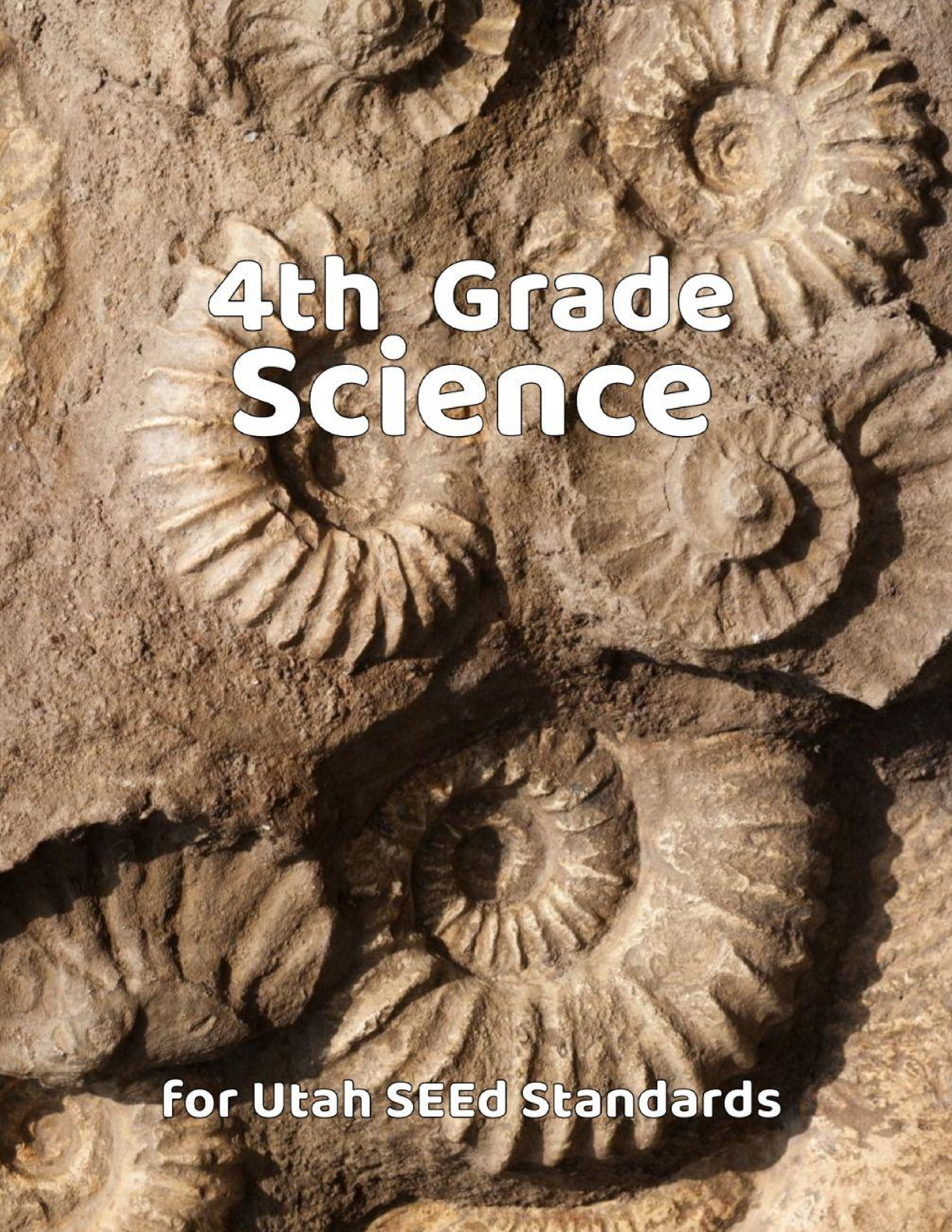

4th Grade Science

for Utah SEEd Standards

4th Grade

for Utah SEEd Standards

Utah State Board of Education OER

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USBE OER

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

Students as Scientists

What does science look and feel like?

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

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

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

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

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

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

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

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

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

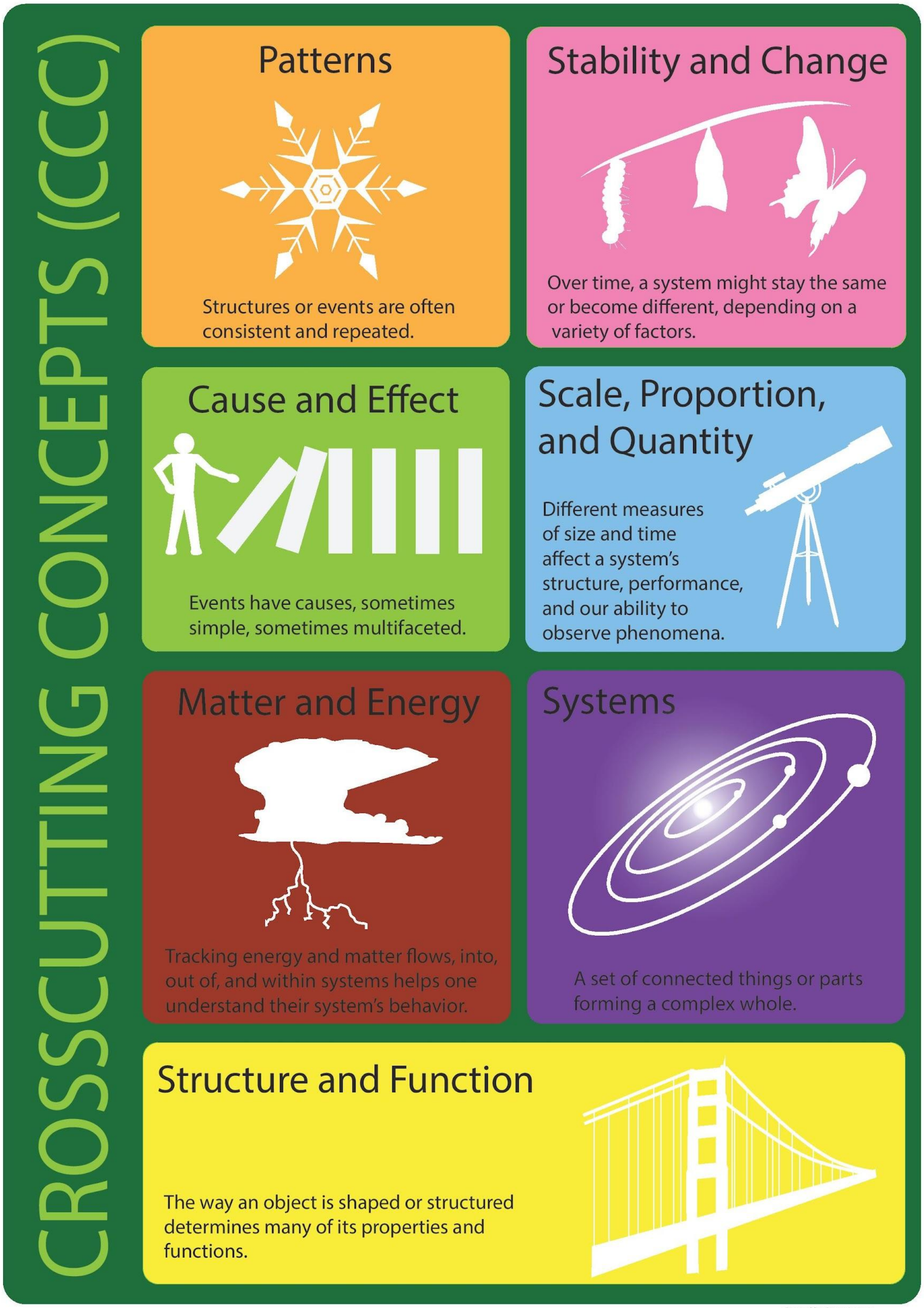
Adam Johnston
Weber State University

Science and Engineering Practices

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

Crosscutting Concepts

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



Created by Susan Larson

What is involved in Engineering Design?

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

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

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

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

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CHAPTER 1

Strand 1: Organisms Functioning in Their Environments

Chapter Outline

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Studying living organisms can provide information about environments both past and present. Plants and animals have internal and external structures that help the organism's growth, survival, behavior, and reproduction. Animals use their senses to understand and respond to their environment. Some kinds of plants and animals that once lived on Earth can no longer be found. Fossils from these organisms provide evidence about the types of organisms that lived long ago and their environments. The presence and location of certain fossil types indicate changes that have occurred in environments over time.

1.1 Survival (4.1.1)

Phenomenon

The Great Salt Lake is a unique wetland environment because of its salty water. The lake is one of the saltiest bodies of water in the world and can be up to eight times saltier than the ocean. Only specific animals are able to live in the Great Salt Lake because of this harsh environmental situation.

Although there are very few living things that can live directly in the salty water of Great Salt Lake, many plants and animals make their home in the marshes around the lake. In the spring, thousands of birds migrate to Utah, breed, and live in the freshwater marshes of Great Salt Lake. The American Avocet and the Snowy Plover are two examples.

	
Image from wildlife.utah.gov; public domain	*Image from wildlife.utah.gov; public domain*
American Avocet	Snowy Plover

Observations and Wonderings

What are you observing about this phenomenon?

What are you wondering about this phenomenon?

Focus Questions

1. How can birds like the American Avocet and Snowy Plover survive in the marshes around the Great Salt Lake?

2. How do their internal and external structures compare to each other?

3. How do these structures help each bird to be able to grow and survive in the environment around the Great Salt Lake?

4.1.1 Survival

Construct an explanation from evidence that plants and animals have internal and external structures that function to support survival, growth, behavior, and reproduction. Emphasize how structures support an organism's survival in its environment and how internal and external structures of plants and animals vary within the same and across multiple Utah environments. Examples of structures could include thorns on a stem to prevent predation or gills on a fish to allow it to breathe underwater. (LS1.A)

As you read, pay attention to plant and animal structures and how these structures help organisms to grow and respond to their environment.

Organism Survival

How do plants and animals survive in the unique environments found in Utah? The animals and plants of Utah have internal and external structures that allow them to respond to their environment.

Plants are not like animals. Plants cannot move to find food. Instead, plants must have the ability to make their own food and survive where they are. They also cannot move around to find a mate, so plants have adapted in unique ways to grow, pass on their traits, and survive in their environment. Plants also help animals to grow and survive.

Plant Structures

Most modern plants have several structures that help them survive and reproduce. Major structures of most plants include roots, stems, and leaves. Some plants have flowers and seeds as well.

Roots

Roots are important organs in most modern plants. There are two types of roots. First, there are the primary roots, which grow downward. Secondly, there are the secondary roots. These roots branch out to the sides. Together, all the roots of a plant make up the plant's root system.

Two types of root systems

Dandelion
(Taproot System)

Whitestar
(Fibrous Root System)

(Left) Image by Robbie Sproule, https://flic.kr/p/Ljr7r, CC-BY
(Top) Image by F.D. Richards, https://flic.kr/p/uDgDMf, CC-BY-SA

The roots of plants have three major jobs. Roots must absorb water and minerals, anchor and support the plant, and store food.

- Roots have special features that are well suited to absorb water and dissolved minerals from the soil.
- Root systems help anchor plants to the ground. Roots allow plants to grow tall without falling over.
- In many plants, roots store food produced by the leaves.

Two plants that live in the wetlands of the Great Salt Lake are cattail and bulrush.

Image by fietzfotos; pixabay.com; CC0

Cattail

Image by geology.utah.gov; CC0

Bulrush

Cattail and bulrush send their roots down into the soil of shallow water. These plants are often seen growing along lakes, rivers, and marshes. These tall plants provide food and protection for wildlife living in the wetlands. Some birds build their nests above ground on these plants to hide from predators. The roots of cattails are the main food source for muskrats.

Stems

Stems are organs that hold plants upright. Stems allow plants to get sunlight and air. Stems can also hold leaves, flowers, cones, and smaller stems.

Image by jei_lee, pixabay.com, CC0

Stems are needed for transport and storage. Stems carry water and minerals from roots up to the leaves. Some plants store the food they produce in their stems (like sugar cane or asparagus). The stem is like an elevator for the plant. The stem allows movement from the top of the plant to the bottom and back up. Without this connection between roots and leaves, plants could not survive. In many plants, stems also store food or water during cold or dry seasons.

Leaves

Leaves are the keys, not only to plant life, but to virtually all life on land. The primary role of leaves is to collect sunlight. This sunlight is needed for the plant to make food. Leaves vary in size, shape, and how they are arranged on stems. You can see examples of different types of leaves in the figure below.

Moss

Fern

Pine tree

Maple tree

Moss (upper left): Thomas Bresson, http://commons.wikimedia.org/wiki/File:2012-12-23_16-48-11-mousse.jpg, CC-BY 3.0
Fern (upper right): Allie_Caulfield, http://commons.wikimedia.org/wiki/File:2011-03-05_03-13_Madeira_179_Monte,_Jardim_tropical_Monte_Palace.jpg, CC-BY 2.0
Pine tree (bottom left): Dcrjsr, http://commons.wikimedia.org/wiki/File:Whitebark_pine_Pinus_albicaulis_needle_clusters.jpg, CC-BY 3.0
Maple tree (bottom right): Jean-Pol GRANDMONT, http://commons.wikimedia.org/wiki/File:0_Acer_saccharinum_-_Tervueren.JPG, CC-BY 3.0

Variation in Plant Leaves

Each type of leaf is well suited for the plant's environment. Leaves have very important functions:

- Leaves absorb sunlight and use it to make food for the plant.
- Some plants use leaves to store water (cactus) or food (spinach or lettuce).

Image by Crusier, https://commons.wikimedia.org/wiki/File:Picea_abies_forest.JPG, CC-BY-SA

Flowers

Image by Suzanne deDiase, pixabay.com, CC0

Utah State Flower Sego Lily

Many plants have flowers. Flowers make pollen, which is needed to make seeds from which new plants can grow. Flowers are often brightly colored to attract birds and insects to spread their pollen and bring pollen from other flowers.

Flowers come in many different shapes and sizes. In Utah, the prickly pear cactus blossoms in the spring with pink, yellow, and orange blossoms. These blossoms provide nectar for bees and moths.

Seeds

Many plants make seeds and store their seeds in different ways, including:

- In their fruit, like peaches or oranges
- In pods, like beans and peas
- On a cob, like corn or wheat

Other plants grow seeds from the plant's flower, like a dandelion or the acorns on an oak tree. Seeds are very important to plants because new plants can grow from seeds. Plants pass on their traits through their seeds.

Image by Angeles Balaguer, pixabay.com, CC0

Image by Rajesh Balouria, pixabay.com, CC0

Plants in Utah

Here are some examples of plants in Utah environments and how the plant structures help the plants and other animals survive.

Image by MikeGoad; pixabay.com; CC0

Juniper trees, which are found in Utah's forests, have needle-like or scaly leaves that stay green all year. Juniper trees never lose their leaves. The needles of the coniferous trees use less water than the broader leaves of deciduous trees.

Image by analogicus; pixabay.com; CC0

The prickly pear cactus has adaptations to help it survive the hot desert habitat. The leaves have a thick waxy covering, which helps keep the water inside the plant longer. The spines of needles on the cactus protect it from sun and wind.

Image by naturell; pixabay.com; CC0

Sagebrush is a very common desert plant throughout Utah. It grows about four feet tall and gives off a very strong odor. Sagebrush is used by some animals for shade, protection from predators, and food for mule deer, caterpillars, and other animals.

Image by 12756913; pixabay.com; CC0

Utah's state tree, the Aspen tree, is deciduous. Deciduous trees drop leaves before the cold or dry season, and grow new leaves in the spring. When the weather gets colder, the leaves turn brilliant colors before falling to the ground. The trunks of the trees are white with grayish black marks running through the bark. Not only do birds use the aspen for nesting, but some animals also use it as food.

pixabay.com; CC0

Beavers are master builders and use their long front teeth for gnawing on Aspen trees. They eat the top tender leaves and use the rest to build their lodges. They also store a supply of small trees, branches, and twigs at the bottom of their homes to help them survive the winter months.

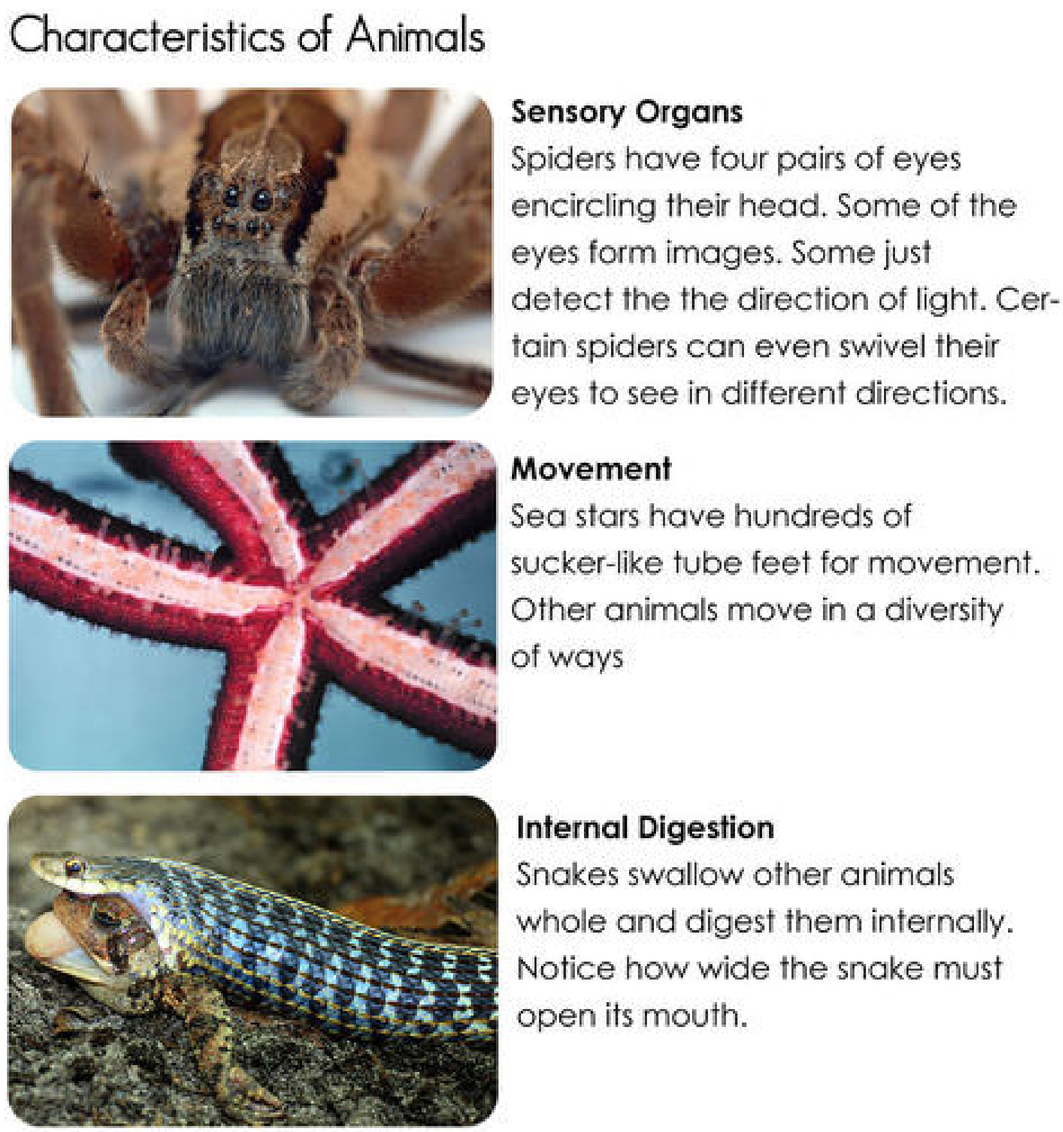
What is the Difference Between Plants and Animals?

Animals cannot make their own food. Animals get nutrients by eating other living things. Animals consume food by eating other organisms. Plants make their own food. This is one way to tell plants apart from animals.

Animal Structure and Function

Animals can look unique. They can also do unique things. Animals can sense the world around them. Most animals have sensory organs. This means animals can hear, smell, touch, and taste. Animals can also move around. Movement allows animals to search for food.

- Animals can sense the world around them. They can sense light and sound. Most animals have a brain. The brain interprets these senses. The brain tells the body what to do.
- Animals can move. An animal's brain works with its muscles. The brain sends signals to the muscles. It tells the muscles to move. Animals can look for food. Animals can avoid threats.
- Animals consume other living things. This is how animals get their food.



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Animal Body Structures

Animal bodies can take many different forms. Some animals have no limbs, some have two, some have four, and some have more. The number and structure of animal limbs affect how an animal moves and interacts with the environment. Different types of animal limbs include - wings, flippers, tails, tentacles, hands, and feet.

