4th Grade Science

for Utah SEEd Standards

2020-2021

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Utah State Board of Education OER
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AUTHOR

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

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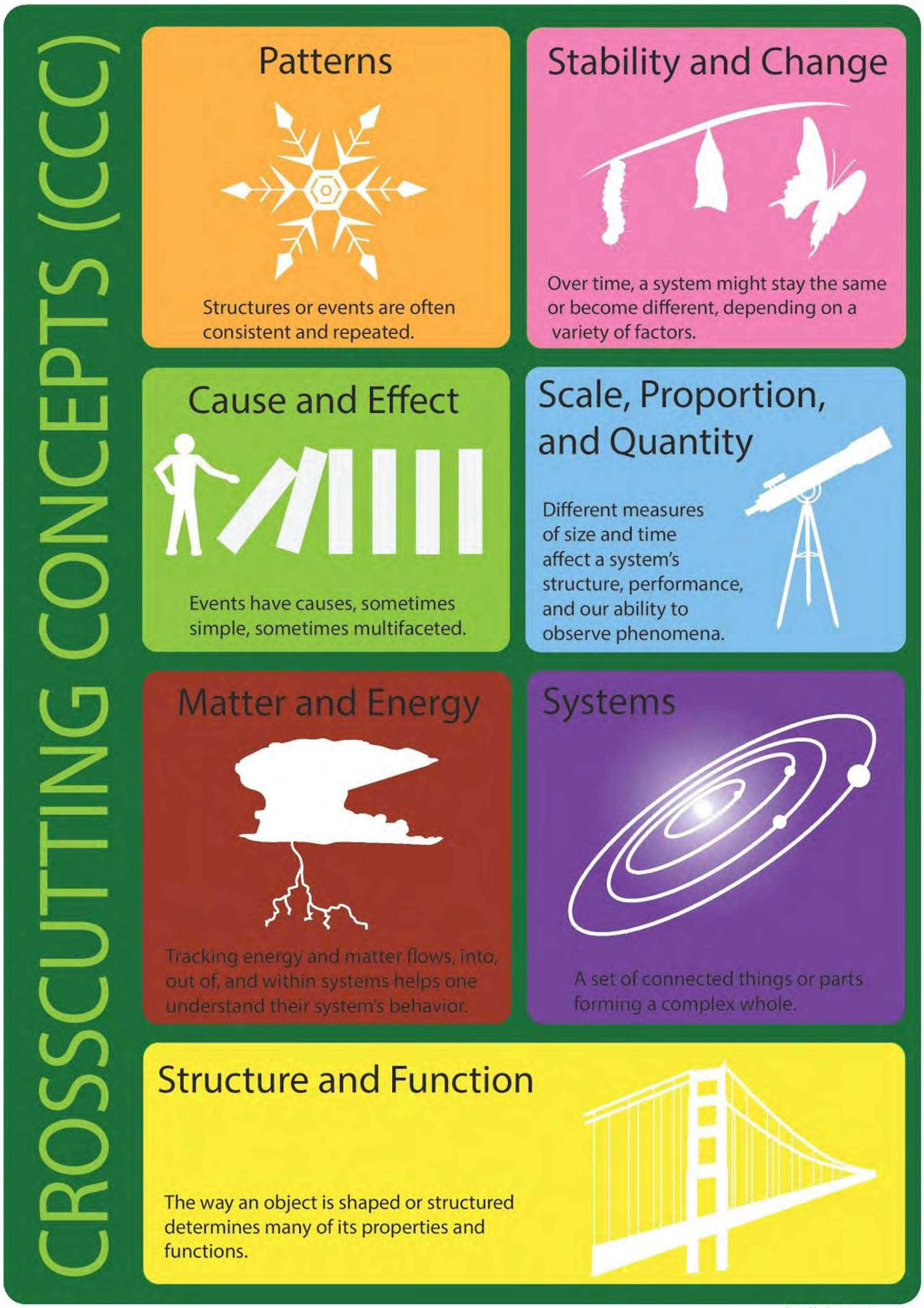
Cross Cutting Concepts

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



A Note to Teachers

This Open Educational Resource (OER) textbook has been written specifically for students as a reputable source for them to obtain information aligned to the 4th Grade Science Standards. The hope is that as teachers use this resource with their students, they keep a record of their suggestions on how to improve the book. Every year, the book will be revised using teacher feedback and with new objectives to improve the book.

If there is feedback you would like to provide to support future writing teams please use the following online survey: http://go.uen.org/bFi

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CHAPTER 1

Strand 1: Organisms Functioning in Their Environments

Chapter Outline

Through the study of organisms, inferences can be made about environments both past and present. Plants and animals have both internal and external structures that serve various functions for growth, survival, behavior, and reproduction. Animals use different sense receptors specialized for particular kinds of information to understand and respond to their environment. Some kinds of plants and animals that once lived on Earth can no longer be found. However, fossils from these organisms provide evidence about the types of organisms that lived long ago and the nature of their environments. Additionally, the presence and location of certain fossil types indicate changes that have occurred in environments over time.

1.1 Survival (4.1.1)

Explore this 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 a few animals are able to live in the Great Salt Lake because of the salty water.

Although there are very few living things that can live in the salty water of Great Salt Lake, there are many plants and animals that make their home in the marshes near the lake. In the spring, thousands of birds migrate to Utah and live in the freshwater marshes of Great Salt Lake. One of them is a gull, and another the great blue heron.

Image by Antonios Ntoumas, pixabay.com, CC0

The great blue heron is one of the largest birds that live in the marshes of the Great Salt Lake.

Image by terrysartifacts, pixabay.com, CC0

How can these animals survive in such a harsh environment? How do their internal and external structures compare to each other? How do these structures help each bird to be able to grow, to pass on their traits, and to survive in that harsh environment? Construct an explanation as to what internal and external structures the Great Blue Heron, and Gull have that could help them survive in the Great Salt Lake wetland environment.

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, observe the internal and external structures (the shapes and parts) of plants and animals in their Utah environments. Then find evidence of how those structures fit a specific function of helping them to survive in that environment, to grow, to pass on their traits, or responding to their environment.

Organism Survival

How do Utah's plants and animals survive in the unique environments found in Utah? Plants and animals usually live naturally in areas where they can survive. The physical environment plays a part in an organism's choice of where it lives. An organism's natural environment has everything it needs to live. There are many kinds of environments that plants and animals like to live in. 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, they must have the ability to make their own food and survive where they are. They also cannot move around to find a mate, so they have adapted in unique ways to grow, to pass on their traits, and to survive in their environment. They help the animals around them do all those things too.

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)

The roots of plants have three major jobs. They 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. They allow plants to grow tall without falling over.
- In many plants, roots store food produced by the leaves.

Plants that live in wetlands are cattail (- long-leafed plant with stiff sticks containing brown fuzzy sections that look like a cat's tail), and bulrush (- spiked leafy plant that clusters together and sometimes has flowers with six bristles). These two wetland plants root in the soil of shallow water. They 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 so they can hide from their predators. The roots of cattails are the main food source for muskrats.


Image by EVA Bonner (Royalgray), pixabay.com, CC0

Stems

Stems are organs that hold plants upright. They allow plants to get the sunlight and air they need. Stems also bear leaves, flowers, cones, and smaller stems.

Stems are needed for transport and storage. They carry water and minerals from roots to 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 vice versa. Without this connection between roots and leaves, plants could not survive. In many


Image by jei_lee, pixabay.com, CC0

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 (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 their leaves to store water (cactus) or food (like spinach or lettuce).

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

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

- 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.
- 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.
- 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.

- Utah's state tree, the Aspen tree is deciduous. That means they drop their 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.
- 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.

Image by J Zapell, public domain

Flowers

Many plants have flowers. The flowers are very important to the plant:

the flowers make pollen which is needed to make seeds from which new plants can grow

- flowers are often brightly coloured to attract birds and insects to spread their pollen and bring pollen from other flowers

Image by Suzanne deDisse, pixabay.com, CC0

Utah State Flower Sego Lily

- the flowers make fruit and seeds
- flowers come in many different shapes and sizes
- The prickly pear cactus blossoms in the spring with pink, yellow, and orange blossoms providing nectar for bees and moths.


Image by Angelas Balaguer, pixabay.com, CC0

Seeds

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

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

Other plants grow their 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. This is how they pass on their traits.


Image by Rajesh Balouria, pixabay.com, CC0

Basic structures in animals

Just like plants, animals also have a basic structure. The basic structure of an animal is:

- head
- tail
- body
- limbs
- sense organs

Head

Most animals have a part of their body that we call the 'head'. Even the smallest animal has a part where it's 'brain' is. In most animals the head has:

- a brain (or brain-like structure) - no matter how small

- sensory organs (like the eyes and ears)

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.
- feeding structures (like the mouth and jaws)
-

Tail

Most animals have a tail at the back end of their body. A tail is often pointed but can have many other shapes as well.

Let's look at some more functions of tails. Tails help an animal to:

- move and swing in trees - monkeys for example.
- balance - kangaroos use their tails to balance while they jump for example.
- kill their prey - crocodiles use their tails to spin them around and around when they need to drown their prey; scorpions often have poison in their tails.
- swim - almost all fish use their tails to let them swim.
  - The June Sucker is unique to Utah Lake, Utah. It is listed as an endangered species.
  - What structures does the June Sucker have that allows it to live in Utah Lake?

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

- steer their movement - fish, whales, dolphin, sharks and many others use their tail as a sort of rudder to steer them in a certain direction. Birds' tails are very important rudders too.
- warn others of possible dangers - some deer flash the white underside of their tails to other deer to warn them of possible danger.

Image by Skeeze, pixabay.com, CC0

- pat down the earth - beavers use their powerful tails to pat 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.
- keep it warm - a little squirrel or fox wraps its tail around it like a blanket to keep warm!
- chase away flies - a cow or horse can swish their tail to get rid of flies.
- communicate - dogs show their emotion in their tails. If they are happy to see you they wag their tails. A burglar is not always met with the same wagging tail!

Body

Animals also have different body coverings - which most cannot change when the weather changes. Why do you think a bird is covered in feathers and not scales? Or why does a whale have a smooth thick skin but an octopus has a slimy slippery skin? Why is it that a cat has soft furry skin but a crocodile's body is covered in hard bone-like scales? To survive, Animals need to cover their bodies in special ways for a few reasons:

1. Body coverings need to protect the animal's organs, bones and muscles from their environment, harsh sunlight, bumps and scratches, and from germs and bacteria that might cause infection. A warm, furry body protects a polar bear in the Arctic just like a scaly body protects an armadillo and crocodile.
    a. Beavers 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 summer and winter.

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

2. Animals need to blend into their environment either to hide from predators or camouflage themselves to stop prey from seeing them (for example mountain lions). Animals use camouflage for two reasons: Animals use it to hide from predators. In other words, their camouflage helps them to hide from other animals that eat them. Animals, like the Bobcat and its spotted fur, also use it to hide from their prey. In other words, when they are hunting it helps them to sneak up on other animals without being seen. Animals are camouflaged in different ways.
3. Some animals have a body covering that protects them from predators. 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.

