of Cow vs. Chicken—cartoon rendering from Encyclopedia Britannica
- Digestive Track of Human vs. Rabbit—cartoon rendering from open textbook website
- Internal Organs of Human vs. Mouse—cartoon rendering from an advocacy group

What structures are used for obtaining resources (e.g., sunlight, water, gases) that aid in survival, growth, and reproduction in plants?

Background

The leaves on plants are responsible for absorbing sunlight and carbon dioxide. The roots of the plant absorb water and other nutrients into the plant for transportation through the xylem. The cellular components in the leaves then use sunlight, water, and carbon dioxide to perform the process of photosynthesis and produce sugar and oxygen. The production of sugar is necessary for plant growth and reproduction because the plant uses sugar for energy. The sugars are transported throughout the plant by the phloem.

Healthy plants can grow to maturity and reproduce. Many plants reproduce through pollination, though other methods do exist.

Not all plants have visual defensive mechanisms like thorns or burs. Some may use chemicals that affect how they taste or smell to protect themselves from predators.

Activity and Considerations

Activity

Have students compare plants from different ecosystems to see how and why some of their structures may differ. As a class, grow two or more different types of plants side by side in different areas around the room and see how successful they are over time (suggestions: bean, radish, pea). After the activity has been completed, other variables (the amount of water or light) can be changed to determine how each variable affects a plant's growth.

Considerations

Only vascular plants are being considered for this standard and guiding question.

Which behaviors help animals survive and reproduce (e.g., migration, hibernation, herding)?

Background

Animal behavior is a key factor for survival in the wild. Some behaviors are similar across species, while others may be unique to a specific group. The list below provides some common examples:

- Migration—helps animals stay in a tolerable climate and increases their chances of finding food and reproducing
- Hibernation—important for animals living in cold environments with limited food supplies that must closely ration their metabolic rates
- Caring for Young—while different types of animals may have different lengths of care, it is common to see animals caring for their offspring at least at birth
- Defending Territory—this type of behavior is typically associated with predators, but many animals are territorial due to limited resources
- Communication—this may be verbal or nonverbal, but communication is important with animal groups across species

Activity and Considerations

Activity

Have students generate a list of various animal behaviors they have observed. From the list, formulate reasons why an animal may have acted each way and whether it would help that animal survive longer. If the setting allows, birds, squirrels, or other small animals can be observed outside a classroom for this activity. The instructor can provide a list of common behaviors to look for or use a list as a discussion point after students make observations.

Considerations

It is important to recognize that behaviors can be classified as instinctual or learned. Domesticated animals are good ways to show learned behavior. For example, a dog running toward the door if it hears its leash has been picked up is demonstrating a learned behavior.

Resource

- List of Squirrel Behaviors—webpage from *National Geographic*
- Generation Genius — 13-minute video on animal group behaviors

4.LS.10

Grade 4
From Molecules to Organisms: Structures and Processes
4.LS.10 Obtain and communicate information explaining that humans have systems that interact with one another for digestion, respiration, circulation, excretion, movement, control, coordination, and protection from disease.

Connections to *A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*:

Focus for Scientific and Engineering Practice(s):

- Obtaining, Evaluating, and Communicating Information
- Engaging in Argument from Evidence

Focus for Crosscutting Concept(s):

- Systems and System Models

Focus for Disciplinary Core Idea(s):

- Structure and Function

Guiding Questions

- What is the overall purpose of each of the main human body systems (skeletal, muscular, nervous, immune, digestive, excretory, circulatory, respiratory)? (p. 99)
- Which major organs make up each organ system? (p. 99)
- How can the interrelatedness of two or more body systems be modeled? (p. 106)
- What evidence would be needed to claim that human body systems work together to provide a larger function? (p. 106)
- Which body systems work together to circulate materials throughout the body? (p. 107)
- Which body systems work together to aid in gas exchange? (p. 108)

- Which body systems work together to eliminate waste materials? (p. 109)
- Which body systems work together for body movement? (p. 110)
- Which body systems work together to protect humans from disease? (p. 112)
- What happens to the human body when a body system fails? (p. 112)

Key Academic Terms:

body system, digestive system, mouth, stomach, esophagus, intestine, circulatory system, heart, blood, vessel, nervous system, brain, spinal cord, nerve, excretory system, kidney, bladder, liver, absorption, respiratory system, lung, trachea, immune system, skin, skeletal system, bone, muscular system, muscle

Safety Considerations

Please refer to the Alabama K–12 Science Safety Guidelines.

What is the overall purpose of each of the main human body systems (skeletal, muscular, nervous, immune, digestive, excretory, circulatory, respiratory)?

Which major organs make up each organ system?

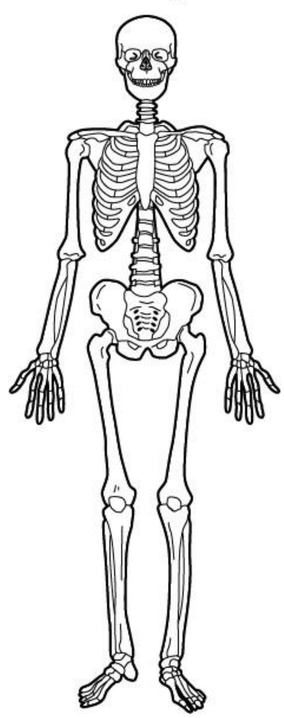
Background

The human body is made up of several different systems, each responsible for carrying out specific functions. Systems also work together for specific functions. For example, the respiratory and circulatory systems send nutrients throughout the body and remove waste products to ensure health. The excretory system removes waste. The nervous system collects information from the environment and generates a bodily response. The skeletal and muscular systems help the body move, and the immune system fights off disease and infection.

Skeletal and Muscular Systems

The skeletal system includes all the bones and joints in the human body. This system acts as a base for muscles to attach for movement and as protection for soft tissues and organs. Bones connect to each other through ligaments and tendons at areas called joints. A drawing of a human body skeleton is shown below.

Skeletal System

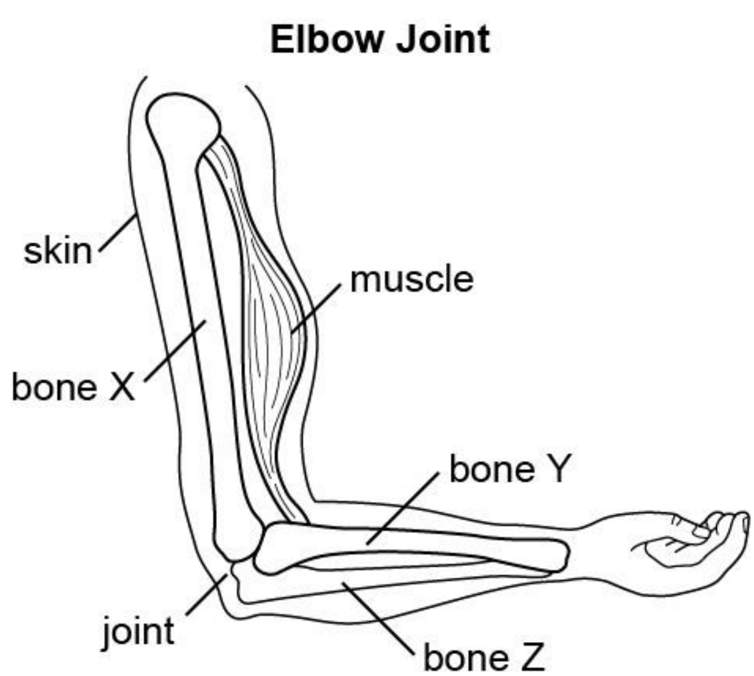


The muscular system is responsible for movement in the human body. There are different types of muscles that perform different tasks inside the body. Muscles move by contracting, meaning the fibers in them shorten or lengthen to provide movement.

The three muscle types are listed below.

- Skeletal muscle
  - Contracts on command (voluntary)
  - Moves bones
- Smooth muscle
  - Does not contract on command (involuntary)
  - Found in organs
- Cardiac muscle
  - Does not contract on command (involuntary)
  - Found in the heart

The drawing below shows an elbow joint where parts of the skeletal and muscular systems work together to provide movement of the arm.



Nervous System

The nervous system functions by sensing the environment inside and outside of the human body and transmitting signals between the brain and all parts of the body. The nervous system contains three main components: the brain, the nerves, and sensory organs like the eyes, ears, nose, tongue, and skin.

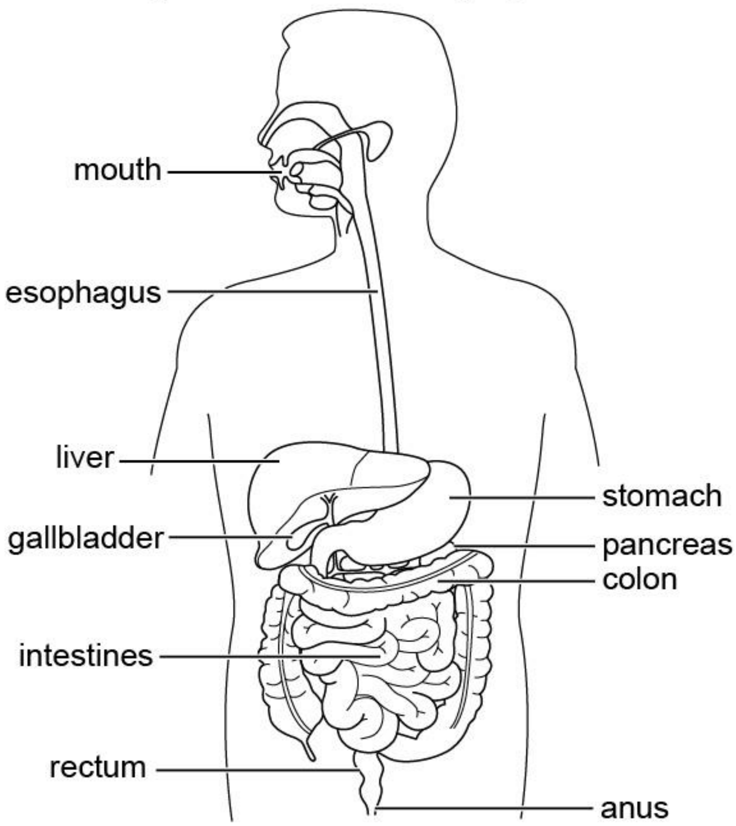
Immune System

The immune system functions to keep the human body healthy by protecting it from diseases and microscopic invaders called pathogens. White blood cells are used to destroy bacteria and pathogens that enter the body. When a cut or scrape becomes inflamed, the body sends more blood and white blood cells to the area to fight off infection.

Digestive and Excretory Systems

The digestive and excretory systems help the body absorb nutrients and remove waste. The main parts of the digestive and excretory systems are shown in the drawing below.

Digestive and Excretory Systems



Some parts of the digestive and excretory systems are listed below.

- Mouth—mechanical and chemical predigestion
- Esophagus—pathway to the stomach
- Stomach—mechanical and chemical digestion
- Intestines—chemical digestion in which most nutrients are absorbed into the body and the rest is discarded as waste
- Anus—opening where solid waste exits the body

Circulatory and Respiratory Systems

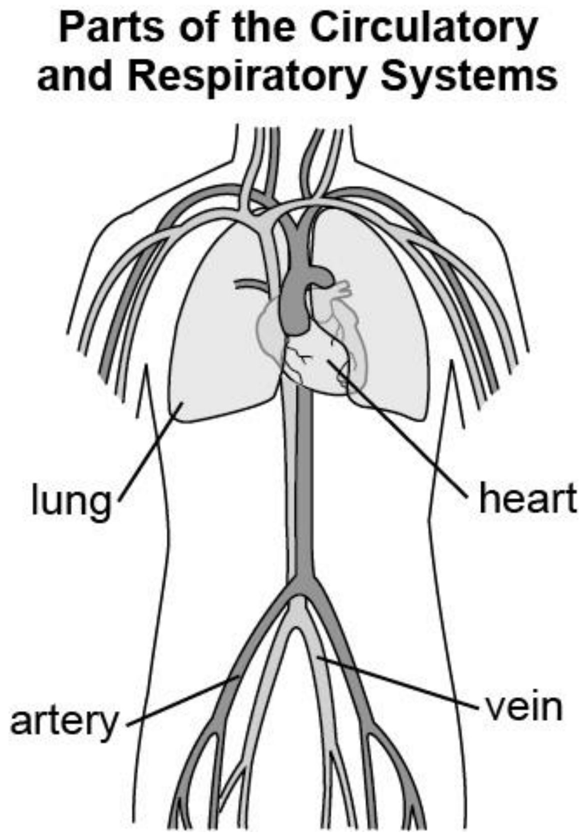
The respiratory and circulatory systems help circulate oxygen and nutrients to all the organs in the human body.

The main parts of the respiratory system are listed below.

- Larynx—vocal cords
- Trachea—lined with cartilage so that it can't collapse (can feel with your fingers), contains hairs to prevent dust, mucus, and bacteria from making it to the lungs
- Lungs—gas exchange with blood, expand and contract when the diaphragm muscle moves

The main parts of the circulatory system are listed below.

- Heart—four chambers that work together to pump blood throughout the body
- Arteries—carry blood away from the heart to different organs in the body
- Veins—carry blood toward the heart



Activities and Considerations

Activity 1

Place students in small groups and have them trace one student's outline on a piece of butcher paper. Assign each group a different body system and have the groups cut out organs from the system and glue them into their proper locations on the outline. Groups should also include a short summary of what the system does to help the body and how each organ works in the system. If time allows, groups can meet up and find connections between their assigned body systems.

Activity 2

Students can create a foldable diagram to show the systems of the human body independently of each other. On the back side of the diagram, students can write the main function of each type of system.

Activity 3

This activity allows students to investigate behavioral reactions between the nervous system and the muscular system. Behaviors are a type of response that organisms make based on changes in their environment. They help organisms survive and reproduce. Behavioral responses involve different parts of the body working together, including cells, organs, and whole body systems.

Materials:

- Large space
- Stopwatch
- Whistle or bell
- Meter stick or tape measure

Procedure:

1. Place students in pairs.
2. Instruct one of the students (student X) in each pair to close both eyes and hold out both hands.
3. The other student (student Y) will touch student X's right index finger. When student X feels the touch, student X should wiggle the left index finger.
4. Perform this action several times. Students should think about how the message gets from the right index finger to the left index finger. *How is the brain involved?*
5. Have students measure the distance between student X's right index finger and student X's head and the distance between the head and the left index finger.
6. Record the measurements in a table. The instructor can calculate the average distance of the students.
7. Have all the students join hands.
8. The first student should have a stopwatch, and the last student should have a whistle or bell.
9. Instruct the first student to squeeze the hand of the second student and start the stopwatch at the same time.
10. When the second student feels the squeeze, the second student should squeeze the hand of the third student, etc.
11. When the last student feels the squeeze, the last student should blow the whistle or ring the bell, which will signal the first student to stop the stopwatch.
12. The instructor can add up the total distance the message traveled and find the speed of transmission of the message for the whole class.

