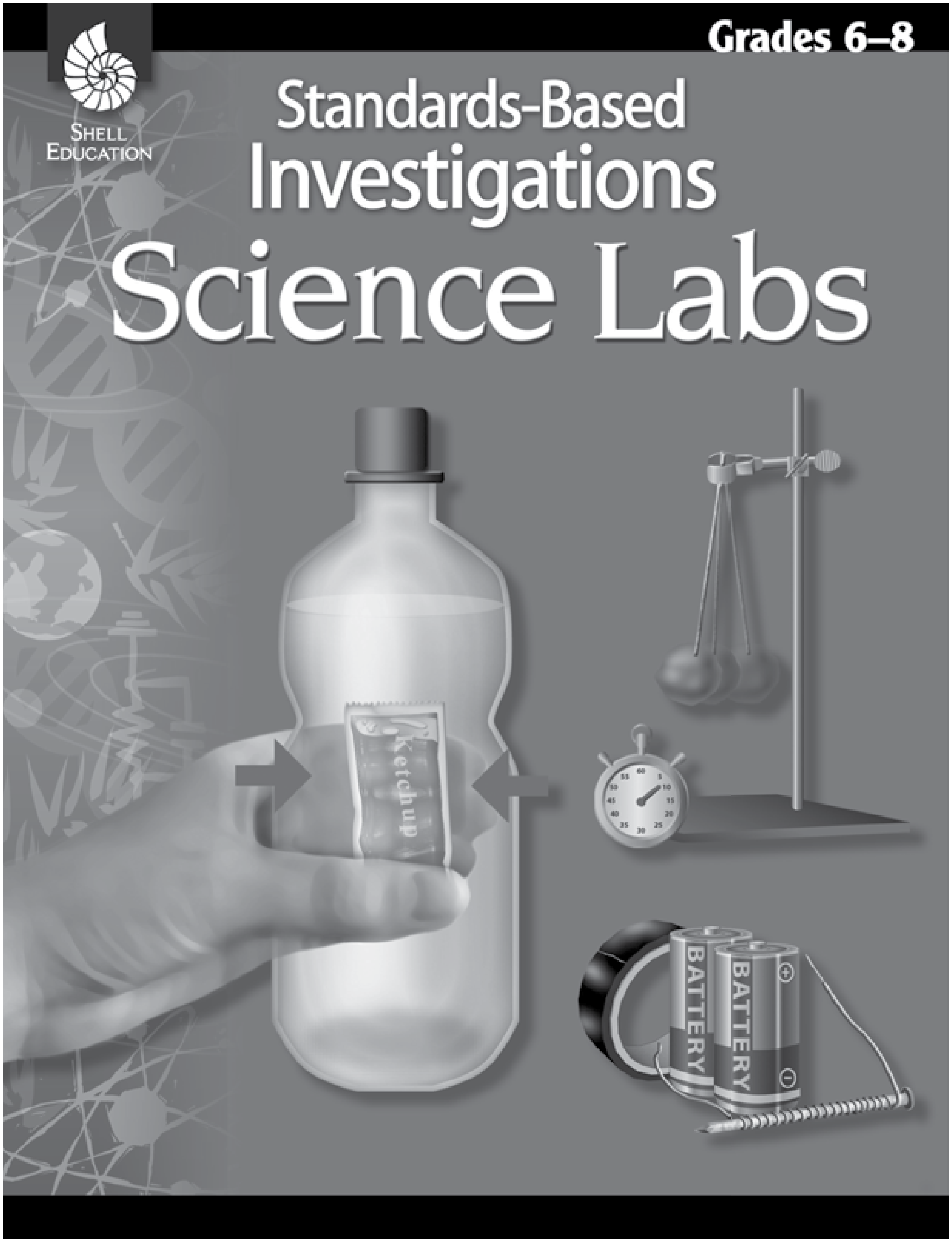
Digital Resources Included

Grades
6–8

Standards-Based Investigations
Science Labs



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Introduction and Research Base

Why a Focus on Science?

Over three decades ago, the American Association for the Advancement of Science began a three-phase project to develop and promote science literacy: Project 2061. The project was established with the understanding that more is not effective (1989, p. 4).

Inquiry-Based Learning

As Project 2061 began, researchers questioned the appropriateness and effectiveness of science textbooks and methods of instruction. Since textbook instruction puts more emphasis on learning correct answers and less on exploration, collaboration, and inquiry, the Association asserts that this manner of instruction actually "impedes progress toward scientific literacy" (1989, p. 14).

This same concern resurfaced over a decade later by Daniels and Zemelman (2004) who call textbooks "unfriendly." When most adults are choosing literature, they do not pick up their son's or daughter's science textbook. Daniels and Zemelman assert that today's textbooks are best used as reference books when students need large amounts of information on a particular topic within a subject area. Instead, they recommend the use of "authentic" sources.

Project 2061 recommends pedagogical practices where the learning of science is as much about the process as the result or outcome (1989, p. 147). Following the nature of scientific inquiry, students ask questions and are actively engaged in the learning process. They collect data and are encouraged to work within teams of their peers to investigate the unknown. This method of process learning refocuses the students' learning from knowledge and comprehension to application and analysis. Students may also formulate opinions (synthesis and evaluation) and determine whether their processes were effective or needed revision (evaluation).

The National Science Education Standards view inquiry as "central to science learning" (p. 2 of Overview). In this way, students may develop their understanding of science concepts by combining knowledge with reasoning and thinking skills. Kreuger and Sutton (2001) also report an increase in students' comprehension of text when knowledge learning is coupled with hands-on science activities (p. 52).

Values, Attitudes, and Skills

Scientists work under a distinctive set of values. Therefore, according to the American Association for the Advancement of Science, science education should do the same (1989, p. 133). Students whose learning includes data, a testable hypothesis, and predictability in science will share in the values of the scientists they study. Additionally, "science education is in a particularly strong position to foster three [human] attitudes and values: curiosity, openness to new ideas, and skepticism" (1989, p. 134). Science Labs addresses each of these recommendations by engaging students in thought-provoking, open-ended discussions and projects.

Within the recommendations of skills needed for scientific literacy, the American Association for the Advancement of Science suggests attention to computation, manipulation and observation, communication, and critical response. These skills are best learned through the process of learning, rather than in the knowledge itself (1989, p. 135).

Water Cycle

This chapter provides activities that address McREL Science Standard 1.

Student understands atmospheric processes and the water cycle

Knows the composition and structure of the Earth's atmosphere	*How Is the Sun Like Baseball?, page 15*
Knows the processes involved in the water cycle and their effects on climatic patterns	*Rocks: What Are They Good For?, page 12* *How Is Rain Made?, page 14* *How Does a Greenhouse Work?, see Teacher CD*
Knows that the Sun is the principle energy source for phenomena on the Earth's surface	*How Is the Sun Like Baseball?, page 15* *How Is Sunlight Passed Around?, page 106*
Knows factors that can impact the Earth's climate	*What Do Greenhouse Gases Do?, page 19*
Knows how the tilt of the Earth's axis and the Earth's revolution around the Sun affect seasons and weather patterns	*How Is the Sun Like Baseball?, page 15*
Knows ways in which clouds affect weather and climate	*How Is the Sun Like Baseball?, page 15*
Knows the properties that make water an essential component of the Earth system	*How Can I Build a Water Molecule?, page 21* *How Does Water Stick Together?, page 24* *How Is Water the "Universal Solvent?", page 28* *How Does Water Move?, page 30* *How Does Floating Work?, page 32*

How to Teach the Water Cycle

Dihydrogen Oxide

Dihydrogen Oxide, AKA H_2O, AKA water, is a familiar material which offers a wealth of opportunities for play and exploration. Students will have seen water in several different forms—liquid water, solid ice, and gaseous steam. Water changes state easily, back and forth, from one form to another. Other materials do the same—wax and chocolate, for example. But only water easily offers all three states—solid, liquid, and gas—in our everyday experience. And it's never possible to get the wax and chocolate back just the way they were!

Water

Water is the liquid state of the material. Liquid water is essential for life. Liquid water takes the shape of the container in which you put it, whether it be a bucket, cup, or jug. It flows downhill, but it won't go up except in a flood (although you can make a continuous column of water flow over and down if you use a siphon). Students will have had a lot of experience with water and its qualities in the bath, swimming pool, and ice cube tray.

Ice

Ice is the solid form of water. It is formed when pure water drops in temperature below 0°C (32°F). An amazing quality of water is that it expands as it freezes—tops are pushed off milk bottles and car radiators can be cracked. Frozen water takes up more space than it did as a liquid. As a result, the ice is less dense than water—the same amount of mass in a larger volume.

Steam

Strictly speaking, the billowing clouds that come from a boiling kettle are water vapor. Steam itself—water in its gaseous state—is invisible. You can see where it is by looking carefully at the spout of a boiling kettle—you can just see a clear space between the spout and the vapor. This invisible gas is true steam.

The stuff that fills the bathroom, making condensation run down the cold mirror and windows, is water vapor—liquid water in tiny droplets. It condenses on cold surfaces. This process is called condensation, and the liquid that condenses is called condensed water. However, if you tell your neighbors that you are having trouble with condensed water on your double-glazing, they may think you're a bit of a show off.

Lighter than Water

Water particles bonded together make ice. Unfortunately for the *Titanic*, ice is lighter than water. This is a very unusual but important fact that comes up time and again in this book. It is very unusual for a solid material to weigh less than its liquid. Apart from water, only a material called bismuth behaves like this. (You might have come across this pinkish metal if you have had a gastric ulcer. It is used in soothing medicines.)

Once you understand particle theory, you can understand why this should be. When water freezes, its particles form a kind of cage—a rigid pattern in which the particles are held away from each other. So there is more space in an ice cube than there is in water.

Where Does Rain Come From?

Rainwater isn't new. It's been round and round the water cycle forever. All of Earth's water is trapped in this endless cycle of change. When you drink a glass of water, you can be fairly sure that at least one of the molecules at one time was part of the water drunk by a hero of yours, or by a historical character.

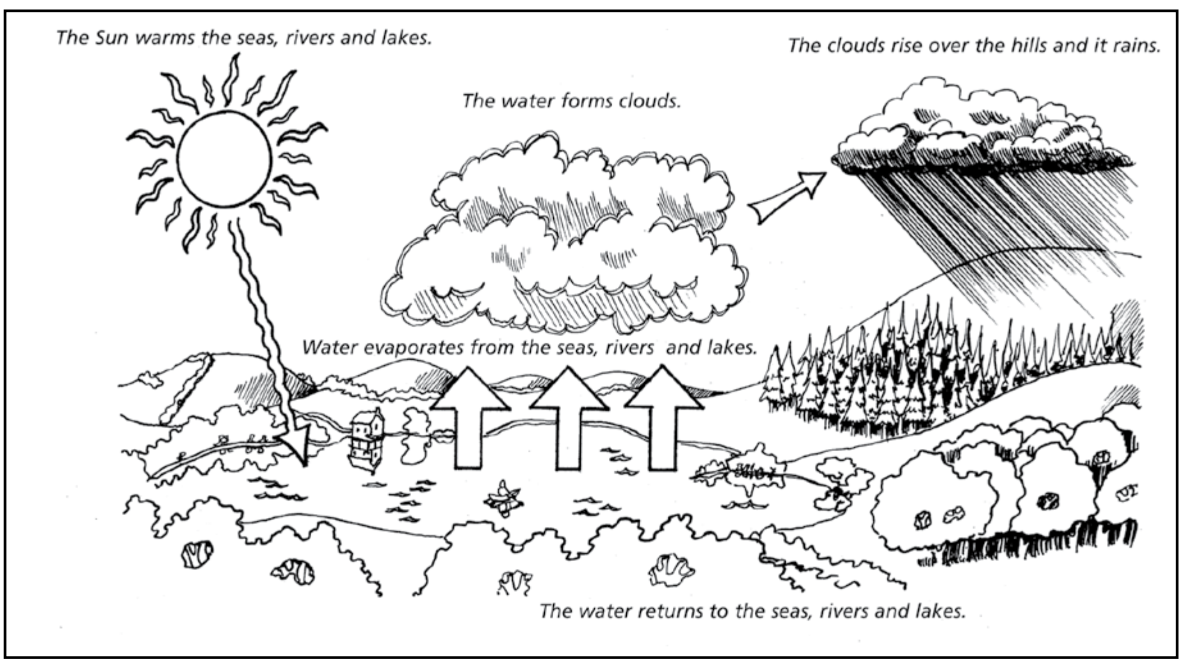
It's statistically likely. It has been estimated that a molecule of water from a glass poured into the sea at New York will wash up on the beach in California in a matter of months. On the way, it will have had amazing adventures—as part of the sea, a pond, a river, a cup of tea, or a glass of cola.

You don't have to look far to see examples of the water cycle all around you. Consider, for example, getting caught out in the rain. When you get home, you take off your wet clothes and put them in the washing machine. By the time you have done this, the weather has brightened up, and you hang the clothes outside to dry. The water returns to the sky. These simple actions demonstrate a simple water cycle. While the basic story of the water cycle is the same, the variations are enormous.

Water Evaporates

Molecules of water close to the surface are in constant movement. If they have enough energy, they break free of the water and lift into the sky. This can happen at any time. If you leave a saucer of water on a windowsill, meaning to put a potted plant in it later, the water will evaporate at room temperature. By the time you put the potted plant there a day or two later, the water level will have dropped. The water is evaporating.

Evaporation happens much faster if you put a bit of energy into the system. If you heat the water, the molecules get excited and break off with far more regularity. The water may "steam." It loses water molecules fast and if you are not careful, it will boil dry. The more energy you apply, the faster the evaporation. Boiling



water is losing molecules fast. While they are above boiling point, the water molecules are actually a gas—water gas.

What's in a Cloud?

You have probably flown through a cloud if you have flown in an airplane. But you have also walked through one if you have seen mist or fog on the ground. Both clouds and mist are made up of water vapor, condensed into minute water particles that float in the atmosphere or roll across the hills.

As the water vapor rises, it cools, and it clumps or condenses, often around tiny dust particles. The smog of the big cities is caused by water condensing around waste from fires or car exhaust.

The cloudiness of water vapor is what makes it hard to see on misty days. If there is a fair amount of water vapor in the air, it is hard to see great distances. When you visit a hot, dry country, you may be astonished by the clarity of distant things and the sharpness of the colors. There is little water vapor in the air to spoil your view.

So the water cycle starts when the water around us—in the seas, rivers, streams, ponds, swimming pools, and even in that dish on the windowsill—evaporates from the surface and rises into the sky, to form clouds.

There's a big role for trees here, as they pull water from the ground and lose it through their leaves—a process known as transpiration.

A handy spin-off of this evaporation process is that the water that rises into the atmosphere is clean. It has left all its impurities behind. There are even rings of impurity left on that saucer. The pure water has gone up to form clouds.

Down Came the Rain

Clouds are unstable. As they rise and cool, the water condenses. Droplets run together to form bigger and bigger drops. Finally, these drops are so big that they can no longer hang in the air, and they fall as rain.

Condensing is the process of combining the water molecules. You see it taking place in your bathroom. Reaching a cold surface, water vapor from your shower condenses into water droplets, and these run down the mirror or window. We call these droplets (incorrectly) condensation. In fact, it is condensed water. It's the process that is condensation.

Up in the clouds, the condensed water droplets start to fall. Because this usually happens at quite a height, it is more likely to occur in mountainous or hilly places, or close to them.

If clouds are carried by the wind over high ground, they may rise higher and higher, getting colder and colder. The water vapor freezes. (Snow is frozen vapor, not frozen liquid.) and a crystal of ice is formed in these high clouds. As updrafts push the clouds higher still, more water vapor joins the crystals, and when they are too heavy to be suspended any longer, they fall as snow. If more water gathers around the frozen particle, it forms a hailstone.

Rivers and Streams

Once it has fallen as rain, the water's journey is far from over. Many possibilities arise. A droplet of rain may join a stream or river. It may soak into the ground, only to pop up somewhere else in a spring or well. It may scarcely touch the earth, hardly arriving before it evaporates away again.

Or it may start a long adventure that includes pushing a turbine around to generate electricity, being boiled for a cup of tea, passing through one or more humans, being cleaned in a sewage treatment plant, falling through a shower head, and being mixed with lemonade mix. It may wash your car, water your garden, or boil your potatoes. It may be drawn into a plant and combined with oxygen to produce more plant material and food for animals. Eventually, it may find itself back in the sea. And the whole cycle begins again.

A drop of water may travel thousands of kilometers between the time it evaporates and the time it falls to earth again as rain or snow. On the way, it may be partly responsible for some extreme weather conditions.

Storms

Thunderstorms are heavy storms with rain, thunder, and lightning. We usually get them in the summer because then the ground gets hot, and the rising warm air forms tall clouds with a flat "anvil" top. Electricity crackles in these clouds, caused by water particles rubbing together. When the charge has built up, it snaps to the ground as a flash of lightning. The air heated by the lightning flash creates shock waves that we hear as thunder.

Lightning travels at 140,000 km per second. That's half the speed of light. While the streak is very narrow (less than two cm wide), it can be 43 km long. You can survive being hit by lightning as long as it goes to Earth without passing through your heart. Park ranger Roy Sullivan claimed to have been hit by lightning seven times between 1942 and 1977.

Counting the seconds between flash and bang can give you an idea of the distance between you and a storm. Allow three seconds for a kilometer and five seconds for a mile.

Thunderclouds can grow to be 15–20 km high. Their anvil shape is caused by high winds at that height, blowing the top sideways. Some of the water in them stays unfrozen, even at minus 40°C. But clouds also contain fragments of ice that are growing onion-like, layer by layer. They then may become too heavy to be held up by currents of air and so fall to the ground as hail. If the air currents are really fast (as much as 145 kph), the hailstones may grow to the size of oranges before they drop from the cloud.

Hurricanes and Tornadoes

A hurricane (called a typhoon in the Northern Pacific and a cyclone in the Indian Ocean) originates close to the equator when a central calm eye is surrounded by inwardly spiraling winds. As the sea temperature rises, water evaporates into whirling, unstable storm clouds. A hurricane is a wind of force 12 or more on the Beaufort scale and is accompanied by lightning and torrential rain. Hurricane Gilbert in the Caribbean in 1988 gusted up to 320 kph. A cyclone in the Bay of Bengal in November 1970 caused the sea to rise ten meters, crashing into the Ganges delta to drown at least 300,000 people and one million farm animals.

The Seasons

Earth is going around the Sun. The time it takes to complete a full orbit—365 and a quarter days—we call a year.

Earth's axis is at a slight angle to the Sun. This angle stays the same as Earth orbits the Sun. Any point on Earth's surface will spend some of the year leaning towards the

How to Teach the Water Cycle *(cont.)*

Sun and in strong sunlight. This is summer in this part of Earth. It will spend some of the year leaning away from the Sun, and then it will be winter in this part of Earth.

Daylight hours are longer in the summer and shorter in the winter. Between the summer and the winter is spring, when daylight hours get longer and it gets warmer, and autumn, when daylight hours get shorter and it gets colder. On one day in the spring and one in autumn, day and night are exactly the same length. These days are called the equinoxes.

Daylight Times

In the summer, the Sun shines early in the morning. The evenings are long and children play outside until quite late. You may even go to bed while it is still light outside. Then in the winter, daylight time is shorter. The mornings are dark and you spend the evenings indoors.

Earth is tilted as it orbits the Sun. In the summer, the Sun appears in the sky for longer and climbs higher. In the winter, the Sun appears in the sky for a shorter time and does not climb so high. The changes in daylight time follow a pattern, and it is possible to predict this pattern to the minute.

Here are some sunrise and sunset times for London in the month of June 2000. The sunrise times are the time to the minute that the Sun rose. So on June 8, 2000, the Sun rose at 4:44 in the morning—nearly a quarter to five. The sunset times are the times the Sun set. So on June 8, 2000, the Sun set at 20:14 (8:14 at night), or nearly a quarter past eight.

Date	Sunrise	Sunset
1st	04:48 A.M.	8:08 P.M.
8th	04:44 A.M.	8:14 P.M.
15th	04:42 A.M.	8:19 P.M.
22nd	04:43 A.M.	8:21 P.M.
29th	04:47 A.M.	8:20 P.M.

Rocks: What Are They Good For?

Name ________________________________

What You Need:

- two pots
- a tray big enough for both pots
- soil
- two small plants
- small pebbles
- water

What To Do:

1. Fill the pots halfway with soil.
2. Dig a little hole in each pot and place a plant in each.
3. Cover the soil in one pot with pebbles. Leave the other pot with just soil.
4. Place both pots on the tray and put them outside or by a sunny window. Water them both.
5. Leave the plants alone for two weeks. Do not water them. Observe what you see. Draw the plants at three stages of the experiment.

Plant with Rocks	Plant with No Rocks
Start of Experiment	Start of Experiment
Soil is:	Soil is:

Rocks: What Are They Good For? *(cont.)*

What To Do: *(cont.)*

Plant with Rocks	Plant with No Rocks
End of Week One	End of Week One
Soil is:	Soil is:

Plant with Rocks	Plant with No Rocks
End of Week Two	End of Week Two
Soil is:	Soil is:

Next Question

Do different kinds of rocks or different sizes of rocks produce different results? Design and perform an experiment to find out.

Notebook Reflection

What conclusions can you make based on your results? How could your findings be used by a landscape architect designing a garden? What could your findings tell a scientist studying a forest?

How Is Rain Made?

Name ______________________________

What You Need:

- metal bowl
- boiling water
- ice cubes in ice cube tray
- a scale

What To Do:

1. Weigh the filled and frozen ice cube tray. It weighs ______________________ .
2. Put the metal bowl on the scale.
3. Pour boiling water into the metal bowl. The water weighs ________________ .
4. Wearing the oven mitts, hold the ice cube tray above the bowl.
5. Observe what happens. Draw it in the space below.

6. Weigh the ice cube tray again. It weighs _______________________________ .
7. Weigh the metal bowl filled with water. It weighs ______________________ .

Next Question

Did any of the water in the ice cube tray escape? What about the water in the bowl? Where are the water drops coming from?

Notebook Reflection

Imagine you are a molecule of water in the water cycle. Describe your trip from the oceans, into the clouds, falling as rain, and flowing through rivers back to the ocean.

How Is the Sun Like Baseball?

Name ______________________________

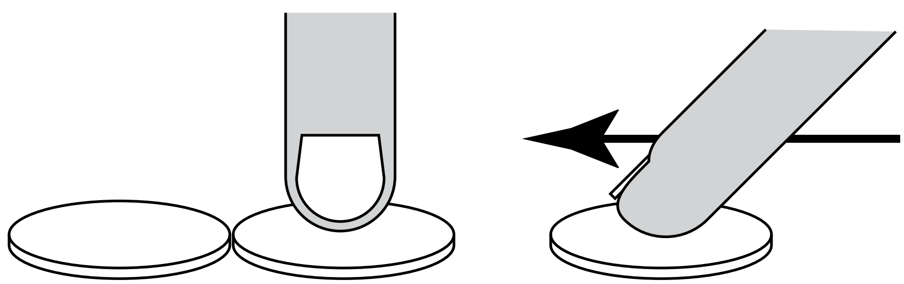
What You Need:

- 3 pennies
- notebook paper
- game sheet (page 18)

What To Do:

1. Split into groups of four people. Each person in the group then picks his or her team. The teams are: Water Cycle, Winds, Ocean Currents, and Plant Growth. Go to Batting Practice to warm up for the game.

2. Batting Practice: Put three pennies together in a line so that they are touching. Use one index finger (pointer) to push down on the center or anchor penny. This will lock that penny into place and keep it from moving. Use the index finger on the other hand to slide one of the outside pennies (the energy delivery penny) away from the setup. Hold the energy delivery penny off to the side for a second and then slam it into the anchor penny.



The energy that gets delivered to the third penny (the traveling penny) will make it move even though the center (anchor) penny stays absolutely still. This is also a model for a fusion reaction in the Sun. The traveling penny also represents atomic particles and solar energy that blast away from the Sun.

3. Batter up! Take turns batting. One person bats by aiming (moving) the anchor penny and the energy delivery penny, to try to send the traveling penny into the scoring zone for his or her team. The batter is trying to add energy to that zone by using the model of nuclear fusion. The Water Cycle batter aims for the Water Cycle zone, etc.

What To Do: *(cont.)*

4. If the traveling penny ends up in the correct zone, the batter will be able to advance one base.
5. Keep track of your position and score by writing the base (1st, 2nd, or 3rd) and the effect of that base on a sheet of notebook paper. Use the Scorecards below to find the effect of each base in each zone.

Winds		Water Cycle	
1st	Thermals make hot air rise.	1st	Groundwater evaporates.
2nd	Cooler air sinks.	2nd	Cool air condenses the water vapor into clouds.
3rd	Coriolis effect spins air.	3rd	Precipitation falls.
Run	Trade Winds Blow!	Run	Water Cycle Completed!
Ocean Currents		**Plant Growth**	
1st	Hot waters along the equator (a) rise and (b) power hurricanes.	1st	Photosynthesis charges electrons with enough energy to make ATP.
2nd	Gulf Stream delivers energy (heat) to England's climate.	2nd	Sugars and carbohydrates are synthesized.
3rd	Cold, dense water sinks off the Labrador coast.	3rd	Energy is used for cell division and other processes.
Run	Great Ocean Conveyor Belt established!	Run	Solar energy is stored as chemical energy in fruit and stems.

How Is the Sun Like Baseball? *(cont.)*

What To Do: *(cont.)*

6. If the penny ends up touching a line or travels out of the zone, the batter does not advance. The attempt will count as a strike. Three strikes and the batter is Out! and must step out of the batter's box.

   Sorry. There are no home run hits at this ballpark. If the traveling penny is sent out of the park, that means that so much energy came from solar flares, or another star close by going supernova, that everything on the surface of the Earth got fried.

7. After a player bats one time, it is the next player's turn to bat. Play until one team scores five runs.

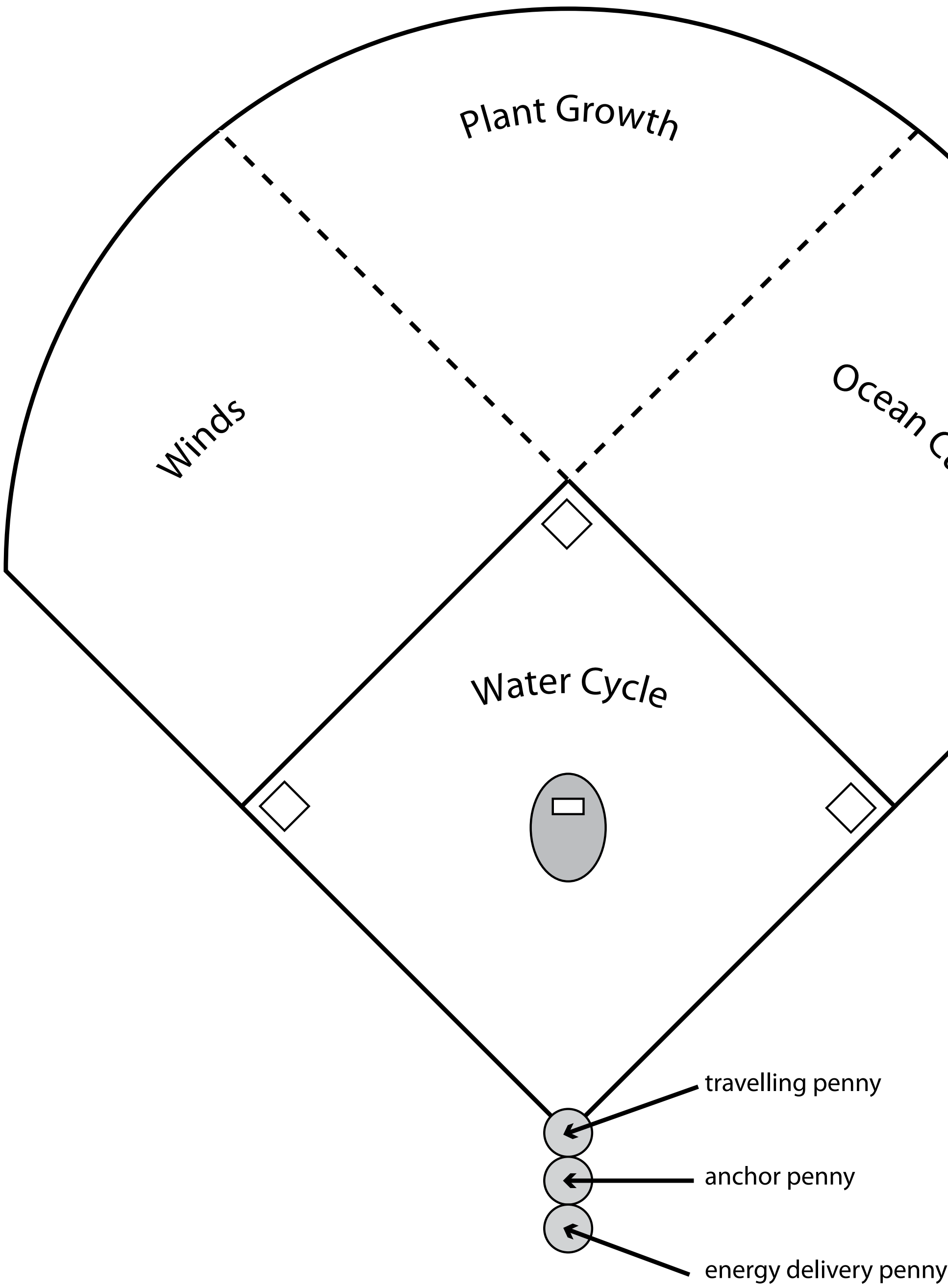
Next Question

Use classroom resources and the Internet to research one of the following questions: Does the Sun release the same amount of energy all the time? What effect do sunspots have on the energy output? Is there any connection between solar energy output variations and ice ages, droughts, or massive extinctions?

Notebook Reflection

Look up and write down the definitions of the base terms. Draw a diagram showing each system. Remember to show how the Sun is the major source of energy for all these systems. Draw a diagram showing the part that convection cycles play in the winds and ocean currents processes.

How Is the Sun Like Baseball? *(cont.)*



What Do Greenhouse Gases Do?

Name ________________________________

What You Need:

- three large plastic jars, all the same size
- three thermometers
- tape
- spray cans with hydrocarbon propellants
- smoke

What To Do:

1. Use tape to hang the thermometers from the lid inside each jar.
2. With an adult's help, fill one jar with smoke and another jar with hydrocarbons from the spray can. Put lids on all three jars.
3. Place the three jars out in the Sun. Make sure you can read the thermometers without moving the jars.
4. Predict which jar will have the highest temperature over three days.

   ______________________________ will have the highest temperature because

   ____ .
5. Measure the temperature of each jar throughout the day for three days.

	Smoke Jar	Hydrocarbon Jar	Air Jar
Day 1, Reading 1			
Day 1, Reading 2			
Day 1, Reading 3			
Day 2, Reading 1			
Day 2, Reading 2			
Day 2, Reading 3			
Day 3, Reading 1			
Day 3, Reading 2			
Day 3, Reading 3			
Average Temperature			

What Do Greenhouse Gases Do? *(cont.)*

What To Do: *(cont.)*

6. Was your prediction correct? Why? ____________________

____

____

____

____

Next Question

Use the Internet or classroom resources to research greenhouse gases and air pollution. Find out about the Kyoto Protocol. Write a report on the subject using your three jars as examples.

Notebook Reflection

What do you think was happening inside the three jars? Why were some hotter than others?

How Can I Build a Water Molecule?