Image by Steve Bidmead, pixabay.com, CC0

4. Males often use their body covering to attract female attention. A peacock boasting with his beautiful tail feathers or a lion with his mane is meant to attract females.

Limbs

Most animals use their limbs to move. Animals can walk, run, climb or swim using their limbs. Some animals like chimps and squirrels can use their front or upper limbs to handle objects. A beaver's back feet are webbed for swimming. The front paws, much like human hands, are made for holding food, working on dams, and digging.

Animals can have wings, webbed feet, tentacles, fins, legs, arms, flippers and long slithery bodies. The jackrabbit can run up to 35 miles per hour to escape predators such as coyotes, foxes, and large snakes.

Putting It Together

Bird that live in the Great Salt Lake wetland environment:

Image by Antonios Ntoumas, pixabay.com, CC0

How can these animals survive in such a harsh environment? How do their internal and external structures compare to each other? How do these structures help each bird to be able to grow, to pass on their traits, and to survive in that harsh environment?

Image by terrysartifacts, pixabay.com, CC0

After having read the chapter, refine your explanation as to what internal and external structures the Great Blue Heron, and Gull have that could help them survive in the Great Salt Lake wetland environment.

1.2 Information (4.1.2)

Explore this Phenomenon


Image by Utah Division of Wildlife Resources, public domain

Do Ground Squirrels talk to each other?

The Uinta ground squirrel lives in large colonies. Members of the species 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.

Before a coyote can get too close to their underground burrows, they start to chatter loudly to each other, warning them to hide!

Why would the squirrels do that? How did they know that the Coyote would hurt them? How did they send the message of danger near to the other squirrels?

Use this chapter to help you develop a model of a system to describe how the ground squirrel could have sensed the coyote was near. Use a model to describe how he warned his colony environment.

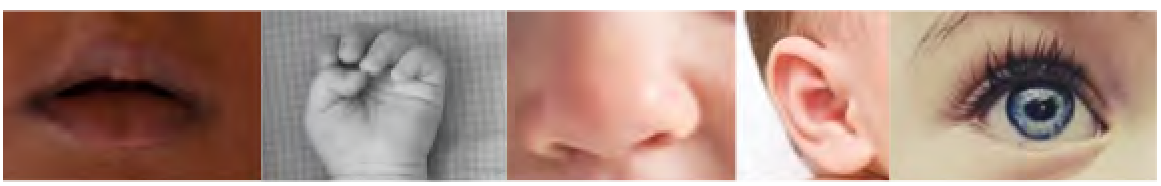
4.1.2 Information

Develop and use a model of a <u>system</u> 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)

In this chapter, focus on describing how animals use systems to receive, process and store information to respond to the world around them. Identify how these systems help these animals to survive.

Sensing Information

Animals, including humans, are able to respond to their environment in many different ways. Some ways we learned about in the last chapter, but they can also use their senses to help them respond to the world around them. Can you name the five senses?



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Taste, touch, hearing, smell and sight. Did you know some animals have senses that are much better developed than those of humans. Dogs for example can sense things and help humans with this.

Image by [illegible], CC-BY

- Sniffer dogs help to find people who are trapped under building rubble, mudslides or snow and tell the rescue workers where the victims are. These dogs also smell drugs or bombs and alert the police.
- Eagles, buzzards, hawks and other birds of prey have extremely sharp eyes as

they have to see small rodents from very far away.

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

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- Bats, dolphins and some whales use a special sense called echolocation. They send out special sound waves and can find prey or objects that they might bump into from quite far away.
- Butterflies, bees and earthworms have another special sense called chemoreceptors - they taste through their skin or feet.
- Animals such as ants, cockroaches or crayfish have special sense receptors that can sense something moving 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. He is using her senses, and learning about the world through play. What senses do you think she might be using? Do you think she might be learning about her environment? Playing in a sandbox is fun for young children. It can also help them learn about the world.

What body system helps you learn?

As these girls 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. It may be needed later. It will then have to be retrieved. All these processes are controlled by the nervous system.

Image by klimkin, pixabay.com, CC0

Introduction to the Nervous System

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.

Image by FaceMePLS, https://flic.kr/p/9is6Tm, CC-BY

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 it controls?

- Sense conditions inside of your body, such as temperature
- Control your internal body systems and keep them in balance
- Prepare your body to fight or flee
- Use language, think, learn, and remember

The main organs of the nervous system are the brain and the spinal cord. They 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 the electrical messages around the body. The 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

For example, 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 them. This includes the muscular and skeletal systems. Together these systems allowed Michelle to react. As a result, Michelle's body became balanced again and she survived.

The Senses

The senses are also part of the nervous system and include several sense organs—the eyes, ears, mouth, nose, and skin. Each sense organ has special receptors that 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 nerve impulses to the brain, and the brain “tells” us what we are tasting or smelling. We can then respond to that information.

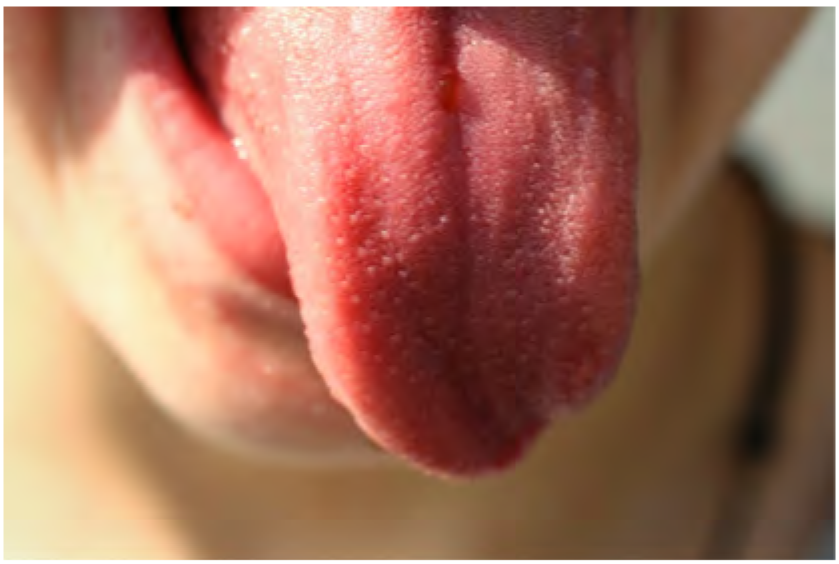


Image by 1045373, pixabay.com, CC0

Touch is the ability to sense pressure. Pressure receptors are found mainly in the skin. Some touch receptors sense differences in temperature or pain. Think back to when you were a little child, did you ever touch a hot stove? Your skin sensed the high temperature and the pain, told your brain, and you were able to respond using your nervous, muscular and skeletal systems to pull your hand away quickly and hopefully 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 what if she had heard someone yell warning her of the hole, she might have been able to avoid it completely! Sight and sound helps us respond to our environment. Can you think of 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


Image by Utah Division of Wildlife Resources, public domain

Do Ground Squirrels talk to each other?

Why would the squirrels do that? How did they know that the Coyote would hurt them? How did they send the message of danger near to the other squirrels?

Develop a model of a system to describe how the ground squirrel could have sensed the coyote was near. Use a model to describe how he warned his colony environment.

1.3 Change Over Time (4.1.3)

Explore this Phenomenon

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

Photo by Terasa Peterson CC0

Why would we find fossils of ocean dwelling life forms in the deserts of Utah?

1. Write down your wonderings.

Use data and graphs from the chapter to gather evidence and analyze the stability and change of our Utah environments.

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)

In this chapter, you will see how fossils teach us how ancient organisms might have lived and survived in their environments. Comparing fossils to the organisms and environments of today, find evidence of any changes. Analyze the data you find about what changes occurred after millions of years to environments that were once stable.

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

Pixabay.com, CC0

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, 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 one another, and to organisms of 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.

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

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

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!

Fossils can teach us so much. By studying fossils of plants and animals, scientists can also 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 hard 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-atm), pixabay.com, CC0

Image by Alain Bosc, pixabay.com, CC0

Footprints can tell us how much it weighed, how big it was, and even what 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, they 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.

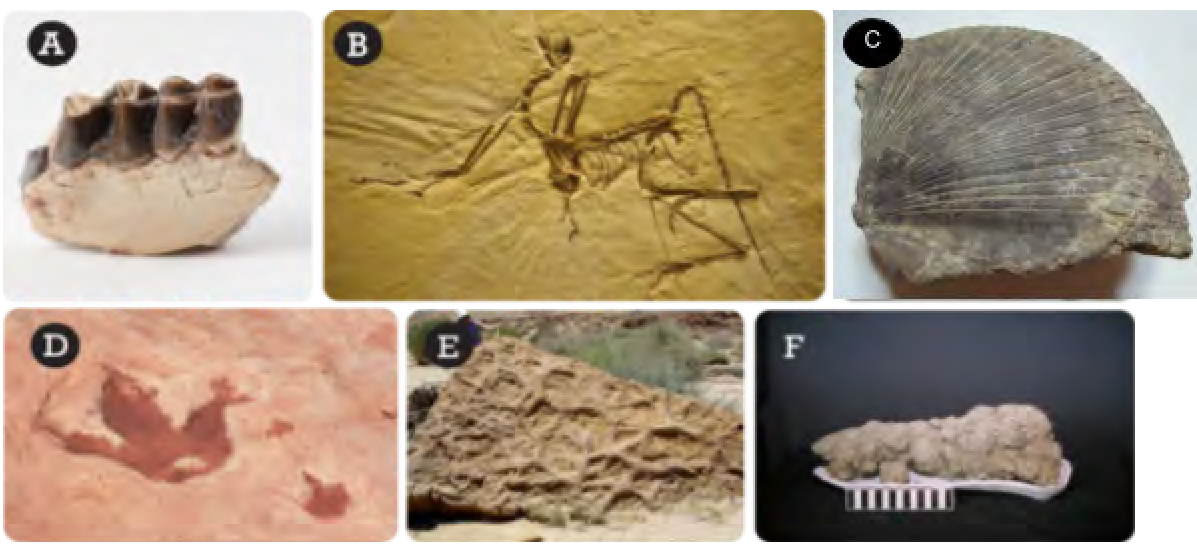
Image of extinct trilobite fossil by WikiMediaImages, pixabay.com, CC0

When this extinct species is compared with an organism found in today's oceans, the Horseshoe Crab, there are remarkable similarities found.

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

What changes do you notice? What questions do you think of when you see these two species compared?

For thousands of years, people have found fossils. The fossils caused many questions about Earth's past. How did these organisms live? What type of world did they live in? Fossils can tell us a lot about Earth's history.



(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
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(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.

