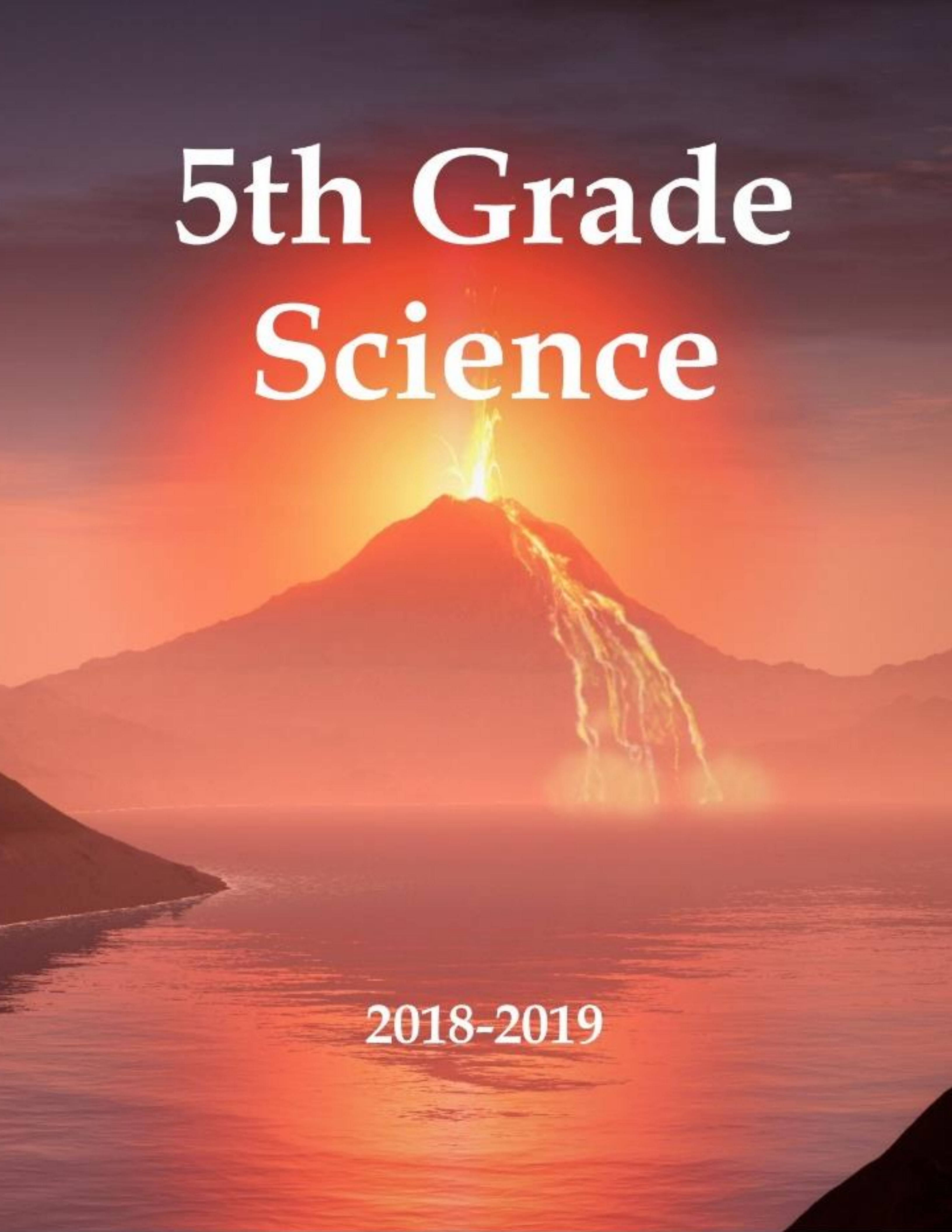
5th Grade Science



2018-2019

5th Grade
Utah Science Standards

Utah State Board of Education OER
2018-2019

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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

Making Science

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?

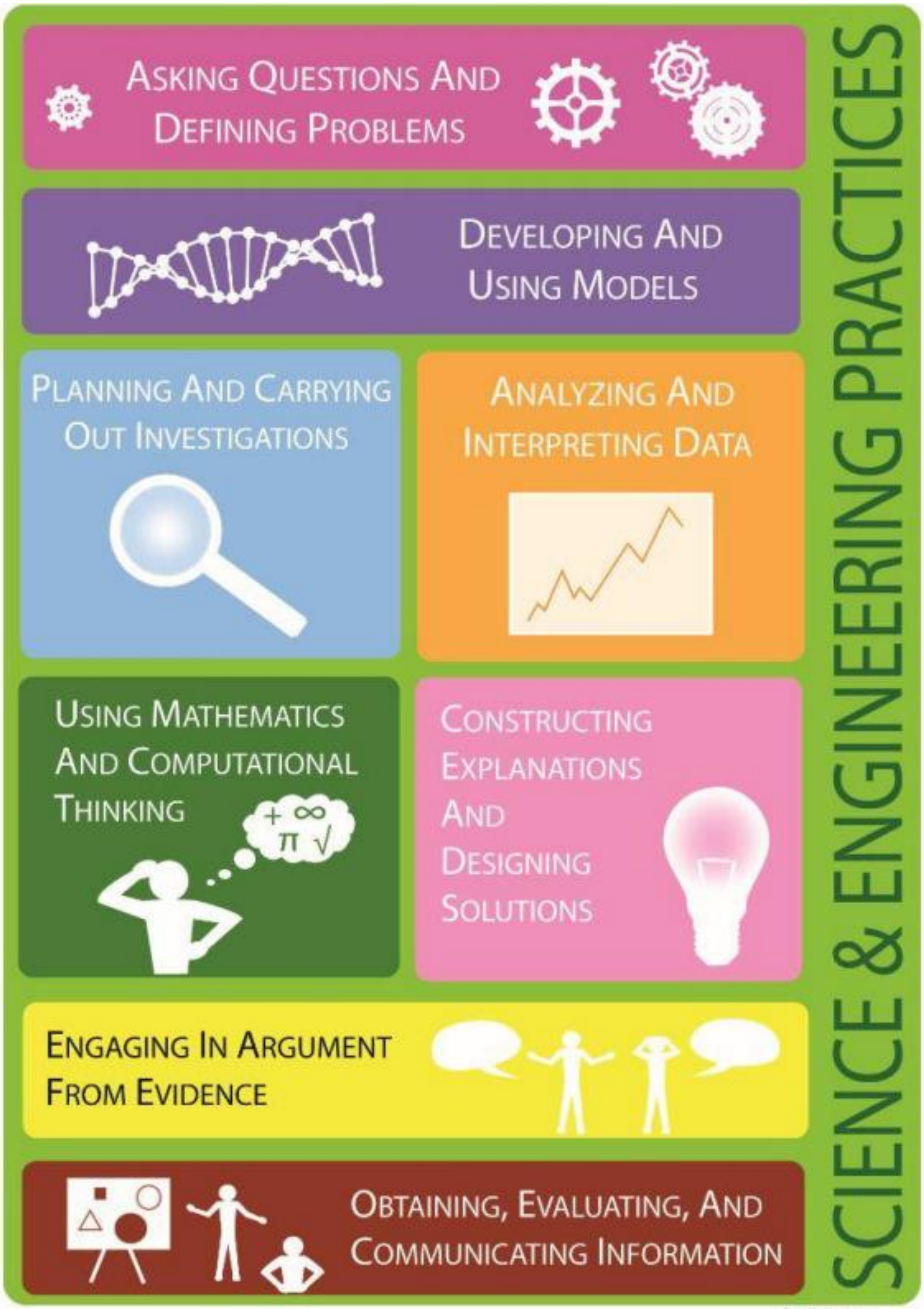
Just as there is science to be found in a puddle or a pit or a simple rock formation, there's science in a soap bubble, in a worm, in the spin of a dancer and in the structure of a bridge. But this thing we call "science" is only there if you're paying attention, asking questions, and imagining possibilities. 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

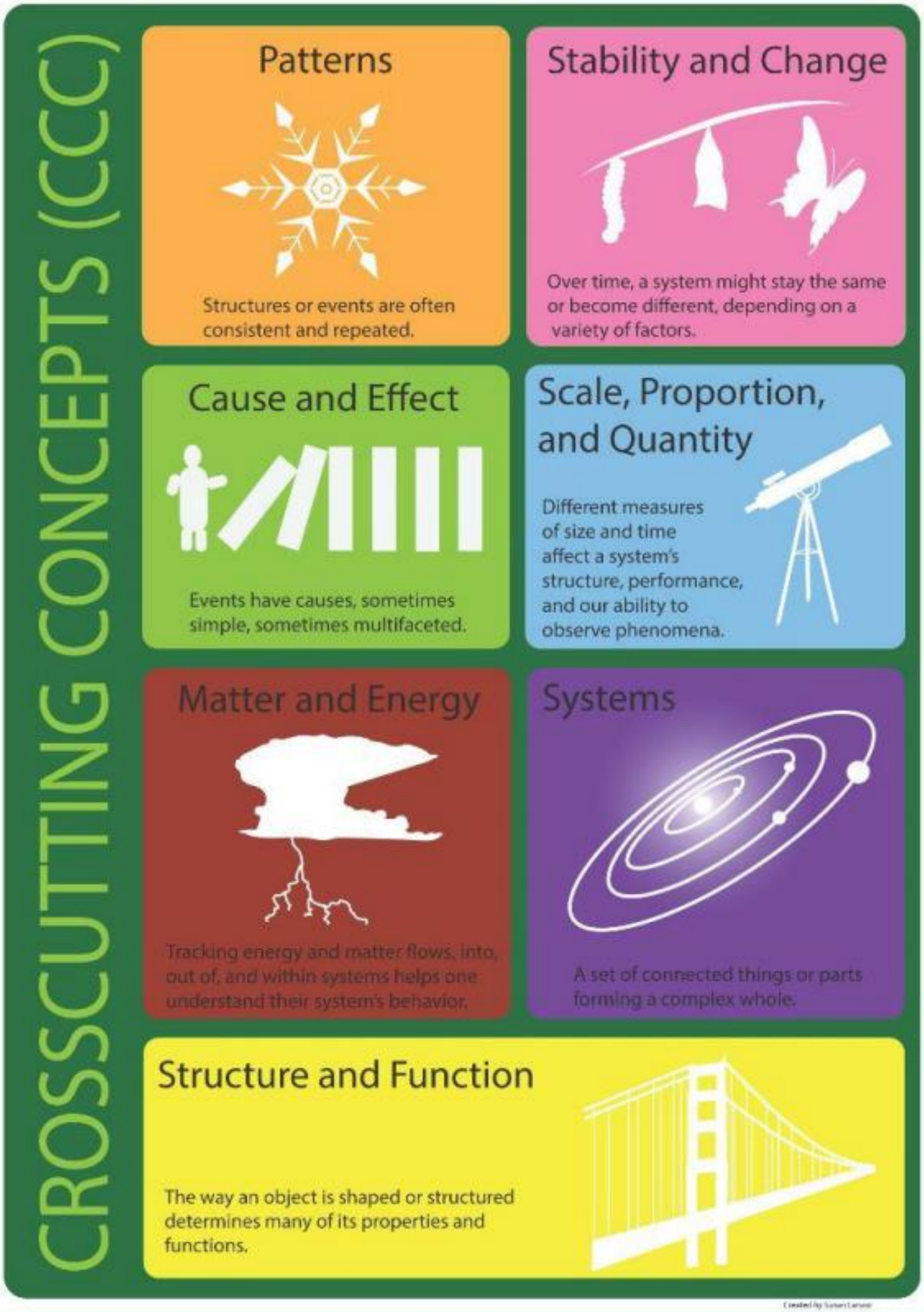
Science and Engineering Practices

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



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 3rd 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/b62

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CHAPTER 1

Standard 1: Physical and Chemical Changes

Chapter Outline

Standard 1: Students will understand that chemical and physical changes occur in matter.

Objective 1: Describe that matter is neither created nor destroyed even though it may undergo change.

1. Compare the total weight of an object to the weight of its individual parts after being disassembled.
2. Compare the weight of a specified quantity of matter before and after it undergoes melting or freezing.
3. Investigate the results of the combined weights of a liquid and a solid after the solid has been dissolved and then recovered from the liquid (e.g., salt dissolved in water then water evaporated).
4. Investigate chemical reactions in which the total weight of the materials before and after reaction is the same (e.g., cream and vinegar before and after mixing, borax and glue mixed to make a new substance).

Objective 2: Evaluate evidence that indicates a physical change has occurred.

1. Identify the physical properties of matter (e.g., hard, soft, solid, liquid, gas).
2. Compare changes in substances that indicate a physical change has occurred.
3. Describe the appearance of a substance before and after a physical change.

Objective 3: Investigate evidence for changes in matter that occur during a chemical reaction.

1. Identify observable evidence of a chemical reaction (e.g., color change, heat or light given off, heat absorbed, gas given off).
2. Explain why the measured weight of a remaining product is less than its reactants when a gas is produced.
3. Cite examples of chemical reactions in daily life.
4. Compare a physical change to a chemical change.
5. Hypothesize how changing one of the materials in a chemical reaction will change the results.

1.1 Changes in matter

What is everything around us made of?

Matter is any **substance** that has mass and takes up space. Everything you can see and touch is made of matter, including you! There is even some matter you cannot see, like air. Matter cannot be created or destroyed, but matter can undergo changes.

States of Matter

What is a solid?

A solid is anything that holds its shape. A solid cannot be a liquid or a gas. These tables and chairs are solid objects. The floor under the tables and chairs is a solid. The glass windows in the background are also solids.

https://flic.kr/p/amFB2D

What is a liquid?

https://flic.kr/p/UWVEZk

A liquid is anything that can fill the shape of its container. As you can see in this image the water curves with the sides of the glass. Water, milk, and blood are all examples of liquids.

What is a gas?

Gas, matter that takes the volume and shape of a container, is all around us. It is the air we breathe, the steam coming off of a boiling pot, and smoke from a fire.

Oxygen is a gas that humans need to breathe and live. Trees use carbon dioxide, another common gas. Gases are necessary for many living things to survive.

Video on gases: http://go.uen.org/b4C

Look at the following pictures of where a gas is being used.

Has your bike ever gotten a flat? You can use a bike pump to push gas into your tire to air it back up.

Balloons are filled with helium gas. You cannot see the gas, but it is there as the balloons are blown up and floating.

A scuba diver has an oxygen tank on his back to breathe underwater.

Visit the following simulation to explore more about states of matter: http://go.uen.org/b4D

Using Properties to Describe Matter

Weight is the measurement of how heavy something is based on the force of gravity. We can use a scale to measure weight. You are most familiar with pounds when you weigh items. In science, a unit we can use to measure weight is grams or kilograms. For example, if you weigh 80 pounds, we could also say you weigh 36 kilograms.

A giant candy bar weighs 200 grams. If you cut the candy bar in half, how much would each half weigh? Each half would weigh 100 grams. What do you think would happen if you melted the chocolate bar? What would it weigh then? Because matter is not created or destroyed, it will still weigh 200 grams even though the solid candy bar is now a liquid. The candy bar has just undergone a **physical change,** a change in state from a solid to a liquid.

Guess how much a 500 gram bottle of root beer weighs if you freeze it in a freezer? You are right again. It is going to weigh 500 grams because it is still the same matter. Freezing or melting does not change the amount of weight in a substance, this is also a physical change, from a liquid to a solid.

Pretend that you ordered a bike online and it gets delivered in three different boxes. The bike pieces in each box weigh 2000 grams (or about 5 pounds). If you stack all of the pieces on scale, how much will they weigh? If you said 6000 grams you are right. Now put the bike together and put it on the scale. What will the bike weigh?

Have you ever made Kool-Aid? To make it, you add water, sugar and the Kool-Aid into a container and mix it together. Does mixing different types of matter change the weight?

What will the total weight of Kool-Aid mixture be after mixing them together?

- 2 gallons of water weighs about 8000 grams.
- 1 cup of sugar weighs 200 grams
- 1 Kool-Aid weighs 5 grams

The total weight after mixing them together is 8205 grams.

When you make Kool-Aid, the sugar and Kool-Aid **dissolve** in the water when it is mixed. When something dissolves in water, it breaks apart into tiny pieces that are too small to see. If you could shrink down super tiny and jump into a cup of Kool-Aid, you would see that the sugar is still sugar and the Kool-Aid is still Kool-Aid. They are just really tiny because they dissolved in water. When substances are mixed together, their individual weights do not change. This is another example of a physical change.

Chemical Reactions

Sometimes when you mix substances together, they react with each other and actually form new substances. This is called a chemical reaction. Even during chemical reactions, the weight of the substances will not change. Have you ever made slime? To make slime, you mix borax (a type of laundry detergent), white glue, and water together. These substances experience a reaction and slime is formed. Even though slime is totally different from borax, glue and water, it will weigh the same amount.

Example:

1 cup of white glue= 250 grams

1 cup of water=236 grams

2 teaspoons of borax= 10 grams

After you mix the 3 ingredients together how much will the slime weigh? ____________________

In Review:

Matter is all around you. Even though matter might look different when it is melted or frozen, when it is mixed together, or when a chemical change occurs, matter is not created or destroyed. It is still the same matter and will still have some of the same properties, like weight.