Name ________________________________

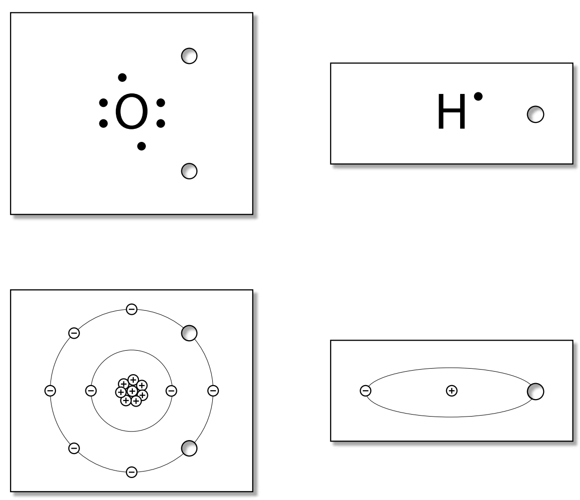
What You Need:

- index card
- scissors
- hole punch
- paper clips
- small disk magnets
- thread

What To Do:

1. Cut an index card in half, lengthwise. Then cut one of the halves in half horizontally.

2. The big piece represents an atom of oxygen. On the lined side of this piece write "Oxygen" and draw the Lewis diagram (electron dot diagram) of this atom. Each dot represents pairs or single electrons that orbit the atom's nucleus.



3. On the blank side, draw eight protons marked + in the center of the card. Eight is the atomic number of the element and represents how many protons are in the nucleus of an atom of oxygen. The plus sign is used to illustrate that protons have a positive charge.

4. Draw a circle around the nucleus with two electrons marked –, one on the right side and one on the left side of the circle. Electrons have a negative charge.

5. Draw a bigger circle around that. Draw six electrons on the circle: top, bottom, left, right, upper left, and lower left.

What To Do: *(cont.)*

6. The second or outer circle (also called an energy shell) could hold eight electrons but only has six. Use the hole punch to put two holes on the right side of the circle.
7. Both of the small pieces of the index card represent hydrogen atoms. On the lined side of each small piece, write "Hydrogen" and draw the Lewis diagram (electron dot diagram) of this atom.
8. On the blank side of the card, draw one proton marked + in the center of the card. Hydrogen only has one proton and one electron.
9. Draw an oval around the proton. This energy shell could hold two electrons, but hydrogen has only one. Draw one electron marked – on one end of the oval and use a hole punch to make a hole in the opposite end.
10. Put one magnet on the desk and get it to move around by repelling it with another magnet. This is a model of why only two electrons would fit in the first circle or orbit of an atom. Any more would just repel each other.
11. Place a magnet on one of the holes in the big circle (the second shell) of the oxygen card. Place it with the north pole up. Place another magnet on the electron on the hydrogen card. Place it south pole up. Slowly slide the cards toward each other. Describe what happens.

    ____

    ____

12. Electrons are drawn to the outer shells of other atoms so the outer shells become filled. Slide the hydrogen card under the oxygen card so you can see the hydrogen's electron through one of the holes in the oxygen card. Use tape to keep the hydrogen card in place. Repeat this with the second hydrogen card.
13. The oxygen atom is much more massive than hydrogen. Because the hydrogen atoms tend to be pulled toward it and to be grouped on one side of the oxygen, a weak polarity is established. This makes the right side of the hydrogen atom have a slightly positive charge. Because the left side of the oxygen atom is experiencing the same effect, it has a slightly negative charge. It is this weak,

How Can I Build a Water Molecule? *(cont.)*

What To Do: *(cont.)*

unbalanced polarity (like magnetic poles) that makes water so unique. Draw a positive sign (+) on the right side of each hydrogen atom and a negative sign (–) on the left of the oxygen atom.

14. Punch holes next to the + and – signs. Thread paper clips into the holes. The paper clips represent the molecule's ability to attach to other atoms and molecules.

15. Draw a diagram of your result:

Next Question

Use classroom resources and the Internet to research hydrolysis. How would hydrolysis affect your water model?

Notebook Reflection

Draw a diagram of H_2O and label the parts—atoms, protons, neutrons, and electrons. Include the charges of each subatomic particle.

How Does Water Stick Together?

Name ______________________________

What You Need:

- penny
- eyedropper
- notebook paper
- paper towel

1. Place the penny on the paper towel "tails" side up. Make sure the penny is clean and dry. Do not use soap to clean the penny.
2. The goal is to see what happens when drops of water are piled up on top of a penny. Before beginning to drop water, write a prediction (hypothesis) of how many drops you think will fit before all the water spills over the edge of the penny.

   Hypothesis: ____

   ____
3. Move the eyedropper close to the penny. Gently add five drops to the top of the penny. Draw what the water and penny look like.

How Does Water Stick Together? *(cont.)*

What To Do: *(cont.)*

4. Add five more drops to the top of the penny. If the eyedropper is too high or too far away from the penny, the speed of the falling drops may ruin the demonstration. Make sure that all arms are off the table or desk! Any shaking will also cause the water to fall apart. Draw what the water and penny look like.

5. Are the water molecules spreading out or are they starting to stick together?

____

What To Do: *(cont.)*

6. Add five more drops to the penny, draw it, and add five more drops. Draw each stage.

7. Look closely at the penny through the water bulge. If the penny is clean enough and new enough, you might be able to see the face of Abraham Lincoln looking back at you. He can barely be seen between the middle columns in the Lincoln Memorial building that is in Washington, D.C. Why do you think the image is magnified? ______________________________

____

8. Keep adding drops of water to the penny. Do this slowly and gently so that as many drops fit on the penny before the water spills over. As soon as it spills over, write the actual number of drops it took. How close was your hypothesis?

____

9. Dip one corner of the paper towel into the water. Describe what happens to the water.

____

____

What To Do: *(cont.)*

10. Very, very slowly, lift the paper towel a short distance out of the water. Notice how the water sticks to the bottom of the towel as long as it can. Draw what happens.

Next Question

Place a piece of cardboard over a cup filled halfway with water. Hold everything over the sink while you carefully and gently turn the cup and cardboard completely over. Gently remove your hand. What happens?

Do not try this over the head of another student—unless you are outside on a warm day, have the teacher's permission, have a towel, and have the absolute permission of the brave student under the water!

Notebook Reflection

Look up and write down the definitions of adhesion, cohesion, and surface tension. Draw a diagram representing those effects at work in the lab. Draw a raindrop and explain its shape using the terms above. Write about what it feels like to be in water—how does it feel against your skin?

How Is Water the "Universal Solvent?"

Name ______________________________

What You Need:

- 1 nine-ounce plastic cup of water
- ground black pepper
- one drop of liquid dish soap
- blue painter's tape
- string
- marshmallow or a piece of clay
- scissors
- water molecule model (see page 21)

1. Pour water into the plastic cup.
2. Gently sprinkle the ground black pepper over the surface of the water. The pepper should float on top of the water.
3. Drop one drop of dish soap in the center of the cup. Draw a diagram of what happened. Note how much time it took for this action to happen.

4. Based on what you know about the behavior of water, write down why you think this happened.

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What To Do: *(cont.)*

5. With a partner, tear off a square of blue painter's tape and stick it on top of your water molecule models. This represents the pepper floating on the water molecules in your cup.

6. String your water molecule models onto a string so that one molecule's positive end is next to the other molecule's negative end. Hold the string tightly between you. Since the water molecules have polarity, how do they act toward each other? ____

____

7. Squeeze a marshmallow onto the string between your molecules. This represents a soap molecule. Soap molecules can attach to one water molecule, but not two. What happens to how your two water molecules act? __________

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8. Your pull on your end of the string can represent the pull of all the other water molecules in the cup. The two molecules on the string no longer attract each other, but the rest of the water does. Cut the string. What happens to the water molecules and the blue tape "pepper" on top?

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Next Question

Use classroom resources and the Internet to research water's role in life. Why is it important for living things to have so much water available? What happens to organisms if they don't have enough water?

Notebook Reflection

Draw a diagram on a molecular level of what happens when the dishes get washed at home. Include water attaching to grease molecules and soap breaking the bonds of water molecules.

How Does Water Move?

Name ______________________________

What You Need:

- small cup of water
- strip of coffee filter
- water-based marker
- notebook paper
- water molecule model (see page 21)

What To Do:

1. About one and a half inches from one end of the coffee filter strip, write down the initials (or names if they fit) of the individual or group with the water-based marker.
2. Place that end of the coffee filter strip over the edge of a small bowl of water so that it just dips into the water. Lay the rest of the filter out of the bowl so that the dot is on the downward side of the strip.
3. Watch this setup for a while. Write down what happens to the water and the coffee filter over time. Draw what happens to the "black" initials.

What To Do: *(cont.)*

4. If time runs out for this activity, leave the coffee filter where it is. Because the strip has the name or initials on it, finding it will not be difficult later in the period. It will be worth a second look.
5. Find another student and use the paper clips on your water molecule models to connect the positive side of the hydrogen atoms to the negative side of an oxygen atom. Keep matching up atoms, positive to negative, until a long chain of water molecules is created. How might this be related to what happened to your initials?

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Next Question

How could you make water "travel" from one glass to another by using these principles?

Notebook Reflection

Write about a time when something, a sock, a paper towel, etc., got left somewhere and it "soaked up" water. Describe what happened in steps.

How Does Floating Work?

Name ________________________________

What You Need:

- small paper clip
- various small items for float or sink tests
- cup of water
- notebook paper
- water molecule model (see page 21)
- small, cheap magnets

What To Do:

1. Write down a prediction (hypothesis) of what will happen if the paper clip gets put in the water. Will the paper clip, which is made of metal, sink or float?

____

2. Make sure the paper clip is dry. Gently and slowly place the paper clip flat on the top of the water. Describe what happened to the paper clip.

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3 Gather other materials (erasers, coins, buttons, etc.). Before each item is put in the water, write down a prediction whether the object will sink or float. After placing each item in the water, describe what happened to the object in relation to the cohesion of the water molecules.

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4. Talk about all of the float/sink tests. Write down anything that seems like a general rule that might apply to the whole sinking and floating business.

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How Does Floating Work? *(cont.)*

What To Do: *(cont.)*

5. Together with other students, use the paper clips on your water molecule models to connect the positive side of the hydrogen atoms to the negative side of an oxygen atom. Keep matching up atoms, positive to negative, until two long chains of water molecules are created. Hold the chains between you and a partner. Have another student place a piece of paper, a paperback book, or even a broomstick across the chains. What happens? How might this relate to Steps #1–#4?

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Next Question

Try the experiment again using a cup of syrup or a cup of very salty water. Do you get different results? Considering how you were able to make chains of water molecules, what conclusions can you draw about syrup and saltwater?

Notebook Reflection

Compare the paper clip to other metal things (e.g., battleships and aircraft carriers). Describe what happened, using the ideas behind cohesion and buoyancy, when the Titanic floated and when it sank.

Geology

This chapter provides activities that address McREL Science Standard 2.

Student understands Earth's composition and structure.

Knows that the Earth is comprised of layers including a core, mantle, lithosphere, hydrosphere, and atmosphere	*How Is Earth Like a Book?, page 39*
Knows how land forms are created through a combination of constructive and destructive forces	*How Can I Eat Seattle?, page 44* *How Do Stalagtites and Stalagmites Form?, see Teacher CD*
Knows components of soil and other factors that influence soil texture, fertility, and resistance to erosion	*What Makes Soils Different?, page 42*
Knows that the Earth's crust is divided into plates that move at extremely slow rates in response to movements in the mantle	*How Is Earth Like a Book?, page 39* *How Can I Eat Seattle?, page 44*
Knows processes involved in the rock cycle	*How Are Igneous Rocks Formed?, page 47* *How Are Sedimentary Rocks Formed?, see Teacher CD* *How Are Metamorphic Rocks Formed?, see Teacher CD*
Knows how successive layers of sedimentary rock and the fossils contained within them can be used to confirm the age, history, and changing life forms of the Earth	*How Is Earth Like a Book?, page 39* *What Can I Find by Digging Up Climatasaurs?, page 48*
Knows that fossils provide important evidence of how environmental conditions have changed on the Earth over time	*What Can I Find by Digging Up Climatasaurs?, page 48*

How to Teach Geology

Is Soil Made from Dinosaur Droppings?

We live on a rocky planet. Wherever we are, even in the middle of the ocean, there are rocks beneath our feet. These rocks were formed as Earth began to cool.

That cooling process is far from over. Under the hard, cold crust of Earth, the mantle and core of the planet are still intensely hot. They are so hot that molten rock periodically bursts through the crust as volcanoes.

Much of the rock on Earth's surface was formed from this original material, the so-called igneous rocks. But some have been eroded, transported, and laid down in layers of sediment (sedimentary rocks). Some of these have been subjected to intense heat and pressure and have changed or metamorphosed (metamorphic rocks).

Rocks are constantly being broken down. The final product of this breakdown is soil or "earth." Unlike the student who guessed that earth was made of dinosaur droppings, we know that soil is a rich, complex material.

Beneath Our Feet

Earth is like a giant soft-boiled egg. Earth's core—the yolk of the egg—is incredibly hot and liquid. Earth's mantle—the white of the egg—surrounds it and is also hot and liquid. It breaks out in places as volcanoes.

Earth's crust—the shell of the egg—is cold and hard. It is made from solid rock. Wherever you are on Earth, even if you are on a ship in the middle of the sea, there is rock beneath you. You are on solid ground.

Just a minute. The school field isn't rock, nor is the park or the garden. That's because the rock is covered with a layer of earth or soil. If you dig down through this soil, you will find rock under it. Everywhere.

Plate Tectonics

About 200 million years ago, the landmasses of Earth were together as one supercontinent. This single landmass was called Pangea. We also know that the hot, molten magma under the surface of the crust pushed the lands apart. And this motion continues today!

The mid-ocean ridge is a huge underwater mountain range. It has a large crack running down its center. That crack is in Earth's crust. It allows molten magma to seep up. When magma reaches the surface, it is called lava. The lava cools and forms new rock on the ocean floor.

Molten magma rises to the surface through cracks in Earth's crust. This makes new crust. Does that mean there is more crust on the surface of Earth now than in the past? No. Geologists had a theory. If Earth oozed molten magma in one place, then it must reabsorb crust somewhere else.

Sure enough, studies began to show that the Atlantic Ocean floor is expanding. But the Pacific Ocean floor is shrinking. It was found that the Pacific Ocean floor dives down into deep trenches under continents. These trenches are called subduction zones. The expanding and shrinking ocean floors are an example of how Earth is really a recycler. Rocks are created and later recycled.

There are two basic types of plates on Earth. Oceanic plates are under the ocean water. Continental plates make up the continents. Plates have three main types of boundaries, or edges. They are divergent, convergent, and transform.

- Divergent boundaries are where two plates move away from each other.
- Convergent boundaries are where two plates crash into each other.
- Transform boundaries are where two plates slide past each other.

Each boundary behaves in a different way. The different boundaries can be found all over the world. The boundaries also make land features such as mountains and valleys.

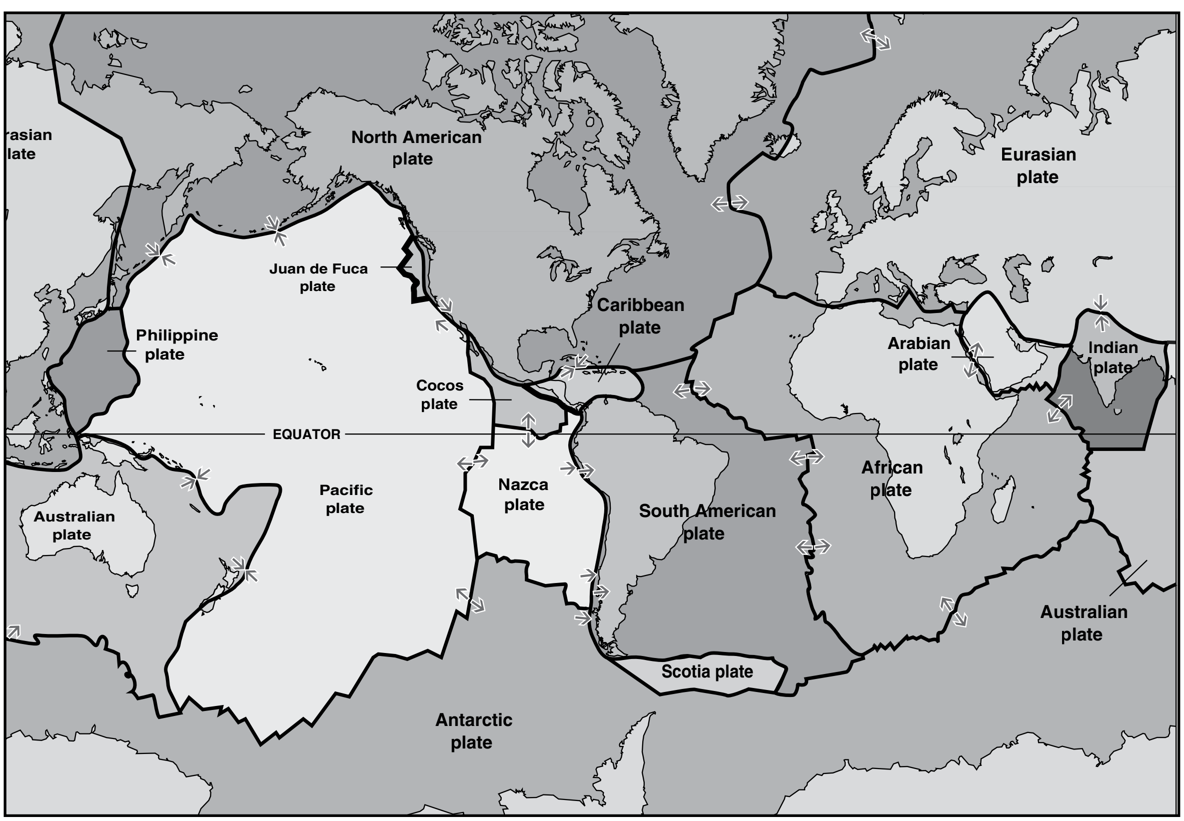
Divergent Boundaries

Iceland is a tiny island made from the divergent boundary of the mid-ocean ridge. Two plates are moving away from each other very slowly. They move at a rate of two to four centimeters per year. Volcanoes are common on the island nation of Iceland. The movement of the plates causes magma to burst up and through Earth's crust. This action forms volcanoes. The cooled material from the volcanic eruptions formed the island.

Convergent Boundaries

Plates can form convergent boundaries in one of three ways. Each type of convergent boundary has its own results.

An ocean-ocean collision happens between two ocean plates. Right now, such a collision is causing the Mariana Trench. The fast-moving Pacific Plate is crashing into the Philippine Plate. As the Pacific Plate dives into Earth's mantle, it is melted. This causes earthquakes and volcanoes. The Mariana Islands were made in this way.



An ocean-continental collision is happening in South America right now. An oceanic plate is being subducted under a continental plate. This is happening near Peru and Chile. That is why earthquakes and volcanoes are very common in this area of the world.

In a continent-continent collision, two plates collide head-on. They "fight it out" before one plate finally subducts under the other. A lot of material builds up as it is scraped off one plate before it subducts. The Himalayas are the highest mountains in the world. They are the result of a collision that started about 50 million years ago. The Indian and Eurasian continental plates crashed together to form the very tall mountain range.

Transform Boundaries

The San Andreas fault in California is a transform boundary. It falls between the Pacific Plate and the North American Plate. These two plates are sliding past each other instead of colliding into each other. This sliding motion has caused major earthquakes in California all along the state. Most transform boundaries are found in the ocean, but the San Andreas fault is on land.

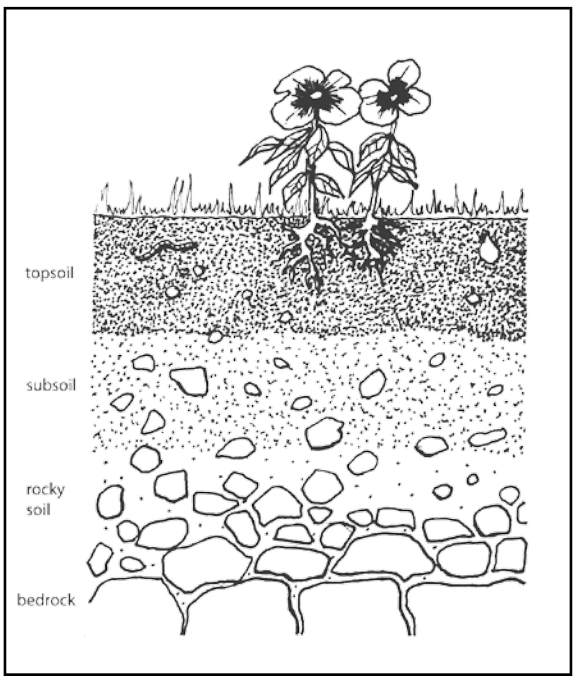
Where Soil Comes From

The weather transforms rocks. Remember we talked about the fact that water expands when it freezes? Well, even the strongest rock can be split by the "ice wedge"—water entering cracks in the rock, freezing, expanding, and splitting the rock apart. Smaller rocks are acted on by wind and rain, the sea, or plant or animal action. Finally, they break down to tiny particles which, mixed with organic matter from plants or animals, make up our soil. Soil is important to plant growth, of course. And plant roots are important for securing the soil against weathering.

A Soil Profile

We are always digging up the ground. We dig holes to build houses and roads and to lay pipes and cables. If there is some digging near you, you might be able to visit it with a class or a group. Stand somewhere safe. Look into the hole that has been dug. You will see the soil profile.

- Topsoil: dark, rich, and full of rotting plants
- Subsoil: different in color; tightly-packed soil
- Rocky soil: a layer of rock that is breaking down to become soil
- Bedrock: this is the rock beneath the soil



How to Teach Geology *(cont.)*

From Rock to Soil

But where does all this soil come from?

Rock is hard, but when the sun shines on it in the day, it swells up. When it is cold at night, it shrinks away. All this swelling and shrinking causes bits to break off. In the middle of winter, cracks fill up with water. The water freezes and the ice begins to push the rock apart. The ice splits the rock open. The river that sweeps past it bangs rocks against it, knocking off chips of rock.

Eventually, the rock crumbles to stone. The stones are rubbed and banged together by the river. The stones become gravel, then grains of sand, and then a fine powder. The powder becomes mixed with bits of rotting plants, living bacteria, tiny fungi that live off the rotting plants, trapped air, and water. The rock becomes soil.

Fascinating Fossils

Fossils are evidence of past life. They are the remains or imprints of living things from long ago. They can be leaf prints, footprints, shell prints, or skeleton prints. The waste from living things can even become fossils!

Fossils are made in different ways. They can be made when a living thing dies and becomes buried by sediments, such as ash from a volcano, mud, sand, or silt. They can be frozen in ice. They can be mummies, too. Some fossils have been buried in tar for thousands of years.

Most fossils are made when the soft parts of a living thing decay. The hard parts are turned into something like rock. The minerals in the sediments seep into the hard parts of the living thing. They become preserved as fossils. Other fossils are made when the whole living thing is frozen or mummified. Then, the soft parts are included, too.

Fossils are more likely to be made when a living thing dies near a body of water than on dry land. Near water, it is likely to be quickly buried. Over thousands of years, the sediments settle into layers that become sedimentary rock. Fossils are often found in sedimentary rock.

How Is Earth Like a Book?

Name ________________________________

What You Need:

- 6 3″ x 5″ lined note cards
- 2 twist ties
- hole punch

What To Do:

1. Stack the note cards so that the blank (unlined, white) side is always facing up. Number each side of the cards starting with the number one in the corner on the top blank side. Punch two holes on the left side of the stack so that when all the writing is done, the cards can be tied together with the twist ties and can be opened like a book.
2. Write the title “My Earth Book” on card side #1. This is the title card of the book. It may be decorated at home.
3. Flip that card over. The lined side #2 should be facing up. Write the title for this card, “Atmosphere,” above the red line on the card.

Write these words on the left side of card side #2.	On the white card side #3, draw these.
exosphere	satellite
thermosphere	fast moving molecules of air (just a few)
ionosphere	an aurora
mesosphere	rocket
stratosphere	the tops of clouds
troposphere	a jet plane/clouds

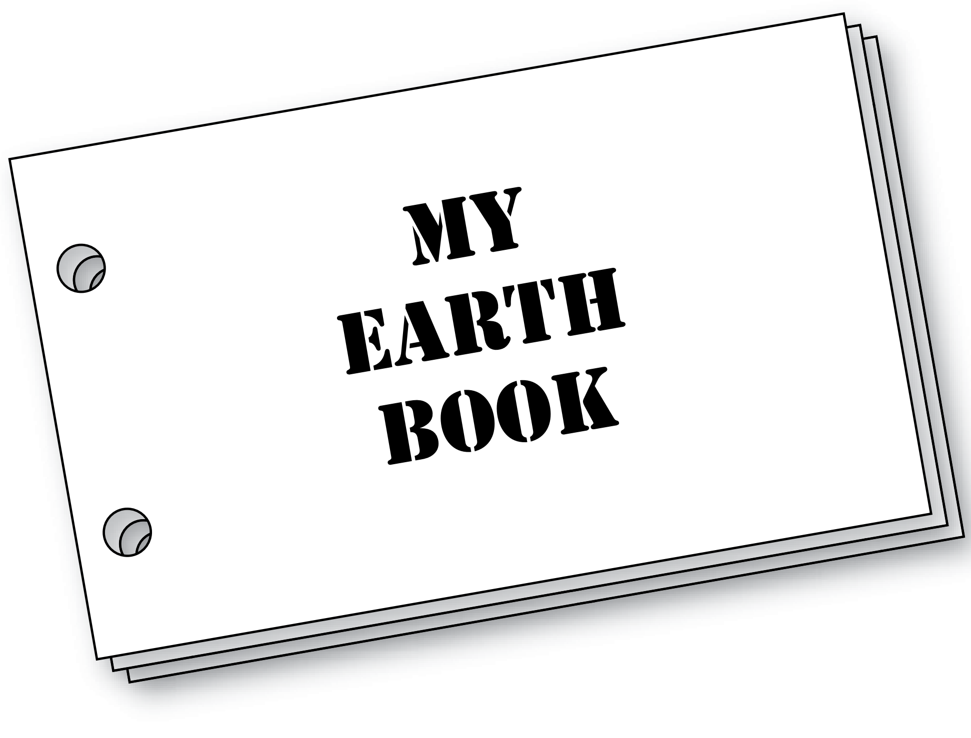
Write the definition for each of the words on the card.

What To Do: *(cont.)*

4. Flip card side #3 over. The lined side #4 should be facing up. Write the title for this card, "Hydrosphere," above the red line on the card.

Write these words on the left side of card side # 4.	On the white card side #5, draw these.
surface currents	winds blowing on the top of the ocean
deep currents	salt water (H2O + NaCl)-density differences
Great Ocean Conveyor Belt	arrows: red for warm water and blue for cooler water
calcium carbonate	seashells and fish bones
upwelling	nutrients brought to the surface by cold water

Write the definition for each of the words on the card.



What To Do: *(cont.)*

5. Flip card side #5 over. The lined side #6 should be facing up. Write the title for this card, "The Earth," above the red line on this card.

Turn card side #6 sideways. Write these words along the side of the left side of card side #6 from the bottom up: *core, mesosphere, asthenosphere, lithosphere*.

Turn the card back and write these words on the left side of card side #6.	On the white card side #7, draw these.
continental crust	continental crust riding up and over oceanic crust (a few dots to show low density)
oceanic crust	oceanic crust colliding and subducting underneath continental crust (a lot of dots to show high density)
mantle	convection cycles in the mantle
outer core	a couple of hot metallic blobs rising like a lava lamp
inner core	solid metal

Write the definition for each of the words on the card.

Next Question

Review your Earth Book. In how many layers in the Earth Book would the element carbon be found? How does each layer affect life on Earth? What effect does each layer have on the layer above or the layer below?

Notebook Reflection

What would happen to something if it were to travel through all the layers of the Earth system? Design a ship that could make the entire journey. Compare each layer to the one below it.

What Makes Soils Different?

Name ________________________________

What You Need:

- four small containers or plastic bags
- petri dishes
- microscope and slide
- litmus paper

1. Collect four soil samples from four different parts of your school or neighborhood. Put them each in a different container and label where you got them.
2. In a petri dish, mix each soil sample with water to make a liquid slurry.
3. Place one drop of the slurry onto a slide. Examine it under a microscope.
4. Draw or write about what you see:

Sample #1	Sample #2

Sample #3	Sample #4

What To Do: *(cont.)*

5. Use litmus paper to test the pH level of each slurry.

Sample #1	Sample #2

Sample #3	Sample #4

6. Were there any differences in what you saw in the soil samples? Were there differences in their pH levels? Why might this be so?

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Next Question

Draw a map of the area where you found your soil samples. Label anything that might explain the things you saw through the microscope or the pH levels of the samples.

Notebook Reflection

Compare and contrast your four soil samples. What might explain their differences? What might explain their similarities?

How Can I Eat Seattle?

Name ________________________________

What You Need:

- graham cracker
- teaspoon
- tub of whipped topping or a can of whipped cream
- butter knife
- 3 fish-shaped crackers
- small, shallow bowl or tub.
- small amount of chocolate syrup
- bowl

What To Do:

1. Gently break the graham cracker into two halves. The whipped topping represents weathered rock. Put a spoonful of the whipped topping on top of one cracker half. The cracker half with the topping on it now represents the part of the Earth's crust known as the North American Plate. The other half now represents a piece of oceanic crust known as the Farallon Plate.
2. Lift up the North American Plate (the graham cracker with the whipped topping on it) so that it is touching the Farallon Plate and tilted at a 30–45° angle. Use the knife to scrape the whipped topping down slope and onto the Farallon Plate. This represents weathered rock being washed downhill and forming sedimentary rock on the oceanic crust.
3. Drop the fish-shaped crackers onto the sedimentary rock (the whipped topping) that is on the oceanic crust. Seashells, fish bones, and carbon dioxide that have been absorbed by the seawater make up the calcium carbonate in limestone.
4. Take the Farallon Plate cracker and begin to slide it under the North American Plate cracker. Most of the whipped topping should be scraped off the Farallon Plate and onto the edge of the North American Plate. This action is called subduction. This is how the Costal Range of mountains in California formed. Notice that some of the whipped topping is dragged under the North American plate. Draw what you see.

What To Do: *(cont.)*

5. Hold onto the corner of the Farallon Plate as most of the cracker slides under. The tip of this corner now being held represents one of the last sections of the Farallon Plate that is still diving under the North American Plate by Seattle, Washington. This part is called the Juan de Fuca Plate.

6. Dip the leading edge of the the Farallon Plate cracker into the chocolate syrup and then return it to the position under the North American Plate cracker. When carbonate rich oceanic crust is jammed back down into the mantle it takes water with it. Water allows rocks to melt at a lower temperature.

   The chocolate syrup is a model of the crust melting. The syrup (melted rock) is not the same as the graham cracker. In fact, the syrup is a liquid. This means that the melted rock material would rise to the surface through cracks in the crust. This is what created the Cascade Volcanoes that line the northwest edge

Name ______________________________

What To Do: *(cont.)*

of the North American Plate by Seattle. Once this melted magma reaches the surface of the Earth's crust it will be exposed to sunlight, hot and cold temperatures, animal burrowing, and other activities that weather it down (change it into the whipped topping). The exercise could begin all over again. This is why it is called a rock cycle.

7. Slide almost all of the Farallon Plate under the North American Plate cracker. This action caused the North American Plate to bulge up and stretch out. As a result, the western part of the North American Plate has broken into many mountain ranges and rift valleys.

8. Draw what you see. Label mountains and valleys.

9. Eat it all. Clean up any mess.

Use classroom resources and the Internet to research another tectonic scenario.

Describe what it would be like to be standing on top of the graham crackers.

How Are Igneous Rocks Formed?

Name ______________________________

What You Need:

- saucepan
- two greased trays with lips
- hot plate
- measuring cups and spoons
- 4 cups sugar
- 1 cup water
- 2 tablespoons vinegar
- 1 teaspoon baking soda

What To Do:

1. With an adult's supervision, heat 2 cups of sugar, 1 tablespoon of vinegar, and ½ cup of water in the saucepan. Boil on a medium heat for 20 minutes.
2. Test to see if the mixture is ready by dropping a spoonful in a cup of cold water. If it forms a small, hard ball, proceed to the next step.
3. Pour the mixture onto a greased tray and allow it to cool.
4. Crack the hardened mixture into pieces for examination.
5. Repeat Steps #1 and #2 and then add the baking soda. Pour into another greased tray, cool, and break apart.
6. Examine the pieces. Draw what you see.

Next Question

Obtain some samples of igneous rocks. Compare them with your pieces. How are they similar? How are they different?