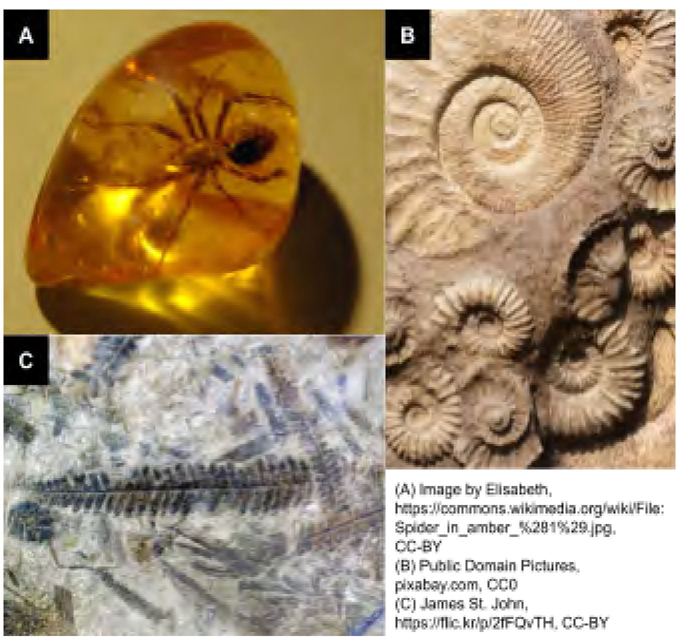
Why Fossilization Is Rare

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. Others may be broken down by the elements. Insects too may break down remains.

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) 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

(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.

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 living organisms.

Fossils can tell us about where the organism lived. Was it land or marine? Fossils can even tell us if the water was shallow or deep. Fossils can even provide clues to ancient climates.

Fossil Environments

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

Fossils of ocean animals on the top of Earth's tallest mountain? It's hard to believe, but it is true. These fossils were found on at the top of Mt. Everest. Mt. Everest is the highest mountain on Earth. These fossils showed that this entire area 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. Plants do not grow in Antarctica. According to fossils, they once did. 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?

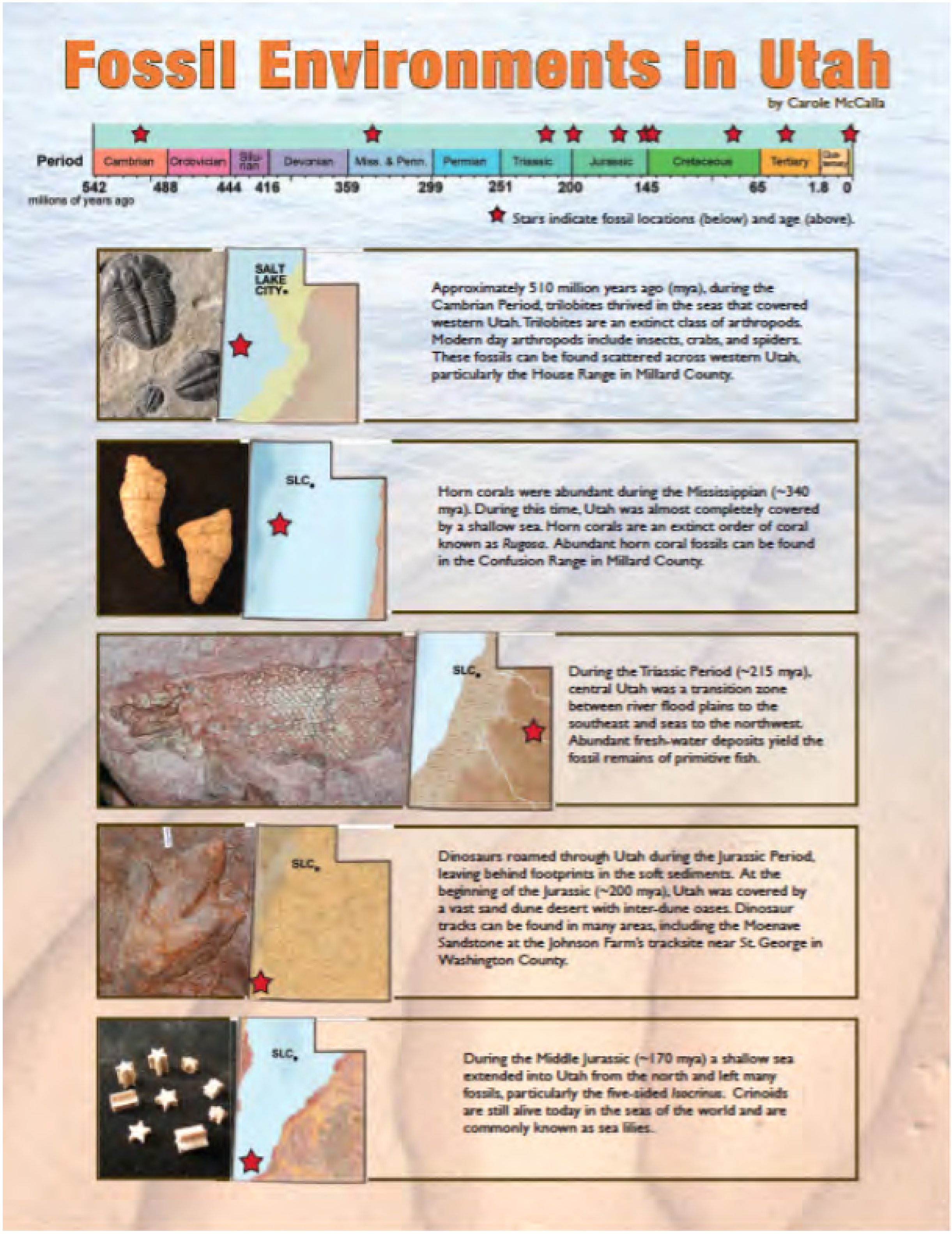
Now like a great detective, we need to take these clues from Earth's history and use them to make inferences about Utah's past. The environment of Utah long ago was very different from what it is today.

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 today. All this evidence was put into the following infographic on Fossil environments in Utah.

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

Period: Cambrian, Ordovician, Silurian, Devonian, Miss. & Penn., Permian, Triassic, Jurassic, Cretaceous, Tertiary, Quaternary

542, 488, 444, 416, 359, 299, 251, 200, 145, 65, 1.8, 0 millions of years ago

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

SALT LAKE CITY

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.

SLC

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.

SLC

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.

SLC

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.

SLC

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.

UGS publication PI-93, Courtesy of the Utah Geological Survey

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
2006

UGS publication PI-93, Courtesy of the Utah Geological Survey

Putting It Together

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

Photo by Terasa Peterson CC0

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

- Why do we find fossils of ocean dwelling life forms in the deserts 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)

Explore this Phenomenon

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 all of a sudden 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?

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

How can we use the patterns as evidence to explain the environment that caused them?

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)

You will observe rock layers in this chapter, and find patterns. By finding patterns in the data provided, we can 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 and how they lived and died. Fossils are the record keepers of Earth. Not all the records are easy to read. Some may be lost, others may be just a part of a record, but still they 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, they form a sediment. Over time, new layers of mud and sand are deposited on 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 glued 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 colours. 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

Can you see the different coloured layers in this sedimentary rock?

Image by Stefan Andrej Shambora, https://flic.kr/p/Jhn42, CC-BY

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 form 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 also show the age of the rock, or specific life forms and climate conditions of that layer of sediment.

Because sediment is often deposited in layers, and 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.

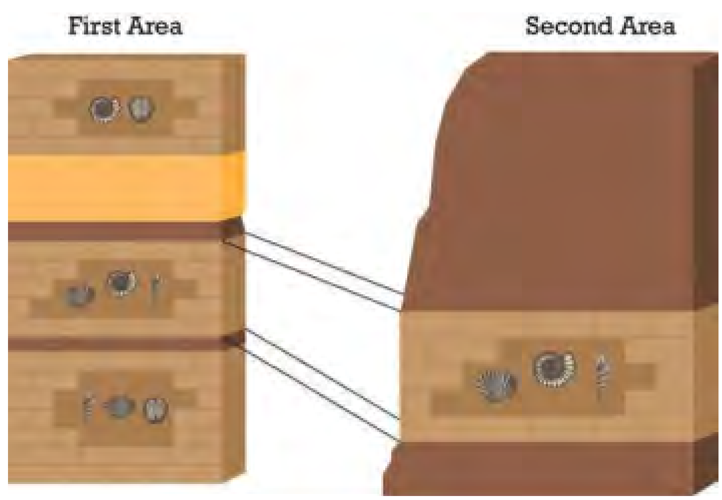
By using the geologists' motto, "the present is the key to the past," geologists can determine what the area might have looked like at various times in the past.

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, they can learn about what plants and animals once lived in the area. If they 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 them 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 Earth's history are called index fossils. Index fossils are commonly used to match rock layers. You can see how this works in Figure below. If two rock layers have the



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 same index fossils, then they're 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. They may cover very large areas. This is especially true if they formed at the bottom of ancient seas. Seas are very large areas of water. Over time, sediment builds up on the seabed. They 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."

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.

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

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. They 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 all of a sudden 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?

How can we explain the patterns of the dents or ripples? Was there any evidence in the chapter to explain this?

How can we use the patterns as evidence to explain the environment that caused them?

CHAPTER 2

Strand 2: Energy Transfer

Chapter Outline

Image by Skeeze, pixabay.com, CC0

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)

Explore this Phenomenon

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

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. Wow! But the next time he comes up to bat, he bunts the ball and it barely goes a few feet. What changed?

Use the information in this chapter to construct an explanation of what caused the ball to travel at different speeds.

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)

The faster an object moves, the more energy it has. In this chapter, observe the relationship between speed and energy. Use your evidence to explain or support 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.

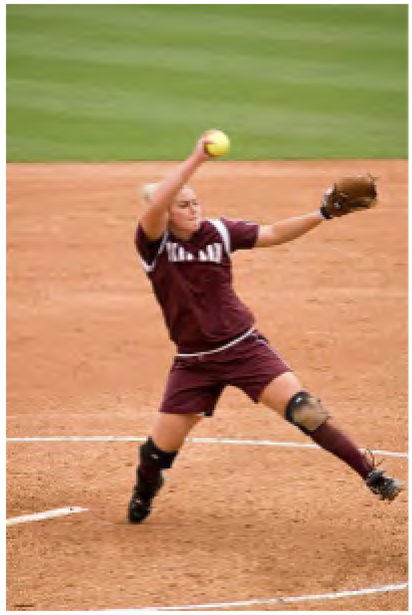
What do all the photos in the Figure below have in common? All of them show things that are moving. Anything that is moving has energy. For example, the hammer in the photo is doing the work. It is pounding the nail into the board. In other words, the hammer has energy and is causing a change by moving 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.
Image by Stuart Seeger, http://commons.wikimedia.org/wiki/File:Pitching_3.jpg, CC BY 2.0

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, you might 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 20 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 the ball. It could go faster after a hard hit, or slower after a gentle kick.

The speed will affect what objects are moved. If the water is moving very slowly, small objects can be moved. If the water moves quickly, what do you think will happen? Yes, larger objects can be moved. Why does this happen? Slow-moving water has little energy. Fast moving water has much more energy. The amount of energy is important. Heavy objects need more energy to move them.

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

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.