Think like a scientist

1. What is everything made of?

2. What are some properties we can use to describe matter?

3. What are the similarities and differences of solids, liquids, and gases?

4. Explain why a melted ice cube weighs the same as a solid ice cube.

Please visit the following websites to explore more of the basics of matter.

http://go.uen.org/b4E http://go.uen.org/b4F

1.2 Physical Changes

Is it possible for a substance to be changed, but still remain the same substance?

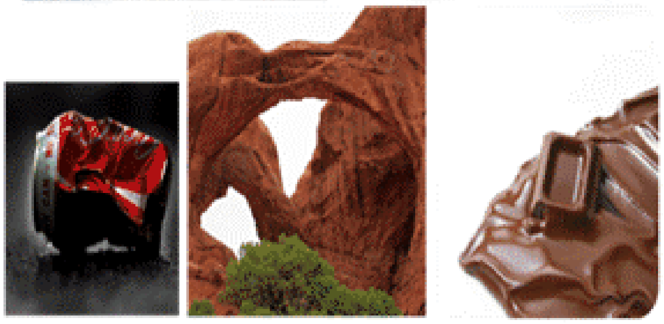
You hit a baseball out of the park and head for first base. You're excited. The score is tied, and now your team has a chance of getting a winning home run. Then, you hear a crash. Oh no! The baseball hit a window in a neighboring house. The glass has a big hole in it, surrounded by a web of cracks. The glass has changed. It's been broken into jagged pieces. But the glass is still glass. Breaking the window is an example of a physical change in matter.

When glass breaks, its physical properties change. Instead of one solid sheet of glass, it now has many pieces.

A **physical change** in matter is a change in physical state. Glass breaking is just one example of a physical change. In each example, matter may look different after the change occurs, but it's still the same substance.

Cutting a log into smaller pieces changes its size and shape, but it's still wood.

Braiding hair changes how the strands are arranged but not their other properties.



Crushing a metal can changes its shape. But the crushed can is still made of metal and has the same properties, such as the ability to conduct heat.

Crisp squares of chocolate melt into a shapeless puddle in the heat. The puddle tastes yummy because it's still chocolate.

Wind-blown sand has worn away this rock to create an arch, but the rock's composition has not changed. The bits of rock worn away by the wind still contain the same minerals as they did when they were part of the large rock.

The shape of an ice cube changes as it melts and becomes a liquid. However, the matter does not change. It is still water. Melting is an example of a change of state. The melted ice cube may be refrozen, so melting is a reversible physical change. Physical changes that involve a change of state can sometimes be reversible. Other changes of state include evaporation (liquid to gas), freezing (liquid to solid), and condensation (gas to liquid).

Let's read a story to try to understand this a bit more.

The Story of Steven

Steven is a boy in first grade at a school in a small village, which gets very hot in summer. He loves to play soccer. After school he often goes over to soccer field to play a game with his friends. They really like having Steven play with them. Even though he is a few years younger, he is very talented and also fun and caring. Steven especially likes Joe and they play well together as a team.

One day after school, Steven thought he would do something nice for his friends, and surprise them with popsicles after they were finished playing. Steven bought 5 ice popsicles, one for himself and one for each of the other kids. He put the popsicles in a bowl and placed some ice blocks around them to keep them cool. Steven then ran off to join the others playing soccer.

After the game, Steven ran back to the bowl to get the popsicles. But he got such a shock when he got there. They were all gone! He was so upset and started to cry. The other kids saw that Steven was upset and ran over to see what was wrong.

“Hey Steven, what’s wrong? Did you hurt yourself while playing?” Joe asked.

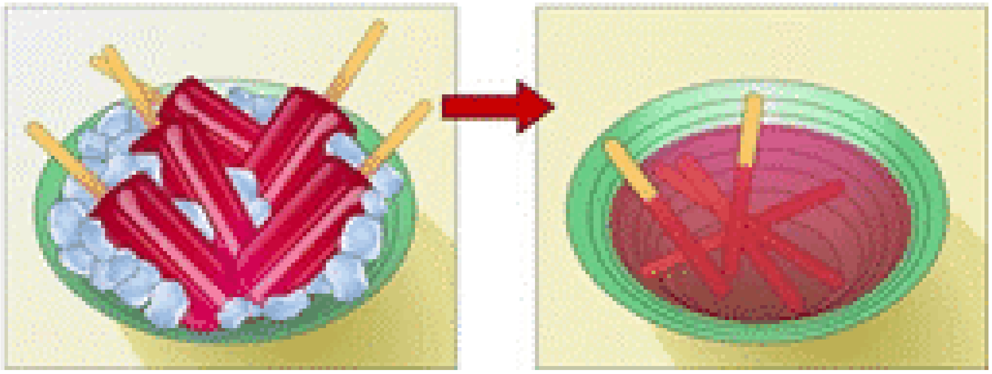
“No, I didn’t. I bought some popsicles for all of you as a surprise and when I came back to get them, they were all gone! I think someone stole and ate them and just left the sticks! Look!” Steven cried out.

“Oh no, don’t cry Steven! It’s not your fault, and no one stole them or ate them either,” Zach said while patting Steven on the back.

“Yes, Steven, actually we learned in class today about what happened to your popsicles,” said Sophie, “and I can explain it to you too. Do you see that your bowl is actually not empty? There is a liquid in it. And it also has a red color, which was the color of your popsicles.”

“Yes, I see that,” answered Steven, “but then how did that happen?”

Tom then answered, “Your popsicles melted from the heat in the air around us. Even if the sun was not so hot, they would have melted! For something to stay frozen it needs to be at a very cold temperature, like in a freezer.”



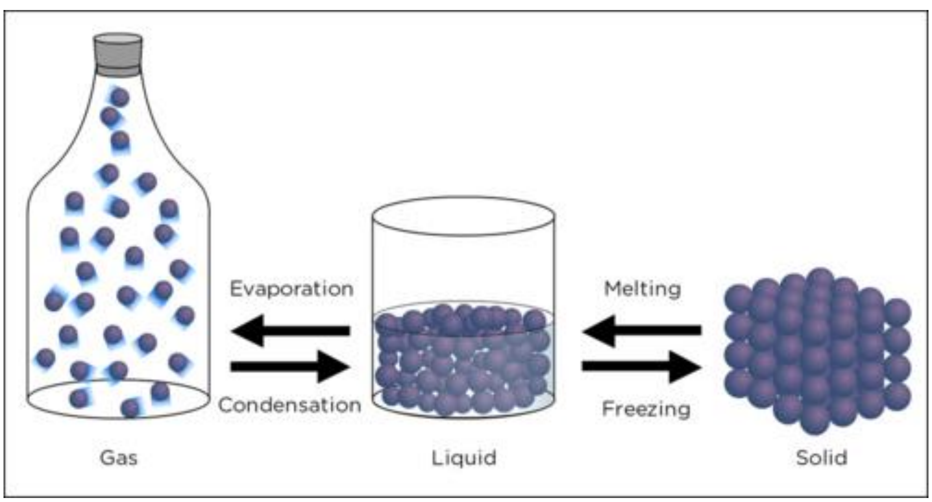
“Yes, melting is when heat causes the solid popsicles to change into a liquid,” Sophie replied, “So no one stole the popsicles, they just melted.”

“Oh ok, I see,” said Steven, “I must be really silly not to know that!”

“No, not at all Steven! We only learned about it today in class!” laughed Zach.

“I know what we should do!” shouted Joe, “Let’s go to the store now. I have some extra change and we can buy some more frozen popsicles!”

They all really liked this idea, especially Steven, who was now laughing. So off they all went, the kids and Steven, and bought some more popsicles and sat under the tree to eat them.



Heating and cooling can cause a change of state

We have seen that melted solids can be solidified again. The process can be reversed, or turned around, by adding or removing **heat.**

Let's review what we have learned from Steven's story.

Here is a summary of the different state changes:

Change of state	**Heating or cooling?**	**We call the process**
Solid to a liquid	Heating	Melting
Liquid to a gas	Heating	Evaporating
Gas to a liquid	Cooling	Condensing
Liquid to a solid	Cooling	Freezing or solidifying

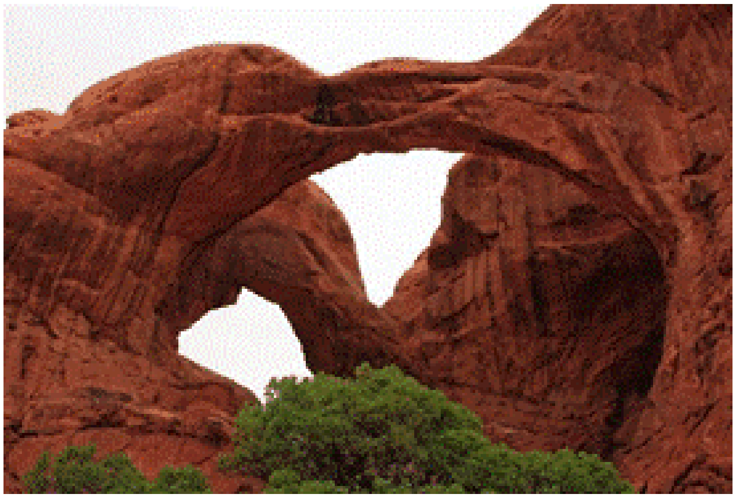
The science of chocolate. http://go.uen.org/b4G

Dissolving

Dissolving – combining matter with a liquid into a solution-is also a reversible physical change. When 3 grams of salt are dissolved in 5 grams of water, the salt is in a solution. The solution will weigh 8 grams, the total weight of the salt and water. The salt and water can be separated again when the water evaporates. After the water evaporates, the salt left behind will still weigh 3 grams.

Because the type of matter remains the same with physical changes, the changes are often easy to undo. For example, braided hair can be unbraided. Melted chocolate can be put in a fridge to harden to a solid. Dissolving sugar in water is also a physical change. How do you think you could undo it?

These stunning rock arches in Utah were carved by wind-blown sand. Repeated beating by the sand wore away the rock, bit by bit, like sandpaper on wood. The bits of



rock worn away by the sand still contain the same minerals or matter as they did when they were part of the large rock. Only the size and shape of the rock have changed, from a single large rock to millions of tiny bits of rock. Changes in size and shape are physical changes in matter.

You can learn more about physical changes and why they occur by watching this video at http://go.uen.org/b4I and this video http://go.uen.org/b4J

Want to buy a car – cheap? Notice there is no specification such as "in good condition" or "needs a little work". The car in the photo is beat up. The body is damaged and the windows are broken.

But this is still a car. It has the components of a car, even though you may not want to buy it in its present condition. You could change that condition by fixing the dents, repainting the car and replacing the broken windows. With those changes, you might have a car worth driving.

But not all physical changes can be reversed. When a piece of wood is ground into sawdust, the change is irreversible since the sawdust cannot be changed into the same piece of wood that it was before. Cutting the grass or pulverizing a rock are other irreversible physical changes. Even though these physical changes cannot be reversed, they are still physical changes because the matter hasn't changed into a new substance.

Q: Can you identify the physical changes in the diagram below?

A: The paper is being cut into smaller pieces, which is changing its size and shape. The ice cubes are turning into a puddle of liquid water because they are melting. The tablet is disappearing in the glass of water because it is dissolving into particles that are too small to see. The lighthouse is becoming coated with ice as ocean spray freezes on its surface. These are examples of matter undergoing a change of state.

Think like a Scientist

1. Is it possible to change something and have it still be made of the same “stuff” it was made of before?

   What do you call this change?

   Is it possible to have the same material as a solid, liquid and gas?

2. How can water be a solid, liquid and gas?

3. What does it mean when we say that matter is changing state?

   How do you know when an object has changed state?

4. Give an example of a physical change that is not reversible.

1.3 Chemical Changes

Communities often use fireworks to celebrate important occasions. Fireworks create awesome sights and sounds!

Do you know what causes the brilliant lights and loud booms of a fireworks display?

The answer: chemical changes.

A **chemical change** occurs whenever matter changes into a brand new substance with different kinds properties. A chemical change is also called a chemical reaction.

Many complex chemical changes occur to produce the explosions of fireworks.

An example of a simpler chemical change is the burning of methane. Methane is the main component of natural gas, which is burned in many home furnaces. During burning, methane combines with oxygen in the air and changes into the gases carbon dioxide and water vapor.

Did you ever make a “volcano” using baking soda and vinegar? What happens when you combine baking soda and vinegar? They produce an eruption of foamy bubbles. This happens because a chemical change occurred. When vinegar and baking soda combine, they form carbon dioxide, a gas that causes the bubbles. It’s the same gas that gives soft drinks their fizz. The materials that combine together in a chemical change are called **reactants**. The new substances that are made are called **products.**

This girl is pouring vinegar on baking soda. This causes a bubbling “volcano”. Not all chemical changes are as dramatic as this “volcano”. Some are slower and less obvious.

These chemical changes all result in the formation of new substances with different chemical properties. Do you think any of these changes could be reversed?

Identifying Chemical Change

Most chemical changes are not as dramatic as exploding fireworks, so how can you tell whether a chemical change has occurred? There are clues. You just need to know what to look for.

A chemical change has probably occurred if bubbles are released, there is an unexpected change of color, or an odor is produced. Other clues include the release of heat or loud noises. Examples of chemical changes that produce these reactions are shown in the figure below.

Evidence of Chemical Change

- Gas bubbles released (not by evaporation)
- An unexpected color change occurs
- An unexpected odor is produced
- A new substance is made
- An unexpected change of temperature
- An unexpected noise is given off

An example of matter changing color is a penny changing from reddish brown to greenish brown as it becomes tarnished. The color change indicates that a new chemical substance has been produced. Copper on the surface of the penny has combined with oxygen in the air to produce a different substance called copper oxide.

Food spoiling is a change that produces an odor. What type of chemical change do you think is happening?

When wood burns, it produces a smoky odor. Burning is a chemical change.
Fireworks produce heat, light, and loud sounds. These are all signs that a chemical change has occurred.

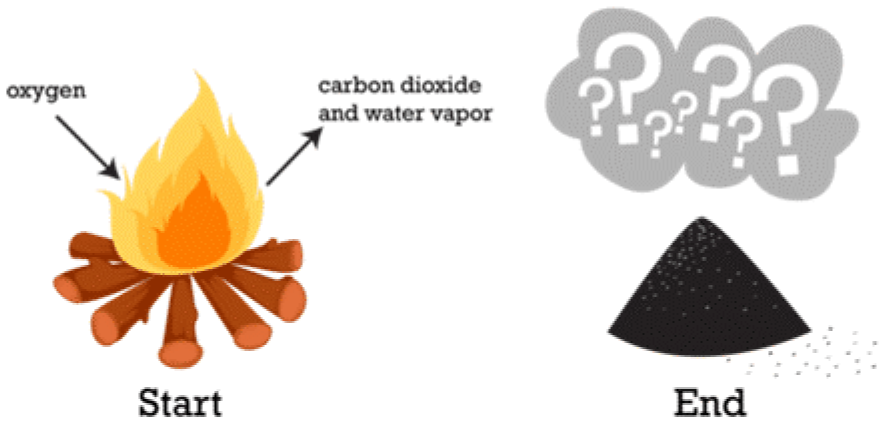
Can Chemical Changes be Reversed?

Because chemical changes produce new substances, they often cannot be undone. For example, you can't change ashes from burning logs back into wood.

Some chemical changes can be reversed, but only by other chemical changes. For example, to undo tarnish on copper pennies, you can place them in vinegar. The acid in the vinegar combines with the copper oxide of the tarnish. This changes the copper oxide back to copper and oxygen, making the pennies reddish brown again. You can try this at home to see how well it works.

Watch the following video and see if you can identify the clues that indicate a chemical reaction has occurred. http://go.uen.org/b8f

Conservation of Mass



If you build a campfire, like the one in the picture of the fire, you start with a large stack of sticks and logs. As the fire burns, the stack slowly shrinks. By the end of the evening, all that's left is a small pile of ashes. What happened to the matter you started with? Was it destroyed by the flames? It may seem that way, but the same amount of matter still exists. The wood changed not only to ashes, but also to carbon dioxide, water vapor, and other gases. The gases floated off into the air, leaving behind the ashes.

Burning is a chemical process. Is mass destroyed when wood burns?

Assume you had measured the mass of the wood before you burned it. Assume you had trapped the gases released by the burning wood and measured their mass and the mass of the ashes. What would you find?

The ashes and gases combined have the same mass as the wood you started with.

This example illustrates the law of conservation of mass. Conservation of mass states that matter cannot be created or destroyed. Even when matter goes through a physical or chemical change, the total mass of matter always remains the same.

For a fun challenge, try to apply the law of conservation of mass to a scene from a Harry Potter film at this link: http://go.uen.org/b4K

1.4 Summary Section

Science Language that Students Should Know and Use

- **Matter:** Anything that has mass and takes up space
- **Dissolve:** When substances break into tiny pieces in a solvent like water.
- **Liquid:** matter that has a definite volume but takes the shape of its container.
- **Solid:** matter with a definite shape and volume.
- **Substance:** a specific kind of matter with similar characteristics.
- **Weight:** the measure of the force of gravity on matter
- **Gas:** matter that takes the shape and volume of its container
- **Physical change:** a change in state from one form to another
- **Chemical change:** when substances react with each other to create a new substance
- **Product:** something that is made, for example, a new substance from a chemical change.
- **Reactants:** the substances mixed together in a chemical reaction
- **Heat:** measurement of the amount of energy

Summary

- Physical changes are changes in the physical form of matter but not in the chemical makeup of matter. An example of a physical change is glass breaking.
- Chemical changes are changes in the makeup and chemical properties of matter. An example of a chemical change is wood burning.
- Matter cannot be created or destroyed even when it changes. This is the law of conservation of mass.
- A chemical change occurs when matter changes into an entirely different substance with different chemical properties. Burning is an example of a chemical change.
- Signs of chemical change include the release of bubbles, a change of color, production of an odor, release of heat and light, and production of loud sounds.
- Because chemical changes result in different substances, they often cannot be undone. Some chemical changes can be reversed, but only by other chemical changes.