Variation of Utah Animal Characteristics

Here are some examples of animals that live in Utah environments and how the animal structures help their growth, survival, behavior, and reproduction.

Image by Wayne Linton, pixabay.com, CC0

The jackrabbit is a common desert animal of Utah. To keep out of the sun on hot days, the jackrabbit stays hidden under shrubs or near clumps of grass. The jackrabbit uses “ear-conditioning” to lose one-third of its body heat through its very large ears. This helps it to keep cool in the hot desert.

Mule deer flash the white underside of their tails to warn other deer of possible danger. This helps the group avoid predators.

Image from wildlife.utah.gov; public domain

Image by USFWS, https://ecos.fws.gov/ecp0/profile/speciesProfile?spcode=E050, *public domain*

The June sucker is unique to Utah Lake, Utah. It is listed as a threatened species. The June sucker uses light and dark colors to camouflage in order to hide from predators.

Beavers use their powerful tails to pat the ground down hard and solid. Utah beavers also use their broad flat tails to steer when swimming, for support when sitting, and to slap the water as a warning to others when danger is near.

Image by NPS/Jim Ecklund; Public Domain

Image by Andrea Bohl (Wildfaces), pixabay.com, CC0

Beavers also have thick coats of fur with an oily covering, a layer of fat under the skin, and a special circulation system that helps keep them warm during winter.

Image by Doug Burkett; www.NPS.gov; public domain

Bobcats are camouflaged with spotted fur. Animals use camouflage to blend into their environment. Camouflage allows animals to hide from predators or sneak up on prey.

Image by Steve Bidmead, pixabay.com, CC0

The porcupine's body is covered with quills that are weapons used for protection against coyotes, bobcats, and other predators. When a porcupine becomes frightened, it shakes its body. Loose quills come out and stick into the attacker's skin.

Males often use their body covering to attract female attention. A male black chinned hummingbird has shiny, purple feathers around its neck while the female black chinned hummingbird is all brown and white.

Male Black Chinned Hummingbird

Image by user:MDF; https://commons.wikimedia.org/wiki/File:Archilochus-alexandri-003.jpg; CC BY-SA

Female Black Chinned Hummingbird

Image by Alan Vernon; https://commons.wikimedia.org/wiki/File:Female_Black-chinned_Hummingbird_in_flight.jpg; CC BY

Putting It Together

Birds that live in the Great Salt Lake wetland environment:

	
Image from wildlife.utah.gov; public domain	*Image from wildlife.utah.gov; public domain*
American Avocet	Snowy Plover

Focus Questions

1. How can birds like the American Avocet and Snowy Plover survive in the marshes around the Great Salt Lake?

2. How do their internal and external structures compare to each other?

3. How do these structures help each bird to be able to grow, pass on their traits, and survive in the environment around the Great Salt Lake?

Final Task

After having read the chapter, refine your explanation as to what internal and external structures the American Avocet and Snowy Plover have that allow them survive in the Great Salt Lake wetland environment.

1.2 Information (4.1.2)

Phenomenon

Images by Utah Division of Wildlife Resources, public domain

Have you ever heard squirrels chatter? Do ground squirrels talk to each other?

The Uinta Ground Squirrel often live in large colonies, meaning there are a lot of ground squirrels living together. Their natural predator is the coyote, which eats small animals.

As a coyote approaches the squirrels' underground burrows, the squirrels start to chatter loudly to each other, screeching and barking.

Observations and Wonderings

What are you observing about this phenomenon?

What are you wondering about this phenomenon?

Focus Questions

1. Why would the squirrels make loud screeching noises as a coyote approaches their burrow?

2. How did the squirrels know the coyote was approaching their burrow?

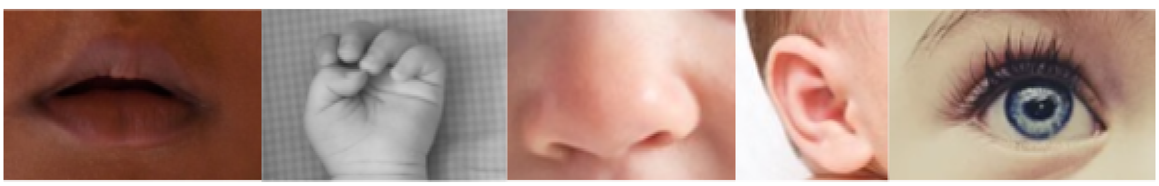
4.1.2 Information

Develop and use a model of a system to describe how animals receive different types of information from their environment through their senses, process the information in their brain, and respond to the information. Emphasize how animals are able to use their perceptions and memories to guide their actions. Examples could include models that explain how animals sense and then respond to different aspects of their environment such as sounds, temperature, or smell. (LS1.D)

Describe how animals use systems to receive, process, and store information to respond and survive the world around them.

Sensing Information

Animals, including humans, are able to respond to their environment in many different ways. Animals use their senses to help respond to the world around them. Can you name the five senses?



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The five senses are taste, touch, hearing, smell, and sight. Did you know some animals have senses that are much better developed than those of humans?

Image by husin.sani, https://flic.kr/p/2P4v4U, CC-BY

- Trained dogs help find people who are trapped under building rubble, mudslides, or snow and alert rescue workers to where the victims are located. Dogs can also be trained to smell drugs or bombs and alert the police.
- Eagles, buzzards, hawks, and other birds of prey have extremely good eyesight and can see small rodents from very far away.

- Elephants, cats, and dogs can hear sounds that human ears cannot hear.

Adapted from image by Gundula Vogel on pixabay.com, CC0

- Bats, dolphins, and some whales use a sense called echolocation. These animals send out special sound waves to help find prey or objects that are far away.
- Animals, such as ants, cockroaches, or crayfish, have special sense receptors that can sense movement from miles and miles away!

Image by Scott & Elaine van der Chijs, https://flic.kr/p/6VhFqT, CC-BY

Human children learn and respond to the world around them by using their senses. This young child is playing in the sand. The child is using their senses and learning about the world through play. What senses do you think the child might be using? Do you think the child might be learning about their environment?

What body system helps you learn?


Image by Kilimkin, pixabay.com, CC0

As these children are studying, many things are taking place. Their eyes have to see the words. Their brains then have to figure out what the words mean. The brain also has to store the information coming in because that information may be needed later. The information will then have to be retrieved. All these processes are controlled by the nervous system.

Introduction to the Nervous System


Image by FaceMePLS, https://flic.kr/p/9is5Tm, CC-BY

Michelle was riding her scooter. She hit a hole in the street. She started to lose control of her scooter. She thought she would fall. In the blink of an eye, she shifted her weight. This quick action helped her to keep her balance. Her heart was pounding. The good news is that she did not get hurt. How was she able to react so quickly? Michelle can thank her nervous system.

Staying balanced when riding a scooter requires control over the body's muscles. The nervous system controls the muscles and maintains balance.

The nervous system does not just control muscles and balance. The nervous system also lets you sense the world around you. What type of things do you think the nervous system controls? The nervous system controls

- conditions inside of your body, such as temperature.
- internal body systems and keeps systems in balance.
- your body to prepare to fight or flee during times of danger.
- language use, thinking, learning, and remembering.

The main organs of the nervous system are the brain and the spinal cord. These organs carry signals to the rest of the body. The messages released by the nervous system traveled through nerves, just like the electricity that travels through wires. The nerves quickly carry electrical messages around the body. The electrical signals travel through the spinal cord and up to the brain. Signals travel back and forth along this pathway.

Image by Raman Oza (sbtlneet), pixabay.com, CC0

Think of what happens when Michelle starts to fall off her scooter. Her nervous system sensed something was wrong. She realized she was losing her balance. Her brain immediately sent messages to her muscles. Some muscles tightened while others relaxed. These actions also moved her hips and her arms. All these actions together helped her keep her balance and not get hurt.

The nervous system works together with your muscles and bones. All the body systems work together to keep us alive. We wouldn't survive without these systems.

The Senses

The senses are also part of the nervous system and include several sense organs, including - eyes, ears, mouth, nose, and skin. Each sense organ has special receptors that work with the brain to cause us to respond in such a way to help us survive. For example, the nose has receptors that respond to chemicals, which we know as odors. Taste and smell are both abilities to sense chemicals. Like other sense receptors, both taste receptors and odor receptors send electrical signals through the nerves to the brain. The brain "tells" us what we are tasting or smelling. We can then respond to that information.

Image by 1045373, pixabay.com, CC0

Touch is the ability to sense pressure. Pressure receptors are found mainly in the skin. Other touch receptors sense differences in temperature or pain. Think back to when you were a little child; did you ever touch something hot? Your skin sensed the high temperature and your nerves sent a message to your brain. Your brain interpreted that sense information as pain and told your muscles to move away. You pull your hand away quickly and hopefully do not get burned!

Image by PDPhotos, pixabay.com, CC0

Hearing is the ability to sense sound waves, and the ear is the organ that senses sound. The ear sends information to the brain. The brain interprets the information it receives and "tells" us what we are hearing.

Sight is the ability to sense light, and the eye is the organ that senses light. The eye sends information to the brain. The brain interprets the information and “tells” us what we are seeing.

If Michelle had been able to see the hole in the road, or if she had heard someone warning her of the hole - she might have been able to avoid it completely! Sight and sound helps us respond to our environment.

What is an example from your own life where sight or sound helped you respond to your environment?

Image by Harsh Vardhan Art, pixabay.com, CC0

Putting It Together

Images by Utah Division of Wildlife Resources, public domain

Have you ever heard squirrels chatter? Do ground squirrels talk to each other?

The Uinta ground squirrels often live in large colonies, meaning there are a lot of ground squirrels living together. Their natural predator is the coyote, which eats small animals.

As a coyote approaches the squirrels' underground burrows, the squirrels start to chatter loudly to each other, screeching and barking.

Focus Questions

1. Why would the squirrels make loud screeching noises as a coyote approaches their burrow?

2. How did the squirrels know the coyote was approaching their burrow?

Final Task

Develop a model of a system to describe how the ground squirrel could have sensed the coyote was near. Use a model to describe why the squirrels made the loud noises.

1.3 Change Over Time (4.1.3)

Phenomenon

While hiking around in the deserts of Utah, your family comes across some fossils of sea shells. There is no water for miles.

Left: by Terasa Peterson CC0
Right: by PublicDomainPictures; pixabay.com; CC0

Observations and Wonderings

What are you observing about this phenomenon?

What are you wondering about this phenomenon?

Focus Questions

1. Why would fossils of ocean dwelling life forms be found in the deserts of Utah?
2. What patterns can you identify in fossils?

4.1.3 Change Over Time

Analyze and interpret data from fossils to provide evidence of the stability and change in organisms and environments from long ago. Emphasize using the structures of fossils to make inferences about ancient organisms. Examples of fossils and environments could include comparing a trilobite with a horseshoe crab in an ocean environment or using a fossil footprint to determine the size of a dinosaur. (LS4.A)

Fossils teach us how ancient organisms might have lived and survived in their environments. Compare and analyze fossils to find evidence of change.

What Can Fossils Tell Us About the Past?

Do you like mysteries? If you do, then you will love to learn about fossils—the remains or evidence of ancient organisms.

Image shared by Smithsonian Institute, https://flic.kr/p/69wehv, public domain

This is an old photograph of people searching for fossils.

These people are splitting open pieces of rock called shale. They are looking for fossils in the rock. The layers of the shale split apart and occasionally reveal the shape of a leaf or an animal in the rock. This rock is called a fossil.

Fossils provide clues to Earth's history. Fossils provide important evidence that helps determine what happened and when it happened in prehistoric times. Fossils can be compared to other fossils and compared to organisms living today. For example, finding fossils of organisms can help scientists figure out what the organisms may have looked like to compare them with organisms of today. This information can be used to make predictions about past environments.

This is a picture of some marine fossils that look very similar to the shells of today.

Image by Jelle, https://flic.kr/p/Hbh3Y, CC-BY-SA

How do scientists use fossils to learn about the history of the Earth? For recent history dating back thousands of years ago, we have written information in books that have many recorded events. This means we can read what people who lived long ago wrote about during certain time periods. However, no human was around millions of years ago to record what really happened.

Scientists have to use other ways to find out about what life was like on Earth millions of years ago. To do this, scientists use fossils. Fossils are actually our most valuable source of information about the ancient past!

By studying fossils of plants and animals, scientists can gather information on how these organisms matured, what they ate, their environment, their climate, and how they interacted.

Image by Jill White (whitejillm), pixabay.com, CC0

The bones of the Tyrannosaurus Rex tell us it was very, very big! A fossil footprint can tell a lot of things about a prehistoric animal, which is an animal belonging to a period of time before recorded history.

Image by Adolfo Beato (adolfo-ahn), pixabay.com, CC0

Image by Alain Bosc, pixabay.com, CC0

Footprints can tell us how much an animal weighed, how big it was, and even the speed at which it was running!

Scientists compare fossils to other fossils to see if they belong to a certain family of organisms. If a match is not found, there is a possibility that an unknown type of organism that existed long ago has been discovered.

Scientists also like to see if the fossil they found is like any of the organisms that exist today. They compare the shape, size, and structure of fossils they have found to see if they match any organisms found today. With this information, scientists try to understand how species have changed over millions of years.

For example, trilobites, which are extinct ocean shellfish, are probably the most common fossils collected in Utah. They range in size from as small as a dime to as large as a dinner plate. There are remarkable similarities found when trilobites are compared with an organism found in today's oceans, the horseshoe crab.

Image of extinct trilobite fossil by WikiMediaImages, pixabay.com, CC0

Trilobite fossil

Images by Goodfreephotos.com (left) and annqussarano (right), pixabay.com, CC0

Today’s horseshoe crab

What similarities and differences do you notice between the trilobite fossil and today’s horseshoe crab? What do you wonder when you see the two species compared?

People have found fossils for thousands of years. Finding fossils have inspired people to ask questions like

- How did these fossil organisms live?
- In what type of world did these fossils live?

Fossils can tell us a lot about Earth's history.

What Are Fossils?

Fossils are preserved in two ways. Fossils can be the remains of organisms or traces of them. These organisms lived in Earth's past.

Most fossils that are found are hard parts from ancient organisms. These hard parts are remains such as teeth, bones, and shells. Preserved traces can include footprints, burrows, or even waste. Examples of these kinds of fossils are pictured in the Figure below.

(A) furtwangl; https://flic.kr/p/61ahBX; CC-BY 2.0
(B) Hannes Grobe/AWI; http://commons.wikimedia.org/wiki/File:Archaeopteryx-8-senkenberg_hg.jpg, CC-BY 3.0
(C) Jan Helebrant, https://flic.kr/p/foQMtZ, CC-BY-SA
(D) edmondo gnerre; https://flic.kr/p/5pwzxi, CC-BY
(E) Mark A. Wilson (Department of Geology, The College of Wooster); http://commons.wikimedia.org/wiki/File:ThalassinoidesIsrael.JPG, public domain
(F) Courtesy of the U.S. Geological Survey; http://commons.wikimedia.org/wiki/File:Coprolite.jpg, public domain

A variety of fossil types are pictured here. Preserved remains: (A) teeth of a cow, (B) nearly complete dinosaur skeleton embedded in rock, (C) sea shell preserved in a rock. Preserved traces: (D) dinosaur tracks in mud, (E) fossil animal burrow in rock, (F) fossil feces from a meat-eating dinosaur in Canada.

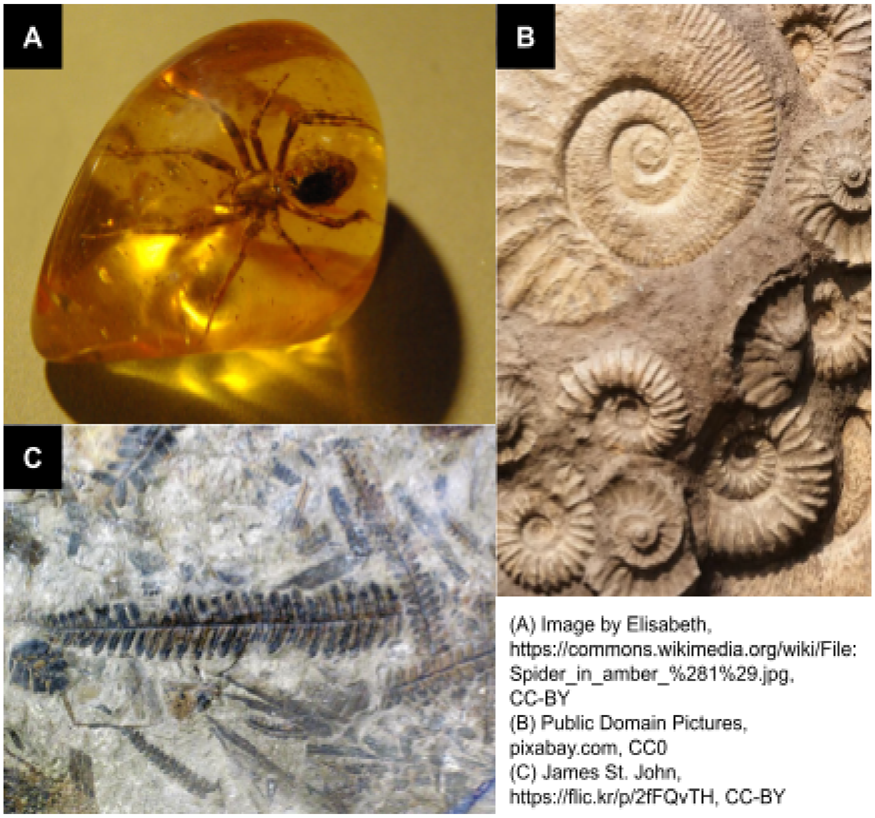
Why Fossilization Is Rare

For fossils to form, conditions must be just right. It's very unlikely organisms will become a fossil. Why don't many dead organisms get turned into fossils?

The soft remains of many organisms are eaten by other animals. Insects may break down remains. Other remains may be broken down by the elements, like sunlight, wind, and rain.

Hard parts are much more likely to become fossils than soft parts. Even an animal's hard parts are unlikely to become a fossil. Fossils of soft organisms, from bacteria to jellyfish, are very rare.

There have been many organisms that have lived in Earth's past. Only a tiny number of them became fossils. Still, scientists learn a lot from fossils. Fossils are our best clues about the history of life on Earth.



(A) This spider looks the same as it did the day it died millions of years ago!

(B) These shell fossils were found in a rock.

(C) These ferns were fossilized.

(A) Image by Elisabeth, https://commons.wikimedia.org/wiki/File:Spider_in_amber_%281%29.jpg, CC-BY
(B) Public Domain Pictures, pixabay.com, CC0
(C) James St. John, https://flic.kr/p/2fFQvTH, CC-BY

Fossils provide evidence about life on Earth. They tell us that life on Earth has changed over time. Fossils in younger rocks look like animals and plants that are living today. Fossils in older rocks are less like organisms alive today.

Fossils can tell us about where an organism lived - on land or in a marine habitat. Fossils can tell us if the water was shallow or deep. Fossils can provide clues about ancient climates.

Fossil Environments

Fossils give clues about major geological events. Fossils can also give clues about past environments.

Can fossils of ocean animals be found on the top of Earth's tallest mountain? It's hard to believe; but, yes, it is true. Ocean animal fossils were found at the top of Mt. Everest. Mt. Everest is the highest mountain on Earth. These fossils showed that Mt. Everest was once at the bottom of the sea. It can only mean that Mt. Everest was uplifted. In fact, the entire Himalaya mountain range was raised. It was forced up from the collision of two continents. Fossils of plants are found in Antarctica. Now, Antarctica is almost completely covered with ice and plants do not grow there. According to fossils, plants once did grow in this area. This means that Antarctica was once warmer than it is now. These fossils tell us about Antarctica's past climate.

Image by National Park Service, public domain

What can we learn from fossil clues like this fish fossil found in the Wyoming desert?

Like a great detective, we need to take these clues from Earth's history to make inferences about Utah's past. The environment of Utah long ago was very different from what it is today.

A Prehistoric Environment

Using the fossils found in various locations of Utah, we can infer how Utah's environments have changed over time. We can infer that much of Utah was once covered with a shallow sea. We can determine this because many sea-life fossils have been found in Utah, including trilobites.

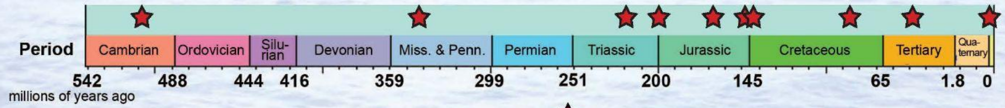
Fossils of coral have also been found in our state, and coral only lives in warm, shallow bodies of water.