Data Table

Student's Name	Distance from Right Index Finger to Brain	Distance from Brain to Left Index Finger	Total Distance

Considerations

As each system is taught, be sure to include how it can work with other systems in the body.

Often, arteries are taught as the pathway for oxygen-rich blood and veins as the pathway for deoxygenated blood. This general rule can lead to greater misconceptions at the middle school and high school level. The correct and most accurate way to approach this system is to stick to the convention that arteries carry blood away from the heart and that veins carry blood towards the heart.

Resource

- Human Body Foldable—website that hosts a printable template for human body systems

How can the interrelatedness of two or more body systems be modeled?

What evidence would be needed to claim that human body systems work together to provide a larger function?

Background

The many systems of the human body are constantly communicating and working together. An abundance of evidence can be gathered that supports the idea of human systems working together. Some examples include the following:

- healing wounds or broken bones
- expressing emotion
- playing sports and movement

Activity

Present students with various scenarios and have them list the systems of the human body that are most likely responsible for responding to the scenario or causing it to occur. For example, a student trips and starts to drop their book bag. A possible student response is listed below.

1. The nervous and sensory systems detect what is occurring and send signals to the muscular and skeletal systems.
2. The muscular and skeletal systems interact to stop the student from falling and aid in catching the book bag.

Other scenarios that can be presented to students. Have the students identify the different body systems that work together in each scenario.

- Hearing an alarm clock go off (nervous, muscular, skeletal)
- Walking on hot pavement (nervous, muscular, skeletal)
- Running (nervous, circulatory, respiratory, muscular, skeletal)
- Eating (skeletal, muscular, circulatory, digestive)

Which body systems work together to circulate materials throughout the body?

Background

The circulatory system is responsible for the transportation of nutrients and immune responses throughout the body. Veins and arteries are analogous to a highway system that allows for transportation. Veins and arteries are found in many sizes in different body parts. Veins move blood towards the heart but lack muscular help for movement. Arteries move blood away from the heart and often have muscular assistance to help push the blood forward.

Activity and Considerations

Activity

Students can model the journey of a red blood cell using a comic format. The depth at which this journey is shown is up to the individual instructor. Extensions could include how the systems help with nutrient transport and oxygen and carbon dioxide exchange.

Considerations

There are things, like cholesterol or sickle cells, that may obstruct the pathways of the circulatory system. This may be an opportunity for cross-curricular instruction with health or physical education.

Resources

- Summary of a Red Blood Cell—quick read for instructors to become familiar with the general process
- Human Liver—detailed information on liver function and how it works with the circulatory system
- Engineering a Circulatory System—activity from the Exploratorium Website
- Comic Templates—website that has printable templates for comic creation

Which body systems work together to aid in gas exchange?

Background

The circulatory and respiratory systems work closely together to regulate levels of oxygen and carbon dioxide in the body. The lungs are responsible for the inhalation of oxygen, which is then passed into the bloodstream. This oxygenated blood enters the heart and is pumped throughout the body through arteries in the circulatory system. Oxygen is exchanged for carbon dioxide throughout the body. The carbon dioxide moves back toward the heart in the bloodstream through veins. The heart pumps blood containing carbon dioxide back to the lungs, where the gas is exchanged for oxygen. The lungs expel the carbon dioxide with each contraction and inhale oxygen with each expansion.

Activity and Considerations

Activity

Have students find their resting heart rate and record it on a piece of paper. They should also make observations such as descriptions of breaths. Then, have students engage in a physically demanding activity. At the end of the activity, have them find their heart rate again and make similar observations.

Students can make connections between the circulatory and respiratory systems from this activity by keeping track of breaths per minute as well. They should observe the general trend that as heart rate increases, the number of breaths per minute should also increase.

Engage in a discussion about how the systems must work harder in certain situations. As an extension, students could talk about how long it takes to return to the resting rate and why some individuals may return to their resting rate faster than others.

Considerations

This guiding question may have an opportunity for cross-curricular application with physical education or health.

Resource

Resting Heart Rate—how to measure resting heart rate

Which body systems work together to eliminate waste materials?

Background

The digestive and excretory systems work together to remove waste from the human body. The digestive system is responsible for the collection and removal of solid waste through the intestine and anus while liquids (blood) move through the kidneys, liver, and bladder.

Activities

Activity 1

Have students construct filters that work to separate solids of different sizes and liquid mixtures to see a connection between the two body systems that help with elimination of waste materials.

Activity 2

Demonstrate the digestive and circulatory process with student interaction.

Procedure:

1. Blend some simple foods like banana or toast with water to show mechanical digestion. This represents the mouth and stomach.
2. Send the mixture through a funnel and tube, allowing it to fall onto a baking sheet. This represents the intestine.
3. Use sponges to soak up liquids and squeeze the liquids out into a bucket. This represents the absorption of nutrients in the liver, kidneys, and bladder.
4. Put solid waste from the baking sheet onto paper towels to remove more moisture. This also represents the intestine.
5. Using a paper towel, form the solid waste into cylindrical shape. This represents the formation of stool before leaving the body through the anus.

Resources

- Kidney Filtering—detailed engineering project with printable material
- Kidney Filtering—simplified filtering investigation

Which body systems work together for body movement?

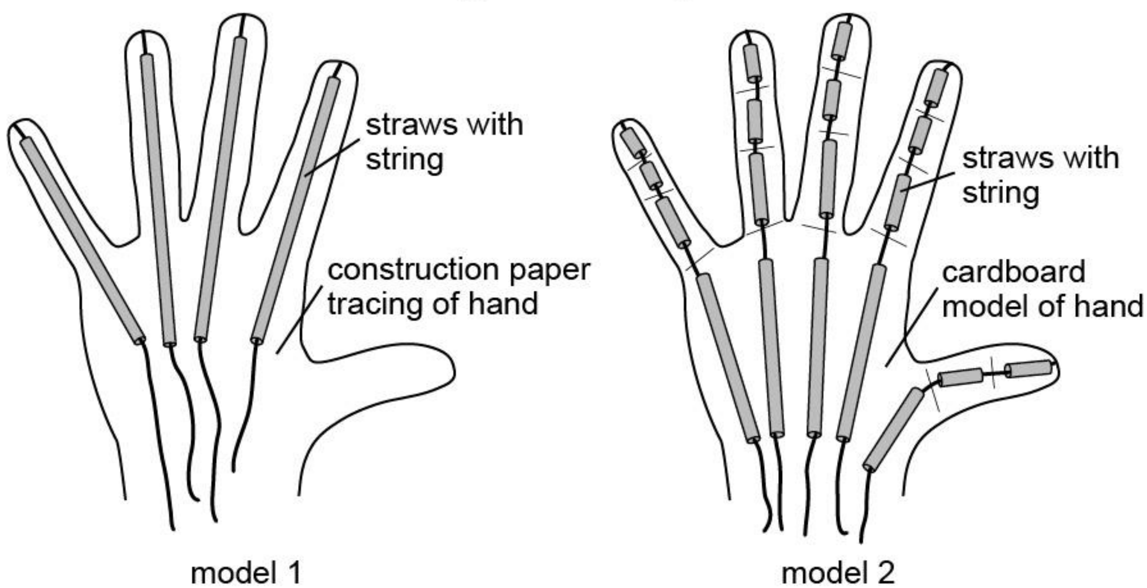
Background

The nervous, circulatory, respiratory, muscular, and skeletal systems all work together to facilitate movement in the human body. The nervous system sends out signals for muscle contraction, which moves the bones to which the muscles are attached. The circulatory and respiratory systems provide the muscles with the nutrients they need to function.

Activity

Have students try to create a functional model of a joint. This can be done a variety of different ways depending on the materials available in the classroom. Students should be attentive to interactions between muscles and bones for this activity. Items like rubber bands work well as muscle groups or tendons. Two ways of constructing hinge joint models are shown below.

Hinge Joint Examples



Model 1 shows a tracing of a hand where the palm has been glued to a sturdy surface. The fingers on the hand are free to bend down when pulled by the strings.

Model 2 shows a cardboard cutout of a hand tracing. The fingers on the hand have been purposefully creased and supported by straws to help them flex appropriately when pulled by strings.

Resource

- Hand Models—website with materials list and directions for hand model creation

Which body systems work together to protect humans from disease?

What happens to the human body when a body system fails?

Background

The immune system is the primary force that protects the human body, but it works with every other system. For example, the immune and lymphatic systems may work together to create mucus and then need the excretory and respiratory systems to help expel it from the body.

If an entire body system fails, death is the most likely result. Partial failure of a system can likely be sustained due to medical advances and technology. Organ transplants, antibiotics, vaccinations, and medications bolster and support our body systems whether they are functioning appropriately or need assistance.

Considerations

Discussion on these topics may bring up emotional responses with students. It is important to know your students and anticipate possible negative responses they may experience due to discussions or activities.

Resources

- Why You Feel Awful When You're Sick—TEDEd video on YouTube
- How do Pain Relievers Work—TEDEd Video on YouTube
- How do Vaccines Work—TEDEd video on YouTube
- How does Your Immune System Work—TEDEd video on YouTube
- Getting Under Our Skin Playlist—curated videos from TEDEd YouTube Account

4.LS.11

Grade 4
From Molecules to Organisms: Structures and Processes
4.LS.11 Investigate different ways animals receive information through the senses, process that information, and respond to it in different ways (e.g., skunks lifting tails and spraying an odor when threatened, dogs moving ears when reacting to sound, snakes coiling or striking when sensing vibrations).

Connections to *A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*:

Focus for Scientific and Engineering Practice(s):

- Developing and Using Models
- Constructing Explanations
- Planning and Carrying Out Investigations

Focus for Crosscutting Concept(s):

- Systems and System Models
- Structure and Function

Focus for Disciplinary Core Idea(s):

- Information Processing
- Structure and Function

Guiding Questions

- What are animal senses? (p. 115)
- How do animals sense and perceive their environment (e.g., sound, light, color, odor, temperature)? (p. 115)
- What is perception? (p. 117)
- How do animals process what they sense around them? (p. 117)

- What is a behavioral reaction or response? (p. 119)
- What role do memories have in an organism's response to the environment? (p. 119)

Key Academic Terms:

sense, reaction, response, stimulus, behavior, sense receptor, memory, perception, behavioral output

Safety Considerations

Please refer to the Alabama K–12 Science Safety Guidelines.

What are animal senses?

How do animals sense and perceive their environment (e.g., sound, light, color, odor, temperature)?

Background

Senses are ways of gathering input, or information, from the environment. Different organisms use different senses to survive in different environments. Some examples of senses that organisms use are listed below.

- Touch
- Smell
- Taste
- Sight
- Sound
- Electric and magnetic field sensitivity

Animals use specialized organs and cells to sense changes in the environment and to communicate those changes throughout their body systems.

Common organs for each sense are listed below.

- Skin, hairs, nerves—help in sensing contact through touch
- Nose—identifies smells (Other mechanisms are used by non-mammals. For example, insects use pores.)
- Tongue—identifies tastes (Other mechanisms are used by non-mammals. For example, insects use specialized cells on their feet.)
- Eyes—identify light or other forms of electromagnetic radiation
- Ears—identify sound waves
- Unknown—the specific mechanism or organ that helps organisms sense Earth's magnetic field is still being researched and debated

Activity

Have students brainstorm a list of how animals can use their senses to receive, process, and respond to information in different ways. Use examples from the standard to lead discussion.

Resources

- Sea Turtle Navigation—Newsela article that can be adjusted to different reading levels
- List of Interesting Animal Senses—neuroscience researcher’s website

What is perception?

How do animals process what they sense around them?

Background

Perception is the process of decoding information sensed from the environment and reacting to it consciously or subconsciously (voluntarily or involuntarily). The root of perception lies with stimuli, which come from the environment. A stimulus is sensed by the appropriate receptor on the animal and a signal is sent to the brain. The brain then translates this information and sends a response back to the appropriate muscles or body systems.

Illustrated models typically include flow diagrams or numbered lists that show the order in which the systems interact with one another.

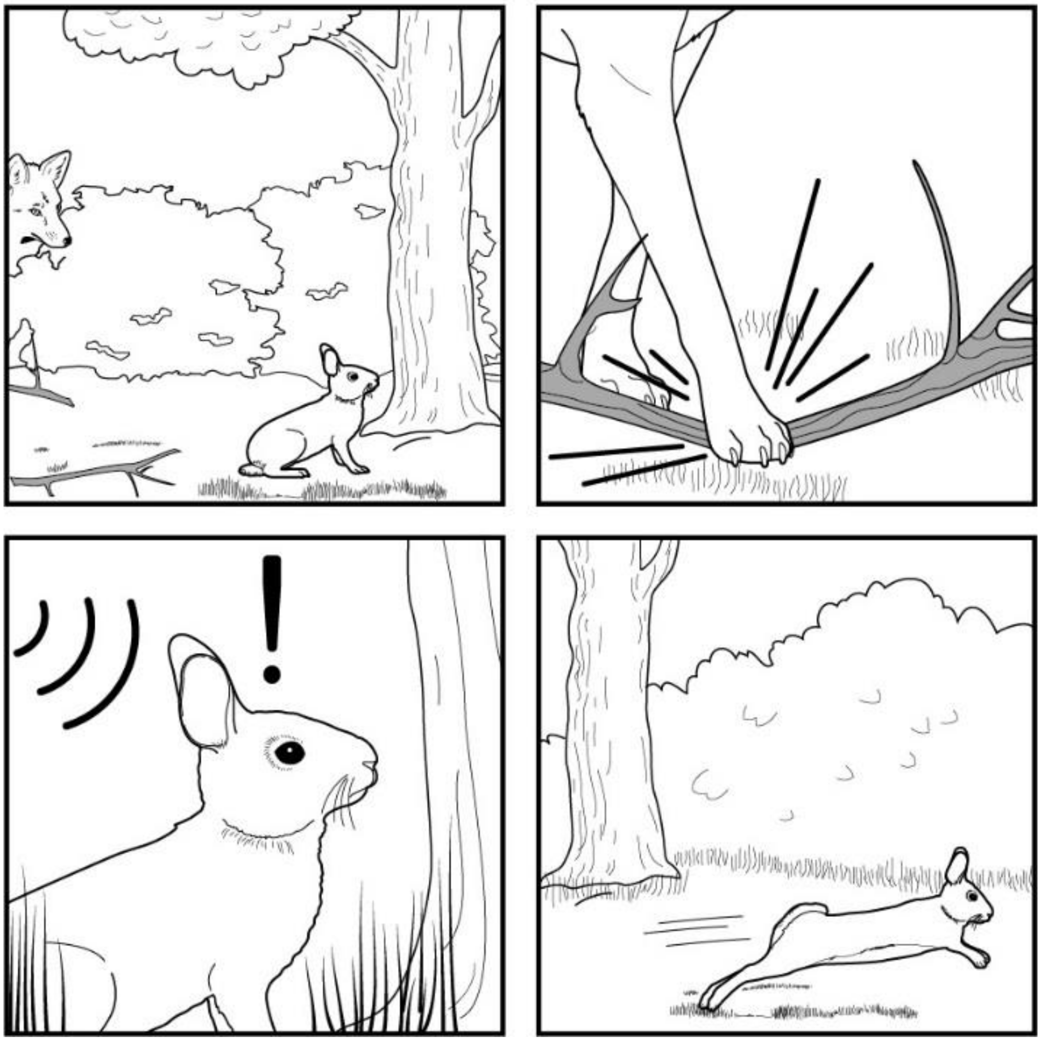
Activity

Have students create short cartoons that show characters perceiving stimuli from the environment. In addition to the cartoon, students can include a more traditional model that helps to justify or explain their creations.