Notebook Reflection

Igneous rocks are formed when rock material is melted and then allowed to cool. Describe how both batches of candies are similar.

What Can I Find by Digging Up Climatasaurs?

Name ______________________________

What You Need:

- colorful candies
- ruler
- salt
- sand
- die
- 300 mL (10 oz) clear plastic drinking cup

What To Do:

1. Take a cup and sift in a layer of sand. This will be your "dig site" that you provide for your partner team.
2. Roll the die to determine which climatosaur would have been alive when the first layer of sedimentary rock was deposited in the cup. Use the Species Chart below to put the correct color of candy on the bottom of the cup.

Climatosaur Species Chart

If the die is:	then the species is	and has the adaptations for this type of climate	Color of Candy
1	wetosaurus	extremely wet/hot	green
2	mildodon	mild precipitation, moderate temperatures	yellow
3	coldosaur	dry/cold	blue
4	dryoraptor	extremely dry/hot	orange
5	bacteria	not enough sunlight	red
6	hairy mammal	extremely cold	brown

3. The climatosaour can be laid on its side or stood up on its side by the edge of the cup so that the fossil can be seen. That position will determine how long that particular species lived.
4. Pour enough salt into the cup to hold the candy against the side of the cup.

What Can I Find by Digging Up Climatasaurs?

What To Do: *(cont.)*

5. Roll the die again to determine what climatosaur could be alive during the next period of sedimentary rock formation. Hold the candy against the side of the cup and add a layer of sand.
6. Continue rolling the die and alternating sand and salt layers until the cup has six layers (three layers of salt, three layers of sand) with a candy in each layer.
7. Trade the cup with another group.
8. Use a ruler and the Climatosaur Species Chart to fill in the chart for every layer of sedimentary rock. Each millimeter represents one million years. List how long the period lasted, what species lived then, what the atmospheric condition was, and your best guess as to why the climate changed from the last period.

Dig Site Analysis

Layer	Duration	Species Found	Atmospheric Conditions	Climate Change Guess

Next Question

Put two of the dig sites (cups) together. Imagine each dig site came from a different part of the world. What could you say about conditions across the planet?

Notebook Reflection

What type of fossils would be trapped in sedimentary rock layers that are being made today? What would those fossils say about Earth's atmospheric conditions?

Astronomy

This chapter provides activities that address McREL Science Standard 3.

Student understands the composition and structure of the universe and the Earth's place in it.

Knows characteristics and movement patterns of the nine planets in our Solar System (e.g., planets differ in size, composition, and surface features; planets move around the Sun in elliptical orbits; some planets have moons, rings of particles, and other satellites orbiting them)	*What Makes Planets Bulge?, page 55* *What Causes an Eclipse?, page 56*
Knows how the regular and predictable motions of the Earth and Moon explain phenomena on Earth (e.g., the day, the year, phases of the Moon, eclipses, tides, shadows)	*What Causes an Eclipse?, page 56*
Knows characteristics of the Sun and its position in the universe (e.g., the Sun is a medium-sized star; it is the closest star to Earth; it is the central and largest body in the Solar System; it is located at the edge of a disk-shaped galaxy)	*How Is a Star Put Together?, page 59*
Knows that gravitational force keeps planets in orbit around the Sun and moons in orbit around the planets	*What Causes an Eclipse?, page 56*
Knows characteristics and movement patterns of asteroids, comets, and meteors	*What Is a Comet Made Of?, page 63*
Knows that the planet Earth and our Solar System appear to be somewhat unique (e.g., the Earth is the only celestial body known to support life), although similar systems might yet be discovered in the universe	*How Is a Star Put Together?, page 59* *How Is the Sun Like Baseball?, page 15*

How to Teach Astronomy

Astronomy: It's a Big Subject

For many reasons, teaching about Earth in space is not easy. Children come to school with their own ideas about space, and some of those ideas are very difficult to dislodge.

They may believe, for example, that the Sun moves and Earth stands still. Given that the Sun apparently moves across the sky, this is understandable. Although the idea was questioned by Copernicus and later disproved by Galileo, the movement of the Sun was accepted science until the fifteenth century. This reflects our own observation, of course. Other commonly-held incorrect ideas include the theory that the Moon covers the Sun at night; that the shadow of Earth is what causes the apparent change in the shape of the Moon; and that the Sun is slightly further away from Earth in the winter (when in fact the opposite is true during winter in the northern hemisphere).

Three Important Concepts

Where Earth, Sun, and Moon are concerned, there are three important concepts to tackle. With these understood, the relationships of Earth, Sun, and Moon become clear.

1 Size

Earth, Sun, and Moon are all spherical—a function of the force of gravity, which pulls all matter toward the center of an object. Since the heavenly bodies are subject to their own force of gravity, they are all pulled towards their middles, and so tend to be ball-shaped. Very small objects in space don't have this large gravity force and so remain irregular in shape.

The heavenly bodies are subject to other gravity forces. The Sun's gravity keeps Earth and all the other planets in orbit. Earth's gravity keeps the Moon in orbit.

Because books often need to fit all three into a small picture, students have little idea of their relative sizes. You could fit a million Earths into the Sun. The differences are literally astronomical.

	Circumference	Diameter
Sun	4,370,880 km	1,392,000 km
Earth	40,076 km	12,756 km
Moon	10,915 km	3,476 km

2 Distance

If you model the Sun with a beach ball, Earth is about the size of a pea and the Moon the size of a peppercorn. Then the beach ball and pea would be placed 40 meters apart to approximate scale. In reality, Earth is about 152 million km from the Sun.

The Sun and the Moon appear to be the same size in the sky. The Sun is much further away, so although it is much bigger than the Moon, both look the same size. In the same way that you can cover a distant mountain with your thumbnail, so—rarely—the Moon covers the Sun, blotting it out completely. This event is called a solar eclipse.

3 Movement

The Sun is actually moving and spinning, together with the whole Solar System and the galaxy. For the sake of simplicity, let's imagine it is still. Earth orbits the Sun and spins as it does so. Both orbit and spin are counter-clockwise viewed from above. The orbit gives us our year; the spin gives us day and night.

Fascinating Fact

Earth spins at more than 1,600 km an hour. It also travels around the Sun at over 100,000 km an hour. We don't sense this movement. For us, Earth feels as though it is standing still.

Day and Night

Earth spins on its axis. Every 24 hours, it makes one complete rotation. It rotates counter-clockwise, seen from above. We call this complete turn a day. Part of Earth is always facing the Sun. This part is in daylight. Part will be facing away from the Sun. For this part of Earth, it is nighttime. As Earth spins, each part of Earth moves from light to dark and back to light again—from day to night, and back to day. From Earth, it looks as though the Sun is moving across the sky. However, it is Earth that is turning while the Sun stands still.

The Moon

The Moon is orbiting us. Since it always has its face turned towards us, the back of the Moon (incorrectly called the "dark" side) is constantly away from us. For this to happen, the Moon has to spin as well as orbit. Rotation and orbit are synchronized, so as it moves around Earth, the Moon turns to keep the same side facing Earth.

The Moon's orbit is not in the plane of the other planets. Since it bobs up and down, it can appear in many places in the sky (and during both day and night, though it is blotted out by the Sun's brightness as often as not).

The Moon is not a light source. It reflects the Sun's light. Because the Moon orbits around Earth through the month, it presents different sides to the Sun. When we on Earth can see all of the sunlit side, we call this a full Moon. When we can only see a little bit of the sunlit side, we call it a crescent, and so on.

The Seasons

Earth is going around the Sun. The time it takes to complete a full orbit—365 and a quarter days—we call a year.

Earth's axis is at a slight angle to the Sun: 23.5° to be exact. This angle stays the same as Earth orbits the Sun. Each pole spends some of the year leaning towards the Sun and in strong sunlight. This is summer in that hemisphere. It spends some of the year leaning away from the Sun, and then it will be winter there.

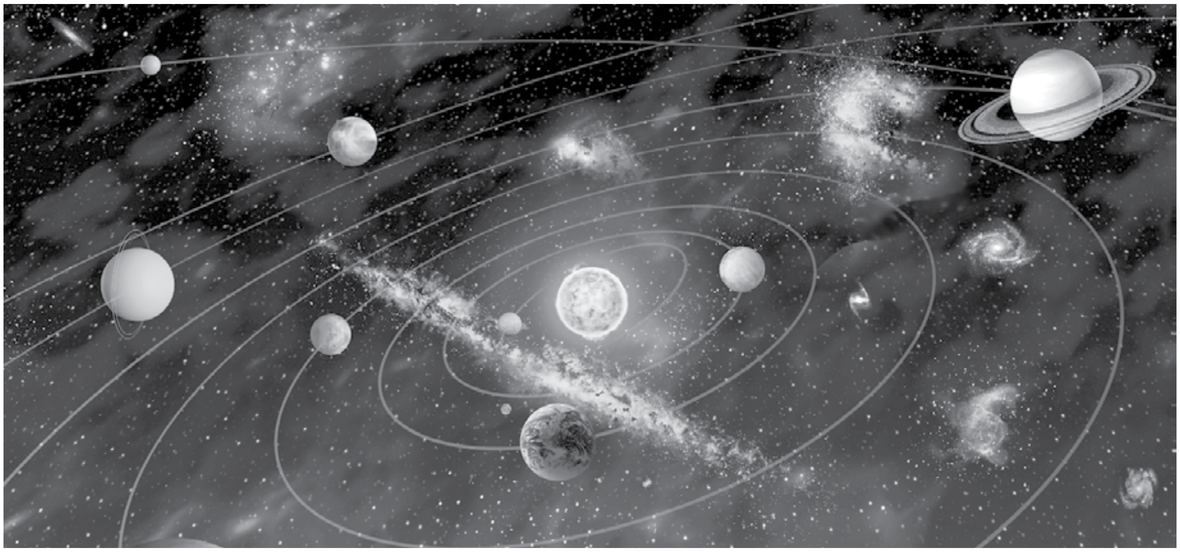
Planets in the Solar System

There are eight known planets orbiting the Sun. They are, in order from the Sun outwards:

- Mercury
- Venus
- Earth
- Mars
- Jupiter
- Saturn
- Uranus
- Neptune

Together, these planets make the Solar System. The planets vary greatly in size—and they aren't as close together as shown here!

How to Teach Astronomy *(cont.)*



Sizes and Distances

The planets vary greatly in size. Jupiter, the biggest, is 143,000 km across at the equator; Mercury, the smallest, less than 5,000 km across. If you model the planets using fruit, then Jupiter could be a watermelon and Mercury a blueberry, while Earth would be about the size of a strawberry.

The distances between the planets are enormous. If a house were your model of the Sun and you set off with your planet fruits, you would have to carry them away down the road to model the distances. The Mercury blueberry might not even be in the same town! Mercury orbits the Sun every 88 Earth days, but Neptune takes 165 Earth years to make a complete orbit.

It is even further to the nearest star (after our Sun). If Earth were a football, the next star would be on the other side of the planet!

Fascinating Fact

The Sun is a gigantic light source. Its surface is at a temperature of over 5,000° C. In the center, where nuclear reactions are turning hydrogen to helium, the temperature is 15 million° C. Although the Sun is around 150 million kilometers from us, its light can still harm your eyes if you look straight at it. Light from the Sun is reflected by the rocky Moon, which makes the Moon shine at night and gives us moonlight.

Fascinating Fact

Some parts of the Solar System are very hot—it is 465° C on Venus. Some are very cold—it is –220° C on Pluto.

How to Teach Astronomy *(cont.)*

Many Moons

Earth is not the only planet with a moon. Mars has two moons: Phobos and Deimos. Jupiter has at least 16 moons, including Io and Europa. Saturn has about 23 moons, Uranus has 15, and Neptune has 8.

Other Citizens of the Solar System

In addition to the planets and their moons, the Solar System also has a number of other bodies within the orbits of the planets. Some of these also orbit the Sun, but others are merely drifting or orbit the planets, instead.

Dwarf planets like Pluto and Ceres are rocky bodies that have enough gravity to pull themselves into a sphere. Unlike planets, however, they are not large enough to clear their orbital path, and share the path with other objects. Ceres orbits within the asteroid belt; Pluto's orbit crosses Neptune's.

Comets have an icy head and a tail of dust and gas. They don't always trail their tail behind them. In fact, because the tail is always pointed away from the Sun, the tail goes first through half its orbit.

Asteroids are pieces of rubble. There is a belt of asteroid rubble between Mars and Jupiter.

Meteors are stony objects, some as small as a grain of sand. When they burn up in Earth's atmosphere, we call them shooting stars. Meteorites are larger. Some crash through the atmosphere and hit Earth.

Who's Orbiting Who?

Galileo said Earth orbited the Sun. He was prosecuted by the Inquisition because people didn't believe him. They believed the evidence of their own eyes. They saw the Sun rise, climb into the sky, sink, set, and dip below the horizon. They believed they saw a moving Sun. However, the Sun doesn't move around Earth. Earth moves around the Sun. To us on the moving Earth, this looks exactly the same as a moving Sun. No wonder people were confused!

Hazel on the Train

Here's an example to help illustrate this sometimes confusing concept.

Hazel was sitting in a train with her mother. She looked out of the window on her left. She could see into another train. She looked out of the window on her right. She could see the station. There were people standing on the platform. She looked back to her left. The windows of the train next to her were moving slowly past her window.

"That train is leaving the station!" she said to her mum.

"No, dear," said her mother. "That train is standing still. WE are leaving the station!"

Hazel looked to her right. Sure enough, they were passing the people on the platform. Her train was moving.

Hazel's train is like Earth, and the other train is like the Sun. Hazel's train is moving, and the other train is standing still.

What Makes Planets Bulge?

Name ________________________________

What You Need:

- cardstock (6 cm x 50 cm)
- hole punch
- stapler
- dowel
- modeling clay
- hand drill

What To Do:

1. Cut two strips of cardstock 3 cm wide and 50 cm long. Make holes in each end of the strips just large enough to fit over the dowel.
2. Staple the two strips together to form a circle with the holes lining up at each end. Slip the dowel through the holes and secure one side of the circle to the rod with modeling clay. The other side of the circle should slide up and down easily.
3. Insert the free end of the dowel into the mouth of a hand drill and tighten the drill. Start turning the drill slowly with the rod pointing upwards. Gradually increase the speed of the drill and observe what happens to the shape of your "planet." Draw each stage.

Slow Rotation	Medium Speed	Fast Rotation

Next Question

Jupiter rotates once every ten hours. By contrast, Venus rotates once every 5,391 hours. Based on the experiment, what can you speculate about the two planets' shapes?

Notebook Reflection

Write a letter from a fast-spinning planet to a slow-spinning planet reflecting on their different shapes.

What Causes an Eclipse?

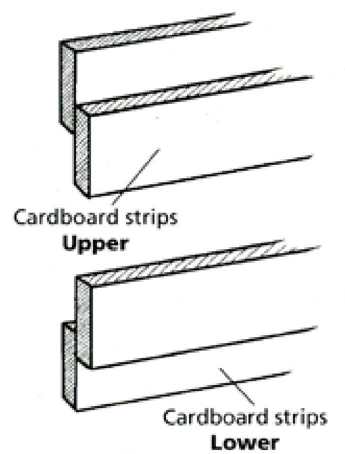
Name ________________________________

What You Need:

- scissors
- glue
- ruler
- tape
- cardboard box
- orange cellophane
- black paper
- cardboard
- flashlight
- thin, clear, stiff plastic

What To Do:

1. In the center of the upper part of the box, neatly cut out a 3 cm diameter circle. Cover the inside of this with orange cellophane and fix it in place with tape. This represents the Sun.

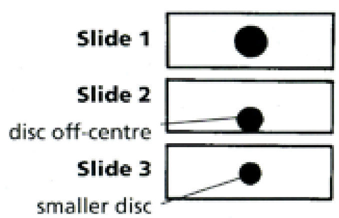


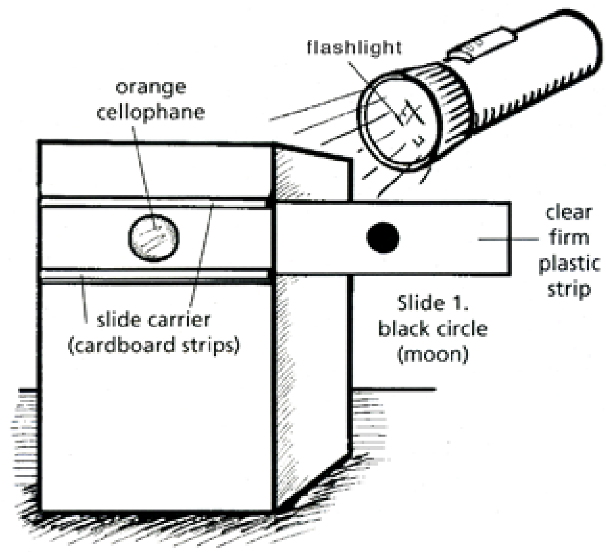
2. Cut four 1 cm wide strips of cardboard and glue them onto the box front as shown above. This forms a slide carrier.
3. Cut three 12 cm long strips of the clear, stiff plastic just wide enough to fit in the carrier you have made. Cut a circle of black paper (to represent the moon) a little less than 3 cm diameter and glue it to the center of your first slide. This moon disk must be exactly centered with the Sun circle in the box.

What Causes an Eclipse? *(cont.)*

What To Do: *(cont.)*

4. Make two additional slides as shown below. Slide 2 represents a partial eclipse; slide 3 represents an annular eclipse.





5. To show a total eclipse of the Sun, have the room darkened and switch on the flashlight. The circle of light showing represents the Sun. Now slowly move Slide 1 through the carrier. The black disk will begin to cut off the light just as the moon obscures the Sun in an eclipse. Describe what you see:

____

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6. Continue moving the slide across the face of the Sun until the total eclipse is visible. What do you observe now?

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What To Do: *(cont.)*

7. Continue to move the slide until the eclipse wanes and the Sun is the only image visible. Describe what this process looks like.

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8. Repeat Steps #5-#7 with the other slides. Describe how they are both similar and different than the total eclipse.

Partial Eclipse: ____

____

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____

Annular Eclipse: ____

____

____

____

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Next Question

The Latin word annulus means "ring." Why do you think an annular eclipse is called that?

Notebook Reflection

Describe in your own words how an eclipse comes to be. Include the motion of the planets.

How Is a Star Put Together?

Name ______________________________

What You Need:

- "snack-sized" paper plate (seven inches)
- sheet of graph paper
- crayons or markers
- paper clips
- white glue
- red plastic coffee stirring stick
- split peas (hydrogen atoms)
- lentil beans (deuterium/helium atoms)
- pinto beans (helium-3 atoms)
- small red cinnamon candy

What To Do:

1. Place the paper plate face down in the center of the graph paper. Use a pencil to trace around the paper plate. Set the plate aside.
2. At the center of the circle, draw a two-and-a-half-inch diameter circle. Label this "the core." Read the following aloud: "The pressure in the core is so great that two hydrogen atoms are forced together. This creates deuterium/helium. In this process, called fusion, matter is converted into energy ($E = mc^2$)."
3. Put two split peas in the core.
4. Slide them until they smash into each other.
5. Put a lentil bean (deuterium/helium) in the core.
6. Glue the peas and lentil in place and draw action arrows to show the direction that they moved.
7. Read the following aloud: "When another hydrogen atom combines with deuterium, helium-3 is created. More matter is converted into more energy. Gamma rays are also released."

What To Do: *(cont.)*

8. Put in another split pea and slide this hydrogen atom until it hits the lentil.
9. Put a pinto bean (helium-3) in the core.
10. Glue the peas and pinto in place and draw action arrows to show the direction that they moved.
11. Read the following aloud: "Two helium-3 atoms are forced together by the tremendous pressure to form ordinary helium-4. This process converts more matter into more energy and releases two hydrogen nuclei. This will continue as long as there are enough hydrogen atoms in the Sun."
12. Put another pinto bean in the core, and slide the two pinto beans until they are touching.
13. Take two split peas and slide them away from the collision of the two pinto beans.
14. Glue the peas and pintos in place and draw action arrows to show the direction that they moved.
15. Draw a five-inch diameter circle around the core. Label this "the radiative zone." Read the following aloud: "Energy radiates out from the core. However, this zone has so many atoms, is so densely packed, that light, absorbed and released by all those atoms, can take millions of years to pass through."
16. Put a small bunch of split peas, lentils, and pinto beans close together in the radiative zone. They should all touch.
17. Slide a cinnamon candy out from the core until it hits the pile. Push it through the pile, noting how it has to bump into all the atoms to get through.
18. Glue other beans to the paper around the candy to show that it will keep bumping into the other atoms.
19. Draw an action arrow showing how the photon radiated out from the core and then draw zigzag arrows to show how it bumped into the other atoms.

How Is a Star Put Together? *(cont.)*

What To Do: *(cont.)*

20. Label the remaining space "the convective zone." Read the following: "Hot gases rise because they are less dense then "cooler" gases. Cooler gases sink because they are denser than hotter ones. This is called a convection cycle."

21. Place a paper clip in this zone heading from the radiative zone out and use a pencil to trace around the clip. Remove the clip.

22. Place a bean on the oval that was just drawn. Slide it around the oval for a few "laps."

23. Go over the original circle with a red crayon or marker. Label the outside edge the "photosphere."

24. Read the following: "The photosphere is referred to as the surface of the Sun. The gases here are dense enough to see. Once light has left the photosphere it only takes eight and a half minutes to reach Earth, 93 million miles away."

25. Label the space just outside of the red line "the chromosphere."

26. Read the following aloud: "The chromosphere is part of the Sun's atmosphere. The gases here are so thin here the only time they can be seen is during a total lunar eclipse."

27. Place your hand, with the knuckles on the back facing down, on the photosphere. Wiggle your fingers.

28. Use an orange crayon or marker to trace around your fingers all the way around the photosphere.

29. Label the remaining space on the page "the corona." Read the following aloud: "The corona is the outer atmosphere of the Sun. The Sun has many magnetic fields. Some of them create giant loops of magnetic field lines. When some of these field lines break they send the material in the corona shooting across space. This blast off of material is called a coronal mass ejection (CME)."

30. Draw a horseshoe magnet in the convective zone so that the ends are just touching the outer edge of the photosphere.

What To Do: *(cont.)*

31. Put some split peas, lentils, and pinto beans in the corona.

32. Hold one end of the red coffee stirring stick down firmly on one edge of the drawn horseshoe magnet. Pull the other end of the stirring stick back on the paper until it touches the other end of the magnet.

33. Let one end go! This should launch some of the atomic particles out into space like a hockey stick smacking a puck.

34. Glue some of the peas and beans and draw action arrows behind them so it looks like the stirring stick flung them away.

35. Use a pencil to draw a dark spot where one end of the magnet touches the photosphere. This dark area represents a sunspot.

Next Question

Look up and write down the temperatures and thickness of each part of the Sun.

Notebook Reflection

Describe the trip from the center of the Sun out into space from the point of view of a hydrogen atom.

What Is a Comet Made Of?

Name ________________________________

What You Need:

- large bowl
- plastic sheet or bag
- water
- dirt, pebbles
- molasses
- dry ice
- wooden stirring spoon
- space heater with fan

What To Do:

1. Line a bowl with a plastic sheet or plastic bag.
2. Pour in about 500 mL water and about the same amount of earthly matter: dirt, pebbles, and molasses. Stir these materials together.
3. Put on gloves and carefully add 2 kg (4.4 lbs) of crushed dry ice. Stir the mixture well as it freezes together. This is your "comet head."
4. Upturn the bowl onto the table and peel off the plastic. Take a moment to observe your comet head. Describe what you see.

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5. Place your comet head in front of the heater and turn the fan to its lowest setting. Describe what you see and hear.

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What Is a Comet Made Of? *(cont.)*

What To Do: *(cont.)*

6. Now turn the heater up. Draw what you see.

Comet Head (very far from Sun)

Low Fan Setting (far from Sun)

High Fan Setting (close to Sun)

Next Question

Draw out the orbit of a typical comet. Pick six points along the orbit and draw how the comet and its tail would appear there. Which way does the tail point?

Notebook Reflection

Imagine you were a comet whose orbit brought you close to the Sun every hundred years. Describe your journey. What happens to you along the way?

Heredity

This chapter provides activities that address McREL Science Standard 4.

Student understands the principles of heredity and related concepts.

Knows that reproduction is a characteristic of all living things and is essential to the continuation of a species	*How Do Seeds Travel?, page 69*
Knows that for sexually reproducing organisms, a species comprises all organisms that can mate with one another to produce fertile offspring	*How Do Seeds Travel?, page 69* *How Big Should My Dog House Be?, page 71*
Understands asexual and sexual reproduction (e.g., in asexual reproduction, all the genes come from a single parent; in sexual reproduction, an egg and sperm unite and half of the genes come from each parent, so the offspring is never identical to either of its parents; sexual reproduction allows for greater genetic diversity; asexual reproduction limits the spread of disadvantageous characteristics through a species)	*How Do Seeds Travel?, page 69* *How Big Should My Dog House Be?, page 71*
Knows that hereditary information is contained in genes (located in the chromosomes of each cell), each of which carries a single unit of information; an inherited trait of an individual can be determined by either one or many genes, and a single gene can influence more than one trait	*How Is DNA Put Together?, page 73*
Knows that the characteristics of an organism can be described in terms of a combination of traits; some traits are inherited through the coding of genetic material and others result from environmental factors	*How Big Should My Dog House Be?, page 71*

How to Teach Heredity

Students are growing and changing, illustrating how we all change as we mature and age. They may well have had experiences with birth and death through family or their pets; they may be beginning to understand the cyclical nature of life.

Reproduction is the process of making young. Each species reproduces its own kind. People make people. Dogs make dogs. Trees make trees. Reproduction is needed for species to survive.

Asexual Reproduction

There are two forms of reproduction. In asexual reproduction, something can reproduce all by itself. It does not need a partner. One parent cell divides. It forms two new cells. The cells are identical to the parent cell. Bacteria cells reproduce asexually. Most plants have the ability to reproduce asexually, too.

Sexual Reproduction

Sexual reproduction involves the combining of genetic material from both parents to produce a new individual. It happens with both plants and animals. Sometimes the product of the process doesn't even look alive. Some students believe that hens' eggs and seeds are not alive, though in changed circumstances either may produce new life—though not, of course, "breakfast eggs" which are not fertilized.

Research has shown that for many students, new life is formed from components or parts—new human babies manufactured "in a mommy's tummy" from bits, and chicks assembled from kits of legs, wings, head, and body floating around inside the egg.

It's just not like that. All life begins as a single cell—usually the result of combining the cells of two different parents. But there can be reproduction without fertilization—asexual reproduction and even cloning.

Sexual reproduction has the great advantage that it mixes the characteristics of parent organisms and gives them a big stir. The resulting offspring has characteristics from both parents.

Making a Baby

When animals reproduce sexually, they make special sex cells, each containing half a complete set of DNA. Fertilization is the process that combines these two cells to make a new one. The new cell will have a complete set of DNA.

Because the male cells—the sperm—need water to swim in, many animals reproduce in water. Amphibians like toads and frogs need to return to the water to breed. Land animals have developed internal fertilization. The male puts the sperm inside the female's body. Then the new animal develops in a mini-pond—the egg—or inside the mother in the womb. The egg, or the mother's womb, provides a food supply for the developing animal. Eggs are laid and eventually hatch. Mammals are born when the young animal is pushed from the mother's body.

Do Plants Have Babies?

While many students can accept that animals reproduce sexually, very few believe that plants reproduce sexually, perhaps because they may equate sexual reproduction with copulation.

How Plants Reproduce

Most green plants have special structures called flowers. Flowers are the reproductive parts of the plant. Flowers are fine examples of biodiversity. There is a huge range of types, in many colors, patterns, and shapes. But they all have the same aim—the continuation of the species.

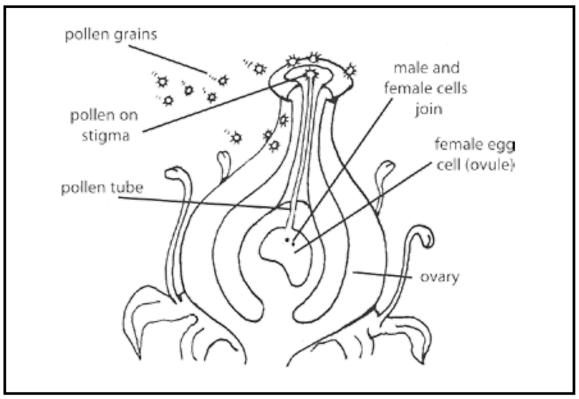
The geranium is a plant with soft, furry leaves. Often, the flowers are red or pink. You can make new plants from an old one. Carefully break off a side branch from the main stem by pulling it downwards. Press your cutting into a small pot of compost or soil. Water it regularly. It will grow roots and eventually become a plant exactly like its parent. You have created a clone!

Life follows a distinct cycle, with birth, growth, and reproductive phases—always ending in death. Understandably, animal metamorphosis—the spectacular life-cycle in which animals undergo huge changes, such as caterpillar to butterfly or tadpole to frog—catches the imagination. But most animals produce young that resemble the adult—even those that go through partial metamorphosis—a "nymph" stage.

Plant reproduction can be equally interesting, especially if—like many primary-aged students—you believe that seeds grow in packets at the gardening store!

Male and female plant cells must be brought together for seeds to form. This process is called pollination. The male stamens produce pollen in their anthers. The pollen is carried to another flower by the wind or by insects. When the pollen grain reaches the stigma of another flower, it grows a pollen tube down to the female ovule. The ovule is fertilized and forms a seed. The ovary becomes a fruit: the container of the seed.

Green plants carry flowers, whose sole purpose in life is to ensure that their ovum is fertilized by pollen from another plant, either wind-blown or delivered by insects. Flowering plants produce seeds which are carried away, ensuring that when the new plants grow, they do not compete with their parents. The seeds are commonly carried on (strawberry) or inside (apple) fruits. These fruits are often intended to be eaten–which is good news for us and for other animals. The seeds may be discarded, or they may pass through the eater to reach the ground and germinate. Seeds of other fruits—like the tufts of the dandelion—are carried on the wind.



What Is a Chromosome?

How can we understand why humans are the way we are? We have to look at our cells. We must look at a material found in the center of our cells. This material is our chromosomes.

Chromosomes are found in each of our cells. We have 23 pairs of chromosomes. That means each cell has 46 in all. Chromosomes are made up of alleles. Each one has more than 2,000 alleles along its length. Alleles are instructions for cells.

How to Teach Heredity *(cont.)*

Because chromosomes come in pairs, alleles come in pairs, too. Each cell has two sets of instructions for everything. Two paired alleles work together to make a gene.

A zebra's genes give it stripes. A bird's genes give it wings. Our genes give us fingers and everything else that makes us human. Stripes, wings, and fingers are all traits. Those traits start in the cells. Each cell follows its gene's instructions on how to develop and work. All the cells work together to make stripes, wings, or fingers.

Remember how each cell has two sets of instructions for everything? A full set of chromosomes has 23 pairs. Each pair has one chromosome from the mother and one from the father. If the father were blonde and the mother were blonde, the chromosomes they gave the baby would have blonde alleles. Then the baby would be blonde.

Sometimes the mother and father do not have the same alleles. Then the baby gets chromosomes with different alleles on them. The father's chromosome may have the attached earlobe allele. The mother's chromosome may have the unattached earlobe allele. The baby's cells follow both sets of instructions at the same time. What kind of earlobes will the baby have?

Some alleles are dominant. Others are recessive. If a dominant allele is present, that trait will show up. So, if two dominant alleles are present, the dominant trait will show up. When one dominant and one recessive allele are present, the dominant allele will still show up. However, if two recessive alleles are present, the recessive trait will show up.

Alleles are passed down over generations. A recessive allele can "hide" behind dominant alleles for many generations before popping up and surprising the whole family with blue eyes or red hair.

How Do Seeds Travel?

Name ______________________________

What You Need:

- a map of your school grounds
- plastic bag
- disposable gloves
- tape

What To Do:

1. Explore your school grounds looking for seeds. Don't take seeds off of plants; just find them on the ground (or in the air).
2. When you find seeds, tape one onto the map where you found it. Put another in your bag.

