Rourke's World of Science

# ENCYCLOPEDIA

Volume 1

# Human Life

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# What Is Life?

Look around you. All the stuff, or matter, in the world is either living or non-living. Stuff such as rocks, metals, plastic, water, and air are non-living.

Living things include plants and animals, humans and other mammals, insects, birds, and reptiles. Add the living things such as worms and millipedes in the soil, and the fish, crustaceans, and such in the sea. Add all the living organisms that are too small for you to see like the bacteria, molds, and viruses. The world is teeming with life.

Different forms of life are alike in many ways. They all need water and energy to live, grow, and reproduce. Green plants make their own food but animals need to eat. They both convert, or turn, food into energy. Most living things need oxygen and water.

*The girl and the plants and animals around her are living things. The paper bag she is holding is non-living.*

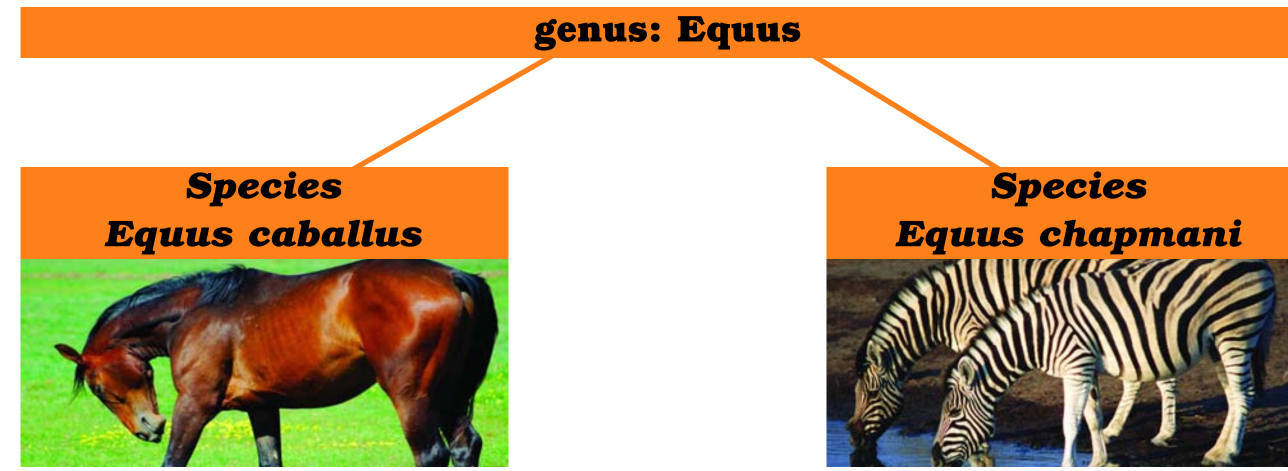
*You should drink about 64 ounces (1.8 kilograms) of water every day.*

## Classifying Living Things

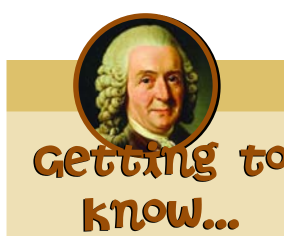
Classification is how scientists organize and name plants and animals. When scientists discover a new animal or plant, they compare it to similar living things. Then they place the new specimen in a group with which it shares the most attributes, or characteristics. Scientists divide living things into kingdoms, phyla and subphyla,



classes, orders, families, genus, and species. Each group describes the attributes of the living thing in more detail. All known plants and animals have scientific names. Each Latin scientific name tells us the living thing's genus and species. A horse's scientific name is *Equus caballus* and a zebra's is *Equus chapmani*. They are in the same genus.




### Linnaeus




Carl von Linné was born in Sweden in 1707. We know him by his Latin name, Carolus Linnaeus. Linnaeus was interested in nature and plants. He taught himself about biology and botany, the study of plants.

He devised a system to classify all the plants and animals known at that time. He described living things and grouped them by their shared physical characteristics. For instance, he put animals with backbones, or vertebrae, in one group and those without a backbone in another. He put animals that laid eggs in one group and those that bear live young in another. Linnaeus gave each group and each kind of living thing a Latin name made up of two descriptive words. Scientists refer to this system as the binomial (two names) system of nomenclature (naming).

In 1735 he published a series of books, *Systema Naturae* which described and named all the animals and plants known at that time. Scientists today still use his binomial classification system to organize and understand all living things.

## Humans

Scientists classify humans in the animal kingdom. We belong to the subphylum Vertebrata. This means that we have spines or back bones. We are in the class Mammalia (mammals), animals that nurse their young. Humans are in the order Primates. They are omnivores with opposing thumbs and a big brain. The genus and species name for human beings is *Homo sapiens*. These Latin words mean *man* and *knowing*.

**Characteristics of Primates**

- tendency towards walking upright on two feet
- having five fingers and five toes
- opposing thumbs
- flexible shoulder joints and strong collarbones, or clavicles
- binocular vision - using both eyes to produce three dimensional (3-D) view
- omnivorous - eating both plants and animals
- long gestation (pregnancy) periods for animals of their size
- social behavior - spending time with each other
- large brain size relative to body
- vocalization - producing a variety of sounds from vocal cords

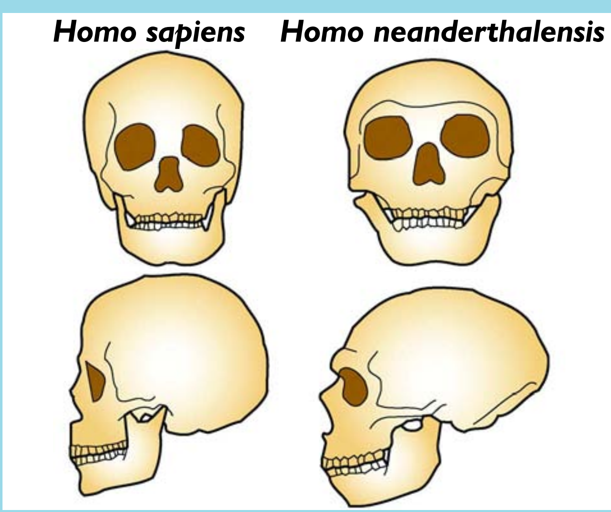
Find out more

**Early Humans**

Long before *Homo sapiens*, there were other types of human-like primates, or humanoids, called *Homo neanderthalensis*. They had thick bones and smaller brains than *Homo sapiens*. Scientists found evidence that they used some tools.

Scientists believe that modern *Homo sapiens* evolved from *Homo erectus*. *Homo erectus* comes from the Latin words for man and upright. *Homo erectus* had a larger brain than the Neanderthals. Scientists have found evidence that they used stone tools for hunting and cooking food.

*Homo sapiens* began to appear 250,000 years ago in Africa, Europe, and Asia. Over time, they spread to America and Australia. They had even larger brains than *Homo erectus* and smaller jaws and teeth. *Homo sapiens* developed language to communicate with one another.



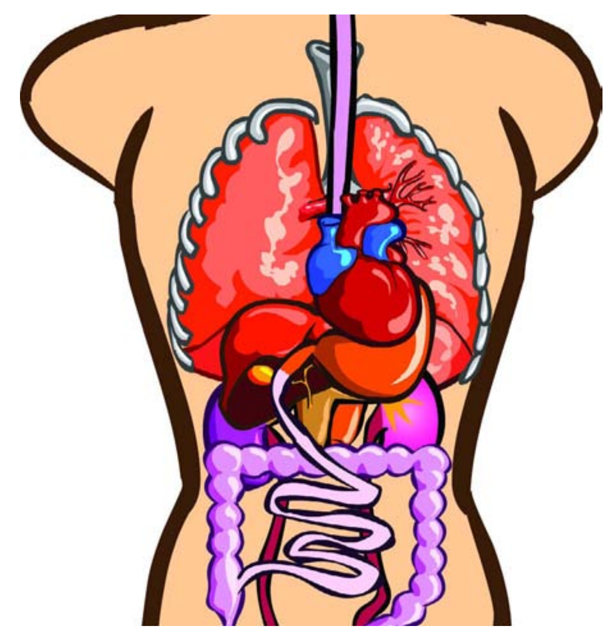

*Skull comparisons*



# The Human Body: Organs and Systems

Your body is like a complex machine. Many parts make up your body and work to keep you going. Some parts, like your eyes and hands, are easy to see. Some parts, like your vocal cords, hide inside your body. When you hum, the vibrations you feel are your vocal cords at work.

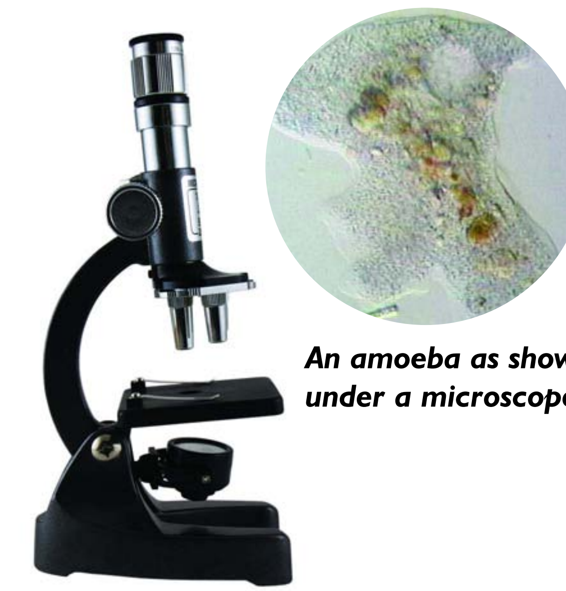
Some parts of the body are so small you can't see them without a microscope. The smallest parts are cells. Groups of similar cells form tissue, and tissues form organs. Your heart, lungs, and brain are examples of organs. A group of organs work together to form a system such as the digestive system.



*Groups of cells make up tissue. Tissue forms organs. Organs work together as systems.*

## Cells

Cells make up all living things. Some microscopic organisms, such as amoeba and paramecium, consist of just a single cell. But most animals have millions of cells.



*An amoeba as shown under a microscope.*

WORDS to KNOW

**evolve** (i-VOLV)**:** to change slowly

**humanoid** (HYOO-min-oyd)**:** having human-like characteristics

**specimen** (SPESS-uh-muhn)**:** a sample or an example used to stand for the whole group

**successive** (suhk-SESS-iv)**:** following in a logical or sequential order

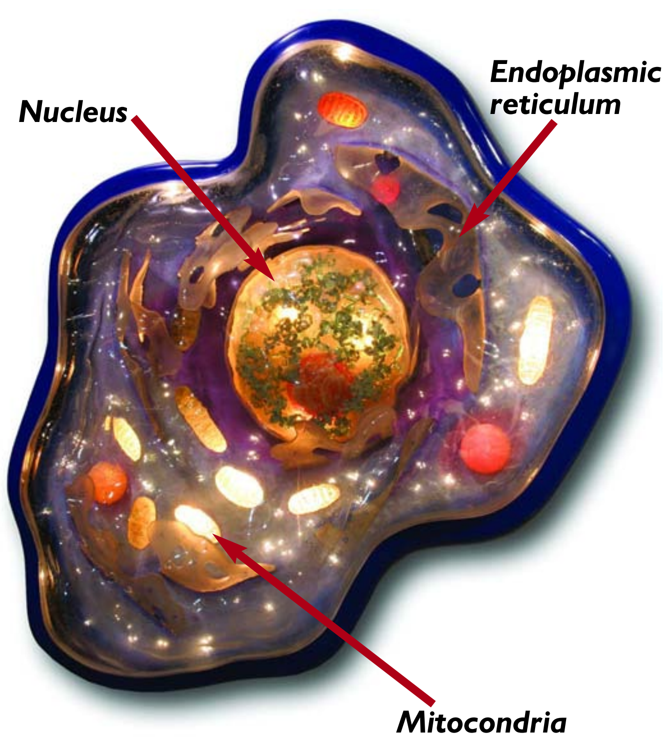
**teem** (teem)**:** to be very full, to swarm

A jell-like substance called protoplasm fills every cell. A thin cell membrane surrounds the protoplasm (picture a plastic baggie filled with jelly). Plant cells differ in that they may have walls of cellulose outside the membrane.

The cell membrane allows water, oxygen, and nutrients in and carbon dioxide and other wastes out.

### Organelles

In addition, most cells contain specialized parts, or organelles, that have specific jobs. The cells contain a nucleus, mitochondria, and an endoplasmic reticulum.




The nucleus contains the genetic material that controls what each part of the cell does. Mitochondria are "cellular power plants" that convert food to energy. The endoplasmic reticulum (*endo* means inside) is a folded membrane that makes proteins and fat.

**Find out more**

Your outer skin cells, hair, toenails, and fingernails, are all dead cells.

Several layers of cells make up your skin, the largest organ of your body. The living and active cells are in the bottom layers, closest to the blood supply. The live cells in the bottom layers push up the cells that die to the surface. Every four weeks, you have grown a completely new skin!

*Magnified view of human skin.*

## The Nerves and Brain

Your nerves, spinal cord, and brain form the nervous system. Long, thin neurons or nerve cells make this system work.

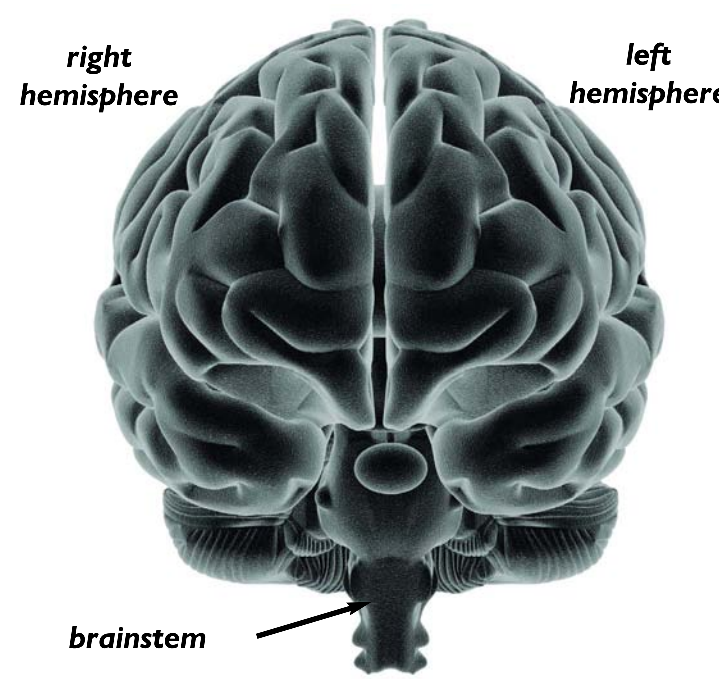
Many neurons make a strand to form long nerves. Between the ends of each neuron in a strand is a gap, or synapse. Electrical signals, to and from the brain, travel along a nerve by jumping across the synapse.



### Brain Areas

The brain has two sides, or hemispheres. The left hemisphere controls the right side of the body. The right hemisphere controls the left side of the body. The brain is so complex that scientists are always learning new things about what all of its parts do.

The lower part of the brain is the brain stem. It controls involuntary functions, such as breathing and blinking. These functions happen without you having to think about them.




*This X-ray shows a front view of a brain, clearly showing the two hemispheres.*

The middle part of the brain is the cerebellum. It controls balance and movement of muscles. Electrical signals start in the brain, travel along nerves in the spinal cord inside your spine, and then out to your muscles. Many muscles work together for the body to walk, eat, or play the drums.

The upper and inner part of the brain is the cerebrum. It responds to the electrical signals from your eyes, ears, and other sense organs. The cerebrum processes the signals, turning them into sights, sounds, smells, tastes, and sensations. The cerebrum also controls thought, memories, and speech.

Injury to some parts of the brain can make people forget things. They may even forget who they are. In some cases of brain damage, the individual must learn how to walk, speak, or read again.

**Words to Know**

**axon** (AK-sohn): the usually long part of a nerve fiber that carries signals away from the nerve cell body

**involuntary** (in-VOL-uhn-ter-ee): done without a person's control

**respond** (ri-SPOND): to react to something

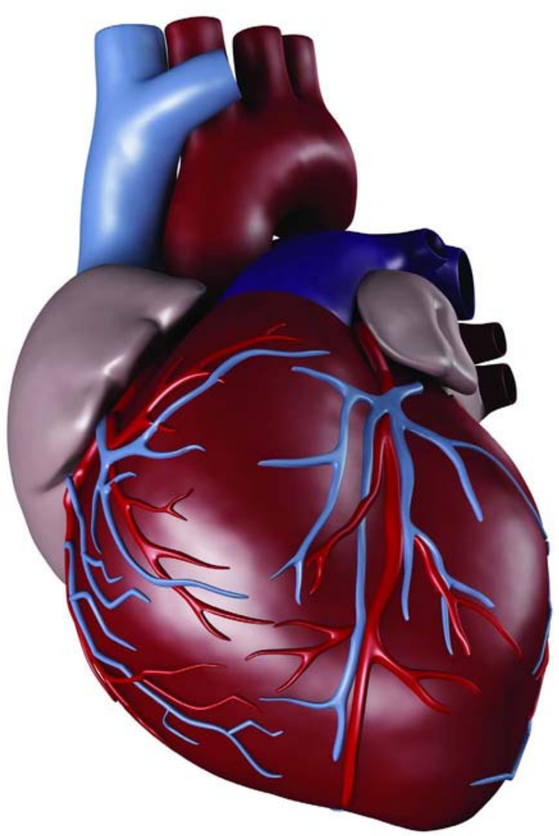
**strand** (strand): something that looks like a thread or string

**synapse** (SIN-apse): the junction across which a nerve impulse passes from one axon to another, or from an axon to a muscle cell

## The Heart and Blood

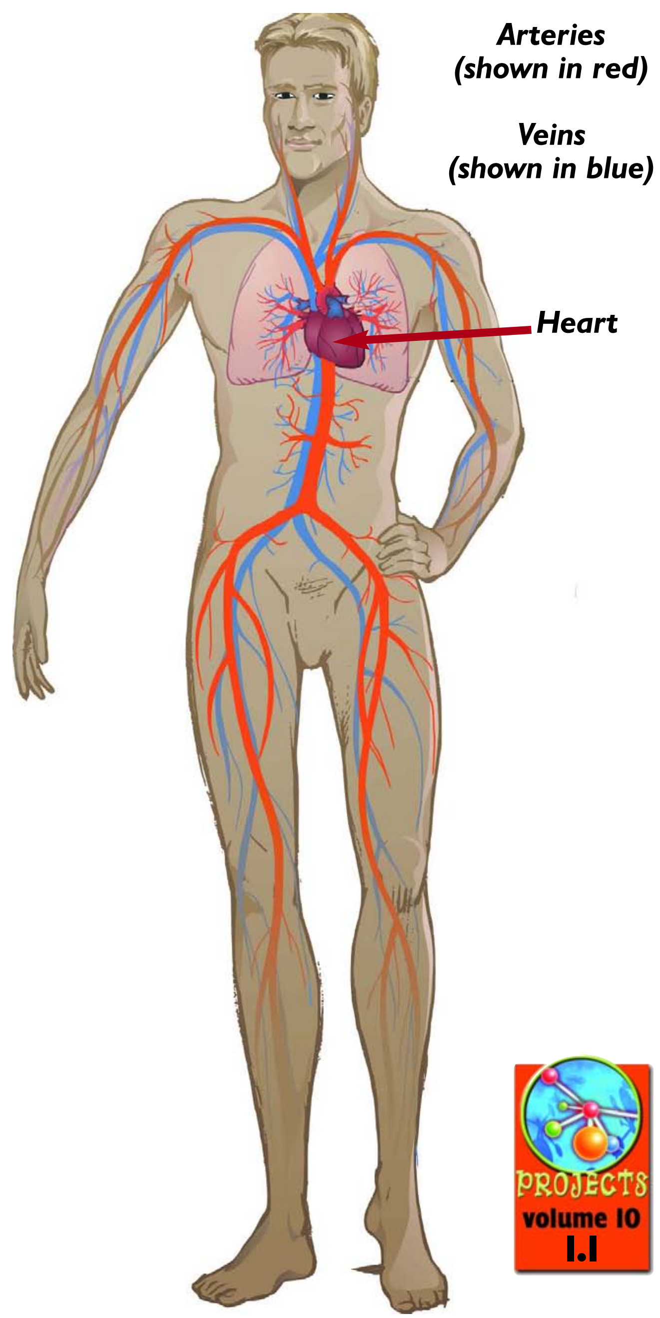
Your heart and blood vessels are in charge of your blood's circulation. The heart, a large and strong muscle, is the pump. It consists of four chambers: right and left atriums and right and left ventricles. The atriums receive blood and the ventricles send blood out.

The heart squeezes, or contracts, many times in a minute to keep blood flowing to all parts of the body. You can feel your heartbeat. Place your fingers gently on the side of your neck below the chin. You should feel a repetitive beat or pulse.



### Blood Vessels

Arteries are the blood vessels that carry blood from the heart to the rest of your body. Veins are the blood vessels that bring the blood back to the heart. The blood vessels closest to the heart are larger than the ones that supply your organs and your arms and legs.