An example of the traditional model and a cartoon, both describing a rabbit reacting to sound, are shown below.

1. Sound is produced.
2. Ears sense sound.
3. Message is sent to brain.
4. Brain identifies sound as dangerous.
5. Brain signals rabbit to run.

Stimuli Cartoon



Resource

- Comic Templates—website that has printable templates for comic creation

What is a behavioral reaction or response?

What role do memories have in an organism's response to the environment?

Background

When animals respond to stimuli, the response can be instinctual or learned. An instinctual response is innate, while a learned response can be shaped over time through experience.

Memories of past experiences help to shape future reactions. If an animal has a positive memory of an experience and can associate it with a current stimulus, they are more likely to repeat that behavior in the future. The opposite is true for negative associations. These memories assist the animal in avoiding dangerous situations.

Memories do not have to have happened to the specific animal for this to be true. If an animal witnesses the experience of another, positive or negative, it can form a memory that can serve later as an associated behavioral response. Some organisms can teach learned behaviors to their offspring or others.

Activities and Considerations

Activity 1

Have students discuss learned and instinctual behaviors in humans and how these behaviors might differ in dogs or cats. Discuss training animals, like dogs or cats, and what techniques would be most effective to train them.

Then, examine how wild animals might acquire new behaviors based on responses to the environment and determine whether this is advantageous (e.g., squirrels visiting a bird feeder).

Activity 2

Show the two videos included in the Resources section on the next page and discuss the use of tools by animals in the wild. The use of tools was once thought to be unique to humans. The discovery of tool use by wild animals has changed how scientists view the intelligence of animals.

Considerations

Instructors could find videos or articles about animal behaviors and incorporate them into class discussions. Octopuses are very intelligent creatures, and there are many stories about how a captive octopus demonstrates learned behavior.

Resources

- Animals Adapting to Urban Settings—*National Geographic* article about animals responding to changes in their natural habitats
- Avian Garbage Collectors—article about a French theme park that trains birds to pick up trash
- CrowBox Project—open-source vending machine to train birds
- Chimpanzees and Tools—video from the Jane Goodall Institute documenting chimpanzees using tools in the wild
- Crows and Tools—video by The Atlantic showing the use of tools by crows in the wild

4.ES.12

Grade 4
Earth's Systems
4.ES.12 Construct explanations by citing evidence found in patterns of rock formations and fossils in rock layers that Earth changes over time through both slow and rapid processes (e.g., rock layers containing shell fossils appearing above rock layers containing plant fossils and no shells indicating a change from land to water over time, a canyon with different rock layers in the walls and a river in the bottom indicating that over time a river cut through the rock).

Connections to *A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*:

Focus for Scientific and Engineering Practice(s):

- Constructing Explanations and Designing Solutions

Focus for Crosscutting Concept(s):

- Patterns
- Cause and Effect

Focus for Disciplinary Core Idea(s):

- The History of Planet Earth
- Earth Materials and Systems

Guiding Questions

- What is a fossil? (p. 123)
- What types of materials are usually found as fossils? (p. 123)
- How can a fossil help describe the environment when a rock layer formed? (p. 123)
- What types of rock and fossil evidence indicate that Earth has changed over time? (p. 123)

- How can fossil evidence be used to explain processes that occurred on Earth? (p. 123)
- How can patterns found in rock formations be used to explain processes that occurred on Earth? (p. 126)
- How can patterns in rock layers be used to determine the relative ages of rock layers and fossils? (p. 126)
- How can a model be used to show the formation of rock layers? (p. 126)
- How are canyons usually formed? (p. 131)

Key Academic Terms:

deposition, erosion, volcanic eruption, earthquake, canyon, rock layer, landslide, fossil, evidence, pattern, rock formation, time scale, intrusive, plutonic, extrusive, volcanic

Safety Considerations

Please refer to the Alabama K–12 Science Safety Guidelines.

What is a fossil?

What types of materials are usually found as fossils?

How can a fossil help describe the environment when a rock layer formed?

What types of rock and fossil evidence indicate that Earth has changed over time?

How can fossil evidence be used to explain processes that occurred on Earth?

Background

A fossil is a type of evidence that shows the existence of prehistoric organisms. Fossils can be remains, imprints, or casts of organisms that formed over a long period of time. Shells, teeth, and bones are common fossil types because of their hard and slightly porous characteristics. To make a fossil, an organism must be covered with some type of sediment (mud, sand, tar, etc.) and then exposed to high amounts of pressure over time. Minerals leach into the pores of shells, bones, and teeth and eventually completely replace the original structures.

Fossils help to show the types of organisms that lived in a specific location over time. For example, fossils of ocean organisms may be found in mountain regions, suggesting that the area used to be underwater. Fossils may also provide clues for the location of ancient bodies of water and provide insight into past environmental conditions.

The formation of fossils provides evidence that Earth goes through physical changes over time. From mountain formation to continental movement, pieces of evidence are available worldwide that help humans better understand the history of Earth.

Activities

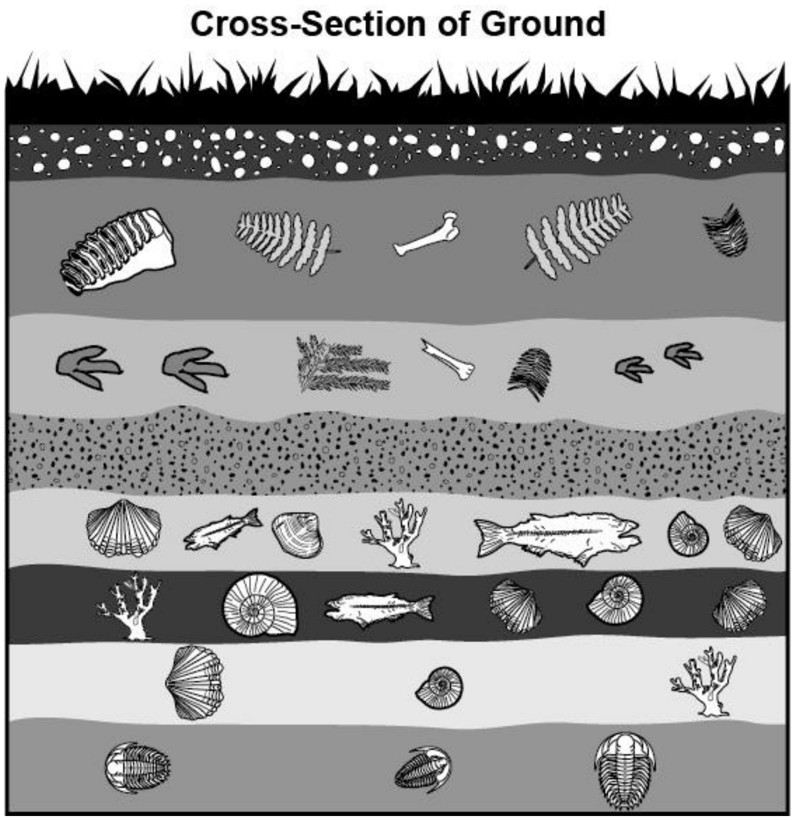
Activity 1

Provide students with some small toy animals and a variety of mediums. Students should press their toy into the different mediums and see if there are differences in the imprint left behind. This can guide discussions around the conditions needed for the fossilization process to occur.

Activity 2

This activity involves a geologic column model, which is a cross section of part of Earth's crust. These models are used to show changes in sediment, tectonic activity, and the fossil remains of organisms that lived during the time of each layer's development. Provide students with a similar model to the diagram below. Ask the students a variety of questions and lead them in a discussion. Some sample questions and answers are listed below.

1. What possibly caused the difference in color in each layer?
    a. Different types of sediment were deposited over time.
2. What can be concluded when aquatic (marine) organisms are in one layer and land animals are in the layer directly above them?
    a. The environment changed.
3. Which layer is the oldest?
    a. Bottom layer
4. Which layer is the youngest? Why?
    a. Top layer. It was formed most recently, above the other layers.
5. Why do some organisms appear in some layers but not in others?
    a. Organisms may migrate (move to new areas). A fossil doesn't always form when an organism dies. An environmental change may have occurred.



Resources

- [Four Lesson Plans on Fossils]—provided by Ohio State University
- [Fossil Fondue]—website that contains materials list and activity outline

How can patterns found in rock formations be used to explain processes that occurred on Earth?

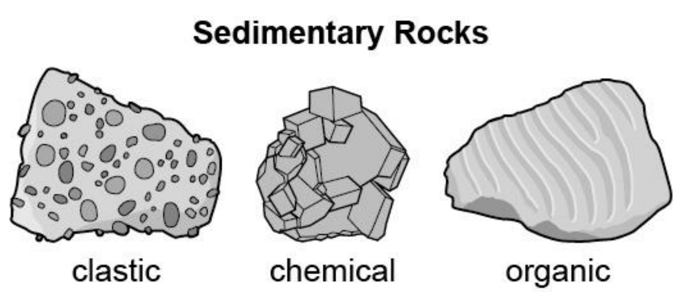
How can patterns in rock layers be used to determine the relative ages of rock layers and fossils?

How can a model be used to show the formation of rock layers?

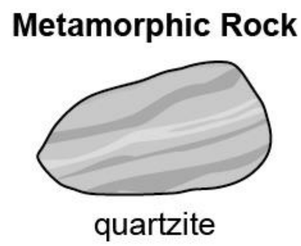
Background

There are three main ways that rocks are formed on Earth, and there are recognizable traits in them that provide evidence for their formations. Fossils form in sedimentary rock. The three types and their recognizable traits are listed below.

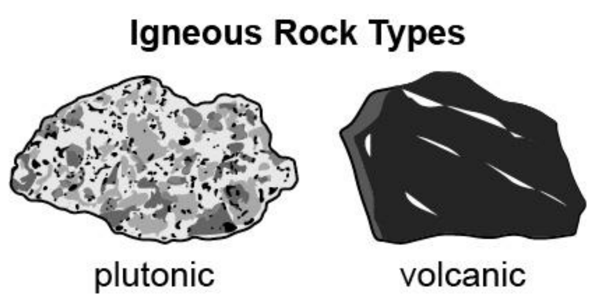
1. Sedimentary rock—formed when layers of materials (pieces of rock, sand, mud, etc.) are pressed together tightly or combine due to chemical activity. There are three subtypes of sedimentary rocks.
    a. Clastic—small pieces of rock get pressed together into a larger rock
    b. Chemical—liquid evaporates and leaves minerals behind, which form a rock
    c. Organic—fossilized material is exposed to high pressure and forms a rock



2. Metamorphic rock—formed when rocks and minerals are chemically changed, due to extreme temperature and pressure, deep within Earth. They have a distinct banding pattern due to the high levels of pressure.

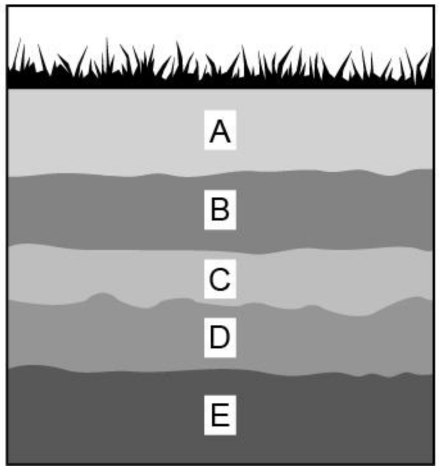


3. Igneous rock—formed by the cooling of lava or magma.
   a. Plutonic (intrusive)—formed slowly by magma below the surface of Earth (internal). Typically has large minerals that can be observed without a microscope. Granite is one example.
   b. Volcanic (extrusive)—formed quickly by lava above the surface of Earth (external). May appear glassy, like obsidian, and requires the use of a microscope to view minerals.



The law of superposition provides an easy rule for distinguishing the age of the layers in rock formations. The law states that layers closer to the bottom of the formation must be older than layers near the top. The model below shows relative dating using the law of superposition.

Relative Dating Using the Law of Superposition



The model shows that layer E is the oldest because it is located below all other layers.

Activities

Activity 1

Students can do a variety of activities around crystal formation. Rock candy can be grown in class to show how large crystals take longer to form than small ones. The instructor can also illustrate this by showing students a comparison of an evaporated salt solution and a boiled salt solution.

Activity 2

Have students build a geologic cross section (geologic column) to demonstrate the law of superposition (rock layering).

Materials:

- Stopwatch
- Graduated cylinder
- Metric ruler or tape measure
- Collection of sediment pieces
    - Two colors of chocolate chips, two colors of dried beans, two colors of plastic beads, etc.

Directions:

1. Make a data table like the one shown below.
2. Divide students into groups of two.
3. Have one student in each group pick one sediment piece at a time and place it in the graduated cylinder during a 15-second period.
4. The other student will repeat step 3 with the other colors of sediment.
5. Take turns until 6 layers have been built.
6. Use the ruler to measure the height of each layer in centimeters.
7. Record the data in the table.

Data Table

Rock Layer	Height of Rock Layer (centimeters)
A	
B	
C	
D	
E	
F	

Students can use the following discussion questions:

- Did the thickness of each layer vary?
- Which rock layers in the model are oldest or youngest?
- What do the different colors represent?
- If a fossil of a fish was found in two layers, what can be concluded about the relative age of the fish?

Activity 3

Students can create an edible treat that has a variety of layers. As each layer is created, they can discuss an Earth process that likely formed each layer.

Resources

- Five Crystal Recipes—retail website that sells crystal kits and provides do-it-yourself instructions
- Generation Genius – rock layering activity
- Edible Rock Activities—linked resource is for Sedimentary rock activity, but igneous and metamorphic activities exist on website as well

How are canyons usually formed?

Background

Canyons are formed by the process of erosion caused by rivers over long periods of time. A difference in elevation between the head water and the outlet of the river is essential for the formation of a canyon. A greater difference in elevation produces a faster water flow, resulting in more erosion of the canyon walls by the moving water. The canyon walls are formed by stronger layers of stone (granite or sandstone) that were able to resist the force of erosion from the river.