Putting It Together

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

Let's follow up. What did the batter do differently with his bat to cause the ball to travel at a fast speed? What did he do for the ball to travel at a slow speed? What caused the ball to travel at different speeds?

2.2 Collisions (4.2.2)

Explore this Phenomenon

Image by gregkorg, 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.

Image by Skeeze, pixabay.com, CC0

Make observations of what you see the pool balls doing, and ask. What changed? 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 changes 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)

What causes changes in energy? Observe what changes when two objects collide. Use the examples in this chapter to ask questions about the changes in energy of the objects. Such as, how does the change in speed or motion change the energy of that 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. 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.

Image by emirkrasnic, pixabay.com, CC0

What happens when I drop an egg on the floor?

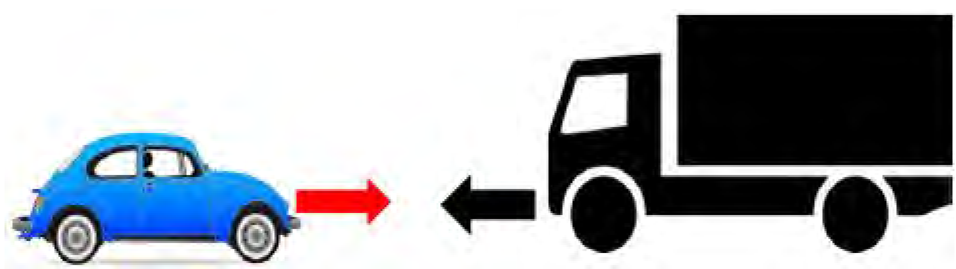
Why did the egg break?

The egg was moving, so it had energy, but then the egg transferred its energy to the floor when it collided and that lack of energy stopped its motion.

What happens in a car accident? For a car moving at around 35 mph, the driver is also moving at 35 mph. To stop the car, the driver inside must slow down his speed to zero mph as smoothly as possible. Otherwise, the result of a car accident would be the same as flinging a body at 35 mph at a brick wall... ouch! Changes in speed from a collision 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.



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.

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

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.

Image by Skeeze, pixabay.com, CC0

Make observations of what you see the pool balls doing. What changed? What caused the colored pool balls to speed across the table in all different directions?

2.3 Energy Transfer (4.2.3)

Explore this Phenomenon

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

The man is playing an electric guitar. He plucks the strings of the guitar with great skill. The sounds of the music thrill the crowd. The bright stage lights add to the excitement. Unfortunately, the lights can also make it uncomfortable for the musician. It can get really warm on stage.

Do you know why?

What do you observe in the picture that could be energy? How many forms of energy can you identify in this picture?

In this chapter you will gather evidence from observations and use that to plan and carry out an investigation into the transferring of energy from place to place.

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)

Energy can be transferred in different ways and between objects. Use this chapter as a tool to plan your investigation into energy. Plan how to use the most appropriate method to gather evidence of what the energy does and how it changes.

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.

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.

Example 3:

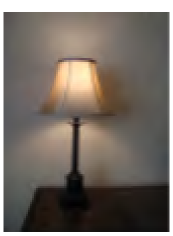
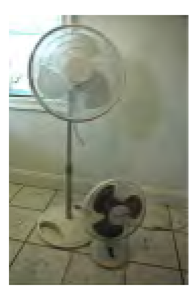
A flashlight will not work when you turn it on unless it has batteries. The input energy for the flashlight to work comes from the energy in the batteries which is changed to electricity. The output energy from the flashlight is light and heat.

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  Image by Clker-Free-Vector-Images, pixabay.com, CC0		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.

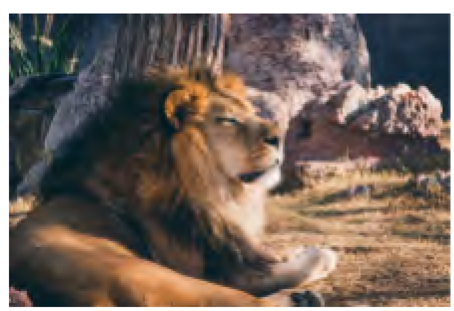
Living things need energy from the Sun to survive. That energy comes to us as light.
Image by Johannes Plenio (jplenio), pixabay.com, CC0

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

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

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.

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.

A trumpet player in a marching band

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.

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

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

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 man playing the electric guitar. What do you observe in the picture that could be energy? How many forms of energy can you identify in this picture?

After reading this chapter, what evidence do you now have of the energy in this picture being transferred from place to place?

2.4 Energy Conversions (4.2.4)

Explore this Engineering Design Problem

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. 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.

Draw a diagram of your room, what do you already know about this situation that will help you design your device?

What items are already available in your room or home?

After reading this chapter, think about what energy forms you would convert in your alarm system.

4.2.4 Energy Conversions

Design a device that converts <u>energy</u> 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 see how energy can come in many forms. By designing a device to take one form of energy and converting it to another form of energy, you are making energy usable! Modifying your device to have the least amount of energy lost to other unwanted forms of energy improves the efficiency of your design.

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

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

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.

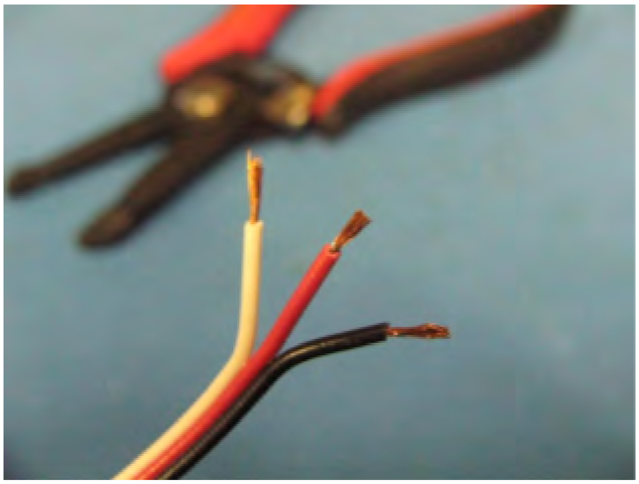
Renewable Energy Source	Example
Sunlight Sunlight can be used to heat homes. It can also be used to produce electricity. This conversion is made possible by solar cells. However, solar energy may not always be practical. Some areas are just too cloudy.	 Image by Jon Callas, http://www.flickr.com/photos/joncallas/5586087273/, 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/fSPwrE, 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. 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.

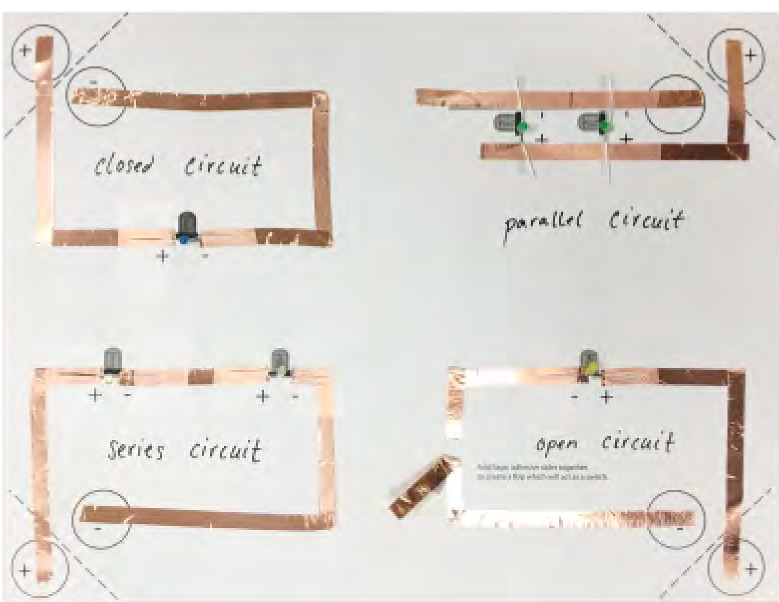


These electric cables are made of copper wires surrounded by a rubber coating.
Image by solarbotics, http://www.flickr.com/photos/solarbotics/5414548592/, CC BY 2.0

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.

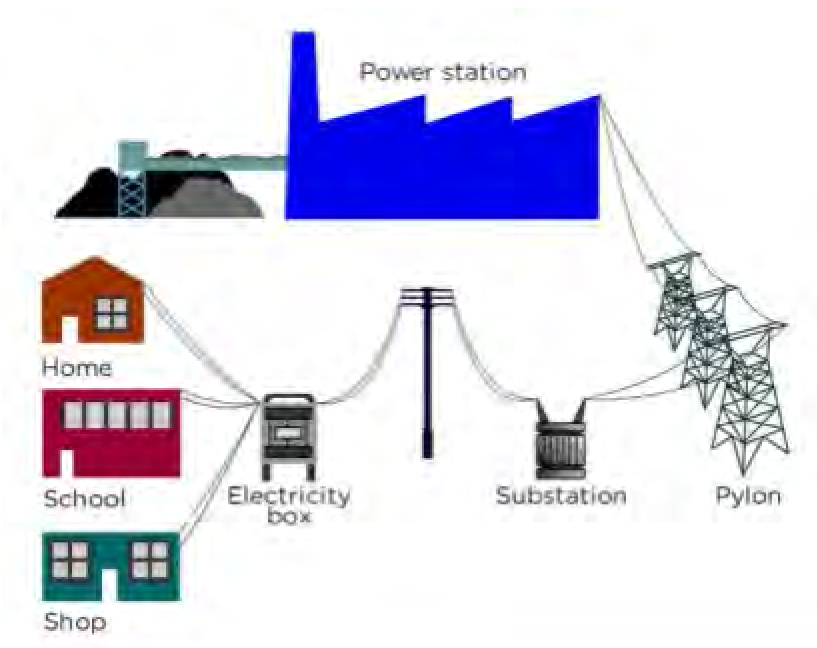
Electricity is transferred in a huge circuit to our homes

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.



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

This diagram shows how electricity is transferred from the power station to your home. Continue the diagram (use the space below) to draw the path of electricity once it is in your home and goes through the wires, wall socket and plugs to get to an appliance, such as the TV.

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

Machines that 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 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 another type of energy.

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 great hope for energy production. Wind turbines do not produce pollution.

Image by Steppinstars, pixabay.com, CC0

As you can see in this picture, their job is to catch the wind. Wind turbines provide us with electrical energy. This energy supports our homes, schools, and offices.

Moving Water

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

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

Historically, the power of moving water was captured by simple water wheels. Water wheels have been used for a long time. They are used to capture the energy from moving water. More recently, engineers have come up with a different way to capture the power of water. A flowing stream only contains a little energy. In contrast, falling water has a lot more useful energy.

Heat

Did you ever cook over a campfire? The man in this picture is cooking his lunch. He waits as his food absorbs energy. First, the energy from the fire needs to heat 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

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. Sometimes that is exactly what we want them to do. A light bulb is an electrical machine that produces light. Light bulbs help us see at night and in dark places. We want light bulbs to give off light. That's their job.