Think Like a Scientist

1. What is a physical change in matter?

2. What happens during a chemical change in matter?

3. State the law of conservation of mass.

4. When a plant grows, its mass increases over time. Does this mean that new matter is created?

Why or why not?

5. Butter melts when you heat it in a pan on the stove. Is this a chemical change or a physical change?

How can you tell?

6. Compare and contrast physical and chemical changes in matter. Give an example of each type of change.

Resources

- See Activity from Sci-Ber Text, “Changes in Matter” – It’s the Law. http://go.uen.org/b4L
- Discover chemical and physical changes to the copper in the Statue of Liberty over time on this site. http://go.uen.org/b4M

CHAPTER 2

Standard 2: Earth's Surface

Chapter Outline

Standard 2: Students will understand that volcanoes, earthquakes, uplift, weathering, and erosion reshape Earth's surface.

Objective 1: Describe how weathering and erosion change Earth's surface.

1. Identify the objects, processes, or forces that weather and erode Earth's surface (e.g., ice, plants, animals, abrasion, gravity, water, wind).
2. Describe how geological features (e.g., valleys, canyons, buttes, arches) are changed through erosion (e.g., waves, wind, glaciers, gravity, running water).
3. Explain the relationship between time and specific geological changes.

Objective 2: Explain how volcanoes, earthquakes, and uplift affect Earth's surface.

1. Identify specific geological features created by volcanoes, earthquakes, and uplift.
2. Give examples of different landforms that are formed by volcanoes, earthquakes, and uplift (e.g., mountains, valleys, new lakes, canyons).
3. Describe how volcanoes, earthquakes, and uplift change landforms.
4. Cite examples of how technology is used to predict volcanoes and earthquakes.

Objective 3: Relate the building up and breaking down of Earth's surface over time to the various physical land features.

1. Explain how layers of exposed rock, such as those observed in the Grand Canyon, are the result of natural processes acting over long periods of time.
2. Describe the role of deposition in the processes that change Earth's surface.
3. Use a timeline to identify the sequence and time required for building and breaking down of geologic features on Earth.
4. Describe and justify how the surface of Earth would appear if there were no mountain uplift, weathering, or erosion.

2.1 Weathering and Erosion

Do mountains look the same as they did 100, 1000, or even 1,000,000 years ago?

Do you like to be absolutely certain about things?

One thing you can be certain of is that the Earth's surface is always changing. Take a look outside. Every landform you see at one time used to be something else. A mountainside may have been at the bottom of a sea. A canyon may have formed from a plateau. A stream may have changed its course. The sand between your toes may have come from rock, carried from the top of a mountain by a glacier and dumped in a riverbed.

Some changes happen quickly, while other changes take thousands, or even millions, of years. Whether the changes happen in an instant or over thousands of years, you can count on the fact that Earth's surface is always changing.

Weathering—the breaking down of earth's materials into smaller pieces—is a process that takes a very long time. Weathering breaks large boulders into rocks, rocks into pebbles, and pebbles into soil or sand. These pieces of rock are called sediments.

Sediments are different sizes of rock particles. Boulders are sediments; so is gravel. Silt and clay are just smaller sediments. The small rock you pick up on the playground may once have been part of a large boulder on the mountain.

You cannot watch for millions of years as mountains are built, or as those same mountains gradually wear away, but you can see evidence a change has occurred.

Powerful forces of weathering include wind, water, temperature, chemical changes, and living organisms.

The following are types of weathering:

- Temperature: Water seeps into small cracks in rock. When the temperature falls below freezing, water expands as it becomes ice. Freezing and thawing make the cracks bigger until some of the rock breaks away.
- Living Organisms: The roots of plants can grow in cracks. As the roots grow larger, they split the rocks.
- Water: Water can help break rock into very small pieces. Rocks carried down a swiftly moving river weather as they bump against each other.
- Wind: Particles carried by wind smooth and polish rocks.
- Chemical Change: Weathering may cause minerals on the Earth's surface to change form. The new minerals that form are stable on Earth's surface.

Animations of different types of weathering processes can be found here: http://go.uen.org/b4N

There are two types of weathering: Physical and Chemical

Physical weathering, also called mechanical weathering, break rocks into smaller pieces. Rocks change physically without changing their composition. Smaller pieces of rock have the exact same minerals as the original rock. These are some forms of physical weathering:

- Ice Wedging: main form of physical weathering in any climate that has freezing temperatures.
    - Breaks apart large amounts of rock.
    - Common in Earth's polar-regions and at higher elevations.
- Abrasion: one rock bumps against another rock; smooths sharp or jagged rocks.
    - Caused by gravity as a rock tumbles down a mountainside or cliff.
    - Caused by moving water as rocks bump against each other.

    - Caused by winds carrying pieces of sand which can sandblast surfaces.
    - Caused by ice in glaciers, which carry bits and pieces of rock. Rocks embedded at the bottom of the glacier scrape against the rocks below.
- Organisms: plants and animals can cause physical weathering.
    - Plant roots grow larger, wedging open cracks.
    - Burrowing animals can break apart rock as they dig for food or make living spaces for themselves.
- Humans: digging or blasting into rock to build homes, roads, and subways or quarrying stone.

Chemical weathering and physical weathering are different. In chemical weathering, minerals in the rock change their chemical makeup. They become a different type of mineral or even a different type of rock. Chemical weathering is the result of chemical reactions that change the rock. Think about what you know about chemical changes.

Most minerals form deep within Earth's crust. Deep inside, temperature and pressure are higher than at Earth's surface. Minerals that were stable deep in the crust are not stable under surface conditions. That's why chemical weathering happens. Minerals formed by high temperature and pressure change into minerals that are stable at the surface.

Chemical Weathering

There are many types of chemical weathering. Remember, water is an agent of physical (mechanical) weathering. Water is also an agent of chemical weathering. That makes water a double agent!

Carbon dioxide and oxygen are also agents of chemical weathering. As rock is broken down by oxygen and carbon dioxide, new chemical compounds form. An examples of chemical weathering is rusting metal.

Several years ago the copper dome on the Utah State Capitol building was replaced. When it was first changed, it was a bright copper color. Now it is a dull green! Why? The copper color changed through chemical weathering. This is an example of a chemical change.

Water is an amazing molecule. Other minerals change by adding water to their structure. Water reacts with the minerals in the rocks to create new substances.

Carbon Dioxide

Carbon dioxide (CO_2) combines with water when it rains. This creates a weak acid, called carbonic acid. This happens so often that carbonic acid is commonly found in nature. Carbonic acid slowly dissolves rock. It eats away at sculptures and monuments.

While this is normal, more acids are created when we add pollutants to the air. Any time we burn fossil fuels, it adds nitrous oxide to the air. When we burn coal rich in sulfur, it adds sulfur dioxide to the air. As nitrous oxide and sulfur dioxide react with water, they form nitric acid and sulfuric acid. These are the two main components of acid rain. Acid rain speeds up chemical weathering.

Oxygen

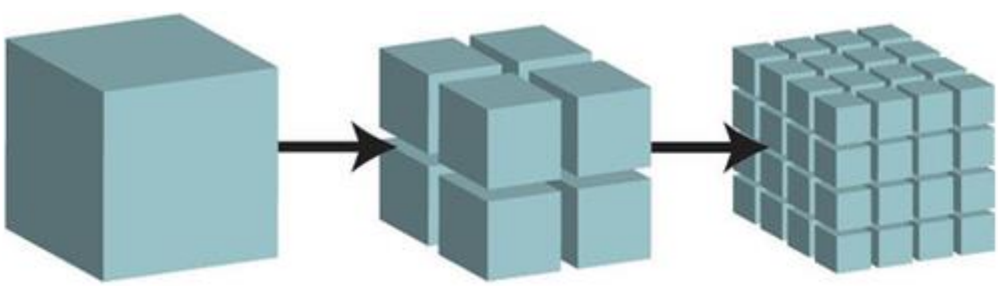
Oxygen reacts with elements at the earth's surface in a process called oxidation. You are probably familiar with the rust that forms when iron reacts with oxygen. Many minerals are rich in iron. Red rocks are full of iron oxides. As iron changes into iron oxide, iron oxides makes the red color in soil commonly found in Southern Utah.

Plants and Animals

Plants and animals also cause chemical weathering. As plant roots take in nutrients, they remove elements from the minerals. This causes a chemical change in the rock.

Physical weathering increases the rate of chemical weathering. As rock breaks into smaller pieces, the surface area of the pieces increases. With more surface exposed, there are more places for chemical weathering to occur.

Let's say you want to make hot chocolate on a cold day. It would be hard to get a big chunk of chocolate to dissolve in a cup of milk or hot water. Maybe you could make hot chocolate from smaller pieces like chocolate chips, but it is even easier to add chocolate powder to your milk. This is because the smaller the pieces are, the more surface area they have. Smaller pieces dissolve more easily.



As rock breaks into smaller pieces, overall surface area increases.

Erosion

Erosion—the movement of earth materials from one place to another—also contributes to our changing landscape.

Water is the most powerful erosional force on earth. Rain carries soil away as it washes over the land, leaving behind gullies, valleys, and canyons. The paths of some rivers have changed as water **erodes** the banks. Rivers and streams have formed many natural wonders including **arches**—curved rock formations, which are formed by a combination of erosional forces.

Ice, rain, and wind continue to weather the arches found in Utah's Arches National Park. One well-known arch is Delicate Arch, shown in the photo below. Someday, erosion will cause the arches to collapse, but until that time, we can enjoy their spectacular beauty.

Running water from streams and rivers can form a **butte**—an isolated hill with steep, even sides, and a flat top. Hard rock on the top of the butte protects the softer rock below from erosion. Mesas are much larger landforms similar to buttes that form in the same way.

The photo below shows a large mesa near Price, Utah.

Water erosion from rivers and streams can cut through layers of rock to form deep canyons, such as the Grand Canyon and canyons in Canyonlands National Park.

Wind erosion moves soil in the air from place to place on Earth's surface. This is especially true in arid climates like Utah's climate. When there is soil in the air, gravity pulls the soil out of the air and deposits it somewhere else. When the wind blows away smaller, finer particles, this leaves behind a desert "pavement" with rocky, pebbled surfaces. Particles moved by the wind hit other landforms, weathering their surfaces by abrasion.

Glaciers—slow-moving, large masses of snow, ice, rocks and dirt--form in cold regions on Earth. Here snowfall does not melt and oftentimes causes erosion. The weight of the snow builds up over time and is compacted by its own weight. After thousands of years, it turns to ice and becomes very heavy.

Gravity can pull the glacier slowly down a mountain slope. As it inches along, the glacier erodes the surface beneath. Valleys form as boulders and rock carried in the ice scrape the rock beneath the glacier. Glaciers also polish and scratch the land beneath them as they travel across its surface. You can see these features when glaciers melt and you walk across smooth rock surfaces at the bottoms of canyons. The next image shows evidence of former glaciers in Utah; a U-shaped canyon in the Wasatch Mountains.

Rivers may form canyons with steep walls, but those canyons have a V-shape, like the lower section of Big Cottonwood Canyon on the east side of the Salt Lake Valley.

The glacier in the last image is changing the landscape. Glaciers erode and deposit landforms that tell us stories about Earth's history. They show the direction a glacier flowed and how far it traveled. Glaciers create fantastic and unique features in mountain areas. What evidence of past glaciers do you see in valleys near you?

A horn, like the one in the next picture, is a sharp peak left behind when glaciers erode all sides of a mountain.

Gravity causes erosion because of weathering. Weathered material falls from a cliff because there is nothing to hold it in place. Rocks falling to the base of a cliff create a slope. Landslides occur when falling rocks hit other rocks causing them to fall. When there is high precipitation, mud will form and contribute to the cause of the landslide.

Multiple landslides created the mass weathering seen on the cliff in the last picture.

Humans may cause erosion when they disturb the natural landscape in agricultural and urban areas.

Agricultural Erosion

- Agriculture is the largest contributor to soil pollution caused by humans.
- Farming removes native plants, and plowing land loosens up nutrient-rich dirt that may be blown away.
- Animals grazing on farmland can expose dirt and pull up plants.

Urban Factors

- Construction and urban development greatly reduces the amount of water and rainfall that enters the ground, which results in erosion nearby. This happens because soil is covered with pavement and other surfaces.

- Mountain biking and hiking can lead to erosion, since these activities disturb the landscape in ways that may prevent plant growth.

Watch short videos on chemical and physical (mechanical) weathering: http://go.uen.org/b4O http://go.uen.org/brP

2.2 Earthquakes and Volcanoes

What causes volcanoes, earthquakes, and uplift?

Volcanoes

Volcanoes are openings in the Earth's crust that allow hot, melted rock (magma), ash, and gases to erupt outward. Volcanoes can change the Earth's surface in a short period of time. More than half of Earth's surface is made up of volcanic rock. Volcanoes are evidence that we live on an active, changing planet.

Do you know how a volcano forms? Most form along cracks in the earth's crust and reach far below the surface where temperatures are hot enough to melt rock.

You would want to watch a volcanic eruption from a great distance, since many are violent and spit out huge quantities of lava, gas, rocks, and ash. Other eruptions pour out rivers of lava but cause little damage. Volcanoes can erupt underwater, forming huge ranges of volcanic mountains on the ocean floor.

Volcanic Stages

- Active volcanoes are currently erupting, or showing signs they will erupt soon.
- Dormant volcanoes have no current activity, but have erupted recently.
- Extinct volcanoes have had no activity for a long time, and will probably not erupt again.

Different Types of Volcanoes

Scientists who study volcanoes are called Volcanologists. These scientists have sorted the different types of volcanoes into three categories: composite, shield and cinder cones.

Composite volcanoes, also called stratovolcanoes, have steep sides that meet at a crater at the top of the structure. Their eruptions are large and explosive. Examples of this type of volcano are Mt. St. Helens in the United States and Mt. Vesuvius in Italy.

Shield volcanoes are large, flat structures. The eruptions of these volcanoes are not explosive. An example of a shield volcano is Mauna Loa on the Big Island of Hawaii.

Cinder cone volcanoes are small, steep, and cone-shaped. Cinder cones usually erupt only once and shoots out pumice, a light, airy igneous rock.

Volcanoes are useful because their eruptions enrich soil. The ash from volcanoes is rich in minerals, especially nitrogen. Nitrogen, found in many fertilizers, is good for farming.

However, volcanic eruptions can injure people and damage property. Volcanologists try to predict when they will erupt. They use gas detectors, tilt meters, and seismographs to measure the movement of Earth. If unusual gases are present or Earth is shaking, volcanic eruptions may follow.

For more information about volcanoes, follow the link below:

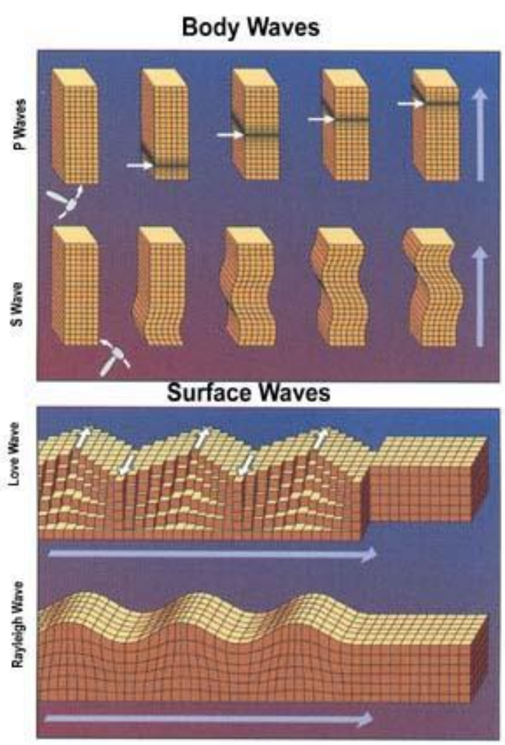
http://go.uen.org/aZm

Earthquakes

Earthquakes are waves of energy that pass through Earth caused by a sudden shift of the crustal plates along fault lines. Earthquakes can cause sudden changes that alter Earth's landscape dramatically.

You know you are in an earthquake if the ground starts to shake. Tremendous forces under Earth's surface build up pressure, which is released in waves along a fault. Imagine you are bending a Popsicle stick. When the pressure is great enough, the stick snaps in two. The energy released by the snap produces waves that travel through the stick to your hands.

The fault, however, doesn't come apart like the stick. Portions of Earth's crust slide past each other, creating waves. Some of the waves are surface waves. Other waves, called body waves, travel through the Earth's interior. In an earthquake, body waves are responsible for the sharp jolts. Surface waves are responsible for the rolling motions that cause most of the damage.



Visit the following website to explore a simulation all about waves and their movement.

http://go.uen.org/b4Q

Earthquakes can create landforms on the Earth's surface. Mountains can form during an earthquake as the valley rocks slide down and the mountain rocks move up.