   We found ____________________________________ different types of seeds in

   ____ different places.
3. Choose two different seeds. Draw and describe them both below.

Seed #1	Seed #2
Picture	Picture
Characteristics: We found it:	Characteristics: We found it:

How Do Seeds Travel? *(cont.)*

What To Do: *(cont.)*

4. Your seeds got to the places you found them somehow. Do the following tests on each seed and fill out the table below. Does the seed fly when you blow on it? Does the seed float when you drop it? Does the seed stick to fluffy material?

Fliers	Non-fliers
Floaters	Non-floaters
Stickers	Non-stickers

Next Question

Share your seeds with the rest of the class. Create a pictograph on the board displaying the most common seeds and the rarest seeds. Why might this be?

Notebook Reflection

Design the ultimate traveling seed. Draw a diagram and label its parts. Describe in a paragraph how it travels through its environment.

How Big Should My Dog House Be?

Name ______________________________

What You Need:

- 2 coins

What To Do:

1. Form groups of two people. You will be finding out how big your new dog will be, so you can get the right doghouse for the backyard.
2. Both you and your partner flip a coin to find out if the next generation of puppies will be roughly the same size, bigger, or smaller than the original ancestors, the gray wolves. In dogs, a single gene is responsible for the production of a protein hormone called insulin-like growth factor 1 (IGF 1). The more growth hormone that this gene produces, the bigger the dog will be. Just because there is a gene that has a function, that does not mean that the gene is working all the time. Repressor proteins are chemical structures in cells that can shut down a gene.
3. Use the table below to find out if the next generation of puppies will be roughly the same size, bigger, or smaller than the original ancestors, the gray wolves.

   Heads = S for short. Tails = T for Tall

   TT means that generation will be one step taller than the parents. (The gene has been switched on.)

   TS or ST means that generation will be the same size as the parents. (The gene is working—sometimes.)

   SS means that generation will be one step shorter than the parents. (The gene has been switched off.)
4. Place an "X" on the appropriate line for the first generation after the gray wolves.

How Big Should My Dog House Be? *(cont.)*

What To Do: *(cont.)*

5. Flip the coins again. Use the table to see if that generation of dogs stays the same size, gets smaller, or gets taller. Place an "X" on the appropriate line. Continue flipping, circling, and making "Xs" until the fifth generation is reached.

Now you know what size of doghouse you will eventually need.

Generations:	1st	2nd	3rd	4th	5th	Size
					___	St. Bernard Sized
				___	___	Great Dane Sized
			___	___	___	Greyhound Sized
		___	___	___	___	Blood Hound Sized
	___	___	___	___	___	Labrador Sized
Grey Wolves	___	___	___	___	___	German Shepherd Sized
	___	___	___	___	___	Collie Sized
		___	___	___	___	Beagle Sized
			___	___	___	Pug Sized
				___	___	Dachshund Sized
					___	Chihuahua Sized

Next Question

Use classroom resources and the Internet to research genetic repressor proteins like IGF-1. How do these proteins work? How do they affect genes in an animal's cells? Where do they come from in the first place?

Notebook Reflection

People use breeding (genetic theory) to produce the dogs that have the characteristics they are looking for. Some people want tiny lap dogs while others are happy with giants that can run alongside them at the park. What other genes can be manipulated to produce cute, strong, or helpful dogs?

How Is DNA Put Together?

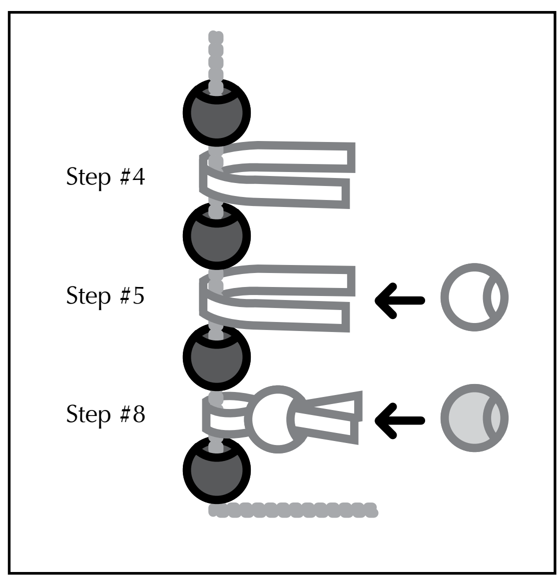
Name ______________________________

What You Need:

- bag of colorful beads—at least four colors
- bag of black and white beads
- twelve-inch pipe cleaner
- wire cutters or pliers
- twist ties

What To Do:

1. Find a partner. Throughout this exercise, one of you will act as the Left and one will act as the Right. At certain times during this exercise you will work together. Other times you will work separately.
2. Take one pipe cleaner each and make a small right-angle bend at one end to keep the beads from sliding off.
3. Slide a black bead down the stem until it reaches the bend. This represents the phosphate molecule that is part of the bigger molecule deoxyribonucleic acid (DNA).
4. Take a twist tie and place it on the pipe cleaner just above the phosphate. Bend it once around the pipe so that both "legs" of the twist tie are at a right angle to the pipe cleaner. Both legs must be the same length.
5. Slide a sugar (white bead) down, over the legs of the twist tie so that it touches the pipe cleaner.
6. Repeat Steps #3–#5 eight times.
7. Choose four colors of beads to



What To Do: *(cont.)*

represent the bases. Write the colors that your team chooses in the table below. The bases are: adenine, thymine, cytosine, and guanine. The bases get connected to each other, in pairs, by hydrogen bonds. Keep in mind that the bases pair up. Adenine only connects to thymine. Guanine only connects to cytosine. This means that the colors chosen for a pair of bases should be pretty close to each other.

Bead color	Base
	adenine (A)
	thymine (T)
	cytosine (C)
	guanine (G)

8. Now the Right must turn away from the work area and not look. The Left picks any one of the colored beads. To finish making their side of this DNA model, a base (colored bead) must be added to each of the twist ties. Take one and slide it down the legs of the first twist tie so that it touches the sugar (the white bead). Now one nucleotide is complete.

9. Repeat Step #8 four times. For this exercise, the order of the colors does not matter. However, in life, everything depends on the order in which the bases are placed in a DNA molecule. This order determines whether the cell is a wing on a fly, the trunk on an elephant, or a root in a giant sequoia tree.

10. Now the Left sits to the side to help. The Right now sits at the work space. At this point, the Right makes the decisions about the bead colors.

11. The Right "reads" the partial DNA that is in the work space and determines which base (colored bead) is on the sugar of the first twist tie. The Right then reads the table above to determine which base would match with the one already on the twist tie. (A=T and C=G).

What To Do: *(cont.)*

12. The Right takes the appropriate base (colored bead) and slides it down the first twist tie on their pipe cleaner until it touches the white sugar bead.
13. Repeat Step #12 until all four of the Left's beads have a match on the Right's pipe cleaner.
14. Now it is the Right's turn to add bases. The Right should add four base beads to the remaining four twist ties on their pipe cleaner like the Left did in Steps #8 and #9.
15. Then it is the Left's turn to find matching bases and add them to the remaining four twist ties on their pipe cleaner.
16. Once both pipe cleaners have eight bases, set them side-by-side so the matching bases line up. Check each other's matches to make sure you have them all correct.
17. Wrap the ends of the twist ties around each other to connect the bases. The nucleotides on either side of the DNA molecule are connected with hydrogen bonds. The knot of twist ties will represent those bonds.
18. Hold the bottom of the "ladder" and the top. Give both a gentle twist. Now it should look like a double helix.

Next Question

Separate the two sides of the DNA again. Drag one side of the DNA ladder over a drawing of a ribosome. Ribosomes "read" the nucleotides and use those as instructions to make proteins for the cell. How does the structure of DNA make this possible?

Notebook Reflection

Draw a diagram of the DNA molecule that you made. Label its parts, and use arrows and captions to explain how it is put together and how it is used inside the cell.

Biology

This chapter provides activities that address McREL Science Standard 5.

Student understands the structure and function of cells and organisms.

Understands cell theory	*How Magnificent Is HOC?, page 82*
Knows that cells convert energy obtained from food to carry on the many functions needed to sustain life	*How Magnificent Is HOC?, page 82*
Knows the levels of organization in living systems, including cells, tissues, organs, organ systems, whole organisms, ecosystems, and the complementary nature of structure and function at each level	*How Magnificent Is HOC?, page 82* *How Does an Arm Work?, page 85* *What Is Spit Good For?, page 87* *How Does the Eye Work?, page 90* *Do All Hands Work the Same?, see Teacher CD*
Knows that multicellular organisms have a variety of specialized cells, tissues, organs, and organ systems that perform specialized functions	*How Does an Arm Work?, page 85* *What Is Spit Good For?, page 87* *How Does the Inner Ear Work?, page 89* *What Are Thumbs Good For?, page 92* *Do All Hands Work the Same?, see Teacher CD*
Knows that organisms have a great variety of body plans and internal structures that serve specific functions for survival	*How Does an Arm Work?, page 85* *Do All Hands Work the Same?, see Teacher CD*
Knows how an organism's ability to regulate its internal environment enables the organism to obtain and use resources while living in a constantly changing external environment	*How Magnificent Is HOC?, page 82* *What Is Spit Good For?, page 87*
Knows that organisms can react to internal and environmental stimuli	*What Gives a Zebra Its Speed?, page 102*
Knows that disease in organisms can be caused by intrinsic failures of the system or infection by other organisms	*What Gives a Zebra Its Speed?, page 102*

How to Teach Biology

Cell Theory

The foundation of modern biology is cell theory. Cell theory has three parts:

- All living things are made of cells.
- Cells are the smallest part of living things that are themselves alive.
- All cells come from other cells.

Cells are microscopic clumps of chemicals bound by membranes. Inside the cell, complex organic chemicals receive materials from outside of the cell, break those materials apart to release energy and nutrients, and then use that energy and nutrients to make new materials that the cell needs. The chemicals receive "instructions" from the cell's DNA—itself an incredible complex organic chemical. In fact, the instructions are passed along from the DNA to the rest of the cell through chemical reactions.

The vast majority of living things on planet Earth, both in number and by biomass, are organisms made up of one cell. The rest of the living world—and the part that we're most familiar with—consists of organisms made of more than one cell: plants, animals, and the occasional fungus.

Animals

Animals are multicellular heterotrophs. They are composed of more than one cell (multicellular), and they eat other organisms to survive (heterotroph).

The hardest part of any animal's life is staying alive! To do this animals need to:

- eat
- keep warm
- evade hunters

Food

Animals need food for energy. They release that energy by a cellular process called respiration. (It mustn't be forgotten that plants respire, too; they do not produce food as a selfless activity to support the animal kingdom.) Respiration and the release of energy from food require oxygen. Animals are unable to store oxygen. It is the need to regularly renew oxygen stores that leads them to breathe in different ways—through breathing tubes (insects); through gills (fish and young amphibians); through their skin and the lining of their mouths (frogs); or with lungs (reptiles, birds, and mammals).

This process releases the energy needed for life. Animals need to maintain this process to survive. This makes the finding and ingesting of food an imperative for every animal on Earth.

Heat

Living things function because of chemical reactions in their bodies. These chemical reactions run faster and more efficiently in warmer conditions. Their body temperature varies with their environment. Cold-blooded animals become less active in cold conditions—or may boost their body temperature by basking in the sun.

Mammals and birds maintain their body temperature as if they had an internal thermostat. Since these animals need to maintain these temperatures, they are affected by seasonal change. They may stay active throughout the cold conditions, evade them by going somewhere warmer (migration), or become inactive for weeks at a time (hibernation).

How to Teach Biology *(cont.)*

Run, Hide... or Fight Back.

Animals have a variety of ways of evading their predators. They might be able to outrun them—as in the case of the hare escaping the fox. But if they can't, then what other tricks do they have up their sleeves? One option is camouflage, by which the animal changes in some way to match its surroundings. Examples include the changing color of the chameleon and the stick insect who looks just like the twig she is sitting on.

Some animals need have no fear of enemies because they are so unpleasant-tasting, or poisonous, that they can be vividly-colored, advertising their unpleasantness. A bright red ladybird presumably tastes disgusting to a bird. Many spiders and scorpions have a deadly bite or sting, and some tarantulas are happy to stand back and fire irritating hairs at their enemies.

Perceiving the World

Animals need sense organs to find their way around. Putting the sense organs at the front or top of the body makes them more useful. If the animal is a secondary consumer—a predator or carnivore—the sense organs are likely to be forward-facing, enabling it to see its prey and to catch it efficiently. If the animal is a primary consumer, or herbivore, then its sense organs are likely to survey the surroundings more generally. It needs to be aware of predators and danger. Cats have eyes on the front of their heads; mice have them on the side. Cats have excellent, stereoscopic forward vision to catch mice; mice have good all-around vision to spot and avoid cats.

Fascinating Facts

What Is a Life-Cycle?

The process of birth, growth, reproduction, aging, and death is the animal's life-cycle.

Animals' longest-known life span

adult mayfly	3 days
mouse	3 years
guppy	5 years
large beetles	5–10 years
swallow	9 years
coyote	15 years
giant spider	20 years
toad	36 years
lobster	50 years
crocodile	60 years
sea anemone	70 years
elephant	77 years
blue whale	80 years
golden eagle	80 years
sturgeon	100 years
tortoise	100–150 years
human	113 years

Plants

Plants are multicellular autotrophs. They are composed of more than one cell (multicellular), and they produce their own food (autotroph).

Plants Are Alive!

Yes, plants are alive, too! Piaget first identified the stages that students move through in their understanding of "the life concept." His research suggests that at a young age, movement is equated with life. Things that appear to move by themselves—including rivers and the Sun—are deemed alive.

If that type of confusion seems improbable, consider the apple you are about to eat for your lunch. You may have difficulty in believing that it is alive—not the plant from which it came, but the apple itself. It respires using its own food source, excretes waste gases, and could reproduce, given the right conditions for its seeds. No wonder that, while all 8- to 11-year-olds appear to agree that plants grow, only 69 percent of them regard plants as living.

Animals clearly show the seven life processes, but plants—which may look dead at some times of the year—show them all, too.

1. Nutrition: Green plants can make their own food, but they need that food to grow and live.
2. Growth: Plants grow, sometimes very slowly. But a new seedling grows a lot faster than a human baby!
3. Reproduction: Plants can produce seeds or spores. Some plants reproduce by growing new plants from special stems or roots.
4. Respiration: Plants need oxygen to live, and they produce carbon dioxide. Fortunately for us, they produce a lot of oxygen, too!
5. Sensitivity: Plants are sensitive to their surroundings. Climbing bean plants sense a stick, and twine around it.
6. Excretion: Plants produce waste products—a little carbon dioxide and a lot of oxygen.
7. Movement: Plants move. Some move quite fast, like mimosa, the sensitive plant that closes its leaves when you touch it. Others move more slowly, like the dandelions that open for the Sun, and close at night.

Making Their Own Food

Green plants are the only living things able to make their own food. They combine water with carbon dioxide from the air and chlorophyll from the leaves to produce glucose (a type of sugar). This process needs light energy, usually from the Sun, and is called photosynthesis. Plants also need to absorb tiny quantities of mineral salts and other nutrients from the soil and we confuse this process by calling it "feeding" the plant. Plants don't feed—they are food producers and the first step in most food chains.

Don't forget that plants also respire, just like us. They don't breathe by mechanically drawing air into and expelling it from the body, but they use oxygen in their cells in the process that releases energy from stored foods. At night, they respire but do not photosynthesize. During the day, they are doing both. Fortunately for life on Earth, the amounts of oxygen plants use are exceeded by the amounts they produce.

How to Teach Biology *(cont.)*

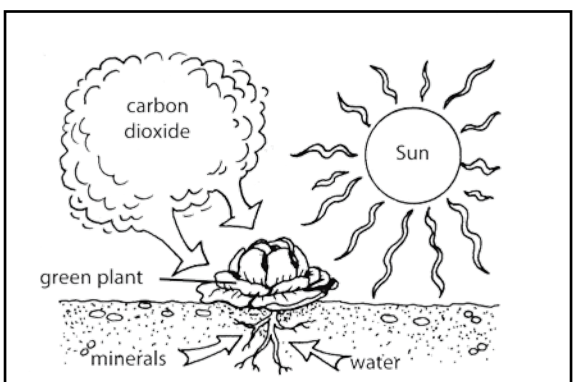
Take a deep breath; here we go. To start with, photosynthesis takes place in two stages. In the first, sunlight is used to split water into oxygen and hydrogen. This depends upon the ability of a green pigment in plants called chlorophyll to split water molecules. The oxygen is now a waste product—which is a good thing for those of us who favor breathing.

Next, a reaction takes place which doesn't need light. It takes place in a billionth of a second. The hydrogen (actually split into bits by now) is used to convert carbon dioxide into carbohydrates—basic building blocks for sugars, starch, and a wide range of materials. One of these is cellulose, the material that plant cell walls are made from. As a result, the plant has food for activity and material for growth, both of which we can exploit by eating a cucumber sandwich.

Why Are Plants That Shape?

To make their food by photosynthesis, plants need to catch the light of the Sun. Their whole structure is aimed at collecting and using as much sunlight as possible.

They have a branching root system that can grip the soil. There is as much tree below the ground as above it (the roots of a tree are roughly the same size and extent as its canopy). They have a strong stem (sometimes a trunk) that can hold the leaves up high—and above the leaves of competitors—and a mathematically—precise leaf pattern.



If you want to see the effectiveness of the leaf pattern, stand under a tree on a sunny day. The leaves are laid out to ensure that even the lower ones make use of the light missed by those above them. The result is nearly complete coverage.

Fungi Are NOT Plants!

Fungi are either saprotrophs or parasites. Saprotrophs eat non-living matter. Parasites get their energy and nutrients from a host organism without killing it first. Fungi may be multicellular, in the case of mushrooms, or unicellular, in the case of yeast.

Fungi are not green—they cannot make their own food like plants. They produce spores, not seeds. Their structure can spread for miles under the ground.

Microorganisms

Most single-celled or unicellular organisms are presently grouped into three kingdoms: protoctista, bacteria, and archaea. However, this is a temporary classification solution at best. These three kingdoms represent more diversity of life than all the other kingdoms combined.

Students call microorganisms "bugs" or "germs." These names include small invertebrates, bacteria, and viruses. The names are associated with dirt, death, and disease. Students may think of microorganisms as things that walk about inside us, eating, breeding, and making us ill. Given the opportunity, they would probably exterminate all microorganisms, thus inadvertently bringing the world to a speedy end!

How to Teach Biology *(cont.)*

Few students are aware of the beneficial effects of microorganisms and have little idea of their importance in decay and recycling. They may not understand that we live surrounded by microorganisms of all sorts, and that we are dependent on them for our health and well-being.

It's difficult to teach about microorganisms because you're teaching about something that is invisible to the naked eye. It's very hard to envision a microscopic world of the size and complexity that exists. It is harder still to give students actual experiences of that world.

In promoting the benefits of microorganisms, point out that they are essential to making leavened bread, cheese, yogurt, vinegar, and many protein meat substitutes. They are essential to the production of many medicines and the breakdown of sewage.

Fascinating Facts

Algae

The term "algae" can mean any number of different organisms that have little to no relation to each other and very little in common. Everything from seaweed to cyanobacteria has been counted as an algae at one time or another, to the point that the term itself is problematic at best.

Mini-Beasts

Some of the most accessible animals available to students are "mini-beasts"—insects, pillbugs, centipedes, even earthworms. These fascinating creatures can give students an up-close look at the basic needs and structure of animal life. These animals do not fall into a neat category. They are not all insects, but include arachnids, annelids, and even crustaceans in the case of the pillbug. This text refers to these scientific gold mines as "mini-beasts" and includes a number of labs investigating their small and educational world.

How Magnificent Is HOC?

Name ______________________________

What You Need:

- chocolate kisses (hydrogen atoms)
- "O"-shaped cereal (oxygen atoms)
- small elbow macaroni shells (carbon atoms)
- spent matches (heat)
- flashlight
- cinnamon candy (energy)
- "snack-sized" paper plates (seven inches)

What To Do:

1. Form teams of three people to sit around a table or combined desks. Put small piles of hydrogen (chocolates), oxygen ("O"-shaped cereal), and carbon (elbow macaroni) on separate paper towels in the center.
2. Determine which person will be The Environment. Give them a paper plate. The person sitting to the left of The Environment becomes a Chloroplast. The next person becomes the Mitochondrion.
3. The Environment puts one carbon atom (C) and two oxygen atoms (O) close together on the plate to represent a molecule of CO_2. Repeat this until six molecules of CO_2 are on the plate.
4. The Environment then puts two hydrogen atoms (H) and one oxygen atom (O) close together on the plate to represent a molecule of water.
5. The Environment provides sunlight energy: lay the flashlight on the desk pointing to The Chloroplast and turn it on. Put a cinnamon candy on the plate.
6. The Environment slides the plate to The Chloroplast.
7. At some time during this round, The Environment should create night by turning the flashlight off. After The Chloroplast has demonstrated respiration (Steps #8-10), turn the flashlight on long enough for The Chloroplast to finish.

What To Do: *(cont.)*

8. When the flashlight is on, The Chloroplast gets energy from the Sun: pick up the cinnamon candy from its pile.
9. The Chloroplast then uses the cinnamon candy to push the atoms of gas around the plate until they have been recombined to form $C_6H_{12}O_6$ and a separate group of six "Os". The molecule $C_6H_{12}O_6$ is a simple sugar called glucose and is food for cells.
10. The Chloroplast gives out oxygen: put the six "O's" on the desktop toward The Mitochondrion.
11. When the light source has gone, stop the photosynthesis process. The Chloroplast takes in oxygen by moving a couple of additional oxygen atoms from the paper towels and putting them onto the plate.
12. The Chloroplast gives out carbon dioxide by picking up a couple of CO_2 molecules off the plate and putting them on the desktop. This respiration occurs in plants at night.
13. Once glucose has been synthesized, The Chloroplast carefully slides the plate to The Mitochondrion. The energy gets lost after all the pushing around (put the cinnamon candy back in its pile).
14. The Mitochondrion takes in oxygen by picking up the 6 "O's" that are on the desk next to the plate.
15. The Mitochondrion breaks down the molecule of glucose by moving the $C_6H_{12}O_6$ atoms apart. Rearrange the atoms into six CO_2 sets and six H_2O sets, and get some energy from this chemical interaction by picking up a cinnamon candy from its pile.
16. The Mitochondrion stores this chemical energy in the molecule adenosine triphosphate, also called ATP. Write "ATP" on the plate and put the cinnamon candy on the letters.
17. The Mitochondrion releases some energy, in the form of heat, during this breaking down process by putting a matchstick on the plate.

What To Do: *(cont.)*

18. The Mitochondrion gives out carbon dioxide by putting the CO^2 sets back on the table.

19. Once the plate has been around the circuit, stop. Everybody rotate to the next station to the right. Repeat the directions. The team keeps rotating until every person has been at every station.

Next Question

How could you model muscle cells burning energy outside of mitochondria's slow process?

Notebook Reflection

Draw a chloroplast and mitochondrion diagram that shows the flow of the different gases, the use of energy, the production of energy and the formation of ATP.

How Does an Arm Work?

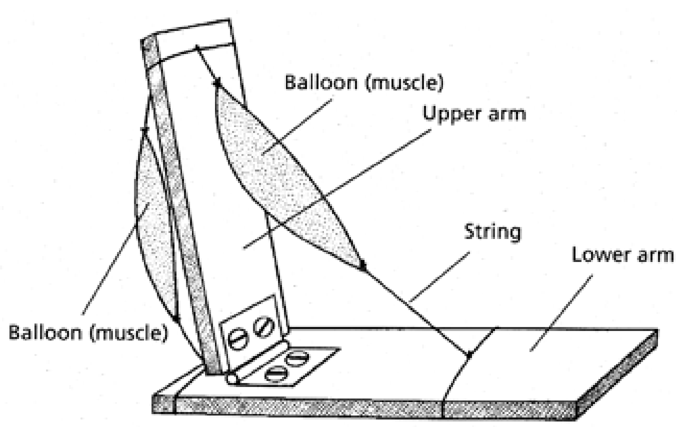
Name ______________________________

What You Need:

- two wooden strips (30 cm x 5 cm x 1 cm)
- small door hinge
- electric drill
- screwdriver
- 2 balloons
- string

What To Do:

1. Place the hinge on one end of a wooden strip. Make sure the hinge projects well over the end of the strip. Mark the holes, then drill and screw the hinge onto the wooden strip. This represents your upper arm.
2. Line up the other side of the hinge on the second wooden strip near to the open end as in the diagram. This represents your lower arm. Mark the holes, then drill and screw the hinge down. Make sure the joint can open and close freely.
3. To represent your muscles use two balloons which have been slightly inflated. Tie the end of each balloon with a piece of string.
4. Attach the balloons to the two wooden strips as shown below.



How Does an Arm Work? *(cont.)*

What To Do: *(cont.)*

5. Hold the upper arm of the model firmly and move the lower arm up. What happens?

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____

____

6. Now move the lower arm back down. What happens now?

____

____

____

Next Question

The muscles in your body can only contract and pull. How can your bicep and tricep (the muscles modeled in the experiment) work together to move the arm both ways if they can only pull?

Notebook Reflection

Consider your own arms. Move them up and down and back and forth. Feel the muscles underneath your skin. Describe what you feel. How do your observations relate to the experiment?

What Is Spit Good For?

Name ________________________________

What You Need:

- 6 small dry cookies
- paper towels
- timer
- water
- plastic cups

What To Do:

1. Put one cookie on a paper towel on the table.
2. Use another paper towel to dry out your mouth. Put a cookie on your tongue and close your mouth. Wait 180 seconds.
3. What happened to the cookie in your mouth? Compare it with your "control" cookie on the table. What are the differences?

____

____

____

4. Put one cookie in a cup of water.
5. Drink some water and swallow. Put another cookie in your mouth. This time, swirl saliva around it for 180 seconds.
6. What happened to the cookie in your mouth? Compare it with your "control" cookie in the water. What are the differences?

____

____

____

7. Crush a cookie and put the crumbs in a new cup of water.
8. Put one cookie in your mouth. Chew it for 180 seconds without swallowing.

What Is Spit Good F or? *(cont.)*

What To Do: *(cont.)*

9. What happened to the cookie in your mouth? Compare it with your "control" cookie, crushed up in the water. What are the differences?

____

____

____

10. Summarize the effects of saliva on your three samples compared to your three control samples. What does saliva do to food?

____

____

____

Next Question

Does saliva work at the same rate on different foods? Devise an experiment to find out. Include a control group and a way to measure saliva's effects on different foods. Try your experiment.

Notebook Reflection

Describe in a paragraph and diagram how you think saliva works. How important is saliva? What would life be like without it?

How Does the Inner Ear Work?

Name ______________________________

What You Need:

- petri dish
- drinking glass
- modeling clay
- tuft of straight hairs (such as from an old paintbrush)
- plastic wrap
- scissors
- tape

What To Do:

1. Insert the ends of some hairs into a lump of modeling clay.
2. Fix the lump onto the inside surface of the petri dish. Attach it about halfway down the side.
3. Add water to the dish until the hairs are just covered. Carefully place the plastic wrap over the top and secure it with tape.
4. Invert the drinking glass and fix the petri dish on top of the glass using a little glob of clay.
5. Rotate the glass very slowly. Which way do the hairs bend? ________________
6. Now rotate the glass the other direction. Which way do the hairs bend this time? ____
7. Now rotate the glass quickly for 5–6 turns to make the water whirl around, then stop it abruptly. What does the water do? How does this affect the hairs?

____

____

Next Question

Research the inner ear. Describe the vestibular system in your own words. Why does it have three canals and not just one?

Notebook Reflection

Inside your inner ear, you have three small canals filled with fluid and lined with small hairs. It helps you with your balance. How is the inner ear like the experiment?

How Does the Eye Work?

Name ________________________________

What You Need:

- scissors
- round fishbowl
- candle
- black card
- white card
- modeling clay

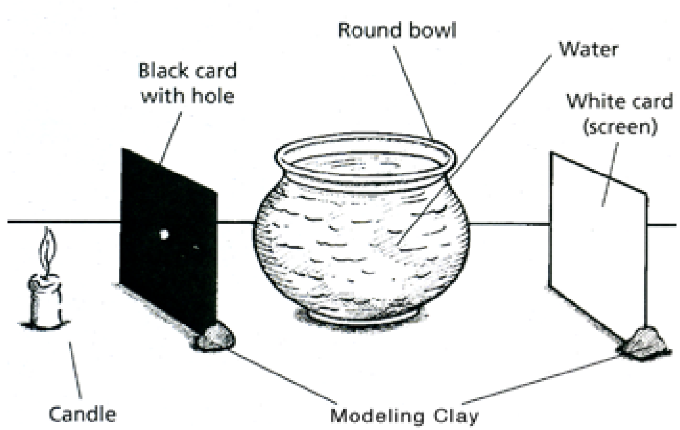
1. Fill the fishbowl with water.

2. Cut a small round hole in the center of the black card.

3. Use the modeling clay to support the two cards so that the black card and the white card are on two sides of the fishbowl.

4. Light the candle and set it in front of the black card.

5. Draw the curtains so the room is dark.



How Does the Eye Work? *(cont.)*

What To Do: *(cont.)*

6. Describe what you see on the screen.

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____

____

7. Move the white card closer and further away from the bowl. What changes?

____

____

____

Next Question

Our eyes have an iris, a lens, and a retina much like the black card, fishbowl, and white card in the experiment. However, the distances between them don't change. How does our eye work differently to keep the image in focus? Find out.

Notebook Reflection

Draw a diagram of the experiment, labeling the different pieces. Describe the path of light in a paragraph. Then draw a diagram of the human eye. Label the different pieces and describe the path of light. How are they similar?

What Are Thumbs Good For?

Name ________________________________

What You Need:

- a broom
- a cup
- water

1. Touch your thumb to each of your other fingers. Can you do it easily? ________
2. Touch your pinky finger to each of your other fingers. Can you do it? Easily?

    ____

3. Write your name in the space below without using your thumb to hold the pen.

    ____

4. Put your pen down on the table. Now write your name in the space below without using your thumbs to pick up or hold the pen.

    ____

5. Fill a cup halfway with water. Pick it up using your whole hand. Then try to pick it up without using your thumbs. What was different? __________________
6. Use the broom to sweep the floor. Then set the broom aside and do it again without using your thumbs. What was different? __________________________

Next Question

Find out about the hands of animals. How are they different from ours? What can people do with their hands that animals can't? What can animals do that people can't?

Notebook Reflection

What did you learn about your thumbs? What do they do that the other fingers don't do? What can you do without your thumbs? What do you need thumbs to do?

How Does Streamlining Work?

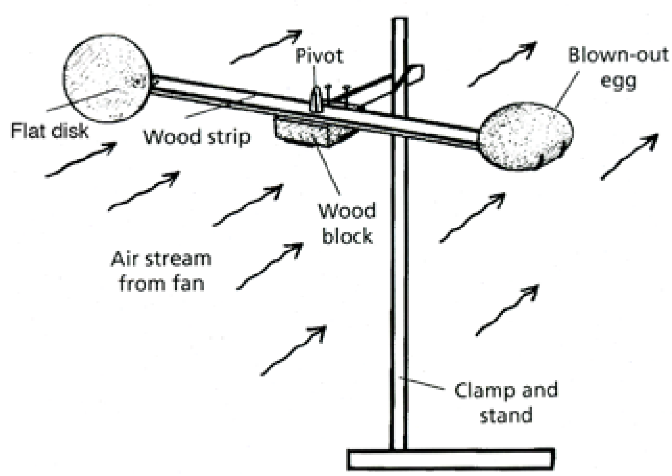
Name ______________________________

What You Need:

- egg
- needle
- metal disk
- wood strip 20 cm x 3 cm x 1 cm
- electrical or duct tape
- electric drill
- pen
- sand
- fan
- tissue paper

What To Do:

1. Carefully poke a hole in the egg with the needle. Stir the needle around inside the egg to break up the yolk. Carefully poke another hole on the other side of the egg. Over a sink or trashcan, blow into one hole. The contents of the egg should drop out the other side.
2. Drill a hole in the center of the wood strip large enough for the pen tip, but not the whole pen, to poke through. The wood strip should be able to spin on top of the pen.
3. Use thin strips of tape to attach the metal disk and egg to the ends of the wood strip.
4. Plug one hole in the egg with a small bit of tape and then pour sand into the other hole so that the egg balances evenly with the metal disk.