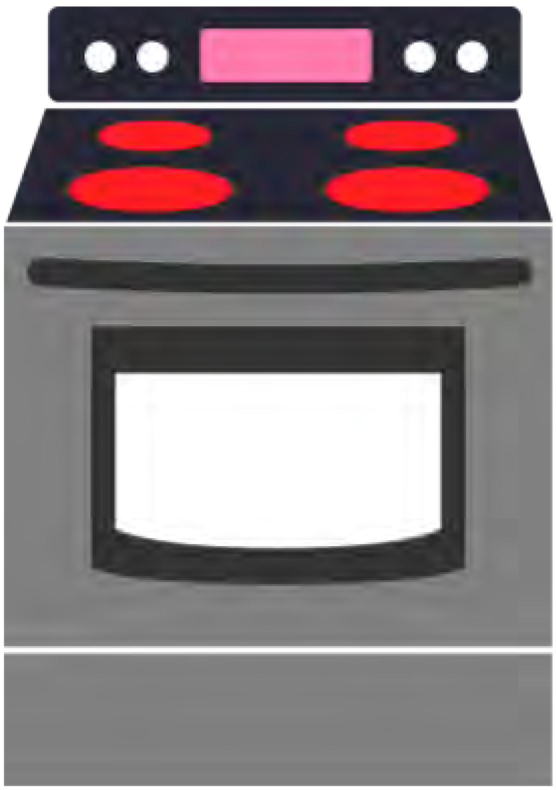


Image by George Mutambuka *(thegiwi), pixabay.com, CC0*

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 produce light. 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. 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.

Write a sentence that clearly describes the problem.
Next, write end goals that will help you know you have successfully solved the problem. These are your criteria for success.

Now, write the limitations or constraints you have to solving the problems such as cost, time, and materials. Brainstorm possible solutions to your problem.

Which of your possible solutions best meets the items you listed in your criteria and constraints?

Draw a design of your solution.

What was your initial energy form and your final energy form?

How might you revise your prototype to make it more effective?

CHAPTER 3

Strand 3: Wave Patterns

Chapter Outline

Image by OpenClipart-Vectors, pixabay.com, CC0

Waves are regular patterns of motion that transfers 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)

Explore this Phenomenon

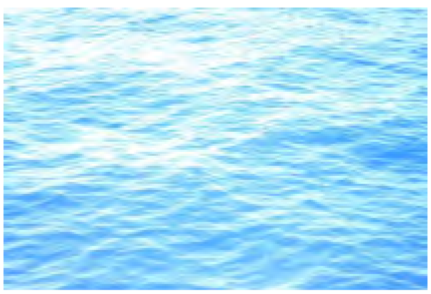
Image by Tim Marshall, https://unsplash.com/s/photos/surf-waves, CC0

Waves across an ocean always seem to have a calming effect. Watching waves you can start to see patterns. What pattern do you see? What physical model could you use to mimic that pattern you see 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)

All waves have similar features. There are patterns in their amplitude and wavelength that we will learn about in this chapter. We can use those patterns of amplitude and wavelength to develop a model to better describe the waves we see in the world around us.

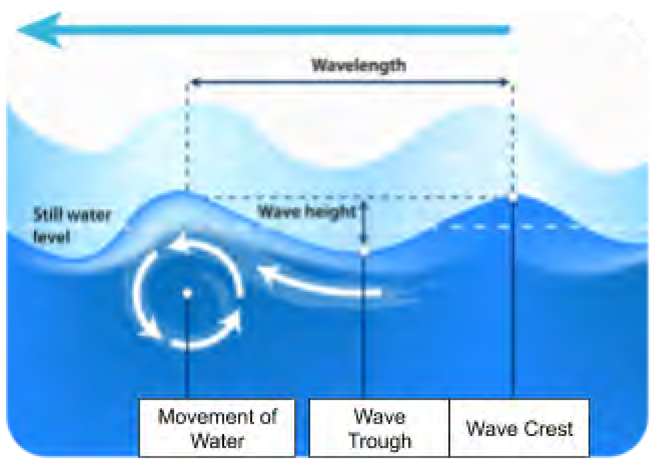


Waves cause the rippled surface of the ocean.
Image by kyle wyss. https://flic.kr/p/9201bB, CC BY 2.0

Waves

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 Figure below. 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 picture shows how water moves when a wave goes by.



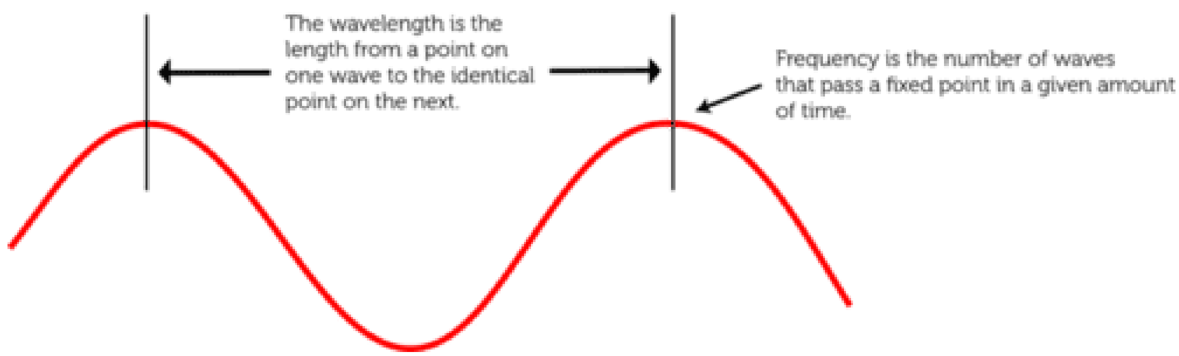
A wave travels through the water. How would you describe the movement of water molecules as a wave passes through?
Adapted from image by Hana Zavadska, CK-12 Foundation, CC-BY-NC 3.0

The Size of Waves

Figure previous 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, the distance from the top of the wave to the bottom of the wave, or the distance between a crest and a trough is called the amplitude. This is the height of a wave. The horizontal, the distance from the beginning of one wavelength to the same position on the next wave or the distance between two crests 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 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 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, the waves can be huge and extremely destructive. They are waves that have an enormous amount of energy. Tsunamis can travel at speeds of

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

800 kilometers per hour (500 miles per hour). Usually tsunami waves travel through the ocean unnoticed.

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

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

When Waves Meet

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 the medium 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 doorknob, and move the other end 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

After having read this chapter, what pattern do you see? Do you have an idea for what physical model could you use to mimic that pattern you see in the waves?

3.2 Light and Sight (4.3.2)

Explore this Phenomenon

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

What do you see in this picture? Why are there two sets of mountains, two buildings, and two forests in this picture? Can you explain what caused this to happen using a model?

4.3.2 Light and Sight

Develop and use a model to describe how visible light waves reflected from objects enter the eye <u>causing</u> 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.

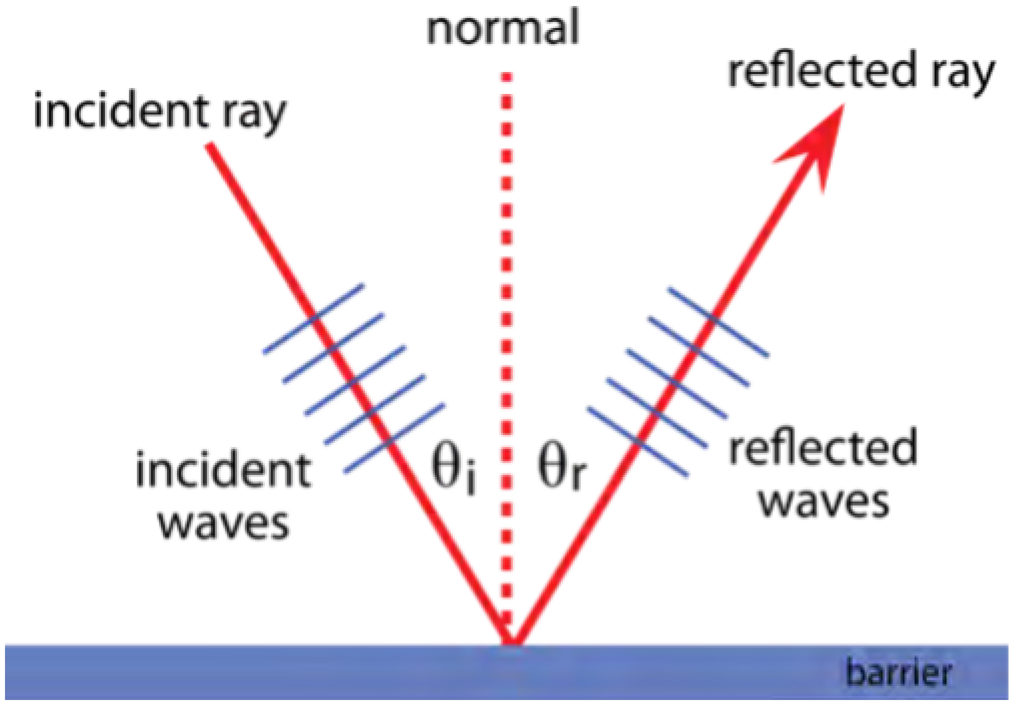
This chapter will help you better understand that sight is caused by moving light waves entering your eye. The cause and effect relationship between visible light waves that have reflected from objects, and your eye causing those objects to be seen, can be further explored by developing a model of this relationship and using it to describe this regular event.

Light

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

Look at this sign. The sign is upside down. So 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



The Law of Reflection

Light rays, (rays are the path that light waves travel) strike a surface. They 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. So 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 than a ball, they react in a similar manner.

The diagram above shows how light rays travel as they strike a surface. Incoming light rays are the incident ray, 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, they may look fuzzy or blurred. Like 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.

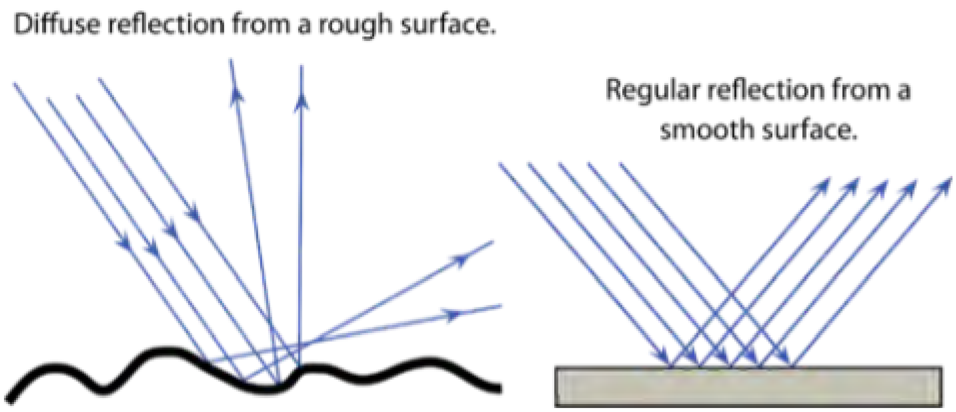
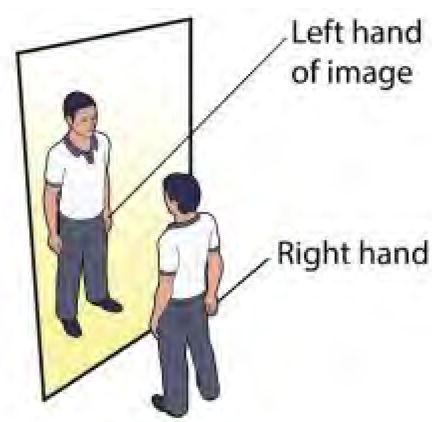


Image by Samantha Bacic;CK-12 Foundation, CC BY-NC-SA 3.0

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, they appear 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 is 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, the light enters our eye so we can see it.