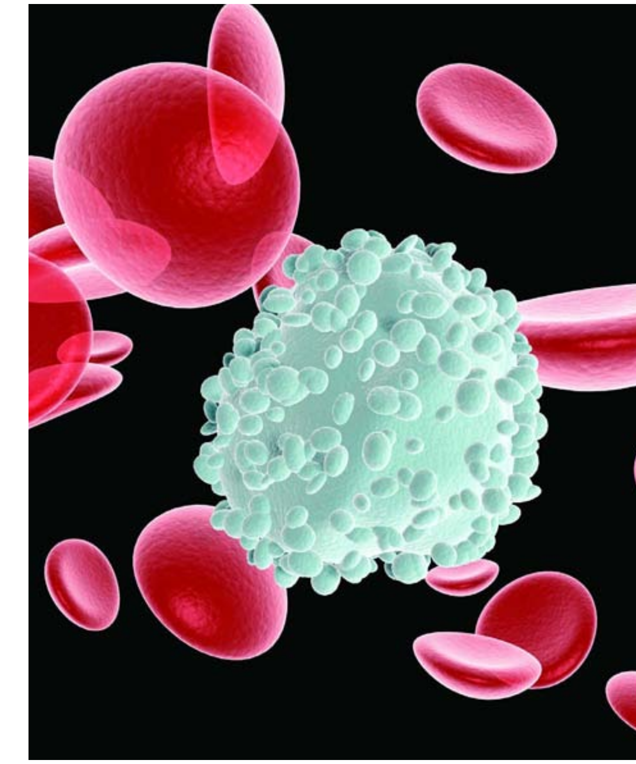

The arteries and veins eventually end in small blood vessels called capillaries. They are the blood vessels at the cellular level, delivering oxygen and nutrients and carrying away carbon dioxide and waste products. The capillaries are so thin that blood cells travel through them single file.

### Blood Cells and Plasma

Red blood cells and white blood cells in a yellow liquid, or fluid, called plasma is what makes up your blood. You can see plasma if you have a blister. The liquid in the blister is plasma.

A red blood cell (erythrocyte) is doughnut shaped and does not have a nucleus. It contains hemoglobin, a special substance that carries oxygen. White blood cells (leukocytes) come in various sizes and shapes and have a nucleus. White blood cells fight infection and disease. They attack the microscopic organisms we call germs.

Plasma, the liquid part of the blood, contains platelets (thrombocytes) that help blood clot when blood vessels are injured. The blood must clot or the body cannot heal itself.



***If you looked at your blood through a microscope, the red and white cells would look like this.***

**Find out more**

Hemophilia, an inherited disease, is a condition in which a person's blood will not clot at all. A person with hemophilia must be very careful. It is hard to stop the bleeding even on a very small cut.

**WORDS TO KNOW**

**circulation** (sur-kyuh-LAY-shun)**:** the movement of blood in blood vessels through the body

**clot** (klot)**:** to become thicker and more solid

**inherit** (in-HER-it)**:** passed down through genes from parent to child

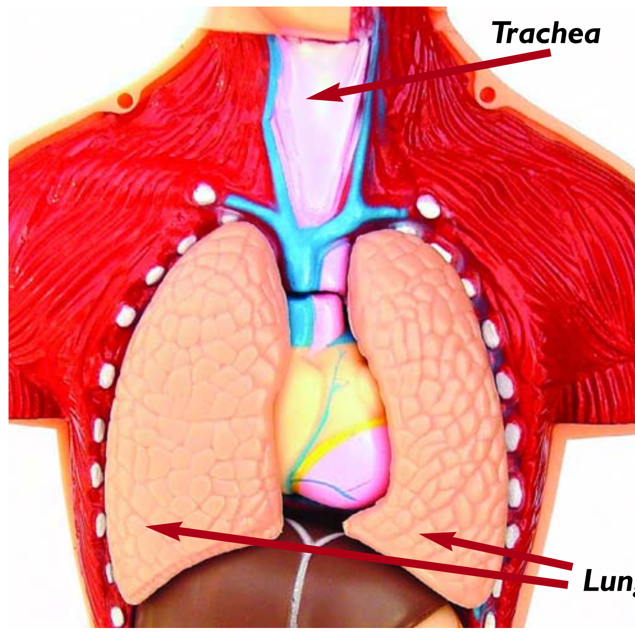
## The Lungs

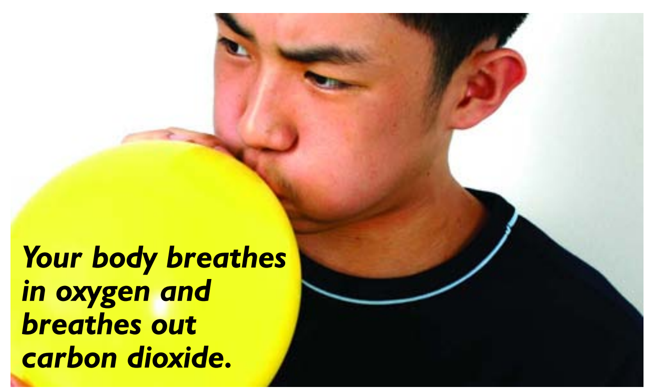
Two lungs and a windpipe, or trachea, make up your respiratory system. The system delivers oxygen to your cells and carries away carbon dioxide.

### Breathing

When you breathe in, air moves down your throat through the trachea (windpipe). The trachea branches out into smaller and smaller tubes called bronchioles. They end finally, deep in your lungs, in little round sacs called alveoli. These look like bunches of grapes. Capillaries crisscross the very thin walls of the alveoli. Your capillaries transport the red blood cells that carry oxygen.

When you breathe out, air comes from your lungs and out your nose or mouth. Breathing is the only way your body gets oxygen ($O_2$) and gets rid of the carbon dioxide ($CO_2$) produced by your body's cells.



*Your body breathes in oxygen and breathes out carbon dioxide.*

Breathing becomes difficult if the passages become smaller, or constrict. This is what happens in the disease called asthma. You can still breathe with one damaged lung but not if you damage both lungs. Smoking and breathing fumes or chemicals can damage your lungs irreparably.

**Words to Know**

**capillary** (KAP-uh-ler-ee): the smallest blood vessels in your body

**carbon dioxide** (KAR-buhn dye-OK-side): a gaseous chemical compound of oxygen and carbon

**irreparable** (ihr-REP-er-uh-buhl): not able to be repaired

**oxygen** (OK-suh-juhn): a colorless gas component of air

**passage** (PASS-ij): a hall, tube, or tunnel



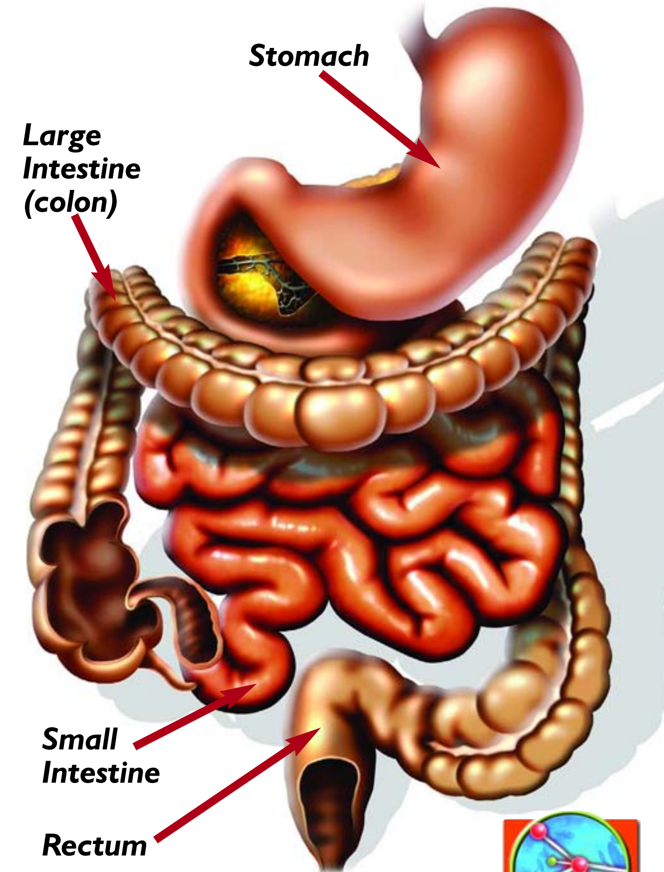
## The Stomach and Intestines

The stomach and intestines make up most of the gastro-intestinal system. The prefix *gastro* means stomach. Your mouth, salivary glands, esophagus, liver, and pancreas are also important parts of the GI (short for gastro-intestinal) system.

We also call this system the digestive system because it breaks down, or digests, the food you eat. When you chew and swallow, food travels down your esophagus. The esophagus ends at a large sack-like organ called the stomach.

The food then moves into the small intestine and finally into the large intestine.

*After you swallow food, muscles in your esophagus move it down into your stomach.*

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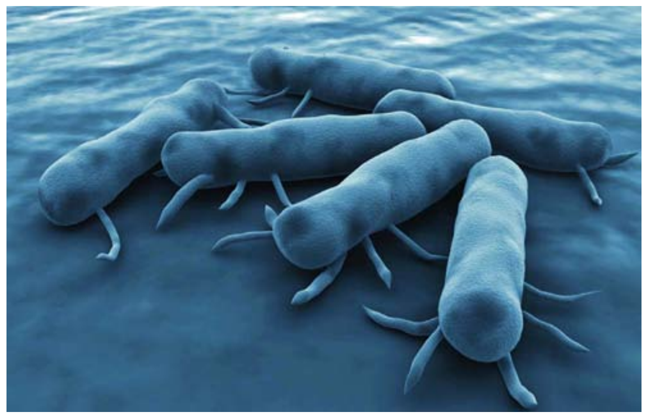
The intestines, known also as guts, are tubes with muscles and capillaries lining their walls. The intestine walls are as thin as plastic wrap. Digested food, broken down into small molecules, passes into the capillaries.

Food that is not absorbed in the small intestine enters the large intestine, or colon. The lowest part of the large intestine is the rectum. The remaining undigested food is called feces. Feces leave the body through an opening called the anus.

## When Digestion Goes Wrong (Bellyaches)

Sometimes, your stomach and intestines may hurt. If you ate food that contained harmful bacteria, food poisoning is causing the pain.



*Salmonella is a dangerous bacteria that causes food poisoning. This is how it looks when viewed through a microscope.*

When the body tries to get rid of the toxins produced by the bacteria, it moves the food quickly through the intestines. The feces retain a lot of water that would normally be absorbed. We call this diarrhea.

The opposite of diarrhea is constipation. Constipation is when food moves too slowly through the digestive tract, or system, and the undigested food becomes dry and hard.

WORDS to Know

**absorb** (ab-SORB): to soak up liquid

**bacteria** (bak-TIHR-ee-uh): microscopic living things that exist all around you and inside you

**toxin** (TOK-sin): a poisonous substance

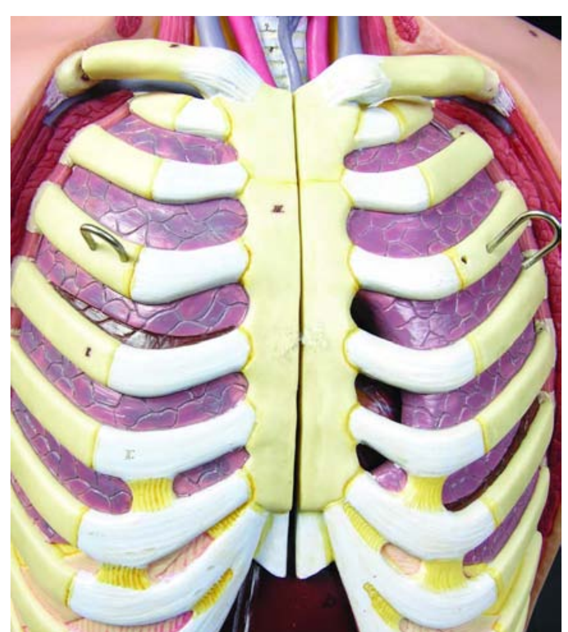
# Bones and Muscles

Two hundred and six bones form your skeleton. The skeleton is a framework that supports the rest of your body.

## Bones

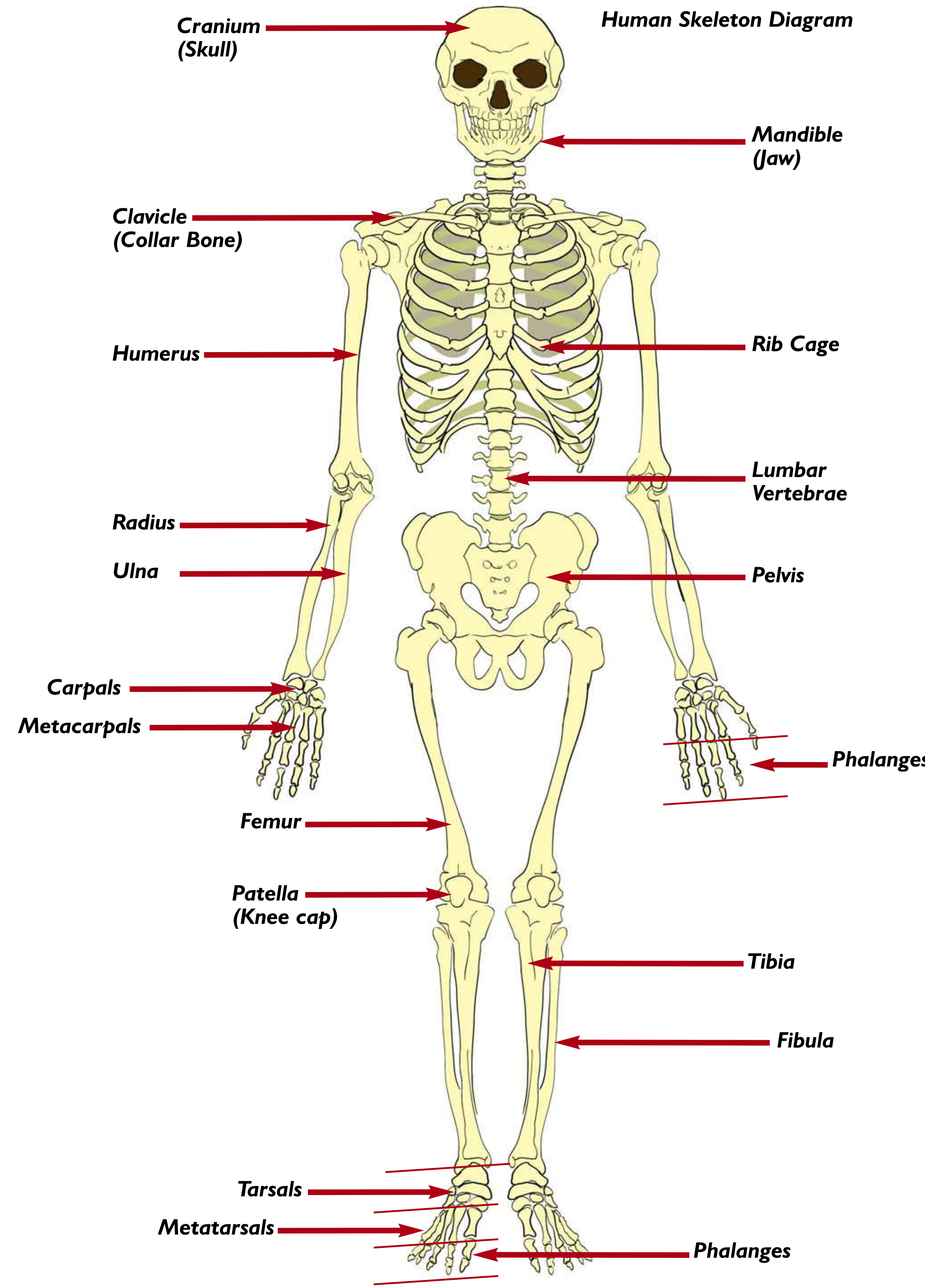
The outside of a bone is hard. Many bones end in smooth cartilage, a tough but softer tissue. The end of your nose is cartilage. Many bones are hollow and filled with a gooey material called marrow that produces red blood cells.

Some bones provide protection for the nervous system. The skull protects your brain. The vertebrae that form your spine protect your spinal cord. Your ribs form a cage to protect your heart and lungs.



*Ribs protect the heart and lungs.*





## Joints

Other bones allow you to move. Ligaments attach bones together at joints. Ligaments are a stiff, slightly elastic tissue. Soft cushion-like discs between each set of vertebrae allow your spine to bend and twist.

## Muscles

Skeletal muscles move your bones and give your body its shape. Tendons are a tough, rubbery tissue that attaches your muscles to your bones. A muscle contracts when it receives a signal from your brain. When the muscle contracts, the attached bones move. Make a muscle with your biceps. What happens to your lower arm?

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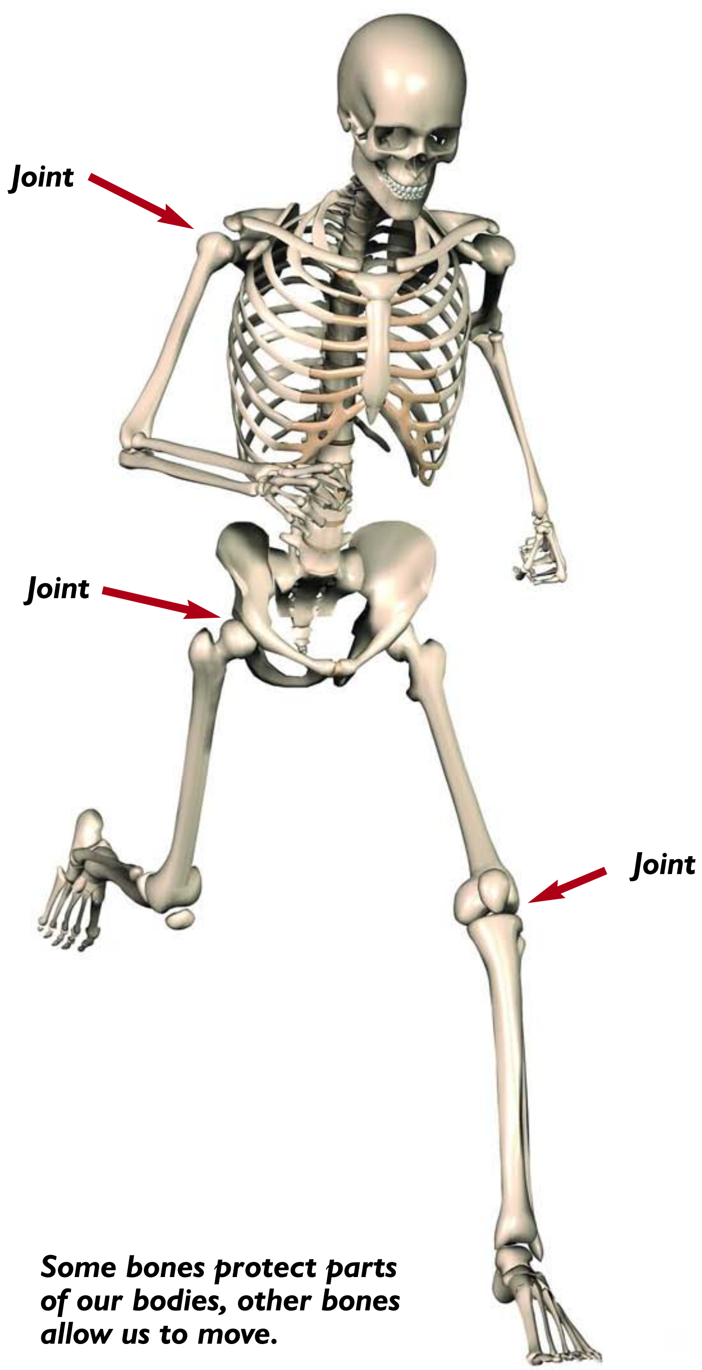
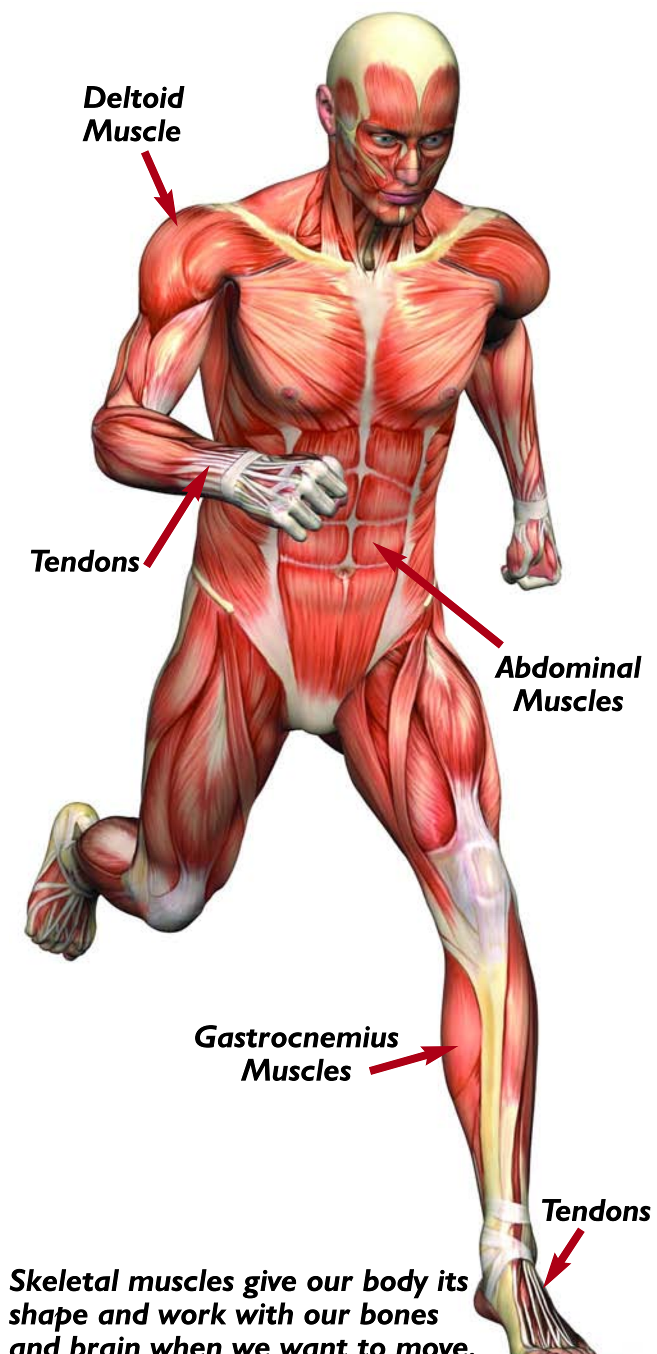



*Some bones protect parts of our bodies, other bones allow us to move.*



**Involuntary Muscles** work without you thinking about them. For example, smooth muscles that line your intestines keep food moving through. The smooth muscles in arteries control the flow of blood. The cardiac muscle beats, or contracts, in a regular way called a rhythm.