What To Do: *(cont.)*

5. Place the strip on top of the pen and hold the pen one meter in front of the fan. Turn on the fan and observe what happens.

____

____

____

6. Take the strip off of the pen and hold the egg half in front of the fan. Hold the tissue paper out next to the egg's surface on the top, side, and bottom. What can you say about the air flow?

____

____

____

7. Now hold the metal disk half in front of the fan and repeat the procedure with the tissue paper. What is the air flow like on this end?

____

____

____

Next Question

Repeat the experiment with different shapes, such as a ping-pong ball, a cone, or a toy airplane. Compile a table showing which shapes are the most streamlined.

Notebook Reflection

Draw pictures of birds, sea animals, and burrowing animals. Describe in words how each one is streamlined, and explain why you think that is.

Ecology

This chapter provides activities that address McREL Science Standard 6.

Student understands relationships among organisms and their physical environment.

Knows that all individuals of a species that exist together at a given place and time make up a population, and all populations living together and the physical factors with which they interact compose an ecosystem	*What Gives a Zebra Its Speed?, page 102*
Knows factors that affect the number and types of organisms an ecosystem can support (e.g., available resources; abiotic factors such as quantity of light and water, range of temperatures, and soil composition; disease; competition from other organisms within the ecosystem; predation)	*What Gives a Zebra Its Speed?, page 102*
Knows ways in which organisms interact and depend on one another through food chains and food webs in an ecosystem (e.g., producer/consumer, predator/prey, parasite/host, relationships that are mutually beneficial or competitive)	*What Gives a Zebra Its Speed?, page 102* *How Do Consumers Trade Off?, page 104* *How Is Sunlight Passed Around?, page 106*
Knows how energy is transferred through food webs in an ecosystem (e.g., energy enters ecosystems as sunlight, and green plants transfer this energy into chemical energy through photosynthesis; this chemical energy is passed from organism to organism; animals get energy from oxidizing their food, releasing some of this energy as heat)	*How Do Consumers Trade Off?, page 104* *How Is Sunlight Passed Around?, page 106*
Knows how matter is recycled within ecosystems (e.g., matter is transferred from one organism to another repeatedly, and between organisms and their physical environment; the total amount of matter remains constant, even though its form and location change)	*How Do Ecosystems Recycle?, page 109*

How to Teach Ecology

It's easy to forget that the natural world underpins our very lives, especially if you live in an urban environment. When your food comes prepackaged, and the only plants you see are in parks and flower shops, you can overlook the close relationship we all have with the natural world. Perhaps that's why we choose to take breaks in the countryside and succumb to the attraction of gardening. These activities bring us closer to the plants and animals we depend on.

Do Animals Need Plants?

We certainly do! Without plants, animals, including us humans, wouldn't survive—and I don't mean just because we eat them!

If we were dependent on the stored oxygen in the atmosphere for breathing, life on Earth would be finite. When the last of the oxygen had been used up (or actually, long before), most life on Earth would end. Even if we were to stop being so wasteful with the stuff—burning it or pumping it through our forms of transport—it would not last forever. It has to be renewed. Fortunately for us, green plants and algae are very good at that. All our oxygen is recycled again and again.

We would die long before the oxygen ran out, though. The reason for that is that the waste gas we breathe out—carbon dioxide—is poisonous in large quantities, and a buildup in the atmosphere would kill us. Fortunately, plants have a use for carbon dioxide. They recycle that too, using it to make food for themselves (and often, for animals) and produce oxygen!

This handy cycle ensures that life on Earth can continue indefinitely. True, plants need oxygen too, and yes, they produce some carbon dioxide, but this is far outweighed by the amount of oxygen they produce.

Plants give us more than just oxygen! We don't need plants just for gases. We can eat them (or we eat the animals that eat plants), and we use plant products for clothes, shelter, furniture, and medicines.

Without plants there would be no animal life on Earth. We need them. It is this complex relationship between plants and animals that makes their study so interesting.

It is the breakdown of this relationship, by pollution and the wholesale destruction of the rainforests, that threatens us and all other living things.

Do Plants Need Animals?

You wouldn't think so, would you? Everything they need is right there where they are growing. They have carbon dioxide from the air, water from the rain, and a pinch of mineral salts from the soil. Combining all these produces a living growing thing.

Do animals do anything for plants? Well yes, they do. They produce a large part of the carbon dioxide needed for plants to photosynthesize and live.

Just as important, animals provide a useful delivery system for living things that are literally rooted to the spot. If you have some dusty, yellow pollen that you are wanting to get to that plant over there, then what better way than hitching a lift on a furry insect traveling from flower to flower? Usefully, the honeybee has very casual standards of personal hygiene—and no clothes to brush. So it will fly off with pollen on its coat. Indeed, plants can even afford to sacrifice a bit as bee food—hence the pollen sacs on the bee's legs. Plants provide a few encouragements—sweet nectar, bright colors, and even markings (bee lines) that help with a safe landing.

Bees, flies, other insects, some birds, and other animals offer this helpful service—and it doesn't stop there. When the pollen has been delivered, the egg has been fertilized, and the seeds have formed, they need distributing, too. Animals also provide a convenient—if erratic—delivery service for seeds.

The outsides of animals—the fur of mammals and the feathers of birds—provide a convenient hanging place for hooked burrs and sticky seeds. The insides happily accept tasty fruits and, if the seeds are resistant to digestion (with a hard coat), they will pass through the eater and be deposited somewhere far away, together with some waste matter rich in organic material (otherwise known as manure).

Many seeds are transported like this. Even the huge stones of the avocado tree are carried away by the birds that eat the fruit—though it is probably just as well that they don't pass right through the bird but are regurgitated. Otherwise the resplendent quetzal bird might be famed for its constipation!

It's as if the fruits of many seeds had a sign hanging on them saying, "Eat me." Their color, taste, and smell are all inviting, and it doesn't take long before an animal accepts their invitation. And if they don't? The fruit falls to the ground with its precious packet of seeds and may germinate anyway. But, without the animals—especially the birds—that feast on their fruits and carelessly drop their seeds from the skies, a lot of plants would be rooted to the spot in every sense.

The Biosphere

Earth is packed with living things. Every plant and animal lives in an environment on Earth. One more name for this environment is the "biosphere." The biosphere is the part of our Earth that supports life—the land, the water, and the lower atmosphere.

A Habitat

A plant's habitat is its address—the place where it lives. An animal's habitat is its address, too. Because most animals move around, an animal's habitat is wider and bigger. A cave, a woodland, a pond, or a forest floor are all habitats. So are canals, gardens, and playgrounds.

Habitats are places that provide a source of raw materials for growth and activity; a source of energy, either from the sun or from the plants that harness the sun's energy; shelter from changing conditions, from weather and from predators; and a place to dump the products of living.

An Environment

We use the word "environment" to describe our surroundings on Earth. Our environment is everything that affects us—the place where we live, our home and school, our weather, our food, water, and the air we breathe, the plants and animals we affect and that affect us, the special animals we call our friends and family—and also the strangers whose work and behavior affect us.

The Ecosystem

The plants and animals in a habitat are linked through food chains and webs. The animals may live by eating plants found in their habitat or by eating other animals that in turn eat the plants. This link between plants and animals and their habitat is called an ecosystem.

How to Teach Ecology *(cont.)*

Lions eat gazelles that eat the green plants found on the African plains. They are in the same ecosystem. Gazelles don't eat seaweed, and lions don't eat penguins. They are not found in their habitat and so are not a part of their ecosystem.

Energetic Ecosystems

Ecosystems are about energy flow. Forget any romantic view of nature. Think of the plants and animals as links in this flow of energy. The first link in this chain is the green plant kingdom. Plants capture the sun's energy through a process called photosynthesis, whereby they make their own food. This energy is passed on to animals who eat the plants (herbivores) and then to meat-eating animals that eat the herbivores (carnivores). At any stage, nutrients are returned to the soil through the decomposition of waste—excrement and dead bodies—and the cycle is complete. So even the soil and the physical surroundings are part of the pattern.

This is not an efficient process—each link in the chain needs to keep some energy for itself. The plants need to live and grow. So do the animals. In addition, creatures like us need to stay warm—an expensive business in terms of energy. We can waste a lot of this energy as heat loss, too.

The whole thing is pretty fragile. The removal of just one species can unravel the ecosystem with terrifying speed. That's why environmental protesters can get so hot under the collar. Take, for example, the spread of myxomatosis among rabbits. This disease was welcomed by farmers when it began to wipe out these cuddly pests. But the decimation of the rabbit population was catastrophic for foxes, who began to look for food elsewhere, wandering suburban streets in search of full trash cans. At the other end of the scale, wild plant populations exploded, uncropped by rabbits. Suppose the fox population had been wiped out instead. The result would have been an explosion of rabbit numbers (remember, they would breed like rabbits!) and the green plants would be grazed to extinction. And then the starving rabbits would begin to die....

Food Chains

Why don't lions eat oranges?

Because they can't peel them, silly!

There are food chains in every habitat that ensure that organisms survive. You can see these food chains as a sort of energy flow and, ultimately, all that energy begins with the sun. It is the sun's energy that plants convert to their own structures, and hence to food. Green plants are the first link in most food chains.

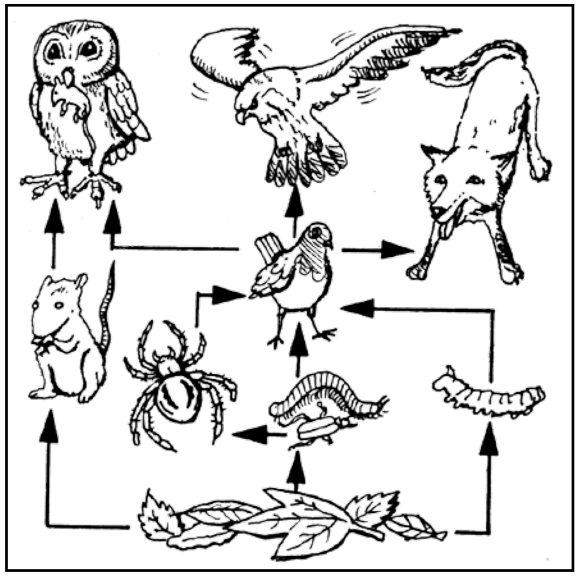
After green plants, the next link is the plant-eaters. Finally, predators live off plant-eaters and also off each other. Food chains show how plants are eaten by plant-eaters, and plant-eaters are eaten by meat-eaters.

Of course, it's never quite as simple as that. Food chains with the direct line of the grass—zebra—lion type don't show the whole picture. Grass is eaten by more than just zebras; zebras eat more than just grass and are themselves eaten by more than just lions. And the lions eat more than just zebras.

Food Webs

It is easier to understand this in terms of food webs. Aphids live off plants and ladybirds live off aphids. But the ladybird could meet any number of fates from insect-eating birds, who might themselves take a fancy to a juicy aphid….

A food web shows the animals that might live on or around a tree for example. In every food web, there are many different food chains. The food web in a woodland, for example, might involve some plant-eating consumers like grasshoppers and mice. A secondary consumer like a frog might not tackle a mouse but will make a meal of a grasshopper. Snakes are partial to frogs, but not averse to a mouse or a grasshopper, either. Hawks will eat a snake—or jump that link and go straight for a mouse.



Fascinating Fact

Not all food chains start with a green plant. There are deep-sea life forms that can harness chemical energy. These bacteria live in total darkness near the hydrothermal vents of the Pacific Ocean, in very high temperatures. Deep-sea animals eat the bacteria as other animals eat plants.

Just Another Bypass

Of course the biggest ecosystem destroyer has two legs—and giant earthmovers and an unlimited supply of concrete. When a new road is pushed through a habitat, it rattles not just the plants and animals living there, but others that depend upon them. Well-meaning conservationists have attempted to save habitats by moving them—rolling up a meadow to make room for a supermarket, for example. But other factors—the soil, the exposure, the microclimate—are different, and these projects are seldom successful. It's not just the plants and animals that matter. It's every aspect of the ecosystem. The more we learn about the environment, the more we discover how closely everything is interlinked.

Changing Habitats

Habitats change naturally. They may change daily, when the sun comes up and goes down, or the tide goes in and out. They may change with the seasons, as it turns first cold and then warm again. They may change completely over short periods of time: after an earthquake, a flood, or a volcanic eruption. They may change completely over a longer period of time, as a river changes course or rocks wear away. Ponds dry up, trees die and are replaced by new young trees, and grass withers in a hot summer.

Habitats are also changed by outside influences. Faced with yet another grazed knee, the principal of a primary school decided that the uneven paving slabs would have to go. A smooth layer of asphalt was the answer: no breaks, no gaps, no edges to trip over. The job was quickly done; but a small habitat was destroyed.

The small plants had had a grip on the thin soil between the slabs; ants had nested in the soft bedding sand; worms, beetles, and other small invertebrates lived under and between the stones. Birds were occasional visitors: the thrush that had found both snails and a handy anvil and the woodpecker that had feasted on ants when the tree insects were few. With the birds gone, the neighborhood cat no longer lurked with a view to catching a bird.

We can't help environmental change, but we can be sensitive to the rolling effects of our actions. On a much larger scale, desertification is the process that renders fertile land arid and dead. Around the world, a hundred square kilometers are lost to desert every day. In Africa, a series of droughts has enlarged the Sahara southwards. These droughts may be linked to world climate change. But heavy grazing and deeper wells have disturbed the fertile Sahel region, so that the Sahara is growing at around 5 km a year.

So, habitats are always changing. Most plants and animals can adapt to small changes in their habitat. But some cannot. Most animals can move when the habitat changes and find somewhere else to live. Plants cannot. Animals may survive seasonal change by migrating or by hibernating. Big changes to a habitat can destroy populations of animals and plants. Some of those big changes are made by people.

Extinction

Plants and animals that cannot adapt to changed conditions die out. And because humans have been responsible for more environmental change than any other factor, humans have been responsible for a great many extinctions. More animals have become extinct in the past 300 years than in all the years before because of humans. We have changed habitats by farming, clearing trees, and building roads and houses. Animals like the dodo, the Tasmanian wolf, and the Balinese tiger have died out.

We Can't Stop Change

Some of the most major changes are the result of the human factor. By our use of land, we can change habitats and affect the lives of plants and animals. Our changes may be damaging—green field site development—or for the better—the landscaping of old industrial sites. We are learning to protect environments, recognizing the delicacy of environmental balance and the vulnerability of the natural world.

This may go against your lifestyle. You may be an inner-city dweller who never sees a blade of grass. But you are as dependent on the environment as anybody. And remember—nowhere is without life. You just need to get out more and look around you!

We are rightly concerned about environmental change—and especially environmental damage. But we would be wrong to think that habitats are unchanging. Every habitat is changing, even without human intervention. Animals and plants unable to survive these changes—annual, seasonal, or daily—will soon be extinct.

What Gives the Zebra Its Speed?

Name ________________________________

What You Need:

- candy-coated chocolates
- notebook paper
- pencil or flexible drinking straw (bent in the shape of a hook)

What To Do:

1. Put a pile of candies in the center of a piece of notebook paper. This represents a herd of prey. Separate the red and orange candies (predators) from the pile and put them on the edge of the notebook paper. There should be no more than three red predators and three orange predators in the scene at any time.

2. This is a two-person (or team) exercise. One person will be the Herd Master and will try to get as many of the healthy animals as he or she can off one end of the paper by pushing them toward safety (one inch at a time) with a pencil or straw. The goal of the Predator Pusher is to push a predator (one inch at a time) until it touches a prey.

3. Each turn the Herd Master can move any three animals. The Predator Pusher can also move any three predators. Use the chart below to see how many one-inch pushes each animal gets.

Color of Candy	Organism	Number of Pushes
brown	adult herd animal	two
green	fast, young herd animal	two
blue	old herd animal	one
yellow	sick herd animal	one
orange	slow predator	one
red	fast predator	two

What To Do: *(cont.)*

4. If a fast predator (red) touches a prey, it will consume the energy of that animal. Remove the prey from the paper. This predator may continue hunting.
5. A predator that is in poor health due to injury, disease, or old age would not be able to move as fast as younger, healthier predators. If a slow predator (orange) touches a prey, it must sit in place for one turn and digest the food. Then remove the prey from the board.
6. If a predator does not eat within three turns, it dies and must be removed from the board.
7. Predators always go first. Predators should wait to start this activity until they think the prey is not paying attention.
8. At the end of the activity, write down the number of each color still left on the paper. Then switch roles and play again.

Next Question

Think strategically. What could the predators do to make sure more predators get more food? What could the herd animals do to make sure more herd animals escape?

Notebook Reflection

Describe the game from the point of view of one of the predators or as one of the herd animals. What things would be most important to your survival?

How Do Consumers Trade Off?

Name ________________________________

What You Need:

- colorful candies
- notebook paper
- pencil
- die

What To Do:

1. Form a pile of candies and cover them over with a piece of notebook paper or a paper towel so that they can't be seen. Two people play this game. The only candies each player gets to keep will be the ones given to him or her by the other player. Determine who will go first and decide who will be the Producer and who will be the Consumer.

2. Without looking, the first player will use a pencil to poke and prod one candy out from the pile. Use the chart below to determine what the candy represents. If the candy is one of the right colors, he or she (Producer or Consumer) can pass it to the other player. If it is not a color that the other person needs, the candy goes back into the pile where nobody can see it. Then it is the next person's turn.

Organism	Can give	Which is	To the	So that it could…
consumer	brown	nitrogen (N)	producer	use nitrogen compounds from the soil
consumer	blue	water (H_2O)	producer	make sugar from H_2O and CO_2
consumer	red	carbon dioxide (CO_2)	producer	make sugar from CO_2 and H_2O
producer	orange	oxygen (O or O_2)	consumer	respire (exchange gasses)
producer	green	sugar ($C_{12}H_{22}O_{11}$)	consumer	use the chemical energy stored in fruit
producer	yellow	carbohydrates	consumer	use the chemical energy stored in plants

How Do Consumers Trade Off? *(cont.)*

What To Do: *(cont.)*

3. Draw a consumer/producer diagram on the notebook paper. Include arrows to show the direction in which each element or compound flows and how all materials are recycled.

Next Question

Use classroom resources and the Internet to research aquatic habitats. Diagram the relationships between those organisms.

Notebook Reflection

Write about what would happen to a food web if a toxin or poison were to be introduced at any point.

How Is Sunlight Passed Around?

Name ______________________________

What You Need:

- flashlight or lamp
- colored cereal in a cup or bowl
- sandwich baggie
- glow-in-the-dark items
- die
- peanut
- clamp to hold the peanut while it burns (alligator clip, forceps)
- matches

1. Plant Phase. Write the formula for simple sucrose, $C_6H_{12}O_6$, on a piece of paper. Put the cup of colored cereal where it can be reached. Assign one color of cereal to represent carbon (C) and another color to represent oxygen (O). Pick two colors that are close to each other, like blue and green, to represent hydrogen (H). These elements are found in water (H_2O) and CO_2.
2. Put the glow-in-the-dark item under the flashlight or lamp for one minute to add "sunlight" energy.
3. Turn the flashlight or lamp off. Turn down the other lights in the room so that it is dim enough to see the glow of the item. As quickly as you can, pull a piece of cereal out of the cup and put it on the paper towel. Keep pulling until the glow on the glow-in-the-dark item stops glowing. You must stop when the glow fades from the item.
4. Turn the room lights up to bright. Try to arrange the colored cereal on the paper towel to create one molecule of sucrose ($C_6H_{12}O_6$). If there are enough to make one entire molecule of sucrose, then put that collection of colored cereal into the baggie. Only whole molecules of sucrose may be placed in the baggie. Plants are called producers because they use the energy of sunlight and certain elements to produce food.
5. Repeat Step #3 and #4 until at least two full molecules of sucrose are in the baggie. The energy from the light is necessary to rearrange the elements. The colored cereal in the baggies represents stored energy in a sugar-rich "fruit," vegetable, or a blade of grass.

What To Do: *(cont.)*

6. Animal Phase. Leave the bag on a table or desk. Roll the die to see which type of animal to enact.

   Anybody who rolls a 1, 2, 3, or 4 must act like a first order consumer (plant eater or herbivore). These animals may eat only plants. First order consumers compete with other first order consumers for the plants, and they must compete with second order consumers for survival.

   Anybody who rolls a 5 must act like a second order consumer (meat eater or carnivore). These animals must attack the plant eaters and compete with the other meat eaters for the chance to eat the plant eaters.

   Anybody who rolls a 6 is a decomposer. Any time a decomposer reaches a baggie of a sucrose molecule, it may dump the bag back into the cup. This is what decomposers do. They break up chemicals and return the elements to the soil.

7. The Competition. All animals go to the walls of the room. Plant eaters get a head start. They take three steps toward each of their separate goals (the baggies of stored energy). After this, all the animals and decomposers will take one step together for turn after turn. Whenever two animals get within two arms' reach of each other they start the Engagement.

How Is Sunlight Passed Around? *(cont.)*

What To Do: *(cont.)*

8. The Engagement. The two animals get ready to stare each other in the eyes. Someone yells, "Go!" The animals keep staring. The first one to blink, loses. The winner gets to take any stored energy baggies that other animal had. See the chart below.

plant eater	versus	plant eater	Winner gets the food.
plant eater	versus	meat eater	If plant eater wins, the meat eater cannot engage this animal for at least one turn. If the meat eater wins, the plant eater must sit down and wait for the decomposers.
meat eater	versus	meat eater	Winner gets the food. Loser must sit and wait for the decomposers.
decomposer	versus	anything	If decomposer wins, the animal turns over the food.

9. Continue playing until there is only one animal left. An adult must put the peanut in the clamps and be in charge of this part. Light the peanut. The last organism left standing will survive as long as the peanut keeps burning. The peanut burns because it, like all the other plants, transferred sunlight energy into chemical energy and found a way to store the extra. One byproduct of the peanut burning is heat.

Next Question

Look for pictures and diagrams of the nitrogen cycle. Compare and contrast the transfer of nitrogen throughout this exercise.

Notebook Reflection

Write about the journey that each element has as it passes through all the organisms. How much do all the organisms depend on each other?

How Do Ecosystems Recycle?

Name ________________________________

What You Need:

- jumbo craft sticks
- twist ties
- flashlight or lamp
- notebook paper

What To Do:

1. In this activity, you will walk from one station to the next to show how matter is recycled within an ecosystem. Start at the Producers Station.
2. At the Producers Station, turn the flashlight on and read the following aloud: "Producers use sunlight to break up and rearrange the elements in gases, nutrients, and water (CO_2, H_2O, and nitrate compounds). This produces sugars ($C_{12}H_{22}O_{11}$), carbohydrates, and other organic molecules. The number of plants and animals that can grow in an area is limited to the amount of usable (fixed) nitrogen that is available. Nitrogen is necessary for proteins, nucleic acids (including DNA), and other life structures."
3. Pick up six craft sticks. Write one of these labels on each of the sticks: carbon, hydrogen, and oxygen. Write "A nitrogen" on one and "B nitrogen" on the other of the last two sticks. Turn each stick over. On the back, divide the stick into three sections. Label them P, C, and D.
4. Write how producers use each element in the "P" section on the back of each stick. Use the chart below.

Element Stick Front	Element Stick Back
carbon	$C_{12}H_{22}O_{11}$ carbohydrates
hydrogen	$C_{12}H_{22}O_{11}$ carbohydrates
oxygen	$C_{12}H_{22}O_{11}$ carbohydrates
A nitrogen	proteins
B nitrogen	proteins

What To Do: *(cont.)*

5. Put all of the element sticks in a stack. Wrap two twist ties around this stack, one on each end.
6. Turn off the flashlight, take the bundle of sticks, and go to the Consumers Station.
7. At the Consumers Station, pass the bundle of sticks from one person in the group to another. This represents the movement of the elements from first-order consumers (herbivores) to second-order consumers (carnivores). Consumers use the elements for protein synthesis and energy.
8. Break up the bundle of sticks. Consumers use the elements to release energy. Write how each of the chemicals from the producers is used by consumers on the back of each stick in the "C" section.

Element Stick Front	Element Stick Back
carbon	proteins stored energy
hydrogen	proteins stored energy
oxygen	proteins stored energy oxidation
A nitrogen	proteins
B nitrogen	proteins

9. Remove an A nitrogen stick and walk this stick over to the Decomposer Station, leave it there and walk back to the Consumer Station. Some nitrogen compounds are returned to the soil as animal wastes. The B nitrogen stick will stay with the rest of the element bundle.
10. Wrap the twist ties around the bundle again. Take the bundle of the remaining element sticks to the Scavengers Station.
11. At the Scavengers Station, untie one of the twist ties on the bundle of element sticks. Scavengers are the first step in the breakdown of organic matter.

What To Do: *(cont.)*

12. Take the loose bundle of element sticks to the Decomposers Station.

13. At the Decomposers Station, read the following aloud: "Decomposers break down organic matter into materials that can be used by producers to synthesize the larger molecules like sugars and carbohydrates."

14. Untie the last twist tie.

15. Pick up an "A Nitrogen" stick at this station and write nitrates and NH4+ on the back of the stick. Bacteria will convert nitrogen into plant-usable ammonium (NH4). Other bacteria in the soil will then change ammonium into usable nitrates.

16. Write how decomposers rearrange the elements to create new chemicals in the "D" section of the back of each stick.

Element Stick Front	Element Stick Back
carbon	stored energy
hydrogen	NH4+
oxygen	oxidation
A nitrogen	nitrates NH4+
B nitrogen	nitrates NH4+

17. Carry each of the element sticks, one at a time, to the Producers Station.

Next Question

What could you change about the lab to demonstrate an ecosystem with too few producers or scavengers?

Notebook Reflection

Draw the complete food web somewhere on the notebook paper. Label and give examples of organisms for each step.

Matter

This chapter provides activities that address McREL Science Standard 8.

Student understands the structure and properties of matter.

Knows that matter is made up of tiny particles called atoms	*How Does a Mass Spectrometer Work?, page 119* *Why Do Crystals Have Regular Shapes?, page 123*
Knows that atoms often combine to form a molecule	*How Are Crystals Created?, page 121* *Why Do Crystals Have Regular Shapes?, page 123*
Knows that states of matter depend on molecular arrangement and motion	*How Do Smells Travel?, page 118* *How Are Crystals Created?, page 121* *Why Do Crystals Have Regular Shapes?, page 123* *How Do Gas Particles Move?, page 124* *What Is Air Pressure?, page 126* *How Do Stalagtites and Stalagmites Form?, see Teacher CD*
Knows that elements can be grouped by similar properties	*How Does a Mass Spectrometer Work?, page 119*
Understands the conservation of mass	*How Does a Mass Spectrometer Work?, page 119*
Knows methods used to separate mixtures into their component parts	*How Does a Mass Spectrometer Work?, page 119* *How Can I Separate Shavings from Sand?, page 128* *How Can Dirty Water Get Washed?, see Teacher CD*
Knows that substances react chemically in characteristic ways	*What Pushes the Water Out?, page 130* *How Can Dirty Water Get Washed?, see Teacher CD*
Knows factors that influence reaction rates	*How Can Dirty Water Get Washed?, see Teacher CD*
Knows that oxidation is the loss of electrons, and commonly involves the combining of oxygen with another substance	*What Pushes the Water Out?, page 130*

How to Teach Matter

The world is full of stuff. In fact, it's made from stuff—including you, me, and this book. Scientists call this stuff matter—a confusing word if you are a student being told that something "doesn't matter." Because in the scientific sense, matter is the substance of the universe. It's all the stuff in the world: rocks, wood, plastic, and steel. It's rare and expensive, like gold and diamonds, or common and cheap, like soil and water. It's everywhere. Different materials have different properties.

By looking at the properties of materials, how they are used, and how they might be changed, this subject prepares students for their later understanding of chemistry.

It is important to tackle work on matter in a logical order. Only then can students understand that materials differ; that they can be grouped and classified in many ways; that this classification can help us to choose the right materials for a task; and finally, that there are ways of changing materials that make them suitable for a range of needs and tasks.

Particle Theory

Particle theory is simply the idea that everything is made up of very tiny bits, or particles. An understanding of this is enormously helpful when learning about materials. And it isn't difficult to understand.

A selection of great and good scientists were asked to imagine that all the science knowledge in the world was to be destroyed but they could save one piece of information. What would it be? Almost without exception, they chose the same idea—rejecting evolution, electricity, and Newton's laws of motion. The fact they wanted to pass on to succeeding generations was that all matter is made up of tiny particles.

Words like "atom," "molecule," and "particle" are in general use—sometimes correctly, sometimes not. Most young students could make a stab at explaining what particles are, or at least that they are "very, very small bits." Some might even know that they are mostly space. Understanding what particles are is a great help to understanding the behavior of materials.

Atoms

An atom is the smallest particle of a material that still retains the characteristics of that material. That is, a bar of iron is made of iron. Cut off a piece, and it's still iron. Cut off a piece of that piece, and it's still iron. You can keep cutting and cutting until you've got just one single iron atom—and it's still iron.

However, if you cut that atom in half, what you have ceases to be iron. What you would have is a collection of subatomic particles: protons, neutrons, and electrons. Now, if you really had split that iron atom, the subatomic particles would clump back together (after releasing a whole lot of fission energy) immediately. Those new groups of subatomic particles would be new atoms of different elements, no longer iron and no longer with the characteristics of that material.

Molecules

Molecules are groups of atoms which are chemically stuck together. The molecule often has different characteristics than the molecules that went into it. Sodium and chlorine, for instance, are quite poisonous—but sodium chloride, also known as table salt, is essential to human life.

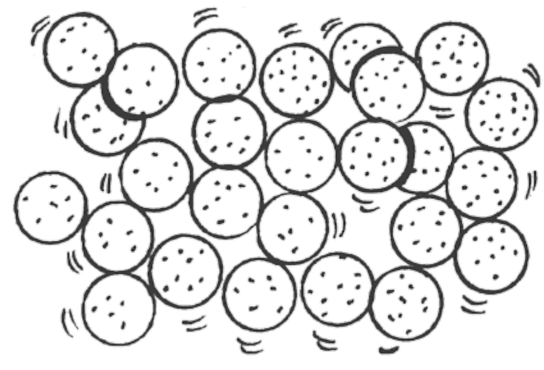
How to Teach Matter *(cont.)*

Solid, Liquid, and Gas

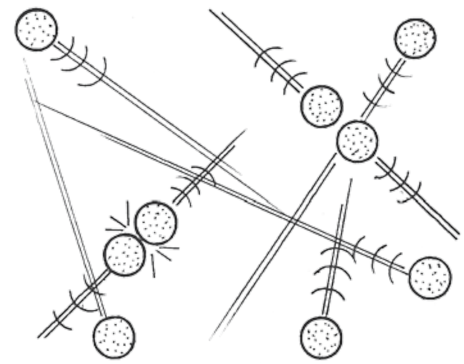
Materials can be divided into solids, liquids, and gases. This isn't as easy as it sounds. There are some materials that behave in ways that put them in more than one group. Water, for example, can be found in all three states. In addition, it's very hard to prove to students that gases exist.

- If the particles are closely bonded together—able to vibrate but not part from each other—then the material is a solid.
- If the particles are close but not packed, so that they can move around, the material is a liquid.
- If the particles are widely spaced and move around, occasionally crashing into one another, the material is a gas.

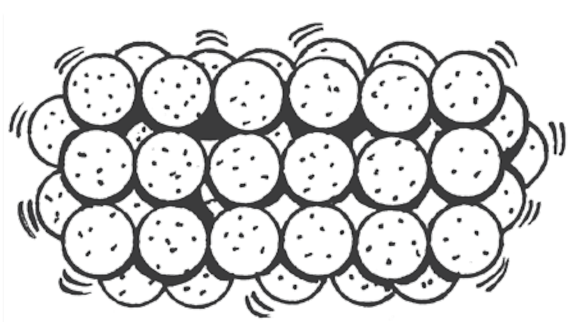
These three are called the states of matter.