Activity

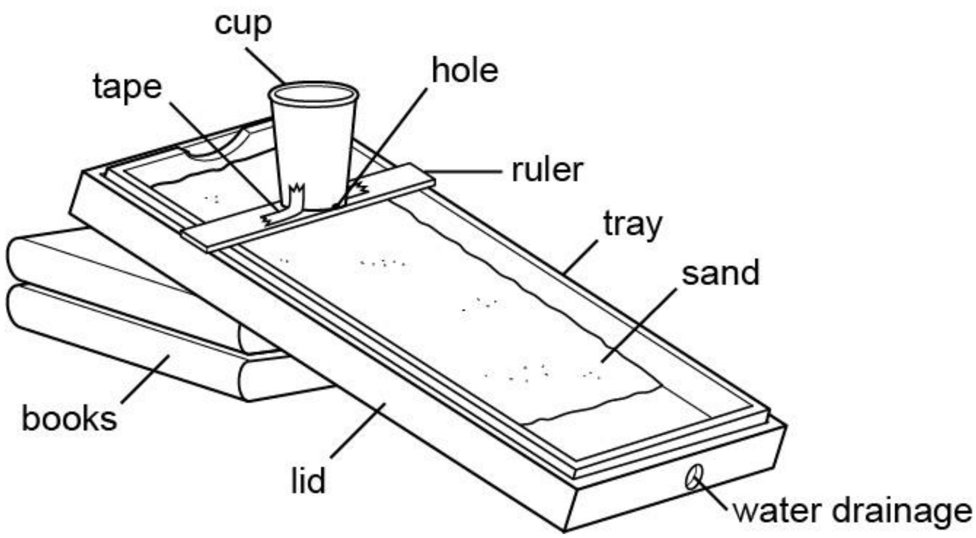
The instructor can set up a stream table for a demonstration, or student groups can build their own.

Materials:

- 2–4 books
- Plastic or foam cup
- Water
- Ruler
- Baking tray, shallow pan, or lid to a plastic container
- Tape
- Sand

Directions:

1. Set up a stream table similar to the example shown in the drawing below.
2. Make sure to pack the sand tightly on the tray, leaving an empty space at the bottom of the tray.
3. Cut or poke a small hole at the bottom of the cup, facing the stream tray.
4. Fill the cup with water.



Have students make predictions and record their observations over a long period of time. Water should travel through the sand, carving out a stream or series of streams. Students should observe that canyons form this way. Over many years, the canyon walls will become taller as the flowing water breaks down rock and carries it downstream.

Resources

- Little River Canyon—encyclopedia of Alabama page about a canyon located in Cherokee and DeKalb County, AL
- Dismals Canyon—Encyclopedia of Alabama page about a canyon located in Franklin County, AL
- Stream Table Construction—YouTube video that shows a simple method of creating a stream table
- Stream Table Lesson Plan—four-day lesson provided by the South Coast Science Project
- Stream Table Activities—directions and lesson provided by *Science Friday* where the construction of the stream table is identical to the linked video above

4.ES.13

Grade 4
Earth's Systems
4.ES.13 Plan and carry out investigations to examine properties of soils and soil types (e.g., color, texture, capacity to retain water, ability to support growth of plants).

Connections to *A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*:

Focus for Scientific and Engineering Practice(s):

- Planning and Carrying Out Investigations

Focus for Crosscutting Concept(s):

- Systems and System Models
- Cause and Effect
- Patterns

Focus for Disciplinary Core Idea(s):

- Earth Materials and Systems
- Biogeology

Guiding Questions

- What is soil and how is it formed? (p. 135)
- Which properties should be investigated to differentiate and categorize soil types? (p. 135)
- How does texture and particle size affect the properties of soil? (p. 135)
- Which soil nutrients are needed for optimal plant growth? (p. 135)
- Why do different soils have different colors? (p. 135)
- What type of soil holds water best? (p. 139)
- How does moving water affect surface soil? (p. 139)

- What role does erosion play in soil formation? (p. 139)

Key Academic Terms:

soil, decomposition, sand, silt, clay, organic matter, constant, variable, absorbency, infiltration, erosion

Safety Considerations

Please refer to the Alabama K–12 Science Safety Guidelines.

What is soil and how is it formed?

Which properties should be investigated to differentiate and categorize soil types? How does texture and particle size affect the properties of soil?

Which soil nutrients are needed for optimal plant growth?

Why do different soils have different colors?

Background

Soil is a mixture of organic and inorganic materials that support a variety of organisms. Soil contains a balanced mixture of sand, silt, and clay and can be referred to as loam. Soil is mostly formed from rock that has been eroded through various Earth processes. Plants may take root and help keep the soil from blowing or washing away. Decaying plants add to the soil profile and expand the variety of material in the soil. More plants and animals will continue to add to the soil profile and contribute nutrients over time. Soil formation is a very slow process that takes many years.

Silt is a type of soil found mostly in aquatic environments. Silt is formed from very fine particles of rocks and minerals. As silt is carried by water, it can be deposited in large quantities and can add rich nutrients to the area where it rests.

Plants obtain nutrients from the soil and rely on the availability of nitrogen, phosphorus, and potassium.

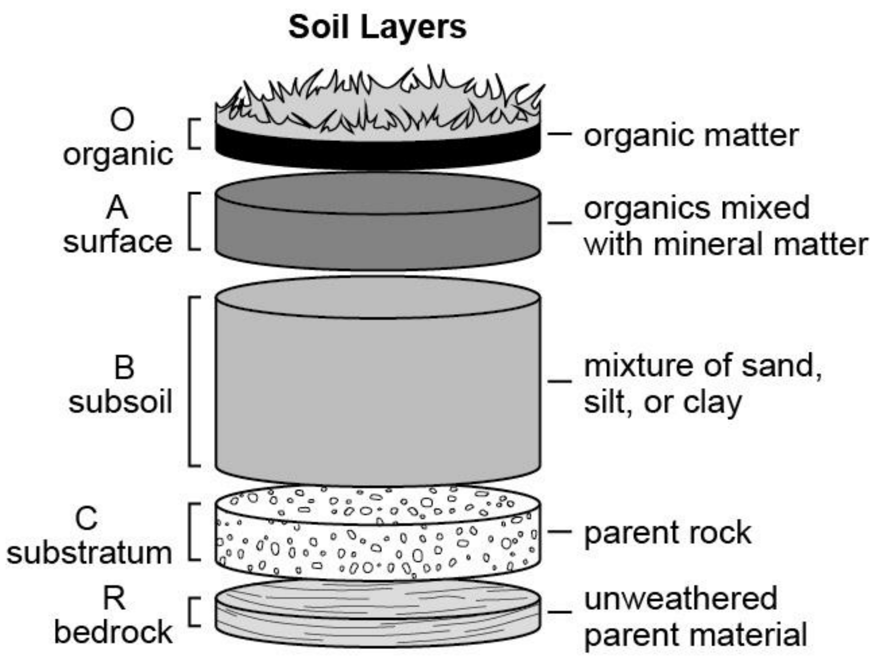
Nitrogen is very important in sustaining the chlorophyll in plants for the process of photosynthesis. Nitrogen is commonly a main component in fertilizer because it is constantly needed by plants to sustain plant growth.

Phosphorus helps provide energy needed to perform photosynthesis. It is also responsible for plant growth and reproduction. Plants that have adequate amounts of phosphorus are strong and healthy.

The color of soil depends on the soil's minerals, their chemical interactions, and the amount of moisture in the environment. The color of a soil shows mineral composition and provides scientists with an easy-to-view gradient called a horizon.

This list below describes some common soil colors and their mineral content.

- Yellow/red—iron rich
- Dark brown/black—high organic content
- Green—abundance of glauconite (iron/potassium/silicon)
- White—abundance of calcite (calcium carbonate)



There are many different types of investigations students can perform with soils. Depending on the investigation, different variables can be manipulated or held constant. The list below is not exhaustive but serves as a primer.

Soils exist as mixtures of three general types with different characteristics, which are listed below.

1. Loam—dark material, rich with organics (humus), allows for some water drainage, mixture of sand and clay
2. Sandy—large particles, good water drainage, lacks nutrients, highly impacted by erosion
3. Clay—small particles, poor water drainage, can be rich in nutrients but difficult for plants to access

General textures are summarized in the list below.

- Loam soil—maintains shape after being squeezed when dry, can be easily shaped and handled without breaking when moist
- Sandy soil—course and/or gritty when handled, falls apart in the hand after being squeezed when dry, falls apart in hand after being touched when wet
- Clay soil—small grains, smooth, breaks into clumps, sticky when wet

If students are collecting water from an infiltration experiment, the following trends could be anticipated:

- Loam—medium volume of collected water
- Sand—high volume of collected water
- Clay—low volume of collected water

If students are collecting data on erosion, runoff, or settling rate of soil due to water, the following trends could be anticipated:

Soil Type	**Erosion Risk**	**Amount of Runoff**	**Ability to Settle from Water**
Loam	Moderate	Moderate	Moderate
Sand	Low	Low	High
Clay	Moderate	High	Low
Silt	High	Moderate	Low

Activities

Activity 1

Have students complete a chart comparing the properties (texture, particle size, permeability) of sand, silt, and clay.

Activity 2

Have students try to roll dry soil into long, thin shapes that resemble snakes. Students will then make observations. Then, the students will add small amounts of moisture to each type of soil using an eyedropper and repeat the steps to see if the results change.

Activity 3

Have students bring in soil samples from different neighborhoods or well-known locations and try to categorize them based on observable characteristics.

Resources

- National Soil Survey Center—official YouTube channel, which contains useful playlists
- Alabama State Soils—PDF of state specific information presented by the Soil Science Society of America
- Soil Crayons—activity from USDA that showcases the colors of soils
- Soil Lesson Plans—hosted by the USDA on their webpage
- Soil Sponge Model—website and lesson available from Dr. Dirt
- Dirt Pudding and Soil Horizons—website and lesson available from Dr. Dirt

What type of soil holds water best?

How does moving water affect surface soil?

What role does erosion play in soil formation?

Background

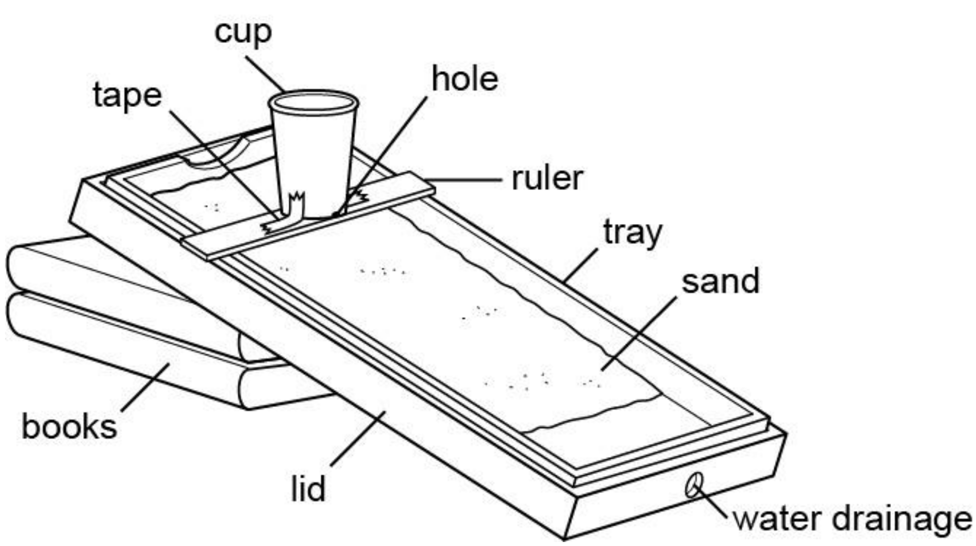
Loam is the type of soil best at allowing water to drain while still maintaining adequate moisture for plants and other organisms. Sand is also good for water drainage but dries quickly and can't maintain high moisture levels. Clay is poor for both infiltration and drainage. This can be problematic for soils depending on the location of the clay in the horizon and the amount mixed into the loam.

Moving water causes erosion but how much erosion it causes depends on the amount of organic material, the elevation, the soil type, and the volume of water.

Erosion moves sediment to new locations and can be an important factor in some ecosystems. Erosion is necessary for the formation of new soil in environments and can occur from a variety of processes.

Stream tables serve as good models for water erosion, infiltration, and runoff for soil experiments. They can illustrate the formation of canyons, rivers, streams, deltas, etc. Stream tables can be purchased from retailers in ready to use kits or be locally sourced from common materials.

Stream Table



Materials:

- 2–4 books
- Plastic or foam cup
- Water
- Ruler
- Baking tray, shallow pan, or lid to a plastic container
- Tape
- Sand

Directions:

1. Set up a similar stream table to the example shown in the drawing on the previous page.
2. Make sure to pack the sand tightly on the tray, leaving an empty space at the bottom of the tray.
3. Cut or poke a small hole at the bottom of the cup, facing the stream tray.
4. Fill the cup with water.

Activities

Activity 1

Have groups of students perform this experiment using basic materials.

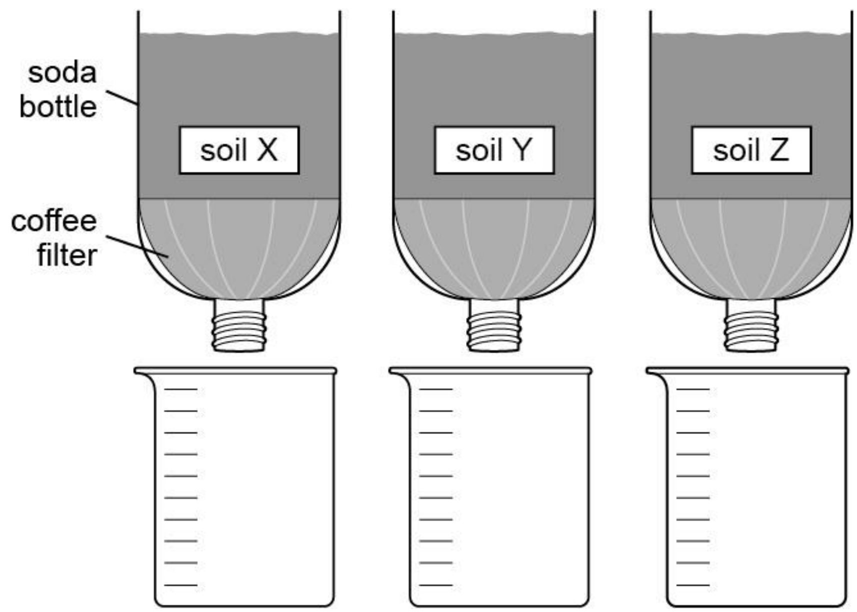
Materials:

- 3 empty plastic bottles
- Coffee filters
- Water
- 3 beakers
- 3 types of soil
    - Sand, clay, and loam can be purchased from a local garden center. Also, basic potting soil and sand can be used in different ratios.

Directions:

1. Cut the base off the plastic bottles.
2. Remove the caps.
3. Place a coffee filter in each bottle as shown below.
4. Fill each bottle with a different type of soil.
5. Slowly pour equal amounts of water into each bottle.
6. Record the time it takes the water to filter through each bottle.
7. Record the amount of water collected in each beaker.

Water Retention Experiment



Discuss the results with the students. Ask students to observe how well the soil maintains moisture to aid in plant growth and development. Identify the following experimental characteristics of the experiment.