During an earthquake, a fault may slip deep underground and leave no evidence on the surface that an earthquake has occurred. Earthquakes in the ocean may cause a tsunami, a large ocean wave.

Scientists use technology to measure and record the strength and locations of earthquakes. They measure earthquakes in various ways, including from 1-10 on the Richter scale. Any earthquake measuring a 6 or higher is a very significant earthquake. Scientists try to predict when and where earthquakes will occur because earthquakes cause loss of life and property damage every year all over the world.

Uplift

Uplift is the upward movement of Earth's crust. It occurs when part of Earth's surface rises above the surrounding land by great forces of heat and pressure deep within the Earth. Uplift formed the Colorado Plateau, creating nearly all the spectacular variety of Canyon County in Southern Utah.

Imagine you are in a raft floating down the Colorado River through the Grand Canyon. One of the first things you will notice are the steep canyon walls on both sides of the river. You may ask, why are the walls so steep? Why do you see different layers of rock exposed?

Millions of years ago, much of the western United States was covered by a shallow sea. The area of the Grand Canyon was once flat, marshy land under the sea. Scientists have determined many seas have come and gone, leaving different layers of rock formed during various time periods. Some of the layers contain fossils of sea creatures now exposed in the walls of the canyon.

Uplift formed a high, flat plateau. As the land rose, water cut a channel down through the plateau, creating a deep canyon. The oldest rocks at the base of the Grand Canyon are about 2 billion years old. Each layer above the base was formed under different conditions.

Different types of sedimentary rocks weather differently. In the photo of the Grand Canyon below, you can see some layers create cliffs. The cliffs are formed by hard rocks that do not weather easily. Hard rock layers that resist weathering and erosion form the top of the canyon. Softer layers form slopes made from rocks that weather more easily.

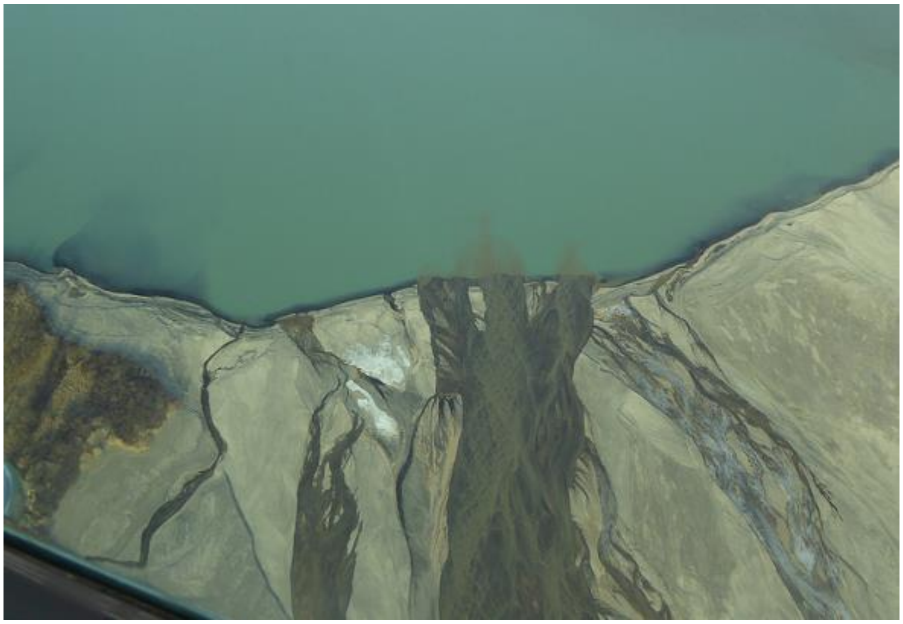
It took thousands of years for erosion to uncover the rocks of the Grand Canyon. In your lifetime you won't notice many changes because the changes happen so slowly.

Thousands of years from now, however, the Grand Canyon will look different than it does today.

Watch a short video about mountain building: http://go.uen.org/b0h

2.3 Deposition

How does deposition change the Earth's surface?



Deposition creates many interesting landforms including beaches, sandbars, deltas, and sand dunes. **Deposition** occurs when weathered rocks, soil, and sediments are moved by erosion to a new location and left there.

Deposition happens when wind, water, or glaciers carrying sediments are no longer strong enough to move the sediments, and they drop to the earth.

Rivers and streams fill with melting snow in the springtime. The water rises and moves quickly down from the mountains into the valleys. When the streams spread out across the land and into other bodies of water, they become less powerful; this is when deposition is likely to happen.

Deposits form at bends in a river, as well as in places where rivers empty water into lakes, seas, and oceans. Rivers, like the Colorado River, carry enormous loads of sand and soil that is picked up from erosional processes. In the spring, the water of the Colorado River looks like chocolate milk because of all the sediment in the water.

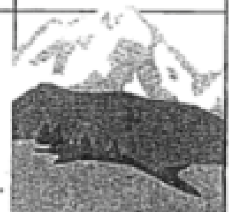
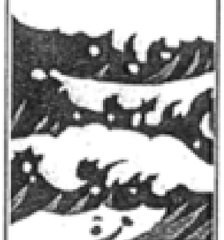
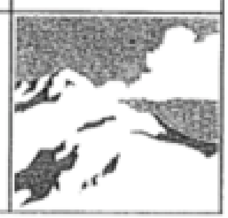
The word deposition has the same root as the word deposit. Think of it this way: when you earn some money and want to save it for a special purchase, you may deposit it the bank. The money is still the same, and it is still yours, but you have put it in a different place in order to save it.

Deposition works the same way. Wind and water move sediments and deposit them in a new location. As these sediments build up, you can easily see the results of deposition.

In Southeastern Utah, erosion has created stream meanders into the twists and turns of the San Juan River. Sediments from one part of the bank have been deposited in new landforms as the river twisted and turned through the landscape. The twists and turns are called goose necks. The previous satellite image shows the amazing path the river has cut.

Animations of deposition can be found here: http://go.uen.org/b4R

Waves transport sediments along a coast and create beaches through deposition. Waves have higher energy during winter than in summer, so sand is pushed onto shore in the summer, and pulled offshore during winter. People try to control the processes of erosion and deposition by building groins, breakwaters, and seawalls.

Geologic Era	Time (In Million Years Ago)	Geologic Events	
Cenozoic	0 to 65 MYA	Thick glaciers in much of the world. Rocky Mountains, Alps, Andes, and Himalayas form. Glaciers cover North America.	
Mesozoic	65 MYA to 248 MYA	Widespread volcanic activity Age of the dinosaurs American and Europe/African continents move apart.	
Paleozoic	248 MYA to 544 MYA	Age of Ocean life Appalacchian Mountains begin to form. Warm, shallow seas cover much of North America. Two ancient continents are found near the equator.	
Precambrian	544 MYA to 4,600 MYA	Earth's first ice age occurs. First sedimentary rocks form. Oceans form. Earth forms.	

Scientists use a variety of timelines to identify the sequence of events and the time required to build up and break down the geologic feature on Earth.

When you look at the timeline, notice how old the earth is and how remarkable all of the changes to its surface have been.

Volcanoes, uplift, and earthquakes build up new landforms. Weathering and erosion wear those landforms away.

Changes like weathering, erosion, and uplift take thousands, or millions of years. Without weathering and erosion, the rock you find on the playground today would still be on the top of the mountain, a tiny piece of the boulder from which it came. Without volcanoes, uplift, and earthquakes, the surface of the Earth would look the same as when it formed, a smooth sphere. Earth's surface is constantly changing.

We live on an incredible, changing planet. What we observe in our landscape today will be vastly different in 10,000 years. In the future, people will look back and wonder what the landscape looked like in our day. We won't be there to tell them, but the evidence in rocks, soil, and geologic features will reveal what we see today.

2.4 Summary Section

Science Language Students Should Know and Use

- Arch: curved rock formation, formed by a combination of erosional forces.
- Butte: an isolated hill with steep, even sides, and a flat top.
- Deposition: the dropping of sand or rock carried by wind, water, or ice, which creates the layering of earth materials by wind, water, or glaciers.
- Earthquake: energy waves passing through Earth caused by a sudden shift of Earth's crust along **faults**.
- Erode: to wear away.
- Erosion: the movement of earth materials from one place to another.
- Fault: a crack in Earth's crust that allows the crust to slip.
- Geological**:** relating to the structure of Earth and the changes that have taken place over the years.
- Glacier: slow-moving, large mass of snow, ice, rocks and dirt.
- Uplift: upward movement of Earth's crust.
- Volcano: opening in the Earth's crust that allows hot, melted rock, ash, and gases to erupt outward.
- Weathering: the breaking down of earth's materials into smaller pieces.

Think like a Scientist

1. What are the geological processes that change Earth's surface over time?

2. Describe how the Grand Canyon was formed.

3. What is the difference between weathering and erosion?

4. What are the types of weathering?

5. How do volcanic eruptions change the landscape?

6. What is deposition?

7. How do seismic waves and faults combine to cause earthquakes?

8. Compare and contrast what the Earth looks like now to what it would look like if there was no mountain uplift, weathering, or erosion.

Use the following links to further explore these concepts:

http://go.uen.org/b4S http://go.uen.org/b4T

http://go.uen.org/b4U

CHAPTER 3

Standard 3: Magnetism

Chapter Outline

Standard 3: **Students will understand that magnetism can be observed when there is an interaction between the magnetic fields of magnets or between a magnet and materials made of iron.**

Objective 1: Investigate and compare the behavior of magnetism using magnets.

1. Compare various types of magnets (e.g., permanent, temporary, and natural magnets) and their abilities to push or pull iron objects they are not touching.
2. Investigate how magnets will both attract and repel other magnets.
3. Compare permanent magnets and electromagnets.
4. Research and report the use of magnets that is supported by sound scientific principles.

Objective 2: Describe how the magnetic field of Earth and a magnet are similar.

1. Compare the magnetic fields of various types of magnets (e.g., bar magnet, disk magnet, horseshoe magnet).
2. Compare Earth's magnetic field to the magnetic field of a magnet.
3. Construct a compass and explain how it works.
4. Investigate the effects of magnets on the needle of a compass and compare this to the effects of Earth's magnetic field on the needle of a compass (e.g., magnets affect the needle only at close distances, Earth's magnetic field affects the needle at great distances, magnets close to a compass overrides the Earth's effect on the needle).

3.1 Magnetism

What has the ability to push or pull objects without touching them?

Magnets

There is an old folktale about a Greek shepherd named Mangus. The tale tells about a time Mangus climbed a mountain to rescue a lamb and he found that the iron nails in his sandals stuck to pieces of a particular rock. This type of rock attracts iron and is called lodestone. Lodestone is a **natural magnet** – a mineral made magnetic by Earth's magnetic field. The magnetic field is the area around a magnet where the magnet has power to attract magnetic material.

In 1269 A.D., a French scientist, Peter Peregrinus of Maricourt, wrote a letter describing the properties of lodestones. He discovered that there were two points on opposite sides of the lodestone that he called the North Pole and the South Pole. He found that small bits of iron were attracted most strongly at these points. He also found that a small piece of iron shaped like a needle would stand straight up at those two points.

When he placed the lodestone in a small wooden bowl floating in a larger container of water, the north pole of the lodestone turned the dish around until its north pole was pointing north.

He discovered that “the north pole of one lodestone attracts the south pole of another, while the south pole attracts the north.” On the other hand, he found that two north poles or two south poles repelled – to push objects apart - each other. When he cut lodestones into smaller pieces, he found that each smaller piece had both a north and south pole.

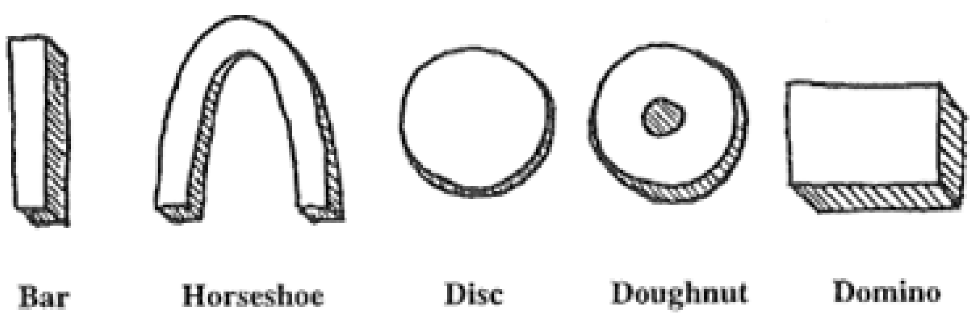
Check out this video to make the same kind of compass at home: http://go.uen.org/b4V

Today, we are able to make objects that have the same properties as lodestones. They are called magnets.

Permanent Magnets

A **permanent magnet** is an object that keeps its magnetism after it has been magnetized. Magnets are commonly made of iron and nickel. Strong permanent magnets can be made by combining other elements with iron, like neodymium and boron or aluminum, nickel and cobalt.

Permanent magnets are often named for their shape. Common shapes include: bar, horseshoe, disc, doughnut, and domino magnets. In disk or domino-shaped magnets, the flat surfaces are the poles. A horseshoe magnet is simply a bar magnet that has been bent into a “U” shape. When a magnet is broken or cut, each piece has a north and south magnetic pole. No matter what shape a magnet may be, it has a north and south pole.



Watch this video demonstration of the awesome force of a large “neodymium magnet”

Warning: Do not try this at home! http://go.uen.org/b4W

A Compass

A **compass** is an instrument used to determine geographic direction on Earth. It is made from a free swinging magnetized needle that points north and south. A bar magnet with a string tied to the middle will rotate until one end points north and the other end points south.

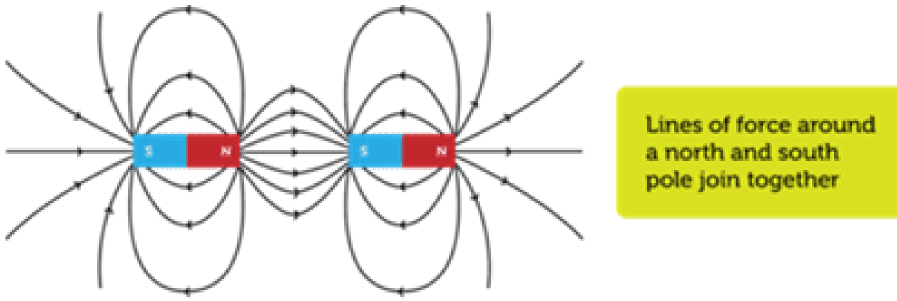
Magnets exert forces on other objects without touching them. There is something in the space around a magnet that cannot be seen. It is called a magnetic field.

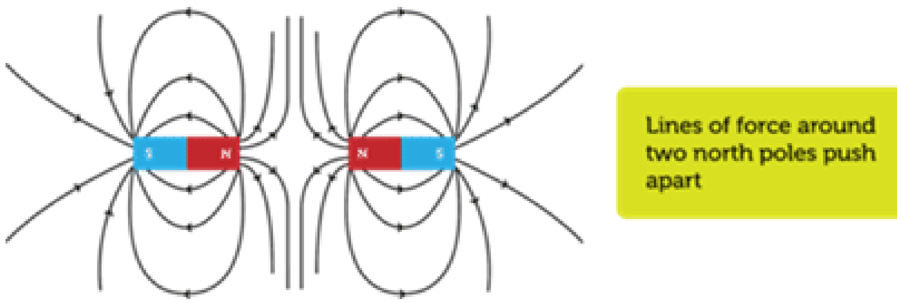
We think of the magnetic field going out from the north pole of a magnet, arching around and returning to the magnet at its south pole. The direction of the magnetic field at any location near a magnet is the direction in which a compass needle points at that location. A compass can be used to show the direction of the magnetic field at points in space around a magnet.

The following picture shows how the magnetic field of a bar magnet can be traced with the aid of a compass. Iron filings are also used to show the pattern of the magnetic field. If you shake iron filings around a bar magnet, they will line up to the magnetic field.

When two magnets are brought close together, their magnetic fields interact. The lines of force of the north and south poles attract each other just as those of the two north poles repel each other. The animations at the following URL show how magnetic field lines change as two or more magnets move in relation to each other.

Explore the following website to explore more about magnets. http://go.uen.org/b4X





Temporary and Electromagnets

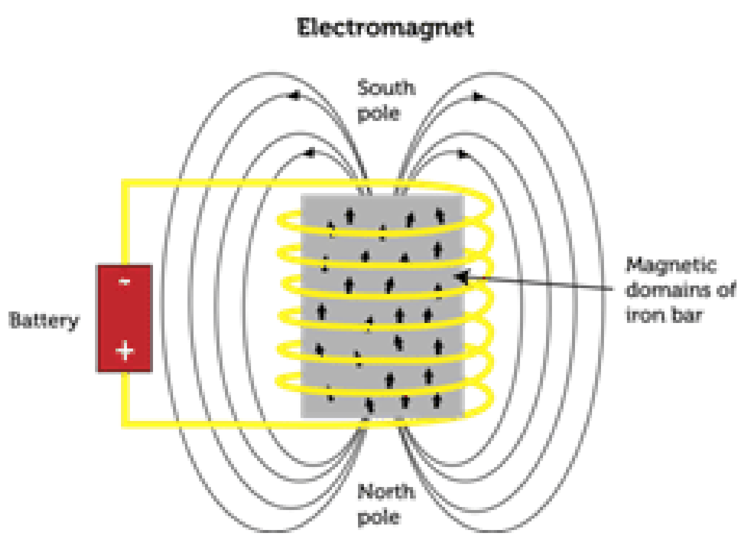
You can make a **temporary magnet** – a magnet that does not keep its magnetism - from a steel nail by taking a magnet and rubbing the nail in the same direction several times. Once the nail is magnetized it will pick up small nails and pins. If it doesn't you may need to rub the needle more. To demagnetize these types of magnets, you can hit them or heat them.