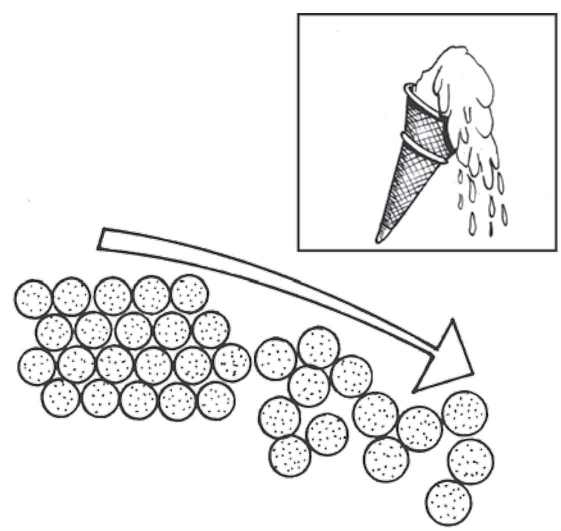
Liquid



Gas



Solid



Melting

How to Teach Matter *(cont.)*

Changes with Temperature

The changes between the three states of matter are connected to changes in temperature. Increase the temperature, and a solid becomes a liquid, or a liquid a gas. Very occasionally, a solid becomes a gas without a liquid stage. Reduce the temperature, and gas becomes a liquid, or a liquid solidifies.

Fascinating Facts

And Glass Is a Liquid

Let's just get this one out of the way. It comes up later, but it's a favorite in trivia contests and among well-read students. Glass is a liquid.

Liquids flow. The thicker the liquid, the slower the flow. At room temperature, water flows freely while syrup flows slowly. Syrup has a higher viscosity than water. It takes an age to flow from the bottle. But glass has an even higher viscosity than syrup. You can't imagine windows made from syrup. But glass has such a high viscosity—it is so thick—that you can cut it into sheets and put it into windows. Over time, it flows downward. Clear evidence of thickening can be seen at the bottom of century-old windows. The bottom of the pane is thicker than the top.

Melting and Freezing

When solids melt, they become liquids. They can flow, pour, and fill a shape. Some solids melt when they are heated. Butter melts to become a liquid. Chocolate melts, too. Both become solid again when they are cooled. The cooling process is called freezing—even if it's not very cold to you or me.

Chocolate is not changed much by the melting, but butter loses water when it melts. The butter is changed by the melting. You can't change it back.

Evaporation and Condensation

Evaporation is the process by which a liquid turns into a gas. Extra heat jostles the liquid molecules around until they're so excited, they don't even stick together any more. They're now a gas.

Condensation is a process by which a vapor or a gas turns back to a liquid. Water vapor condenses on a cold window and collects in a liquid form again.

Changing Matter

The concept of materials changing is a difficult one. It's not surprising that students recognize changes when they are spectacular—a color change, a flame, smoke—but not when they are unexciting.

They may feel that "stuff disappears." There was a match, it was lit, and now it's gone. They may think that the product was somehow inside the original material—thus rust may be thought to ooze out of a corroding nail. They may simply think that one material has "turned into" another—the flour and water have turned into bread—without a word of explanation.

How to Teach Matter *(cont.)*

Sometimes we need to bring the material back to show that it was there all along.

Can You Make Bread from Toast?

Matter changes in two ways: physically and chemically. The difference between physical and chemical change is that whereas physical change is only a change in form—the substance is still there—chemical change is when new and irreversible substances are created. Sugar dissolving in tea is a physical change, but baking a cake is a chemical change.

Some physical changes are irreversible. Try sawing your leg off to see what I mean. No chemical change has taken place, but reattachment could be difficult.

So think of it this way:

Physical changes involve the rearrangement of particles: mixing, separating, putting them in a different state (solid, liquid, gas), or otherwise doing something to them without actually changing the particles themselves.

Chemical changes give you something new. The particles have been changed by splitting or combining with others or by changing partners so that they produce a new material you didn't have before.

So making sawdust is a physical change (which is irreversible), but making ammonia from hydrogen and nitrogen is a chemical change which is reversible—you can get the hydrogen and nitrogen back.

Although most physical changes are reversible and most chemical changes are not, there are exceptions!

Toast some bread. What kind of change happens? Can you reverse it? What is the material that forms on the surface of the bread? Burned toast is carbon. That's a new material, so the change is a chemical one. If you cut your toast in half, though, that change is physical—no new materials are made; the toast is just in two parts instead of one.

Does Salt Disappear in Water?

If you ask students what happens when something dissolves, they will often tell you that it "disappears." This seems to be true of materials that dissolve to make a colorless liquid—like salt or sugar. But dissolving instant coffee produces a material where the coffee has far from disappeared—it is clearly there throughout the changed, colored liquid.

Students' views may reflect their observations. Consider the following: "When I add sugar to my tea, it just disappears. You see the same thing when you add salt to water; first it's there and then it's not. The water won't weigh any more with the salt in it—it's just disappeared. You could go on adding salt if you liked. It would just go on filling the spaces."

Dissolving takes place when one substance is dispersed through another to become a single material. This material is called a solution. In theory, the substances involved could be solids, liquids, or gases. In practice, students will come across this most often when they add something solid to a liquid—for example, salt to water or sugar to tea. The solid and the liquid are called the solute and the solvent.

When a solid dissolves, it becomes dispersed throughout the liquid. If you were to sample any part of the liquid, you would find the solid there. This is not what happens when you add something insoluble to liquid (when it lies at the bottom or floats on the top) or something that forms a suspension, like flour (where the bits float about until they sometimes sink to the bottom).

When a white or colorless solid is added to water, it appears to disappear. Tasting safe materials in solution proves that the solid is still there. Colored solids may color the water, and the students can see how they color the whole of the solvent evenly.

Diffusion

Open a new air freshener, put it on a table, and then walk around the room. How quickly does the smell fill the room? Where do you have to stand so that you cannot smell it? Everything is made up of tiny particles. They are closely packed in solids, freer to move in liquids and freest of all in gases. How does that explain your air freshener?

The solid material in the freshener is losing particles. The particles are floating off and arriving in your nose, an organ designed to accept the tiny particles in a gas. Although your nose isn't in direct contact with the air freshener, you know it is in the room!

Can't Take Any More!

When the solvent cannot dissolve any more of the solute—the water cannot dissolve any more salt, for example—then the solution is saturated. Students may observe that salt will not go on dissolving in water forever. You can increase the amount of solute that the solvent will dissolve by raising the temperature of the solution, but as soon as the temperature falls, the solid comes out of solution again.

Raising the temperature of the solute and stirring are familiar ways of speeding up dissolving. These two methods work because both encourage the release of the tiny particles of solid into the liquid. As a student once said when explaining dissolving, "If you dropped me in hot water and then hit me around the head with a spoon, I'd let go of my friends, too!"

Dissolving should not be confused with melting. Melting is the change of state from solid to liquid with increased temperature. Dissolving is one substance dispersing into another substance. However, some materials melt and dissolve simultaneously. Jelly can become a liquid and disperse through the water when stirred with hot water.

What Really Happens?

What happens to things that dissolve? Surely the salt has to go somewhere? When you add a solid that will dissolve to a liquid, it begins by filling the spaces between the particles of liquid. Rather like a theater with a fixed number of seats, the liquid will take so many arrivals before it is full. When it is full, the liquid can take no more, and is said to be saturated. The excess, like disappointed film-goers, is rejected and sinks to the bottom. Strangely, the level of the solute actually falls at first.

But some materials, like sand, don't dissolve. They may sink to the bottom of the liquid or, if they are low density, they may sit in mid-water or in suspension. If you put the liquid through a filter, only dissolved particles pass through. Large, undissolved particles are netted and stay behind. If you then let the water evaporate, you will be left with the dissolved solid, which may form crystals.

How Do Smells Travel?

Name ______________________________

What You Need:

- eucalyptus oil
- lavender oil
- 2 saucers

What To Do:

1. Watch your teacher pour about 15 milliliters of eucalyptus oil into a saucer and place it somewhere in the room. Note the time it was poured:______________

2. Raise your hand when you first smell the oil.

	first person	me	last person
time smelled			
distance from oil			

3. Now watch your teacher pour the same amount of lavender oil into another saucer and place it somewhere else in the room.

Note the time it was poured:____

4. Raise your hand when you first smell the new scent.

	first person	me	last person
time smelled			
distance from oil			

Next Question

Do different scents travel at different speeds? What factors might change the spread of a scent through a room? Devise an experiment to find out.

Notebook Reflection

How do you think the scent traveled from the saucer to your nose? How can the data you gathered help support your theory?

How Does a Mass Spectrometer Work?

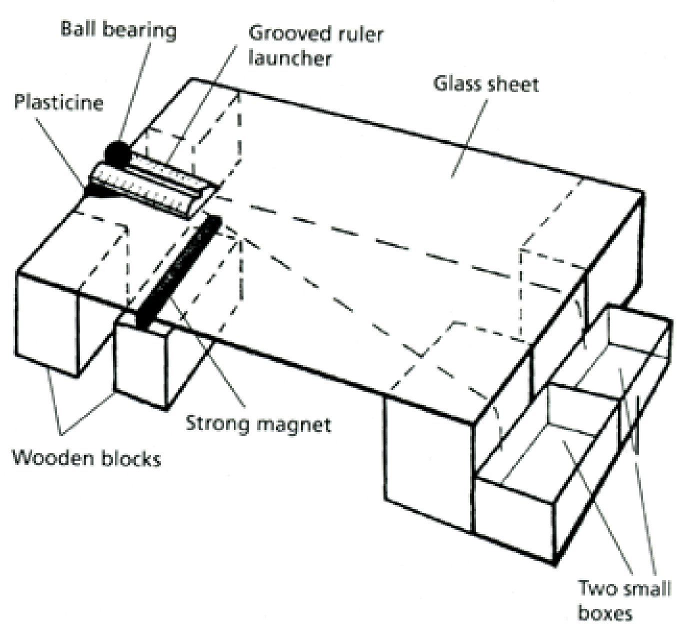
Name ________________________________

What You Need:

- sheet of glass or plastic about 18 cm x 12 cm
- block spacers
- strong magnet
- ball bearings of different sizes
- 5 cm length of a grooved wooden ruler
- ruler
- modeling clay
- a towel
- scale

What To Do:

1. Support the sheet of glass on four block spacers with the strong magnet positioned underneath the sheet on a lower spacer. Place the towel, folded thin, at the other end of the model.
2. Saw 5 cm off the end of a grooved wooden ruler and attach it with modeling clay at the end of the glass sheet above the magnet. This is your launcher.



What To Do: *(cont.)*

3. Weigh the different ball bearings and then release them down the ruler. What happens as the balls of differing masses roll down the launcher onto the glass and past the magnets? ______________________________________

4. The ball bearings will drop off the glass and onto the towel. Measure how far from the center of the glass they end up.

	weight	resting place
ball bearing #1		
ball bearing #2		
ball bearing #3		
ball bearing #4		

5. Can you find a pattern?

____

____

____

Next Question

Scientists have sent mass spectrometers to other planets in unmanned probes. The probes used mass spectrometers to analyze the soil and atmosphere. What would the scientists be able to learn from that?

Notebook Reflection

The ball bearings of different weights represent atoms of different atomic masses. Describe how a real mass spectrometer would work, separating atoms instead of ball bearings.

How Are Crystals Created?

Name ________________________________

What You Need:

- 2 beakers
- boiling water
- 2 shallow bowls
- 2 spoons or stirring rods

chemicals, including:

- table salt
- sugar
- laundry detergent
- baking soda
- copper sulphate

What To Do:

1. Choose two of the chemicals provided by your teacher.
2. Label your two bowls with your name and the names of your chosen chemicals.
3. Set up your beakers on a cleared table. Your teacher will pour boiling water into each.
4. Use a spoon or stirring rod to mix your chosen chemical into the water until no more will dissolve. You have created a saturated solution.
5. Pour the solution into the appropriate bowl.
6. Repeat Steps #2–#4 with the second chemical, using a different stirrer.
7. Place the bowls where they will be undisturbed for three days.
8. Observe the two bowls over the next three days.

How Are Crystals Created? *(cont.)*

What To Do: *(cont.)*

Chemical: Day 1	Chemical: Day 1
Chemical: Day 2	Chemical: Day 2
Chemical: Day 3	Chemical: Day 3

9. Describe in words what happened in both bowls.

____

____

Next Question

Compare your results with the rest of the class. What were the similarities? What were the differences?

Notebook Reflection

Can you explain what happened in the bowls? What evidence do you have to support your theory?

Why Do Crystals Have Regular Shapes?

Name ______________________________

What You Need:
- large round balloon
- 13 ping-pong balls

What To Do:

1. The ping-pong balls will each represent individual molecules of a crystal. The balloon will be the forces that compress around the forming crystals.
2. Push the 13 ping-pong balls into the balloon. You can do this by stretching the neck of the balloon and pressing a ball into it. If it gets stuck half-way, try blowing hard. Also try squeezing the outside of the balloon neck and so manipulate the ball through. The 13 ping-pong balls should barely fit; if they all fit easily, the balloon is too large for the experiment.
3. Now blow up the balloon to half or three-quarters its size. Pinching the neck between thumb and forefinger of one hand and holding the balloon in the other, vigorously shake the balloon as you slowly let out the air. Describe what happens throughout the process.

   ____

   ____

   ____

4. Repeat Step #3 again, watching for new observations.

   ____

   ____

   ____

Next Question

An icosahedron is the most closely packed arrangement of 13 spheres. What shapes can you get with different numbers of ping-pong balls? Try it out.

Notebook Reflection

Describe in your own words how the experiment produces the same shape every time. How might this relate to crystals and how they form?

How Do Gas Particles Move?

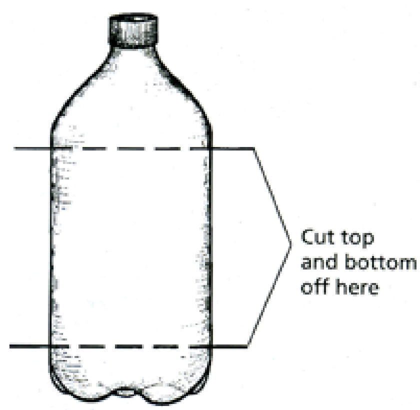
Name ________________________________

What You Need:

- clear 2-liter bottle
- scissors or craft knife
- rubber bands
- coarse plastic mesh or screen
- polystyrene packing pellets
- colored marker
- electric fan

What To Do:

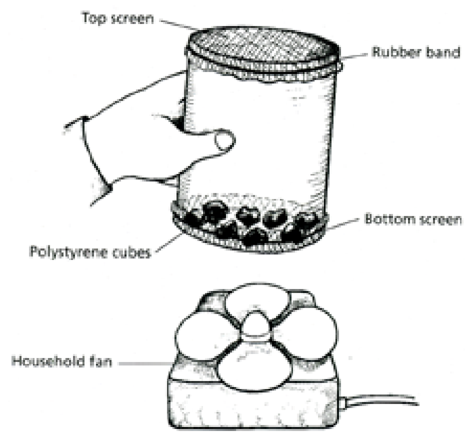
1. Cut the top and bottom off the plastic bottle as shown below.



2. Attach the coarse plastic mesh over the bottom of the plastic bottle and fix it with rubber bands.
3. Cut up the packing pellets into small pieces and put them in the plastic bottle. Cut them small, but not so small they will fall through the plastic mesh.
4. Color one of the polystyrene pieces with the marker.

What To Do: *(cont.)*

5. Secure another piece of plastic mesh over the top of the plastic bottle.



6. Hold the bottle over a fan switched to low speed so that air blows upwards through it. Watch your colored piece carefully. Describe its path.

____

____

____

____

Does it always have the same speed? ________________________

What does it collide with? ____________________________

Next Question

Take the top off of your bottle and color four more polystyrene pieces new colors. Perform the experiment again and try to keep track of the colored pieces. What does their motion say about how gas molecules move?

Notebook Reflection

Imagine you were a gas molecule much like the colored piece of polystyrene. Describe your "day" as a gas molecule bouncing around with other molecules. Where does all that energy come from? What would high pressure and low pressure feel like?

What Is Air Pressure?

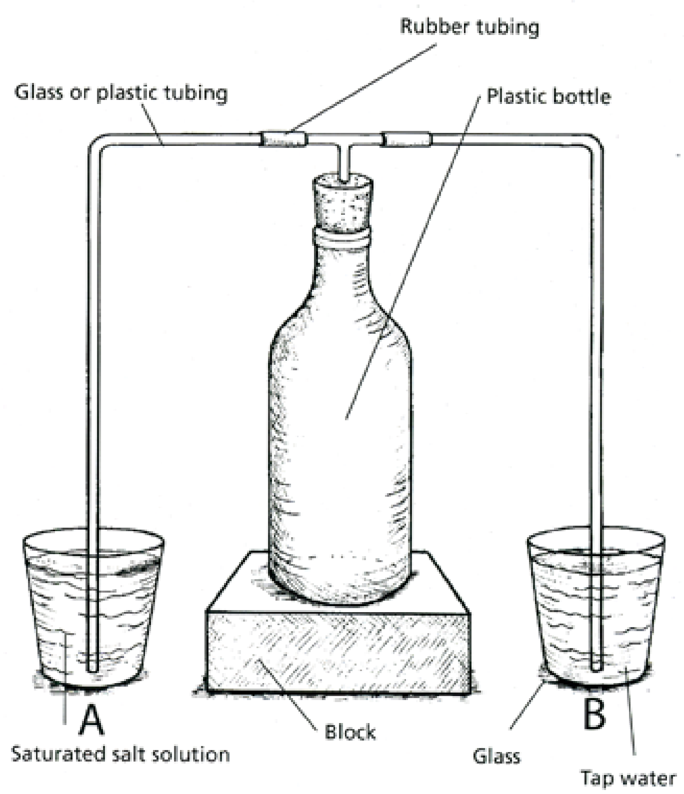
Name ______________________________

What You Need:

- scissors
- plastic soft drink bottle
- blocks
- cork to fit bottle
- glass or plastic tubing
- rubber tubing
- T-piece tubing
- 2 glasses
- modeling clay
- water
- table salt

What To Do:

1. Drill a hole through the cork and pass the stem of the T-piece through. Use modeling clay to make the seal airtight.
2. Use two short pieces of rubber tubing to connect the arms of the T-piece with two pieces of bent glass or plastic tubing.
3. Place the cork in the bottle and the tubing ends in the glasses. Use books or blocks so the bottle can stand up between the glasses.



What To Do: *(cont.)*

4. Label the glasses "saturated salt solution" and "water." Fill each appropriately.
5. Squeeze the plastic bottle and release it. What happens?

____

____

____

____

Next Question

Did the salt solution and the water rise to the same level? Why do you think this is? What other liquids would rise to different levels?

Notebook Reflection

Describe what happened inside the bottle and in each tube.

How Can I Separate Shavings from Sand?

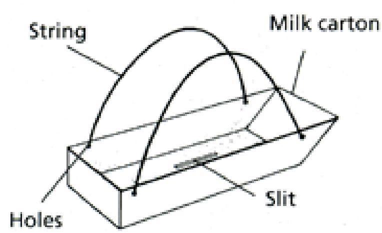
Name ______________________________

What You Need:

- milk carton, washed
- scissors
- hole punch
- iron rod
- insulated electrical wire
- string
- stand
- shoe box
- cardboard
- large battery
- pliers
- iron filings
- sand

What To Do:

1. Create some "iron ore" by mixing sand and iron filings in equal amounts.
2. To make the hopper, cut the milk carton in half lengthwise. Cut a narrow 2 cm long slit in the base of the hopper. Use the hole punch to make four holes in the sides. Make two handles out of string and thread them through these holes.



3. To make the collecting box, divide the shoe box in half with a piece of cardboard taped in place.
4. Hang the hopper from the stand so that it sits directly above the collecting box. The hopper's slit should line up with the divider in the collecting box.
5. Make an electromagnet by winding insulated wire 100 times around the iron rod. Leave 15 cm of wire free at each end. Remove 2 cm of insulation from each end and attach them to the terminals of the battery. Secure the electromagnet to the stand.

What To Do: *(cont.)*

6. Pour the iron ore into the hopper. Adjust the placement of the hopper, electromagnet, and collection box so that the ore separates as it falls. Describe how it works.

____

____

____

____

Next Question

What other materials can be separated in this way? For what materials does this process not work? Can you devise new processes for these other materials?

Notebook Reflection

How could this process be used on real iron ore? What would be different? What problems do you imagine engineers would have to prevent in an industrial process?

What Pushes the Water Out?

Name ________________________________

What You Need:

- 2-liter bottle, clear
- cork to fit bottle
- glass tube
- electric drill
- vinegar
- water
- tissue paper
- baking soda

What To Do:

1. Drill a hole through the cork small enough that the glass tube fits in it very snugly. Slide the tube in so that about 2 cm of tube sticks out of the top and the cork and glass can be put into the mouth of the bottle.
2. Pour 750 mL vinegar and 750 mL water into the bottle.
3. Cut out a 10 cm square of tissue paper. In the center, place 10 mL baking soda and roll up the tissue to form a narrow packet.
4. Go outside. Have the cork and glass tube ready. Drop the baking soda packet into the bottle, and quickly put the cork into the bottle. What happens?

At first,

____

Then,

____

____

Finally,

____

____

Next Question

The vinegar and baking soda created a chemical reaction, producing carbon dioxide. Why didn't the pressurized gas escape out the top?

Notebook Reflection

Imagine the experiment as a story with three characters: the water, the vinegar, and the baking soda. Write a short dialogue that occurs as the experiment takes place.

Energy

This chapter provides activities that address McREL Science Standard 9.

Student understands the sources and properties of energy.

Knows that energy is a property of many substances and most chemical and nuclear reactions involve a transfer of energy	*How Does an Electrophorus Work?, page 137* *How Does an Electroscope Work?, page 141* *How Can I Make a Battery?, page 146*
Understands the law of conservation of energy	*How Does an Electrophorus Work?, page 137* *How Does a Turbine Work?, page 139*
Knows that heat energy moves through conduction, convection, and radiation	*How Are Light and Heat Related?, page 154* *How Does Heat Travel?, see Teacher CD*
Knows how the Sun acts as a major source of energy for changes on the Earth's surface	*How Is the Sun Like Baseball?, page 15* *How Is the Sun Put Together?, page 59* *What Can Sun Damage Do?, see Teacher CD*
Knows that electrical circuits provide a means of transferring electrical energy to produce heat, light, sound, and chemical changes	*How Does a Turbine Work?, page 139* *What Is a Morse Code Tapper?, page 142* *How Does a Dimmer Switch Work?, page 144* *How Can I Make a Battery?, page 146* *How Can an Electromagnet Flip a Switch?, see Teacher CD*
Knows that vibrations move at different speeds in different materials, have different wavelengths, and set up wave-like disturbances that spread away from the source	*What Disturbs the Flame?, page 148* *What Do Sound Waves Look Like?, page 149* *How Does Sound Travel?, page 150* *What Changes a Sound's Pitch?, page 152*
Knows ways in which light interacts with matter	*How Does a Camera Work?, page 156* *How Does Light Scatter?, page 157*
Knows that only a narrow range of wavelengths of electromagnetic radiation can be seen by the human eye; differences of wavelength are perceived as color	*How Are Light and Heat Related?, page 154* *How Does a Camera Work?, page 156* *How Does Light Scatter?, page 157* *How Do Colors Combine?, see Teacher CD*

How to Teach Energy

Students will have a great deal of experience with energy but a difficult time identifying what energy they encounter every day. Many will suggest electricity, but they also encounter heat, light, and sound every minute of every day of their lives.

Heat and Temperature

Temperature is a measure of how hot something is, not how much heat there is in it. A bucket of hot water may have considerable heat in it, but it is not at the same high temperature as a light bulb or a sparkler firework.

Thermometers measure the level of heat in degrees. There have been several scales for measuring temperature, but the most common is the Celsius scale, named after Anders Celsius. This scale calls the freezing point of water 0° C, and the boiling point of water 100° C.

If the sun is shining through the windows, or the heat is on, you may be warm. If the windows and doors are open, and the heat is off, you may be feeling chilly. If you have a thick sweater on, you may be warm, even if the room is cold. Several factors determine how cold you may feel—how cold the room is, how warm your body is, and how warm the heater is. To know each of these factors, we have to compare temperatures with the temperature of our bodies. However, our bodies are not accurate measuring instruments.

You can see this for yourself by conducting the following short experiment. Fill three bowls with water. Fill one from the hot tap (not too hot!), one from the cold tap, and one using half hot and half cold water. Put your bowls in a row: hot, warm, and cold. Put one hand in the hot water and one in the cold. Count to ten. Now put both hands in the warm water.

What do you notice? Because one hand has become used to hot water and the other to cold, they don't do a very good job of telling you how warm the warm water is. Why is using your body a poor way of measuring temperature? While a thermometer will give you an objective measure, based on a defined scale, your hands relate the temperature to previous experiences. The hand that has been in cold water senses the warm water as hot. The hand that has been in hotter water senses the warm water as cold. We have all had this sort of experience in the swimming pool, moving from toddler pool to main pool, from pool to hot shower. The sea can also feel very cold after you have been sitting on a warm beach.

Light

Light is a form of energy. The energy of light is called radiant energy. To radiate means to send out rays or waves. Only a certain type of radiant energy can be seen with the human eye. We call this visible light.

We can see because of light. Light bounces off objects and travels to our eyes. Our eyes and brain work together to translate that light into what we see.

How Light Is Made

Everything is made of very tiny particles: atoms and molecules. Heat causes particles to become excited and move faster. The excited particles then radiate light.

Have you ever seen the bottom of a pan that is heating on the stove? Did it look like the hot pan was turning colors? When heated, the atoms on the surface of the pan start to bump into each other. This causes them to give off extra energy. This radiant energy is what scientists call light.

Light travels in waves much like water moves in waves. The amount of energy that a wave carries determines the color of the light. Waves differ from each other in length, rate, and size. These are called wavelength, frequency, and amplitude. Wavelength relates to the color of the light.

What happens when a light wave hits the atoms that make up everything? Several things might happen.

- The light can change direction, or refract.
- Some of the light rays can reflect off of the surface.
- The light can be absorbed into the material.

Refraction

Light rays bend as they travel through the surface of transparent material. Transparent means that light can be seen through it and move through it. This bend in the light is called refraction. It occurs when light travels through different materials at different speeds.

Reflection

The return of a wave of energy after it strikes a surface is called reflection. Smooth and polished surfaces like mirrors reflect more light than surfaces that are rough or bumpy.

When light reflects from a smooth surface, all of the light rays reflect in the same direction. A mirror is smooth, so you can see your image in it. When light reflects from a rough surface, the rays reflect in many directions. It is impossible to see your reflection in paper, because the surface is rough.

Absorption

When it comes to color, absorption is the key. Look at the clothes you're wearing. What colors are they? The truth is, the colors are not in the clothing. The colors come from reflected and absorbed light. We see the colors because of the light that is reflected and sent to our eyes.

You know that light is made of waves. Each color has its own frequency. When visible light strikes an object, each frequency behaves differently. Some frequencies are absorbed. They are not seen. Some are reflected. The reflections are what appear as the color or colors of an object.

White light is made of all the colors of the rainbow. These colors are red, orange, yellow, green, blue, indigo, and violet. Some people know the colors as ROYGBIV. Now, look at something red. You can see just by looking at it that the object absorbs the frequencies for OYGBIV. But R, or red, is reflected. Your eyes pick up that reflection, and you see the object as red.

The important idea is that the color is not in the object. It is in the reflected light.

Sound

Sound comes from vibrations. Just like with light, atoms within substances move. Their movement creates sound waves. As the waves move through matter, they cause vibrations. The vibrations are picked up by the ear and sent as impulses to the brain. The brain translates them as the sounds we hear.

Sound Waves

Not all sound waves are alike. The

differences let us hear various sounds. Scientists have discovered that sounds and sound waves differ in the following ways:

- Wavelength is the distance between the troughs on either side of a single wave.
- Amplitude is measured in the height of the sound wave. It relates to the loudness or softness of a sound. When a wave is high, the sound is loud, and the amplitude is large. When a wave is low, the amplitude is small and the sound is soft.
- Frequency of sound relates to speed. The number of cycles per second that waves pass a given location is the frequency. The brain understands frequency as pitch. Fast vibrations cause high pitch. Slower vibrations make lower-pitched sounds. A tweeting bird makes a high-pitched sound. A roaring lion makes a low-pitched sound.

The Speed of Sound

Sound waves pass through all forms of matter. These include gas, liquid, and solid. The speed of sound changes as the waves pass these different states of matter. Sound waves move:

- slowly through gases.
- more quickly through liquids.
- fastest through solids.

Temperature also affects the speed of moving sound waves. Higher temperatures cause sound to move faster. At normal room temperatures, sound travels about 343 meters per second. That is like traveling 1,217 kilometers per hour!

The Doppler Effect

As you've read, pitch is the highness or lowness of sound. The frequency of a sound determines its pitch. High-pitched sound has a higher frequency. Low-pitched sound has a lower frequency.

Have you ever noticed that the pitch of a fire truck's siren is high when it comes toward you? Then it is lower as it passes and moves away. What causes this?

As the fire truck approaches you, the waves reach you more frequently. The pitch is higher than if the fire truck were not moving.

This pitch change, which was caused by a moving object, is called the Doppler effect. The firefighters on the truck do not hear any change in pitch. Their distance from the source of the sound does not change. The Doppler effect only comes into play when the distance changes.

Electricity

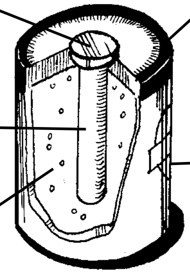
How Does the Battery Work?

It's a common misconception that batteries are somehow full of electricity. Some students think that connecting them up in a circuit uses all this electricity up, and then the battery is empty or "dead." But that's not how it is.

Electricity is a flow of minute particles called electrons, passed hand to hand like "pass the parcel." These electrons are in the materials that make up the circuit, but the battery provides the "push" that makes the electrons flow.

The energy for the push of a battery comes from chemical reactions in the battery. It's when these chemicals have all changed and there is no longer the material for the chemical reaction that we say the battery is dead.

Understanding the Flow of Electricity



The mistaken idea that electricity rushes out of the battery or the wall outlet, dashes to the radio, does its job, and disappears exhausted is not helped by the fact that a single cable operates most electrical appliances. Electricity apparently flows into the device to be "used up." You might show the students a piece of unconnected two-strand wire to show that electricity flows to a device and back again. There are two wires inside the cable.

The way electricity flows is affected by the components in the circuit. The electric current in a circuit is exactly the same wherever you decide to measure it. If there was electricity staggering back to the battery, you might expect there to be weak or strong points. But electricity flows a bit like water from a pump. The battery is the pump pushing the electricity around.

Complete Circuits

A circuit must be complete for the electricity to flow. All the components, linked in a complete circuit, are needed for a bulb in the circuit to light. Look closely at a flashlight bulb (when the light is off!). The wire filament inside is part of the circuit. The electricity flows right through the bulb.

Electric current has a direction from the negative to the positive terminal of the battery. When it was first investigated, it was thought that it flowed from positive to negative. However, this has now been shown not to be the case. And it certainly doesn't flow in both directions at once (the idea of "clashing currents" that students sometimes hold) despite the battery having two terminals.

An Analogy of an Electrical Circuit

You may need to use an analogy to explain the flow of electricity in a circuit to students. There is evidence that analogies help students to understand the invisible flow of electricity, but no analogy is perfect.

Use a loop of rope to represent the circuit. A student pushing the rope around in a circle represents the battery. If another student in the ring holds the rope more tightly, they create a resistance. They are behaving like a light bulb. An analogy of a switch would be a very tight grip on the rope: a resistance that no amount of pushing will overcome.

The bulb lights because the moving electrons collide with the fixed atoms in the thin filament wire (the filament wire resists the flow of the electrons). The moving electrons transfer energy from the battery to the bulb. The bulb glows—because it is in a glass globe that contains no oxygen, it can't burn away.