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

We can also see objects give off light, but can reflect light. The reflected light enters our eye so we can see it.

Light seems white, but 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 Teivan Pettinger, https://flic.kr/p/9eWqU9, CC-BY

Image by frankieleon, https://flic.kr/p/6y497Q, 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 enters my 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. It 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.

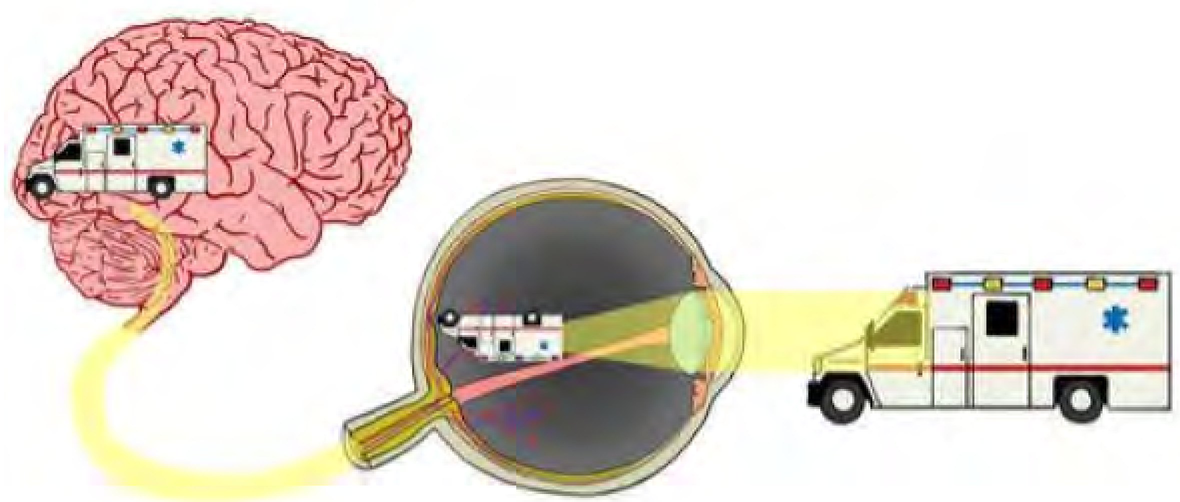


Image by Laura Guerin, CK-12 Foundation, CC BY-NC 3.0

Putting It Together

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

What do you see in this picture? Can you explain why there are two sets of mountains, two buildings, and two forests in this picture? What caused this to happen?

3.3 Information Transfer (4.3.3)

Explore this Engineering Design Problem

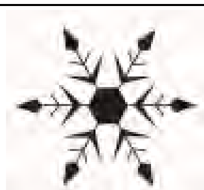
Image by David Porter (pooch_eire), pixabay.com, CC0

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 them all summer. There is no cell signal at camp unless you are on the nearby hill, which is very popular so talking isn't an option or texts as your secrets will be overheard or read by noisy campmates! Plus, you can't hike to the hill at night, and it is not easy to charge your phone, but you still 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. There can be more than one solution to your dilemma. You only have limited resources available to you while at camp so as not to be noticed. You have flashlights, camera, rope or string, mirrors, cups, and the environment around you.

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? What if it is night, how will you get your message to your best friend then? You can have multiple solutions.

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)



Wave patterns can be used as evidence to help us design solutions to problems we have of transferring information over long distances. In this chapter you will learn about the patterns of how waves are bent using lenses and applied in telescopes or eyeglasses, giving us the ability to see farther. Digitizing the 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, using waves. By applying wave patterns to solve our information transfer problems, we have invented many devices that make modern life possible.

Speed of Waves

Waves transmit energy through space, light waves that move through space help us see things that are far away. Part of this is because light waves move very fast. If you could move as fast as the speed of light it would only take you 8 minutes to travel from the sun to the earth!

Has this ever happened to you? You see a flash of lightning on the horizon, but several seconds pass before you hear the rumble of thunder. The reason? The speed of light waves are much faster than the speed of sound waves.   But the speed of sound is still very fast. It travels a far distance much quicker than we can, but not as fast as light 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. Obviously, sounds can vary in loudness, and 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 they have traveled from the source of the sound.

- 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 picture. 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.

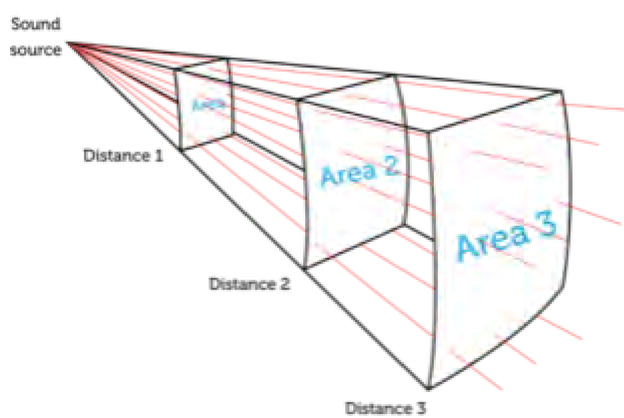


Image by Christopher Auyeung (CK-12 Foundation), CC BY-NC 3.0

Bending Light

When light passes from one medium (for example from air to water) to another, it changes speed. You can actually see this happen. Think about when you are in a swimming pool. If you toss a coin to the bottom of the pool you can still see it through the water. However, if you reach down to pick it up where you see it is not there, you have to reach further for it. This is because the light was moving really fast as it entered the water, then it slows down, which causes it to bend. Therefore, where we see the coin appears differently than where it actually is.

Image by ScienceGiant, pixabay.com, CC0

If light strikes a new substance at an angle, the light appears to bend. This is what explains the pencil looking broken in the picture above. The bending of light is called refraction. So, does light always bend as it travels into a new medium? If light travels straight into a new substance it is not bent.

Optical Telescopes

People have been making and using lenses for magnification for thousands of years. However, the first true telescopes were made in Europe in the late 16th century. These telescopes used a combination of two lenses to make distant objects appear both nearer and larger. The term *telescope* was coined by the Italian scientist and mathematician Galileo Galilei (1564–1642). Galileo built his first telescope in 1608 and subsequently made many improvements to telescope design.

Telescopes that rely on the refraction, or bending, of light by lenses are called refracting telescopes, or simply *refractors*. The earliest telescopes, including

Galileo's, were all refractors. 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.

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

Around 1670, another famous scientist and mathematician — Sir Isaac Newton (1643–1727) — built a different kind of telescope. Newton used curved mirrors to focus light and so created the first reflecting telescopes, or *reflectors*. The mirrors in a reflecting telescope are much lighter than the heavy glass lenses in a refractor. This is significant, because:

- To support the thick glass lenses a refractor must be strong and heavy.
- Mirrors are easier to make precisely than it is to make glass lenses.
- Because they do not need to be as heavy to support the same size lens, reflectors can be made larger than refractors.

(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
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Larger telescopes can collect more light and so they can study dimmer or more distant objects. The largest optical telescopes in the world today are reflectors.

Amateur Astronomers

Amateur astronomers enjoy observing and studying stars and other celestial objects. Both professional and amateur astronomers use telescopes. A telescope is an instrument that makes faraway objects look closer. This is possible because of the collection of light waves in a way that helps us see further away.

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 modern life possible.

What Are Electronic Devices?

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, they include mobile phones, TV remotes, DVD and CD players, and digital cameras, to name just a few. Can you think of other electronic devices that 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.

The parts of a computer that send, process, or store digital signals are pictured and described in the picture. They include the CPU, hard drive, ROM, and RAM. The motherboard ties all these parts of the computer together.

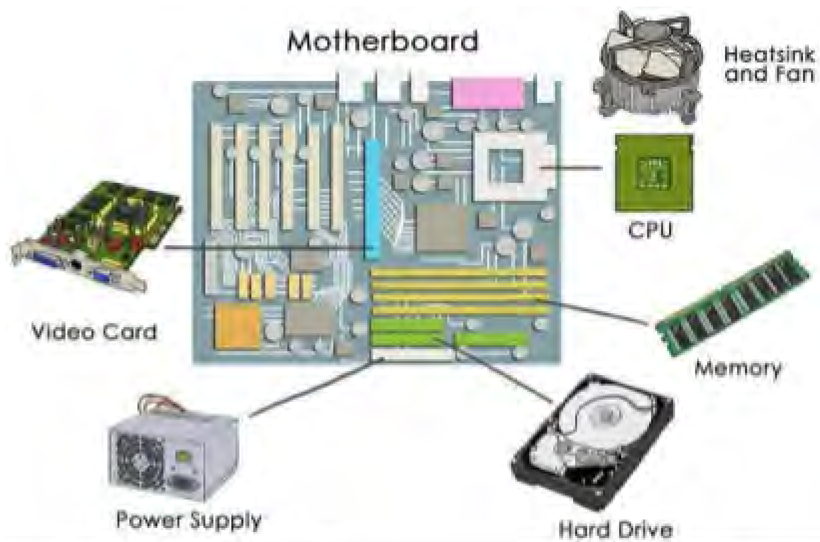

Image by Laura Guerin, CK-12 Foundation, CC BY-NC 3.0

- The CPU, or central processing unit, carries out program instructions.
- The hard drive is a magnetic disc that provides long-term storage for programs and data.
- ROM (read-only memory) is a microchip that provides permanent storage. It stores important information such as start-up instructions. This memory remains even after the computer is turned off.
- RAM (random-access memory) is a microchip that temporarily stores programs and data that are currently being used. Anything stored in RAM is lost when the computer is turned off.
- The motherboard is connected to the CPU, hard drive, ROM, and RAM. It allows all these parts of the computer to receive power and communicate with one another.

Which part(s) of a computer are you using when you type a school report? You are using the RAM to store the word processing program and your document as you type it. You are using the CPU to carry out instructions in the word processing program, and you are probably using the hard drive to save your document.

Electronic devices—such as computers, mobile phones, remotes, 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!

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, 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 them all summer. There is no cell signal at camp unless you are on the nearby hill, which is very popular so talking isn't an option or texts as your secrets will be overheard or read by noisy campmates! Plus, you can't hike to the hill at night, and it is not easy to charge your phone, but you still 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. There can be more than one solution to your dilemma. You only have limited resources available to you while at camp so as not to be noticed. You have flashlights, camera, rope or string, mirrors, cups, and the environment around you.