- Manipulated variable: type of soil
- Responding variable: amount of water that fails to infiltrate (move through) the soil
- Controlled variables: amount of soil used, amount and frequency of water added, angle of each soil, and type of soil used

Activity 2

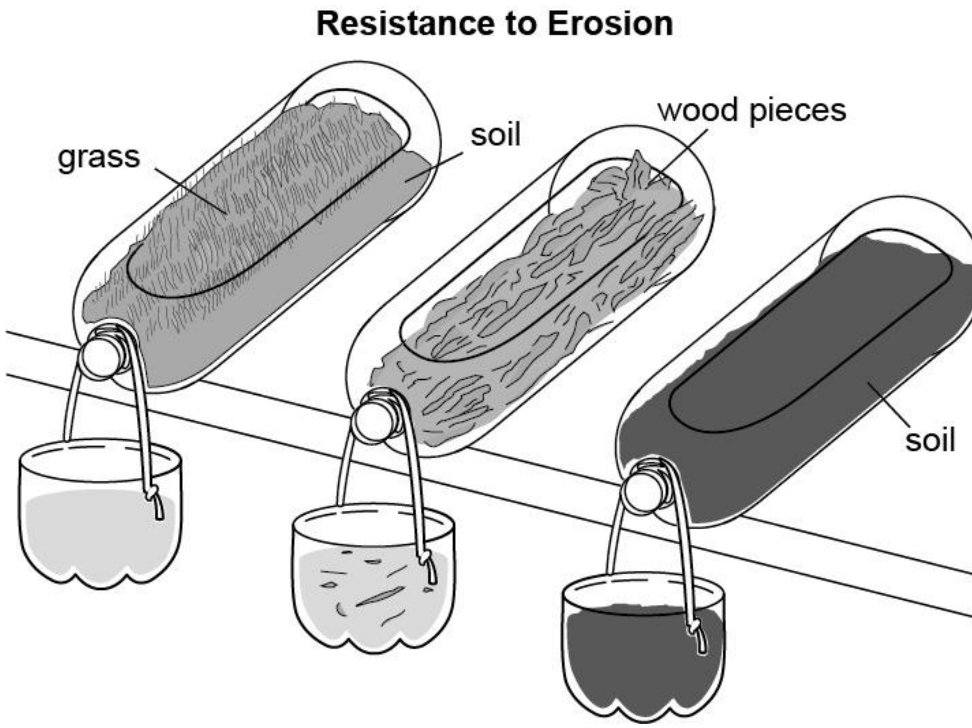
Have groups of students perform this experiment using basic materials.

Materials:

- 3 plastic bottles
- String
- 3 types of soil or mediums
  - A section of sod can be purchased from a local garden store. Also, the instructor or a volunteer can remove a small section of the top surface of a lawn.

Directions:

1. Cut the bottom section off the plastic bottles.
2. Remove the caps.
3. Cut holes in the bottom sections and use the string to secure them to the openings of the bottles.
4. Place a soil type (medium) in each of the bottles.
5. Position the bottles at an angle with the hanging section over a ledge. A tabletop works well for this.
6. Have students pour equal amounts of water at the higher end of each bottle.
7. Record the amount of time it takes for the water to reach the hanging section of each bottle.
8. Observe how much material is moved out of the bottle (erosion).



Discuss the results with the students. Ask students to observe which factors help soil maintain its position. Identify the following experimental characteristics of the experiment.

- Manipulated variable(s): plants vs. no plants, angle of incline, speed of water, amount of water, and soil type
- Responding variable: depends on manipulated variable
- Controlled variables: depends on manipulated and responding variables

Activity 3

Have students use stream tables to model the formation of canyons and investigate other characteristics and landforms created by the process of erosion.

Resources

- Stream Table Construction—YouTube video that shows a simple method of creating a stream table
- Stream Table Lesson Plan—four-day lesson provided by the South Coast Science Project

4.ES.14

Grade 4
Earth’s Systems
4.ES.14 Explore information to support the claim that landforms are the result of a combination of constructive forces, including crustal deformation, volcanic eruptions, and sediment deposition as well as a result of destructive forces, including erosion and weathering.

Connections to *A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*:

Focus for Scientific and Engineering Practice(s):

- Engaging in Arguments from Evidence
- Constructing Explanations
- Obtaining, Evaluating, and Communicating Information

Focus for Crosscutting Concept(s):

- Cause and Effect
- Patterns
- Scale, Proportion, and Quantity
- Energy and Matter

Focus for Disciplinary Core Idea(s):

- Earth Materials and Systems
- Plate Tectonics and Large-Scale System Interactions

Guiding Questions

- What are landforms? (p. 146)
- What information supports the claim that landforms result from a combination of forces? (p. 146)
- How can constructive and destructive forces be compared? (p. 146)

- What patterns and evidence support a claim that landform formation is a result of constructive or destructive forces? (p. 150)
- What is the relationship between deposition and constructive forces, and how does the depth and speed of moving water affect the sediment that is carried by that water? (p. 150)
- What is the difference between erosion and weathering, and is weathering a constructive or destructive force? (p. 150)

Key Academic Terms:

landform, constructive force, geologic process, crustal deformation, destructive force, erosion, weathering, volcano, mountain, valley, earthquake, gravity, sediment deposition

Safety Considerations

Please refer to the Alabama K–12 Science Safety Guidelines.

What are landforms?

What information supports the claim that landforms result from a combination of forces?

How can constructive and destructive forces be compared?

Background

A landform is any type of change in topography on the surface of Earth. Some examples are listed below.

- Hills
- Plateaus
- Valleys
- Mountains
- Canyons
- Volcanoes
- Glaciers
- Trenches
- Ridges
- Beaches
- Rivers
- Lakes

The formation or deconstruction of some landforms is easily observed while others must be inferred through geological evidence.

Landforms are affected by two broad categories of forces known as constructive and destructive forces. These two types of forces can be implemented in a variety of ways, but they follow a simple rule. A constructive force helps to build a landform and a destructive force breaks down landforms and objects.

Scientists can easily track constructive and destructive forces in rivers, lakes, and volcanoes, but the constructive forces involved with large-scale objects, like mountains, were debated until the 1960s. Technology has helped scientists gather large bodies of evidence to better support their hypotheses and theories.

Activities and Considerations

Activity 1

The instructor can set up a stream table for a demonstration to observe deconstructive and construction forces in action. There are many examples of stream tables online. Instructions for a basic model are shown below.

Have students perform mini stream table experiments using a baking tray and a variety of mediums. Students can manipulate the following variables:

- Flow of water—A paper cup with holes in the bottom can be covered or uncovered.
- Elevation—The angle of the baking tray can be raised or lowered.
- Obstacles—Rocks or other items can be added to divert the water.

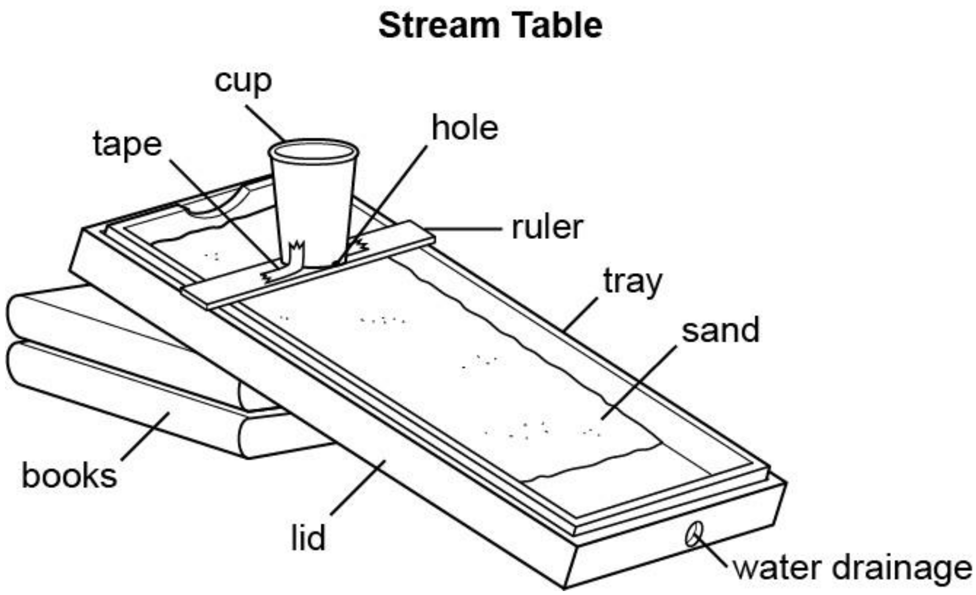
Have students record their observations of destructive and constructive forces in action.

Materials:

- 2–4 books
- Plastic or foam cup
- Water
- Ruler
- Baking tray, shallow pan, or lid to a plastic container
- Tape
- Sand
- Rocks and other objects used for obstacles

Directions:

1. Set up a similar stream table to the example shown in the drawing below.
2. Make sure to pack the sand tightly on the tray, leaving an empty space at the bottom of the tray.
3. Cut or poke a small hole at the bottom of the cup, facing the stream tray.
4. Fill the cup with water.



Activity 2

Students can create volcanoes using different amounts of baking soda, vinegar, and dish soap to see changes in the length of activity and the amount of “lava” produced as a destructive and then constructive force.

Ingredients:

- 1 tablespoon dish soap
- 2–3 drops of red food coloring
- 1 cup vinegar
- 1.5 cups warm water
- 2 tablespoon baking soda

Considerations

Resources for this set of guiding questions are centered around the use and exploration of Google Earth. They allow students an opportunity to take digital field trips and explore the variety of naturally occurring landforms.

Resources

- Landforms from Space—Google Earth Viewer
- 10,000 Years of Volcanoes—Google Earth Viewer
- Grand Canyon National Park—Google Earth Viewer
- Earth Landscapes—Google Earth Viewer
- Stream Table Construction—YouTube video that shows a simple method of creating a stream table
- Stream Table Lesson Plan—four-day lesson provided by the South Coast Science Project
- Disney Short “Lava”—video with lyrics showing constructive and destructive processes

What patterns and evidence support a claim that landform formation is a result of constructive or destructive forces?

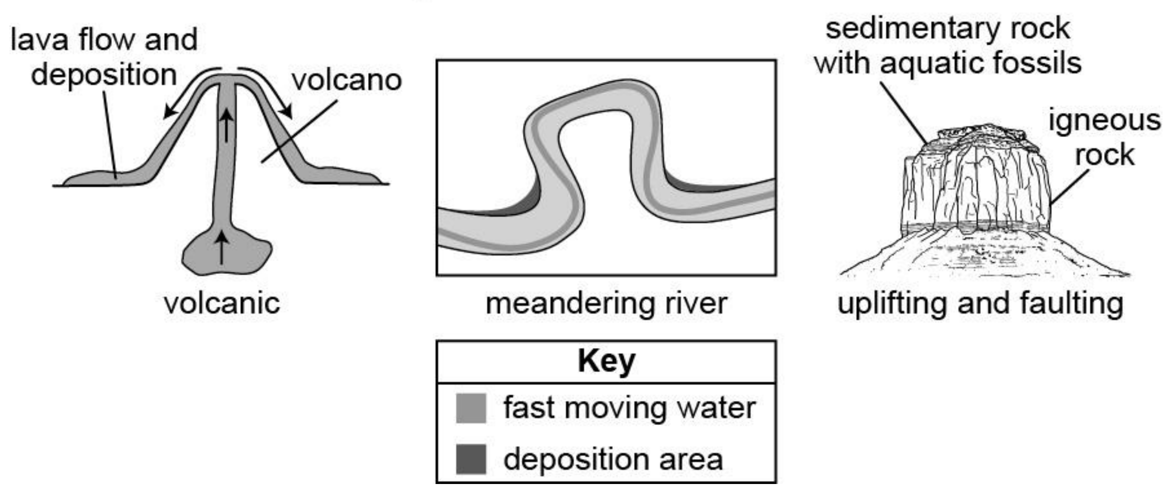
What is the relationship between deposition and constructive forces, and how does the depth and speed of moving water affect the sediment that is carried by that water?

What is the difference between erosion and weathering, and is weathering a constructive or destructive force?

Background

Constructive forces require some type of deposition of material to occur. Volcanoes can gradually build hills and mountains and add nutrients to the soil through the process of deposition. Rock layers and fossils provide evidence of the constructive forces of faulting and uplift. Water can cause meandering rivers, deltas, beaches, spits, and bars due to the deposition of materials as well. Slower moving, shallow water is where most deposition occurs in rivers and streams. Lakes can undergo a process called eutrophication, where organic material is deposited and eventually fills the lake into a solid landform.

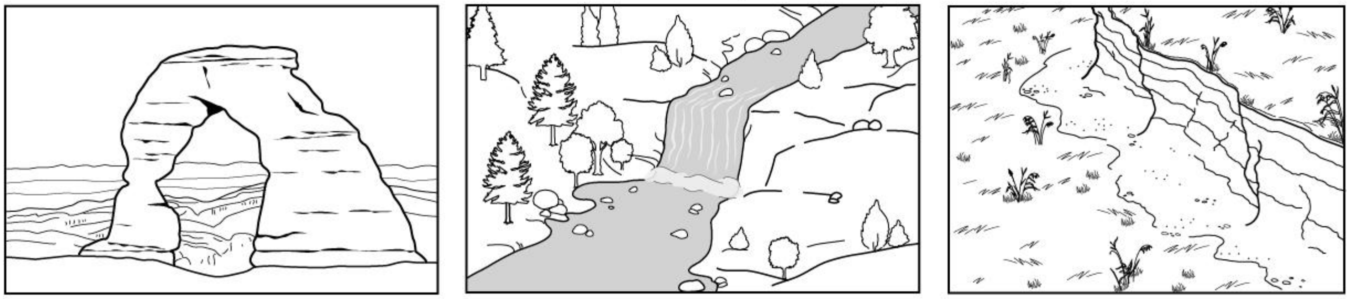
Examples of Constructive Forces



Destructive forces require weathering and/or erosion to occur. Weathering is a physical or chemical break down of material. Physical examples of weathering include the abrasiveness of wind, pressure from roots, shattering due to gravity, and the expansion of water as ice. Chemical weathering involves dissolving in water and/or dissolving due to high concentrations of acid or bases in a solution.

Erosion is the process of moving weathered material and loose soil or sediment. Erosion can weaken the foundation of landforms, which in turn results in more weathering and erosion. The transport of materials commonly occurs with water, but wind also serves as a common method of erosion. Higher elevations are more susceptible to erosion due to the large amounts of potential energy that can be easily converted into motion energy.

Erosion Examples



arch waterfall pasture

Activity and Considerations

Activity

Have students create a scrapbook or collage of local constructive and destructive events in their area. This can include preventive measures as well.

Considerations

If the local area is impacted by a natural disaster, the activity might cause unnecessary distress or anxiety in students. Use professional judgment and local sensitivity when deciding how students should investigate these topics.

Resource

- Deadly Shadow of Vesuvius—Nova lesson that introduces students to the relationship between volcanoes, earthquakes, and tectonic plates

4.ES.15

Grade 4
Earth's Systems
4.ES.15 Analyze and interpret data (e.g., angle of slope in downhill movement of water, volume of water flow, cycles of freezing and thawing of water, cycles of heating and cooling of water, speed of wind, relative rate of soil deposition, amount of vegetation) to determine effects of weathering and rate of erosion by water, ice, wind, and vegetation using one single form of weathering or erosion at a time.