Another example of a temporary magnet is an **electromagnet** – a magnet that can be turned on or off and is made by sending electricity through metal. An electromagnet uses electricity to produce a **magnetic force**.

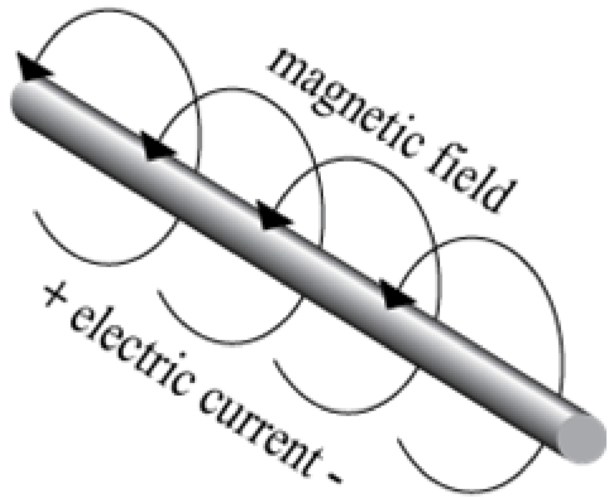
In 1820, Hans Christian Orsted discovered that an electric current in a wire was able to deflect a compass needle. This means that an electric current can create a magnetic field. It was later found that materials like iron can make the magnetic field from an electric current much stronger.

In the picture, the crane is holding a big, round magnet that has picked up metal car parts in a junkyard. The parts practically leap up to the magnet because it's so strong. That's because it's an electromagnet.

An electromagnet is made from a coil of wire wrapped around a bar of iron or other magnetic material. The magnetic field of the coil of wire magnetizes the iron bar by aligning its magnetic domains. You can see this in the Figure. You can learn how to make an electromagnet at this URL: http://go.uen.org/b4Y



The strength of this temporary magnet depends on the number of loops in the wire and the amount of current in the wire. More loops and more current make stronger magnetic fields. The iron core of this temporary magnet is magnetized only while the electric current is flowing. The magnetic force from a wire coil and iron bar can make an electromagnet very strong.



Besides their strength, another advantage of electromagnets is the ability to control them by controlling the electric current. Turning the electric current on or off turns the magnet on or off. The amount of current flowing through the coil can also be changed to control the strength of the electromagnet.

Q: Why might it be useful to be able to turn an electromagnet on and off?

A: Look back at the electromagnet hanging from the crane in the photo. It is useful to turn on its magnetic field so it can pick up the metal car parts. It is also useful to turn off its magnetic field so it can drop the parts into the train car.

Magnets in Today's World

Magnets are used constantly in everyday life. Electric motors use electromagnets that run everything from refrigerators and washing machines to electric trains and robots. TV picture tubes use an electromagnet to help form the screen images. Magnets are essential in business and industry, and are used in everything from cranes and construction machines to copy machines and computers. Magnets help produce electric power in generators, and are used in radar systems and navigation.

Medical science uses magnets for diagnosing diseases with a technique known as magnetic resonance imaging (MRI). In every aspect of our society we depend on this amazing force called magnetism.

The train in this photo is called a maglev train. The word maglev stands for “magnetic levitation”. Magnets push the train upward so it hovers, or levitates, above the track without actually touching it. This eliminates most of the friction acting against the train when it moves. Other magnets pull the train forward along the track. Because of all the magnets, the train can go very fast. It can fly over the tracks at speeds up to 480 kilometers (300 miles) per hour!

3.2 Earth's Magnetic Fields

How is a magnet similar to Earth?

Earth has a magnetic field like a bar magnet. Scientists hypothesize that the Earth's core is made of nickel and iron. Electric currents in the core may be responsible for Earth's magnetic field.

Did you ever see a globe like this one? Magnets in the globe and its stand repel each other, allowing the globe to hover in midair.

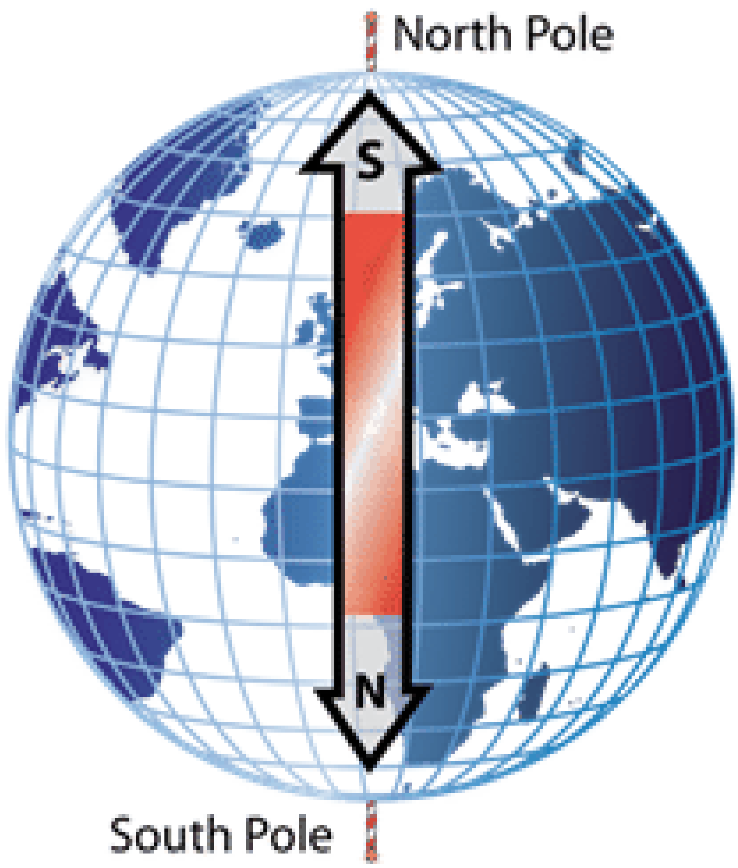
Earth's Magnetic Field

The idea that Earth is like a magnet is not new. It was first proposed in 1600 by a British physician named William Gilbert. He used a spherical magnet to represent Earth. He moved a compass around the spherical magnet and demonstrated that the spherical magnet caused a compass needle to behave the same way that Earth caused a compass needle to behave. This showed that a spherical magnet is a good model for Earth and therefore that Earth is like a magnet.

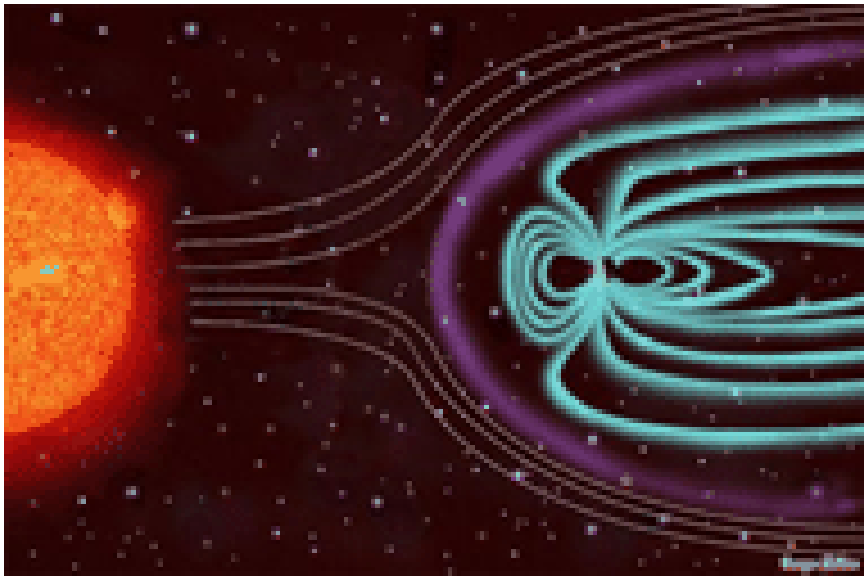
Q: Can you describe Earth's magnetic poles and magnetic field?

A: Earth has north and south magnetic poles. The magnetic poles are not in the same location as Earth's geographical North and South Pole. Because the north pole of a magnet points north, the magnetic pole near the north geographic pole must be a south magnetic pole! Remember, opposite poles attract. The magnetic pole near the south geographic pole is a north magnetic pole. The location of the magnetic poles changes over time.

To find out more about the changing location of the magnetic poles, see: http://go.uen.org/b4Z



Earth's magnetic field in space is called a magnetosphere. The magnetosphere protects Earth's organisms from solar radiation.



Like an Umbrella

The sun gives off high speed charged particles called the solar wind. The lines coming from the Sun in the diagram above represent the path of some of these particles. Notice what happens to the solar wind when it reaches the magnetosphere. It is deflected by Earth's magnetic field. If the particles in the solar wind were able to reach Earth's surface, they could harm most living things. The magnetosphere protects Earth's organisms from the solar wind like an umbrella protects you from rain.

You may recognize the eerie green glow in this cold northern sky as the northern lights, or aurora borealis. But do you know what causes the northern lights? Earth's magnetic field is a major factor.

Q: Can we explain the northern lights?

A: Bursts of energetic particles in solar wind collide with Earth's magnetic field which causes charged particle trapped in Earth's magnetic field to move toward Earth's poles. They collide with atoms in the atmosphere over the poles, and energy is released in the form of light. The swirling patterns of light follow lines of magnetic force in the magnetosphere.

Some organisms—including humans with compasses—use Earth's magnetic field for navigation

One benefit of Earth's magnetic field is its use for navigation. People use compasses to tell direction. Many animals have natural "compasses" that work just as well. For example, the loggerhead turtle in the Figure below senses the direction and strength of Earth's magnetic field and uses it to navigate along migration routes. Many migratory bird species can also sense the magnetic field and use it for navigation. One scientist speculates that they may have structures in their eyes that let them detect Earth's magnetic field.

You can learn more at this URL: http://go.uen.org/b50

Q: In the past, Earth's magnetic poles have switched places and reversed Earth's magnetic field. How might a magnetic reversal affect loggerhead turtle navigation?

A: You can find out at this URL: http://go.uen.org/b51

The following link has more information to explore all about magnets: http://go.uen.org/b52

3.3 Summary Section

- A magnet is an object that attracts certain materials such as iron. All magnets have north and south magnetic poles. The poles are regions where the magnet is strongest.
- The force that a magnet exerts is called magnetic force. The force is exerted over a distance and includes forces of attraction and repulsion. A magnet can exert force over a distance because the magnet is surrounded by a magnetic field.
- There are many different types of magnets:
- Natural magnets: minerals and metals that create their own magnetic field.
- Permanent magnets: magnets that keeps its magnetism after it has been magnetized.
- Temporary magnets: a magnet that does not keep its magnetism.
- An electromagnet is a coil of wire wrapped around a bar of iron or other ferromagnetic material. The magnetic field of the wire magnetizes the iron bar.
- The combined magnetic force of the magnetized wire coil and iron bar makes an electromagnet very strong.
- Electromagnets can be turned on or off and their strength can be changed by controlling the electric current.

Think like a Scientist

1. Compare and contrast permanent, temporary, and natural magnets and their abilities to push or pull iron objects they are not touching.

2. In what ways are permanent magnets and electromagnets alike and different?

3. Compare the magnetic fields of various types of magnets.

4. How is a magnet similar to Earth?

5. Explain how a compass works.

6. What are the uses of magnets in our world today?

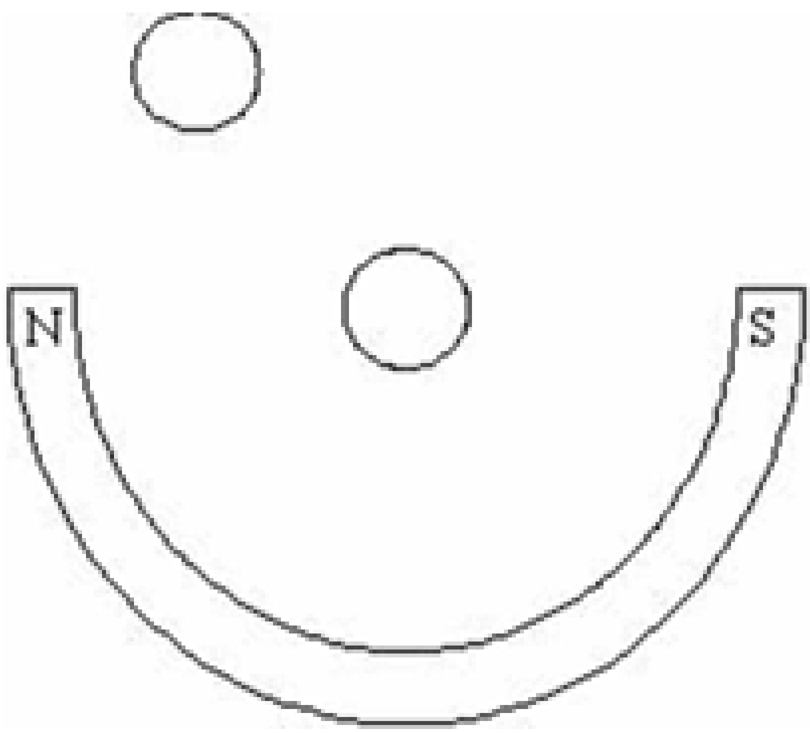
Practice

Fill in the blanks in the sentences below.

1. Increasing the number of loops in the wire coil will __________ the strength of the magnetic field.

2. When the north pole of two magnets are placed next to each other the magnets will _____________ each other. When the North Pole and the south pole of magnets face each other they will_____________.

3. Sketch the magnetic field lines for the horseshoe magnet shown here. Then, show the direction in which the two compasses (shown as circles) should point considering their positions. In other words, draw an arrow in the compass that represents North in relation to the compass magnet.



Online Interactive Activities

- Use a compass to help you find magnetic north on a globe, a map, and in a campground. http://go.uen.org/b53
- Use a magnetic field simulator on this site to pick up iron filings and view magnetic field lines. http://go.uen.org/b54

CHAPTER 4

Standard 4: Electricity

Chapter Outline

Standard 4 **Students will understand features of static and current electricity.**

Objective 1 Describe the behavior of static electricity as observed in nature and everyday occurrences.

a. List several occurrences of static electricity that happen in everyday life.

b. Describe the relationship between static electricity and lightning.

c. Describe the behavior of objects charged with static electricity in attracting or repelling without touching.

d. Compare the amount of static charge produced by rubbing various materials together (e.g., rubbing fur on a glass rod produces a greater charge then rubbing the fur with a metal rod, the static charge produced when a balloon is rubbed on hair is greater than when a plastic bag is rubbed on hair).

e. Investigate how various materials react differently to statically charged objects.

Objective 2 Analyze the behavior of current electricity.

a. Draw and label the components of a complete electrical circuit that includes switches and loads (e.g., light bulb, bell, speaker, motor).

b. Predict the effect of changing one or more of the components (e.g., battery, load, wires) in an electric circuit.

c. Generalize the properties of materials that carry the flow of electricity using data by testing different materials.

d. Investigate materials that prevent the flow of electricity.

e. Make a working model of a complete circuit using a power source, switch, bell or light, and a conductor for a pathway.

4.1 Electricity

How are lightning and the shock your brother gives you after rubbing his feet on the carpet the same?

You're a thoughtful visitor, so you wipe your feet on the welcome mat before you reach out to touch the brass knocker on the door. Ouch! There is suddenly a spark between your hand and the metal, and you feel an electric shock.

What Is Static Electricity?

Static electricity is a buildup of an excess of positive or negative electric charges on objects. This usually happens when negative electrons are transferred from one object to another. The object that gives up electrons becomes positively charged, and the object that accepts the electrons becomes negatively charged. This can happen in several ways.

One way static electricity can build up is through contact between materials that differ in their ability to give up or accept electrons. When you wipe your rubber-soled shoes on the wool mat, for example, electrons are transferred from the mat onto your shoes. As a result of this transfer of electrons, positive charges build up on the mat and negative charges build up on the bottom of your shoes.

Once an object becomes electrically charged, it is likely to remain charged until it touches another object or at least comes very close to another object, if the air surrounding it is dry. That's because electric charges cannot easily escape into dry air. However, a water molecule in the air can easily accept an electron. So, if the air is humid, an object with excess electrons will have them pulled off into the air by water molecules after a short time.

Q: You're more likely to get a shock in the winter when the air is very dry. Can you explain why?

A: When the air is very dry, electric charges are more likely to build up objects because they cannot escape easily into the dry air. This makes a shock more likely when you touch another object.

Some things will produce a much greater static charge than others. Rabbit fur rubbed on a balloon will have a much greater charge than cotton fabric rubbed on a balloon. A wool sweater pulled over clean, dry hair will transfer more charge than a cotton sweater. Objects with excess electric charge can **attract**– draw together-objects. However, it can also **repel**– push away-objects. For example, when your hair acquires extra electrons, the hairs repel each other because they have the same charge. Static electricity can also cause items to attract. When we say that a sock sticks to your clothing because of static electricity, we mean the socks and clothing attract each other because they have opposite charges.