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CHAPTER 4

Strand 3: Observable Patterns in the Sky

Chapter Outline

Image by Guillaume Preat, pixabay.com, CC0

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)

Explore this Phenomenon

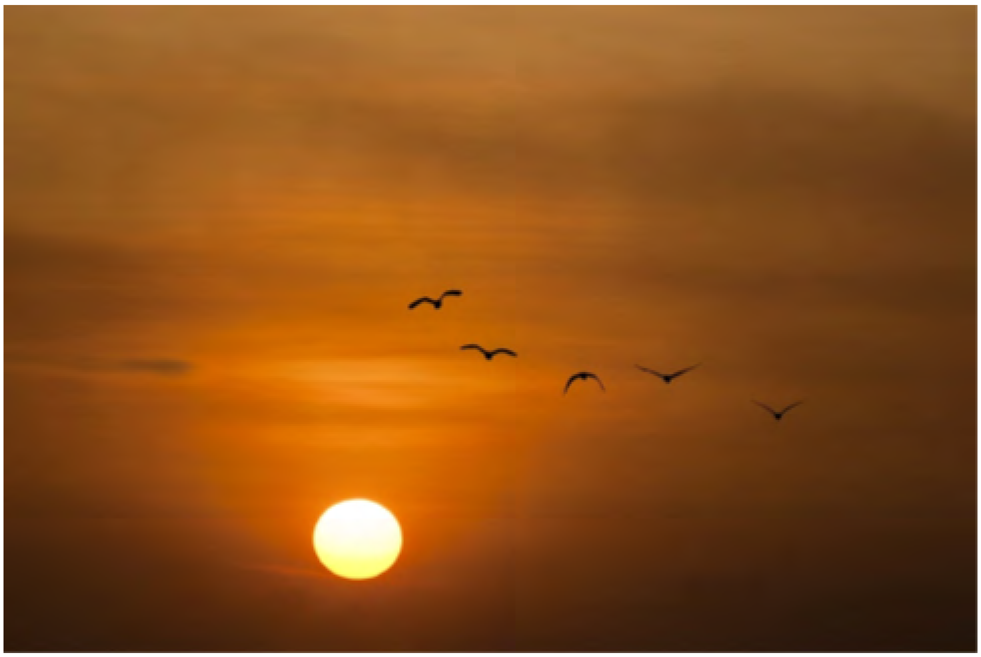


Image by Denis Doukhan (ddouk), pixabay.com, CC0

The sun appears to be much smaller than the earth, in fact if you held your thumb up just right it could cover the size of the sun. Of course, the sun is not smaller than the Earth, nor is it as big as your thumb. What is happening in the sky to have the sun appear so much smaller than the earth?

4.4.1 Sun Brightness

C**onstruct 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)

The sun looks larger in our sky because it is closer to the earth than other stars in the Universe. Actually, it is the only star in our solar system. We will learn in this chapter that the scale of distance helps us better relate and construct an explanation of why the sun is brighter than other stars around us.

The Earth in Space

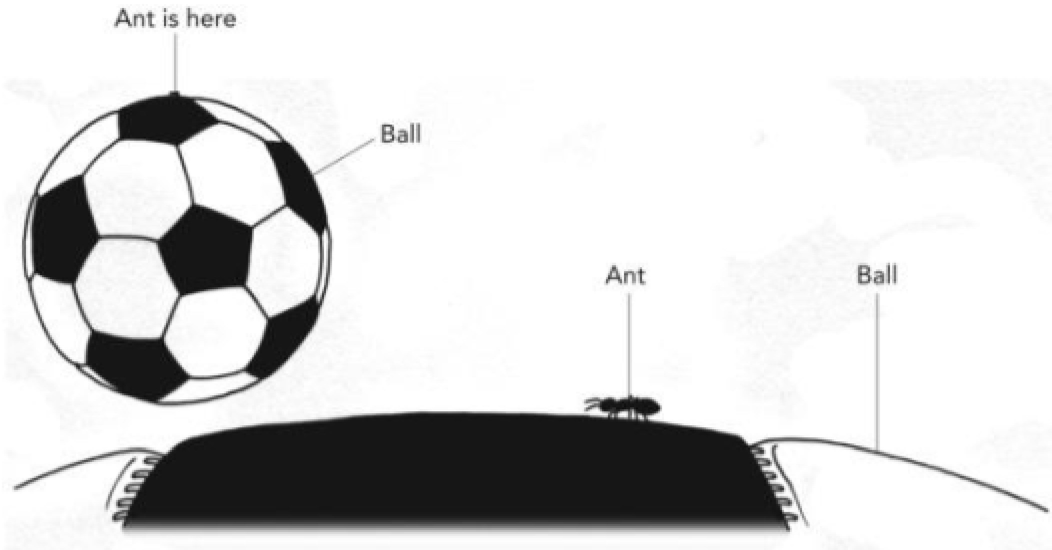
The Earth is a planet in space. From the Earth we can see the Sun, Moon and other stars. Space begins about 100 km, or about 62 miles up from the Earth's surface toward the sky.

The Earth is shaped like a ball

A fun site about astronomy http://www.kidsastronomy.com/

If we were to look at the Earth from space we would see that it is shaped like a ball, or spherical. We see the shape of the Earth when we go very high and get far away from it, for example an astronaut in a spaceship can see the shape of Earth when looking out the window of the spaceship and back at Earth. However, if we look out of the classroom window, the Earth looks flat, not ball-shaped. Many people long ago believed that the Earth was flat. It is so big that we can't see that it is curved so we see it as flat.

Think of an ant on a soccer ball. The ant is so small that the ball looks flat. The ant can't see the other side of the ball, and it can't see that it is a ball. Look at the picture of the ant on the soccer ball.



All the ant can see is a flat surface. He does not even know he is on a round ball because it is so much bigger than he is!
Image by Thunderbolt Kids, http://www.thunderboltkids.co.za/Grade4/04-earth-and-beyond/chapter1.html#, CC-BY-ND

This is the same as us on Earth. We are so small compared to the Earth that when we are standing on the surface, the Earth looks flat to us. We cannot see that the Earth is actually round unless we look at a picture of the Earth taken from space!

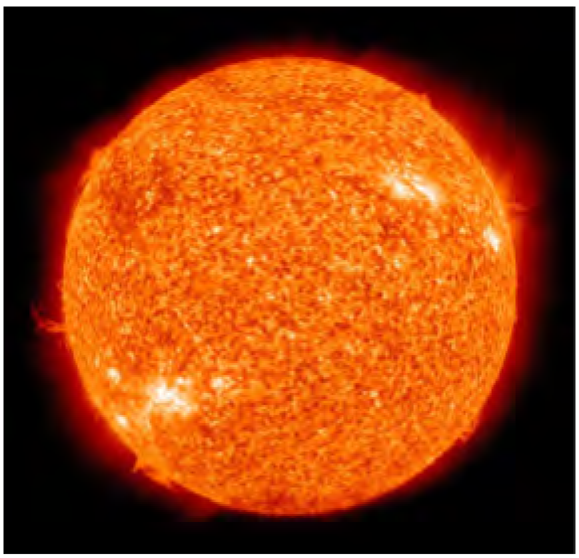
The Sun is the closest star

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 than the other twinkling stars? 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. Let's find out more about the Sun.

The Sun is a huge ball of very hot gas

Our Sun is really a very hot, very big ball of gas. The gas is changing, all the time, and this change gives off energy which makes the Sun very hot.



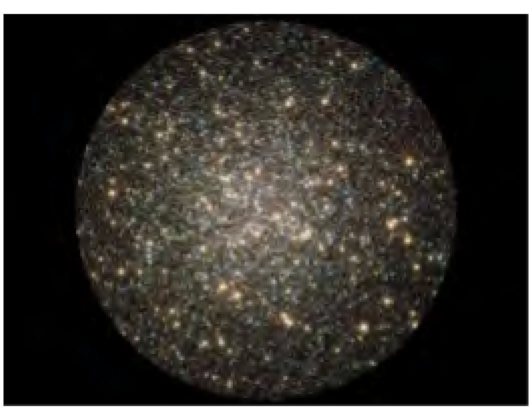
The Sun is over 300,000 times bigger than Earth!
Image by WikiImages, pixabay.com, CC0

The Sun may look smaller than the Earth up in the sky. But this is actually because it is very, very far away. If you went in a car at freeway speed of 75 mph, you would have to travel for 146 years to reach the Sun. The Sun is also much bigger than the Earth.

How big is the Sun, compared to the 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.

So, the Sun is very far away and it is very big and very hot.

Our Sun is like the stars we see in the sky at night. Many of those stars are much bigger than the Sun. They look small because they are so very far away. The only star in our solar system is our sun. All the other stars that we can see are parts of other solar systems in the universe. All the stars are made of gas that is glowing and very hot.



Hundreds of thousands of stars seen through the Hubble telescope
Image by NASA, public domain

The Sun is the nearest star to the Earth. The second-nearest star is called Proxima Centauri. Light from the Sun takes 8 minutes to reach your eyes, but light from Proxima Centauri takes over 4 years to reach your eyes. The Voyager 1 is a spacecraft that launched from Earth many years ago. It is travelling away from the Sun so fast at a speed of 17 km, or about 10 miles every second! If Voyager were to travel to Proxima Centauri it would take more than 73,000 years to arrive.

The Sun is important to life on Earth.

Without the Sun, life on Earth would not be possible. It would be completely dark and freezing cold. In other words, the Sun provides us with light and heat. Because of this light and heat, many other things become possible.

The Sun sends out heat and light to the Earth. The Earth gets only a small part of the heat and light that the Sun sends out but even that is enough to make us feel uncomfortable on a hot day!

We hang our laundry outside to dry. The heat from the Sun helps the clothes to dry.

Image by kelly taylor, https://flic.kr/p/6n5rP9, CC-BY-SA

Some people have special heaters on the roofs of their houses. These are called solar water heaters. They use the heat energy from the Sun to heat water for bathing and washing.

A solar water heater on the roof of a house. The water is in the tank.

Image from http://www.thunderboltkids.co.za/Grade4/04-earth-and-beyond/chapter2.html#, CC-BY-ND

Unfortunately the Sun also has harmful effects on Earth, and especially on people if we do not protect ourselves properly.