Connections to *A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*:

Focus for Scientific and Engineering Practice(s):

- Analyzing and Interpreting Data

Focus for Crosscutting Concept(s):

- Patterns
- Cause and Effect
- Scale, Proportion, and Quantity
- Systems and System Models

Focus for Disciplinary Core Idea(s):

- Earth Materials and Systems
- Biogeology

Guiding Questions

- What are the effects of weathering and erosion on Earth's surface? (p. 154)
- How do the four main agents of erosion (moving water, wind, gravity, and ice) affect Earth's landscape? (p. 154)
- How does repeated heating and cooling (freezing and thawing) affect rocks? (p. 154)

- How do plants affect weathering and erosion? (p.158)
- How can data provide evidence that specific factors affect the rate of soil deposition? (p. 158)
- How do waterfalls affect the surface materials they impact? (p. 158)
- How does the angle of a slope affect the volume and speed of flowing water? (p. 158)
- Given data, what interpretations can be made to relate the angle of a slope and the weathering of the area? (p. 158)

Key Academic Terms:

weathering, erosion, slope, freeze-thaw, expand, contract, volume, deposition, vegetation, speed, soil, rate

Safety Considerations

Please refer to the Alabama K–12 Science Safety Guidelines.

What are the effects of weathering and erosion on Earth's surface?

How do the four main agents of erosion (moving water, wind, gravity, and ice) affect Earth's landscape?

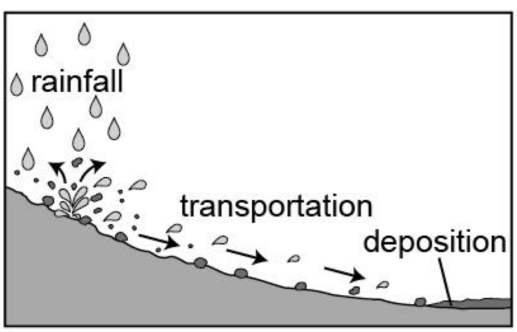
How does repeated heating and cooling (freezing and thawing) affect rocks?

Background

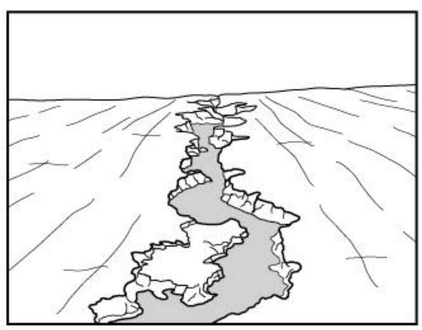
Water has an important role in the weathering and erosion processes. Weathering, physical or chemical, breaks apart material into smaller pieces. Erosion transports the material to new locations. During the process of erosion, weathering can also take place. Material is often broken down into smaller pieces as it travels. Weathering and erosion often happen in unison with each other.

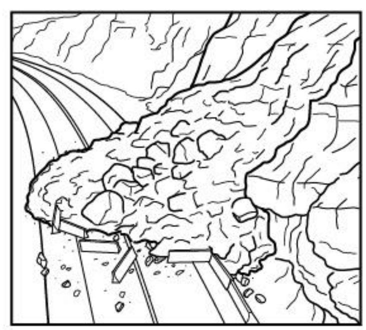
Water is an important participant in the weathering and erosion process. Faster moving water increases the rate of weathering and erosion. Eroding water can shape rivers and waterways on a large scale, but it can also negatively impact housing foundations, crops, and roadways on a smaller scale. Hilly regions along roadsides often need drainage ditches between the main roadways.

Water Erosion

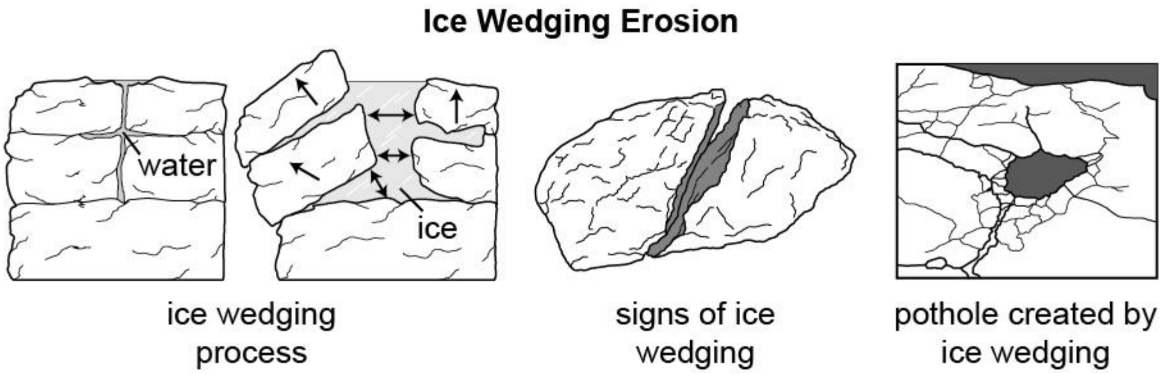


erosion process

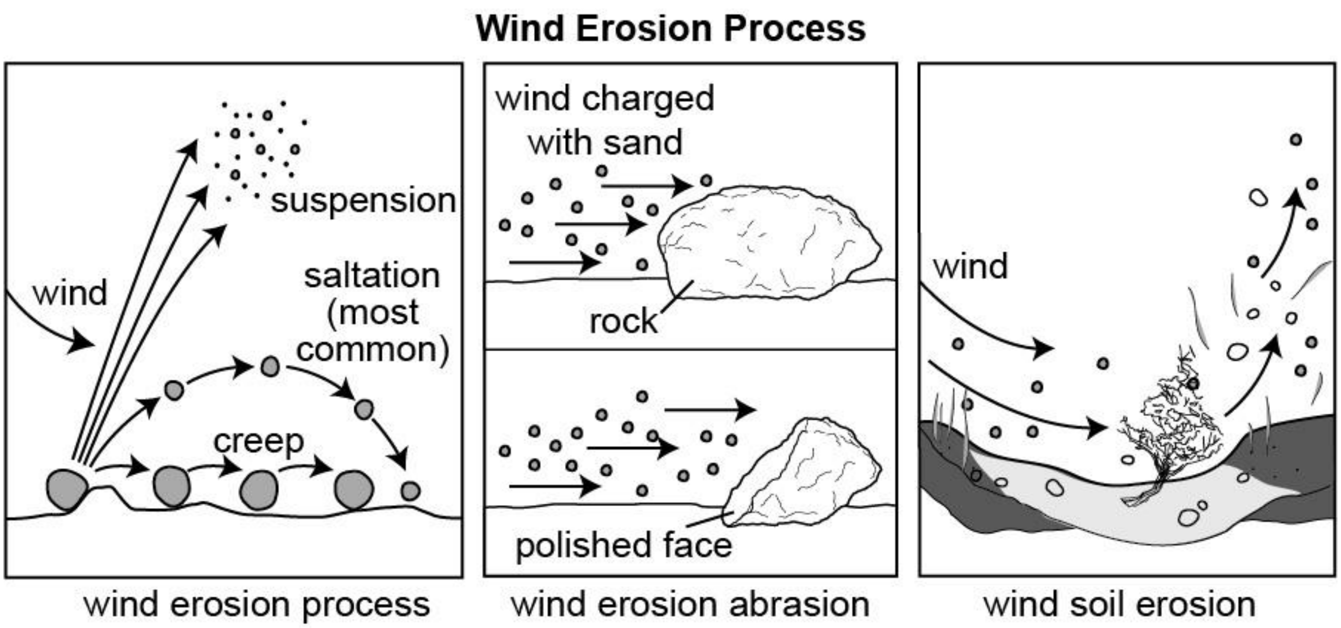

erosion on farmland


erosion on road

Rocks or plants can be used on a hill itself to prevent landslides caused by rain or wind. In climates where the freezing point of water is often reached, the freeze/thaw cycle performs a process known as ice wedging. Liquid water penetrates between rocks, roads, and walkways and then expands as it freezes. The expansion can break apart structures or increase the size of gaps and cracks. If this process happens at tall heights, gravity assists in the weathering process due to the object's potential energy.



Wind constantly weathers and erodes the surface of Earth. Wind commonly moves smaller particles and uses them as an abrasive to weather larger material, like rock faces on mountains. Wind erosion has a large impact on farmers due to exposed soil in fields. As plants and crops begin to grow, the soil is better held together and becomes less affected by wind erosion.



Activities and Considerations

Activity 1

The instructor can gather a variety of images from the internet (wind, water, gravity, ice) and have students categorize them to show what types of erosion and weathering are occurring.

Activity 2

The instructor can demonstrate the different types of erosion.

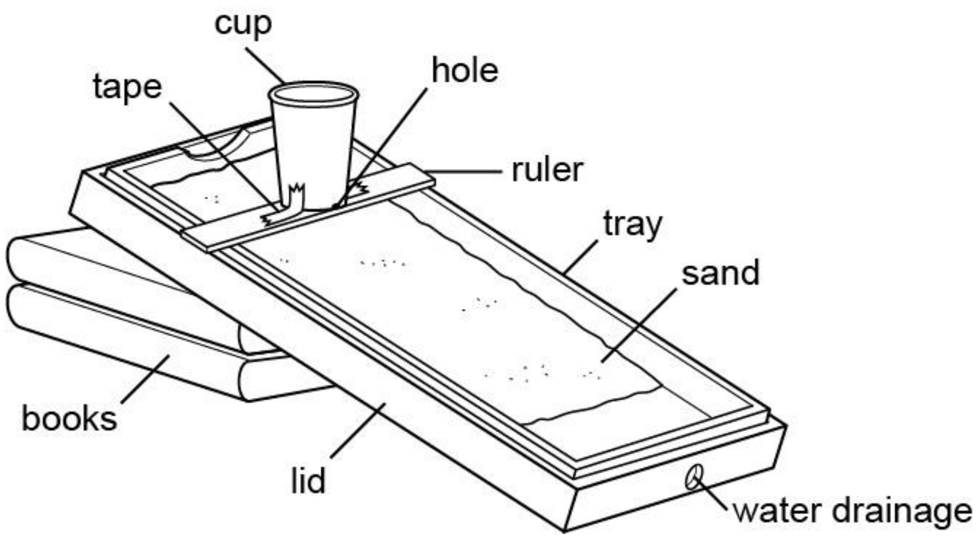
Materials:

- 2–4 books
- Plastic or foam cup
- Water
- Ruler
- Baking tray, shallow pan, or lid to a plastic container
- Tape
- Sand

Directions:

1. Set up a similar stream table to the example shown in the drawing below.
2. Make sure to pack the sand tightly on the tray, leaving an empty space at the bottom of the tray.
3. Cut or poke a small hole at the bottom of the cup, facing the stream tray.
4. Fill the cup with water.

Stream Table



Have students make predictions and record their observations over a period of time. Water should travel through the sand, carving out a stream or series of streams. Students should observe that the water also carries sediment (sand) downhill as it travels. Point out the process of physical erosion and sedimentation that is occurring at the bottom of the tray.

Activity 3

To demonstrate the expansion of frost wedging, plastic water bottles can be filled to different volumes with water and then placed in a freezer overnight.

Considerations

There might be an opportunity for cross-curricular integration with social studies by using the topic of the Dust Bowl to show the impact of soil erosion.

Resources

- Wind Erosion—YouTube video with a wind erosion section that starts at 1:00
- Images of Erosion – *National Geographic* images
- Stream Table Construction—YouTube video that shows a simple method of creating a stream table
- Stream Table Lesson Plan—four-day lesson provided by the South Coast Science Project
- Stream Table Activities—directions and lesson provided by Science Friday where the construction of the stream table is identical to the linked video above

How do plants affect weathering and erosion?

How can data provide evidence that specific factors affect the rate of soil deposition?

How do waterfalls affect the surface materials they impact?

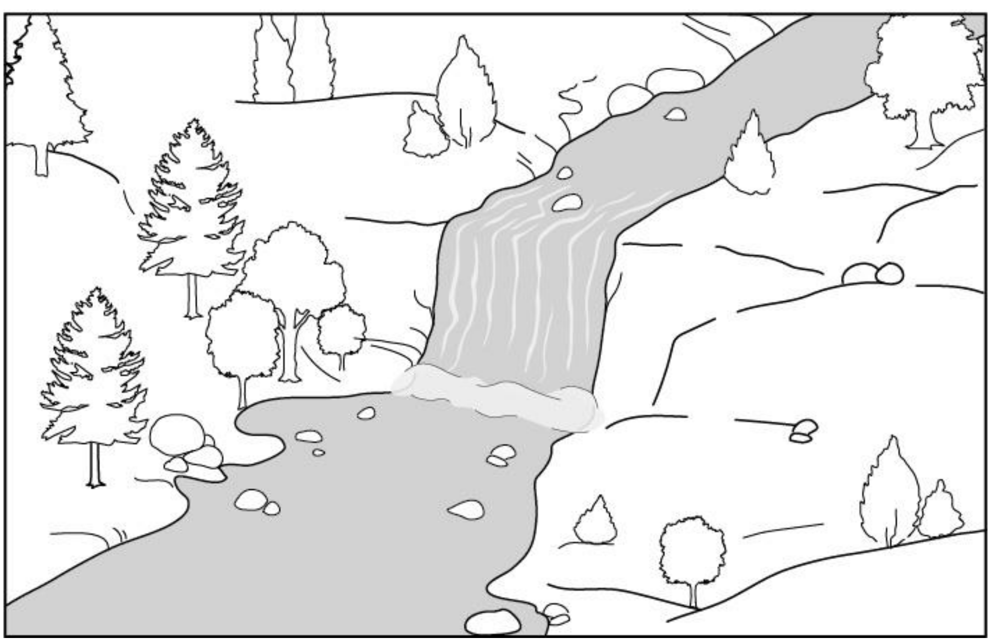
How does the angle of a slope affect the volume and speed of flowing water?

Given data, what interpretations can be made to relate the angle of a slope and the weathering of the area?

Background

Waterfalls are good examples of weathering and erosion by liquid water. Moving water weathers and transports materials over time. Taller waterfalls will have more potential energy due to gravity than shorter waterfalls. The weaker rock below the edge of the waterfall will erode and eventually cause the edge to fall, which leads to a recession of the whole landform.