Dinosaur fossils and coalfields help us infer that parts of Utah were once tropical, a very hot and moist climate. These were conditions suitable for dinosaur life. Dinosaurs could not live in the dry environment of Utah today. More examples of fossil environments in Utah are described in the next graphic.

Fossils also help us to infer why dinosaurs and other organisms became extinct. Fossils tell us there was a mass extinction, or loss of an entire type of organism. Dinosaurs became extinct about 65 million years ago, along with more than half of all the other prehistoric animal and plant species. There are several ideas about what caused the extinction. All these ideas are based on fossil evidence.

Fossil Environments in Utah

by Carole McCalla



Stars indicate fossil locations (below) and age (above).

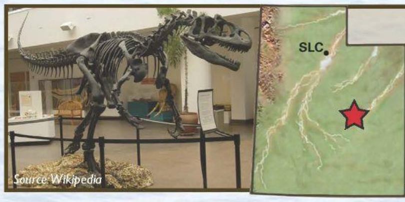
Approximately 510 million years ago (mya), during the Cambrian Period, trilobites thrived in the seas that covered western Utah. Trilobites are an extinct class of arthropods. Modern day arthropods include insects, crabs, and spiders. These fossils can be found scattered across western Utah, particularly the House Range in Millard County.

Horn corals were abundant during the Mississippian (~340 mya). During this time, Utah was almost completely covered by a shallow sea. Horn corals are an extinct order of coral known as *Rugosa*. Abundant horn coral fossils can be found in the Confusion Range in Millard County.

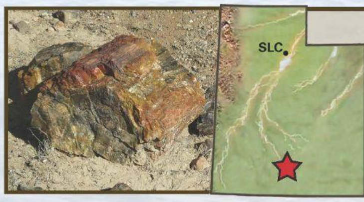
During the Triassic Period (~215 mya), central Utah was a transition zone between river flood plains to the southeast and seas to the northwest. Abundant fresh-water deposits yield the fossil remains of primitive fish.

Dinosaurs roamed through Utah during the Jurassic Period, leaving behind footprints in the soft sediments. At the beginning of the Jurassic (~200 mya), Utah was covered by a vast sand dune desert with inter-dune oases. Dinosaur tracks can be found in many areas, including the Moenave Sandstone at the Johnson Farm's tracksite near St. George in Washington County.

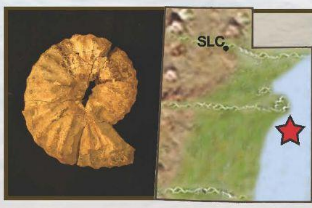
During the Middle Jurassic (~170 mya) a shallow sea extended into Utah from the north and left many fossils, particularly the five-sided *Isocrinus*. Crinoids are still alive today in the seas of the world and are commonly known as sea lilies.



A broad coastal plain covered most of Utah during the Late Jurassic (~150 mya). Forests and lakes provided habitat for dinosaurs such as the Utah state fossil, *Allosaurus,* which dominated the land. Allosaurus was a meat-eating dinosaur that walked on two legs.



Petrified wood from the abundant forests that covered Utah during the Late Jurassic (~145 mya) can be found at Escalante Petrified Forest State Park in southern Utah.



During the Cretaceous (~90 mya), Utah was covered by river plains and coal-forming swamps and an interior seaway to the east. Coal (fossilized plant remains) is Utah's most abundant fossil and can be found throughout central and eastern Utah. The fossilized remains of ammonites can be found in shales that were deposited in the seaway that covered eastern Utah during this time. Ammonites are an extinct group of cephalopods. Ammonites' closest living relatives are the octopus, squid, cuttlefish, and nautilus.

Lush forests and a huge freshwater lake covered part of Utah during the early Tertiary (~50 mya). Plant fossils can be found throughout central and northern Utah in sedimentary rocks of this age.

Several times during the Quaternary (~1.8 mya – 15,000 ya), Utah was covered by glaciers. Ice Age mammals, such as the mammoth, roamed throughout Utah. The photo shows a mammoth tusk that was found near Fillmore, Utah in Lake Bonneville deposits from about the time of the latest glacial event about 15,000 years ago.

Public Information Series 93
Utah Geological Survey
a division of
Department of Natural Resources
2008

Putting It Together

While hiking around in the deserts of Utah, your family comes across some fossils of sea shells. There is no water for miles.

Left: by Terasa Peterson CC0
Right: by PublicDomainPictures; pixabay.com; CC0

Focus Questions

1. Why would fossils of ocean dwelling life forms be found in the deserts of Utah?

2. What patterns can you identify in fossils?

Final Task

Analyzing the data from the previous chapter, what can you interpret about the environments of Utah?

- What do we learn about Utah’s environmental change over long periods of time?

- What was Utah’s environment like in ancient times compared with modern day Utah?

1.4 Evidence of Change Over Time (4.1.4)

Phenomenon

Your family decides to go hiking in Big Cottonwood Canyon. As you drive up the canyon your little brother suddenly yells, “Why are there big dents in that rock?” Your family decides to pull over and take a closer look. Your mom thinks it looks more like ripples than dents.

Courtesy of the Utah Geological Survey.

Observations and Wonderings

What are you observing about this phenomenon?

What are you wondering about this phenomenon?

Focus Questions

1. How can we explain the patterns of the dents or ripples in the rock?

2. How has Earth changed and stayed the same over time?

4.1.4 Evidence of Change Over Time

Engage in argument from evidence based on patterns in rock layers and fossils found in those layers to support an explanation that environments have changed over time. Emphasize the relationship between fossils and past environments. Examples could include tropical plant fossils found in Arctic areas and rock layers with marine shell fossils found above rock layers with land plant fossils. (ESS1.C)

Observe rock layers to find patterns and use evidence based arguments to explain that environments have changed over time.

Fossils

Fossils show us that life on Earth has changed. Fossils tell us about past environments. We can find out which parts of the world were once colder or warmer than they are now. We know where rivers, lakes, or seas once existed. A piece of sandstone with wave-like ripples lets us know that a beach was once located here. We can find out how long ago some plants and animals lived, how they lived, and how they died.

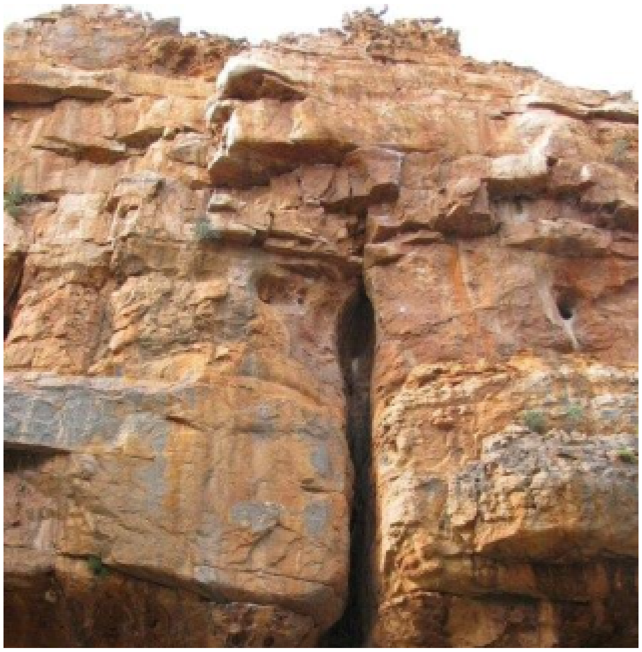
Fossils are the record keepers of Earth. Not all the fossil records are easy to read. Some records may be lost and other records may be incomplete. All fossil records still provide clues to what happened in the past and why Earth is as it is today. Working as detectives, we can look at the clues, put the pieces together, and infer what happened in the past.

Every rock has a unique story to tell. Just as a detective pieces together clues from a crime scene to determine what may have happened, a geologist uses clues within sedimentary rocks to determine what type of environment the rock formed in.

Sedimentary rocks have many characteristics that provide important information about past climates, past life forms, and the ancient geography.

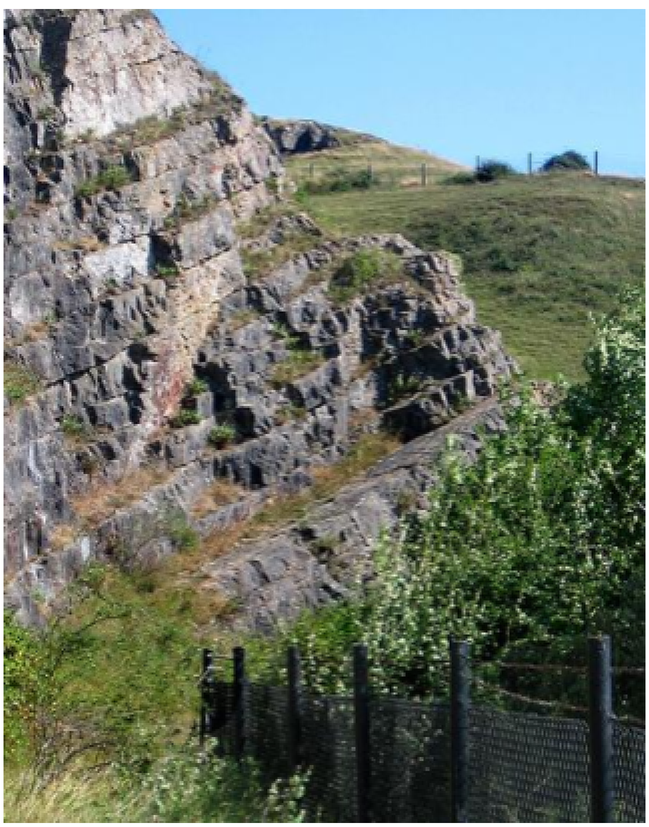
Sediments

When the sand grains collect on top of each other, a sediment is formed. Over time, new layers of mud and sand are deposited on top of the previous layers. Over a very long time, these sediments become compacted and hardened and become a sedimentary rock. This happens because the grains of sand become cemented together and other heavy sediments press down on the grains of sand. Sediments lie on top of each other. We can actually see these layers in sedimentary rock and they are sometimes different colors. Find the sediments in the pictures below.



Sandstone rock in the Cederberg in the Western Cape

Image from http://www.thunderboltkids.co.za/Grade5/04-earth-and-beyond/chapter3.html, CC-BY-ND



Layers of Limestone Sedimentary Rock

Image from http://www.thunderboltkids.co.za/Grade5/04-earth-and-beyond/chapter3.html, CC-BY-ND

Image by Seldom Seen Photography, https://flic.kr/p/78ZCsg, CC-BY

Look at these layers in this sedimentary rock known as shale.

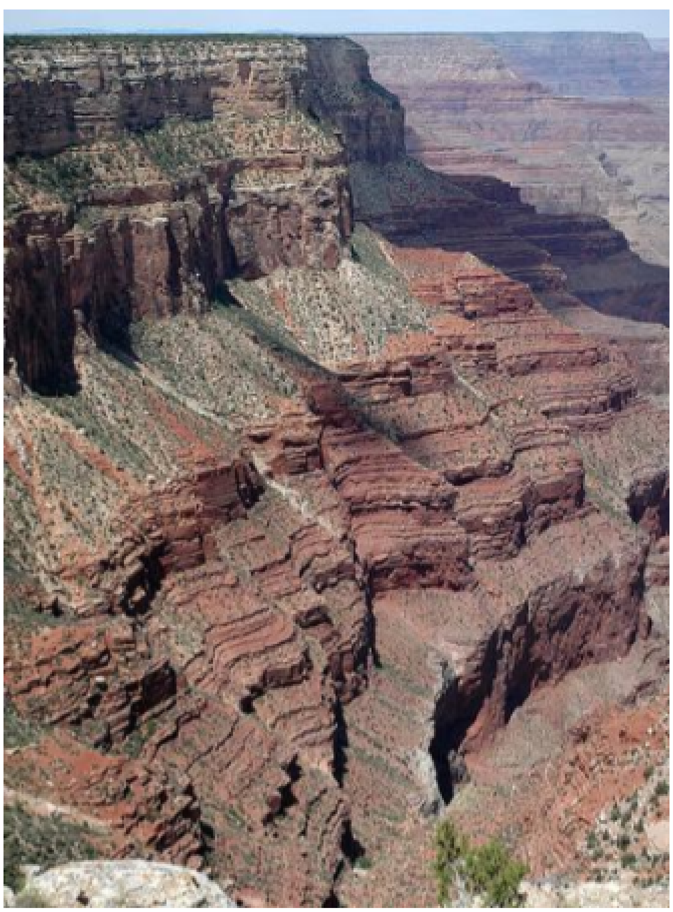


Image by Grand Canyon National Park, https://flic.kr/p/adFNT8, CC-BY

Look at the layers in the sedimentary rock in the Grand Canyon.

The size, shape, and different materials within the rocks can show the energy of the water, wind, or glaciers moving the sediments, as well as the length of time or distance the sediment was carried. Some examples are mudcracks in rocks that must have formed when wet clay was temporarily exposed to the air and dried, or ripple marks in rocks that show which direction the water currents were moving and are typical of rivers, beach deposits, and tidal areas.

Fossils, tracks, and burrow marks in rocks may also show the age of the rock, specific life forms, and climate conditions of that layer of sediment.

Because sediment is often deposited in layers, each layer can reveal details such as slight changes in water conditions or even seasonal changes. There are ripple marks and mud cracks in Big Cottonwood Canyon, which are what was left behind from an ancient beach.

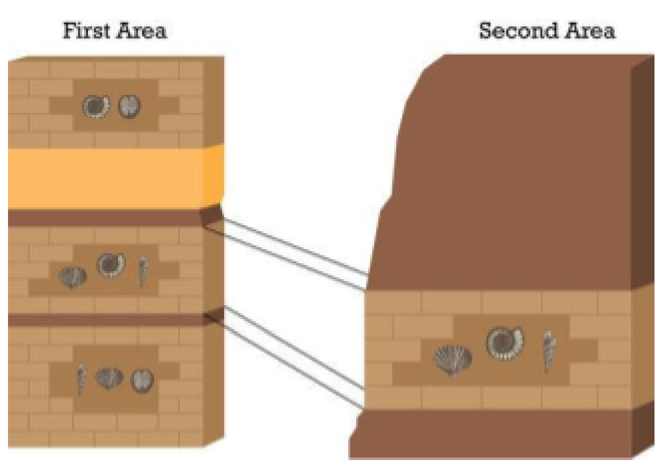
By using the geologists' motto, "the present is the key to the past," geologists can determine what the area might have looked like at various times in the past.

Some geologists study the history of the Earth. They want to learn about Earth's past. They use clues from rocks and fossils. They use these clues to make sense of events. The goal is to place things in the order they happened. They also want to know how long it took for those events to happen.

Consider the study of the layers of rock. A lot can be learned by looking at layers of rock. Scientists can learn about past environments. From fossils, scientists can learn about what plants and animals once lived in the area. If scientists know what type of plant or animal lived in an area, they can get a good idea about the type of climate. The fossil evidence will tell scientists if the area was land or marine.

Index Fossils

Fossils can be used to match up rock layers. As organisms change over time, they look different. Older fossils will look different than younger fossils. Some organisms only survived for a short time before going extinct. Knowing what organisms looked like at certain times also helps date rock layers. Some fossils are better than others for this use. The fossils that are very distinct at certain times of



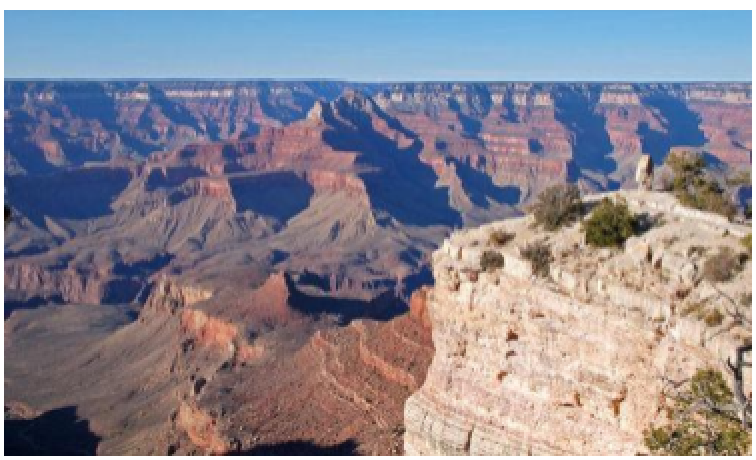
Using Index Fossils to Match Rock Layers. Rock layers with the same index fossils must have formed at about the same time. The presence of more than one type of index fossil provides stronger evidence that rock layers are the same age.
Image by Christopher Auyeung, CK-12 Foundation, CC BY-NC 3.0

Earth's history are called index fossils. Index fossils are commonly used to match rock layers. If two rock layers have the same index fossils, then the layers are probably about the same age.

There is also a lot that can be learned by the position of rocks. We know the rocks on top are always younger than the rocks below. Knowing the age of rocks is very important to scientists. Because new rock layers are always deposited on top of existing rock layers, we know that deeper layers must be older than layers closer to the surface.

The rock layers at the bottom of this cliff are much older than those at the top.
Image by Ron Sanderson, http://www.publicdomainpictures.net/view-image.php?image=26142&#38, Public Domain

Rock layers extend out to the sides and cover very large areas. This is especially true if the rock layers formed at the bottom of ancient seas. Seas are very large areas of water. Over time, sediment builds up on the seabed. The seabed will be covered with the same types of material. As rocks form out of this sediment, it will all be the same type. The rocks may be forced up above the water as Earth's plates move. Rivers may eventually run across this area. The river will cut into the rock and erode it away. The layers of exposed rock on either side of the river will still "match up."



Layers of the same rock type are found across canyons at the Grand Canyon, they are the same age.
Image by Grand Canyon National Park, https://flic.kr/p/cvGYJb, CC-BY

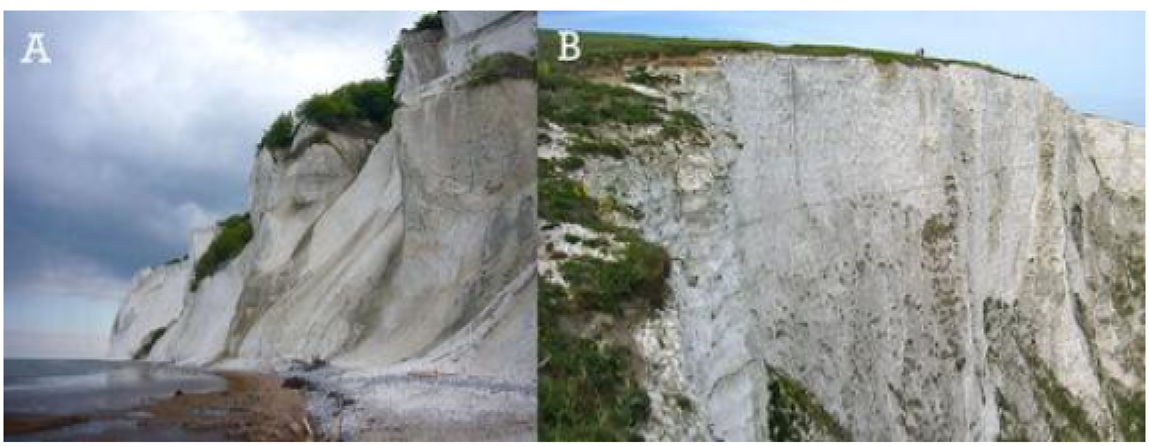
Look at the Grand Canyon. It's a good example of this. You can clearly see the same rock layers on opposite sides of the canyon. The matching rock layers were deposited at the same time. They are the same age.

Matching Rock Layers

It is easy to match rock layers across a river, like with the Grand Canyon picture. Unfortunately, matching rock layers is not always that easy. Sometimes, rock layers are not in the same place. They may be on different continents. So how do we match rock layers in this case? What evidence can we use to match the layers?

Widespread Rock Layers

Some rock layers extend over a very wide area and may even be found on more than one continent. For example, the famous White Cliffs of Dover are on the coast of southeastern England. These are very distinctive rocks. They can be matched to similar white cliffs in France, Belgium, Holland, Germany, and Denmark (see Figure below). Why is this important to us? As it turns out, these cliffs are made of chalk. Chalk is a very soft rock. This rock extends from England to Europe. It extends under the English Channel. Because it is soft the Channel Tunnel connecting England and France was carved into it!



Chalk Cliffs. (A) Matching chalk cliffs in Denmark and (B) in Dover, U.K.

Credit: (A) Chad K, http://www.flickr.com/photos/chad_k/248461570/, CC-BY 2.0; (B) Kyle Taylor, http://www.flickr.com/photos/kyletaylor/3540955820/, CC-BY 2.0

Putting It Together

Courtesy of the Utah Geological Survey.

Your family decides to go hiking in Big Cottonwood Canyon. As you drive up the canyon your little brother suddenly yells, “Why are there big dents in that rock?” Your family decides to pull over and take a closer look. Your mom thinks they look more like ripples than dents. What do you think?