Static Discharge

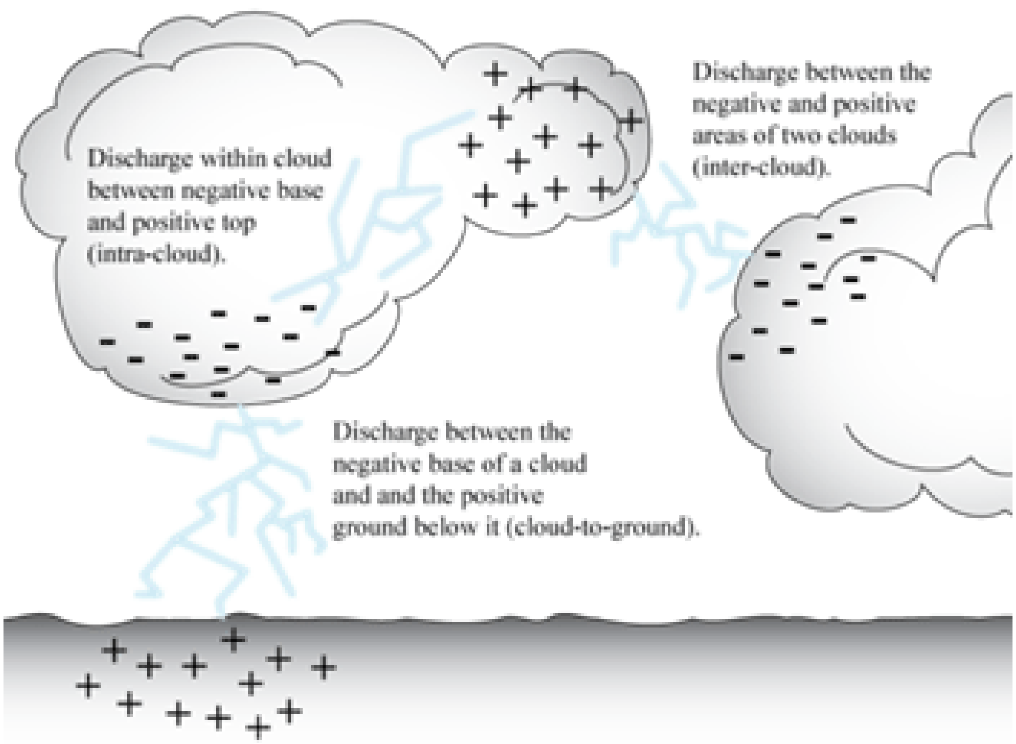
What happens when you have become negatively charged and your hand approaches a metal door knocker? Your negatively charged hand repels electrons in the metal. This will make the electrons move to the other side of the knocker. The side of the knocker closest to your hand is positively charged. As your negatively charged hand gets very close to the positively charged side of the metal, there are strong electric forces at work in the air between your hand and the knocker. Any free electrons in the air are strongly repelled by the negative charges in your hand and strongly attracted to the positive charges in the metal. As they move quickly towards the metal they collide with molecules in the air, knocking electrons out of those molecules. These new electrons are now attracted to the knocker and they collide with more molecules eventually creating an avalanche of electrons moving quickly toward the metal and a lot of positively charged air molecules moving toward your hand. This process results in a sudden flow of charge between your hand and the knocker. The sudden flow of charge is called a static discharge. As electrons recombine with the positively charged air molecules, they give off light, which is the spark you see.

There are other ways to show static electricity repelling or attracting objects without touching it. Watch what happens to a small stream of water when a charged item comes close to it.

- http://go.uen.org/b55

How Lightning Occurs

Another example of static discharge, but on a much larger scale, is lightning. An electrical charge builds up in the clouds. When the charge becomes large enough, or the cloud moves closer to the ground, that static electricity is discharged in what we call a lightning bolt. You can see how it occurs in the following diagram and animation as you read about it. http://go.uen.org/b56



During a rainstorm, clouds develop regions of positive and negative charge. The negative charges in the form of electrons are usually concentrated at the base of the clouds, and the positive charges are usually concentrated at the top. The negative charges repel electrons on the ground beneath them, so the ground below the clouds becomes positively charged.

At first, electrons flowing out of the cloud toward the ground lose their energy in collisions with air molecules so they only travel a short distance. This creates a conducting path so the next group of electrons can follow it and go farther.

This process repeats until the conducting path gets close to the ground. When this happens, the static build up is discharged as current electricity that we call lightning.
At the following URL, you can watch an awesome, slow-motion lightning strike: http://go.uen.org/b57

You'll be amazed when you realize how much has occurred during that split-second discharge of static electricity.

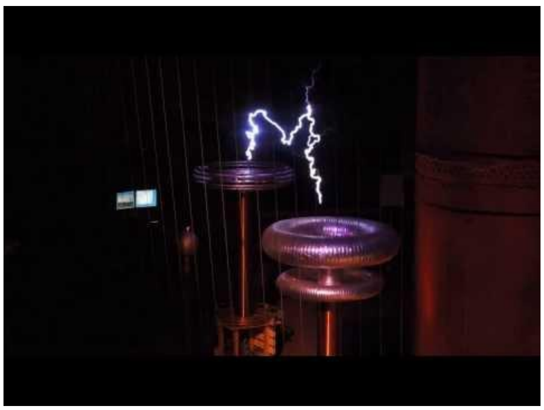
Summary

- Static electricity is a buildup of an excess of either negative or positive electric charges on an object. It occurs when electrons or molecules that have a positive or negative charge are transferred from one object to another.
- A sudden flow of charged particles between objects is called static discharge.
- Examples of static discharge include lightning and the shock you sometimes feel when you touch another object.

Using Static Electricity

Watch the video at the following URL: http://go.uen.org/b58

This odd-looking machine pictured above, is called a Van de Graaff generator. It's located in the Boston Museum of Science. Like other Van de Graaff generators, it generates static electricity. When enough static electricity builds up on its surface, it discharges the electricity as an artificial bolt of lightning. Check out this video to see what else the Van de Graaff generator can do: http://go.uen.org/b59



Static electricity can be entertaining. Not only can you use it to generate artificial lightning with a Van de Graaff generator. You can use it to stick a balloon to a wall or to cause your hair to stand on end. Static electricity is also responsible for the shock you may get when you reach out to touch a metal doorknob.

How does a Van de Graaff generator work, and what causes static electricity? Watch this Bill Nye the Science Guy video to find out: http://go.uen.org/b5a

Watch static electricity in action as a vinyl record gets charged by rubbing it with a wool scarf. http://go.uen.org/b5b

Think like a Scientist

1. How are lightning and the shock your brother gives you after rubbing his feet on the carpet the same and how are they different?

2. What is static electricity? What is static discharge? Where do electrons in static electricity go when the static electricity is discharged?

3. How do electric charges build up on an object?

4. How are static electricity and static discharge related?

5. If a person touches a Van de Graaff generator, his or her hair stands on end. Explain why.

6. A sudden flow of electrons between oppositely charged objects is called static ___________.

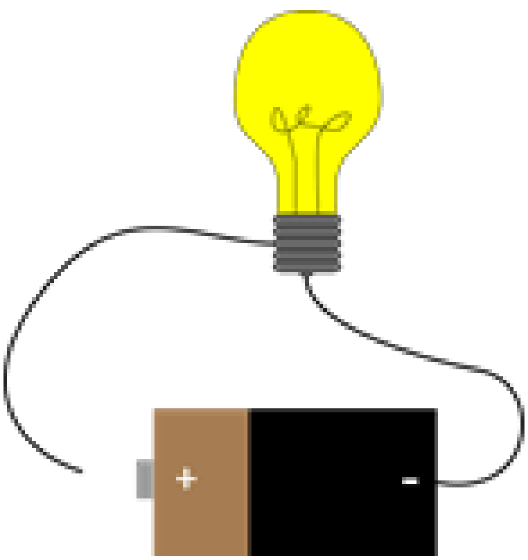
7. Would it be practical to capture, store, and use static electricity to power homes? Why or why not?

4.2 Electrical Circuits

What properties do electrical circuits have?

Electric currents

Electric current, is a closed loop through which electrons can flow. Elevators in skyscrapers, jumbo jets, arcade games, lights, heating, and security. None of these work without electric currents. Clothes washers and dryers, refrigerators, toasters, automobiles, thermostats, computers, televisions, and radios all use electric currents.



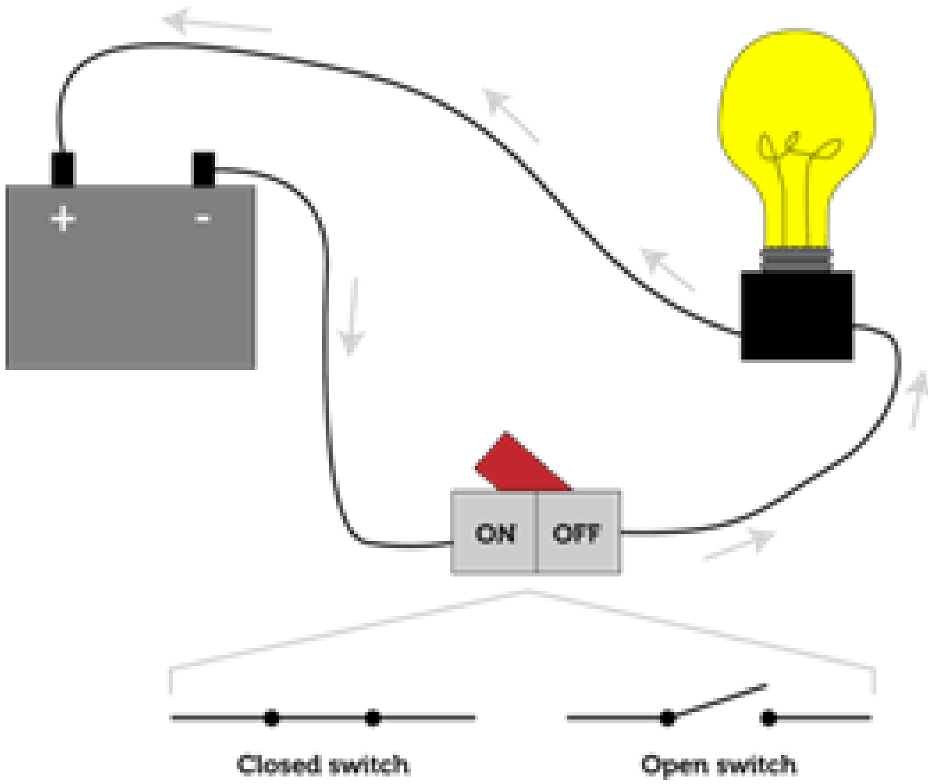
Jose made this sketch of a **battery** – a device that generates electricity by combining certain chemicals – and a light bulb for science class. If this sketch were real, the light bulb wouldn't work. The problem is the loose wire on the left. It must be connected to the positive terminal of the battery in order for the bulb to light up.

Q: Why does the light bulb need to be connected to both battery terminals?

A: Electric current can flow through a wire only if it forms a closed loop. Charges must have an unbroken path to follow between the positive and negative ends of the battery.

Electric Circuits

A closed loop through which current can flow is called an electric circuit.



All electric circuits have three parts: a source of electric current and a path that contains mobile electric charges and a load that shows the electric current is flowing. We call the material that makes this path a conductor – material that allows electricity to pass through easily. A circuit may have other parts as well, such as light bulbs and switches, a device that immediately changes a circuit from complete to incomplete, as in a simple circuit.

- The source of electric current in this simple circuit is a battery. In a home circuit, the source of current is an electric power plant, which may supply electric current to many homes and businesses in a community or even to many communities.
- The conductor in most circuits consists of one or more wires. The conductor must form a closed loop from the current source and back again. In the circuit above, the wires are connected to both terminals of the battery, so they form a closed loop.

- Most circuits have devices such as a light bulb that converts electrical energy to other forms of energy. In the case of a light bulb, electrical energy is converted to light and thermal energy (heat).
- Many circuits have **switches** to control the flow of current. When the switch is turned on, the circuit is closed and current can flow through it. When the switch is turned off, the circuit is open and current cannot flow through it.

Current electricity is a flow of electric charges. Current electricity requires a continuous **pathway** made of a material that contains mobile electric charges to make a **complete circuit**. Current electricity cannot flow if there are any breaks in the path (unless the voltage is high enough to create a spark). A battery, bulb, and wire connected together can make a simple, complete circuit. If the wires are not connected properly it causes a break. Electric current cannot flow through the break, so you have an **incomplete circuit**.

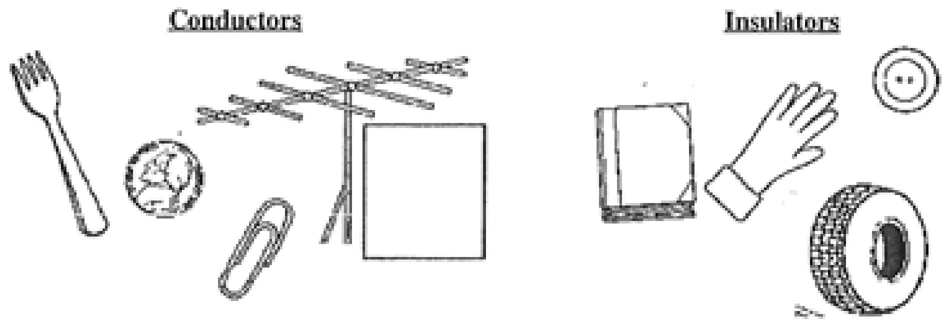
A **power source** is a device that supplies electric current to a circuit. The safest power source for you to use in a circuit is a battery. Other power sources could include a generator, a solar panel, or a fuel cell.

A general term for any device that uses electricity is a **load** – an item that uses electricity to do work. A light bulb is one type of load. Other examples are fans, motors, computers, TVs, and can openers. How many more can you name?

These three basic parts, power source, pathway, and load, can be arranged to do many different things. However, designing a circuit that works as desired requires a lot of planning and a good understanding of electricity. For example, using one battery with two or more light bulbs will result in dimmer lights. Using just one light bulb with two or more batteries will result in a brighter light. To turn a circuit on or off requires a switch. When we turn the lights on in our classroom, the circuit is complete. With a flip of the switch the lights are off and the circuit is incomplete.

Conductors and Insulators

Current electricity flows more easily through some things than others. A **conductor** allows electricity to flow through it easily. Wires and the metal parts of a light bulb are good conductors. Pennies, keys, and nails make good conductors, but conductors are not always metal. Some conductors are liquids.



Insulators are materials that do not allow electricity to pass through them. Plastic is an insulator. Some wires are coated with plastic to keep the electricity from flowing to an unsafe place.

Do you see the wires and peaks on top of this old house? They are lightning rods, and their purpose is to protect the building in the event of a lightning strike. Each lightning rod is an electrical conductor that goes down the side of the building and into the ground. If lightning strikes the building, it will target the rod and be conducted by the rod, which is the ground. Lightning rods may differ in style, but to work they must be good at conducting electricity.

Electric Current and Matter

In order to travel, electric current needs moveable electric charges. It cannot pass through empty space. However, most types of matter resist the flow of electric current. In a metal wire, flowing electrons collide with metal atoms, which absorb their energy. Some types of matter offer more or less resistance to electric current than others depending on the material they are made of.

Electric Conductors

Materials that allow the flow of electricity are called electric conductors. Many metals—including copper, aluminum, and steel—are good conductors of electricity. The outer electrons of metal atoms are loosely bound and free to move, allowing electric current to flow.

Water that has even a small amount of impurities such as salt is an electric conductor as well. That is because salt will dissolve in water, breaking apart into positively charged sodium atoms and negatively charged chlorine atoms. These charged atoms can move in response to electric forces and make an electric current in the water.

Q: What do you think lightning rods are made of?

A: Lightning rods are made of metal, usually copper or aluminum, both of which are excellent conductors of electricity.

Q: You may have heard that rubber-soled shoes will protect you if you are struck by lightning. Do you think this is true? Why or why not?

A: It isn’t true. Rubber is an electric insulator, but a half-inch layer on the bottom of a pair of shoes is insignificant when it comes to lightning. The average lightning bolt has enough energy to force charges to move through most insulators, even the insulators on high-voltage power lines.

Look at the wires in the image below. They are made of copper and coated with plastic. Copper is very good conductor, and plastic is a very good insulator. So, the current flows through the copper wire and cannot easily flow out of the wire through its plastic coating.

We are using electricity all the time. We need to understand it and how to use it safely and correctly.

Key Questions

1. What does it mean if something conducts electricity?

2. What is the difference between an electrical conductor and insulator?

3. Why are insulators important?

4.3 Summary Section

- Electricity must travel through matter. Almost all matter offers some resistance to the flow of electric charges in an electric current. Some materials resist current more or less than others.
- Materials that allow the flow of electric current are called electric conductors. Many metals are good electric conductors.
- Materials that prevent the flow of electric current are called electric insulators. Wood, rubber, and plastic are good electric insulators.
- An electric circuit is a closed loop through which current can flow.
- All electric circuits must have a power source, such as a battery as well as a pathway, which is usually wire. They may have one or more electric devices as well.
- An electric circuit can be represented by a circuit diagram, which uses standard symbols to represent the parts of the circuit.