Waterfall



Data can be used to show direct factors of erosion and deposition. Data points like soil depth, rate of flow, and elevation are used frequently. Models can provide both qualitative and quantitative forms of data for students to analyze. Students should be able to observe a model or a data table and identify the following trends:

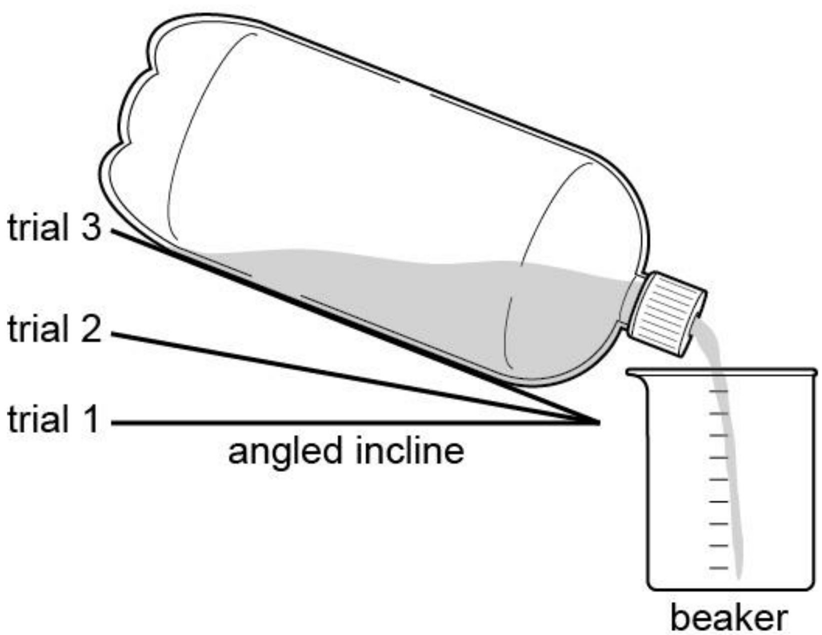
- Steeper slopes will have higher rates of erosion.
- Areas with faster moving water will have higher rates of erosion.
- Areas with little soil cover (vegetation) will have higher rates of erosion.

Activities

Activity 1

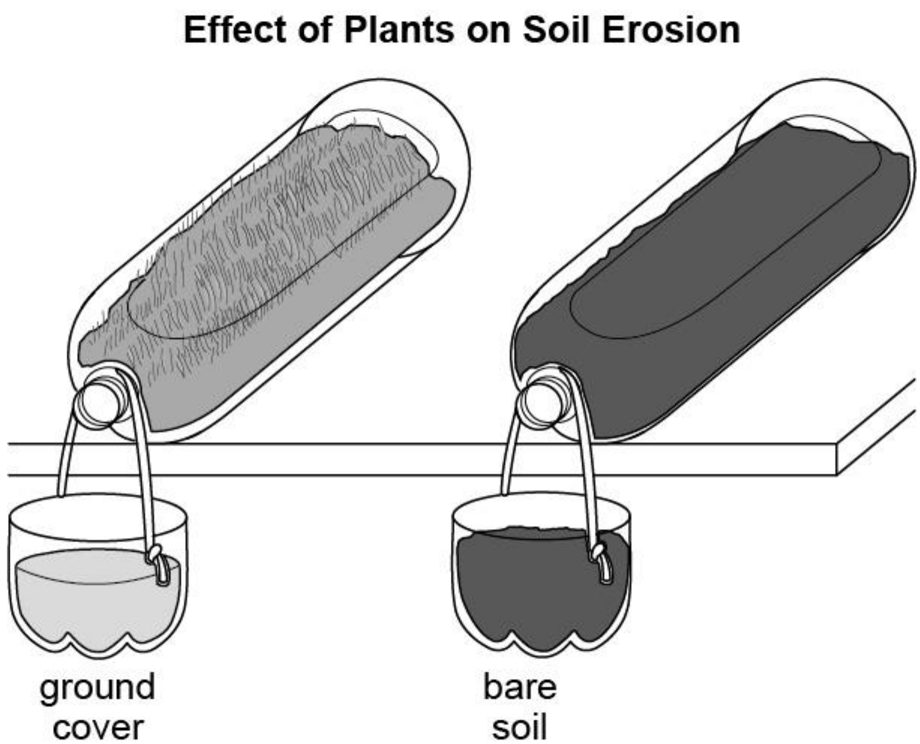
Students can perform a simple experiment to establish a relationship between angle of slope and rate of water flow. The instructor should poke a hole in the cap of a plastic bottle and fill it with colored water. The instructor should place the bottle on a flat surface, uncover the hole, and measure the amount of time required to collect the water that drains into the beaker. These steps can be repeated with the bottle placed at two different angled positions. Have the students compare the recorded times at each position to determine the relationship between angle of slope and rate of water flow.

Angle of Slope and Rate of Water



Activity 2

Demonstrate the difference in erosion by using 2-liter bottles. Both bottles should have potting soil, but one should have grass cover. Set each bottle at a 45° angle and add equal amounts of water to each bottle. Students should observe that more soil is eroded in the bottle without ground cover.



Resources

- Will Niagara Falls disappear?—statement about the erosion of Niagara Falls from the department of tourism
- Erosion Data—information about soil erosion data

4.ES.16

Grade 4
Earth’s Systems
4.ES.16 Describe patterns of Earth’s features on land and in the ocean using data from maps (e.g., topographic maps of Earth’s land and ocean floor; maps of locations of mountains, continental boundaries, volcanoes, and earthquakes).

Connections to *A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*:

Focus for Scientific and Engineering Practice(s):

- Analyzing and Interpreting Data
- Constructing Explanations

Focus for Crosscutting Concept(s):

- Patterns
- Cause and Effect

Focus for Disciplinary Core Idea(s):

- Earth Materials and Systems
- Plate Tectonics and Large-Scale System Interactions

Guiding Questions

- What is a continent? (p. 163)
- What are tectonic plates? (p. 163)
- What features are common to continental and oceanic plate boundaries? (p. 163)
- What features and data can a topographic map provide? (p. 167)
- What patterns of Earth’s features can be shown on a map? (p. 167)
- How can Earth’s ocean floor features be described and categorized? (p. 167)

- How can Earth's land features be described and categorized? (p. 167)
- What is seismic activity? (p. 169)
- Where do most earthquakes occur? (p. 169)
- What is the Ring of Fire and how is it used to describe patterns of Earth's features? (p. 169)
- Where are most volcanoes on Earth located? (p. 169)
- How can the relationship between volcanoes and tectonic plates be described? (p. 169)

Key Academic Terms:

tectonic plate, plate boundary, continental boundary, continental plate, oceanic plate, Ring of Fire, volcano, volcanic arc, earthquake, rift zone, trench, mid-ocean ridge, mountain, topographic map, seismic activity

Safety Considerations

Please refer to the Alabama K–12 Science Safety Guidelines.

What is a continent?

What are tectonic plates?

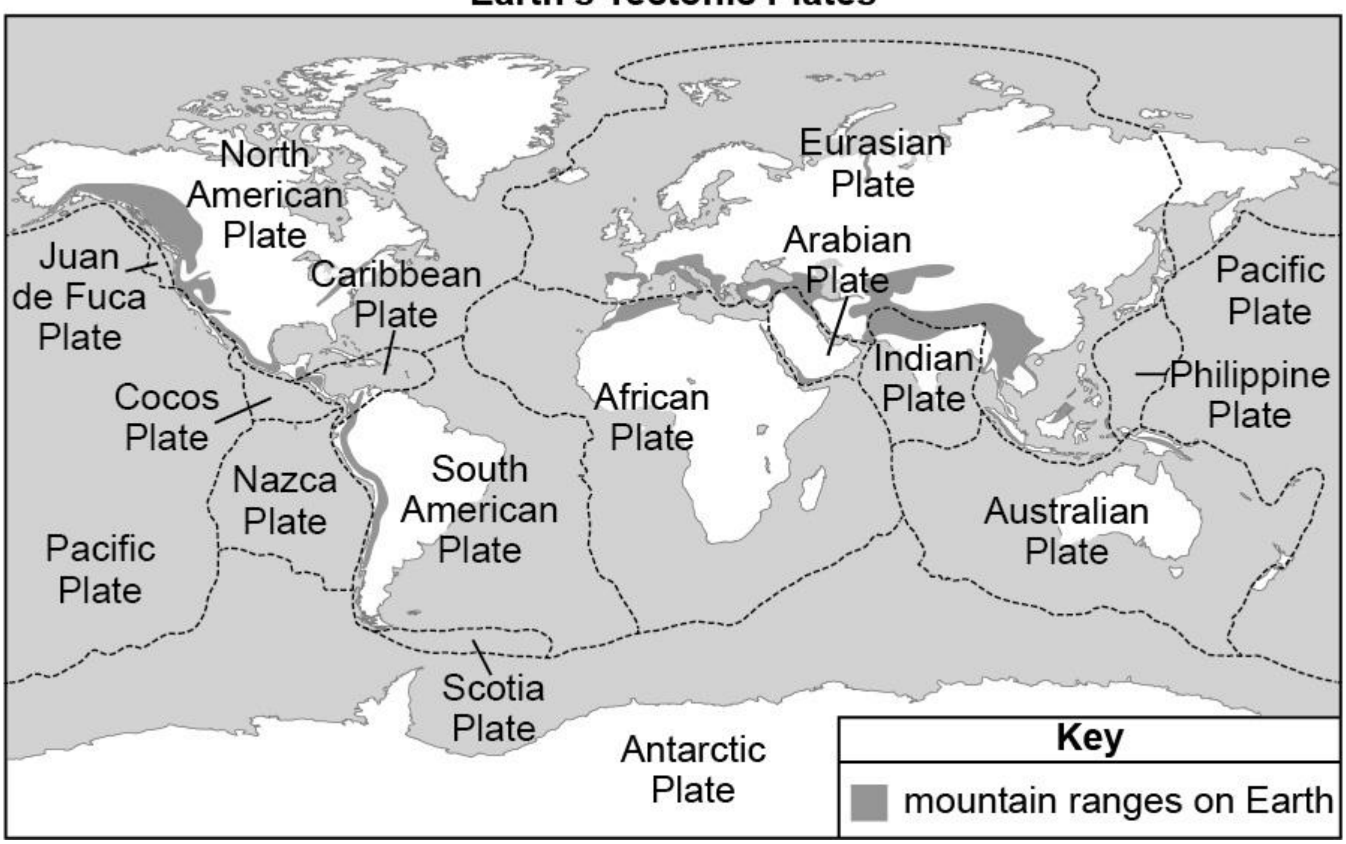
What features are common to continental and oceanic plate boundaries?

Background

In geography, the term continent refers to the seven large pieces of land that make up North America, South America, Europe, Africa, Asia, Australia, and Antarctica. Geologists use this definition of continent but focus more closely on the tectonic plates that the continents rest on and are surrounded by.

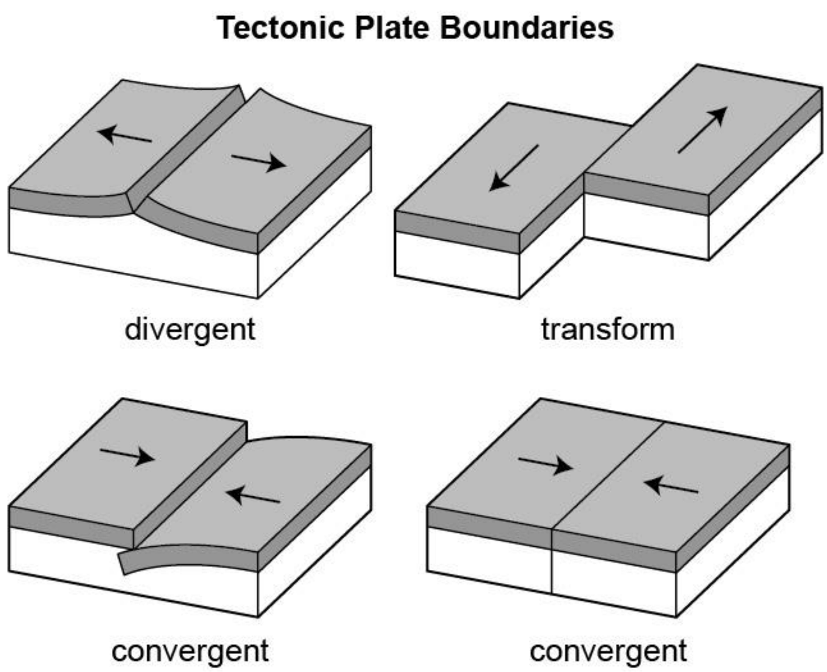
Tectonic plates are large landmasses that move along the top layer of Earth. These plates move at different rates but typically travel between 1–15 centimeters per year. When the plates meet each other, they create distinct landforms around their boundaries.

Earth's Tectonic Plates



There are three types of tectonic plate boundaries.

1. Convergent Boundaries—an area where two plates move toward and collide with one another, resulting in the formation of trenches, mountain ranges, island arcs, or volcanoes
2. Divergent Boundaries—an area where plates are moving away from each other resulting in rifts or mid-ocean ridges
3. Transform Boundaries—an area where two plates slide past one another in opposite directions, resulting in faults



Convergent boundaries can be identified because of the large oceanic trenches that form as the oceanic tectonic plate subducts (slides under) the continental plate. Mountains and volcanoes are typical features to find along coastal areas where subduction occurs. Because the process happens slowly and at such great depths and distances, mountains that are formed due to this process can take shape inland rather than directly on the coast of the continent. Earthquakes are very common at these locations as well.

Activities

Activity 1

Students can be shown different hand models that demonstrate the tectonic plate boundaries. These models encourage movement and should be done while speaking out loud to give students multiple representations.

Convergent Boundaries: Subduction of Oceanic plate under a Continental plate.

1. Start with flat hands with the fingertips of the right hand resting on top of the fingertips of the left hand.
2. Gently push both hands toward each other, slowly curling the fingers of the left hand at a downward angle.

Convergent Boundaries: Two Continental Plates

1. Start with flat hands with the fingertips touching.
2. Gently push both hands toward each other while keeping fingers straight.
3. Raise the fingertips into a peak to show mountain building.

Transform Boundaries: Two Continental Plates

1. Start with flat hands with the pointer finger of the right hand resting next to the pinkie finger of the left hand.
2. Gently push both hands in opposite directions until fingertips reach elbows.

Divergent Boundaries: Oceanic Plates

1. Make fists with the knuckles of each hand touching.
2. Slowly roll fingers in an upward direction so that the center finger joints rise, and knuckles move backward.
3. Continue upward motion until fingertips are touching.

Divergent Boundaries: Continental Plates

1. Start with the knuckles of each hand touching and the fingers pointed downward.
2. Slowly pull both arms away from each other while keeping fingertips touching until a *V* shape is made.
3. Continue pulling away while maintaining a *V* shape until the fingertips no longer touch.

Activity 2

Instructors can model plate tectonic boundaries with different types of food to show the interactions that occur at each type.

Resources

- Plate Boundary Hand Models—YouTube video of an instructor demonstrating their techniques
- Edible Plate Tectonics—detailed lesson plan that can be scaled down for students
- PhET Plate Tectonics—Java simulation that only works on Microsoft Windows

What features and data can a topographic map provide?

What patterns of Earth's features can be shown on a map?

How can Earth's ocean floor features be described and categorized?

How can Earth's land features be described and categorized?

Background

A topographical map allows the viewer to see changes in elevation and landforms on and below the surface of Earth. The contour lines on a topographical map indicate changes in elevation in certain areas. As contour lines become closer together, the slope of the feature is increasing. If the contour lines are far apart, the slope of the feature decreases. Certain topographical maps may use colors to show elevation rather than contour lines. Elevation is measured in relation to the level of surrounding oceans. Alabama, on average, is 500 feet below sea level with the highest point at Cheaha Mountain located in Cleburne county. It is possible to have an area on land that is lower than sea level. For example, Death Valley in California is 282.2 feet below sea level! Knowing how to read a topographical map will help in recognizing familiar patterns (mountains, trenches, etc.) in regions of Earth that may be unfamiliar to the viewer.