Focus Questions

1. How can we explain the patterns of the dents or ripples?

2. How has Earth changed and stayed the same over time?

Final Task

Write an explanation about how we can use patterns as evidence to explain the environment that caused the dents or ripples in the rock in Big Cottonwood Canyon.

CHAPTER 2

Strand 2: Energy Transfer

Chapter Outline

Image by Keith Johnston (KeithJJ), pixabay.com, CC0
https://pixabay.com/photos/soccer-football-soccer-ball-1473977/

Energy is present whenever there are moving objects, sound, light, or heat. The faster a given object is moving, the more energy it possesses.

When objects collide, energy can be transferred from one object to another causing the objects' motions to change.

Energy can also be transferred from place to place by electrical currents, heat, sound, or light. Devices can be designed to convert energy from one form to another.

2.1 Speed and Energy (4.2.1)

Phenomenon

You are watching a baseball game, cheering for your home team, when your favorite player hits a home run. You watch the baseball fly fast and high over the back fence. When a player from the other team comes up to bat, he bunts and the ball slowly goes a few feet.

(Left) Image by Keith Johnston (KeithJJ), pixabay.com, CC0
(Right) Image by Skeeze, pixabay.com, CC0

Observations & Wonderings

What are you observing about this phenomenon?

What are you wondering about this phenomenon?

Focus Questions

1. What do you predict caused one baseball to go over the back fence and the other to only travel a few feet?

2. What do you notice about how each baseball player hit the ball? Did the way they each hit the ball affect how far it went?

3. Which baseball traveled faster, the home run ball or the bunt?

4.2.1 Speed and Energy

Construct an explanation to describe the cause and effect relationship between the speed of an object and the energy of that object. Emphasize using qualitative descriptions of the relationship between speed and energy like fast, slow, strong, or weak. An example could include a ball that is kicked hard has more energy and travels a greater distance than a ball that is kicked softly. (PS3.A)

In this chapter observe the cause and effect relationship between the speed of an object and the energy of that object.

Energy and Speed

Have you ever watched younger children? If you did, then you probably noticed that young children are very active. They seem to be in constant motion. It may even be hard to keep up with them. Where does the ability to move quickly come from? Another way to say this is that kids have a lot of energy. But what is energy?

Young children seem to be full of energy.
Image by Angus Chan, https://flic.kr/p/fdbAY, CC-BY

Defining Energy

Energy is the ability to do work. Another way to say this is, the ability to cause change. When work is done, energy is transferred. This transfer occurs between one object and another. For example, a batter swings a bat and transfers energy. She transfers her energy to the bat. The moving bat, in turn, transfers energy to the ball.

It takes energy to swing a bat. Where does the batter get her energy?
Image by Keith Johnston (KeithJJ), pixabay.com, CC0

Things with energy can do work, they can cause change. One kind of change it can cause can be movement.

What do all the photos in the next figure have in common? All of them show things that are moving. Anything that is moving has energy. For example, the hammer in the photo is doing the work. It is pounding the nail into the board. In other words, the hammer has energy and is causing a change by moving the nail. The movement of the nail is the effect of the energy in the hammer.

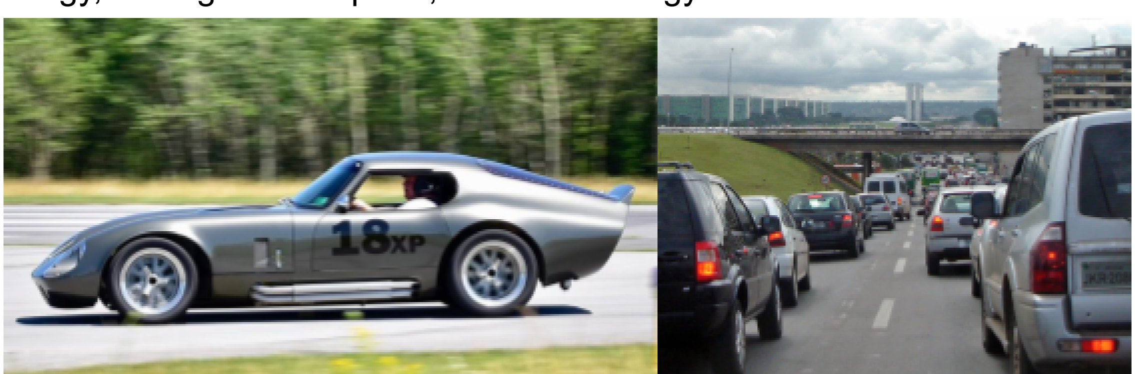
All of these photos show things that have energy because they are moving.
Hammer and nail: Robert Lopez, CK-12 Foundation, CC BY-NC 3.0; Jumping girl: Johan Viirok, https://flic.kr/p/94gotW, CC BY 2.0; Bees: William Warby; https://flic.kr/p/5ye11b, CC BY 2.0; Boy and pinwheel: popofatticus; https://flic.kr/p/6hERx2, CC BY 2.0; Dominoes: Barry Skeates; https://flic.kr/p/bncjuG, CC BY 2.0 Waterfall: Tony Hisgett, https://flic.kr/p/DjUx4, CC BY 2.0

Anytime there is a change in movement, there is energy. The amount of energy in a moving object depends on its mass and speed. An object with greater mass and greater speed has more energy.

Speed is an important aspect of motion. It is a measure of how fast or slow something moves. Have you ever played softball? You may have found it easy to hit the ball as it was tossed toward you slowly. Well, that's only one kind of softball. Fast-pitch softball is a whole new game. The ball is not pitched slowly. Instead, it speeds nearly as fast as a baseball. The speed of the ball makes it harder to hit.

In fastpitch softball, the pitcher uses a "windmill" motion to throw the ball. This is a different technique than other softball pitches. It explains why the ball travels so fast.

Another familiar example is the speed of a car. In the U.S. this is usually expressed in miles per hour. Think about a trip you and your family made in the car, did you go fast and slow? It may depend on the speed limits, traffic, and traffic lights. When you travel by car your speed changes. The faster you go, the more energy the car has, the slower you go, the less energy the car has. For example, if you travel 65 miles per hour on a highway, the car will have more energy because there is more speed. When going through a city you may only be going 25 miles per hour, so there is less energy. You might even have to stop at traffic lights or you slow down as you turn corners. You speed up to pass other cars. The slower your speed, the less energy, the higher the speed, the more energy!



Cars race by in a blur of motion on an open highway but crawl at a snail's pace when they hit city traffic.

(Left) Image by R.A. Killmer, https://flic.kr/p/2hEKMr2, CC-BY-NC-ND
(Right) Image by Mario Roberto Duran Ortiz, https://commons.wikimedia.org/wiki/File:Traffic_Congestion_Brasilia.jpg, CC-BY 3.0

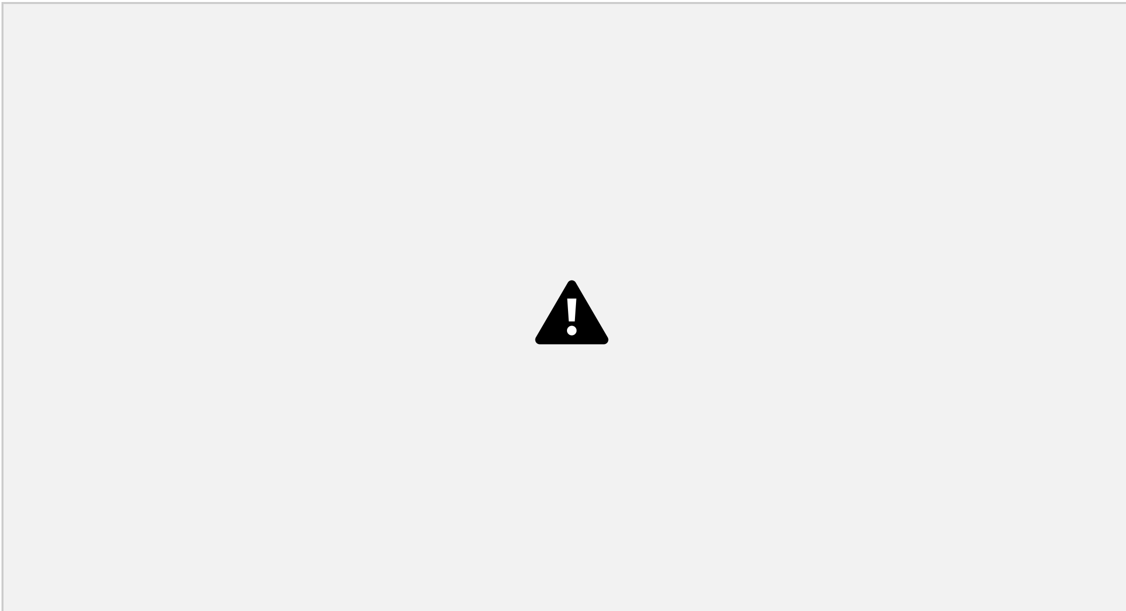
Image by Keith Johnston (KeithJJ), pixabay.com, CC0

Your kick or hit may also change the speed of a ball. It could go faster and travel farther after a hard hit, or slower and travel a short distance after a gentle kick. What causes this to happen? A slow-moving ball has little energy. A fast-moving ball has much more energy. The amount of energy in an object is important for how fast or far an object will travel.

Wind can do the same thing. When the wind is blowing slowly, it can move small bits of material. When it is moving fast, it will move much more material. The wind moves many things. Check out the flag at the front of your school. It may hang down on a calm day. When the wind blows softly it will rustle a bit. There is little energy so the flag doesn't move much. But when the wind blows hard, the flag will fly straight out from the mast. There is more energy so the flag moves a lot.

Calm days mean little energy. Windy days mean more energy.

Putting It Together



When you watch another baseball game you observe the same phenomenon of some hits resulting in home runs and others resulting in bunts.

Focus Questions

1. What caused one baseball to go over the back fence and the other to only travel a few feet?

2. What did the first batter do differently with his bat to cause the ball to travel at a faster speed?

3. Which baseball do you think had more energy, the home run ball or the bunt? What evidence do you have to support your answer?

Final Task:

Use the information in this chapter to construct an explanation of what caused the baseball to travel different distances.

2.2 Collisions (4.2.2)

Phenomenon

When playing a game of pool, your first shot of the game is called a “break” where the stationary colored pool balls collide with a moving cue ball sending them all over the table.

Image by gregkorg, pixabay.com, CC0

Image by Skeeze, pixabay.com, CC0

Observations & Wonderings

What are you observing about this phenomenon?

What are you wondering about this phenomenon?

Focus Questions

1. What changes to the colored pool balls' motion do you observe from the first to the second image?

2. What caused the colored pool balls to speed across the table in all different directions?

4.2.2 Collisions

Ask questions and make observations about the <u>changes</u> in energy that occur when objects collide. Emphasize that energy is transferred when objects collide and may be converted to different forms of energy. Examples could include changes in speed when one moving ball collides with another or the transfer of energy when a toy car hits a wall. (PS3.B, PS3.C)

In this chapter, observe examples of two objects colliding changing the amount of energy in each object.

Energy Conversion

What happens when a diver jumps off the diving board? His energy changes as he falls. In other words, he falls faster and faster, increasing in speed, until reaching the water. Energy of motion from the diver transfers to the water causing a large splash that moves water and causes sound that we hear. These changes in energy are examples of energy conversion. Energy can be converted from one form to another. It can also be transferred from one object to another.

In a collision, you know there is a change or conversion in energy because there is a change in motion.

What happens when I drop an egg on the floor?

Image by emirkrasnic, pixabay.com, CC0

Why did the egg break?

The egg was moving, so it had energy, but then the egg transferred energy to the floor when it collided and to the air as sound and heat when we heard it crack. The transfer of energy to the floor and air causes the egg's motion to stop.

What happens when a car stops? To stop a car, the driver inside must slow down his speed to zero miles per hour as smoothly as possible by pressing on the brakes. When the brakes are applied to the wheels of a car, the car slows to a stop. Where did the energy of motion in the car go? Most of the energy transferred to heat and sound made by rubbing the brakes against the car wheels. Changes in the speed of a car from a collision between brakes and wheels show a transfer, or change, of energy.


Images by (left) Clker-Free-Vector-Images and (right) OpenClipart-Vectors, pixabay.com, CC0

Lift a basketball in one hand. There is energy in this movement. Now lift a ping pong ball. The energy needed to lift a ping pong ball is far less than the energy needed to lift a basketball. That's because the basketball has more mass. Mass is the amount of material in an object. Objects with more mass require more energy to move, to turn, and to stop. We measure an object's mass by weighing it.

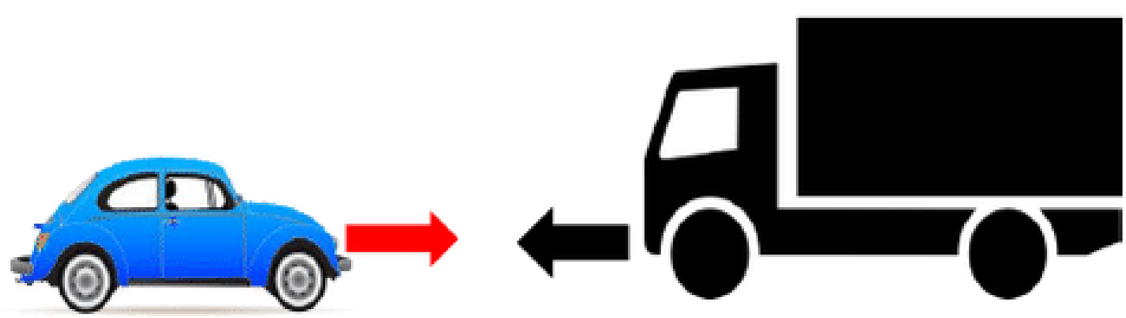


Image by authors; CC0

A large truck has more mass than a small car. If they collide, what do you think will happen? The truck has so much mass that it may continue to move forward. The small car will be pushed back or to the side because it has less mass. There is a transfer of energy, as there is a change in speed or motion of the objects.

You can try this by colliding two balls of unequal size, like the basketball and a ping pong ball. The ping pong ball is pushed back or away by the energy of the basketball because of the increased mass of the larger ball. The larger ball had more energy than the smaller ball. Some other collisions to try:

- Two balls with the same mass.
- A large toy car hits the side of a small toy car.
- Two toy cars with the same mass.
- Can you think of others?

Putting It Together

Image by gregkorg, pixabay.com, CC0

Image by Skeeze, pixabay.com, CC0

When playing a game of pool, your first shot of the game is called a “break” where the colored pool balls, that were previously racked together in a stationary position on the table, collide with a cue ball sending them all over the table.

Focus Questions

1. How can one fast moving ball cause twelve balls to move in different directions when they collide?

2. A few moments after the “break” all of the pool balls come to a stop. What transfer of energy causes all of the balls to stop?

Final Task

What do you observe when a toy car collides with a wall?

What happens to the two objects (toy car and wall) when they collide?

In what way is this similar and different to what happens when a moving pool ball collides with a stationary ball?

2.3 Energy Transfer (4.2.3)

Phenomenon

The man is playing an electric guitar. The audience hears sounds made by the guitar. The bright stage lights illuminate the musician for everyone to see. The lights can also make it get really warm on stage.

Image by David Burke, (Flickr:Orangedrummaboy), https://flic.kr/p/bZYLfC, CC BY-NC-ND 2.0

Observations & Wonderings

What are you observing about this phenomenon?

What are you wondering about this phenomenon?

Focus Questions

1. What do you observe in the picture that could be forms of energy?

2. How is energy transferred from the stage and musician to the audience?

4.2.3 Energy Transfer

Plan and carry out an investigation to gather evidence from observations that energy can be transferred from place to place by sound, light, heat, and electrical currents. Examples could include sound causing objects to vibrate and electric currents being used to produce motion or light. (PS3.A, PS3.B)

In this chapter, investigate various ways that energy can be transferred between objects in the form of sound, light, heat, or electrical currents.

Energy

Whenever anything happens, energy is transferred from one component into another. People, machines and appliances need an energy input to work. They also have an energy output that may be useful.

Let's look at some examples.

Example 1:

A girl is running a race. In order for the girl to have energy to move, she needs energy from somewhere. Her input energy is the energy from the food that she ate. By running the race, she is giving out energy in the form of movement energy and heat.

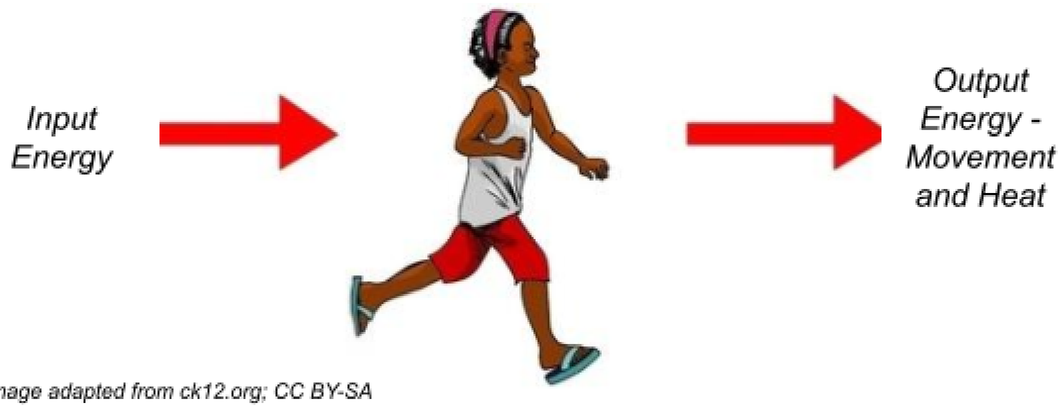


Image adapted from ck12.org; CC BY-SA

Example 2:

A TV will only work if it is plugged in. It needs energy to work. While watching TV, electricity is the input energy and light and sound is the output energy.

Image adapted from ck12.org; CC BY-SA

Example 3:

A flashlight will not work when you turn it on unless it has batteries. The input energy for the flashlight to work comes from the energy in the batteries which is changed to electricity. The output energy from the flashlight is light and heat.

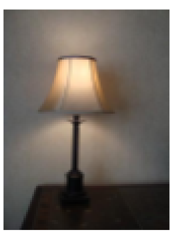
Image adapted from ck12.org; CC BY-SA

Machines and appliances

We use lots of appliances in our lives. These machines and appliances need input energy to make them work. This is usually electricity. The output energy (the work the appliance or machine does) is something that is useful to us.

Next are pictures of different appliances. Each one has input energy (electricity) and output energy which is transferred to the surroundings, such as heat, sound, light or movement.

1. Look at each image and write down the type of output energy that it transfers to the environment.
2. Some of the appliances may transfer more than one type of energy to the surroundings.

Input Energy= Electricity	Output Energy transferred to surrounding=?	Input Energy= Electricity	Output Energy transferred to surrounding=?
Stove 		Kettle 	
Lamp 		Hair Dryer  Image by OpenClipart-Vectors, pixabay.com, CC0	
Vacuum 		Fan 	

In summary, we can say that in appliances and machines, the input energy is normally electricity and the output energy depends on the appliance:

Output Energy Answers

- Heat - from a geyser, stove, kettle, hair dryer
- Sound - from a drill, vacuum cleaner, hair dryer
- Light - from a lamp, torch
- Movement - from an electric fan

Comparing Forms of Energy

Energy comes in many different forms, such as electricity, light, heat, sound, and movement. They all have the ability to do work. Think about when you do work. You need a lot of energy. Maybe your energy comes from a good breakfast. Your body turns the food you eat into energy. This energy gives you the strength to do work. There are many forms of energy. Let's take a closer look at these forms of energy.

Electricity

Electricity flows, or moves, through wires in your home. Anything that is moving has energy. We often refer to this motion, the flow, as electricity. This motion is what makes it possible to watch TV and talk on your cell phone.

Living things need energy from the Sun to survive. That energy comes to us as light.
Image by Johannes Plenio (jplenio), pixabay.com, CC0

Light

Light is energy that moves in waves. Light comes from a light source.

Anything that produces light is called a source, like the sun or a light bulb.

Heat

Do you enjoy standing outside on a warm summer day and feeling the warmth from the Sun on your skin? What about warming your hands on a frosty cold morning in front of a fire? You are feeling heat! We discussed that the Sun provides us with light, but it also provides us with heat.

Look at this lion enjoying lying in the heat from the Sun!
Image by Free-Photos, pixabay.com, CC0

Heat can be found in many different places. Anything that provides us with heat is a source of heat.

Sound

Movement causes sound. In a band, you make lots of different sounds. Every sound that you make involves you moving a part of your body.