The wiring inside the bulb completes a full circuit. The more electricity flowing through the bulb, the brighter the bulb is. Students may think that a large battery will make a bulb brighter. Higher voltage batteries do tend to be larger, but size alone is not an indicator of voltage—for example, 1.5V batteries exist in several different sizes.

How to Teach Energy *(cont.)*

Caution!

It is essential to explain the safe use of wall outlet electricity devices early. Many students will have routine home experience of their use. Do not encourage exploration or investigation of wall outlet electricity. Explain that wall outlet electricity is dangerous and can be lethal.

How Does an Electrophorus Work?

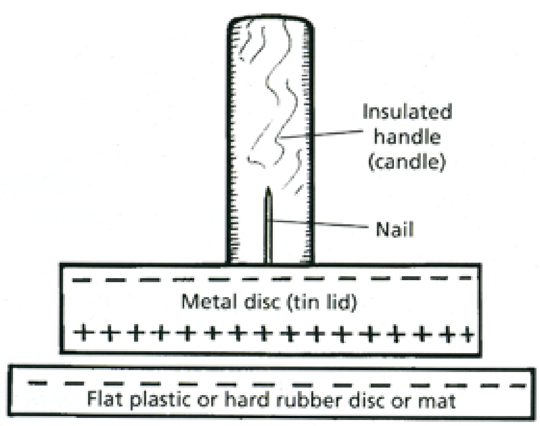
Name ________________________________

What You Need:

- metal lid
- flat head nail
- hammer
- flat plastic, hard rubber, or vinyl surface
- barbecue lighter
- candle
- woolen cloth
- balloon on string
- paper
- scissors

What To Do:

1. Drive the nail through the center of the metal lid. Watch your teacher heat the nail with the barbecue lighter. Push the candle down onto the nail until it touches the lid. You have built an electrophorus.
2. Rub the plastic, rubber, or vinyl surface vigorously with a woolen cloth for 20–30 seconds. This is your dielectric plate.
3. To charge the electrophorus, take the metal lid by its insulated handle and rest it on the plate. Lightly touch the top of the lid with your finger.



How Does an Electrophorus Work? *(cont.)*

What To Do: *(cont.)*

4. Lift the electrophorus off the plate. Listen and watch carefully. What do you observe?

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5. Bring the electrophorus near the tip of your nose. What do you observe?

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6. Recharge the electrophorus by repeating Step #3. Rub a balloon with the woolen cloth. Holding the balloon by its string, bring the electrophorus close to it. What happens?

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7. Recharge the electrophorus. Cut up a piece of paper into small bits of confetti. Hold the electrophorus with the metal side up and have a partner sprinkle the paper over it. What happens?

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Next Question

Use classroom resources or the Internet to research capacitors. How does it relate to the experiment?

Notebook Reflection

Describe the experiment step by step, noting which items (and which sides of items) have which charge.

How Does a Turbine Work?

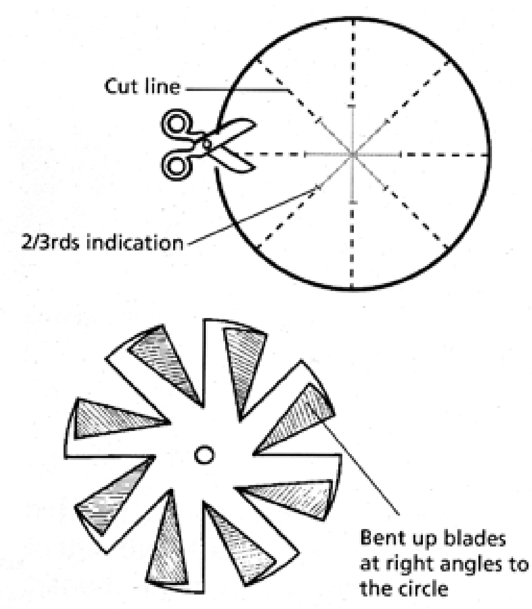
Name ______________________________

What You Need:

- scissors
- compass
- light cardboard
- jar with screw-on lid
- metal punch
- long pin
- Bunsen burner
- tripod

What To Do:

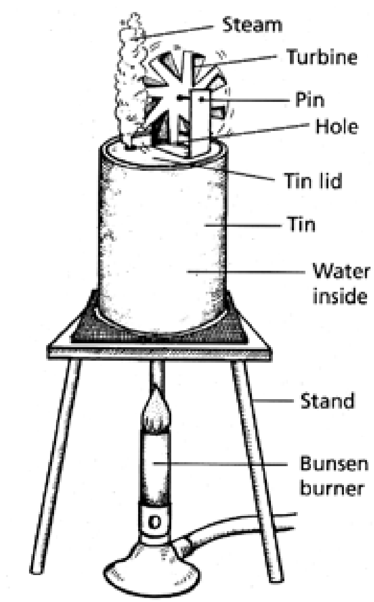
1. Cut a strip of cardboard 12 cm x 2 cm. Bend it into thirds to make a U shape and poke holes in the ends.
2. Cut out a cardboard circle with a radius of 3 cm. Punch a hole in the direct center. Divide the circle into eight equal segments and cut 2 cm down each line. Then fold each flap over as in the diagram below.



3. Push the pin through the holes of the cardboard U and the hole in the center of the circle. The circle should be able to spin freely within the cardboard U.
4. Punch a hole near the side of the jar's lid. On the opposite side of the lid, tape the cardboard U so that the flaps of the circle are directly above the hole in the lid.

What To Do: *(cont.)*

5. Fill the jar with water about three-quarters full. Screw on the lid and place the jar on the tripod above the Bunsen burner.



6. Light the burner. Describe what happens and why.

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Next Question

It takes energy to make the wheel spin. Where do you think that energy comes from?

Notebook Reflection

Describe the process of the energy getting to the wheel. Where is the energy at each stage of the process?

How Does an Electroscope Work?

Name ______________________________

What You Need:

- foil from a chewing gum wrapper
- pair of scissors
- pencil
- clear tape
- drinking glass
- balloon
- scrap of wool cloth

What To Do:

1. Cut the foil in half to make a long, thin strip. Fold this strip in half, lengthwise.
2. Tape the foil strip to the center of the pencil so one half of the foil strip hangs down over one side of the pencil and the second half of the foil strip hangs down over the other side of the pencil.
3. Rest the pencil on the rim of the glass so the foil strips hang down over the sides of the pencil, inside the glass.
4. Blow up the balloon and rub it on the piece of wool. This will create static electricity.
5. Bring the balloon close to the side of the glass. What happens?

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Next Question

Touch your jar to other things. Can you find anything else that produces a reaction?

Notebook Reflection

Describe what you think is happening to the foil strip.

What Is a Morse Code Tapper?

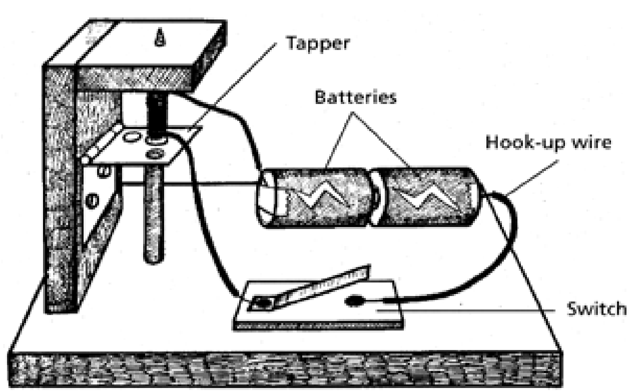
Name ______________________________

What You Need:

- baseboard (15 cm x 30 cm)
- electric drill
- screwdriver
- dowel (4 cm)
- glue
- iron door hinge
- screws for hinge
- long screw
- wooden side arm (20 cm x 10 cm x 1 cm)
- wooden top (10 cm x 10 cm x 1 cm)
- insulated electrical wire
- 2 batteries
- metal strip
- 2 drawing pins

What To Do:

1. Drill a hole in the baseboard about 4 cm away from one end, wide enough for the length of dowel to fit snugly. Insert the dowel and glue in place.
2. Line up the hinge on the wooden side arm as shown below. The hinge should sit open at a right angle resting on the dowel. Mark the holes, drill them, and then screw the hinge securely onto the side arm.
3. Drill a hole through the top board to take the long iron screw. Insert the screw and adjust its height so that the head of the screw will clear the hinge by about 1 cm. When it is secured, drill and screw the top onto the side arm, then secure the side arm to the baseboard.



How Can I Make a Morse Code Tapper? *(cont.)*

What To Do: *(cont.)*

4. Wind a coil of about 50 turns around the screw. Connect one end to a pair of batteries. Connect the other end to a drawing pin in the baseboard. Use a short length of electrical wire to connect the open ends of the battery and the switch.

5. Close the switch. What happens?

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6. Close and open the switch over and over. What happens? How could that result be used to send messages?

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Next Question

Use classroom resources or the Internet to find out more about the Morse code. Work with a partner to tap out a message that they can decode.

Notebook Reflection

Why does the tapper tap? What causes the sound? What causes the motion? Describe an electron's trip through the circuit.

How Does a Dimmer Switch Work?

Name ______________________________

What You Need:

- bulb and bulb holder
- battery
- electrical wires
- tape
- pencil
- craft knife
- pliers

What To Do:

1. Remove 2–3 cm of insulation from the ends of three 20 cm lengths of wire. Connect two of these ends to the two ends of the battery. Connect these ends to the light bulb base. What happens? How bright is the light?

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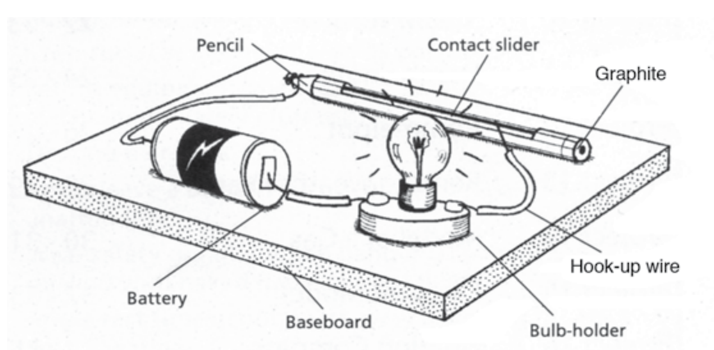
2. Disconnect one of the wires from the light.
3. Separate the two wood strips of the pencil. Pencils are made by sticking together two wood strips—look for the thin line between them. Make cuts about 2 cm in at both ends of the pencil down to the line where the strips join. Squeeze the pencil carefully with the pliers to separate the two wood strips.
4. Connect the loose end of the wire to the pencil tip. Make sure the metal wire is in contact with the pencil's graphite. Connect the third wire to empty contact on the light bulb.



How Does a Dimmer Switch Work? *(cont.)*

What To Do: *(cont.)*

5. Touch the loose wire end to the exposed graphite core of the pencil. What happens?

6. Move the loose wire end up and down the graphite core. What happens? When is the light brightest? When is it dimmest?

Next Question

What other materials can be used in place of the graphite? What happens when you use a piece of wire? What happens when you use a steel spring?

Notebook Reflection

Why does the dimmer work? How is the graphite part of the circuit? How does it control the brightness of the light?

How Can I Make a Battery?

Name ________________________________

What You Need:

- paper towels
- uninsulated electrical wire
- insulated electrical wire
- salt water
- 5 galvanized washers
- lightbulb with base

What To Do:

1. Cut the paper towel into eight squares about the size of the washers. Dampen the paper towel squares with salt water.
2. Make a loop in the uninsulated wire about two inches from one end. Place this on a waterproof surface.
3. Place a paper towel square on the wire loop. Place a washer on top of that. Then place another paper towel square on top of the washer.
4. Bend the wire to form another loop that rests on the top paper towel square.
5. Repeat Steps #3 and #4 until you have all five washers, five loops, and eight paper towel squares stacked in a pile.
6. Connect the bottom wire to one of the bulb's contacts with a length of insulated wire.
7. Attach another length of insulated wire to the other contact on the bulb.
8. Brush the end of the loose insulated wire on the top washer. If your pile is constructed correctly, the bulb should light up!

How Can I Make a Battery? *(cont.)*

What To Do: *(cont.)*

9. Draw, label, and describe how the pile works.

Next Question

Does changing the number of washers and loops change the electricity produced? How could you find out? How could you measure the electricity the different piles produce?

Notebook Reflection

What's going on here? How can a pile of metal pieces and wet paper make electricity? What do you think is happening?

What Disturbs the Flame?

Name ________________________________

What You Need:

- paper
- cardboard tube
- tape
- balloon
- scissors
- rubber band
- candle
- books

What To Do:

1. Roll the paper to make a cone that fits on the end of the cardboard tube. Use the scissors to trim the cone.
2. Use tape to attach the cone to the end of the tube.
3. Cut the end off of the balloon. Stretch the balloon over the other end of the tube. Secure it with a rubber band.
4. Arrange the tube so that the hole in the cone is level with the candle wick. Use books to raise the tube.
5. Place the candle in front of the hole at the tip of the cone, about 2 cm away.
6. Watch your teacher light the candle.
7. Clap your hands at the balloon end of the tube. What happens to the candle?

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8. Clap your hands softly, then loudly. Do you see a difference in the candle's reaction?

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Next Question

How else can you make sound waves visible? Brainstorm some ideas. Draw diagrams of your proposal, complete with labels and a short paragraph. How does it work?

Notebook Reflection

If you stand in front of a large speaker or close to a blasting train whistle, you can feel sound waves, too. Have you ever felt sound waves? Describe your experience. Why could you feel the sound waves?

What Do Sound Waves Look Like?

Name ______________________________

What You Need:

- flat metal or wood square (25 cm x 25 cm)
- thick wooden rod (20 cm long)
- baseboard (10 cm x 10 cm)
- screw and nail
- sand
- violin bow

What To Do:

1. Nail the rod to the center of the baseboard. Drill a hole in the center of the square and down the center of the rod. Screw the square and rod together.
2. Sprinkle a fine layer of sand over the square.
3. Hold your fingers in two places on the edge of the square, and then slide the violin bow across a different point on the edge. Draw the pattern that emerges in the sand. Repeat, placing your fingers and sliding the bow in different places.

Next Question

Try the experiment with other sounds. Tap with a hammer. Squeak a balloon along the edge. What other sounds can you use?

Notebook Reflection

What are you seeing in the sand? Where do the grooves and troughs come from? Why are there different patterns? How do you think that happens?

How Does Sound Travel?

Name ______________________________

What You Need:

- a ticking watch
- wooden ruler
- scissors
- string
- metal cutlery
- tin cans
- nail
- hammer
- paperclips

1. Put the watch to your ear. Listen to it tick. Work with a partner to find out what distance from your ear you can no longer hear the ticking. ________________

2. Do you think the sound of the ticking will travel better through air or through the wooden ruler?

Circle One: Air / Ruler

3. Hold the ruler out straight with the end pressed against the bone behind your ear. Ask your partner to place the watch on the ruler at the distance you wrote down in Step #1. Can you hear the ticking?____________________________

4. Have your partner move the watch closer and further along the ruler. Write down your observations.

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5. Cut a 1-meter length of string. Hang pieces of metal cutlery from the middle of the string.

6. Hold one end of the string in each hand. Ask your partner to knock the cutlery together to make some noise. Write down your observations.

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What To Do: *(cont.)*

7. Now hold one end of the string against the bone behind your ear. Hold out the other end and have your partner knock the cutlery together again. Write down your observations.

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8. Cut a 3-meter length of string. Take two clean, empty cans. Remove any rough or sharp edges with a file. Use a hammer and nail to carefully make a hole in the center of each can's base.
9. Put the bases of the cans together. Thread the string through the holes. Tie the end of the string around a paper clip to keep it in place.
10. Hold the can against your ear while your partner holds the other can against his or her mouth. Move away from your partner until the string is taut. Ask your partner to speak into the can. Write down your observations.

 ____

 ____

11. Experiment with variations on the telephone you've made. Leave the string loose. Bend it around a pole. Use longer or shorter string. How does this change the telephone's operation?

 ____

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Next Question

Replace the string with fishing line or metal wire. Do different materials work differently? Do they work better or worse? Write about your experiments and how they changed the telephone's operation.

Notebook Reflection

Normally we hear sounds through the air, but sound can travel through solids or liquids, too. Based on your results above, do you think that dolphins can hear for longer or shorter distances than humans? Why?

What Changes a Sound's Pitch?

Name ________________________________

What You Need:

- drinking straws
- scissors
- tape
- wooden ruler
- 6 glasses
- water
- pencil

1. Press one end of a straw flat. Cut the sides of that end to form a point.
2. Put the pointed end of the straw in your mouth and blow hard.
3. Now cut 3 cm from the other end of the straw. Blow again. What happened?

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   ____

4. Cut another 3 cm from the straw. Blow again. Now what happened?

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5. Create a mouth organ by cutting straws to different lengths and taping them together. Can you play a simple tune on your instrument?
6. Place a ruler on a table so that half of it hangs over the edge. Hold it firmly at the table end.
7. Flick the other end and listen carefully. Describe what you hear.

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8. Now change the length of the ruler hanging over the edge. Flick it again. What happened? ____

What Changes a Sound's Pitch? *(cont.)*

What To Do: *(cont.)*

9. Slide the ruler back and forth, flicking it as you go. Can you play a simple tune using the ruler? ______________________________
10. Place six glasses on a table. Pour a different amount of water in each glass.
11. Gently tap each glass with a pencil. What do you notice about the sounds you produce?

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    ____
12. Arrange the glasses from lowest sound to highest sound. What do you notice about the heights of the water?

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    ____

    ____
13. Remove or add water to each glass so that the glasses are tuned to play a simple song.

Next Question

Form a band of three students, with each student playing a different "instrument" you have made in class. Create a simple song that you can play together. Perform it for the class.

Notebook Reflection

The straws vibrate the air inside them, which is a gas. The vibrating ruler is a solid. The glasses vibrate the water in them. What have you discovered about the way sound travels through gases, solids, and liquids?

How Are Light and Heat Related?

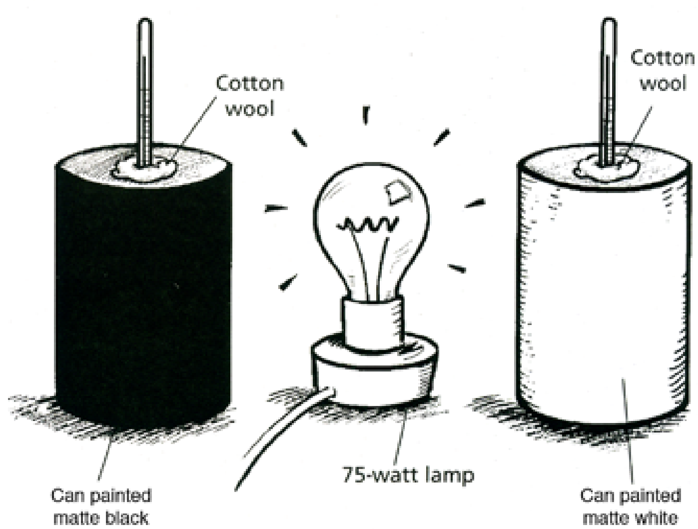
Name ______________________________

What You Need:

- 2 empty metal cans
- 2 thermometers
- black and white paint
- brushes
- drill or punch
- cotton wool
- 75 watt bulb and holder

What To Do:

1. Paint one can matte black and the other can matte white.
2. In the center of the base of each can, punch or drill a hole so that the thermometers can slip through.
3. Pack some cotton wool around each hole, then pass the thermometers through so that the bulb of each thermometer sits at the same height inside the can.



What To Do: *(cont.)*

4. Place the light bulb an equal distance between the two cans, on the previous page. Switch on the lamp and record the temperatures over time.

	black can temperature	white can temperature
initial temperature		
after 5 minutes		
after 10 minutes		
after 15 minutes		

5. Do the cans change temperature at the same rate? Which heats up faster? Why do you think that is?

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Next Question

Repeat the experiment with glossy paint. Try wrapping a can in shiny aluminum foil. Try using a glass jar with the thermometer through the lid. What changes?

Notebook Reflection

What practical uses could this experiment lead to in your life? What if you were an architect? What if you were a gardener? What if you were a spacecraft engineer?

How Does a Camera Work?

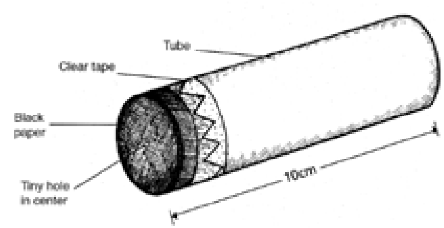
Name ________________________________

What You Need:

- scissors
- tape
- aluminum foil
- cardboard tube
- pin
- wax paper

What To Do:

1. Cut out a circle of aluminum foil bigger than the end of the carboard tube. Fit it over one end of the tube and fix it in place with tape. Make sure the foil is flat and even. At the center of the foil cover, make a tiny hole with a pin.
2. In the same way, cut a circle of wax paper and fix it over the other end of the tube to act as a screen. Make sure the paper is flat and tape it down.
3. On a sunny day go into a darkened room and push the pinhole end of the camera through an opening in the curtains so that you can look outside. What do you see on the wax paper?



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Next Question

Use classroom resources and the Internet to research film. How could you add film to your camera?

Notebook Reflection

Draw a diagram of your camera. Label the parts and the path of light. Show how it works.

How Does Light Scatter?

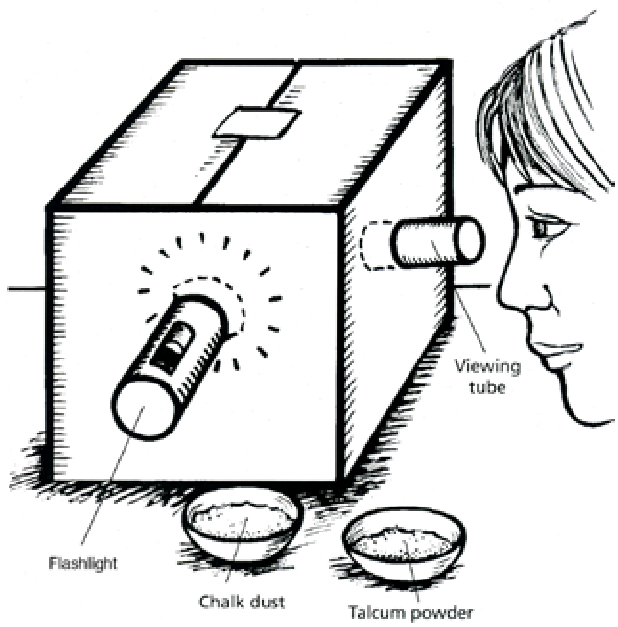
Name ________________________________

What You Need:

- scissors or craft knife
- tape
- white talcum powder
- flour
- chalk dust
- baking soda
- large cardboard box
- cardboard tube
- flashlight

What To Do:

1. Cut a 10 cm length of cardboard tube. In one side of the box, cut a hole just big enough to fit the tube, and fix it there with tape.
2. In the side to the left or right of the side with the tube, cut another hole just big enough for the flashlight. Fit the flashlight into the hole and secure it with tape.



3. Open the top of the box. Sprinkle some talcum powder into the box. Close the lid and switch on the flashlight. Look through the viewing tube. What do you see?

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What To Do: *(cont.)*

4. Repeat Step #3 using the flour, chalk dust, and baking soda. Illustrate and label each kind of dust in the spaces below.

5. Which kind of dust is the most visible? Which is the least visible?

Next Question

Use classroom resources or the Internet to research zodiacal light and gegenschein. How are these phenomena related to the experiment?

Notebook Reflection

If light travels in straight lines, how can you explain seeing light from the flashlight through the viewing tube?

Forces and Motion

This chapter provides activities that address McREL Science Standard 10.

Student understands forces and motion.

Understands general concepts related to gravitational force	*What Do I Weigh on Jupiter?, page 165*
Knows that just as electric currents can produce magnetic forces, magnets can cause electric currents	*What Makes the Coil Move?, page 167* *How Can I Throw Without Touching?, page 169* *How Does the Door Chime Work?, page 170* *How Can an Electromagnet Flip a Switch?, see Teacher CD*
Knows that an object's motion can be described and represented graphically according to its position, direction of motion, and speed	*How Does a Submarine Work?, page 184* *What Is Recoil?, page 188* *What Is Momentum?, page 189* *Why Do the Eggs Move Differently?, page 190*
Understands effects of balanced and unbalanced forces on an object's motion	*What Makes the Horse Prance?, page 172* *How Can a Ballooon Inflate Without More Air?, page 174* *How Tall Can I Build It?, page 176* *What Stops the Water?, page 177* *What Makes an Object Float?, page 179* *How Can I Make a Sinker Float?, page 181* *Which Shapes Float?, page 183* *How Does a Submarine Work?, page 184* *How Does a Siphon Work?, page 186* *What Is Recoil?, page 188*
Knows that an object that is not being subjected to a force will continue to move at a constant speed and in a straight line	*How Does a Submarine Work?, page 184* *What Is Recoil?, page 188* *What Is Momentum?, page 189* *Why Do the Eggs Move Differently?, page 190*

How to Teach Forces and Motion

So What Are Forces?

Forces are behind everything that is happening around us. Forces make things happen.

You probably think this subject is difficult. You are quite right to fear getting too deeply into it because when you do, you will have to suspend your disbelief and your trust in common sense. Forces just don't behave as we would expect them to. Teaching forces is not easy!

Take these examples. Which of them would you think are true?

1. Two balls the same size dropped together from the top of the Leaning Tower of Pisa will both hit the ground at the same moment, even if one is a foam ball and the other is made from lead.
2. A bullet fired horizontally across a field from a gun, and an identical bullet dropped at the same moment from the barrel, will both hit the ground simultaneously.
3. When you sit on a table, it pushes back at you with an equal and opposite force.
4. There are two forces acting on a kicked football once it is in the air—the drag of the air and the downward pull of gravity.
5. The force of gravity is pulling you downward, but you are also pulling Earth towards you with your own force of gravity.

That's right—all of them are true.

Well, almost.

Position, Velocity, and Acceleration

One of the more obscure foundations of physics is position and its derivatives velocity and acceleration. It is very easy to overlook the simple proposition that things have positions, and those positions change. However, all of forces and motion requires this foundational understanding in order to actually work.

Position

Position is where an object is.
That position cannot be measured absolutely—that is, there is no position that describes where the object "really is." Instead, position can only be measured relative to other objects. The blue block is three inches from the red block. The text stops a half-inch from the edge of the page.

Velocity

Velocity is the rate at which position changes. Students will probably be familiar with the idea of speed. Velocity is speed plus a direction: not 50 kph (31 mph), but 50 kph (31 mph) due east.

Acceleration

Acceleration is the rate at which velocity changes. Students may be familiar with the word accelerate, thinking that it means "speed up." However, acceleration is any change in velocity: speeding up, slowing down, or changing direction.

Pushes and Pulls

Forces are pushes and pulls. You can't escape forces—they are around you all the time.

When you are cycling, you need to push on the pedals to move forward. The ground is pulling on your tires to slow you down. The air is pushing in your face. If you stop pedalling, the ground and the air will slow you down until you come to a stop, but their forces keep working.

Attach a trailer on the back of the bike. Now you are pulling. Your force on the trailer is a pulling force. You push the pedals; the bike pulls the trailer! Stop cycling and try sitting still. Surely no forces are acting now? In fact, the force of gravity is pulling down on you. And the ground is pushing back.

The ground? Pushing? Yes, it has to. If the ground didn't push back, you would fall to the middle of Earth. So the ground pushes on your bike, and your bike pushes on you. Good thing, too. You don't want to disappear into Earth!

Faster and Slower

You use forces when you change speed. Hop on a scooter. First, you want to accelerate. Push off with your foot. The ground is pushing back at you and you're away! Want to go faster? It's no good just thinking about it. A bit of force is needed. Foot down, push again, and again. That's better. Now you are really rolling.

Lamppost ahead. Time to slow down. Push your foot to the ground. Slowing… whoops! Bit of a mistake there. The lamppost is still coming up. Brakes on. Put foot down and push backwards. Too late. Contact. Unfortunately, the lamppost pushed back just as hard as you pushed on it. It certainly stopped you.

Changing Direction

You can't change direction without a force, either. It might be the push and pull you give to the scooter handlebars. It might be the push and pull you give to a steering wheel. It might be the twisting force you give to your leg as you jump sideways to catch a ball. (You can see the results of that force if you look at the soles of your shoes. Old shoes get a well-worn jumping-off spot.)

Isaac Newton, the great scientist, stated this as a law in 1687. He said that every object would remain still, or carry on moving in the same direction at a steady speed, unless forces acted on it. This is called Newton's first law of motion.

It doesn't matter whether it is speeding up, slowing down, or changing direction, you need forces for change! Forces make things change direction. Try bouncing a ball. It changes direction when it hits the ground or the wall. But the new direction can be predicted. Try rolling a ball against the wall and seeing which way it bounces off. What do you notice? You can predict the angle—especially if you are a good billiards player!

Two Special Forces

There are two special forces. They are also invisible. They don't need to touch an object. They can act on an object without touching it. They are magnetism and gravity.

Magnetism

Magnets exert forces. The forces act on magnetic materials. Some metals, like iron and steel, are magnetic but not all metals are magnetic. Magnetic metals can be attracted over a distance. Magnets can repel other magnets, too. They can push other magnets over a distance.

Gravity

Gravity works over a distance, as well. All objects have gravity. But for those of us on Earth, the gravitational pull of Earth is the nearest and strongest by far.

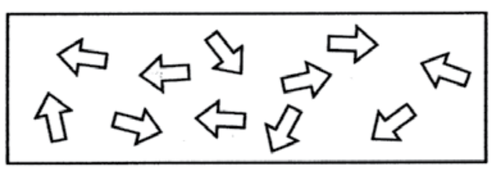
Earth's gravity holds us on the planet. If you drop something, it will always fall downward. Earth's gravity pulls it down.

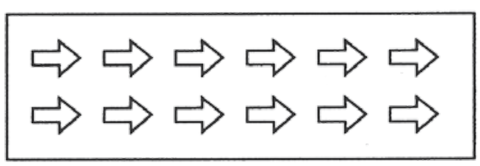
Is Magnetism Magic?

Magnets are magical and mysterious—a sure winner with students. They are also excellent subjects for investigations. All you need are a few well-chosen questions.

How Is a Magnet Made?

A material like iron is made up of countless tiny bits, all of them magnets. Usually, these little bits are facing randomly, like people crowded into a room. When the iron is made magnetic, all the magnetic bits face the same way. It's as if you open a window at one end of the room, and everyone turns to face it.



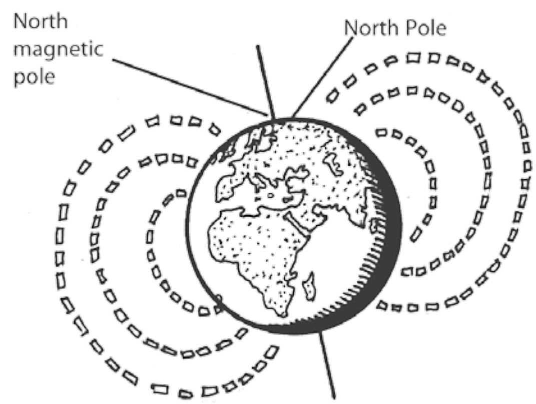


But heat a magnet, give it a good bashing, or let little Jimmy drop it on the classroom floor a few times, and all the magnetic bits will end up facing randomly again. Your magnet is weakened or destroyed. It's a good idea to put your magnets away with "keepers." These bridge the ends or poles of a pair of magnets and ensure that the magnetic force is circled and enclosed. Your magnets will last a lot longer if you do this!

Earth Is a Magnet

Four hundred years ago, a scientist named William Gilbert made a dramatic suggestion. He had looked at the way magnets turned to face north-south. This would happen, he argued, if Earth itself were a huge magnet.