Two Perspectives of a Mountain

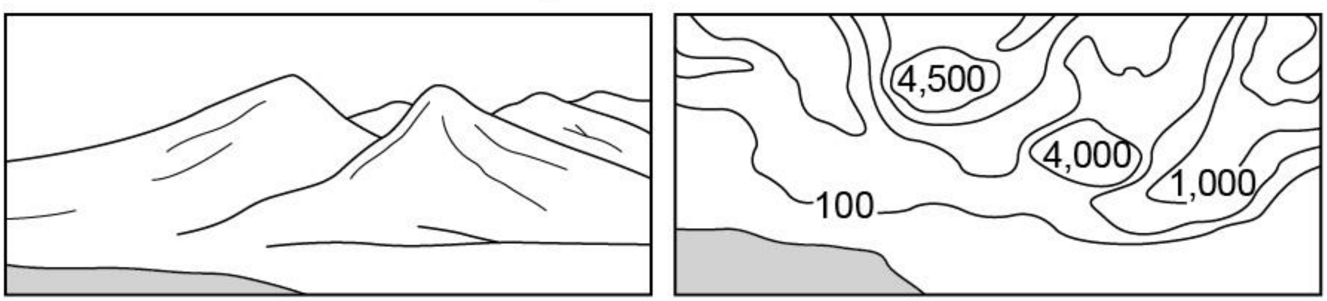


image of mountains topography of mountains

The land and ocean floor features of Earth can be categorized based on their formations. Each formation is either formed by a constructive force or destructive force. Lists of landforms are provided below.

Landforms Created by Constructive Forces	Landforms Created by Destructive Forces
• Volcanoes	• Canyons
• Mountains	• Valleys
• Hills	• Trenches
• Plateaus	• Waterfalls
• Beaches	• Arches

Activities and Considerations

Activity 1

Create a card sort activity where students match profile views of geographic images with their topographical map.

Activity 2

Check with local parks to see if they offer any orienteering opportunities. If not, many different local groups, like 4H or Boy/Girl Scouts, might be able to assist in finding volunteers to come visit a classroom and help with orienteering or topographical map reading.

Resources

- Potato Mountain—hands-on lab from Penn State College of Agriculture Science
- Topography Lesson—USGS lesson plan and worksheets
- Geocaching in Alabama—outdoor enthusiasts website blog post
- Vulcan Orienteering Club—club website
- Topographical Maps—digital and print resource from USGS
- Topographic Map Matching—match maps to landforms

What is seismic activity?

Where do most earthquakes occur?

What is the Ring of Fire and how is it used to describe patterns of Earth's features?

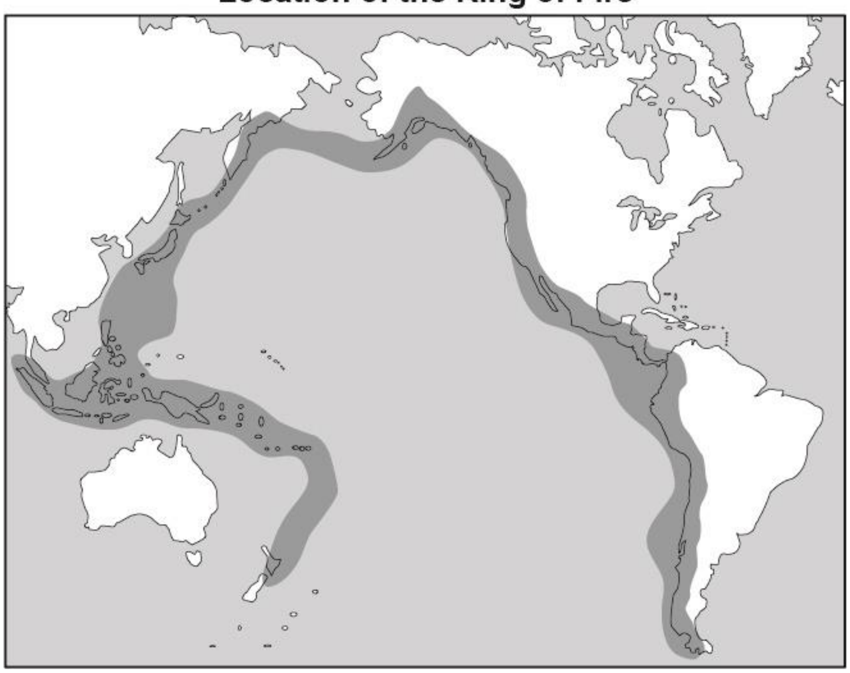
Where are most volcanoes on Earth located?

How can the relationship between volcanoes and tectonic plates be described?

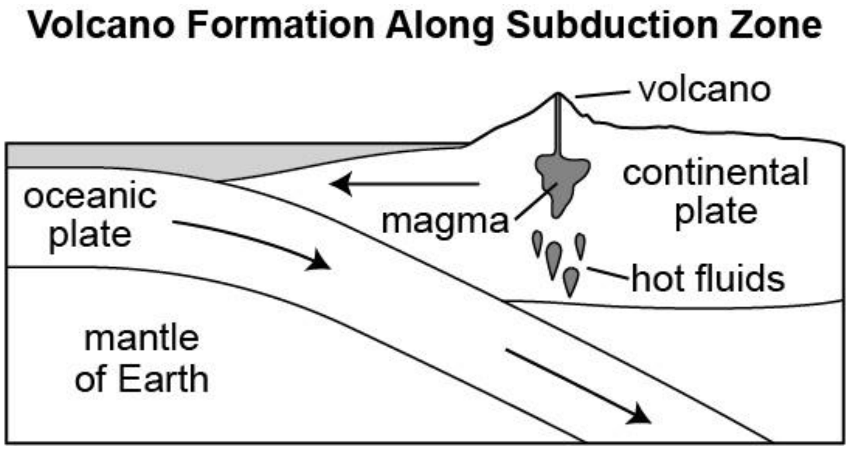
Background

Seismic activity is the transfer of energy in the form of waves from the epicenter of an earthquake. Most earthquakes occur along plate boundaries between oceanic and continental plates. Most of the earthquakes that occur on Earth (about 90%) occur in a region known as the Ring of Fire. The Ring of Fire surrounds the Pacific Ocean and is formed primarily due to areas of subduction, although other tectonic events occur around this region as well.

Location of the Ring of Fire



The subduction process causes the formation of volcanoes, which gives rise to the name "Ring of Fire." As an oceanic plate subducts under the continental plate, melted material rises into the continental area, creating volcanoes. Volcanoes and subduction zones occur together and provide geologists with a reliable, observable pattern.



Activities

Activity 1

Have students observe maps, in print form or digital, that show the location of earthquakes on Earth. Have them compare the earthquake map to a map that shows the location of volcanoes. Engage in discussion about any similarities or differences they notice and what forces or processes might be behind these observations.

Activity 2

Have students form groups to research and build different seismographs using designs from books or websites. As a class, decide on the testing environment for the seismographs and identify all the variables involved. Test each group's seismograph and engage in conversation about design and accuracy.

Resources

- Earthquakes—USGS website that has an abundance of resources
- Build a Seismograph—materials list and directions provided by Scientific American Website
- Geologic Survey of Alabama—website with a variety of information, including earthquake maps and data, provided by the Oil and Gas Board
- PBS Global Earthquakes and Volcanoes Maps—students can determine the link between the earthquakes and volcanoes

4.ES.17

Grade 4
Earth's Systems
4.ES.17 Formulate and evaluate solutions to limit the effects of natural Earth processes on humans (e.g., designing earthquake, tornado, or hurricane-resistant buildings; improving monitoring of volcanic activity).

Connections to *A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*:

Focus for Scientific and Engineering Practice(s):

- Constructing Explanations and Designing Solutions

Focus for Crosscutting Concept(s):

- Cause and Effect
- Scale, Proportion, and Quantity

Focus for Disciplinary Core Idea(s):

- Natural Hazards
- Defining and Delimiting an Engineering Problem

Guiding Questions

- How do natural processes on Earth negatively affect humans? (p. 173)
- How have scientists limited the negative effects of Earth's natural processes on humans? (p. 173)
- How are some scales used to measure the intensity of earthquakes, tornadoes, and hurricanes (e.g., Mercalli, Enhanced Fujita, Richter, Saffir-Simpson, Dartmouth Flood Observatory Scale)? (p. 173)
- How is severe weather monitored in specific areas? (p. 173)

- How can the construction of buildings be changed to withstand the effects of earthquakes, tornadoes, and hurricanes? (p. 173)
- Given a problem, how can students evaluate and design a solution to improve monitoring systems? (p. 173)

Key Academic Terms:

energy, tornado, earthquake, hurricane, volcanic eruption, destructive event, natural disaster, Mercalli scale, Richter scale, Enhanced Fujita scale, Saffir-Simpson wind scale, stilts, tornado shelter, storm surge, monitoring system

Safety Considerations

Please refer to the Alabama K–12 Science Safety Guidelines.

How do natural processes on Earth negatively affect humans?

How have scientists limited the negative effects of Earth's natural processes on humans?

How are some scales used to measure the intensity of earthquakes, tornadoes, and hurricanes (e.g., Mercalli, Enhanced Fujita, Richter, Saffir-Simpson, Dartmouth Flood Observatory Scale)?

How is severe weather monitored in specific areas?

How can the construction of buildings be changed to withstand the effects of earthquakes, tornadoes, and hurricanes?

Given a problem, how can students evaluate and design a solution to improve monitoring systems?

Background

As Earth undergoes various environmental processes, the effects can be negative for human populations. Scientists and engineers study patterns with these processes and work toward designing early warning systems and material for construction to keep humans safe from disaster. Some common scales and their purposes are included in the list below.

- Mercalli Scale—rates earthquakes based on observable damage to the environment
- Enhanced Fujita Scale—rates the strength of tornadoes based on observable damage to the environment
- Richter Scale—measures the local magnitude of an earthquake
- Saffir-Simpson Scale—rates the strength of hurricane winds based on their speed
- Dartmouth Flood Observatory Scale—rates the magnitude of a flood based on discharge

Tools to help monitor some of the processes on Earth include the following:

- Visual cues—residents report changes in weather
- Doppler Radar—tracks windspeed and movement of storms
- Rain and height gauges—collect data on the volume of water in specific areas

- Remote seismographs with satellite connection—provide early warning of seismic activity
- Buoy and tide gauges—measure changes in sea level to warn of a tsunami

Engineers study the impacts of natural disasters on buildings and work toward designing cost-effective solutions that ensure protection. Some common construction strategies include the following:

- Structurally sound rooms that act as shelters in large buildings for storms
- Runoff ponds and ditches that help reduce the impact of floods
- Raised foundations that help reduce the impact of floods, hurricanes, and tsunamis

People often do small things to help their homes be more resistant during a disaster. Some examples include the following:

- Anchoring furniture and pictures, which is helpful during an earthquake
- Boarding up windows, which is helpful during high winds or flood waters
- Installing drain tile and sump pumps, which reduce damage from flooding

Knowing the causes and effects of Earth's processes can aid in deciding how best to protect property and life during a natural disaster.

Activities

Activity 1

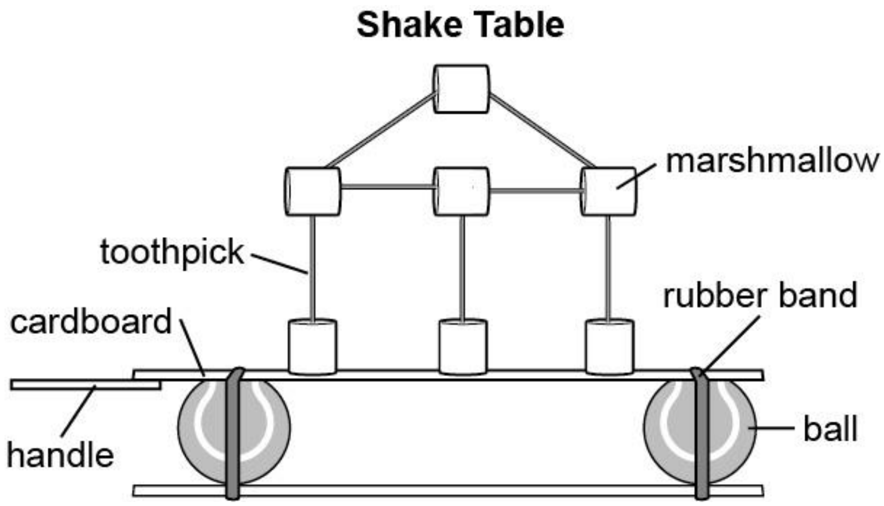
Have students become familiar with natural disasters. After students learn about frequent Earth processes and the natural disasters that may arise because of them, have them design and discuss an early warning system or improve on an existing design.

Activity 2

Have students create a journal, a blog post, or some other content resource that showcases examples of how community organizations or individuals take steps to mitigate the impact of natural disasters. Things like tornado drills at school, severe weather shelter signs at department stores, and runoff ponds can be included.

Activity 3

Earthquakes impact people in certain areas of the world. Engineers help design buildings, roads, bridges, and other structures to withstand the effects of earthquakes. The following activity allows students to build a structure with the effects of earthquakes in mind. It will also allow students an opportunity to test their designs and develop improvements.



Model Structure Materials:

- Toothpicks
- Marshmallows
- Cardboard
- Tape or modeling clay

Building the Model Structures:

1. Students will build their structures using marshmallows and toothpicks.
    a. NOTE: Provide students with height and width guidelines. (e.g., height no greater than 15 centimeters, width no greater than 10 centimeters)
2. Students will secure the base of their structures to a piece of cardboard using tape or modeling clay.

Shake Table Materials:

- 2 pieces of sturdy cardboard
- 2 thick rubber bands
- 2 tennis balls
- 2 binder clips
- Stick for handle (e.g., paint stirrer, wooden spoon)
- Masking tape
- Ruler or tape measure

Building the Shake Table (for instructor only):

1. Place the two tennis balls on one sheet of cardboard.
2. Place the other piece of cardboard on top of the tennis balls and secure the two pieces with the rubber bands.
3. Tape the stick (handle) under the top piece of cardboard.
4. To activate the shake table, hold the bottom piece of cardboard with one hand. Pull the stick (handle) with the other hand and let go. The top section of cardboard will shake back and forth, simulating the effects of an earthquake.

Discuss the observations made by the students. The following sample questions can lead the discussion.

- How did the structure respond to the shaking?
- How safe would you feel in your structure?
- How could you improve your structure based on the results?

Resources

- Flood Observatory—Dartmouth website with lots of information and dynamic maps
- Flash Warning System—PDF from NOAA
- CISN—website from California seismic monitoring
- Building Construction—lesson plan from TeachEngineering website
- Shake Table—instructions for building shake tables in the classroom

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February 15, 2022