When there is not enough rain water, droughts can occur.
Image by Sander Hoogendoorn, https://flic.kr/p/8brX7C, CC-BY

The Sun can damage your skin if you are not careful and do not put sunscreen on when outside.
Image by Phil Kates, https://flic.kr/p/ayf2M, CC-BY-SA

Putting It Together

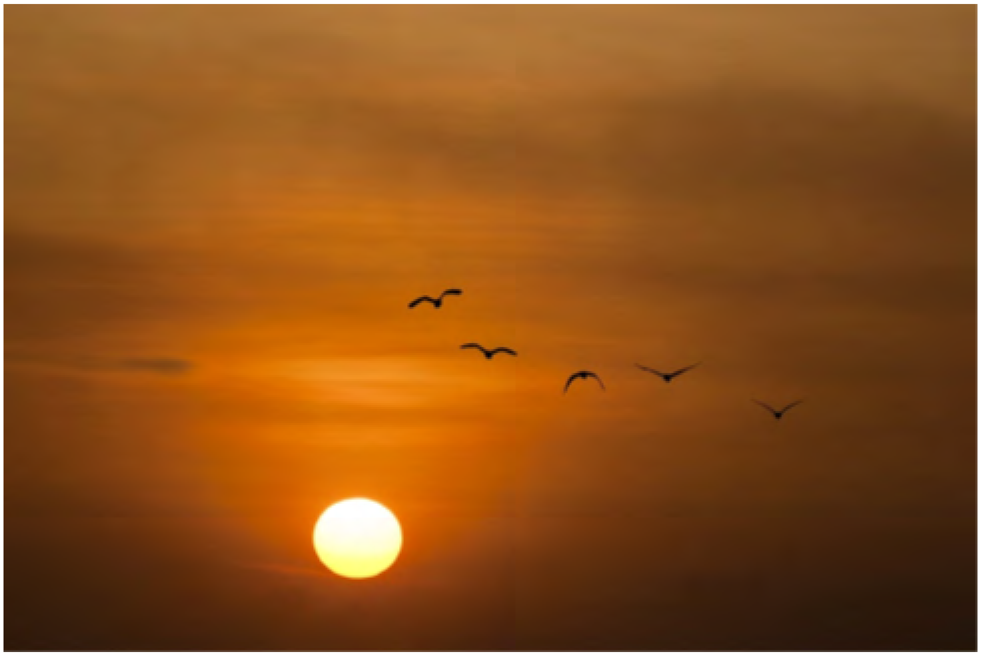


Image by Denis Doukhan (ddouk), pixabay.com, CC0

Is the sun really smaller than the Earth?
How is it that we see the sun in the day and other stars at night?
Explain the way the earth and sun system works, include information about the size and location of the earth and sun.

4.2 Earth's Revolution (4.4.2)

Explore this Phenomenon

Image by nanielin, pixabay.com, CC0

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.

What is causing this change?

How can this change help you understand the movement of the Sun, and the Earth?

4.4.2 Earth Revolution

Analyze and interpret data of observable <u>patterns</u> 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)

There are observable patterns of the Earth, Sun and Moon that we will learn about in this chapter. Using what we can see with our own eyes, these patterns will give us data to analyze and help us explain what we see around us, such as day and night, length and direction of shadows, and star patterns of constellations at different times of the year.

The Earth moves

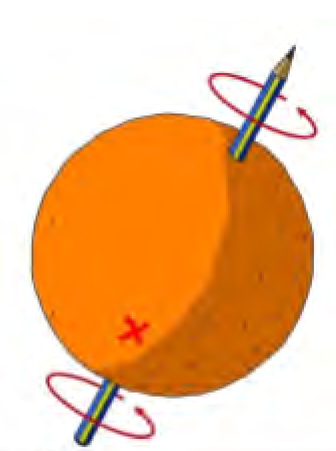


Image by: Thunderbolt Kids, http://www.thunderboltkids.co.za/Grade6/04-earth-and-beyond/chapter1.html, CC-BY-ND

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.

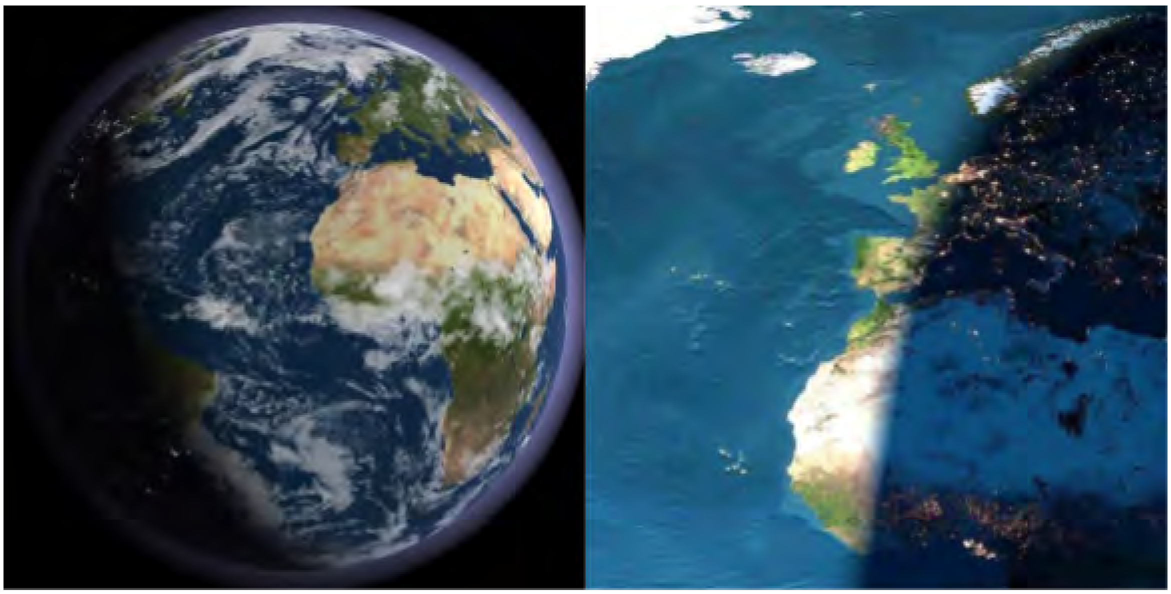
The Earth is like the orange and the pencil is like the axis. The curved arrows show which way the Earth spins.

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

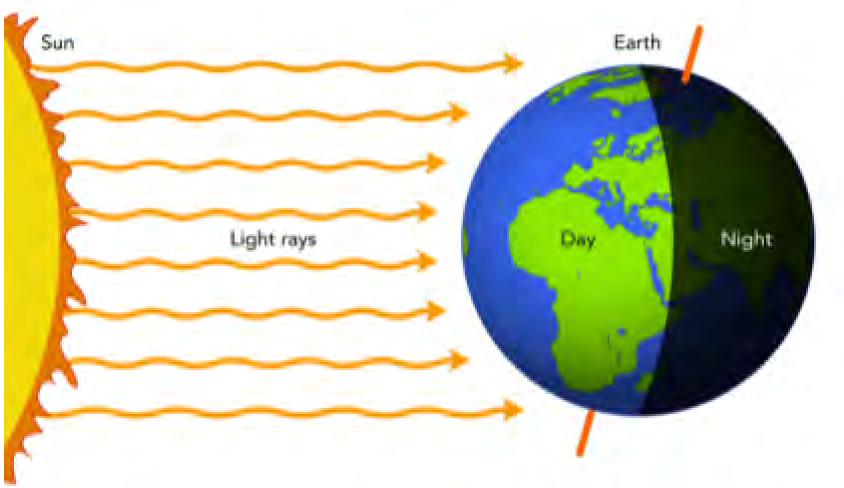
- The Sun shines on the Earth and so we, at X, see the Sun. We call that daytime.
- But the Earth never stops spinning. So we, at X, move around into the shaded part of the Earth. Then we cannot see the Sun any longer and it is nighttime for us at X.

● The Earth spins right around 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 the 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, we move past the Sun. But to us, it looks as if the Sun is moving. The Sun seems to move from the East to the West. 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 actually move.



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 spins round 365 times 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 below the moon.
Image by NASA.gov, public domain

Venus also moves around the Sun but its orbit is a smaller circle than Earth's orbit.

The orbits of the outer planets are actually much bigger than what is shown in this image. 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

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.

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*

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. Figure below shows how this might look.

Earth's Rotation

Imagine a line passing through the center of the Earth. The line extends through both the North Pole and the South Pole. This imaginary line is called an axis. Earth spins around its axis, just as a top spins around its spindle. This movement is called Earth's rotation.

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.

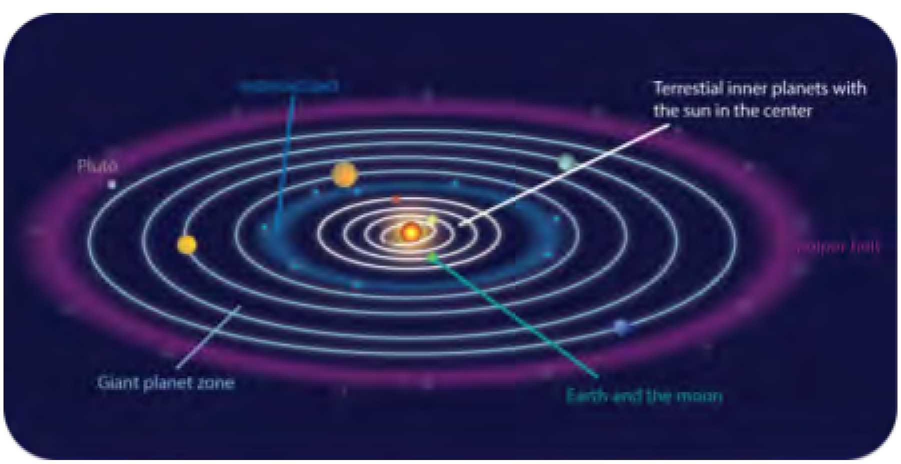
Of course, the Sun is not moving from east to west at all. The Earth is actually rotating on its axis. The Moon and stars also seem to rise in the east and set in the west. We often say that the Sun is “rising” or “setting.” Actually, it is the Earth’s rotation that makes it appear that way. The Moon 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.

Earth’s Revolution

Earth’s revolution around the Sun takes 365.24 days. That is equal to one year. Why does the Earth stay in orbit around the Sun? It is the Sun's gravity (Figure below) that holds the Earth in place. If not for gravity, the Earth would continue to go in a straight line.

Earth's orbit is not a circle. It is somewhat elliptical. So as we travel around the Sun, sometimes we are a little farther away from the Sun. Sometimes we are closer to the Sun.



Earth and the other planets in the solar system make elliptical orbits around the Sun.
Image by Zachary Wilson, CK-12 Foundation, CC BY-NC 3.0

It takes over

eight minutes for light to get from the Sun to Earth. The distance between the Earth and the Sun is about 93 million miles. That's about 150 million kilometers. Earth revolves around the Sun at 27 kilometers per second. It is going really fast. Even at that speed it still takes a long time to go around the Sun. It takes 365.24 days to be exact. Mercury and Venus are closer to the Sun. They take a shorter time to make one orbit. Mercury takes only about 88 Earth days to make one trip around the Sun. All of the other planets take longer. The exact amount depends on the planet's distance from the Sun. Saturn takes more than 29 Earth years to make its journey around the Sun. How old would you be if you were on Saturn?

Putting It Together

Image by nanielin, pixabay.com, CC0

Why does the Sun appear to move across the sky?

How long does it take the Earth to move around the Sun?

How long does it take for the Earth to spin around one time once on its axis?


Utah State Board of Education