*Skeletal muscles give our body its shape and work with our bones and brain when we want to move.*

**Find out more**

Exercise keeps you healthy and strong. You can do two kinds of exercise. Aerobic exercise is one kind. Walking fast, running, jumping rope, or dancing, are all aerobic. During aerobic exercise your heart and breathing rates speed up to get oxygen to your muscles. Aerobic exercise burns carbohydrates and fats. Regular aerobic exercise keeps your heart and lungs working well.

The other kind of exercise is anaerobic. Lifting weights is anaerobic. This kind of exercise makes your muscles bigger and your bones stronger. It is best to do both aerobic and anaerobic exercises. This will give you a healthy heart and strong bones and muscles.

**Words to know**

**contract** (kuhn-TRAKT): to get smaller

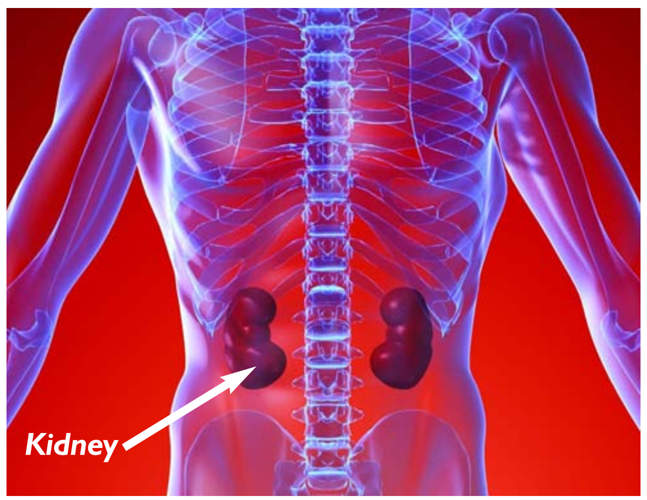
**involuntary** (in-VOL-uhn-ter-ee): done without a person's control

**regular** (REG-yuh-lur): happening or reoccurring at the same time

**vertebrae** (VUR-tuh-bray): the individual bones of the spine

## The Kidneys and Bladder

Your kidneys and bladder form your urinary system. This system regulates, or controls, the amount of water in your body. Your two kidneys are on either side of your spine, against the small of your back, and under your rib cage.




The kidneys take out excess salts and cellular waste products as blood circulates, or flows, through them. The remaining liquid, made up of water and the waste products, is urine. The urine travels in a tube called the ureter to the bladder. The bladder keeps the urine until it leaves the body through another tube, the urethra.

**Words to Know**

**donor** (DOH-nur): someone who gives something

**organ** (OR-guhn): a part of the body that does a specific job

**salt** (sawlt) a chemical: compound formed from an acid and a base

**transplant** (transs-PLANT): to surgically replace a diseased organ with a healthy one

**Find out more**

About 190 quarts (180 liters) of water filters through your kidneys every day, but only about 1.6 quarts (1.5 liters) finally leaves your body as urine.

### Infections or Misfunctions

Things can go wrong in our organs. Medical researchers find or invent things to solve organ problems. Doctors use this information to treat their patients.

- **If you develop a kidney or bladder infection:** Doctors may use antibiotics to fight the germs.
- **If your kidneys don't remove waste products correctly:** You may have to use a dialysis machine to do the work of the kidneys.
- **If both kidneys have damage or stop working:** Doctors can transplant a kidney from another person or donor. The donor survives because people can live with just one kidney.



## The Reproductive Organs

All animals reproduce. In most animals, adult males and females mate, and the union of a sperm and an egg produces an offspring. Each egg and each sperm carries one half of each parent's genetic material.

### Organs

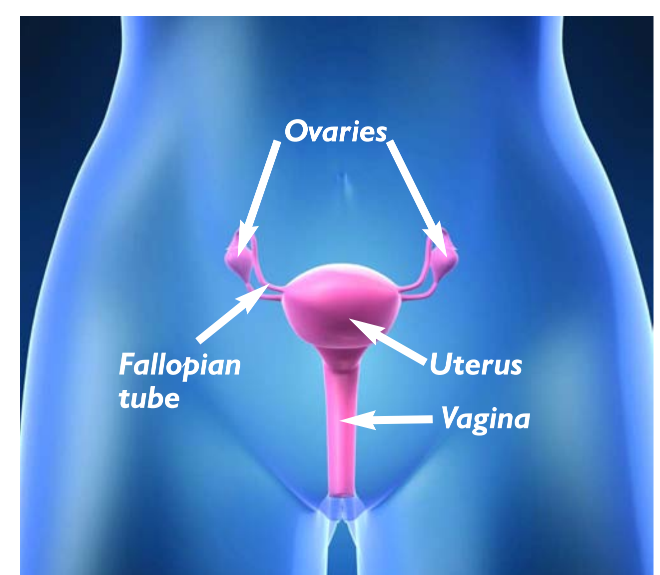
The organs and body parts that produce the sperm and egg make up the reproductive system. They also allow for mating and provide for the development and nurturing of the resulting young.

Women produce eggs. Two ovaries produce the eggs. Every month during ovulation, an egg leaves one of the ovaries. (The Latin word for egg is *ova*.) It travels down the fallopian tube and enters the uterus.

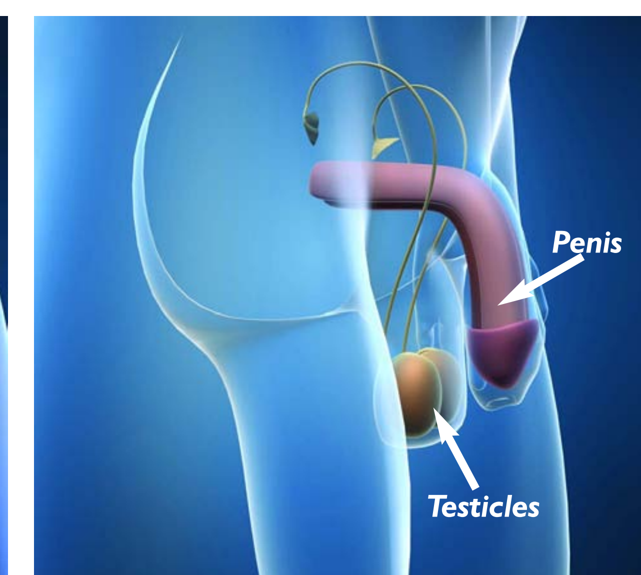
Each month, the uterus wall prepares to receive the egg by building up an extra blood supply. An egg fertilized by a sperm will attach to the wall of the uterus and develop into an embryo and subsequently, a fetus.

An unfertilized egg will break down. It, and the extra blood, will leave the body through a tube called the vagina. Menses, or menstruation, is the shedding of the unfertilized egg and the extra blood from the uterus.

Men produce sperm. Two organs called testicles, or testes, make the sperm cells. A sac called the scrotum protects the testicles. Sperm leave the body through the urethra in the penis.




*Female reproductive organs*




*Male reproductive organs*

### Hormones

Besides producing eggs and sperm, the ovaries and testes produce the hormones that determine female and male characteristics. These characteristics include body hair, beards, breasts, and larynx (vocal cords), as well as muscular and skeletal growth.

*Men grow hair on their face because of a hormone called testosterone.*

**Words to Know**

**genetic material** (juh-NET-ik muh-TIHR-ee-uhl): the cell parts that carry the biological instructions (chromosomes, genes, and DNA)

**hormone** (HOR-mohn): a chemical substance produced in body glands that controls growth and development

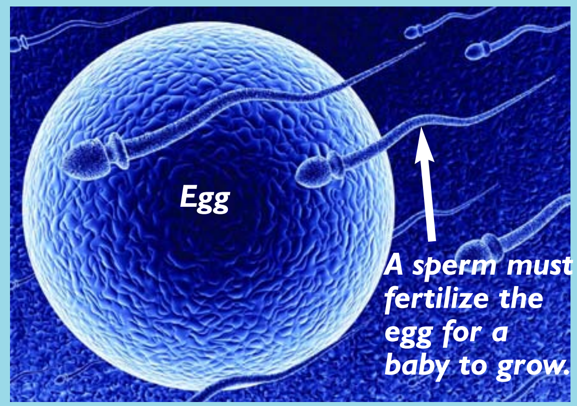
**mate** (mate): to join together for reproduction

**nurture** (NUR-chur): to take care of

**shed** (shed): to fall out, to give off

**Find out more**

The single fertilized egg cell divides and multiplies into millions of cells, forming all the tissues and organs of a new human in the nine months before birth.




*A sperm must fertilize the egg for a baby to grow.*

*Doctors can take photos of a baby inside its mother with an ultrasound machine.*

*A model shows a baby inside its mother.*



# How the Body Works

PROJECTS volume 10 1.4

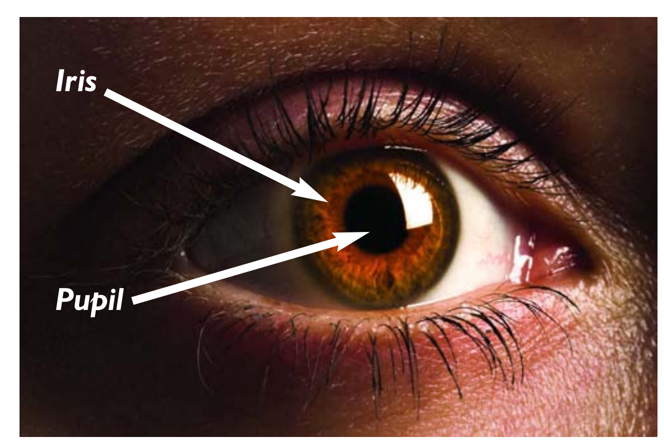
All the organs and systems of your body work together. When they work correctly you move, you fight off germs and diseases, you heal, you learn, you grow, and you age. In other words, you live.

## The Senses

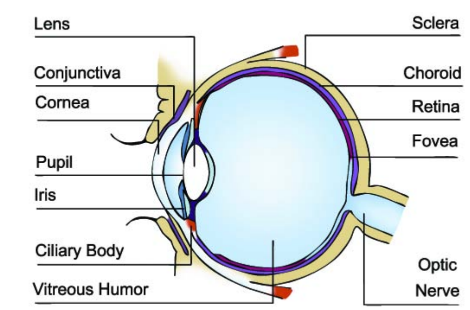
The senses are one way you and your body learn about the world around you. The five senses are sight, hearing, taste, smell, and touch. A different organ controls each sense. Your sensory organs are your eyes, ears, tongue, nose, and your skin and its nerves.

### Sight

What you can see of your eyeball is the white covering, some tiny blood vessels, and the iris. The iris is the colored donut-shaped circle with a black hole in the middle. That black hole is your pupil. Light enters the eye through the pupil. Because the ring of the iris is a muscle, it can contract or expand, making the pupil change in size. This regulates how much light comes into the eye.




The parts of the eye you cannot see are the clear lens in the pupil, the retina, and the vitreous fluid.




**The clear lens** brings light to an area at the back of your eyeball, called the retina. The iris muscles and the cornea, which is a clear layer that covers the eye, hold the lens in place.

**The retina** is made of two different kinds of cells, called rods and cones. These cells change light into electrical signals to send to the brain via the optic nerve.

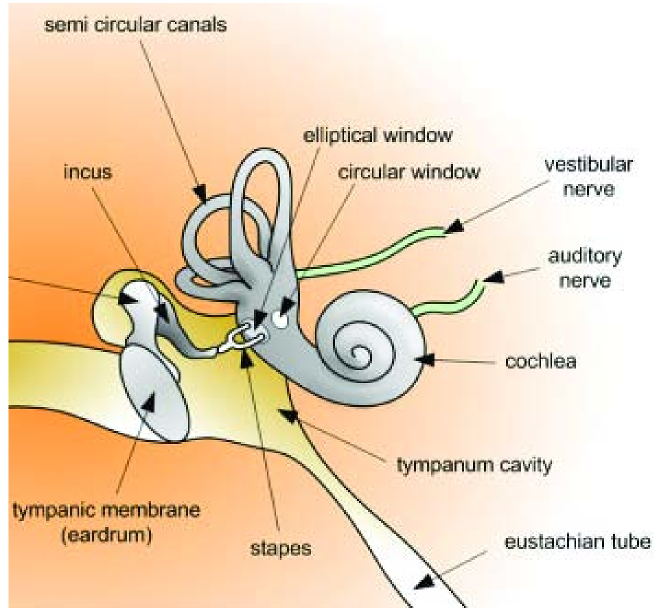
**The vitreous fluid** is a jelly-like fluid that fills the eyeball, maintaining its round shape.

## Hearing

Your ears turn sounds into signals for the sense of hearing. We can only see the outer part of the ear. Sounds in the air travel to a membrane called the eardrum. The eardrum vibrates when sounds hit it.

The middle part of the ear has three tiny bones called ossicles. The ossicles pass on the vibrations to the inner ear. The cochlea, in the inner ear, contains hair-like cells that convert sound waves into electrical signals. The signals travel to the brain via the auditory nerve.

The inner ear also helps us keep our balance and walk erect on two feet. If you have ever suffered an ear infection, you may have found that you lost your balance during the illness.




*Inside a human ear*

## Smell and Taste

The senses of smell and taste are connected. Sensory receptor cells are in your nose and mouth. They respond to chemicals in the air and in food. They generate electrical signals from their interaction with the chemical molecules.

The receptors for smell are in both the nose and mouth. Smell is important for the sense of taste. You may not be able to taste food when you have a cold.

The receptors for taste are the taste buds on your tongue. The four basic tastes you perceive are sweet, bitter, sour, and salty.



*Lollipops usually have a sweet taste.*

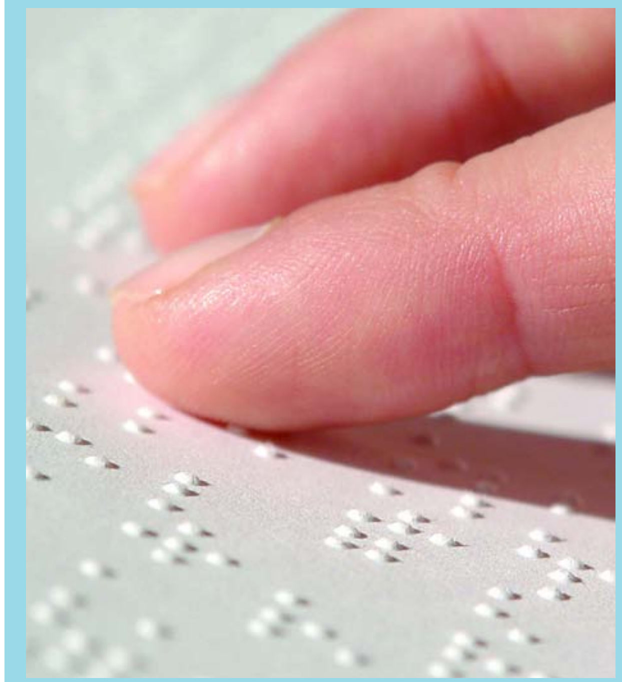
*Lemons have a sour taste.*

## Touch

The sense of touch includes pressure, cold, warmth, and pain. Different receptors in the skin respond to different types of touch. They allow us to distinguish between rubbing and pressure, to identify shapes and textures of things, and to feel the temperature around us or of objects touching us.

**Find out more**

Sometimes when all the senses do not function right, our other senses become more acute. People with limited or no sense of sight can use their sense of touch to learn about their environment. They can read using the Braille system, which converts our alphabet into raised bumps.



**Words to Know**

**acute** (uh-KYOOT): able to detect things easily

**membrane** (mem-BRAYN): a very thin layer of tissue that lines or covers organs or cells

**molecule** (MOL-uh-kyool): the smallest part of a substance that displays the characteristics of that substance

**via** (vye-uh): by way of

# Circulation

Circulation is the movement of blood through your body. Blood moves through your body when your heart and skeletal muscles contract. The job of your circulation system is to bring oxygen and food to your cells and take away the waste products of metabolism.

## Arteries

Let's follow your blood on its journey through the body. We will start in the lungs where it picks up oxygen. From the lungs, blood travels through the pulmonary vein to the left atrium of the heart. It passes through a valve into the left ventricle. It travels out the aorta, the largest artery in your body. The aorta divides into smaller and smaller arteries that connect to millions of capillaries. The capillaries supply the body's cells.

## Veins

At the cells, the blood's red blood cells give up the oxygen and pick up carbon dioxide. Now, the blood returns to the heart. The capillaries connect to small veins. The small veins join larger and larger veins.

The two largest veins, called the *venae cavae*, merge just before they enter the right atrium of the heart. The blood they carry passes through a valve into the right ventricle. The right ventricle pumps the blood out the pulmonary artery into the lungs. The lungs take carbon dioxide from the blood and put in oxygen. The blood returns to the left atrium. The trip starts all over again.