Science Language Students Need to Know and Use

- Attract: to draw together.
- Battery: a device that generates electricity by combining certain chemicals.
- Compass: an instrument used to determine geographic direction on Earth
- Complete circuit: a connected pathway through which electricity can flow; includes a power source, load, and pathway.
- Conductor: material that allows electricity pass through easily.
- Current: the flow of an electric charge
- Electromagnet: a magnet that can be turned on or off and is made by sending electricity through metal.
- Incomplete circuit: a circuit with a gap through which electricity cannot flow.
- Insulators: things that don't allow electricity to pass through them.
- Load: an item that uses electricity to do work.
- Magnetic field: area around a magnet where it exerts magnetic force.
- Magnetic force: Force of attraction or repulsion exerted by a magnet.
- Natural Magnet: a mineral made magnetic by Earth's magnetic field.
- Pathway: a course through which electricity can flow.
- Permanent Magnet: an object that keeps its magnetism after it has been magnetized.
- Properties: used to describe the qualities of matter
- Repel: to push apart.
- Static electricity: an electric charge built up on an insulator

- Switch: a device that immediately changes a circuit from complete to incomplete.
- Temporary magnet: Temporary magnet: a magnet that does not keep its magnetism.

Think like a Scientist

1. What components do electrical circuits have?

2. Draw and label the components of a complete electrical circuit that include switches and loads.

3. Describe the effect of changing one or more of the components (e.g., battery, load, wires) in an electric circuit.

4. Compare and contrast conductors and insulators and give examples of each.

5. Describe how static electricity and current electricity are different.

Online Interactive Activities

- Investigate positive and negative charges as you use a balloon to generate static electricity. http://go.uen.org.b4v
- Try this interactive simulation with "John Travoltage". http://go.uen.org/b0l
- Experiment with the polarization of an aluminum can using contact with glass and rubber rods. http://go.uen.org/b0k
- Check out the difference between series and parallel circuits on this site. http://go.uen.org/b4w
- Create electrical circuits on this website and light them. http://go.uen.org/b4x
- In this online simulation, place batteries and switches in circuits to light bulbs. http://go.uen.org/b4z
- Build various circuits with different requirements on this website. http://go.uen.org/b4y
- Use magnets and coils to uncover Faraday's Law. http://go.uen.org/b4A
- Determine which objects conduct electricity when inserted in a circuit. http://go.uen.org/b4B
- Examine different ways to create electricity using generators, geothermal energy and solar cells. Build your own wind turbine and take a quiz on this site. http://go.uen.org/b06

CHAPTER 5

Standard 5: Heredity

Chapter Outline

Standard 5: Students will understand that traits are passed from the parent organisms to their offspring, and that sometimes the offspring may possess variations of these traits that may help or hinder survival in a given environment.

Objective 1 Using supporting evidence, show that traits are transferred from a parent organism to its offspring.

a) Make a chart and collect data identifying various traits among a given population (e.g., the hand span of students in the classroom, the color and texture of different apples, the number of petals of a given flower).
b) Identify similar physical traits of a parent organism and its offspring (e.g., trees and saplings, leopards and cubs, chickens and chicks).
c) Compare various examples of offspring that do not initially resemble the parent organism but mature to become similar to the parent organism (e.g., mealworms and darkling beetles, tadpoles and frogs, seedlings and vegetables, caterpillars and butterflies).
d) Contrast inherited traits with traits and behaviors that are not inherited but may be learned or induced by environmental factors (e.g., cat purring to cat meowing to be let out of the house; the round shape of a willow is inherited, while leaning away from the prevailing wind is induced).
e) Investigate variations and similarities in plants grown from seeds of a parent plant (e.g., how seeds from the same plant species can produce different colored flowers or identical flowers).

a) **Objective 2** Describe how some characteristics could give a species a survival advantage in a particular environment.
b) Compare the traits of similar species for physical abilities, instinctual behaviors, and specialized body structures that increase the survival of one species in a specific environment over another species (e.g., difference between the feet of snowshoe hare and cottontail rabbit, differences in leaves of plants growing at different altitudes, differences between the feathers of an owl and a hummingbird, differences in parental behavior among various fish).
c) Identify that some environments give one species a survival advantage over another (e.g., warm water favors fish such as carp, cold water favors fish such as trout, environments that burn regularly favor grasses, environments that do not often burn favor trees).
d) Describe how a particular physical attribute may provide an advantage for survival in one environment but not in another (e.g., heavy fur in arctic climates keep animals warm whereas in hot desert climates it would cause overheating; flippers on such animals as sea lions and seals provide excellent swimming structures in the water but become clumsy and awkward on land; cacti retain the right amount of water in arid regions but would develop root rot in a more temperate region; fish gills have the ability to absorb oxygen in water but not on land).

f) Research a specific plant or animal and report how specific physical attributes provide an advantage for survival in a specific environment.

5.1 Heredity

Why doesn't a cow quack and why don't puppies look like kittens?

Has anyone ever come up to you and told you that you look just like your parents? You probably have some **traits** in common with each of your parents. Traits are characteristics that you inherit from your parents. Your parents also have traits that they inherited from their parents (your grandparents.) For a long time people understood that traits are passed down through families. However, the rules of how this worked were unclear. The work of Gregor Mendel was crucial in explaining how traits are passed down to each generation from parent organism to their offspring.

Mendel's Experiments

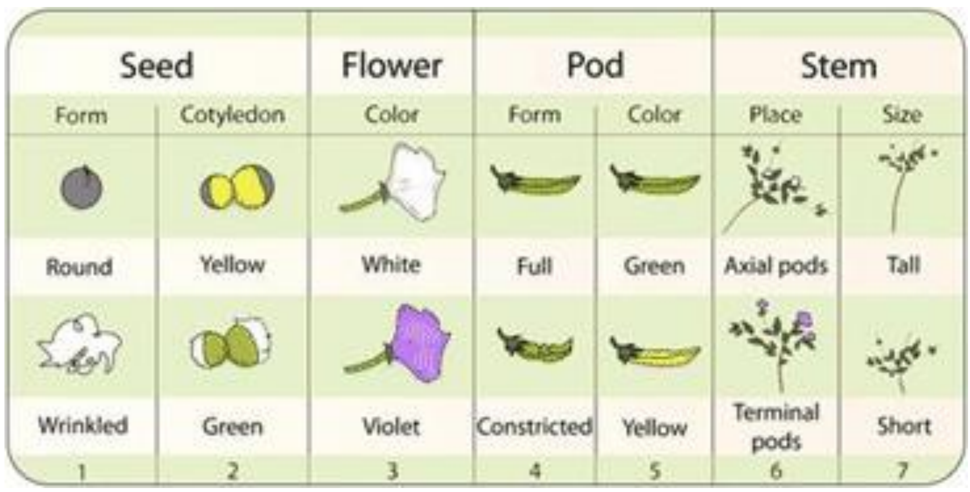
What does the word **inherit** mean? You may have inherited something of value from a grandparent or another family member. To inherit is to receive something from someone who came before you. You can inherit objects, but you can also inherit traits. For example, you can inherit a parent's eye color, hair color, or even the shape of your nose and ears!

Genetics is the study of inheritance. The field of genetics seeks to explain how traits are passed on from one generation to the next.

In the late 1850s, an Austrian monk named Gregor Mendel performed the first genetics experiments.

To study genetics, Mendel chose to work with pea plants because they have easily identifiable traits. For example, pea plants are either tall or short, which is an easy trait to observe. Furthermore, pea plants grow quickly, so he could complete many experiments in a short period of time.

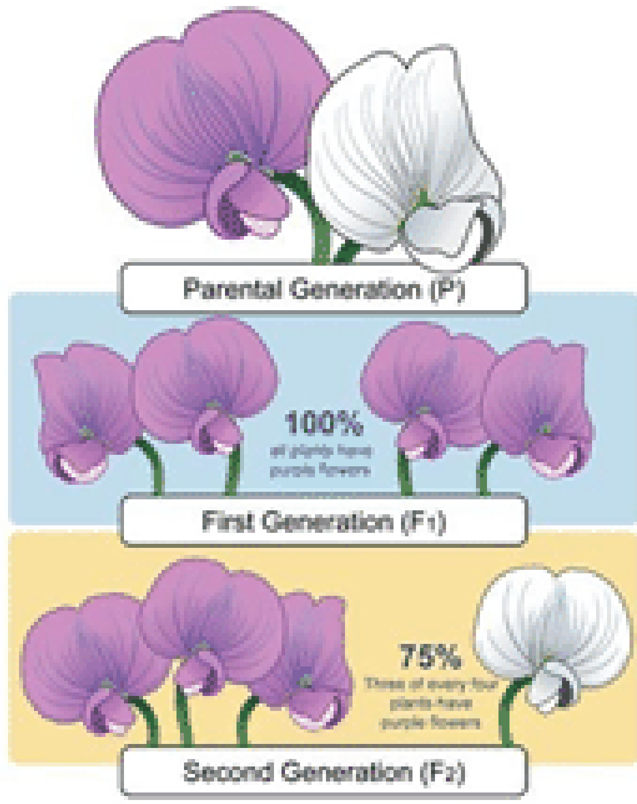
Mendel studied the inheritance patterns for many different traits in peas-- including round seeds versus wrinkled seeds, white flowers versus purple flowers, and tall plants versus short.



In one of Mendel's early experiments, he crossed a short plant and a tall plant. What do you predict the **offspring** (babies) of these plants were? Medium-sized plants? Most people during Mendel's time would have said medium-sized. But an unexpected result occurred. Mendel observed that the offspring of this cross were all tall plants!

Next, Mendel let this generation self-pollinate. That means the pollen from the flowers of the tall plant offspring were mixed **(crossed)** with each other. He found that 75% of the offspring from this second generation of pea plants were tall, while 25% were short. Shortness skipped a generation. But why?

In all, Mendel studied seven characteristics, with almost 20,000 plants from the 2nd generation. All of his results were similar to the first experiment—about three out of every four plants had one way of exhibiting a certain trait, while just one out of every four plants had a different way of exhibiting the same trait.



For example, for the trait of the color of the pea plant flower, he crossed purple flowered-plants and white flowered-plants. Do you think the colors blended? No, they did not. Just like the previous experiment, all offspring in the first generation of this cross were one color: purple. In the second generation, 75% of plants had purple flowers and 25% had white flowers. There was no blending of traits in any of Mendel's experiments.

Mendel's work provided the basis to understand the passing of traits from one generation to the next.

Traits

Some trees grow very tall with thick bark while others are very short with thin bark. It all depends on an **organism**'s heredity from parents to their young. An **organism** is any living thing. Heredity, the passing of traits from parent to offspring, applies to all organisms including humans, plants, insects and even bacteria.

In a pond, every frog is unique because of various traits it inherits from its parents. A **trait** is a characteristic that determines how an organism looks, acts, or functions. An **inherited trait** is a characteristic passed from parents to their offspring. Some examples of inherited traits are fur color, fur with stripes, or fur with spots. The big cats pictured show inherited traits. Can you see similarities and differences between the two cats?

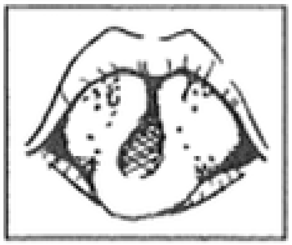
 

Just like dogs will always have puppies, cats will always have kittens, and acorns will always grow into oak trees, people are alike in most ways because we will always look like people!

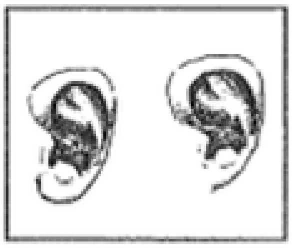
All organisms are made up of small building blocks called cells. A person consists of about ten trillion of these cells which come in over 200 varieties. Cells are the building blocks that give organisms their individual traits and vary from organism to organism. These small differences are enough to keep organisms from looking identical. These differences establish our color of hair and eyes, whether we are tall or short, and whether we have freckles or not. Each of us has inherited his/her own mixture of traits from our parents. Within each building block are special instructions that tell an organism how it will grow and what traits it will develop.

Parent organisms, the producers of offspring, pass these instructions to their **offspring**, the young of an organism. For example, a puppy will inherit its hair color from its parents; a seedling will develop wide, broad leaves from its parent plant; and human beings will inherit a variety of traits. A few of these inherited traits include: ability to roll your tongue, a widow’s peak or straight hairline, attached or unattached earlobes, color of skin and hair, freckles, cleft in chin, naturally curly or straight hair, and a hitchhiker's thumb.

•Ability to roll your tongue

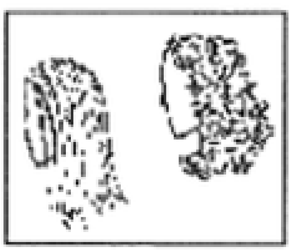


•Attached or unattached earlobes

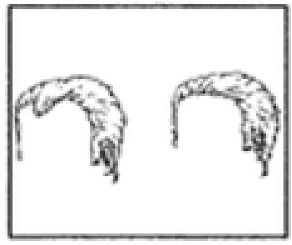


•Freckles

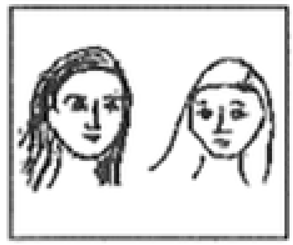
•Naturally curly or straight hair



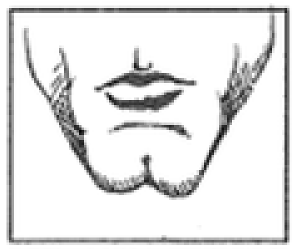
•A widow's peak or straight hairline



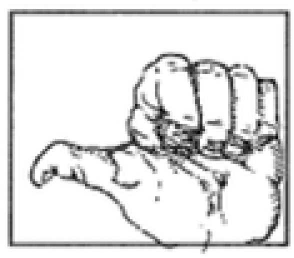
•Color of skin and hair

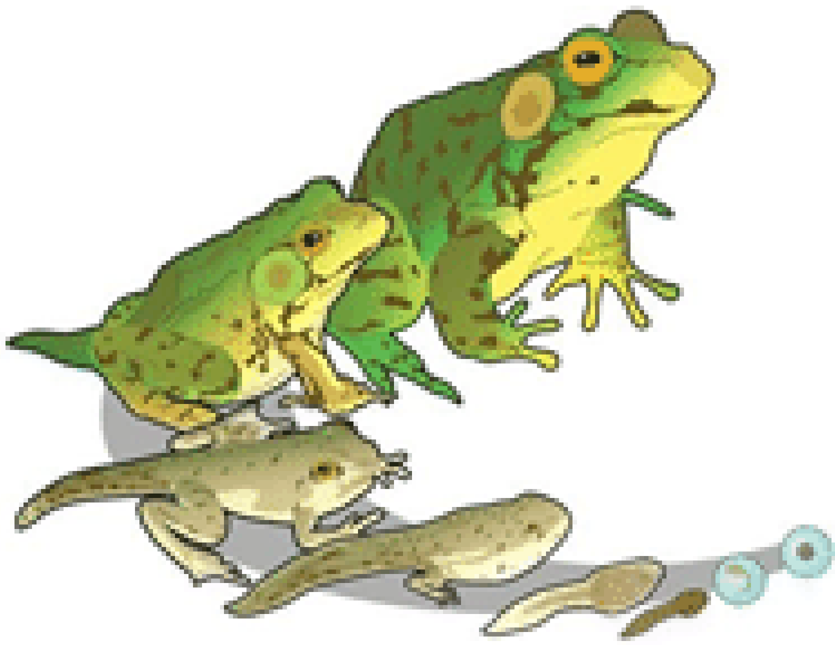


•Cleft in chin



•Hitchhiker s thumb





Sometimes, offspring do not look like their parent organism. However, as they go through their **life cycles**, a series of changes that are normal for that organism, they begin to look more like their parents. For example, the legless little tadpole with its large tail looks very different than it will as a full-grown frog.

Compare puppies in a litter. Even though these puppies have had the same two parents, there are **variations**, differences in the appearance of an inherited trait among the members of a group or **species**, in how they look and act. The differences in paw size, tail length, or hair coloring are examples of variations. Some variations do not have much of an effect on an organism. For example, the different colors of hair puppies from the same litter will have little effect on whether or not each puppy will survive.

However, for some organisms living in the wild, color can be a matter of life or death. For example, a moth with brightly colored orange and yellow wings will not survive very long if its environment is the dark bark of pine trees because the brightly colored moth can easily be seen and eaten by birds. A moth with similar color patterns to its surroundings has a better chance of surviving long enough to produce offspring with similar coloring. These variations give a species, a certain group of plants, or animals that can only reproduce among themselves, a better chance to live or survive.

Learned Behaviors vs. Instincts

Have you ever seen a dog sit on command? Have you ever watched a cat trying to catch a mouse? These are just two examples of the many behaviors of animals. Animal behavior includes all the ways that animals interact with each other and the **environment**. Some animal behaviors are **learned behaviors**, an action that is learned through trial and error or is brought about by the environment. Other behaviors are because of the animal's **instincts**, meaning animals are born with them. Herding for the sheep dog, in the photo below, is both learned and instinctual. The nursing of the piglet is an instinctual behavior, and the children blowing dandelion seeds is a learned behavior.



Each of these are examples of animal behavior. Can you think of other examples of animal behavior besides these three? Which of the behaviors are instincts and which are learned?

Nature vs. Nurture

Scientists have observed that some behaviors seem to be controlled solely by genes and others appear to be due to experiences in a given environment. Whether behaviors are controlled mainly by genes (nature) or by the environment (nurture) is often a matter of debate. This is called the nature-nurture debate.