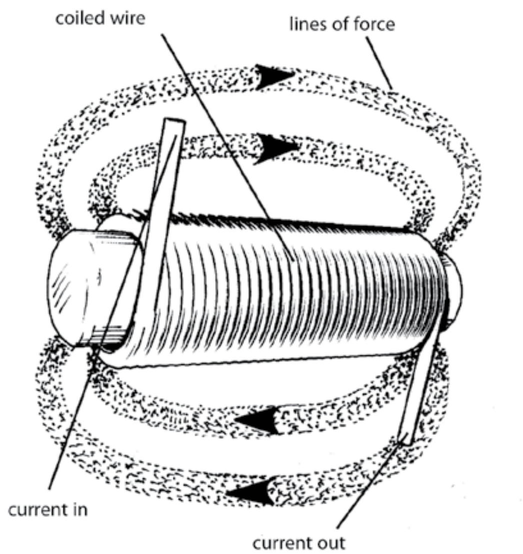
He was right. Around every magnet there is an area, a field, where the invisible force of magnetism is operating. Earth has its own magnetic field. It has poles, just like any other magnet, which are not quite in the same places as the true north and south of Earth.



Electromagnets

The connection between electricity and magnetism was discovered in a classroom. In 1820, Hans Christian Oersted was teaching about electricity when he brought a magnetic compass close to the wire. To his amazement, the compass needle moved suddenly to line up with the wire. He realized that the electricity through the wire was making its own magnetic field.

There is a magnetic field around any wire that carries an electric current. Electromagnets have this wire coiled around a metal core. Electromagnets are magnets that can be switched on and off. When they are off, they are just iron bars inside a coil of insulated wire. When they are switched on, they become powerful magnets that can lift scrap metal, ring doorbells, and pull a steel splinter from your eye.



Can a Magnet Make Electricity?

Electricity plus magnetism produces movement. And movement plus magnetism will produce electricity. If electricity flows through a wire, it produces magnetism and can move a magnet. And the reverse is true. If you move a magnet near a wire, then you generate electricity. You are doing just this if you have a dynamo-powered light on your bike. As you cycle along, you are providing the movement, and the moving magnets in the dynamo generate electricity for the bulb.

This was Michael Faraday's shattering discovery. Without this form of electricity generation, only batteries would provide our electricity. His invention changed the world. Electricity generators contain magnets. When you make the magnets move using a steam turbine, moving water, or the power of the wind, you generate electricity.

Gravity and the Apple Tree

We all dream that we could be as clever as the great scientist Sir Isaac Newton." If only an apple fell on my head," we think, "it would rattle my brain. I could have some brilliant ideas like him."

Bad news. The apple never fell on Newton's head.

Thousands of artists have drawn the apple conking poor old Isaac, and a light bulb lighting up. Idea! Now I can explain gravity.

Sadly, it wasn't like that. As Newton explained to a friend, he was walking in an orchard, puzzling over the problem of gravity, when an apple fell." Why does that apple fall downwards?" he thought. "Why does everything fall downward? It's as if there is a force pulling everything towards the center of Earth."

And there is. That force is gravity. It pulls everything towards the center of Earth. Everything has a force of gravity. The bigger it is, the bigger the force. But the biggest, nearest thing to you is Earth. Without gravity, nothing would stay on planet Earth that wasn't nailed down.

Earth's gravity is pulling down on us all the time. We call that pull your weight. You have weight because Earth's gravity is pulling down on your mass. The mass is the stuff you are made from. Your mass stays the same, wherever you are. But your weight can change.

If you went to another planet, the pull of gravity would change. If that planet were bigger than Earth, the pull would be stronger. If it were smaller than Earth, the pull would be weaker.

Can Heavy Things Fall Slowly?

Everyone finds it very hard to believe that light and heavy things, dropped together, can hit the ground together. Even when you've seen it, you may not believe it! Earth pulls harder on things of greater mass, and you might expect them to fall faster. But their greater mass means they're harder to get moving (just compare pushing a bicycle with push starting a car) and these two just about cancel each other out. Whatever the mass, objects fall at the same speed.

The exception, of course, is where one object has a greater surface area than another, catching the wind. A sheet of paper will float to the ground more slowly than a wadded-up ball; a feather will fall much more slowly than a hammer. The Moon astronauts graphically demonstrated what happens without the slowing effects of the air. A feather on the airless Moon dropped at the same speed as a hammer.

Balanced Forces

You can't see the forces acting on a football. They're invisible. One is the force of gravity. Gravity is pulling the ball down towards the center of Earth. So why doesn't the ball go down? Something is stopping it. The ground is pushing back on the ball. Gravity and the push of the ground are in balance. The ball stays where it is! When two forces are in balance, an object stays still. A space rocket on the launch pad has two forces acting on it—that of gravity pulling it down, and that of the launch pad pushing it up. These forces are in balance, and the rocket stays still. Until the engines start….

Floating and Sinking

Some objects float in liquids. Some sink. Some objects can be made to float, or they can be made to sink.

Objects float when they are lighter than the liquid. Even heavy objects can be made to float, as long as they are filled with air. The air makes them lighter than the liquid. When things are lighter than the liquid, the upthrust of the liquid holds them up. Gravity pulls down. The liquid pushes up. The two forces are in balance. The object stays still. It floats.

A floating object is in balance. The force of gravity is balanced by the upthrust of the liquid. As long as the object isn't too dense—when the force of gravity will exceed the upthrust of the liquid and the object will sink—the object will float, the forces on it nicely balanced.

When Are Forces Unbalanced?

When forces are unbalanced, things move. Take that space rocket. It is blasting off at John F. Kennedy Space Center. It is being held back by gravity, but gravity is a weak force compared to the tremendous thrust of the rocket engines. Because the forces are unbalanced, the rocket climbs into the sky.

When forces are unbalanced, things change shape. When you squeeze some modeling clay, the modeling clay pushes back. But if the modeling clay pushed back as hard as you squeezed, you could never change its shape.

What Do I Weigh on Jupiter?

Name ______________________________

What You Need:

- butcher paper
- markers
- four paint cans with lids and handles
- water

What To Do:

1. Roll out the butcher paper. Draw four circles down the length of the paper. The first circle should be 12 cm in diameter. The second should be 3.5 cm in diameter. The third should be 7 cm in diameter. The last should be 143 cm in diameter (you may need to add paper to the sides for the last).
2. Label the first circle Earth, the second Moon, the third Mars, and the last Jupiter. Color the planets appropriately. Label any features you put in the illustrations.
3. Fill one bucket with 1,320 mL of water, seal it, dry the outside, and place it on top of the Earth illustration.
4. Fill the next bucket with 210 mL of water, seal and dry it, and place it on the Moon.
5. Fill the next bucket with 490 mL of water, seal and dry it, and place it on Mars.
6. Fill the last bucket with 3 liters of water, seal and dry it, and place it on Jupiter.

What Do I Weigh on Jupiter? *(cont.)*

What To Do: *(cont.)*

7. Now take a tour of the Solar System. At each planet, try lifting the bucket off of the planet. On which planet do you have to pull the most? On which do you have to pull the least? Do you see a pattern?

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Next Question

You can complete the Solar System by drawing more planets and preparing buckets for each. Mercury should be 5 cm and 490 mL, Venus 12 cm and 1170 mL, Saturn 120 cm (rings extend to 360 cm!) and 1188 mL, Uranus 51 cm and 1151 mL, and Neptune 49 cm and 1482 mL.

Notebook Reflection

Imagine you were an astronaut visiting the different planets. Each planet has a different gravity, and all your equipment and even your spaceship would weigh different amounts on each planet. What problems would that cause? How might that be useful?

What Makes the Coil Move?

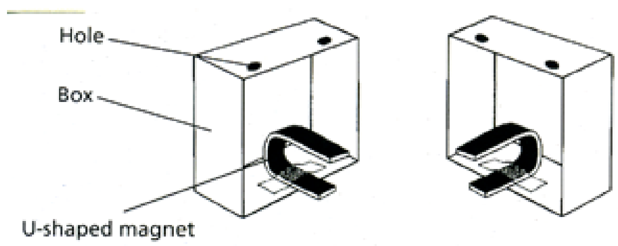
Name ______________________________

What You Need:

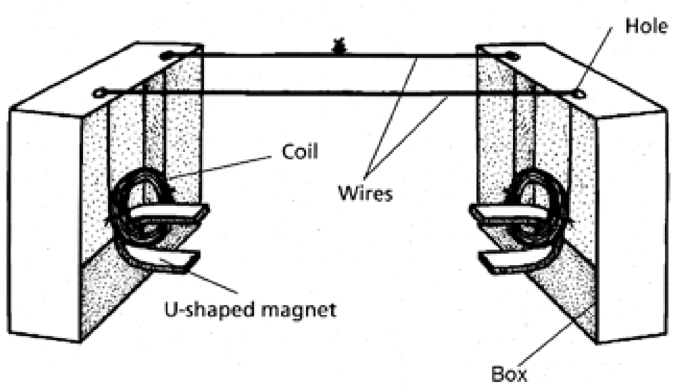
- 2 small cardboard boxes
- 2 U-shaped magnets
- tape
- scissors
- insulated electrical wire (5 m)
- string
- holepunch

What To Do:

1. Tape each U-shaped magnet into a small box as shown below. Make two small holes in the top of each box.



2. Make two coils from a long piece of wire. Each coil should have about 50 turns and have about 50 cm of loose wire on either end. Remove the insulation from the ends.
3. Suspend the two coils in the boxes so that each encircles a magnet arm. Make sure the height of the coils is the same. The coils must be able to swing freely. Tape the wires where they thread through the holes to keep them in place.
4. Set the boxes about one meter apart and twist the wires together to complete a circuit.



What Makes the Coil Move? *(cont.)*

What To Do: *(cont.)*

5. Hold both coils still, then set one swinging. What do you notice about the other coil?

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6. Watch both coils at the same time. Do you notice a pattern?

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Next Question

Find out what happens if you flip one of the magnets over. How do the coils move differently? What happens if you change the height at which they hang? Can you explain this?

Notebook Reflection

Brainstorm different ways that machines and inventions could use the movement of wires around magnets. What could you use this phenomenon to do?

How Can I Throw Without Touching?

Name ________________________________

What You Need:

- scissors
- knife or sandpaper
- glass tube
- shoebox
- 4 C or D batteries
- electrical wire
- tape

What To Do:

1. Punch two holes in the long sides of the box so that you can slide the glass tube through both. Cut out two circles 3 cm across from the box top or other cardboard. Punch holes in their centers. Also, cut out a long rectangle of cardboard 5 cm by 10 cm.
2. Space the circles about 4 cm apart near one end of the glass tube and wind a coil of wire between them. Wind the wire about 300 turns. You should have 10–12 cm of wire left on either side. Strip the insulation off the ends of the wire for 2–3 cm.
3. Tape the batteries together in series. Then tape the rectangle along the side so that one half hangs off the end and can be folded over one end of the battery lineup. Tape this into the bottom of the box.
4. Slide the glass tube into the two holes in the box. Tape one of the loose ends of the wire to the cardboard rectangle so that the end of the wire can touch the battery terminal. Tape the other loose end to the other end of the battery lineup.
5. Straighten out some paper clips and use pliers to cut them into 2 cm lengths.
6. Slide the pieces of paper clip into the end of the glass tube where the coil is. Point the other end at a wall. Fold the cardboard flap to touch the wire to the battery. What happens?

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Next Question

Describe three different uses for this technology.

Notebook Reflection

What do you think makes the paper clips shoot out the end?

How Does the Door Chime Work?

Name ______________________________

What You Need:

- cardboard tube
- insulated electrical wire
- cardboard box
- duct tape or electrical tape
- battery
- craft knife
- soft iron bar
- copper bar

What To Do:

1. Wind 200 turns of insulated wire around the stiff cardboard tube. Leave 15 cm of wire free at each end and strip the insulation off of the last 2 cm of each end.
2. Attach the coil inside the cardboard box with electrical or duct tape. Its bottom should be a few centimeters from the bottom of the box.
3. Secure the battery in the bottom of the box. Connect one end of the wire to one terminal of the battery.
4. Cut a flap directly above the battery so that it can be folded inside to cover the other terminal of the battery. Use electrical tape to fix the other end of the wire to the inside of the flap so that the exposed wire can make contact with the battery terminal.
5. Insert the soft iron bar inside the coil.
6. Hang the copper bar above the box using string.

How Does the Door Chime Work? *(cont.)*

What To Do: *(cont.)*

7. Fold the flap down so that the wire makes contact with the battery. What happens? Why?

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Next Question

Why does the iron bar move, but the copper bar does not? Using school resources or the Internet, research the term ferromagnetic. How does it apply to this experiment?

Notebook Reflection

Most doorbells play more than one chime. How could you design a device to play a short tune? Draw and label your plans and explain how it works in a short paragraph.

What Makes the Horse Prance?

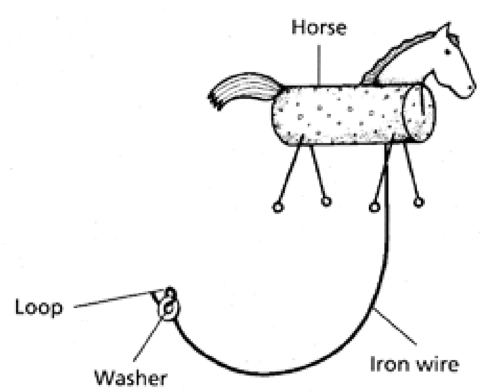
Name ________________________________

What You Need:

- scissors
- cardstock
- glue
- craft knife
- tape
- pliers
- cork from bottle
- stiff iron wire
- washers
- 4 long pins
- paintbrush bristles

What To Do:

1. Insert four pins into the cork to make the horse's legs.
2. Cut out a piece of cardstock in the shape of a horse's head. Cut a slit in the top of the cork and insert the head.
3. Paint your horse.
4. Cut a slit in the back of the cork and insert bristles for a tail.
5. Cut out a 30 cm piece of stiff iron wire. Bend it into a long curve. Make a loop at one end and thread a heavy washer into the loop. Stick the other into the bottom of the cork.
6. Balance your horse on the edge of a table with the wire and washers underneath the table. Describe how the horse stands. Can you explain why?



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What To Do: *(cont.)*

7. Add another washer or adjust the curve of the wire. What do the changes do to how the horse prances?

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Next Question

Tightrope walkers carry a long pole, sometimes with weights on the ends. Why would that help, and why is it similar to the horse? How can you test it?

Notebook Reflection

Why does the horse "prance?" Why doesn't it just rest on the four pins? What do you think is happening?

How Can a Balloon Inflate Without More Air?

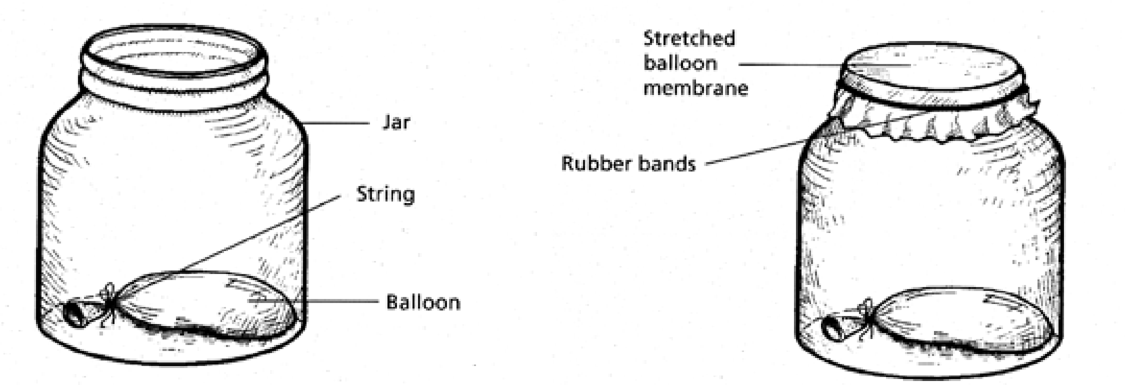
Name ______________________________

What You Need:

- large jar
- 2 balloons
- scissors
- strong rubber bands

What To Do:

1. Blow just a little air into one balloon. Do not fully inflate it. Tie off the bottom and put it in the jar.
2. Cut the end off the other balloon and stretch the balloon membrane over the top of the jar. Fix it in place with rubber bands.



3. Pull up the balloon membrane at its center as far as you can. What happens?

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How Can a Balloon Inflate Without More Air?

What To Do: *(cont.)*

4. What is happening to the air pressure inside the jar? How does that affect the balloon inside?

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5. Now press down on the balloon membrane as far as you can. What happens? Can you explain it?

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Next Question

Use the Internet and classroom resources to find information about Echo 1 and Echo 2, two of the first satellites made by man. How were they similar to the experiment?

Notebook Reflection

Imagine you were the balloon inside the jar. Write a description of how the experiment must have felt from the balloon's point of view.

How Tall Can I Build It?

Name ______________________________

What You Need:

- blocks
- paper
- tape
- ruler

What To Do:

1. Use blocks to build a tall tower. How do you stop it from toppling over?

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2. Next you will build the tallest free-standing tower you can, using only folded paper and tape. Sketch your tower plans. Write down ideas on how to make it as tall as possible.

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3. Build your tower. How high did your tower reach? ______________________

Next Question

What would change if you used different materials, such as heavy cardboard? What wouldn't change?

Notebook Reflection

What worked according to plan? What didn't work? What tricks did you discover halfway through?

What Stops the Water?

Name ______________________________

What You Need:

- plastic bottle with cap
- water
- bowl
- hammer
- nail

What To Do:

1. Carefully use the hammer and nail to punch a hole in the center of the bottle cap. Punch three holes in the bottom of the bottle. Make sure the cap is screwed on tight.
2. Fill the bowl with water halfway.
3. Holding the bottle by its neck, push the bottom of the bottle into the water. Describe what happens inside the bottle and above the cap.

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4. Wait until the level of water inside the bottle is even with the water in the bowl. Cover the hole in the cap with your finger or thumb and lift the bottle out of the water. Hold it above the bowl. What happens?

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5. Holding the bottle over the bowl, lift your finger off of the hole in the cap. What happens? What happens when you put your finger back over the hole?

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What Stops the Water? *(cont.)*

What To Do: *(cont.)*

6. Repeat Step #3 to refill the bottle, then hold the bottle out of the water again. Put your ear near the cap. What do you hear?

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Next Question

How could you get water to go into the bottle faster in Step #3? How could you get the water to get out of the bottle faster in Step #5? Test it. Why does this work?

Notebook Reflection

Imagine that you are inside the bottle. Describe what you would see and feel in each step of the experiment. If you didn't want water to get into the bottle, what could you do from the inside?

What Makes an Object Float?

Name ___________________________

What You Need:

- large, clear, cylindrical container
- tape
- test items
- towels
- scale

1. Fill the cylinder with water halfway. Use a piece of tape to mark the water's level.

2. Choose an item. Predict whether it will sink or float. Put it into the water to find out.

3. Submerge the item all the way under the water and measure how high the water rises. This will give you a rough volume. Take the item out of the water, dry it, and measure how much it weighs.

4. Repeat Steps #2 and #3 for the rest of the items.

Item	Prediction	Sink or Float?	Rough Volume	Weight	Density (weight / volume)
1.					
2.					
3.					
4.					
5.					
6.					
7.					
8.					

What Makes an Object Float? *(cont.)*

What To Do: *(cont.)*

5. Use a calculator to divide each item's weight by its volume. List the density of the items that floated in the first box. List the density of the items that sunk in the second box. Do you notice a pattern?

density of floaters	density of sinkers

Pattern:

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Next Question

You tested the buoyancy of the items in water and calculated their densities. Weigh the cylinder with the water. Then pour in one inch of water. Subtract the weights to find out how much one inch of water weighs. Where does that number fall in relation to the densities of the floaters and sinkers? Can you explain why?

Notebook Reflection

Measuring the rise of the water only gives a rough volume. To measure the exact volume, find the volume of one inch of water in the cylinder. Measure the diameter of the cylinder. Divide by two to get the radius. Multiply the radius by itself, and multiply that number by pi, or 3.14. The result is the volume of one inch of water. Multiply the rough volumes of the items in the table to get exact measurements.

How Can I Make a Sinker Float?

Name ______________________________

What You Need:

- bowl of water
- things that float
- things that sink
- rubber bands

What To Do:

1. Take a "floater." Float it in the water. Draw a picture of it.

2. Choose a "sinker." Attach it to the floater with rubber bands. Put it in the water. Draw a picture of what happens.

the floater	the sinker attached	what happened

3. If the floater doesn't sink with just one sinker attached, attach more sinkers until it hits the bottom.

4. Take a "sinker." Sink it in the water. Draw a picture of it.

How Can I Make a Sinker Float? *(cont.)*

What To Do: *(cont.)*

5. Choose a "floater." Attach it to the sinker with rubber bands. Put it in the water. Draw a picture of what happens.

the floater	the sinker attached	what happened

6. If the "sinker" doesn't float with one floater attached, add more floaters until it stays on top of the water.

Next Question

The density of an object is its weight divided by its volume. High density objects sink; low density objects float. What do you think the densities of the sinkers and floaters are individually? What do you think the densities of the sinkers and floaters are when strapped together? Why?

Notebook Reflection

When you made the sinker float, did it float evenly or lopsided? When the floater sank, which part was on top? Can you explain why?

Which Shapes Float?

Name ________________________________

What You Need:
- modeling clay
- bowl of water

What To Do:

1. Make a shape out of modeling clay. Draw a picture of it. Do you think it will sink or float?
2. Place it in the bowl of water. What happens?

shape	sink / float	what happened?

3. What made a shape float? What made a shape sink? Why do you think that is?

Next Question

How can you make the floating shapes sink? What are you doing to the floating shape to make it sink? Why does this make the shape stop floating?

Notebook Reflection

Modern ships are made of metal. Metal sinks in water, yet metal ships float. Submarines are made of the same kinds of metal. They sink or float depending on what the crew does. Can you explain how metal ships and submarines work?

How Does a Submarine Work?

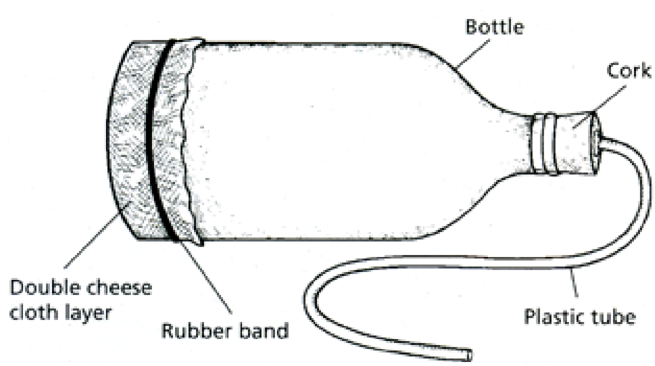
Name ______________________

What You Need:

- 20 oz plastic bottle
- cork to fit bottle
- electric drill
- plastic tubing
- modeling clay
- cheese cloth
- rubber bands
- aquarium or pool

What To Do:

1. Drill a hole through the cork just large enough to take the plastic tubing. Pass about 4 cm of tubing through the cork and seal it in place with the modeling clay.
2. Cut off the bottom of the bottle and place some lumps of modeling clay inside, stuck securely against the inside of the bottle.
3. Wrap a double layer of cheese cloth over the open end. Fix securely in place using strong rubber bands. Insert the cork in the mouth of the bottle.



4. Place your submarine in the aquarium or pool, holding on to the tube. What happens? Why?

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How Does a Submarine Work? *(cont.)*

What To Do: *(cont.)*

5. What happens when you pinch the tube closed? Why do you think that is?

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6. What happens when you blow into the tube? Why do you think that is?

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Next Question

Use classroom resources or the Internet to research how submarines' ballast tanks work. How are ballast tanks similar to the experiment?

Notebook Reflection

Describe in your own words how your submarine model worked. What made it sink? What made it rise? What made it stay at the same depth? Why?

How Does a Siphon Work?

Name ______________________________

What You Need:

- 2 buckets
- clear plastic tubing (1.5–2 m)
- duct tape
- water

What To Do:

1. Set a full bucket of water on a table with an empty bucket below on the floor. Bend one end of the plastic tubing into a U-shape and tape it to the edge of the full bucket so the end rests in the bottom. Make sure the other end can reach down to the empty bucket.
2. Suck through the bottom end of the tube until water hits your lips. Place the bottom end of the tube in the empty bucket. Describe what happens. What do you think is happening?

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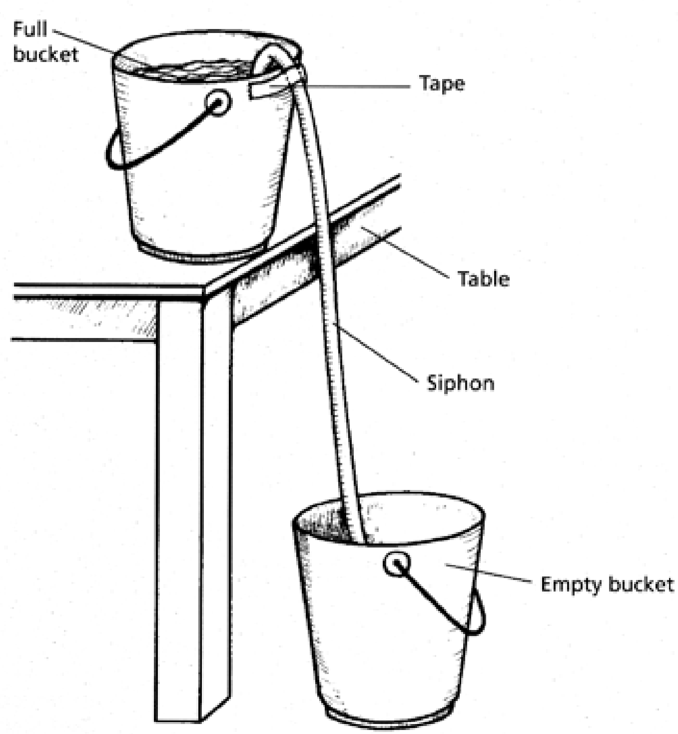

How Does a Siphon Work? *(cont.)*

What To Do: *(cont.)*

3. Take out the tubing and switch the buckets so the top bucket has water and the bottom bucket is empty. Submerge the tubing in the full bucket until there are no air bubbles inside. Seal off the ends with your fingers and replace the tubing where it was before, with one end in each bucket. Have a partner help you tape the tubing in place. What happens this time? Does it work without suction? Why?

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4. Now try Step #3 again, but with both buckets on the table. Set the siphon working and watch what happens. Can you explain it?

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Next Question

Can you link three buckets together with two tubes? Four buckets with three tubes? Design a way to find out.

Notebook Reflection

Describe the path that the water has to take each time. Speculate what is moving the water at each step.

What Is Recoil?

Name ______________________

What You Need:

- scissors
- baseboard (10 cm x 20 cm)
- wooden rod (20 cm)
- thick rubber bands
- clamp and stand
- string
- 3 screws
- screwdriver
- erasers
- matches

What To Do:

1. In the baseboard, fix three screws in a triangle, far apart.
2. Cut two 35 cm lengths of string.
3. About 1 cm in from each corner, drill a small hole and pass the string through the holes. The string should loop down under the board and come up through the holes. Tie the ends of the string to the ends of the rod.
4. Tie the rod to the clamp stand so the baseboard hangs below it.
5. Loop the rubber band over two of the screws at one end of the baseboard. Tie a short piece of string around the middle of the rubber band and tie the other end to the third screw. This should pull the rubber band very tight.
6. Place an eraser in the angle of the rubber band. Light a match and hold it to the string. Describe how the eraser and the catapult move.

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Next Question

Repeat the experiment using smaller and larger erasers. What differences do you observe? Measure the projectile weights and how far the baseboard moves. Create a table of your data. Do you see a pattern?

Notebook Reflection

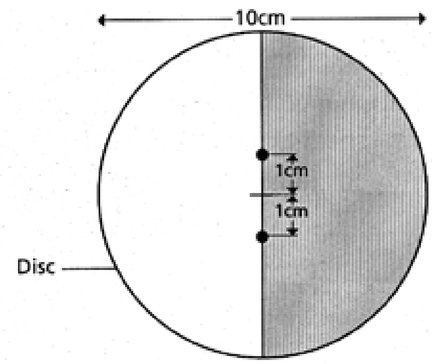
Newton's Third Law says that every action has an equal and opposite reaction. Can you relate that law to the experiment? What is the action? What is the reaction? How are they equal? How are they opposite?

What Is Momentum?

Name ________________________________

What You Need:

- scissors
- cardboard
- string
- ribbon
- pen or pins for punching holes



1. Cut out three 10 cm cardboard disks.
2. At points 1 cm on either side of the centers, make two small holes.
3. Pass 1 meter lengths of string through each of these holes and tie the ends together. You should have a long loop on either side of the disk.
4. Cut eight, 20 cm lengths of ribbon. Glue one end of each to the outer edge of the wheel.
5. Hold the loops in your fingers and have your partner spin the disk to wind up the string. Gently pull the strings to make the disk spin the other way. Relax the pull as the disk slows down and the string will rewind itself again. Gently pull to spin the disk in the other direction.
6. Observe the disk as it spins. What happens to the ribbons?

Next Question

Use classroom resources and the Internet to research centrifugal force. Explain what it is in your own words. How does it relate to the experiment?

Notebook Reflection

Have you ever been in a car that suddenly turned sharply? Have you ever ridden a spinning carnival ride? What did you feel? How is that similar to the experiment?

Why Do the Eggs Move Differently?

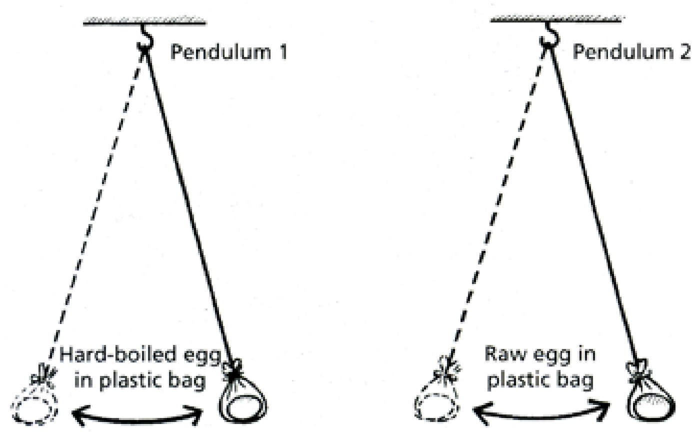
Name ______________________________

What You Need:

- fresh egg
- hard-boiled egg
- permanent markers
- plastic bags
- string
- scissors

What To Do:

1. Label the eggs "Fresh" and "Hard Boiled" with the permanent marker.
2. Place each egg in a plastic bag. Tie a 1-meter string to each bag.
3. Hold out the eggs so that they are at the same height and hanging from the same length of string.



4. Start both eggs swinging the same distance at the same time. Describe what happens. Which egg stops swinging first?

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What To Do: *(cont.)*

5. Take the eggs out of the bags. Place them on the tabletop. Spin each egg, then quickly touch your finger on the top of the spinning eggs. Do you observe a difference in the way they move?

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6. Now try spinning the eggs on their ends. Do you observe a difference now?

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Next Question

Tanker trucks are filled with liquids such as gasoline, milk, or water. Based on the experiment, how would their drivers need to drive differently than if they were hauling wood or cars?

Notebook Reflection

Both eggs are the same shape and about the same mass. Why do you think they move differently? What is the difference between the two eggs' physical properties? How would this affect movement?

References Cited

American Association for the Advancement of Science. 1989. Science for all Americans: A project 2061 report on literacy goals in science, mathematics, and technology.

American Association for the Advancement of Science. 1993. *Benchmarks for science literacy: Project 2061.* Oxford University Press.

Daniels, H., and S. Zemelman. 2004. Out with textbooks, in with learning. *Educational Leadership* (December 2003/January 2004):36–40.

Krueger, A., and J. Sutton. 2001. *EDThoughts: What we know about science teaching and learning.* Denver, CO: McREL.

Lemke, J. L. 1990. *Talking science: Language, learning, and values.* Westport, CT: Ablex.

National Academy of Science. National Science Education Standards. National Academy Press. http://www.nap.edu/readingroom/books/nses/.

Saul, E., ed. 2004. *Crossing borders in literacy and science instruction.* St Louis, MS: International Reading Association, Inc.

Their, M. 2002. *The new science literacy.* Portsmouth, NH: Heinemann.

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