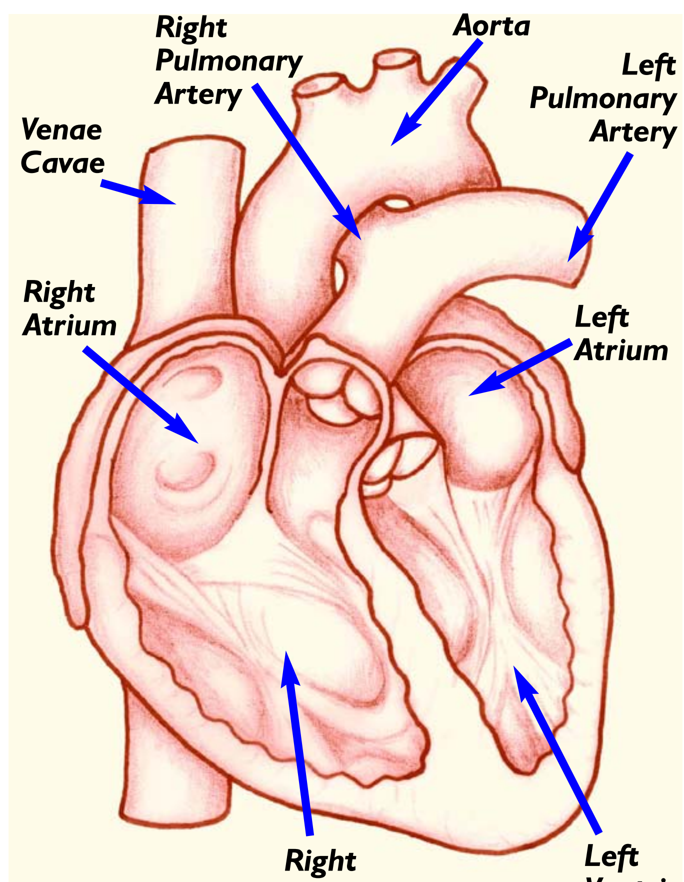
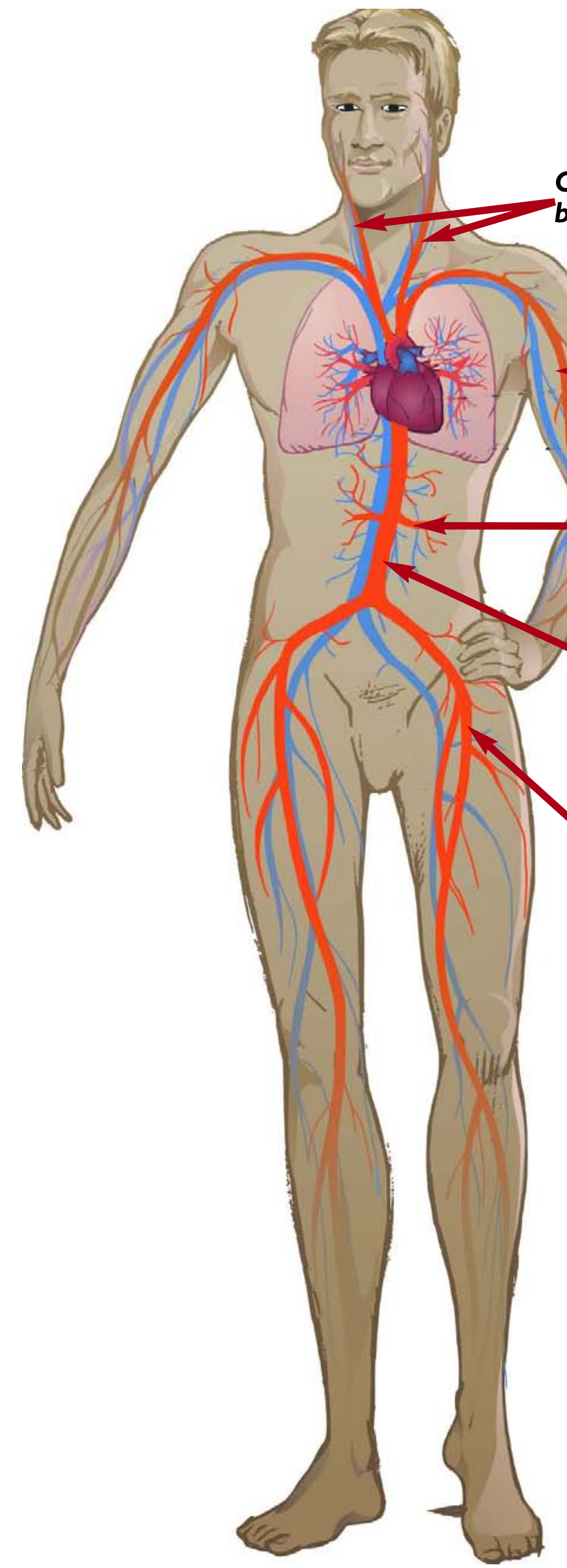



*Illustration of human heart.*




**Average Heart Rates Of Animals**

**In beats per minute**

Large Whale: 20
Elephant: 25
Horse: 44
Giraffe: 65
Large Dog: 75
Humans: 60 -70
Small dog: 100
Cat: 150
Rabbit: 205
Hamster: 450
Mouse: 500

*(Notice the relationship between the heart rate and size of animals)*

**WORDS to Know**

**contract** (kuhn-TRAKT)**:** to get smaller

**merge** (murj)**:** to join together to become one thing

**metabolism** (muh-TAB-uh-liz-uhm)**:** the process of changing food, water, and oxygen into energy and body cells

# Respiration

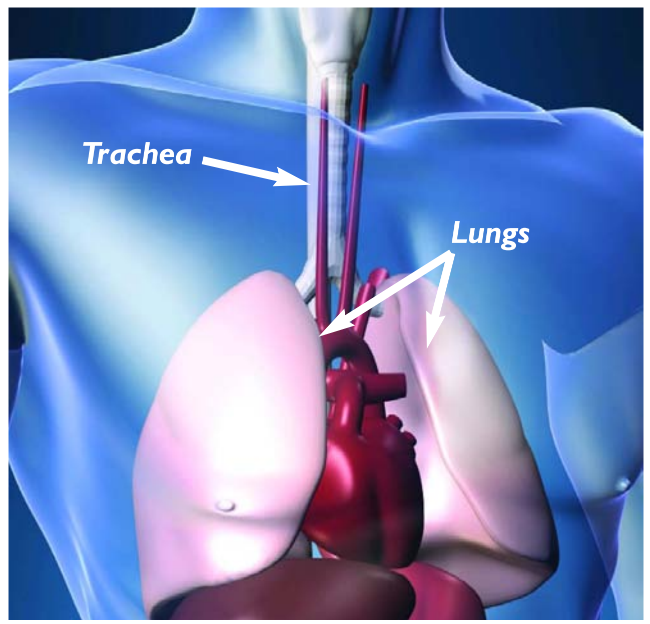
Respiration is another word for breathing. Most living things need oxygen ($O^2$) to produce energy from the food they take in. Your body cells convert food and oxygen to energy in a process called metabolism. Carbon dioxide ($CO^2$) is a by-product of metabolism. Your lungs are the organs taking in $O^2$ and getting rid of the $CO^2$.

## Lungs at Work

A large muscle (diaphragm), located at the bottom of your chest, controls breathing. When you inhale, your diaphragm contracts and moves downward. That creates a vacuum. Air comes in through your nose or mouth to fill that vacuum.

*A voice teacher shows a student how to breath from her diaphragm.*

Air travels down the trachea into your lungs. The muscles in the wall of your chest also help you inhale by expanding the chest cavity.




The air travels deeper into the lungs through the bronchi and bronchioles. When it gets into the grape-like sacs, called alveoli, oxygen in the air moves into the blood through the capillaries. At the same time, carbon dioxide moves out of the blood and into the alveoli.

When you exhale, the diaphragm relaxes and moves upward. This compresses the lungs and air rushes out of the lungs, taking carbon dioxide with it.



Find out more

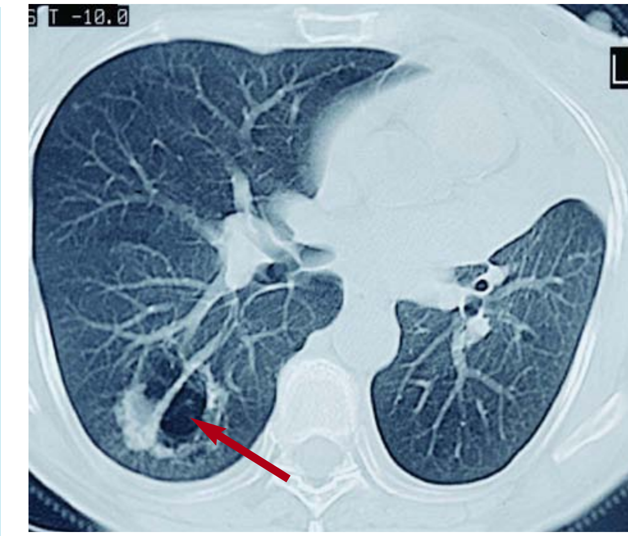
## Hiccups, Sneezes, and Stitches

Hiccups, sneezes, and stitches are all involuntary body phenomena.

Hiccups are short and very sudden gasps for breath. They occur when the diaphragm jerks or spasms involuntarily.

In a sneeze, air rushes down your nose at over 100 miles an hour (161 kph). Test this fact: You can't sneeze with your eyes open.

A side 'stitch', or sharp pain in your side when you run, is a cramp in the diaphragm. Running causes an up and down movement stressing the diaphragm and the ligaments holding all your organs in place. One way to relieve a side stitch is to stop running and place your hand on the right side of your belly. Then gently push up as you breathe in and out deeply.



*This photograph shows the inside of a lung. The black spot is cancer. One of the causes of lung cancer is smoking cigarettes.*

*Asthma is a disease that affects your airways—the tubes that carry air in and out of your lungs. People with asthma often use inhalers to help with their symptoms.*

WORDS to Know

**by-product** (BYE-prod-uhkt): something left over when another thing is produced

**cavity** (KAV-uh-tee): a hole or hollow space in something solid

**compress** (kuhm-PRESS): to press or squeeze something until it is smaller

**cramp** (kramp): pain caused by a muscle tightening suddenly

**phenomenon** (fe-NOM-uh-nom): an event or a fact that can be seen or felt

**vacuum** (VAK-yuhm): a sealed place from which air has been emptied

# Digestion

Digestion is the process that turns the food you eat into very small components that your cells can use. Your cells can handle sugars, amino acids, and fatty acids, but not spaghetti and tacos.

## In the Mouth

First, your teeth tear and grind the food into smaller pieces. The saliva in your mouth makes food softer and easier to swallow. It also contains an enzyme that starts the breakdown process. The enzyme converts starches in the food to sugars. Your tongue and other muscles in your mouth push food into your throat. When you swallow, the food travels down your esophagus and into your stomach.

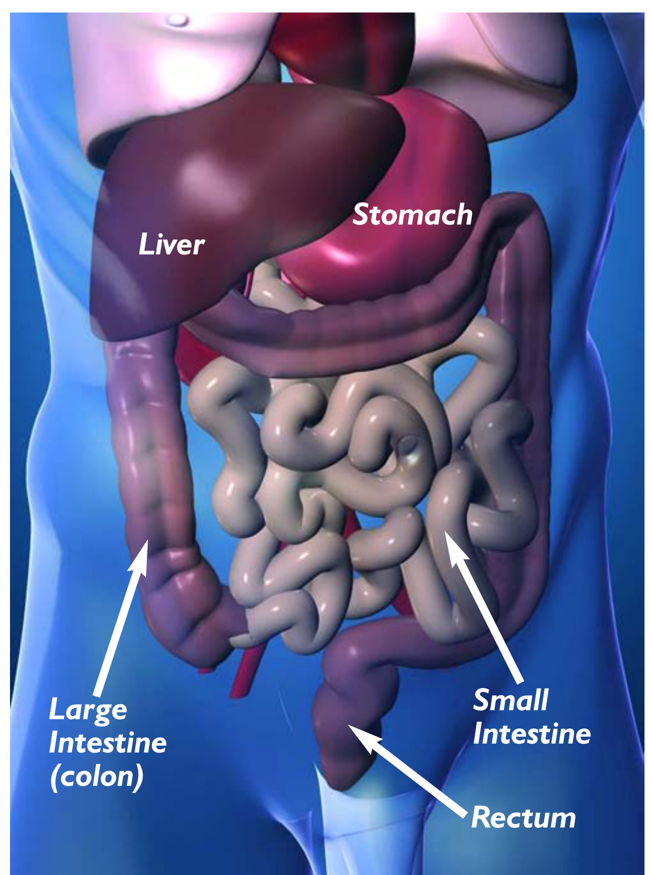
*It's important to chew your food well before swallowing.*

## In the Stomach

The digestive process continues in your stomach. There, food mixes with chemicals the stomach produces called enzymes and acids. Sometimes, as the food digests, gases release and you burp.

## In the Small Intestines

Next, the food mass, now called chyme, moves into your small intestine. Here, some more enzymes, produced in your pancreas, help break down the food further. The pancreas also adds insulin, a hormone that prepares the body for digesting sugar. Your liver, an organ that aids in digestion and eliminating cellular wastes, adds bile. Bile is a liquid that breaks down fat.






The chyme travels through the small intestine. The muscles along the small intestine squeeze and relax. This motion, called peristalsis, pushes the chyme along. Proteins, carbohydrates, and fatty acids from the food are taken in, or absorbed, through the capillaries in the intestinal wall.

## In the Large Intestines

The large intestine absorbs most of the water in the chyme. Some of the water goes to the kidneys, where it becomes urine. The feces that remain leave the body through the rectum.


*USDA food pyramid.*

Find out more

**NUTRITION**

Good nutrition is eating a balanced diet. One that provides all the nutrients you need: fruits, vegetables, grains, and meat/fish/eggs and milk products. Humans need proteins, fats, carbohydrates, vitamins, and minerals.

**Proteins** build and repair your body. Protein foods are meat, fish, poultry, dairy products, beans, and many vegetables.

**Fats and carbohydrates** convert to energy. Fat sources are meat, eggs, fish, dairy, and vegetable oils. Some carbohydrate sources are vegetables, fruit, grains (rice, pasta, bread, cereal), beans, sugar, and honey.

**Vitamins and minerals** help your body use food, fight infections, and repair itself. Vitamin C sources are fruit, particularly oranges and lemons. Vitamin C helps you fight infection. Vitamin A and D are in milk, eggs, and vegetables. Additionally, your skin produces Vitamin D when exposed to sunlight. A and D vitamins keep your eyes, bones, and teeth healthy and strong. Minerals are in all foods. Green vegetables such as spinach and broccoli contain iron. Meat is a source of iron too.

WORDS TO KNOW

**amino acids** (uh-MEEN-o ASS-IDS): chemical compounds with which the body builds protein

**component** (kuhm-POH-nuhnt): a part of a system

**deficient** (di-FISH-uhnt): lacking something necessary

# Genetics

Humans, like all living things, reproduce. When they do, they pass along a 'code' to their offspring. The code is like a set of instructions or directions. It tells the cells of the offspring how to develop and grow. Genetics is the study of the passing of traits from parent to offspring. Here's how that works.

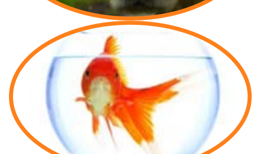
## Chromosomes

All the cells in your body, except red blood cells, have a nucleus. It acts like the cell's headquarters. It contains stick-shaped bits called chromosomes. Every species of plants and animals has a specific number of chromosomes. The chromosomes are arranged in pairs.

Genes are the pieces making up chromosomes. Different combinations of a chemical compound called DNA, **d**eoxyribo**n**ucleic **a**cid, makes up genes. DNA is the set of chemical instructions for cells, telling them what to do.

Humans have 46 chromosomes arranged in 23 pairs. When egg and sperm cells form they contain

**Sample of Species and Chromosomes**

| Species | | Number of chromosomes |
|---|---|---|
| fruit fly |  | 8 |
| snail |  | 24 |
| cat |  | 38 |
| mouse |  | 40 |
| human |  | 46 |
| horse |  | 64 |
| dog |  | 78 |
| goldfish |  | 104 |
| one kind of fern |  | 630 |



only one of each pair. When the egg and sperm come together to form a new individual, the matching pairs reform.

Each pair contains many genes. Genes control different traits such as your hair type, eye color, height, skin color, the size of your ears, the way your pancreas works, even your life span. Traits come from each biological parent. This means they are inherited.

*Because of genes, people often look like their parents.*

## Genes

Thousands of gene pairs determine your physical and mental traits. Some genes dominate over others, controlling the trait.

### Dominant and Recessive Genes

Eye color is a trait controlled by dominant genes. The gene for brown eyes (*Br* in this text) is dominant over the gene for blue. The gene for blue eyes (*bl* in this text) is recessive. Some combinations of pairs could be *Br Br*, *Br bl*, or *bl bl*. You will have brown eyes if you inherit a brown eye gene from either biological parent. That means your eye color gene pair is *Br Br* or *Br bl*.

To get blue eyes you need to get the blue eye gene, *bl*, from both biological parents. You need to have two blue eye genes, *bl bl*, to have blue eyes.

***To get blue eyes you need to get the blue eye gene from BOTH parents.***

***Because the brown eye gene is dominant, you only need to get the brown eye gene from ONE parent to get brown eyes.***

## Boy or Girl

One set of chromosomes, called X and Y chromosomes, tells your cells to develop into a boy or girl. All females have two X chromosomes (XX) and all males have one X and one Y (XY). When eggs and sperm form, the chromosome pairs split. Eggs and sperm thus have just one half of each pair of chromosomes.

***All males have one X and one Y (XY) and all females have two X chromosomes (XX).***

### Words to Know

**combine** (kuhm-BINE): to join or mix two things together

**chromosome** (KROH-muh-sohm): cell part that carries the genes that determine traits

**headquarters** (HED-kwor-turz): the place from which an organization is run

**nucleus** (NOO-klee-uhss): the central part of a cell, containing the chromosomes

**recessive** (ree-SESS-iv): tending to recede, to stay in the background

So an egg, coming from a female, can only have an X chromosome. Sperm, coming from a male, can have either an X chromosome or a Y chromosome. When they combine to form a new individual, they can combine as XX, a girl, or XY, a boy.

### Find out more

**DNA**

Deoxyribonucleic acid, or DNA for short, provides the instructions for growth and activity for each cell of our body. All living animals and plant cells contain DNA.

Human DNA is different from the DNA of plants and other animals. People look different from each other because every person has different DNA (except for identical twins, who have the same DNA). Because everyone's DNA is different, the police can use DNA as a way to identify criminals and victims.

## Genetic Engineering

Scientists, who study genetic traits and diseases, focus on DNA's role. They have learned how to change the DNA in a plant or animal cell to change its inherited traits. For example, they have changed the DNA in rice so that it is resistant to certain fungi or molds. This is called genetic engineering.

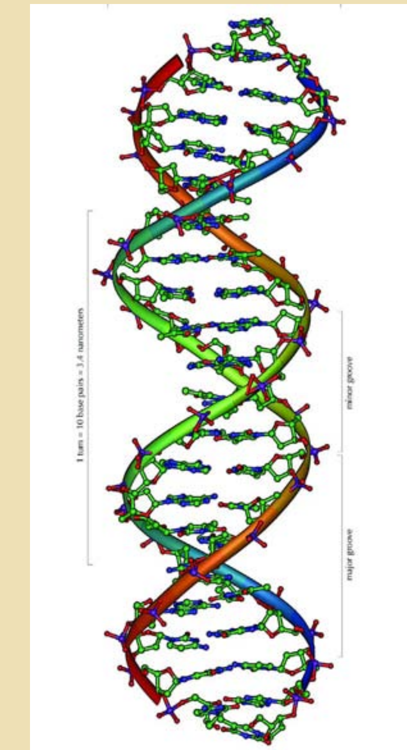


### Getting to know...

**James Watson**

**Francis Crick**

Two scientists, James Watson and Francis Crick, figured out the chemical structure of the DNA molecule in1953. They found that a DNA molecule looks like a twisted ladder (a double helix). Watson and Crick won the 1962 Nobel Prize, one of the highest awards in science, for their discovery.



***The structure of DNA***

# The Life Cycle

The stages of human life are often described as a life cycle. For each individual, however, life is a straight line. Like a story, it has a beginning, middle, and an end. The earliest stage of life is a single cell. The cell divides and, with instructions from genes, forms different tissues. These tissues develop into babies. Babies grow up and become children. Children grow up and become adolescents. Adolescents become adults, and some adults become parents. If they have no fatal accidents or illnesses, people grow old and some become grandparents. Then they die.

## Life Spans

Humans, like all living things, have a life span. A life span is the maximum length of time that individuals of a species could live. The life span of a human is about 120 years.

*This photograph of three generations of a family shows the grandparents with their children and their children's children.*

**A Sample of Animal Life Spans**

| Animal | Years | Animal | Years |
|---|---|---|---|
| Opossum | 4 | Wolf | 18 |
| Muskrat | 6 | Grey Squirrel | 20 |
| Toucan | 6 | Ox | 20 |
| Guinea Pig | 8 | Porcupine | 20 |
| Koala | 8 | Tiger | 22 |
| Kangaroo | 9 | Rattlesnake | 22 |
| Rabbit | 9 | Lion | 35 |
| Prairie Dog | 10 | Horse | 40 |
| Painted Turtle | 11 | Rhinoceros | 40 |
| Sheep | 15 | Hippopotamus | 45 |
| Woodchuck | 15 | Snapping Turtle | 57 |
| Hog | 18 | | |

# Pregnancy and Birth

The start of a life story begins with a pregnancy. Pregnancy refers to the nine months when a single cell develops into a baby inside a mother's body. The pregnancy ends when a baby is born. The nine months of pregnancy are divided into three stages called trimesters. Some mothers feel sick during the first trimester. This is called morning sickness, but it can happen any time of the day.

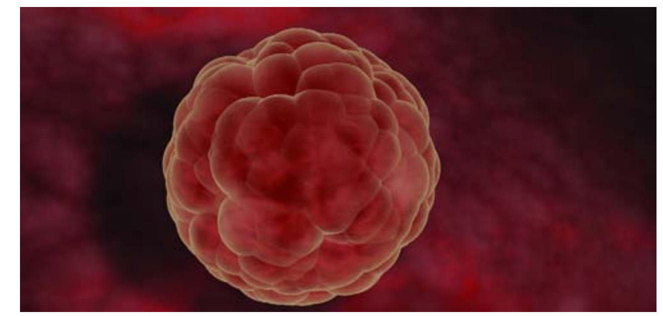
## The First Trimester

Pregnancy begins at the moment of conception. An egg from the mother's ovary is released into the fallopian tube each month. Conception takes place if the egg is joined by a sperm cell. This is called fertilization. The fertilized egg, or zygote, divides. It grows into a clump of cells no bigger than the head of a pin, called a blastocyst.


*This magnified picture shows a sperm fertilizing an egg.*



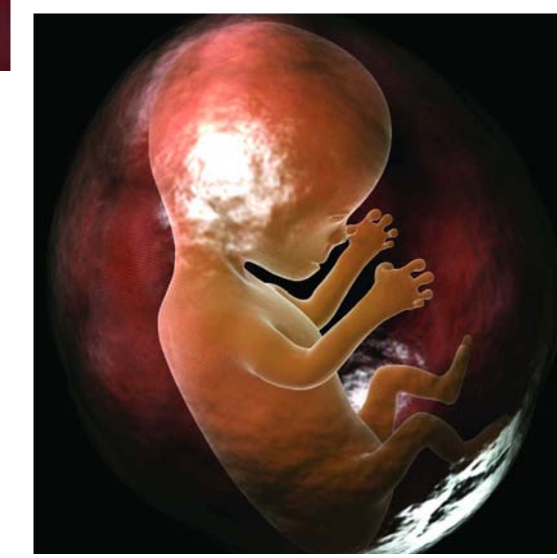
**Embryo.** The blastocyst travels from the fallopian tube into the uterus. It attaches to the tissue inside the uterus. The cells in the blastocyst keep dividing. They form the embryo and placenta.



*A magnified blastocyst*

**Embryo and Placenta.** The embryo is the developing child. The placenta is a membranous vascular organ lining the uterine wall and partially surrounding the fetus. It is attached to the embryo by the umbilical cord. The umbilical cord brings blood, carrying nutrients and oxygen, from the mother to the embryo.