A man plucking the strings on a guitar
Image by Free-Photos, pixabay.com, CC0

Musical instruments use movement in different ways to make sounds. Let us look at a few common musical instruments.

When a guitar string is plucked, the string vibrates and causes a sound wave to occur. We can then easily hear the sounds produced by the guitar.

A group of drum players
Image by Ken Bosma, https://flic.kr/p/bw8bzg, CC-BY

A drum has a thin membrane or skin that is stretched tightly over the opening of something hollow. As the drummer beats this membrane, the membrane vibrates, a type of movement, and makes the sound we hear.

A trumpet player in a marching band
Image by Brian Fitzharris, https://flic.kr/p/cyW8ZQ, CC-BY

The trumpet player blows air, moving it through closed lips into the trumpet. This makes a buzzing sound which causes the air inside the trumpet to vibrate. The vibrating air causes sound which we can hear.

Many musical instruments work because movement causes vibrations which cause sound. We have seen that musical instruments make sounds through vibrations. Can you investigate if other ways of movement can produce sound? Try these few ideas.

Image by http://www.thunderboltkids.co.za/Grade4/03-energy-and-change/chapter4.html#, CC-BY-ND

Sit on opposite sides of a wall and communicate to your friend!
Image by http://www.thunderboltkids.co.za/Grade4/03-energy-and-change/chapter4.html#, CC-BY-ND

Movement

When objects are moving, they have movement or energy. The faster the object is moving, the more energy it has. Look at the examples of movement below.

When I am dancing I have movement!
Image by mohamed_hassan, pixabay.com, CC0

A rocket that is taking off has a huge amount of movement.
Image by WikImages, pixabay.com, CC0

A race car that is travelling has lots of movement.
Image by Pexels, pixabay.com, CC0

While you are riding your bicycle, you have movement.
Image by BigBearVacations, pixabay.com, CC0

Energy for life

Scientists say energy is the ability to do work. We need to understand what this means. A way to think of it is that energy can make something happen. There is a lot happening in this picture below!

1. Look at the following picture.
2. Draw a circle around all the places where you think energy is being used.

Image by http://www.thunderboltkids.co.za/Grade4/03-energy-and-change/chapter2.html#, CC-BY-ND

We use energy for everything we do. Energy can be transferred (moved) from one part of a system to another part. This picture showed many examples of transfer of energy from movement or from electricity to light, to heat, or to sound.

Putting It Together

Image by David Burke, (Flickr:Orangedrummaboy), https://flic.kr/p/bZYLfC, CC BY-NC-ND 2.0

Let's revisit the musician playing the electric guitar on a brightly lit stage. The audience hears sounds made by the guitar. The bright stage lights illuminate the musician for everyone to see. The lights can also make it get really warm on stage.

Focus Questions

1. What types of input energy are used by the lights, guitare, and microphone?

2. What types of energy outputs from the lights, microphone and guitar are observed by the audience?

3. What evidence do you observe that energy transfers from the stage and musician to the audience?

Final Task

Investigate examples of energy transfer in your home or school. Gather evidence that energy is transferred from place to place by electrical currents, heat, sound, or light. Record examples that you observe of each type of energy transfer and evidence of each energy type.

2.4 Energy Conversions (4.2.4)

Authentic Situation

Your little sister keeps getting into your room while you are out playing in the backyard. She has been taking your stuff! You need an alarm system that will notify you when you need to come in from the yard and stop her from getting into your room!

Your device must convert energy from one form to another, and be made from readily usable items in your house. You must be able to identify what energy it started with, and how you converted it to a final form of energy. Use data from testing your device to optimize your solution.

Images by (left) Victoria_Borodinova and (right) La-Belle-Galerie, pixabay.com, CC0

Observations & Wonderings

What is the problem in this situation?

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

What are constraints (limitations) with this situation?

Focus Questions

1. Draw a diagram of your room. What do you already know about this situation that will help you design your alarm system device?

2. What items are already available in your room or home that you could use to create a device that converts the energy from your sister moving into your room to energy that would notify you that she was there?

4.2.4 Energy Conversions

Design a device that converts energy from one form to another. *Define the problem, identify criteria and constraints, develop possible solutions using models, analyze data from testing solutions, and propose modifications for optimizing a solution.* Emphasize identifying the initial and final forms of energy. Examples could include solar ovens that convert light energy to heat energy or a simple alarm system that converts motion energy into sound energy. (PS3.B, PS3.D, ETS1.A, ETS1.B, ETS1.C)

In this chapter we observe devices designed to take one form of energy and convert it to another to solve a problem.

Energy and Everyday Life

We need energy to conduct our daily lives. We use energy all the time, especially electricity. Do you know how most electricity is made? Most electricity is made initially from natural resources. Water is one of our most precious natural resources. A natural resource is anything people can use that comes from nature. Water is just one type of natural resource. There are many other natural resources, such as oil, coal, and natural gas, we call them fossil fuels. Other natural resources are sunlight, moving water, wind, and heat from the earth. Many of these natural resources provide us with energy. In the picture below, you will see how burning fossil fuels

Natural gas burns with a blue flame in this gas stove. Many homes also have natural gas water heaters and furnaces. Some motor vehicles burn natural gas as well.

Petroleum is used to make gasoline, which fuels most motor vehicles. It is also used to make heating oil for furnaces and kerosene for camp stoves.

The majority of electric power in the U.S. is generated by burning coal in power plants like this one.

*(Left) Natural gas: Paul Kretek (Flickr;pa*kr); http://www.flickr.com/photos/limemonkey/486575859/, CC-BY 2.0 (Center) Pumping gas: futureatlas.com; https://flic.kr/p/GFxHL, CC-BY 2.0 (Right) Plant: Kid Cluth (Flickr:Graf Spee) https://flic.kr/p/d4ejcm, CC BY 2.0*

make energy. Fossil fuels will eventually run out. They are a non-renewable energy source.

Natural resources, such as sunlight and wind, will never run out. We can use them as a renewable energy source. We can convert them into other types of energy.

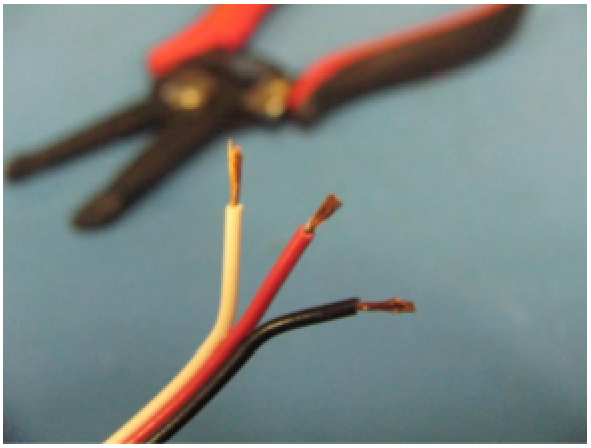
Renewable Energy Source	**Example**
Sunlight Sunlight can be used to heat homes. It can also be used to produce electricity. This conversion is made possible by solar cells. However, solar energy may not always be practical. Some areas are just too cloudy.	 Image by Jon Callas, http://www.flickr.com/photos/joncallas/5598087273/, CC BY 2.0 Solar panels on the roof of this house generate enough electricity to supply a family's needs.
Moving Water Falling water can have a lot of energy. This energy can turn a turbine and generate electricity. The water may fall naturally over a waterfall or flow through a dam.	 Image by NatureClip, https://flic.kr/p/TSPwrE, CC BY 2.0 Water flowing through Hoover Dam. It is located between Arizona and Nevada. It generates electricity for both of these states and also southern California. The dam spans the Colorado River.

Wind Wind is moving air. It has energy that can do work. Wind turbines change the energy of the wind to electrical energy. You need to have a lot of steady wind to make enough energy.	 Image by Fuzzy Gerdes, https://flic.kr/p/6Kkmvv, CC BY 2.0 This old-fashioned windmill captures energy from moving air.. It is used for pumping water out of a well. Windmills like this one have been used for centuries.
Heat Earth's interior holds a lot of heat. It too can be used to produce electricity. A power plant pumps water underground, where it gets heated, then the hot water is pumped back to the plant. There it is converted into electricity. On a small scale, this energy can be used to heat homes. Installing a system for this energy conversion can be very costly. This is because it is necessary to drill a deep hole through hard soil and rock.	 Image by Birgit Juel Martinsen, https://flic.kr/p/9htpPd, CC BY 2.0 This power plant is located in Italy. Here, hot magma is close to the surface.

All of those renewable energy sources converted their energy into electricity. But how do we move that electricity to where we need it for our everyday lives? We use circuits.

Electric Circuits

Electric circuits are paths for moving electricity. Metals are conductors of electricity and plastic is a non-conductor, so the path the electricity follows is the path of the wires. These circuits allow electricity to be used to provide power to lights, appliances, and many other devices you use each day.

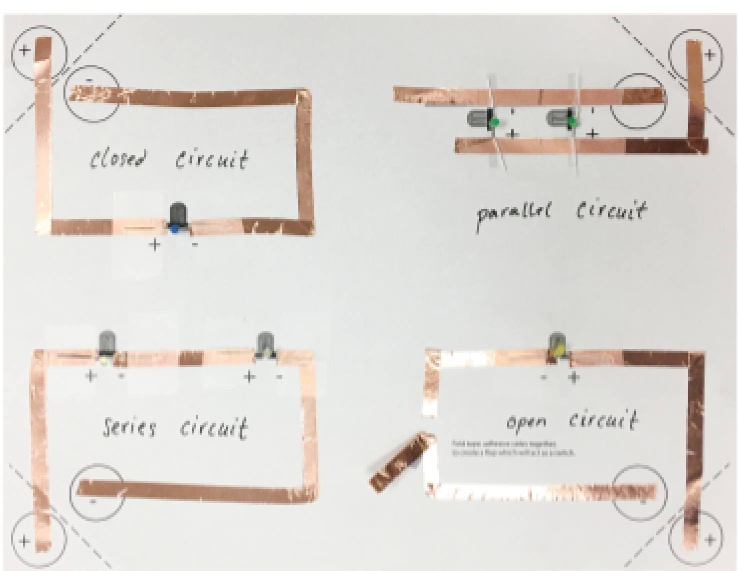


These electric cables are made of copper wires surrounded by a rubber coating.
Image by solarbotics, http://www.flickr.com/photos/solarbotics/5414548592/, CC BY 2.0

An electric circuit must have a power source, wires for the electricity to flow through, and a device, such as a lamp or a motor, that uses the electric current. All of these parts must be connected so that the current continues to flow.

Electric circuits have switches that allow people to control the flow of the electric current through the circuit. When someone flips a light switch in a room or pushes a button on a flashlight, that person is helping to complete the circuit. The current can then flow to the light or the bulb. When the switch is turned the other way, it breaks the circuit and stops the flow of the current.

Try making a paper circuit



Text and images for this activity by National Agriculture in the Classroom, https://www.agclassroom.org/teacher/matrix/resources.cfm?rid=940, CC BY-NC-SA

Paper circuits show how the flow of energy can take many different paths, such as a series, or parallel circuit. The other paths can help transfer electricity into other forms of energy. But in any type of circuit, if the flow is broken then you can't convert electricity into other forms of energy.

Electricity is transferred in a huge circuit to our homes

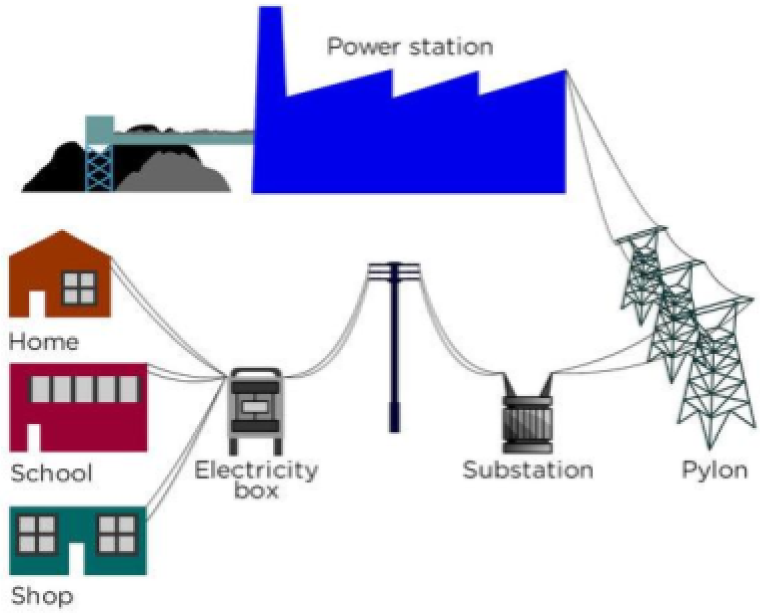
Huge pylons carrying the transmission lines across the country
Image by Walter Bichler (Silberfuchs), pixabay.com, CC0

From a power station, electricity is transferred through transmission lines. The transmission lines are part of the circuit that connects the power stations to where we need to use the electricity.

The transmission lines carry large amounts of electricity to substations in cities and towns.

From a substation, electricity is carried in smaller amounts to an electricity box for our home. From the electricity box, electricity travels through wires to the plug points and light fittings in our homes.

This diagram shows how electricity is transferred from the power station to your home. Once electricity is in your home it goes through the wires, wall socket and plugs to get to appliances, such as your TV.



The transfer of energy from power stations to our homes, schools and shops
Image by http://www.thunderboltkids.co.za/Grade5/03-energy-and-change/chapter2.html#mainselectricity, *CC-BY-ND*

We can create machines that convert energy from one type to another.

Ways to convert energy

Solar Power

Image by Ulrike Leone, (ulleo), pixabay.com, CC0

We know the Sun gives our planet heat and light. The Sun's energy can also be used to power machines. Some buildings have solar panels on their roofs. The solar panels trap the sun's energy. That trapped energy can be converted to electricity that can be used to light up buildings and power computers. It can even heat water!

Smaller solar panels can be used for outdoor solar lights or even just a reflective surface used in a solar oven can harness the energy from the sun and transfer it to heat.

Image by Tom (analogicus), pixabay.com, CC0

Wind

Wind turbines are becoming a more and more common sight on the landscape. For scientists, they represent a clean, renewable energy source.

Image by Steppinstars, pixabay.com, CC0

As wind moves across the landscape it causes the wind turbines to turn. This movement creates energy. Wind turbines convert wind energy into electrical energy. This energy supports our homes, schools, and offices.

Moving Water

Image by Ilona (Couleur), pixabay.com, CC0

People have used moving water as a form of energy for thousands of years. Water power is the energy that comes from moving water. Water power is sometimes called hydropower. Since ancient times, moving water has been used by many industries to do work. Grist mills used moving water to grind wheat and corn. Lumber was cut at sawmills that were powered by moving water. People benefited from being located on rivers and streams.

Historically, the power of moving water was captured by simple water wheels. They were used to convert the energy from moving water to move machines. More recently, engineers have come up with a different way to capture the power of water and convert it to electricity.

Heat

Did you ever cook over a campfire? The man in this picture is cooking food. He waits as his food absorbs energy. First, energy stored in wood is converted to heat and light when the fire burns. Heat from the fire transfers to the pot and heats the water. Soon, all the water in the pot will be boiling hot. The man also feels warm. He feels the heat from the flames. He feels the warmth even though he is not touching the flames. Energy is transferred from the fire to his hands.

Energy from the fire is transferred to the pot and water and to the man sitting by the fire.
Image by Erik Halfacre, https://flic.kr/p/eisbtq, CC BY 2.0

Electrical Machines Heat and Light

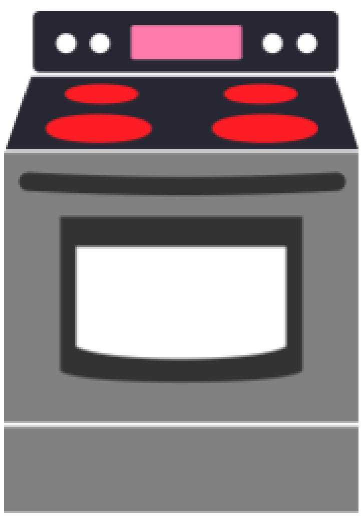


Image by George Mutambuka (thegiwi), pixabay.com, CC0

You have seen a flashlight make light and felt a stove heat up. How do these devices make heat and light? Electricity! Electrical machines can convert electricity into heat and/or light. A light bulb is an electrical device that produces light. Light bulbs help us see at night and in dark places.

Can you think of other electric machines in your house or the world around you? Do they produce heat or light when they do their work? Other machines like televisions, computers, and tablets convert electric energy into light and sound. They light up so you can see the images or pictures on their screens. If you feel a computer when it is turned off it may feel cool. Feel it again when it is on. That extra heat you feel is caused by the electricity flowing through the machine.

Putting It Together

Images by (left) Victoria_Borodinova and (right) La-Belle-Galerie, pixabay.com, CC0

Your little sister keeps getting into your room while you are out playing in the backyard. She has been taking your stuff! You need an alarm system that will notify you when you need to come in from the yard and stop her from getting into your room!

Your device must convert energy from one form to another, and be made from readily usable items in your house.

Focus Questions

1. What problem will your alarm system solve?
2. What are the goals (criteria) for a successful alarm system?
3. What constraints or limitations will you have to solving the problem?
4. What energy does your alarm device start with, and how can you convert it to a final form of energy that you can observe in your yard?

Final Task

Draw a model of your design solution to an alarm system that will notify you when you need to come in from the yard and stop your sister from getting into your room. If possible, at home or school create a prototype of your alarm system. How might you revise the prototype to more effectively convert energy?

CHAPTER 3

Strand 3: Wave Patterns

Chapter Outline

Image by OpenClipart-Vectors, pixabay.com, CC0

Waves are regular patterns of motion that transfer energy and have properties, such as amplitude (height of the wave) and wavelength (spacing between wave peaks). Waves in water can be directly observed. Light waves cause objects to be seen when light reflected from objects enters the eye. Humans use waves and other patterns to transfer information.

3.1 Patterns of Waves (4.3.1)

Phenomenon

Waves can form on different bodies of water including oceans, lakes,and rivers.

Ocean Waves
Image by Tim Marshall, https://unsplash.com/s/photos/surf-waves, CC0

Great Salt Lake waves.
Image by
R. Nial Bradshaw, https://flic.kr/p/hK7eFo, CC BY 2.0

River Waves, *pixabay.com; CC0*

Observations and Wonderings

What are you observing about this phenomenon?

What are you wondering about this phenomenon?

Focus Questions

1. What pattern do you see in these images?

2. What do you think is causing the pattern in the waves?

4.3.1 Patterns of Waves

Develop and use a model to describe the regular patterns of waves. Emphasize patterns in terms of amplitude and wavelength. Examples of models could include diagrams, analogies, and physical models such as water or rope. (PS4.A)

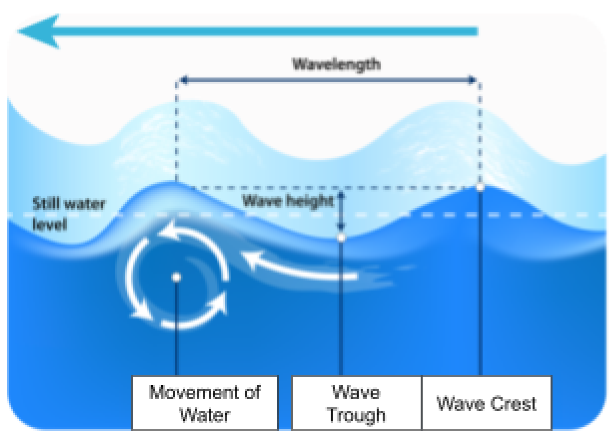
In this chapter, focus on observable patterns in waves we see in the world around us.

Waves

Waves cause the rippled surface of the ocean.
Image by kyle wyss, https://flic.kr/p/92GfbB, CC BY 2.0

If you've ever visited an ocean shore, then you know that ocean water is always moving. Waves ripple through the water, as shown in the image of ocean water. The water slowly rises and falls because of tides. You may see signs warning of currents that flow close to shore. What causes all these ocean motions? All motions are different and have different causes.

Most ocean waves are caused by winds. A wave is the transfer of energy through matter. Ocean waves transfer energy from wind through water. A wave that travels across miles of ocean is actually the energy traveling, not water. The energy of a wave may travel for thousands of miles. The water itself moves a very little distance. This figure shows how water moves when a wave goes by.