Nature refers to the genes an animal inherits and nurture refers to the environment that the animal experiences. It seems that most animal behaviors are not controlled by nature or nurture**,** but by nature and nurture. In dogs, for example, the tendency to like to live in packs (groups) is probably controlled by genes. This is why dogs make good pets for families. But for a dog to sit or roll over on command is a learned behavior. The dog learns that if it does the trick, it will get a treat from its owner.

How Behaviors Evolve

It's easy to see how many common types of behavior evolve. That's because they obviously increase the fitness of the animal performing them. For example, when wolves hunt together in a pack, they are more likely to catch prey. Therefore, hunting with others increases a wolf's fitness. The wolf is more likely to survive and pass its genes to the next generation by behaving this way. Wolves hunt together in packs. This is adaptive because it increases their chances of killing prey and obtaining food.

Inherited Behavior

How do kittens know how to “hunt”? This kitten was probably adopted and separated from its mother at a young age. It never got a lesson in how to stalk and pounce on prey. So how does this kitten know how to attack the ball of yarn? Some behaviors do not need to be learned.

Many animal behaviors are ways that animals act, naturally. They don't have to learn how to behave in these ways. Cats are natural-born hunters. They don't need to learn how to hunt. Spiders spin their complex webs without learning how to do it from other spiders. Birds and wasps know how to build nests without being taught. These behaviors are called **inherited**.

An **inherited behavior** is any behavior that occurs naturally in all animals of a given species. An inherited behavior is also called an **instinct**, behaviors that are inherited from the parent organism. The first time an animal performs an inherited behavior, the animal does it well. The animal does not have to practice the behavior in order to get it right or become better at it.

Inherited behaviors are also predictable, meaning all_members of a species perform an inherited behavior in the same way. From the examples described above, you can probably tell that inherited behaviors usually involve important actions, like eating and caring for the young.

There are many examples of behaviors that are based on an animal's instincts. Did you know honeybees dance? When a honeybee locates a source of food it will return to the hive and do a dance. This dance is called the waggle dance. The way the bee moves during its dance tells other bees in the hive where to find the food. Honeybees do the waggle dance without learning it from other bees, so it is an instinct.

Besides building nests, birds have other instincts. One example occurs in gulls. One of the chicks is pecking at a red spot on the mother's beak, his inherited behavior causes the mother to feed the chick. In many other species of birds, the chicks open their mouths wide whenever the mother returns to the nest. This inherited behavior, called gaping, causes the mother to feed them.

Spider spinning a web

Bird building a nest

Caterpillar making a cocoon

Dolphin leaping from the water

Inherited behaviors are rigid and predictable. All members of the species perform the behaviors in the same way. Inherited behaviors usually involve basic life functions, such as finding food or caring for offspring. If an animal were to perform such important behaviors incorrectly, it would be less likely to survive or reproduce. These inherited behaviors are necessary for **survival** (living) and reproduction (creating a next generation.)

This female gray lag goose is a ground-nesting water bird. Before her chicks hatch, the mother protects the eggs by using her bill to push eggs back into the nest if they roll out. This is an example of an inherited behavior.

All animals have inherited behaviors, even humans. Can you think of human behaviors that do not have to be learned? Chances are, you will have a hard time thinking of any. The only truly inherited behaviors in humans are called reflex behaviors, an involuntary response to a stimulus. They occur mainly in babies. Like instincts in other animals, reflex behaviors in human babies help them survive.

An example of a reflex behavior in babies is the sucking reflex. Newborns instinctively suck on a pacifier that is placed in their mouth. It is easy to see how this behavior evolved. It increases the chances of a baby feeding and surviving. Another example of a reflex behavior in babies is the grasp reflex. Babies instinctively grasp an object placed in the palm of their hand. Their grip may be surprisingly strong. How do you think this behavior might increase a baby's chances of surviving?

Learned Behavior

Learning is a change in behavior that occurs as a result of experience. Compared with inherited behaviors, **learned behaviors**, behaviors in response to a stimulus, are more flexible. They can be modified to better meet changing conditions. This may make them more adaptive than instincts. For example, drivers may have to modify how they drive when roads are wet or icy. Otherwise, they may lose control of their vehicle. Animals learn behaviors in a variety of ways.

Do you play a sport? If you play a sport like soccer, then you realize it takes a lot of work. Remember how you didn't know what you were doing when you first started? You had rules to figure out and skills to practice. Playing a sport is an example of a learned behavior.

Just about all human behaviors are learned. **Learned behavior** is behavior that occurs only after experience or practice. Learned behavior has an advantage over inherited behavior, it is more flexible.

Learned behavior can be changed if conditions change. For example, you probably know the route from your house to your school. Assume that you moved to a new house in a different place, so you had to take a different route to school. What if following the old route was an instinct? You would not be able to adapt. Fortunately, it is a learned behavior. You can learn the new route just as you learned the old one.

Although most animals can learn, animals with greater intelligence are better at learning and have more learned behaviors. Humans are the most intelligent animals. They depend on learned behaviors more than any other species. Other highly intelligent species include apes, our closest relatives in the animal kingdom. They include chimpanzees and gorillas. Both are very good at learning behaviors.

You may have heard of a gorilla named Koko. A psychologist, Dr. Francine Patterson, raised Koko. Dr. Patterson wanted to find out if gorillas could learn human language. Starting when Koko was just one year old, Dr. Patterson taught her to use sign language. Koko learned to use and understand more than 1,000 signs. Koko showed how much gorillas can learn.

Click here for a link to the video, A Conversation with Koko.

http://go.uen.org/aYu

Think about some of the behaviors you have learned. They might include riding a bicycle, using a computer, and playing a musical instrument or sport. You probably did not learn all of these behaviors in the same way. Perhaps you learned some behaviors on your own, just by practicing. Other behaviors you may have learned from other people. Humans and other animals can learn behaviors in several different ways.

5.2 Adaptations

Why don’t cactuses grow in the rainforest, and why aren’t their tropical flowers in the desert?

Adaptations

The characteristics of an organism that help it to survive in a given environment are called **adaptations**. Adaptations are inherited traits that an organism receives from its parents. Within a **population** of organisms, each organism has genes which contain coding for a certain number of traits. For example, a human population may have genes for eyes that are blue, green, hazel, or brown, but as far as we know, not purple or lime green.

Adaptations develop when certain variations, occur within the coding contained within the genes of a population the benefit the organisms ability to survive. **Variations** are differences in organisms from the same species. Because the parent organism survives to pass its variations of a trait to the next generation, the variation continues. The variation may already exist within the population, but often the variation comes from a mutation, a random change in an organism’s genes. Sometimes, mutations are harmful and the organism dies. In that case, the variation will not remain in the population.

Many mutations are neutral and remain in the population. If the environment changes, the mutation may be beneficial and it may help the organism adapt to the changed environment. The organisms that survive pass this favorable trait onto their offspring.

One example of a variation helping an organism adapt to its changing environment is what happened to the peppered moth population during the Industrial Revolution in England. Most of the peppered moths before the Industrial Revolution were light colored, while only some of them had the variation of being darker gray. Because the bark of the trees these moths lived on was lighter in color, the light colored moths were harder for birds to see, so the parent moths with the trait of light-colored genes lived to pass this color trait to their offspring.

Once the Industrial Revolution began, however, the pollution from the coal burned to run the factories greatly increased, and it clung to the bark of the trees, making the bark much darker. Scientists found that the light-colored moth population decreased greatly because now the birds could see them against the soot on the bark of the tree more easily. Scientists also found that the numbers of moths with the variation for dark-colored wings increased. They thought it might be because now the dark-colored moths were harder for the birds to see against the soot on the bark of the trees. This variation of dark-colored wings was now passed on to the next generation of pepper moths as an adaptation that helped the moth survive. What do you think happened when the Industrial Revolution ended in England and the air became cleaner?

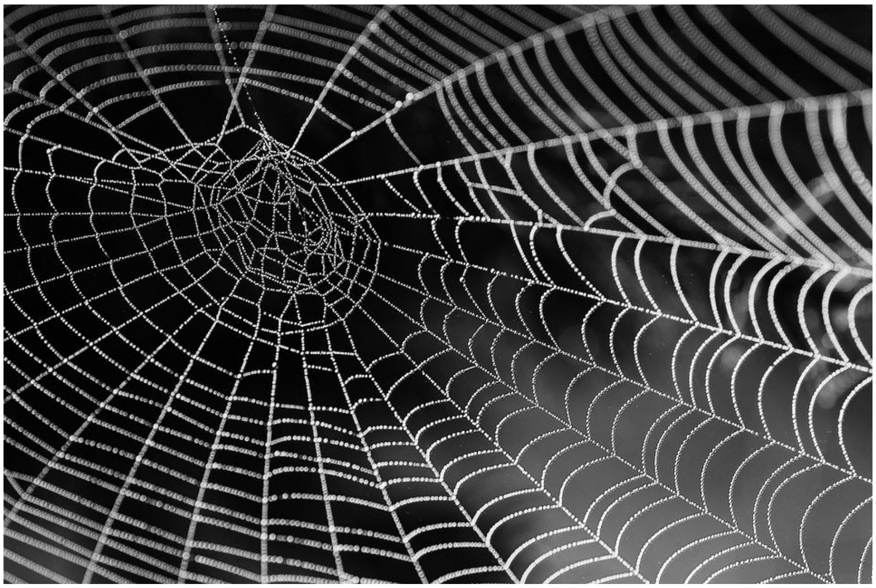
Camouflage is the ability some organisms have to blend into their surroundings. This ability to hide or disguise the presence of, is one way an animal can survive.

Why would an organism match its background? Wouldn't it be better to stand out? An organism that blends with its background is more likely to avoid predators. If it survives, it is more likely to have offspring. Those offspring are more likely to blend into their backgrounds. Can you find the mudskipper fish in this picture?

The octopus is well known for its ability to camouflage- an adaptation that helps in survive in a variety of environments. Watch to see how the octopus can change its color, shape, and texture to help it blend in with the ocean plants and floor.

http://go.uen.org/aZa

Instincts



Instincts are also behaviors that are inherited from the parent organism. These instincts help organisms survive. This explains why salmon migrate upstream to spawn, a cat purrs, a duck swims, a spider spins a web, or a termite rots wood.

Specialized Structures

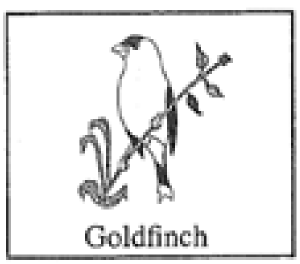
Snowshoe Rabbit

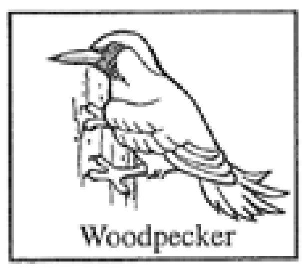
Jackrabbit

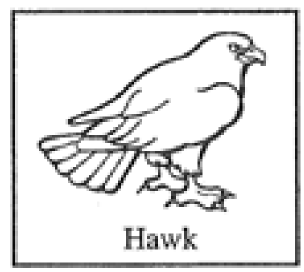
Other variations include **specialized structures**, a body part unique to a species for survival in its environment, the area in which an organism lives. A snowshoe rabbit has small ears and broad feet. Its smaller ears prevent it from losing body heat, enabling it to stay warmer in its cold northern habitat. Its broad-sized feet are well suited to help it travel over snowy terrain.

A jackrabbit lives in the hot, dry areas of the southwest. It has long, large ears and powerful hind feet. These ears provide a large surface area that allows excess heat to escape. The powerful hind legs enable it to outrun predators. Even though they are both members of the rabbit family, the specialized structures of the snowshoe rabbit and jackrabbit enable them to live and reproduce in different environments.

All birds have a beak but all beaks do not look the same. A goldfinch has a short beak for eating seeds. A woodpecker has a slender beak to get insects from under tree bark. A hawk has a hooked beak for ripping and tearing prey, such as rabbits.







Variations among plants can also help them with survival. Pine seedlings compete for sunlight, water, and soil nutrients. Fast-growing seedlings are more likely to crowd out their slow-growing neighbor. How does this variation help the fast-growing seedlings survive to produce offspring (seeds for a new generation of pine trees)?

Most organisms compete for resources such as food, air, water, and space. Variations that make it easier for organisms to find or use a resource are better able to survive.

The environment is constantly changing. Sometimes the changes are gradual, as in cycle of a lake’s life which gradually effects the plant and animal life that live by it. . Other changes may be sudden, such as what happens to an environment after a wildfire, flood, landslide, or violent storms, such as hurricanes.

When an environment changes, some organisms die and other organisms move to a new environment. Some have variations for better survival. The helpful variations will be inherited by some of the offspring. After many generations, most organisms in that species will have helpful variations.

Years ago, when DDT (a poison that kills insects) was used in the environment, a few mosquitoes were resistant to DDT. These mosquitoes with this variation were better suited to survive in an environment that contained DDT. They lived and produced offspring that DDT could not kill. As a result, the population, the number and kind of organisms in an area, of DDT-resistant mosquitoes has grown larger in recent years.

Plant Adaptations

Plants have adapted to a variety of environments, from the desert to the tropical rain forest to lakes and oceans. In each environment, plants have become crucial to supporting animal life. Plants are the food that animals eat. Plants also provide places for animals, such as insects and birds, to live- from tiny mosses, to gorgeous rose bushes, to extremely large redwood trees.

This flower is from an aloe plant. Aloes are succulent plants which have adaptations that allow them to store water in their enlarged fleshy leaves, stems, or roots. This allows them to survive in arid environments.

Plants live just about everywhere on Earth. To live in so many different habitats, plants have evolved adaptations that allow them to survive and reproduce under a diversity of conditions.

Most people think all plants are adapted to live on land. But are they? All living plants today have terrestrial (land) ancestors, but some plants now live in the water. They have had to evolve new adaptations for their watery habitat.

Aquatic plants are plants that live in water. Living in water has certain advantages for plants. One advantage is the water, which all plants need to survive. Therefore, most aquatic plants do not need adaptations for absorbing, transporting, and conserving water. They can save energy and matter by not growing extensive root systems, vascular tissues, or thick cuticles on leaves. Support is also less of a problem because of the buoyancy of water. As a result, adaptations such as strong woody stems and deep anchoring roots are not necessary for most aquatic plants.

Living in water does present challenges to plants, however. For one thing, pollination by wind or animals isn't possible under water, so aquatic plants may have adaptations that help them keep their flowers above water. Water lilies, for instance, have bowl-shaped flowers and broad, flat leaves that float. This allows the lilies to collect the maximum amount of sunlight, which does not penetrate very deeply below the water's surface. Plants that live in moving water, such as streams and rivers, may have different adaptations. For example, cattails have narrow, strap-like leaves that reduce their resistance to the moving water.

Water Lilies

Cattails

Plants that live in extremely dry environments have the opposite problem that aquatic plants do. The focus of plants in desert environments is how to get and keep water. Their adaptations may help them increase water intake, decrease water loss, or store water when it is available.

The saguaro cactus has adapted in all three ways. When it was still a very small plant, just a few inches high, its shallow roots already reached out as much as 2 meters (7 feet) from the base of the stem. As a full-grown plant, its root system is much more widespread. It allows the cactus to gather as much moisture as possible from rare rainfalls. The saguaro doesn't have any leaves to lose water by transpiration (taking in water through its roots and giving off water vapor through its leaves.) It also has a large, barrel-shaped stem that can store a lot of water. Thorns protect the stem from thirsty animals that might try to get at the water inside.

All living things inherit traits and instincts from their parent organisms. They can also learn different behaviors, skills, and abilities to adapt and survive in their environment. For life to go on, organisms must continue to change and adapt to the world around them using the specialized structures they have inherited and the behaviors they have learned.

5.3 Summary Section

Summary

- All organisms inherit traits from their parent organisms.
- Some instincts and traits are inherited and others are learned.
- Adaptations allow plants and animals to survive and reproduce under a variety of diverse conditions.
- Specialized structures help organisms survive in their environment.

Science Language Students Need to Know and Use

- Environment: the surroundings in which an organism lives.
- Inherited: traits or actions that a living thing is born with and does not need to learn.
- Instinct: behaviors that are inherited from the parent organism.
- Learned behavior: an action that is learned through trial and error or is brought about by the environment.
- Life cycle: a series of stages from birth to death of an organism
- Offspring: the young of an organism.
- Organism: any living thing
- Parent organisms: a producer of offspring.
- Population: the number and kind of organisms in an area.
- Specialized structures: a body part unique to a species for survival in its environment.
- Species: a certain group of plants or animals that can only reproduce among themselves.
- Survival: the continuation of life.
- Trait: characteristics that determine how an organism looks, acts, or functions.

Think like a Scientist

1. Why doesn't a cow quack and why don't puppies look kittens? Why do children look like their parents?

2. Compare and contrast learned behaviors and inherited behaviors.

3. How do inherited behaviors help organisms survive?

4. How do learned behaviors help organisms survive?

5. Why don't cactuses grow in the rainforest, and why aren't there tropical flowers in the desert?

7. Compare and contrast the adaptations of a cactus and the adaptations of a water lily.

8. How do specialized structures help organism survive in their environment? Provide examples.

Online Interactive Activities

- Review heredity and why offspring look like their parents and distinguish between physical traits and inherited traits on this site. http://go.uen.org/b07
- Video introduction to inherited traits and Punnett squares. http://go.uen.org/b09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