**An amniotic sac** forms around the embryo. The amniotic sac contains fluid in which the developing embryo floats. This fluid protects the embryo. Different parts of the embryo grow and develop into the different organs and parts that make up a human being. The embryo has formed all of its organs by the end of the eighth week of pregnancy.



*The amniotic sac protects the baby throughout the entire pregnancy.*

**Getting to know...**

### Dr. Apgar

Virginia Apgar was born in New Jersey in 1909. She earned a medical degree in 1933 from Columbia University in New York City. Apgar became an anesthesiologist. An anesthesiologist is a doctor who gives drugs to patients during surgery to prevent pain. Apgar helped during thousands of births. She saw that most of the attention was on the mother. Sometimes, the newborn baby had problems that no one noticed.

In 1952, she created a way to judge whether a baby is healthy. It is called the Apgar Score. A baby is evaluated for color, pulse, reflexes, activity, and breathing. Babies with low scores need help.

## The Second Trimester

The second trimester begins with the fourth month of the pregnancy. The developing baby is now called a fetus.

*This ultrasound of a 21 week old fetus shows the fetus is sucking its thumb.*

**The Fetus** continues to grow and develops fingers, toes, and nails. The uterus gets bigger, or expands, as the fetus grows. The mother's uterus expands to accommodate that growth. In this trimester doctors can test to determine if the fetus is a boy or a girl.

## The Third Trimester

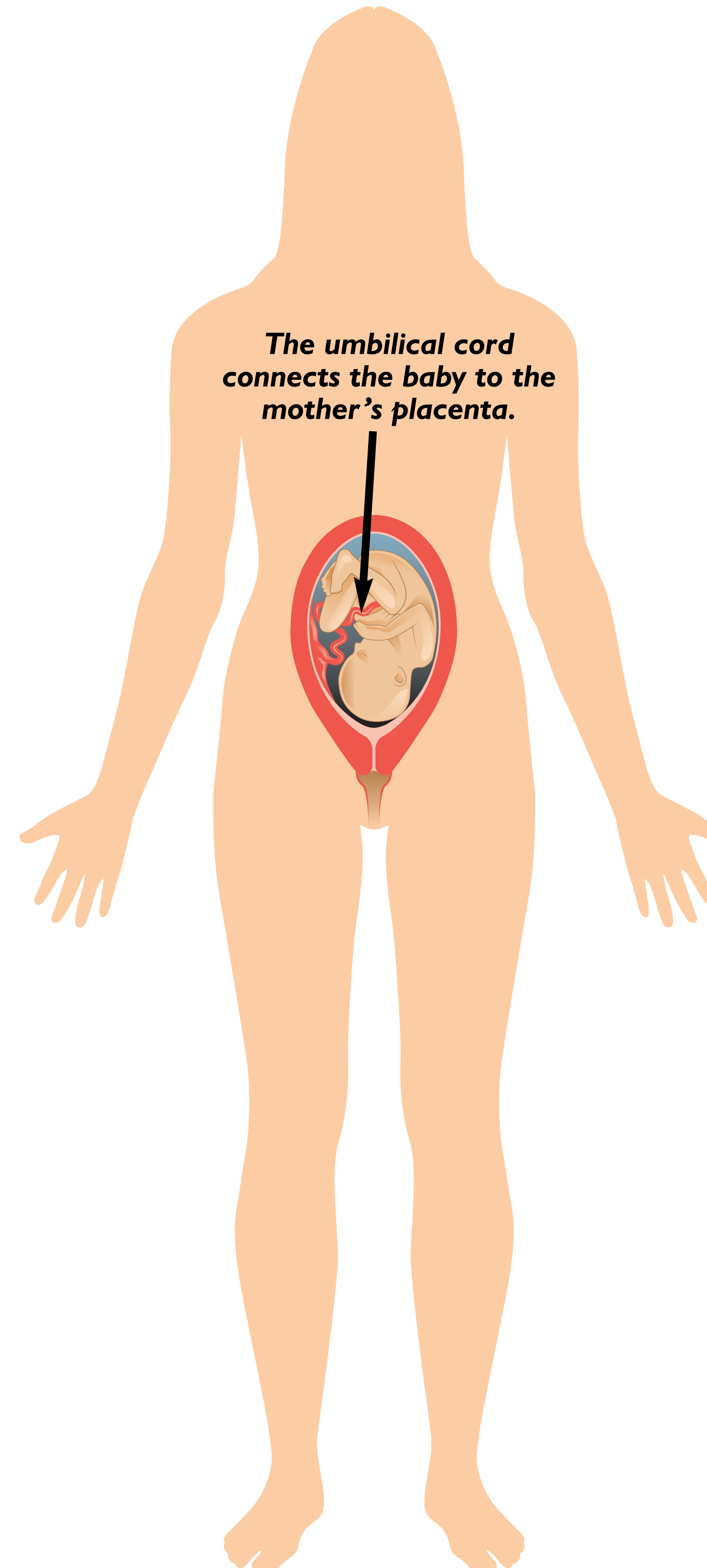
The third trimester begins with the seventh month of the pregnancy. The fetus gains weight and moves often. The mother can sometimes feel it kick inside her. The third trimester ends with labor and birth.

> Find out more
>
> **HUMANS HAVE TAILS**
>
> A human embryo in the fourth week of pregnancy has small bumps for arms and legs and a tail. It is hard to tell a human embryo from a reptile embryo at this point! The tail disappears by the eighth week.

**Labor and Birth.** Giving birth is known as labor. It begins when the muscles of the uterus start to push the fetus out of the body. These movements are called contractions. Contractions cause the cervix, a muscle at the bottom of the uterus, to open wider, or dilate. The baby is born when the cervix is fully dilated.

Sometimes, problems arise during labor. The baby may be too big to fit through the cervix or turned sideways. A doctor can perform a cesarean section to remove the baby. A cut is made in the skin below the mother's belly button and through the uterus.






*Births are easier when the baby is coming head first. When a baby is coming feet first, it is called a breach birth.*

The baby is pulled out through the opening. A cesarean section may be planned if the doctor thinks that the mother or baby will be in danger.

The umbilical cord is cut after the baby is born. You can see where your umbilical cord was connected. Just look at your belly button.

*Your belly button is where you were connected to the umbilical cord.*

### WORDS to KNOW

**accommodate** (uh-KOM-uh-date): to provide room for

**fatal** (FAY-tuhl): causing death

**reflex** (REE-fleks): an automatic action without a person's control

**vascular** (VASS-kyoo-lur): having a network of blood vessels

## Growth

You continue to grow from infancy to adulthood. Growth happens much faster when you are young. No wonder you want to sleep all the time. Your bones keep growing until you reach adulthood. Girls usually stop growing around eighteen and boys, around twenty-one.

Different parts of the body grow at different rates. Your arms and legs grow faster than the head and the rest of your body.

*Babies sleep a lot and grow quickly.*

**WORDS TO KNOW**

**batch** (bach): a group of things that arrive together or are made together

**incisor** (in–SIZH-ur): a front cutting tooth

**molar** (MOH-lur): a broad, flat grinding tooth at the back of the mouth

### Childhood

Your bones are soft at birth. As you learn to roll over, sit up, and crawl, your bones grow harder and your muscles get stronger. Most babies stand and walk by about fourteen months of age.

Your brain grows and changes as you learn new things. When you learn, the number of synapses between nerve cells, called neurons, increases.

### Teeth

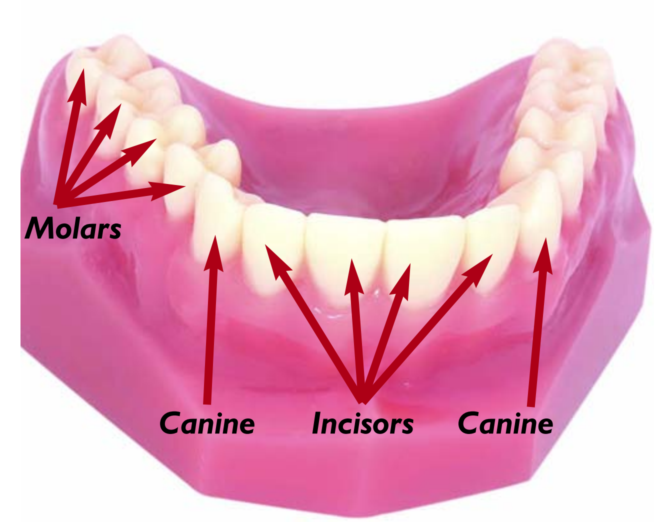
Your teeth grow in then fall out and grow in again. Humans have two sets of teeth. Your baby teeth start to come in when you are about 6 months old. They fall out as early as three years of age. Your



second batch of teeth are your permanent teeth.

Most people have 32 permanent teeth. Your front teeth are called incisors. The pointed teeth on either side of the incisors are called canines because they resemble a dog's fangs. The flat teeth in the back of the mouth are the molars.

The last teeth to come in are the four back molars, called wisdom teeth. Very often they do not come




in at all. Because they may decay under your gums later in life, dentists often remove them when you are in your teens.

## Adolescence and Puberty

Children enter a stage of life called adolescence generally between the ages of 9 and 12. It is the time when the bodies of children begin to grow into their adult sizes. Adolescence begins with puberty and ends with adulthood.

### Puberty

Puberty is when the bodies of males and females change and it becomes possible for them to reproduce. Puberty lasts from two to four years. Hormones control the changes that happen during puberty. Puberty is different for boys and girls.

**In boys,** the hormone testosterone is released into the blood. Testosterone makes the larynx grow and the voice get lower, and hair grows all over the body.

Boys grow tall quickly in a growth spurt. Boys usually have a growth spurt between the ages of 11 and 15. Testosterone and other hormones also make the testes and penis grow larger and be able to release sperm.

**Girls** go through puberty anywhere between the ages of 9 and 17. Hormones cause girls to have a growth spurt usually between ages 9 and 12. The hormone estrogen is released into the blood by the ovaries. Estrogen makes the breasts and other parts of the reproductive system grow.

Menarche is the first time that a girl's body releases an egg from the ovary. Blood and tissue from the uterus leave the body if the egg is unfertilized. This is menstruation. It is also called a period because it happens about once a month.

Adolescence ends when males and females look like adults and physical growth stops.

*Hormones can sometimes cause acne, a disease that affects the skin.*

WORDS to KNOW

**larynx** (LA-ringks): the upper part of the trachea (windpipe) containing your vocal cords

**hormone** (HOR-mohn): a chemical substance produced in body glands that controls growth and development

# Aging

Humans continue to change after adolescence. At maturity they are usually healthy and able to reproduce. Their physical growth has stopped but they continue to change.

## Skin and Hair

As adults age, their skin becomes less elastic, or flexible. When the fat below the skin shrinks and the skin above it grows less elastic, they get wrinkles. Skin also becomes drier.

*As we get older our skin sags and wrinkles.*

As people age their hair may get thinner, lose its color, or pigment, and turn gray. Some people lose their hair and become bald.



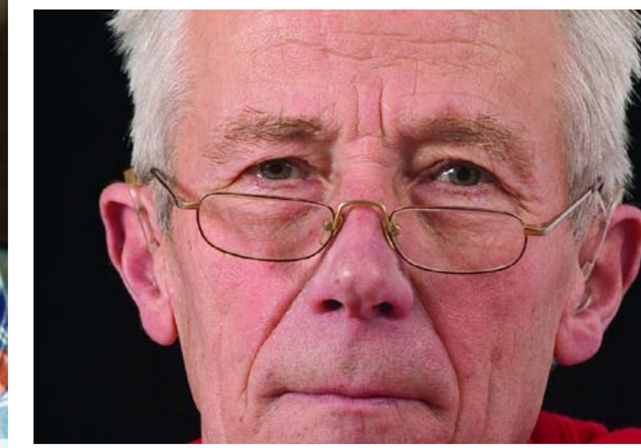
*Some people lose hair as they age.*

## Bones

By the age of 65, some people have begun to get shorter. One of two things can cause this. If their back muscles become weak through lack of exercise and do not support their spine, the vertebrae can squeeze, or compress, the discs between them. Additionally, bones may lose calcium, become brittle, and deteriorate or break. We call this osteoporosis.

## The Senses

The shape of the eyes and lens change during middle adulthood. People often need glasses or contact lenses to read. Older adults may also have trouble seeing in the dark. As people age, they are less able to hear high-pitched noises. They may need hearing aids. The sense of taste and smell lessens as well.



*Some older people need glasses.*

*Some older people need hearing aids.*

## Reproduction

As humans age, they lose their ability to reproduce. Women usually stop ovulating and menstruating between the ages of 45 and 50. The amount of the hormone estrogen also decreases. This is menopause. After menopause, women cannot become pregnant without medical help.

# How Life Ends

Death is the natural end of life. People die when their heart stops pumping blood and when their brain stops sending electrical signals. Humans can die at any point during their lives. They may die from many different causes. Some people die because of an accident. A fatal accident injures organs in the body that cause the heart or brain to stop working. Most people die from an illness or disease. A terminal illness is one with no cure and causes death.

## Life Expectancy

Most people who live past childhood will live until about the age of 78. We call this their average life expectancy. Many people live to be much older but very few achieve the potential human life span of 115-120 years.

*Many older people live in nursing homes when they cannot take care of themselves.*

As medical science has developed, human life expectancy has increased. Vaccination against childhood diseases, refrigeration of foods, and the use of medical procedures and drugs to combat illnesses all work to prevent premature deaths and allow people to live to their potential life span.

**Find out more**

**CENTENARIANS**

Centenarians, men and women who are 100 years old or older, are a fast growing segment of the world's population.

**The stages of life**

*A sperm fertilizes an egg.*

*A baby grows inside its mother.*

*A baby is just at the beginning of his life span.*

*The baby grows into a child.*

*The child grows into an adult.*

*Many middle age adults have children and grandchildren.*

*Some adults live well past middle age, until they are elderly.*



**Average human life span per Country**

| Country | Male (years) | Female (years) | Male and Female Combined (years) |
|---|---|---|---|
| Zambia | 37.08 | 37.41 | 37.24 |
| Botswana | 38.63 | 39.93 | 38.31 |
| Haiti | 47.46 | 51.06 | 49.21 |
| Pakistan | 60.27 | 61.91 | 61.07 |
| Egypt | 61.29 | 65.47 | 63.33 |
| Russia | 61.95 | 72.69 | 67.19 |
| China | 69.60 | 73.33 | 71.38 |
| Mexico | 68.47 | 74.66 | 71.49 |
| United States | 74.24 | 79.90 | 77.12 |
| Israel | 76.57 | 80.67 | 78.57 |
| Italy | 75.85 | 82.41 | 79.03 |
| Canada | 76.02 | 83.00 | 79.43 |
| Australia | 76.90 | 82.74 | 79.75 |
| Japan | 77.51 | 84.05 | 80.70 |

**WORDS to know**

**combat** (kom-BAT): to fight against something

**fatal** (FAY-tuhl): causing death

**hearing aid** (hihr-ing ayd): a device to help a person hear

**segment** (seg-MUHNT): a part or section of something

**terminal** (TUR-muh-nuhl): ending

# Health and Illness

People are healthy when all of their body parts work well. Most of the time, we can stay healthy by eating good food, using our muscles in exercise, getting plenty of sleep, and resting if we start to feel sick. But sometimes, we can suffer injuries or become sick even when we take care of ourselves.

*You can get injured falling off your bicycle.*

## Injuries

Every day, you have a chance of getting hurt. You can suffer an injury or a wound. You may fall down and sprain an ankle or even break a bone. You may hit your head on the ground. You may cut yourself with a pair of scissors or with a piece of paper. These injuries cause pain but are usually not life threatening.

### Bruises

If you fall or hit something, you will probably develop a bruise. You can see a bruise because blood vessels break under the skin and the area turns red, purple, yellow, and even green.

The brain can bruise, too. If you fall and hit your head or get hit with a hard object, you might bruise your brain. Bruising to the brain is a concussion. A concussion is dangerous because there is usually internal bleeding. You may become dizzy or feel sleepy. Most concussions heal with plenty of rest.

*The blue and purple area on this foot shows bruising.*



### Broken Bones and Sprains

Injuries happen to bones also. They can crack or break so badly the two parts separate. A fracture is a small break in a bone. It may heal by itself with rest.


*This picture of an x-ray shows a broken radius bone in an arm.*

A sprain is an injury to a joint such as the ankle or wrist. A sprain happens when the ligaments or tendons twist fast and hard.

### Wounds

We call wounds to the skin abrasions, lacerations, and punctures. An abrasion is a scrape, a laceration is a cut, and a puncture is a hole.

*A fall on concrete may cause an abrasion on an elbow, as seen here.*

You should clean and cover all of them. If a skin wound is deep, you might need a tetanus shot.

*This girl is receiving a tetanus shot to protect her from getting lockjaw.*

## Healing

Healing starts as soon as a wound occurs. In a cutting wound, the first thing that happens is that the blood vessels near the cut become narrower, or constrict. This keeps you from losing too much blood. Then, the blood becomes thick and forms a clot. This clot hardens to make a scab.

*If a wound is deep and won't stop bleeding, adhesive strips or stitches are used.*

Sometimes, the new skin that forms is shiny and smooth. We call it scar tissue. A scar may fade over time or last for years.

A broken bone is more serious. A doctor must put the two pieces together and put a hard cast around the injured part. This keeps the bones from moving while they are healing. Bone cells form a clump, or callus, between the ends of the broken bone. The callous grows and develops into cartilage. Finally, the cartilage turns into bone.

*A cast and crutches help your bones heal.*

### WORDS to KNOW

**clot** (klot): a solidified clump of blood cells and plasma

**internal** (in-TUR-nuhl): inside the body

**suffer** (SUHF-ur): to experience pain, discomfort, or sorrow

**tetanus** (TET-nuhss): a sometimes fatal bacterial disease that causes your muscles to become rigid.

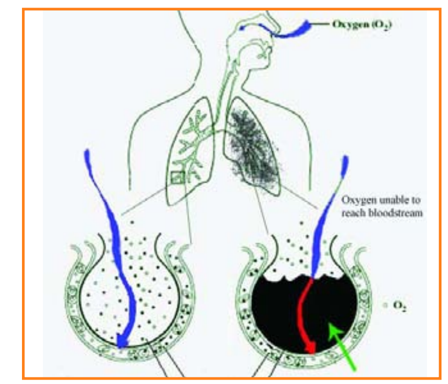
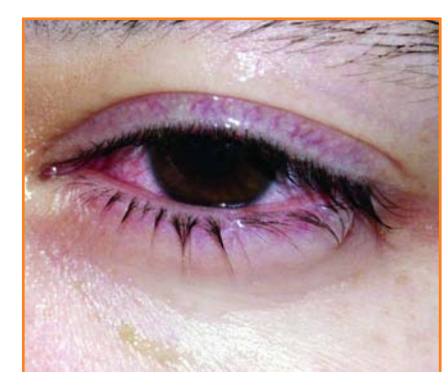


## Infections

Our environment is full of small organisms that can live in our bodies. They may be microscopic bacteria or viruses, parasitic worms, or fungi and molds. Some can make us sick. They can cause an infection.

**Bacterial infections.** Antibiotics can treat most bacterial infections. Some of the infectious diseases bacteria causes are tetanus, pneumonia, whooping cough, tuberculosis, and food poisoning.

**Some common bacterial infections cause the following symptoms:**

| | | |
|---|---|---|
| Pneumonia: |   | lungs filling with fluid, coughing, weakness |
| Strep throat: |  | sore and red throat with white spots, difficulty swallowing, fever |
| Pink eye: |  | red rimmed eyes, excessive mucus, itching |

**Viral Infections.** The symptoms caused by a virus can go away, but the virus never leaves the body completely.

| Some common **viral** infections cause the following symptoms: | | |
|---|---|---|
| Common cold: |  | stuffy head, sneezing, sore throat, runny nose |
| Flu: |  | muscle aches, fever |
| Stomach flu: |  | stomach pain, vomiting, diarrhea |
| Chicken pox and measles: |  | spots or skin rash |
| Viral pneumonia: |  | fever, headache, muscle aches, sweating, sore throat, weakness |



**Other Infections.** Parasites, fungus, and mold infections include such things as ringworm and athletes foot. Drugs can treat these infections.

## Contagious Infections

A disease or illness is contagious if the germs that cause it can be passed between people. Some illnesses pass very easily from person to person.

The viruses that cause colds or the flu are in saliva in the mouth and in mucus in the nose. You can “catch” a cold or the flu if you touch a sick person or things that the person has touched.

Viruses can also live in the air. They come out when the sick person coughs or sneezes. If you are sick, it is important to use tissues and to cover your mouth when you cough and sneeze. Washing your hands is an important defense against all germs.

*Washing hands fights germs.*

Getting to know...

### Louis Pasteur

Louis Pasteur was born in France in 1822. He studied chemistry and physics in Paris and became a professor. Pasteur became interested in why foods spoiled and how diseases spread. He found that small organisms called yeast turn sugar into alcohol. We call this fermentation. He also studied how organisms turn milk sour. Pasteur showed that heating things kills the organisms. The process has his name – pasteurization.

Before Pasteur’s time, people thought that bad smells spread illnesses. Pasteur showed that germs cause disease. He also developed vaccines to give people immunity. He used a rabies vaccine to save a boy bitten by an infected dog.