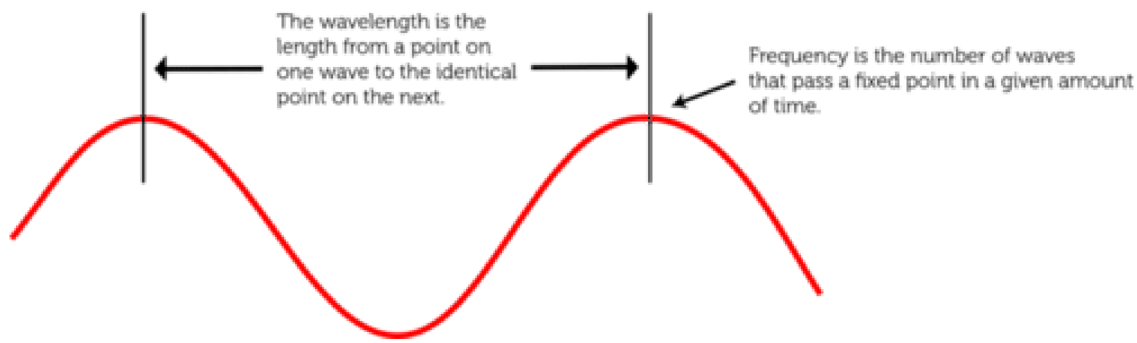
A wave travels through the water. How would you describe the movement of water molecules as a wave passes through?
Adapted from image by Hana Zavadska, CK-12 Foundation, CC-BY-NC 3.0

The Size of Waves

The figure shows how the size of a wave is measured. The highest point of a wave is the crest. The lowest point is the trough. The vertical measurement of the distance from the top crest of a wave to the level of calm water is called the amplitude. This is the height of a wave. The horizontal measurement of the distance from one wave to the next wave is called the wavelength. Both amplitude and wavelength are measures that tell us the size of a wave.

The size of an ocean wave depends on how fast, how far, and how long the wind blows.These things will determine how big the wave will be. For example, some of the biggest waves occur with hurricanes. A hurricane is a storm that forms over the ocean. Its winds may blow more than 150 miles per hour! The winds also travel over long distances and may last for many days. As a result, the waves that occur during a hurricane will be larger than those caused by calmer weather.

Wavelength is the distance between the same space in a wave pattern, for example from trough to trough, or crest to crest. Wave frequency is how many waves pass a certain point in a specific amount of time. The energy of waves depends on their frequency. Low-frequency waves have little energy and are normally harmless. High-frequency waves have a lot of energy and are potentially very harmful.



Tsunamis

Not all waves are caused by winds. Energy moves in waves, so a shock to the ocean can also send waves through water. A tsunami is a wave, or set of waves, that is usually caused by an earthquake. As we have seen in recent years, tsunami waves can be huge and extremely destructive. Tsunami waves have an enormous amount of energy. Tsunamis can travel at speeds of 800 kilometers per hour (500 miles per hour). Usually tsunami waves travel through the ocean unnoticed.

A 2004 tsunami caused damage like this all along the coast of the Indian Ocean. Many lives were lost.
Image courtesy of Dr. Bruce Jaffe/U.S. Geological Survey, http://gallery.usgs.gov/photos/356, Public Domain

Tsunami waves have very small wave heights when they are in the open ocean. In contrast, they have very long wavelengths. If you were at sea, you would not notice it pass under your ship. But when tsunami waves reach the shore, they become enormous. Tsunami waves can flood entire regions. Tsunami waves destroy property and may cause many deaths. The above image shows the damage caused by a tsunami from the Indian Ocean in 2004.

When Waves Meet

When raindrops fall into still water, it creates tiny waves that spread out in all directions away from the drops. What happens when the waves from two different raindrops meet? The two waves interfere with each other.

When two or more waves meet, they interact with each other. The interaction of waves with other waves is called wave interference. Wave interference may occur when two waves that are traveling in opposite directions meet. The two waves pass through each other, and this affects their amplitude. Amplitude is the maximum distance the particles of a material move from their resting positions when a wave passes through.

Image by Zachary Wilson, CK-12 Foundation, CC-BY-NC 3.0

Have you ever done "the wave" at a sporting event? Well, then you have helped to create a wave.

Waves may reflect off an obstacle that they are unable to pass through. When waves are reflected straight back from an obstacle, the reflected waves interfere with the original waves and create standing waves. These are waves that appear to be standing still. Standing waves occur because of a combination of constructive and destructive interference.

How could you use a rope to produce standing waves? You could tie one end of the rope to a fixed object, such as a doorknob, and move the other end of the rose up and down to generate waves in the rope. When the waves reach the fixed object, they are reflected back. The original waves and the reflected waves interfere to produce a standing wave. Try it yourself and see if the waves appear to stand still.

Putting It Together

Image by Tim Marshall, https://unsplash.com/s/photos/surf-waves, CC0

Great Salt Lake waves.
Image by R. Nial Bradshaw, https://flic.kr/p/hK7eFo, CC BY 2.0

River Waves, *pixabay.com; CC0*

Focus Questions

1. What pattern do you see in these images?

2. What do you think is causing the pattern in the waves?

Final Task

After having read this chapter, what patterns do you see?

Describe a physical model that shows the patterns you see in waves.

3.2 Light and Sight (4.3.2)

Phenomenon

In the evening you see an upside down landscape on the surface of a lake.

Image from https://pixabay.com/photos/panorama-bled-island-slovenia-1993645/, CC0

Observations and Wonderings

What are you observing about this phenomenon?

What are you wondering about this phenomenon?

Focus Questions

1. Why are there two sets of mountains, two buildings, and two forests in this picture?

2. What body systems are you using to observe objects in this image?

3. How can you use a model to explain what caused objects to be seen in this image?

4.3.2 Light and Sight

Develop and use a model to describe how visible light waves reflected from objects enter the eye causing objects to be seen. Emphasize the reflection and movement of light. The structure and function of organs and organ systems and the relationship between color and wavelength will be taught in Grades 6 through 8.

In this section observe models that illustrate the cause and effect relationship between visible light waves and objects seen by your eyes.

Light

Image by foolfillment, http://www.flickr.com/photos/foolfillment/206530144/, CC-BY 2.0

Look at this sign. The sign is upside down; how can you still read it? The people who made this sign used science to make it possible to read it upside down. They knew that light can reflect off of many surfaces. Even water can reflect light. Think about how this sign was made. The words are written so that their reflection can be read.

Reflection of Light

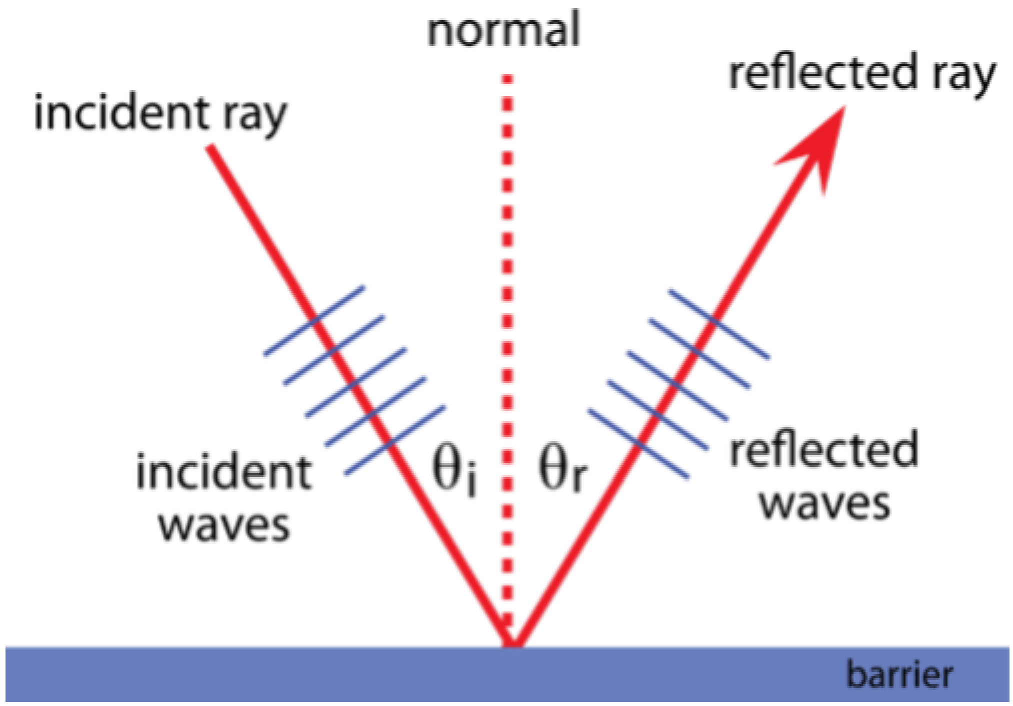


Image by Samantha Bacic, CK-12 Foundation, CC-BY-NC-SA 3.0

The Law of Reflection

Light rays (rays are the path that light waves travel) strike a surface. Light rays are then reflected back. You can predict the angle of the reflected light using The Law of Reflection. Imagine a ball bouncing off a surface. Light can do the same thing. That is, assuming the surface is smooth and shiny. How do you know where light will go after it strikes a shiny surface? It depends on how the light initially strikes the shiny object. Light does not always go straight toward the surface. Therefore, not all light bounces straight back. Sometimes, light can hit a surface at an angle. The angle at which it strikes the surface is the same angle it will bounce off in the opposite direction. While light is different from a ball, both react in a similar manner.

The diagram shows how light rays travel and strike a surface. Incoming light rays are the incident ray and the outgoing light is known as the reflected ray. This action is known as the Law of Reflection.

Reflection needs a very smooth surface to work well. When light strikes a surface that is smooth, it is called regular reflection. The way light rays reflect can be predicted. This also results in an image that you can see clearly. For example, when you look into a mirror you can see your reflection. A mirror has a smooth and shiny surface; the light reflects back to your eye and you are able to see the image clearly.

What if the surface that light strikes is not smooth? In those cases, the reflection will be a diffuse reflection. The objects may not be seen clearly. Instead, objects may look fuzzy or blurred. An example of this is looking at a mountainside view in a body of water when it is windy. You can tell it is a mountain; but, the details are not clearly defined.

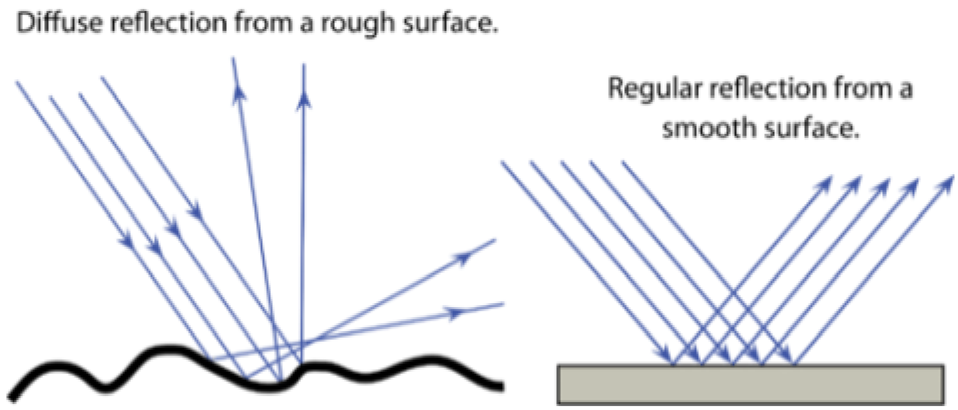
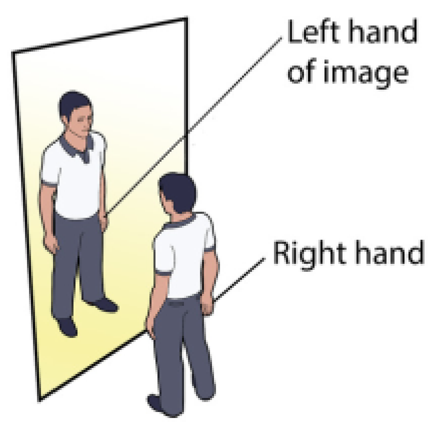


Image by Samantha Bacic;CK-12 Foundation, CC BY-NC-SA 3.0

Left and Right Reversal in a Plane Mirror

You have seen your own reflection in a mirror. The person looking back at you looks just like you. Where does that reflected person appear to be standing? Yes, the reflected person appears to be on the other side of the mirror. That is really strange to think about, but very cool. Have you ever waved at your reflection in a mirror? The reflected image will wave back at you.



Here is something to try next time you stand in front of a mirror. Wave to your reflection with your right hand. Which hand do you think the reflection will wave back with? The same hand? A different hand? You will notice something interesting. The reflection waves back with the hand on the same side as you, but it is their left hand. The image in a reflection appears to be reversed.

This is just like the image of the sign on the lake. Light rays strike flat shiny surfaces and are reflected. The reflections are reversed. Why do you think it appears this way?

We need light to see the world. We can see objects that give off their own light. When the light of the object enters our eye, we can see the object.

We can also see objects that reflect light. The reflected light enters our eye so we can see the object.

Light seems white, but light is really made up of all colors.

The color we see is the color of light that bounces off, or reflects off the object. All the other colors do not bounce off.

Image by Heather M, https://flic.kr/p/4qhvin, CC BY

Image by frankieleon, https://flic.kr/p/6y497Q, CC-BY

Image by Tejvan Pettinger, https://flic.kr/p/9eWgU9, CC-BY

Image by Carl Davies for APAL, https://flic.kr/p/vJfDvW, CC BY 3.0

We need light to see. Any light that bounces off of objects enters our eyes. Without light, we could not see the world.

How We See

Image by Brenda Clarke, https://flic.kr/p/6pshD9, CC-BY

The ability to see is called vision. The brain and eyes work together to allow us to see. The eyes collect and focus visible light. The brain interprets the electrical signals as shape, color, and brightness. The brain also interprets the image as though it were right-side up. The brain does this automatically; so, what we see always appears right-side up. The brain also interprets what we are seeing.

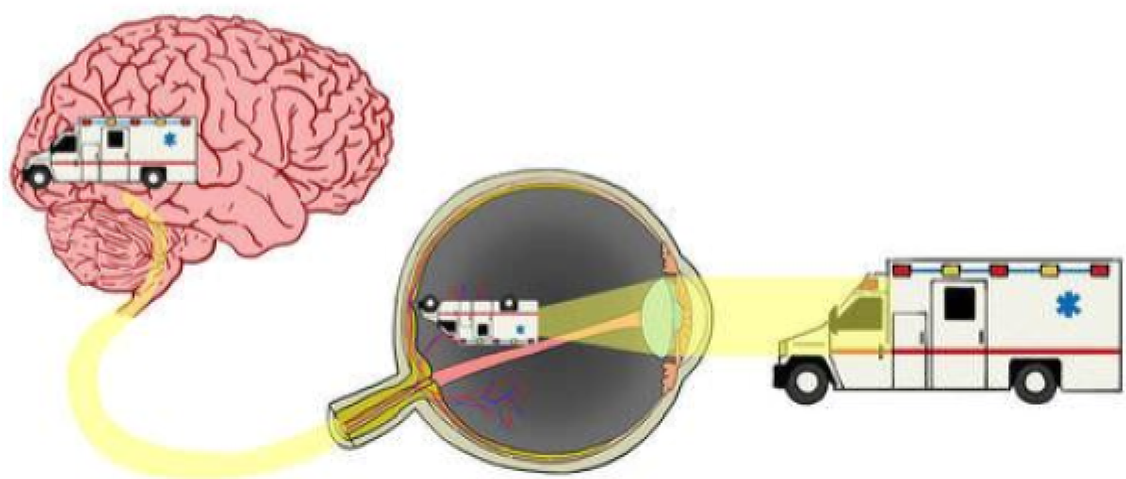


Image by Laura Guerin, CK-12 Foundation, CC BY-NC 3.0

Putting It Together

Image from https://pixabay.com/photos/panorama-bled-island-slovenia-1993645/, CC0

Focus Questions

1. Why are there two sets of mountains, two buildings, and two forests in this picture?

2. What body systems are you using to observe objects in this image?

Final Task

How can you use a model to explain what caused objects to be seen in this image? Include the following in your explanation of a model: 1) light, 2) objects, 3) the path that light follows, and 4) your eye.

3.3 Information Transfer (4.3.3)

Authentic Situation

You have a dilemma. You are stuck at Camp Watnanoga for the summer, while your best friend is on the other side of the lake at Camp Genoa. You won't be able to see your friend all summer. There is no cell phone signal at camp, so talking and texting are not options. You need to be able to communicate with your best friend! You have secrets to share, so you can't be caught! You must be able to communicate during the day and at night. How can you solve your dilemma?

There can be more than one solution to your dilemma. You only have limited resources available to you while at camp. You have flashlights, camera, rope or string, mirrors, cups, and the environment around you.

Image by David Porter (pooch_eire), pixabay.com, CC0

Observations and Wonderings

1. What is the problem in this situation?

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

3. What are constraints (limitations) with this situation?

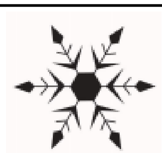
Focus Questions

1. How will you get your message to your best friend without others finding out your secrets on the other side of the lake during the day?

2. How will you get messages to your best friend at night?

4.3.3 Information Transfer

Design a solution to an information transfer problem using wave patterns. *Define the problem, identify criteria and constraints, develop possible solutions using models, analyze data from testing solutions, and propose modifications for optimizing a solution.* Examples could include using light to transmit a message in Morse code or using lenses and mirrors to see objects that are far away. (PS4.C, ETS1.A, ETS1.B, ETS1.C)



In this section, focus on ways that wave patterns are used to design solutions to problems of transferring information over long distances. Digitizing information can also allow for further design solutions to help transfer information over long distances.

Waves

We can see farther and can send and receive information over longer distances by applying wave patterns. We have invented digital devices that make it possible to transmit information over long distances.

Speed of Waves

Waves quickly transmit energy and information over large distances. Light waves that move through space help us see things that are far away. If you could move as fast as light, it would only take you 8 minutes to travel from the sun to the earth or travel around the earth 7 times in 1 second!

Image by texaus1, https://flic.kr/p/2bU2nU4, CC-BY

You see a flash of lightning on the horizon, but several seconds pass before you hear the rumble of thunder. Has this ever happened to you? The reason is light waves travel much faster than sound waves, in fact 1 million times faster! The speed of sound is still very fast. Sound travels much quicker than we can.

A friend whispers to you in a voice so soft that she has to lean very close so you can hear what she's saying. Later that day, your friend shouts to you from across the gymnasium. Now her voice is loud enough for you to hear her clearly, even though she's several meters away. Sounds can vary in loudness and also vary in how far a distance sound can go.


Image by Olya Adamovich (Olichel), pixabay.com, CC0

It's All About Energy

Loudness refers to how loud or soft a sound seems to a listener. The loudness of sound is determined, in turn, by the intensity of the sound waves. Intensity is a measure of the amount of energy in sound waves.

Amplitude and Distance

The intensity of sound waves determines the loudness of sounds; but, what determines intensity? Intensity results from two factors: the amplitude of the sound waves and how far the sound waves have traveled from the source of the sound.

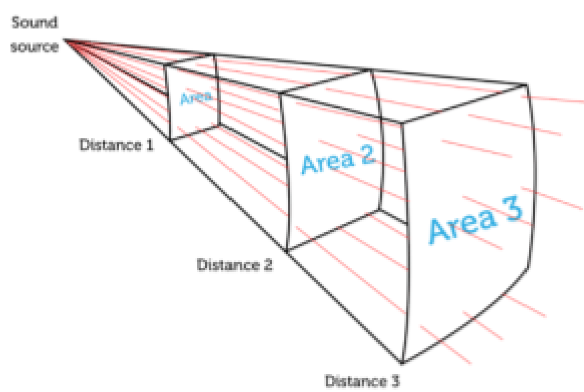


Image by Christopher Auyeung (CK-12 Foundation), CC BY-NC 3.0

- Amplitude is a measure of the size of sound waves. It depends on the amount of energy that started the waves. Greater amplitude waves have more energy and greater intensity, so they sound louder.
- As sound waves travel farther from their source, the more spread out their energy becomes. You can see how this works in this figure. As distance from the sound source increases, the area covered by the sound waves increases. The same amount of energy is spread over a greater area, so the intensity and loudness of the sound is less. This explains why

even loud sounds fade away as you move farther from the source.

- Because sound waves fade away over long distances, cell phones are used to digitize sounds from our voices into light waves. Light waves sent from our phones travel through the air to a cell tower and eventually to the phone of the person being called. The receiving device decodes the light waves and changes them back to sounds that another person can hear.

Seeing Objects that are Far Away

The largest refracting telescope in the world is at the University of Chicago's Yerkes Observatory in Wisconsin and was built in 1897. Its largest lens has a diameter of 102 cm.
Image from http://commons.wikimedia.org/wiki/File:Yerkes_40_inch_Refractor_Telescope-1897.jpg, Public Domain

Telescopes were invented using what we know about light waves. A telescope is an instrument that makes faraway objects look closer.

Early telescopes worked by refracting, or bending, light using two lenses. Many of the small telescopes used by amateur astronomers today are refractors. Refractors are particularly good for viewing details within our solar system, such as the surface of Earth's moon or the rings around Saturn.