Some viral diseases, such as AIDS (acquired immune deficiency syndrome), are not easily passed between people. AIDS is a dangerous disease that makes it hard for the body to fight infections. A virus called HIV causes AIDS.

HIV passes between people only in blood and during sexual contact. A pregnant woman who is HIV positive may give the virus to her developing fetus.

You cannot get HIV or AIDS through touching or by breathing the air around a person who has the disease.

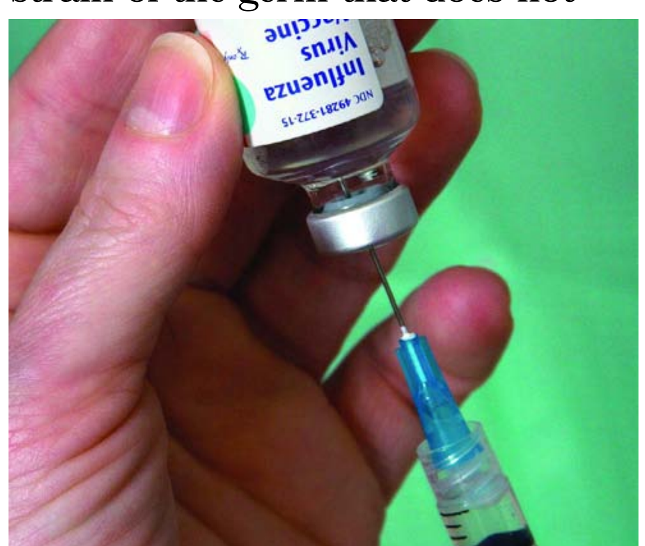
## Immunization

Your body is constantly threatened from the outside. Besides injury, you are open to attack from bacteria, viruses, and fungi. Your immune system is your main defense against these invaders, also know as pathogens or antigens.

### Active Immunity

One of the ways your immune system protects you is by making antibodies. Antibodies are special proteins created by your white blood cells to fight antigens. Some antibodies remain active long after the antigen has been defeated. The body is ready to fight if it meets the antigen ever again. You are immune or have a resistance to the disease caused by that antigen.

**Vaccination** can also deliberately create immunization in the body. Scientists develop vaccines for specific diseases. A vaccine is either a solution or a culture of a strain of the germ that does not cause disease. The vaccine is made by changing or killing the germ. It causes your body to produce the antibodies against the germ.



***A nurse is preparing to administer a flu vaccine to a patient.***

WORDS TO KNOW

**antibiotic** (an-ti-bye-OT-ik)**:** a drug that kills bacteria

**mucus** (MYOO-kuhss)**:** a slimy fluid that coats and protects your mouth, nose, throat, and breathing passages

**parasite** (PA-ruh-site)**:** an organism that gets its food by living inside another plant or animal

**rabies** (RAY-beez)**:** a viral disease that attacks the nervous system. Often fatal, it is transmitted by the bite of an infected bat, dog, raccoon, or such.



Immunity develops slowly but lasts a long time. The response of the immune system is faster and better every time the body meets an antigen. We call this active immunity.

There are vaccines for many diseases such as smallpox, chicken pox, polio, measles, mumps, tetanus, and rabies.

**The End of Smallpox.** The United States Center for Disease Control (CDC) reported that the world's last naturally acquired case of smallpox occurred about 30 years ago. The smallpox case occurred in the Merca District of Somalia on October 26, 1977. Less than 3 years later, in May 1980, the World Health Organization declared the world free of naturally occurring smallpox.

**Getting to know... Edward Jenner**

Edward Jenner, an English doctor, researched the disease smallpox in the late 1700s. He noticed that dairy workers did not get smallpox. He wondered if cowpox, a disease cows suffered, was like smallpox. He wondered if exposure to cowpox gave dairy workers immunity to smallpox. In 1796, Jenner used the germs that cause cowpox to vaccinate a boy against smallpox. It worked.

Jenner's method of vaccination was the start of the control and prevention of other diseases.

### Passive Immunity

Sometimes a person not vaccinated against a disease is exposed to it. Medical help is available. Doctors can inject the person with antibodies produced in other humans or in animals. The antibodies give immediate immunity to the disease for a short time. The antibodies will fight the germs if they try to infect the body. We call this passive immunity.

Since the body has not made its own antibodies, the protection does not last after the injected antibodies are gone.

WORDS TO KNOW

**culture** (KUHL-chur): a growing population of an organism in a lab dish

**expose** (ek-SPOZE): to come in contact with a disease organism

**hypothesize** (hye-POTH-uh-size): to make a temporary prediction or educated guess about the cause or outcome of an event

**passive** (PASS-iv): to let something happen without a fight or resistance

**strain** (strayn): a variety or kind

## Genetic Diseases

Some diseases pass from parent to child as part of the genetic material in chromosomes. Such illnesses are genetic diseases. A disease may develop if a certain dominant or recessive gene is inherited. A disease may also develop if an important gene is damaged or missing.

A person who inherits a dominant gene for a genetic disease will develop that disease. Luckily, recessive genes cause most genetic diseases. That means both parents have to have the gene in their chromosomes and their offspring have to inherit both genes to get the disease.

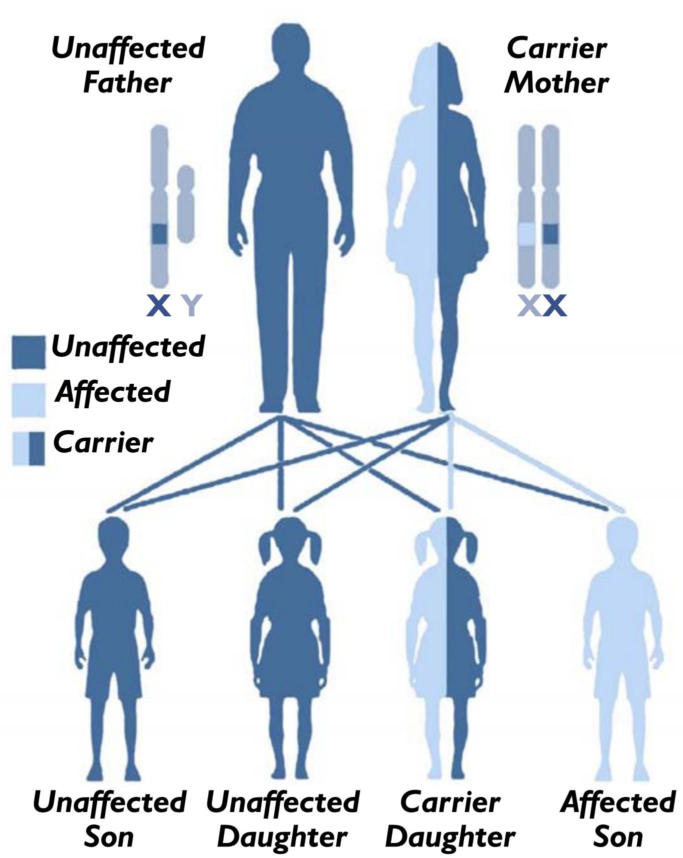
People who inherit one recessive gene for such a disease will not develop that disease. But since they have the gene, they are called carriers, meaning they could pass it along to their offspring.

### Examples of Genetic Diseases

Cystic fibrosis is a genetic disease. It affects the glands that make sweat and mucus. People with cystic fibrosis have thick mucus in their lungs that makes it hard to breathe. They are prone to lung infections.

Hemophilia is a blood-clotting disorder. It is a genetic disease linked to the sex chromosome. The recessive gene that causes hemophilia is on the X chromosome in some families. Girls have two X chromosomes and if they inherit an X chromosome with the recessive gene, their other normal X chromosome dominates and they do not get the disease. But boys only have one X chromosome. So, if they inherit the X chromosome with the hemophilia gene, they get the disease. We call hemophilia a sex-linked disease.

***X-LINKED RECESSIVE, CARRIER MOTHER***






**Affects of genetic diseases.** Some genetic diseases affect a child at birth or develop during childhood. Other genetic diseases do not develop for many years. Some are very serious. The people who develop them do not live long. Other diseases get worse slowly. Drugs or changes in eating habits can manage some of these diseases.

**Genetic Predisposition.** Some diseases are not inherited directly but seem to be common in certain families. Heart disease, diabetes, and some types of cancer may have a genetic link. A person who has several family members with a disease may have inherited a higher chance of developing the disease. Doctors say the person has a genetic predisposition for that disease.

Find out more

### CANCER

A tumor is a lump of tissue that grows in the body. Some tumors are harmless, or benign. Benign tumors do not interfere with body functions and do not spread to other parts of the body. Most do not cause pain. But some tumors are harmful. A tumor is malignant if it interferes with how the body works, if it destroys tissues, and if it spreads to other places. We call such a malignant tumor cancer.

Cancer can grow almost anywhere in the body, such as the brain, lungs, breasts, intestines, bones, liver, stomach, and skin. Cancer cells grow very fast and take nutrients from surrounding tissue. Doctors can remove a tumor if it has not spread too far.
They can also use drugs, or chemotherapy, and radiation to destroy it. It is difficult to cure cancer if the cells have spread to the blood or to the lymph nodes that contain white blood cells.

We are still learning why normal cells become cancer cells. Some people seem to inherit a higher chance of getting certain cancers. Some pollutants in our environment, such as asbestos, increase the risk. Other people do things that increase the risk. Smoking cigarettes can cause lung cancer. Eating a diet high in fat has been linked to colon cancer.

***Chemotherapy can make your hair fall out.***

*Many people are allergic to pollen.*

*Some people receive allergy shots to help with allergic reactions.*

### Words to Know

**clot** (klot): a solidified clump of blood cells and plasma

**colon** (KOH-luhn): the last half of the large intestine

**lymph node** (limf noad): small organs that hold the colorless liquid lymph that bathe your cells and tissues

**membrane** (MEM-brayn): a thin layer of tissue that covers or lines organs and cells

**radiation** (ray-dee-AY-shuhn): X-rays or other electromagnetic waves or particles

## Allergies

Other kinds of antigens challenge your health. They include environmental pollutants (particles and chemicals in the air, food, and water) as well as toxins from insect bites and plants. Your immune system again is your main defense against these foreign materials.

Most antigens are harmless to most people. But someone who is sensitive to dust, pollen, smoke, perfume, animal hair, mold, fungus spores, some metals, certain foods, poison ivy, or insect bites may become sick. The immune system produces an allergic reaction. Symptoms include sneezing, sniffles, coughing, swelling, skin rashes and itchiness, or breathing difficulty.

*One sneeze can send about 40,000 water and mucus droplets into the air.*



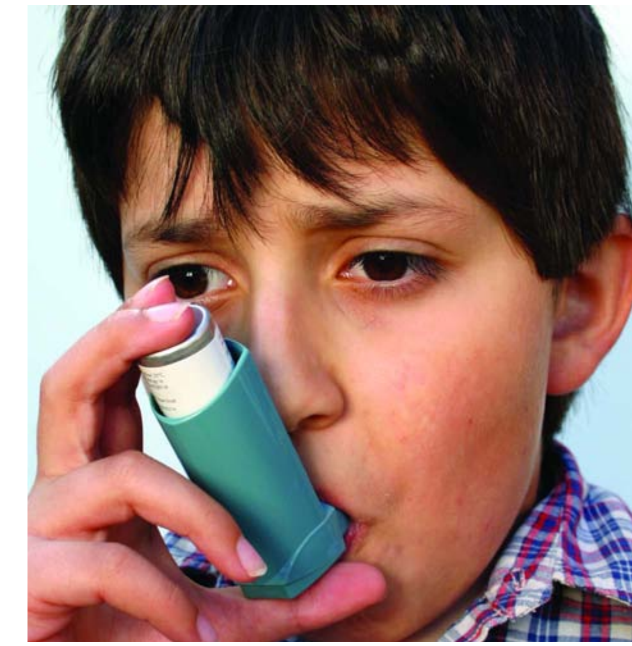
### Hay Fever

Many people are allergic to plant pollen. We call this allergy hay fever. Your nose runs and your eyes itch. Hay fever treatment often includes drugs called antihistamines. They stop the body from making a substance called histamine that causes the symptoms of allergies.

*Springtime flowers often trigger hay fever.*

### Asthma

Many children and adults have a disease called asthma, another allergic reaction. People with asthma have episodes of breathing difficulty. The bronchioles in their lungs get smaller during an allergic reaction. A device called an inhaler can help them breathe in medication and open the passages in the lungs.



*More than 100 million people worldwide have asthma.*

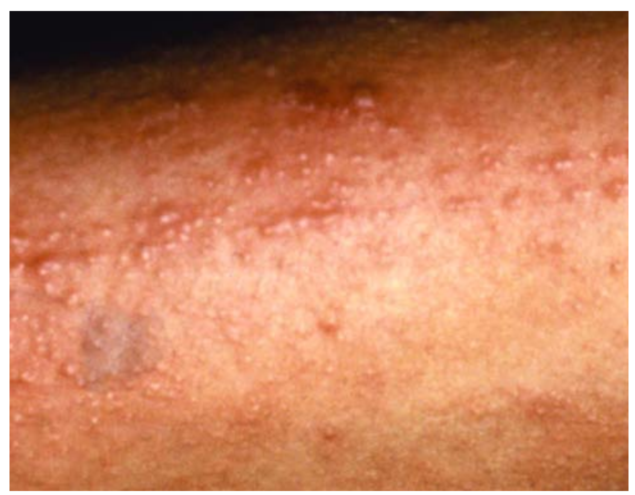
### Life-Threatening Allergies

Other antigens are more harmful and can cause serious and life-threatening allergic reactions. Plant and animal toxins such as venom from a snake or bee sting are particularly dangerous. If you are allergic to bee stings you may have to carry special medications to use if you are stung.

Some people have a very strong reaction to an antigen the first time they meet it. Other people may have stronger and stronger reactions every time they come in contact with the antigen.

*Venom from a snake or a bee sting can be life threatening.*

Poison ivy, poison oak leaves, and some seafood may not cause a reaction the first time you eat or touch them. But the next time you come in contact with them, you may become very sick or develop a severe itchy rash. Some people are so allergic to mussels that one meal, after several exposures, can kill them.



*A poison ivy rash may look like this.*

**WORDS TO KNOW**

**challenge** (CHAL-uhnj): invite to fight

**episode** (EP-uh-sode): an event

**pollen** (POL-uhn): tiny yellow grains produced in blossoms, the male cells of a flowering plant

**toxin** (TOK-sin): a poisonous chemical

**venom** (VEN-uhm): a poison produced by some snakes and insects

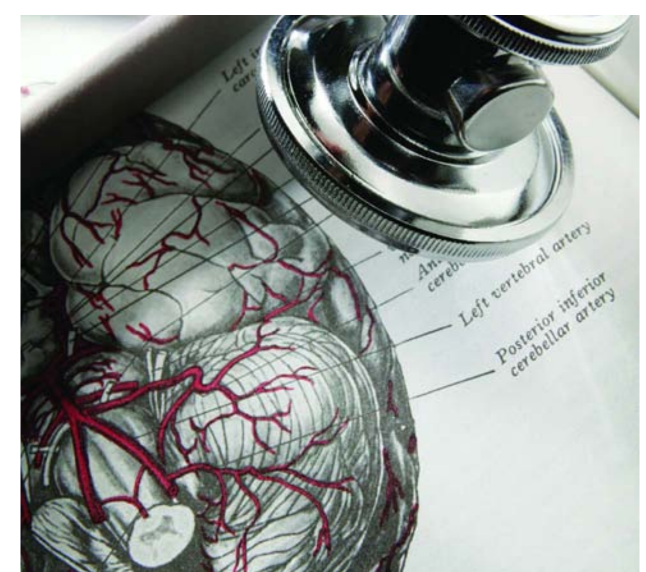
*About 1 percent of the population is allergic to peanuts.*



# People Who Study the Human Body

People are curious. They wonder, they observe, they study, and they learn. One of their favorite subjects is living things. Biology is the study of living things. And one of the favorite subjects of biologists is the human body.

*People can learn about the human body using microscopes.*




*People can learn about the human body from medical textbooks.*

Scientists examine dead bodies to see what is inside. Studying the body's structure is called anatomy. Studying and learning how the body works is called physiology.

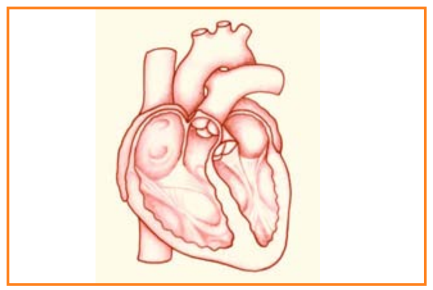
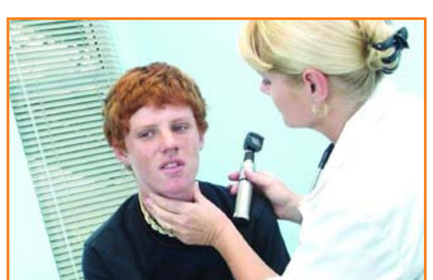
Learning to treat illnesses and injuries is called medicine. A medical doctor, or physician, tries to find out what is wrong with the body. Diagnosing injury and illness is the first step. A doctor then treats injuries and illnesses using drugs, surgery, or other therapies.

*Some illnesses have to be treated with surgery.*

## Specialists

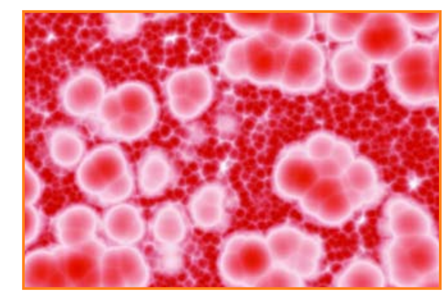
Scientists have learned so much about human physiology. Doctors often choose to concentrate, or specialize, on just one system, organ, or disease.

## MEDICAL SPECIALISTS

| Specialist | | System, Organ, or Disease |
|---|---|---|
| Allergist |  | Allergies |
| Cardiologist |  | Heart |
| Dentist |  | Teeth and gums |
| Dermatologist |  | Skin |
| Endocrinologist |  | Organs that produce enzymes and hormones |



## MEDICAL SPECIALISTS

| Specialist | | System, Organ, or Disease |
|---|---|---|
| Gastroenterologist |  | Digestive system |
| Gynecologist |  | Female reproductive organs |
| Hematologist |  | Blood |
| Neurologist |  | Nervous system, brain |
| Oncologist |  | Cancer |

## MEDICAL SPECIALISTS

| Specialist | | System, Organ, or Disease |
|---|---|---|
| Ophthalmologist |  | Eyes |
| Orthopedist |  | Bones and joints |
| Pediatrician |  | Babies and children |
| Podiatrist |  | Feet |
| Surgeon |  | Repair or removal of internal organs and bones |



### Daniel Hale Williams

Getting to know...

Daniel Hale Williams was an African-American born in Pennsylvania in 1856. He became a doctor and a surgeon. Williams introduced new techniques to prevent infection during surgery.

In 1893, he became the first person to perform a successful heart operation. He opened the chest of a patient stabbed in the heart. He proved that surgery on the heart could be performed without causing death from infection. Today, surgeons perform even more complex repairs of both wounded and diseased hearts.

All these kinds of scientists and doctors help us understand the complex organism that is the human body. Every day, we find out more about how the body works.

## Milestones in Medicine

Scientists and doctors studying human life have made many important discoveries. Bioengineers, chemists, and doctors have developed medical technology based on that growing body of scientific knowledge. They have developed such things as vaccines, X-rays and MRI scans, anesthesia, prosthetic bones and joints, antibiotics, and powerful drugs to fight infections, diabetes, and cancer.

Their discoveries and technological breakthroughs have led to disease prevention and better medical care. Our life expectancy is longer now than it ever was in the past. Modern life is significantly better medically speaking than in the 'good old days.'

*Prosthetic limbs let you play again.*

### WORDS to KNOW

**complex** (kom-PLEKS): very complicated

**diagnose** (dye-ugh-NOHSS): to determine what disease a patient has or what physical or mental problem

**examine** (eg-ZAM-uhn): to look carefully at

## Alexander Fleming

Getting to know...

Alexander Fleming was born in 1881 on a farm in Scotland. He attended medical school at St Mary's Hospital, in London, England. Alexander qualified for the school with distinction in 1906 and became an assistant bacteriologist. His interest was in vaccine therapy and immunology.

Fleming was the first to notice the antibiotic properties of molds and fungi. The story of how he discovered penicillin is legend:

By 1928, Fleming had developed a reputation as a brilliant researcher, but a quite careless lab technician. He often forgot cultures that he worked on and his lab was usually in chaos.

On one occasion, after returning from a long holiday, Fleming noticed that many of his culture dishes were contaminated with a fungus. He noticed a zone around an invading fungus (mold) where the bacteria could not seem to grow. He concluded that that fungus was keeping the bacteria from growing.

After many tests with the fungus and bacteria cultures, Fleming isolated an extract from the fungus (mold) and correctly identified it as being from the penicillin family. He named the extract penicillin. And the rest is history, as the saying goes.

In 1945 he was the co-winner of the Nobel Prize in Medicine "for the discovery of penicillin and its curative effect in various infectious diseases."

Find out more

### THE NOBEL PRIZE

The Nobel Prize is an award that honors men and women "... *who, during the preceding year, shall have conferred the greatest benefit on mankind.*"

The Nobel Prize started in 1895 when Alfred Nobel, a Swedish chemist, engineer, innovator, and inventor of dynamite, wrote his last will, leaving much of his wealth to set up the prizes.

Since 1901, the prize has honored men and women for outstanding achievements in physics, chemistry, medicine, literature, economics, and for work in peace.

Many of the scientists and doctors who contributed to the advancement of scientific and medical knowledge won the coveted Nobel Prize for their work.

Rourke's World of Science

# ENCYCLOPEDIA

Volume 2

# Animal Life

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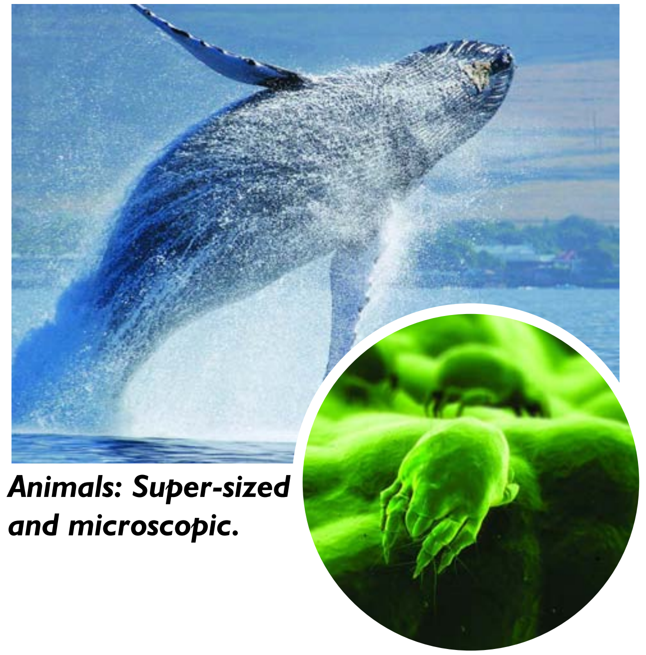
# What Is an Animal?

Animals are living creatures. They include very small creatures such as dust mites and very large creatures such as whales. Animals are multi-cellular organisms that eat food to survive. They cannot get energy from the sun like plants do. Most animals can move on their own.

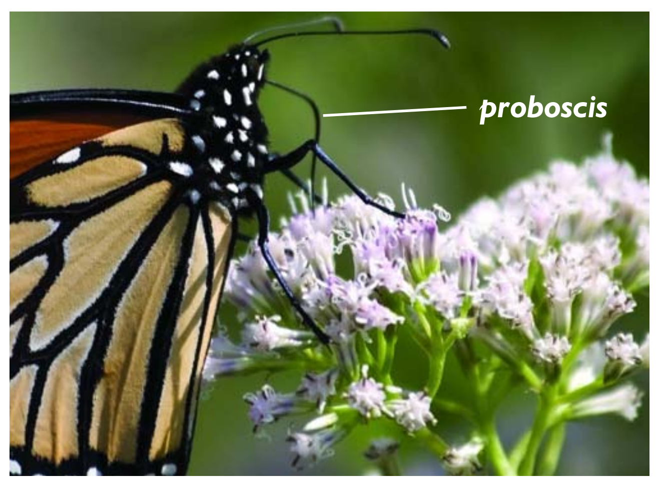


*Animals: Super-sized and microscopic.*

## How do animals eat?

An animal needs to eat in order to live. Animals eat different things and eat in different ways. A butterfly has a proboscis that looks like a tongue and works like a straw. The butterfly keeps its proboscis curled up until it is ready to eat. Then it unrolls its proboscis and dips it into the nectar of a flower and drinks it.

A chameleon shoots out its sticky tongue to catch insects. Squirrels have strong teeth and use them to crack open nuts. Then they carry the nuts in their cheeks back to their homes. An earthworm tunnels through the ground and feeds on bits of rotting plants.




*Squirrels can crack nuts with their strong teeth.*



## How do animals move?

Animals move in many different ways. Some animals use their legs to move. A clam uses one leg to dig into the mud or sand. A penguin waddles on two legs and swims with its wings. A coyote walks or runs on four legs. Ants walk on six legs while a spider crawls around using eight legs.

A snake is an animal with no legs. It must use the muscles and scales in its body to slither across the ground. Birds, bats, and insects use wings to fly in the air. Fish swim in the water. The crocodile can swim in the water, but it can also walk on land using its legs.

*A penguin waddles on two legs.*

*Ants walk on six legs.*

*A coyote walks or runs on four legs.*

*Spiders crawl on eight legs.*

## Where do animals live?

Animals live in every environment on earth from mountain tops to ocean floors. Animals survive in environments which support their habitat. An animal's habitat supplies all the things it needs to survive such as food, water, oxygen, shelter, and temperature.

Some animals live in many different environments that support their habitat. Bald eagles live all over North America in environments that have lakes, marshes, seacoasts, or rivers for catching fish and tall trees for nesting and roosting. Other animals live in one environment. Polar bears live only in arctic environments.

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WORDS TO KNOW

**cellular** (sel-yuh-lur): made of or to do with cells

**energy** (EN-ur-jee): the strength to do active things

**environment** (en-VYE-ruhn-muhnt): the natural world of the land, sea, and air



## How are animals classified?

Animals can be grouped in many different ways. One way scientist's group animals and plants is by scientific classification. Classification starts with the kingdom and then divides them into groups called phyla. The next division is the class. Classes are divided into orders and then families. Families are divided into genus. Finally, genus are divided to identify a specific species. An animal's two-part scientific name comes from the animal's genus and species.

| Class | | Animals in the Class |
|---|---|---|
| Insecta |  | Insects like ants, butterflies, dragonflies, katydids, and ladybugs. |
| Arachnida |  | Spiders and scorpions. |
| Malacostraca |  | Crabs, lobsters, shrimp, crayfish, and pill bugs. |
| Osteichthyes |  | Fish with bony skeletons like tuna, bass, salmon, and trout. |
| Aves |  | Birds like robins, ducks, penguins, and ostriches. |
| Mammalia |  | Mammals like cats, dogs, rodents, bears, whales, apes, and humans. |

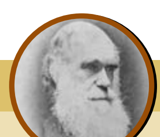
## Do animals change?

Animals evolve, or change, in nature. Scientists believe all plants and animals evolved from a common ancestor over billions of years. Scientists study the changes in different animals by looking at old bones called fossils.

*A fossil of a fish.*

Fossils from millions of years ago show animals very different from those that are around today.

Animal species may evolve between generations because of a mutation. Mutations are changes in DNA. They can be caused by radiation from the sun, chemicals in the environment, or cosmic rays from outer space. Some mutations help an animal adapt to its world. Adaptation is important to the survival of a species. Animals that can adjust to changes have a better chance of surviving and producing offspring. This is called natural selection.



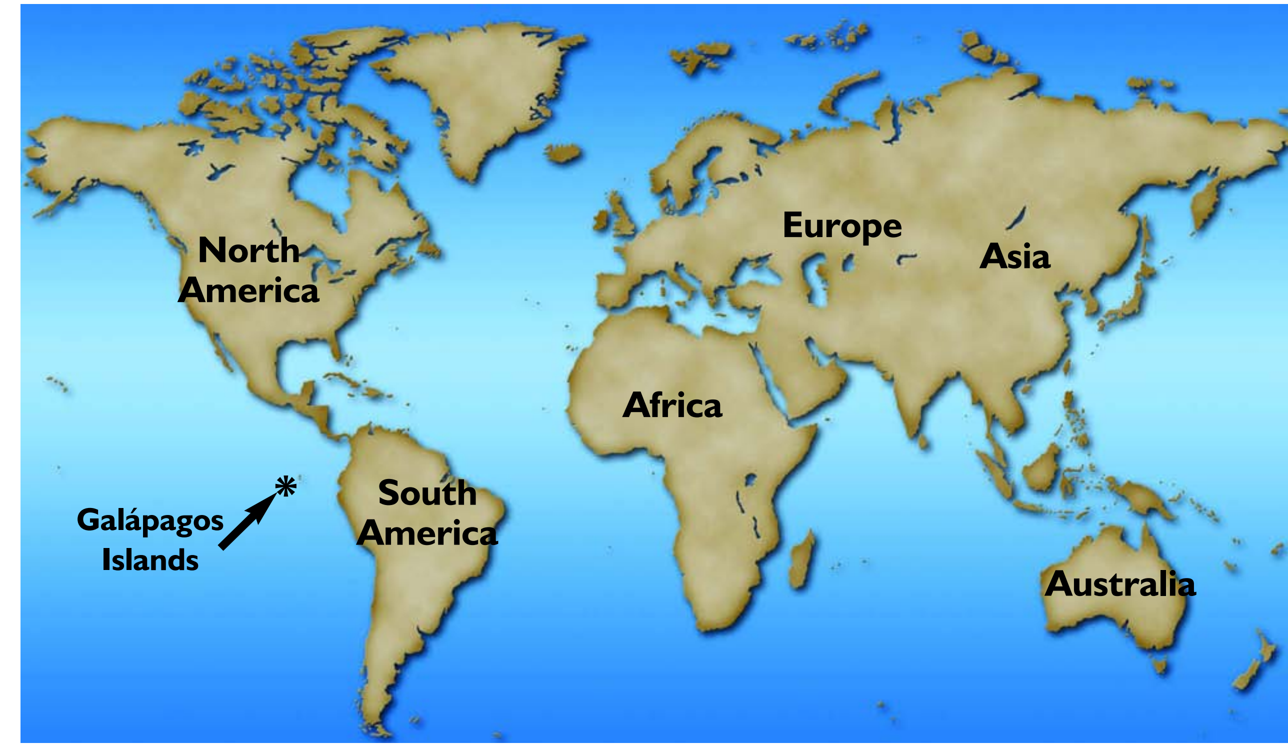
**Getting to know...**

### Charles Darwin

Charles Darwin was born in England in 1809. He was a naturalist. A scientist who studies plants and animals. Darwin began to study evolution after a voyage on a ship called the HMS Beagle in 1832.

The Beagle went to the Galápagos Islands, near the west coast of South America. Darwin studied the birds that lived on the island. He found that the 13 different species of finches there had all descended from the same species of finch from the mainland of South America. The finches had evolved different beaks to eat the different types of foods available to them. Darwin published his book, *On the Origin of Species* in 1859. The book described the theory of natural selection.






*Charles Darwin studied the birds on the Galápagos Islands.*

Humans have affected how animals evolve using artificial selection. For example, people have bred sheep over thousands of years to produce wool for clothing. Those sheep with nice wool were allowed to reproduce. Those with bad wool were not allowed to have offspring.

Sometimes, an entire species is unable to survive. This is called extinction. Most of the fossils scientists find are of animals that are now extinct.

**Find out more**

### Natural Selection Can Occur Overnight.

In 19th century England, the white trunks of many trees turned black from pollution. Suddenly, people noticed there were more black moths than white moths. It was easier for birds to see the white moths on the trees and eat them! The black moths were safe.

**Words to know**

**adaptation** (ad-ap-TAY-shuhn): a change that a living thing goes through so it fits better with its environment

**evolution** (ev-uh-LOO-shuhn): the gradual change of living things over thousands of years

**extinction** (ex-STINGKT-shuhn): when a type of plant or animal has died out

**generation** (jun-uh-RAY-shuhn): the time between the birth of parents and the birth of their offspring

# Types of Animals

There are many different animals in the world. Animals may eat plants or meat to live. They live in different types of environments all around the world. Their bodies help them to survive in their habitat.

## Predators and Prey

Predators are animals that hunt and eat other animals for food. Prey are the animals that predators hunt. A lion is a predator that hunts for prey such as the wildebeest or a zebra. The killer whale will eat sea animals such as sea lions or seals.

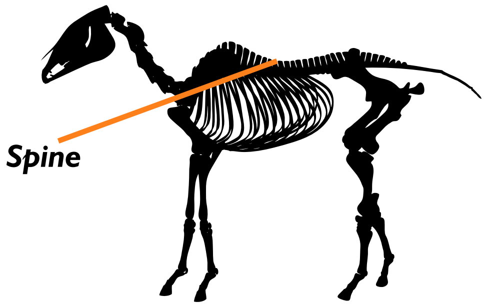
*Lions are predators.*

## Warm-Blooded and Cold-Blooded

Some animals are cold-blooded. These animals depend on heat from outside their bodies to keep warm. Snakes and lizards are cold-blooded animals that bask in the sun on rocks to warm their bodies. The bodies of warm-blooded animals stay at about the same temperature all the time. Humans and other mammals are warm-blooded animals.

## Invertebrates and Vertebrates

Most animals are invertebrates. These animals do not have a backbone, or spine. Some examples of invertebrates are insects, snails, octopi, worms, and jellyfish. Vertebrates have a spine inside their bodies. Mammals, birds, reptiles, amphibians, and fish are all vertebrates.




*Horses are vertebrates because they have a spine inside their bodies.*



## Single-Celled Organisms

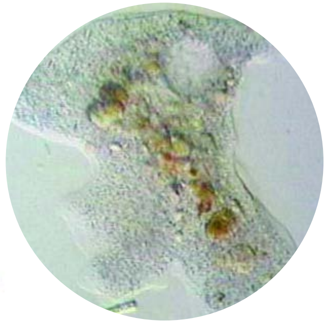
Some organisms are really small, or microscopic. They can be seen only with a powerful microscope. Living things that have only one cell are called single-celled organisms.

Many single-celled organisms used to be placed in the animal kingdom. Today they are part of the Protista kingdom and are called protozoans. Some protozoa eat other organisms. Other protozoa make their own food using sunlight like plants.

Amoebas are one type of protozoa. They live in water and other moist places. Many single-celled organisms live in large groups called colonies. Some types live inside tiny shells. When they die, their shells eventually become chalk.

Bacteria are also single-celled microscopic organisms. They used to be considered animals but because bacteria don't have a nucleus, scientists now put bacteria in the kingdoms Eubacteria and Archaebacteria. Bacteria are the most widespread form of life on the planet. They are found in the air, soil, and water, and in plants and animals. They live in colonies. Bacteria are either round, spiral, or rod-shaped.

Bacteria have different roles in the environment. Some bacteria help digest food in plants and animals. Other bacteria break down dead plants and animals. Harmful bacteria in food and water can make you sick. Bacterial infections inside the body of an animal can be dangerous.



*An amoeba shown under a microscope.*

### WORDS to Know

**cell** (SEL): a basic, microscopic part of an animal or a plant

**infection** (in-FEK-shuhn): an illness caused by bacteria or viruses

**microscopic** (mye-kruh-SKOP-ik): too small to be seen without a microscope

**nucleus** (NOO-klee-uhss): the central part of a cell, containing the chromosomes

**organism** (OR-guh-niz-uhm): a living plant or animal

## Mollusks, Sponges, Starfish, and Worms

### Mollusks

Mollusks are invertebrates with soft bodies. Most mollusks live underwater. They include limpets, clams, oysters, mussels, squids, octopuses, and some snails. Some types of mollusks live on land. They include land snails and slugs. Some mollusks protect themselves by making hard shells around their bodies. Squids and octopuses are the most complex mollusks.

*Clams protect themselves with a hard shell.*

*Garden snails protect themselves with a hard shell.*


### Sponges

Sponges are the simplest form of multi-cellular animals, or animals that are made of more than one cell. Most sponges live in shallow water, but some live deep in the ocean. If a piece breaks off of a sponge it will grow into a new sponge. Sponges eat small pieces of food by pulling them through tiny holes in their bodies. The skeletons of some sponges can absorb water when they die. People sometimes use these skeletons for bath sponges.

*Purple Tube Sponges.*



### Starfish

Starfish, also known as sea stars, are star-shaped organisms that have five arms. The skin on their bodies has many spines. This helps protect them from predators. Starfish move using tube like feet that are found under each arm. Each tube foot has a sucker at the end. The suckers allow starfish to stick to rocks and to hold onto prey. They eat live coral, crabs, and mussels.

*Starfish can cling to rocks using their suckers.*

### Worms

Worms come in many sizes and shapes. Some are flat, and some are round. Tapeworms and flukes have flat bodies. Tapeworms live inside the intestines of vertebrates. One type of fluke lives inside the liver of mammals. Animals that live inside other animals and cause harm to their hosts are called parasites. Roundworms have bodies shaped like a tube. Some are parasites, and some live in the ground or in water.

Segmented worms include earthworms and leeches. These types of worms have long bodies with many sections, or segments. They live in the ground and eat dead leaves. They have no eyes and five blood vessels with valves that work like hearts. Leeches live in water and on land. They have suckers at both ends of their bodies. Some leeches suck blood for food.

*Tapeworms have flat bodies.*

*Roundworm bodies are tube-shaped.*

*Earthworm bodies have segments.*

# Arachnids, Crustaceans, and Insects

Arachnids, crustaceans, and insects are the largest group of invertebrates. All these animals have bodies with several segments.

They have hard shells called exoskeletons. They leave their shells, or molt, as they grow bigger. Then they make new shells.

*A cicada emerging from its shell.*

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## Arachnids

Arachnids include spiders, scorpions, mites, and ticks. They all have eight legs. Spiders live anywhere that there are insects to eat. Some spiders spin webs to catch their prey. The trapdoor spider makes a tunnel in the ground and lines it with silk. The spider waits for an insect and opens its door to catch the prey. They use long teeth, called fangs to kill or stun their prey.

Scorpions have claws to hold their food. Sometimes, they use stingers at the end of their abdomens for defense. Mites are tiny parasites that live on animals, plants, and food. Ticks suck the blood of warm-blooded vertebrates. Both mites and ticks can spread disease.

*Magnified view of a tick on human skin.*

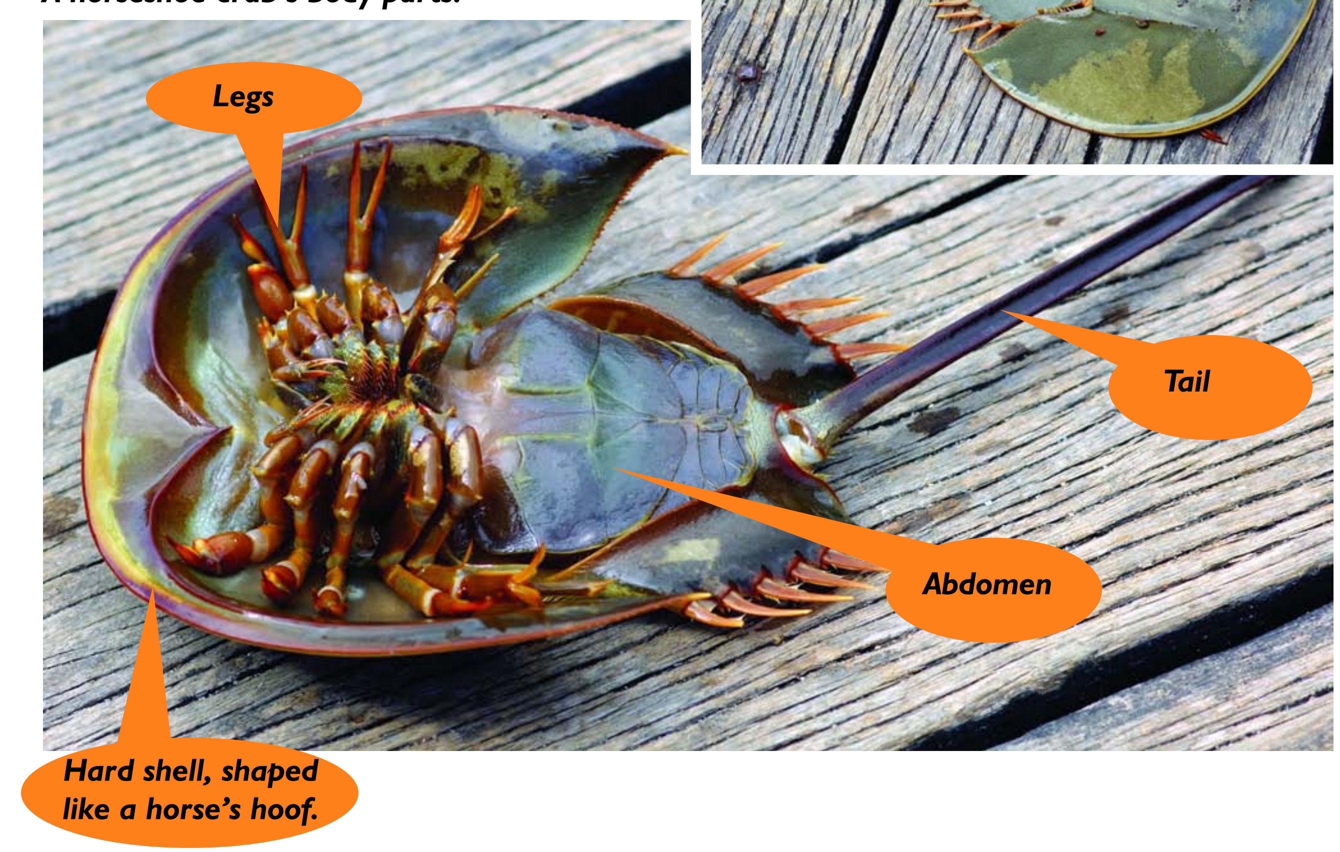


## Crustaceans

Most crustaceans live underwater. Their bodies have many segments that bend when they swim or crawl. Attached to each segment are pairs of legs, claws, or antennas. They have two sets of antennas on their heads. Crustaceans include barnacles, crabs, lobsters, and shrimp. Barnacles cling to rocks, shells, and other animals in the sea. Crabs and lobsters have big claws for holding and eating food. Shrimp breathe and eat with their feet. The only crustaceans that live on land are some crabs and pill bugs, or wood lice.