Around 1670, Sir Isaac Newton, built a different kind of telescope that used curved mirrors to focus light. This type of telescope is called a reflecting telescope, or reflector.

It's much easier to precisely make mirrors than to precisely make glass lenses. Mirrors are also much lighter than heavy glass lenses. For these two reasons, mirrors can be made larger than lenses. This is important because a reflecting telescope can be made much larger. Larger telescopes can collect more light. Larger telescopes can study dimmer or more distant objects. The largest optical telescopes in the world today are reflectors. Telescopes also can be made to use both lenses and mirrors.

(a) Eryn Blaireová; http://commons.wikimedia.org/wiki/File:750.JPG, public domain
(b) Mark J. Roe / Janusz Kałużny; http://commons.wikimedia.org/wiki/File:Salt_mirror.jpg, CC0
(c) User:Namibconsult/Nl.Wikipedia, http://commons.wikimedia.org/wiki/File:Meadelx200_kl.jpg, public domain

What Are Electronic Devices?

If you were born in the last few decades, it's probably impossible for you to imagine life without the computer. The computer is just one of many electronic devices that make sending information over long distances possible.

Many of the devices people commonly use today are electronic devices. Electronic devices use electric current to encode, analyze, or transmit information. In addition to computers, electronic devices include cell phones, tablets, and digital cameras. What other electronic devices do you use?

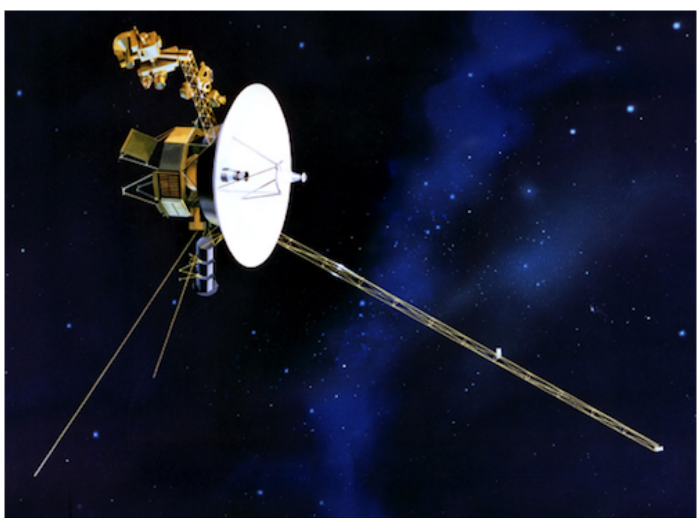
Let's take a close look at the computer as an example of an electronic device. A computer contains integrated circuits, or microchips, that consist of millions of tiny electronic components. Information is encoded in digital electronic signals. Rapid pulses of energy switch electric current on and off in circuits, producing long strings of 1's (current on) and 0's (current off). The 1's and 0's are the "letters" of the code, and a huge number of them are needed.

One digit (either 0 or 1) is called a bit, which stands for “binary digit.” Each group of eight digits is called a byte, and a billion bytes is called a gigabyte. Because a computer’s circuits are so tiny and close together, the computer can be very fast and capable of many complex tasks while remaining small.

Electronic devices—such as computers, mobile phones, and cameras—use electric current to digitize information to either store or send it over long distances. You can send a picture on a cell phone to anyone in the world, or the phone can receive digital information and translate it into a voice for a phone call with grandma to tell her you won 1st prize in the essay contest! Because digital communication is sent by light, you might be talking to your grandma thousands of miles away and hear her response almost instantly.

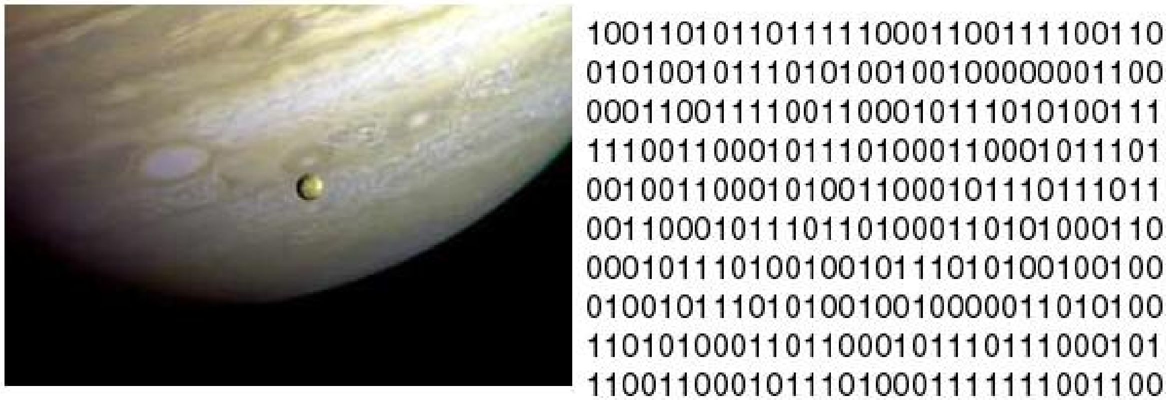
Digitized Information Transmitted over Long Distances

Between 1979 and 1989 the Voyager spacecraft sent digital signals millions of miles using radio waves (light) back to Earth. It sent information it collected from planets and moons in our solar system. The following figures are examples of the digitized 1’s and 0’s sent by Voyager that were received by NASA. The digitized information was decoded by computers into images of the planets Jupiter and Saturn.

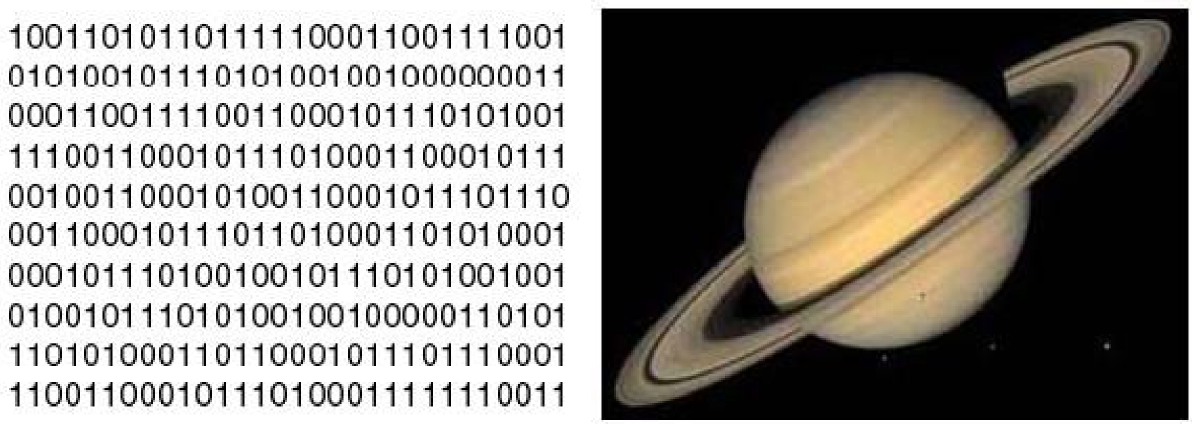


An artist’s rendering of one of the Voyager spacecraft. Public Domain,

https://spaceplace.nasa.gov/voyager-to-planets/en/



spacecraft to Earth decoded by computers to show an image of Jupiter, Public Domain, https://spaceplace.nasa.gov/binary-code/en/



Raw digital signal sent from the Voyager spacecraft to Earth decoded by computers to show an image of Saturn, Public Domain, https://spaceplace.nasa.gov/binary-code/en/

Putting It Together

Image by David Porter (pooch_eire), pixabay.com, CC0

Now that you have read the chapter and learned about many different ways to transfer information, how will that help you solve your problem?

Remember, you are stuck at Camp Watnanoga for the summer, while your best friend is on the other side of the lake at Camp Genoa. You won't be able to see your friend all summer. There is no cell phone signal at camp, so talking and texting are not options. You need to be able to communicate with your best friend! You have secrets to share, so you can't be caught! You must be able to communicate during the day and at night. How can you solve your dilemma?

Focus Questions

1. How will you get your message to your best friend without others finding out your secrets on the other side of the lake during the day?

2. How will you get messages to your best friend at night?

Final Task

Describe how you will get your message to your best friend without others finding out your secrets on the other side of the lake during the day. What if it is night, how will you get your message to your best friend then? You can have multiple solutions.

CHAPTER 4

Strand 3: Observable Patterns in the Sky

Chapter Outline

https://www.nasa.gov/image-feature/the-sun-shines-above-the-earths-horizon, Image by NASA, Public Domain

The Sun is a star that appears larger and brighter than other stars because it is closer to Earth. The rotation of Earth on its axis and orbit of Earth around the Sun cause observable patterns. These include day and night; daily changes in the length and direction of shadows; and different positions of the Sun and stars at different times of the day, month, and year.

4.1 Sun Brightness (4.4.1)

Phenomenon

The sun during the day appears much larger and brighter than the stars at night.

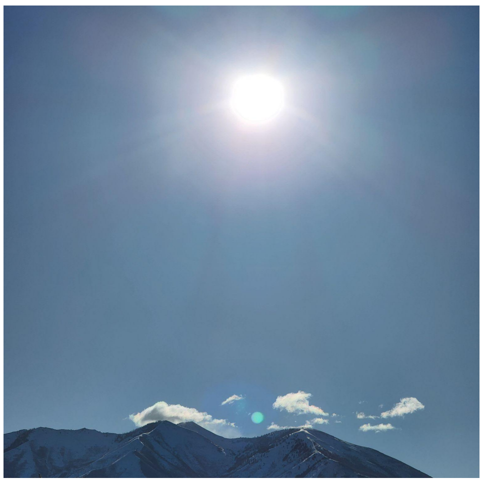


Image by Nate Bartholomew, CC0

Observations & Wonderings

What are you observing about this phenomenon?

What are you wondering about this phenomenon?

Focus Questions:

1. Why is the Sun the only star we see during the day?

2. What causes the sun to appear so much brighter than other stars in the sky?

3. The light from a small flashlight that you hold in your hand also appears brighter than stars in the night sky. How is this phenomenon similar to the sun appearing so much brighter than other stars?

4.4.1 Sun Brightness

Construct an explanation that differences in the apparent brightness of the Sun compared to other stars is due to the relative distance (scale) of stars from Earth. Emphasize relative distance from Earth. (ESS1.A)

In this chapter, you will observe the relationship between the brightness of a star and its distance (scale) from Earth.

The Earth in Space

The Earth is a planet in space. From the Earth we can see the Sun, Moon and other stars. Space begins about 100 km, or about 62 miles up from the Earth's surface toward the sky.

The Sun is the closest star to Earth

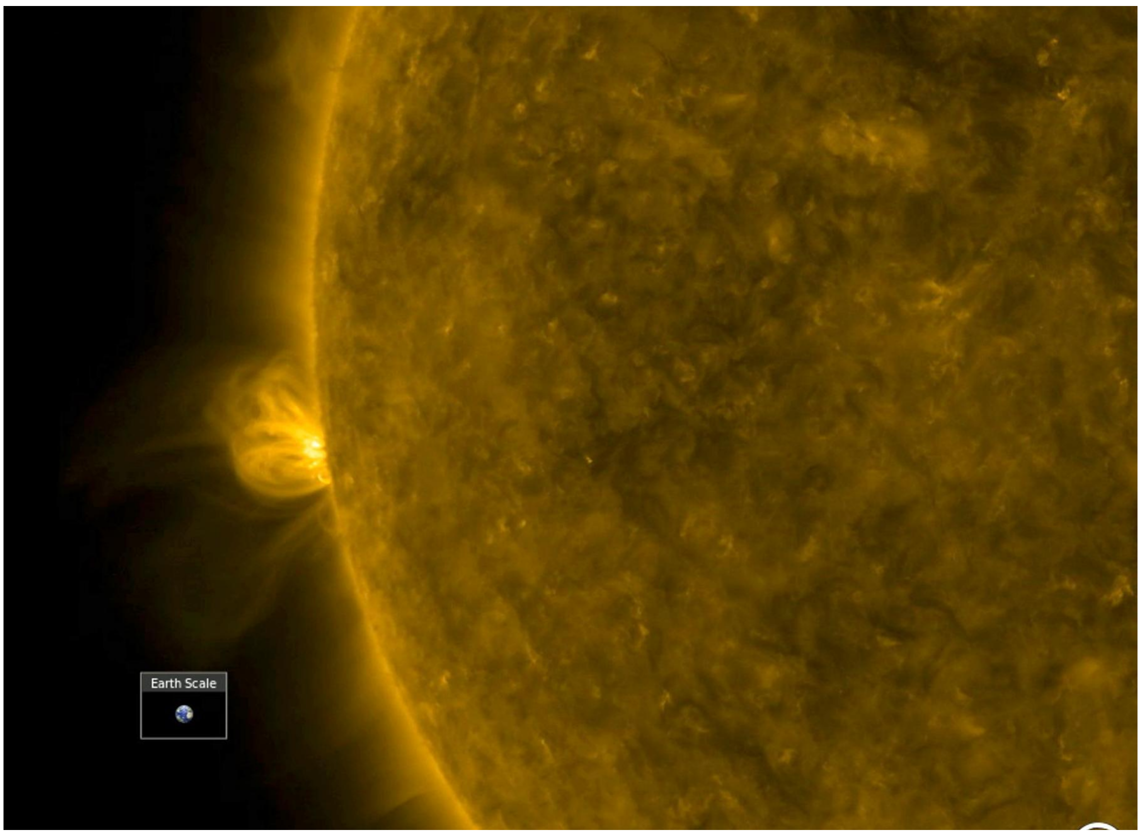
The Sun during different stages of the early morning
Image by Thunderbolt Kids, http://www.thunderboltkids.co.za/Grade4/04-earth-and-beyond/chapter2.html#, CC-BY-ND

The sun is a star. You probably thought that you could only see stars at night. Why is the sun the only star we can see in the daytime? Why does the Sun look so much bigger and brighter than the other stars in our universe? These things happen because the Sun is the closest star to us on Earth. When we talk about close in dealing with space we are talking millions of miles, about 93 million miles to be precise. The other stars in the sky are much, much further away. To give a scale of how much further away, Proxima Centauri is the 2nd closest star to Earth and it is about 260,000 times farther away from us than the Sun.

The Size of the Sun Compared to other Objects in the Universe

Our Sun is a very hot, very big ball of gas. The gas changes all the time, and this change gives off energy which makes the Sun very hot and appear very bright. The light of day comes from the Sun.

The Sun is much bigger than the Earth. How big is the Sun, compared to the Earth? The Sun is about 100 times wider than Earth. If you were to cut a hole in the top of the sun and fill it up with balls the size of the earth, you would need to use about 1 million "earths" to fill up the Sun.

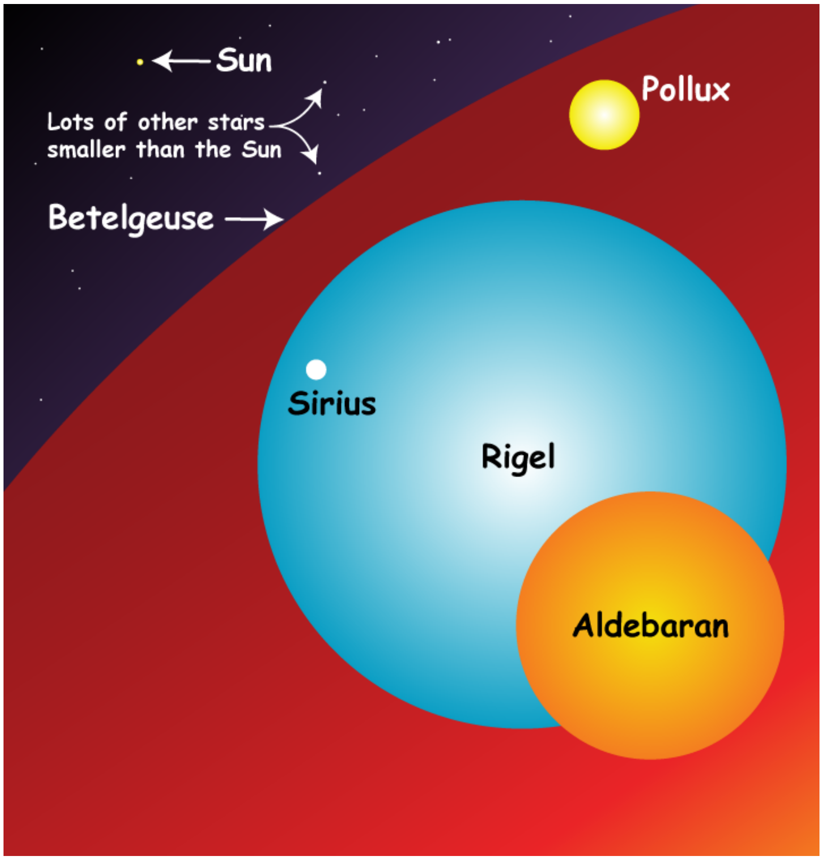


The size of the Sun and Earth shown at the same scale. https://photojournal.jpl.nasa.gov/jpeg/PIA22411.jpg, Image by NASA, Public Domain

The Sun is much larger in size than the Moon. However, they look about the same size in the sky. This happens because even though the Sun is so much bigger it is also much farther away from the Earth than the Moon. Because the Moon and Sun appear to be the same size from our point of view on Earth, the Moon can sometimes block our view of the Sun. This happened on August 21, 2017.

Moon blocking the Sun during the day because they appear the same size from Earth, Image by NASA, Public Domain, https://www.nasa.gov/image-feature/2017-total-solar-eclipse

Our Sun is an average sized star compared to the stars we see in the sky at night. Some of the stars we see at night are hundreds of times bigger than the Sun. They look small because they are much farther away from Earth than the Sun. The only star in our solar system is our Sun. All the other stars that we can see are parts of other star systems in the universe. Like our Sun, all the stars are made of gas that is glowing and very hot.



Comparison of the size of the Sun to other Stars seen in the night sky. Image by NASA, Public Domain, https://spaceplace.nasa.gov/sun-compare/en/

The Sun is the nearest star to the Earth and is located in our solar system. The second-nearest group of stars to Earth is Alpha Centauri. Because it is close to Earth, Alpha Centauri is one of the brightest stars in the night sky. Light from the Sun takes about 8 minutes to reach your eyes, but light from Alpha Centauri takes over 4 years to reach your eyes. Light travels so fast that it could circle the Earth seven times in one second. The amount of time it takes for light to travel from a star to our eyes is called light years (ly). We measure distance to stars using light years. How bright a star appears for us on Earth depends on its distance from Earth. As stars get farther away from Earth they appear dimmer from our point of view.

Putting It Together

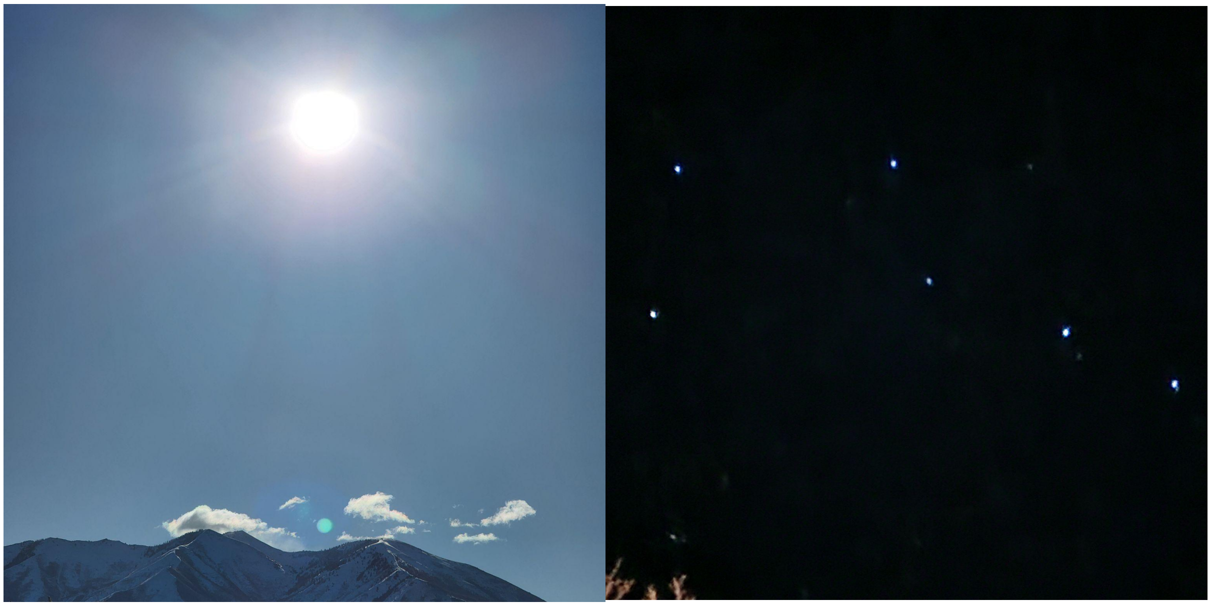


Image by Nate Bartholomew, CC0

The sun during the day appears much larger and brighter than the stars at night.

Focus Questions:

1. Why do some stars appear brighter than other stars in the night sky?

2. If two stars have similar brightness on their surfaces, but one is twice the distance from the Earth, which one will appear brighter to us?

3. Proxima Centauri is the second-closest star to Earth after the Sun. It is located in the Alpha Centauri star group that contains three stars.

Even though Proxima Centauri is relatively close to us we cannot see it without the use of a telescope. What might cause a star so close to Earth to be so difficult to see?

Final Task:

Construct an explanation of why the Sun is the brightest star we observe in the sky when some other stars are hundreds of times larger than the Sun.

4.2 Earth's Revolution (4.4.2)

Phenomenon

While on the playground at lunch recess, you notice that your shadow looks different than it did when you arrived at school. You also notice the change in shadows of other things, like the school, the flagpole, and other students.

Image by [illegible], pixabay.com, CC0

Kids' shadows on the playground in the morning

pixabay.com; CC0

Kid's shadow on the playground at lunchtime

pixabay.com; CC0

Trees' shadows in the early morning

pixabay.com; CC0

Tree's shadow at midday

Observations & Wonderings

What are you observing about this phenomenon?

What are you wondering about this phenomenon?

Focus Questions:

1. How can changes in the length and direction of your shadow help you understand the movement of the Sun in the sky during the day?

2. How do observable patterns of long shadows in the morning and short shadows at lunch give evidence that Earth is moving when we observe the Sun changing positions in the sky throughout the day?

4.4.2 Earth Revolution

Analyze and interpret data of observable patterns to show that Earth rotates on its axis and revolves around the Sun. Emphasize patterns that provide evidence of Earth's rotation and orbits around the Sun. Examples of patterns could include day and night, daily changes in length and direction of shadows, and seasonal appearance of some stars in the night sky. Earth's seasons and its connection to the tilt of Earth's axis will be taught in Grades 6 through 8. (ESS1.B)

In this chapter, you can observe patterns in day and night, length and direction of shadows, and star patterns of constellations at different times of the year.

The Earth moves

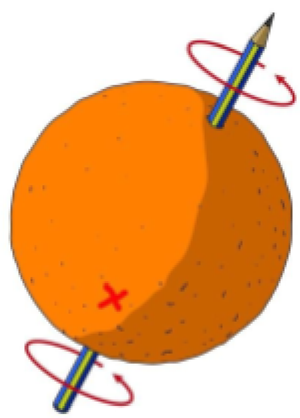


Image by Thunderbolt Kids, [illegible], CC-BY-ND

We know that the Earth moves in two different ways. The Earth orbits the Sun and the Earth also spins on its own axis. But, what does this mean? Imagine an orange with a pencil stuck through it. Look at the following picture. If you hold the pencil in your fingers, you can spin the orange around. The pencil is the axis of the orange.

The Earth does not really have a pencil through it, but it does spin around. We can imagine a big pencil through the middle of the Earth.

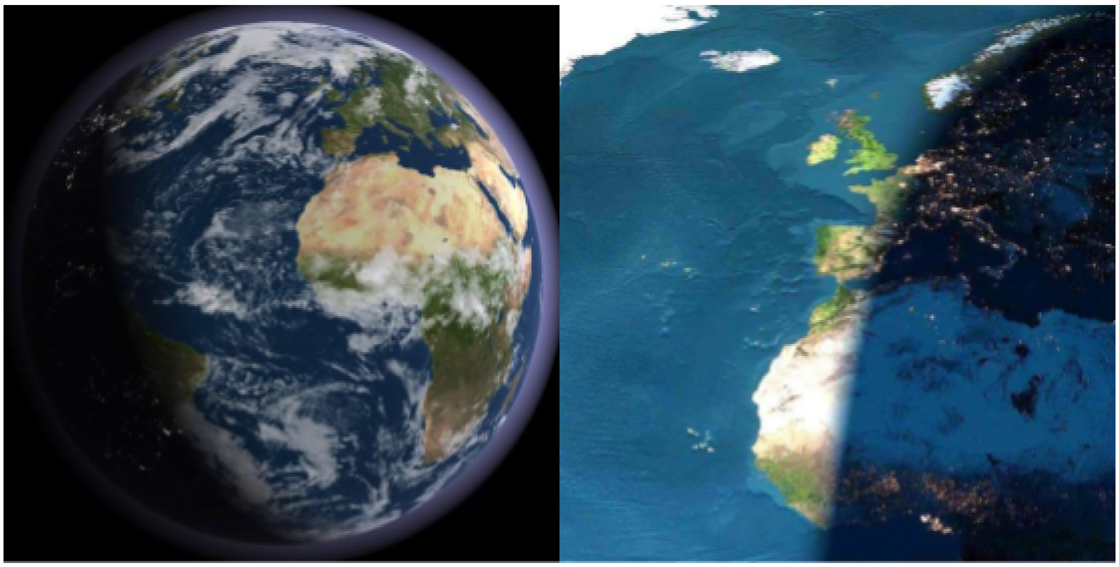
The Earth is like the orange and the pencil is like the axis. The curved arrows show which way the Earth spins.

We are on the Earth. Let us imagine we are at the point where you see the red "X" on the orange:

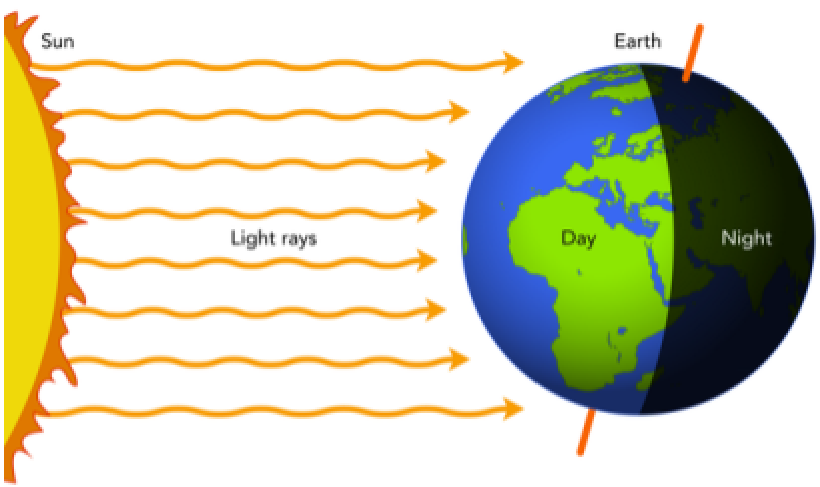
- The Sun shines on the Earth and so we, at X, see the Sun. We call that daytime.
- But, the Earth never stops spinning. At X, we move around into the shaded part of the Earth. Then, we cannot see the Sun any longer and it is nighttime for us at X.
- The Earth completes one rotation in 24 hours, so it will take 24 hours

for us to come around to the same position you see in the picture.
- We call these 24 hours a day. When we say "a day" we really mean a day and night; together they last 24 hours.

If we are at position X, the Sun changes positions in the sky during the day. To us, it appears as if the Sun is moving. The Sun seems to come up (rise) in the East, move across the sky during the day and go down (set) in the West. But the Sun does not revolve around the Earth. The spinning Earth causes the Sun to change positions in the sky.



Images by NASA.gov, public domain



Can you see how the light from the Sun only reaches one half of the Earth as it rotates?
Image by Thunderbolt Kids, http://www.thunderboltkids.co.za/Grade5/04-earth-and-beyond/chapter1.html#, CC-BY-ND

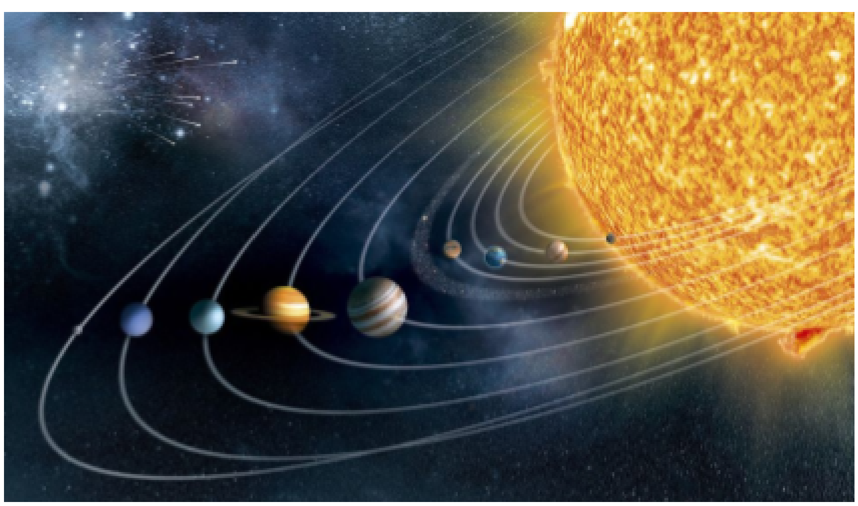
The Earth moves in an orbit around the Sun

The Earth moves around the Sun. While the Earth orbits the Sun, it is also spinning on its own axis. It rotates 365 times on its axis while it completes one orbit of the Sun. That means 365 days pass and we call that a year.

The Earth is a planet. There are 7 other planets also moving around the Sun. You can see one of the other planets on most evenings or early in the morning. This planet is called Venus. It is not a star, although sometimes it is called the morning or evening star.

You can see the planet Venus just after sunset or just before sunrise. In this sunset picture you can see Venus just the below the moon by the horizon.
Image by NASA.gov, public domain

Venus also moves around the Sun but its orbit is a smaller circle than Earth's orbit. Just like Venus there are other planets that we can see in the night sky. We can see Mercury, Mars, Jupiter, and Saturn at different times during the year depending on where they are in their orbits around the Sun. The orbits of the outer planets are actually much bigger than what is shown in this model of the solar system. But, if we tried to draw the orbits to scale, they definitely would not fit on this page!



The planets move in orbits around the Sun. The orbits lie on the same plane, as if they were on a big, flat plate.
Image by NASA.gov, public domain

The Rotating Earth

Imagine a pendulum at the North Pole. The pendulum always swings in the same direction. But because of Earth's rotation, its direction appears to change to observers on Earth

Image by Christopher Auyeung and Laura Guerin, CK-12 Foundation, CC BY-NC 3.0

So how do we know that the Earth rotates on its axis? Before this century, all evidence collected about Earth's motion came from Earth-bound observations. From Earth-bound observation it is easy to see why people used to believe that the Earth was stationary. They believed that it was the Sun and the stars that orbited the Earth. We have learned that it is the Earth that rotates which causes the cycles we see in the sky.

An experiment designed by Léon Foucault, a French scientist, in the year 1851 demonstrates movement of the Earth. He hung a heavy iron weight from a long wire. He pulled the weight to one side and then released it. The weight swung back and forth in a straight line. If Earth did not rotate, the pendulum would never change direction as it moved back and forth. But it did not continue to swing in the same direction. It was thought to change because the Earth was rotating beneath it. The figure shows how this might look.

Day-Night Cycle

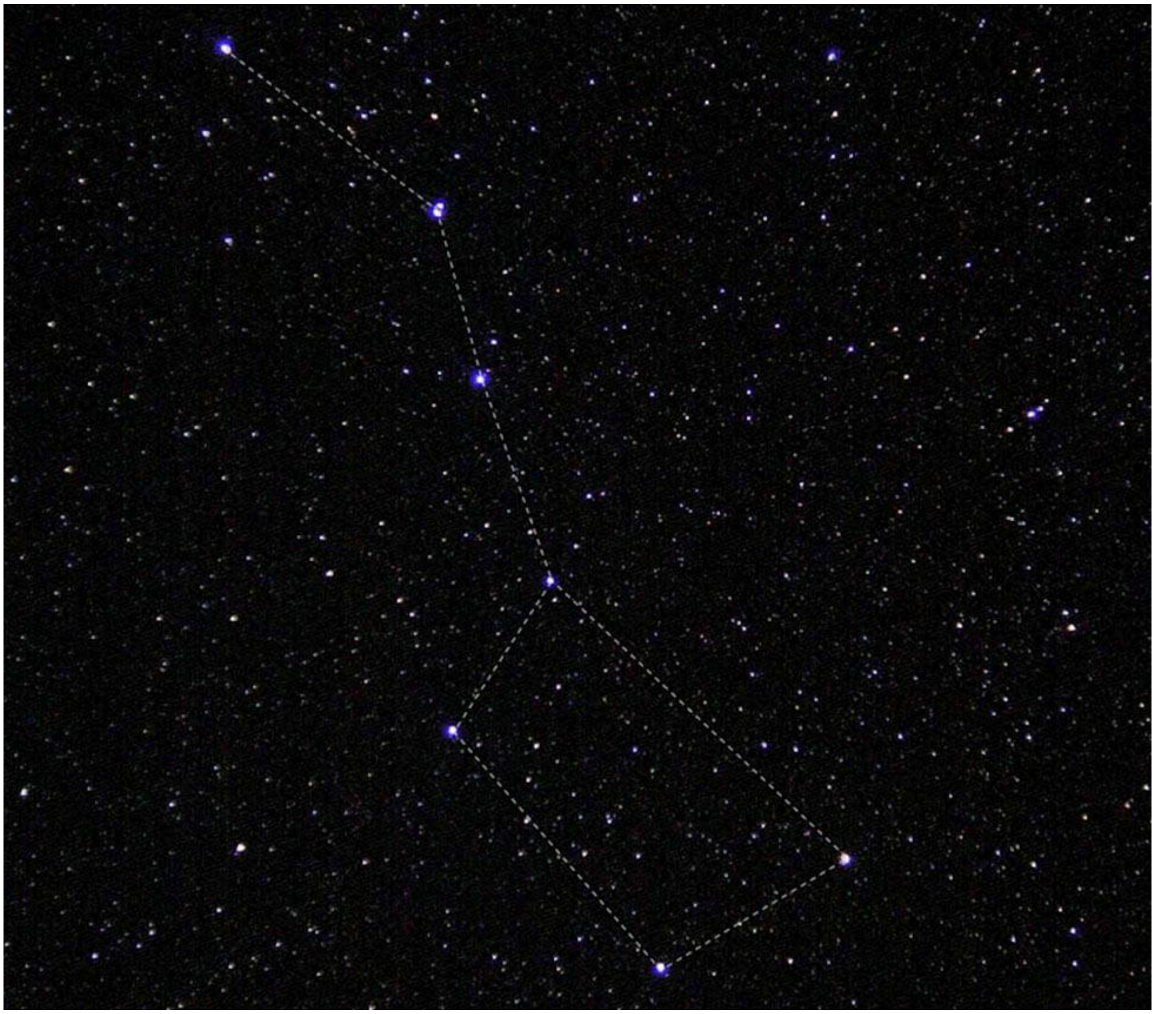
Earth rotates once on its axis about every 24 hours. To an observer looking down at the North Pole, Earth appears to rotate counterclockwise. From nearly all points on Earth, the Sun appears to move across the sky from east to west.

Of course, the Sun is not moving from east to west at all. The Earth is actually rotating on its axis. The Moon and stars also seem to rise in the east and set in the west. We often say that the Sun is “rising” or “setting.” Actually, it is the Earth’s rotation that makes it appear that way. The Moon and the stars at night also seem to rise in the east and set in the west. Earth’s rotation is also responsible for this too. As Earth turns, the Moon and stars change position in the sky. All the motion in the sky that you notice is due to the Earth’s rotation.

The daylight and darkness cycles are determined based on how far north or south they are. At the equator, there is an even amount of daylight and darkness. No matter what day of the year it is, the equator always experiences 12 hours of daylight every 24 hours. At the poles, the amount of daylight varies greatly. In their summer months. The poles receive 24 hours of continuous daylight for 6 months. During their winter months they have 24 hours of darkness. This, too, lasts for 6 months.

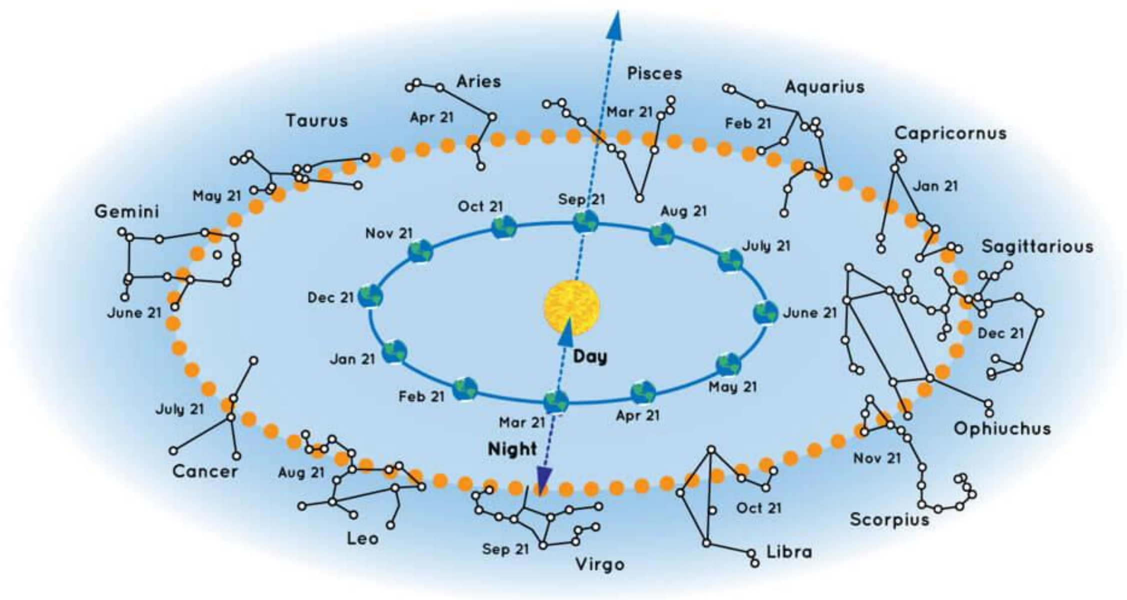
What constellations can you see in the night sky?

A constellation is a group of stars that looks like a particular shape in the sky and has been given a name. These stars are far away from Earth. They are not connected to each other at all. Some stars in a constellation might be close while others are very far away. But, if you were to draw lines in the sky between the stars like a dot-to-dot puzzle – and use lots of imagination – the picture would look like an object, animal, or person.



This group of stars is called the "big dipper." If you trace a line between the stars, it looks like a ladle, or dipper, that you'd use to dip soup from a pot. This photo of the big dipper was taken by an astronaut on the International Space Station, but you can often see this group of stars from the ground, too!
Credit: NASA/Donald R. Pettit, Public Domain, https://spaceplace.nasa.gov/constellations/en/

The constellations you can see at night depend on the time of year. Earth orbits around the Sun once each year. Our view into space through the night sky changes as we orbit. So, the night sky looks slightly different each night because Earth is in a different spot in its orbit. The stars appear each night to move slightly west of where they were the night before. It can be a little confusing to picture how the night sky changes as we orbit the Sun. You can see how it all works in the illustration below.



A chart showing some of the constellations that are visible from the Northern Hemisphere in different times of year. *Credit: NASA/JPL-Caltech, Public Domain, https://spaceplace.nasa.gov/constellations/en/*

For example, say you're in the Northern Hemisphere looking into the night sky on September 21. You'll probably be able to see the constellation Pisces. But you won't see Virgo because that constellation is on the other side of the Sun. During that time of year, Virgo's stars would only be visible during the daytime – but you'd never see them because of the brightness of our Sun.

Putting It Together


Image by [illegible], pixabay.com, CC0

Kids' shadows on the playground in the morning


pixabay.com; CC0

Kid's shadow on the playground at lunchtime


pixabay.com; CC0

Trees' shadows in the early morning


pixabay.com; CC0

Tree's shadow at midday

While on the playground at lunch recess, you notice that your shadow looks different than it did when you arrived at school. You also notice the change in shadows of other things, like the school, the flagpole, and other students.

Focus Questions:

1. Why does the Sun appear to move across the sky?

2. How long does it take the Earth to orbit around the Sun? What is this orbit pattern called?

3. How long does it take for the Earth to spin around one time once on its axis? What do we call one rotation on its axis?

Final Task:

Analyze the chart from the “What constellations can you see in the night sky?” section.

Which constellation can we see in the night sky in December?

Which constellation is NOT visible in June?

What pattern do you notice in the seasonal appearances of some constellations in the night sky?