*Barnacles clinging to a rock.*

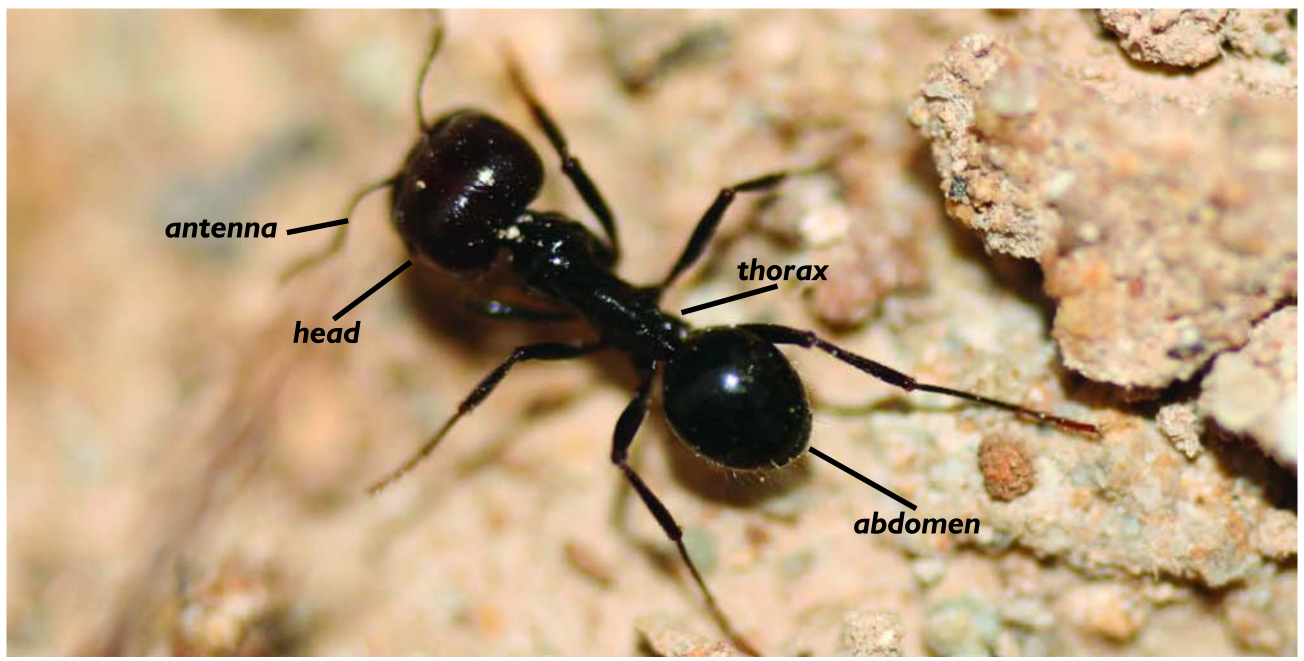
*A horseshoe crab's body parts.*



## Insects

Insects live almost everywhere. Some insects crawl along the ground. Many fly in the air. All insect bodies have three parts. The head has eyes and antennae. The middle part, or thorax, has legs for walking. Most insects have six legs. Some have wings. The back end is called the abdomen.

There are many different types of insects. Ants crawl around in search of food and bring it back to their colony. Dragonflies and beetles fly through the air. Dragonfly wings stick out away from their bodies. Beetle wings fold up across their bodies.




WORDS to Know

**abdomen** (AB-duh-muhn): the back section of an insect's body

**antennae** (an-TEN-uh): a feeler on the head of an insect

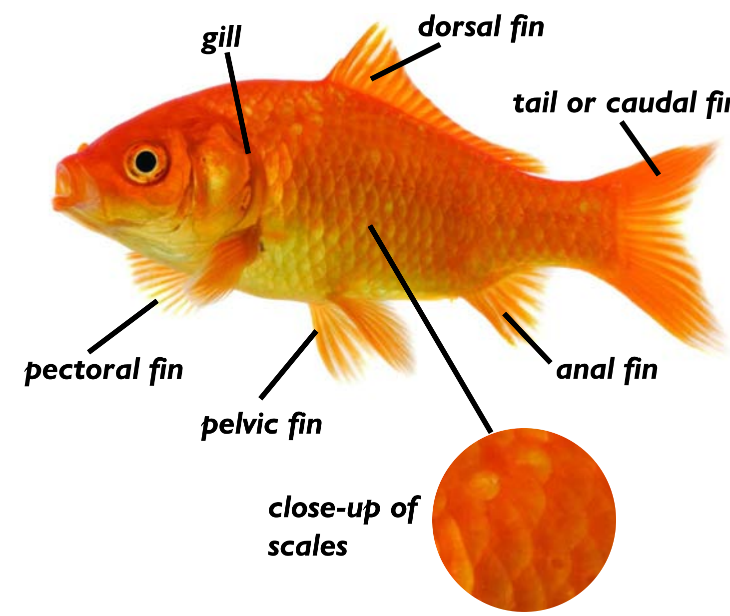
**thorax** (THOR-aks): the part of an insect's body between its head and its abdomen

The eyes of flies are very complex. They are called compound eyes because they have thousands of parts. Bees and wasps have stingers to defend themselves. They can sting people or animals if they are attacked or threatened. Mosquitoes are small. They suck the blood of mammals through a long mouth part called a proboscis.



## Fish

Fish are cold-blooded vertebrates that live in water. Most fish are covered in scales and have fins to help them move. Gills let them breathe underwater. Many fish live in the ocean. The ocean water has salt in it. Other fish live in freshwater, or water that is not salty. Lakes, marshes, ponds, rivers, and streams all contain freshwater. Some people keep fish as pets. The fish live in glass containers called aquariums.




Most fish lay many soft eggs in the water. This is called spawning. The eggs are fertilized by the male fish in the water and are left to hatch on their own. Grunion are silver-colored fish that live in California waters. They wriggle onto the beach under a full moon to spawn. Salmon live in the ocean but return to freshwater to spawn. They swim up streams against the current.

*Salmon fight strong currents to spawn upstream.*

Fish have many ways to protect themselves from predators. A puffer, or blowfish, inflates like a balloon. Enemies are frightened away or are not able to bite the fish. Puffers are also poisonous, and some have spines.

*A porcupine pufferfish.*

The lungfish has both gills and lungs. The lungfish can live in water with little oxygen. It can even breathe air when the water dries up.

*Lungfish.*

Many people think sharks are dangerous. They are good predators, but most are harmless to humans. Sharks skeletons are made of a softer material called cartilage, instead of bone. Sharks have many rows of teeth. Some types of sharks give birth to live offspring. This means that the babies grow inside the mother's body until they are born. The hammerhead shark and tiger shark both give birth to babies this way.

**Words to Know**

**cartilage** (KAR-tuh-lij): a strong, elastic, fibrous tissue

**gill** (GIL): the organ on a fish's side through which it breathes

**lungs** (LUHNGSS): a pair of baglike organs inside many animals chests that they use to breathe

*Jaws from a shark showing the rows of teeth.*

Some sharks, like the grey nurse shark, have eggs that hatch inside the mother. The babies that hatch first sometimes eat the other eggs. Other sharks lay eggs that hatch outside the mother's body. A horn shark egg is covered in a leather-like case to protect the egg while it is waiting to hatch.

*A hammerhead shark.*



## Amphibians

Amphibians are cold-blooded vertebrates. They have a lot in common with both fish and reptiles. Amphibians include frogs, toads, salamanders, newts and caecilians. Frogs have smooth, wet skin. Toads have dry, warty skin and spend more time on land. Salamanders and newts are like lizards, but they do not have scales.

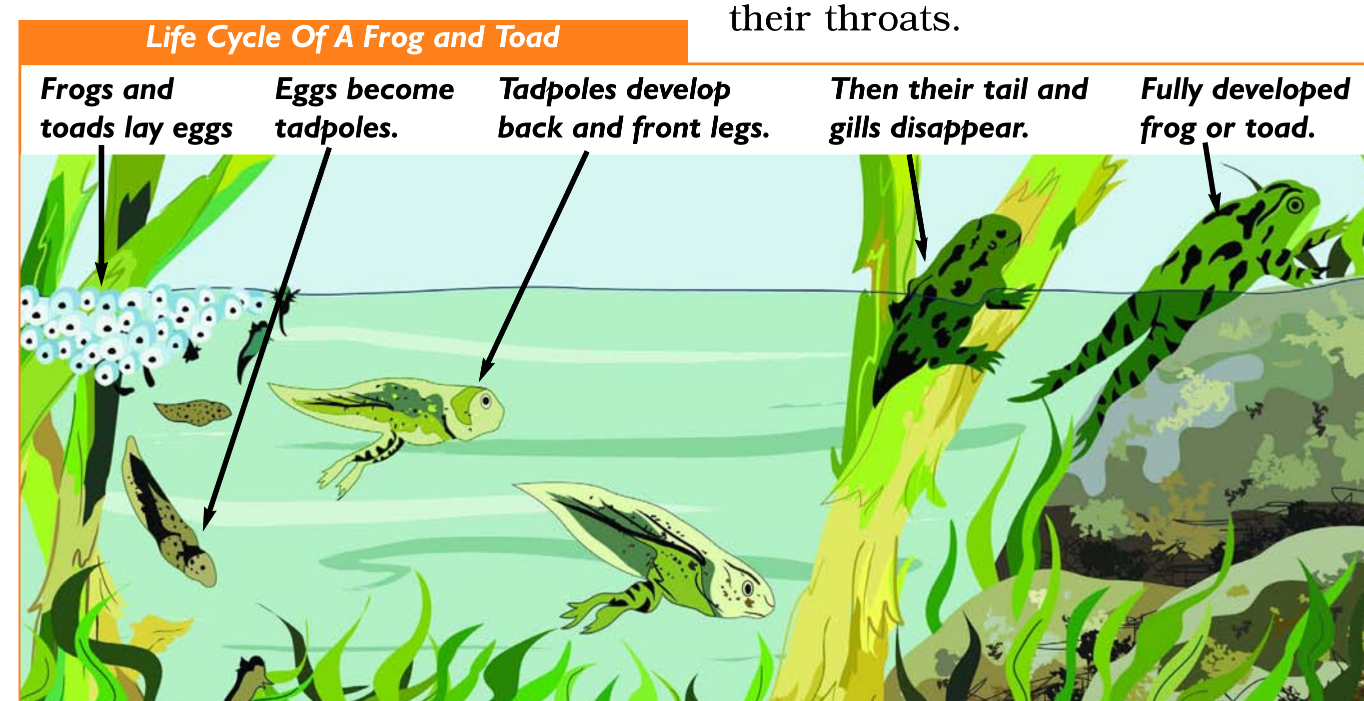
*A frog has smooth, wet skin.*

*A toad has dry, warty skin.*

Most amphibians lay eggs in the water, like fish. The eggs hatch into larvae that have gills and live underwater. The larvae of frogs and toads have tails but no legs. They are called tadpoles. Tadpoles develop back legs and then front legs before their tails disappear.

The larvae of salamanders and newts look more like adults. As an amphibian larva grows, its gills disappear and lungs develop.

Amphibians eat insects and other small invertebrates such as turtles and snakes. Frogs and toads have long tongues to catch their prey. They have long back legs for jumping. Most frogs and toads make loud sounds with their throats.



# Reptiles

Reptiles are vertebrates that have dry skin covered with scales or bony plates. They do not have feathers or fur. Most reptiles lay eggs with tough shells. Many reptiles have short legs while some have no legs at all. They are cold-blooded and breathe air. Reptiles include alligators, crocodiles, lizards, snakes, terrapins, tortoises, and turtles.

## Alligators and Crocodiles

Alligators and crocodiles look very similar. They both have long bodies and tails. Some are very large. Their skin is thick and scaly. Crocodiles have thin noses, and alligators have broader noses.

*Crocodiles have thin noses.*

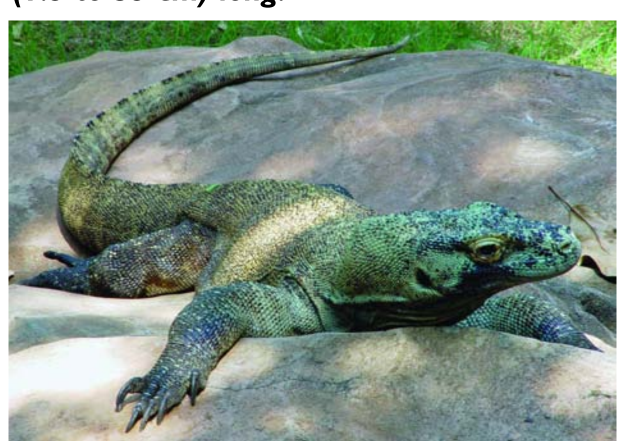
*Alligators have broad noses.*

They have many sharp teeth. Alligators and crocodiles live near water and swim well. They eat fish and often attack animals that come to drink. They lay eggs on land.

## Lizards

Lizards are the largest group of reptiles. They have a small head, short neck, and a long body and tail. Lizards can be small like a gecko or quite large like the Komodo dragon.

*Geckos can be a 1/2 inch to about 14 inches (1.5 to 35 cm) long.*



*A Komodo dragon can get up to 10 feet (3 m) long.*



Most lizards have four legs but some lizards have no legs. They look like snakes except they have eyelids and ears. Other types of lizards can run fast. One type of lizard, the basilisks, can run across the surface of water. Some lizards swim well, and others are good climbers.

*A basilisk lizard.*

Most lizards eat insects but some eat birds or other reptiles and some eat mostly plants. Nearly all lizards lay eggs, but a few types give birth to live offspring. Many lizards can lose their tails to escape when they are attacked. A new tail will grow back in its place. Two types of lizards, the Gila Monster and Beaded lizard are poisonous.

*A beaded lizard.*

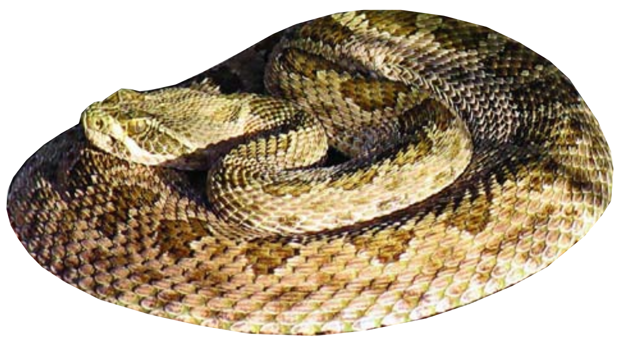
Find out more

### Some Lizards Can Change Colors

The chameleon is a lizard that can become the color of whatever it is sitting on! Well, at least the colors of trees and rocks. The chameleon also has strange eyes. They can spin, or rotate, in different directions at the same time.

## Snakes

Snakes have long, narrow bodies covered in a scaly skin. A snake's skin can be one solid color or it can be multi-colored with different markings or patterns. Snakes do not have eyelids, external ear openings, arms, or legs.



*Snake skin comes in many colors and patterns.*

Some snakes slither quickly along the ground. Others climb trees. And still others swim in the water. Different kinds of snakes live in different habitats. Different types of rattlesnakes are found all over North America. Rainforests are home to boa constrictors. Sea snakes, like the turtle-headed sea snake live in the water.

*A sea snake poking out of the sand.*

Snakes eat other animals. They do not chew their food. They have flexible jaws that open wide to swallow their prey whole. Many snakes eat their prey while it is still alive. Others kill their prey first.

*Snakes' jaws can open wide to swallow prey.*

Boa constrictors and pythons squeeze their prey to death. A poisonous snake injects its prey with venom. Cobras, mambas, and copperheads are all snakes with poisonous venom. A rattlesnake has a special part on its tail that it shakes to warn enemies. Some snakes have special holes, or pits, that sense differences in heat. These snakes can find their prey in the dark.

*A boa.*



## Terrapin, Tortoises, and Turtles

Most terrapins, tortoises, and turtles are very similar. They have large, bony shells covered with big scales. They can pull their heads, arms, and legs inside the shell when they are threatened.
So, why do we have three different names for this group of reptiles? The names are based on the three types of habitats these reptiles live in.

**Terrapins** spend time both on land and in the water. They always live near freshwater areas like marshes, ponds, and streams. Many have adapted to life in brackish, swampy areas. Some terrapins hibernate during the winter months. The box turtle is actually a terrapin.

*A box turtle or terrapin.*

**Tortoises** are turtles that live on land. They have high shells that protect them. Their strong, stumpy legs help them walk on land and dig burrows. Many tortoises have adapted to life in hot, dry areas. They go into underground burrows when the sun gets too hot. Giant tortoises live a long time. Tortoises can live to be over 100 years old.

*A giant tortoise.*

**Turtles** spend most of their lives in the water and lay their eggs on the land. Turtles usually have webbed feet for swimming. Sea turtles live in saltwater. Their webbed feet are like paddles. The biggest reptile is a kind of sea turtle called a leatherback. Other turtles live in freshwater like marshes, ponds, streams, and lakes. They swim but also can be seen basking in the sun on logs, rocks, or the banks of the water.

*A sea turtle.*

Find out more

### Dinosaurs

Dinosaurs were a group of reptiles that lived in the Mesozoic era millions of years ago. The Mesozoic era is divided into the Triassic, Jurassic, and Cretaceous periods. All the dinosaurs died at the end of the Cretaceous period. They became extinct.

Because there were no people during that time, we only know about them from fossils and from related animals that are still alive today. The word "dinosaur" is often used for any large reptile that is now extinct.

Dinosaurs lived mostly on land. Many were very large, like the Brachiosaurus. The smallest dinosaur was the size of a chicken.

Some dinosaurs ate plants. Triceratops was a group of plant-eating dinosaurs with three horns and large, bony plates on their necks. They walked on all four legs.

Some dinosaurs hunted other animals. Tyrannosaurus rex is the species name of a large dinosaur that ate other animals. It had a big head and sharp teeth. It walked on its back legs and had small front legs.

Other reptiles related to dinosaurs lived at the same time as dinosaurs. Plesiosaurs were marine reptiles with flat bodies, long necks, and flipper like feet. The pterodactyl was a reptile that could fly. It had wings and a beak, like birds. But it did not have feathers.

*T-rex skeleton.*



## Birds

Birds are warm-blooded vertebrates. They are the only animals with feathers. Their two front legs are wings. Most birds use their wings to fly. Birds use their hind legs and feet for walking, swimming, or holding onto branches. Most birds have tails.

All birds lay eggs with hard shells. Most birds build nests to keep their eggs safe and warm. They may use leaves, twigs, grass, feathers, or paper.

*A robin's eggs in a nest.*

Birds have sharp beaks for eating. They may eat insects, seeds, nectar, or other animals. A woodpecker has a very hard beak for making holes in tree trunks. Some woodpeckers eat insects found in the holes. Others drink the sap that oozes from the holes.

*Woodpecker*

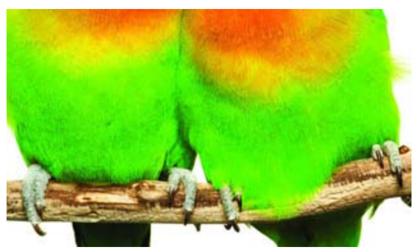
A pelican is a large bird that eats fish. It can carry a whole fish in the large sac in its throat. A hummingbird is a tiny bird with a thin beak. It uses its long tongue to drink nectar from flowers. Hawks and other birds of prey have a hooked beak for ripping and tearing apart prey.

*Pelican*

*Hummingbird*

Birds of prey hunt animals, including other birds. They have long, sharp claws called talons. These birds include owls, hawks, and eagles. Owls can turn their heads to look behind them for prey.

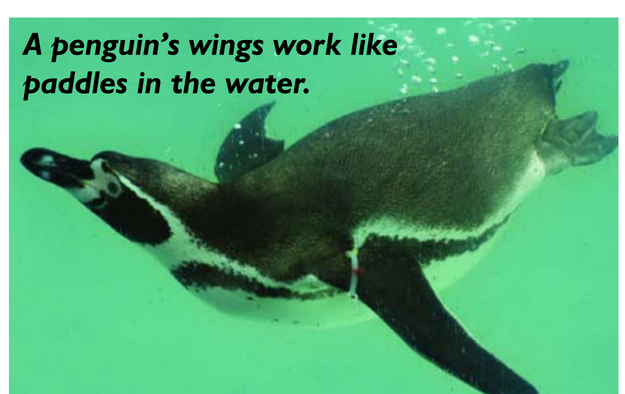

A Barred owl.

| Bird Feet | | |
|---|---|---|
| Birds of prey like hawks, eagles and owls have talons for hunting. | Smaller birds use their feet for perching. Their toes can hold onto branches. | Birds like ducks, swans and penguins have webbed feet for swimming. |
|  |  |  |

Some birds have beautiful feathers. They use them to attract mates. A male peacock has long, colorful feathers in its tail. It spreads its tail like a fan. A parrot has many bright colors. It can repeat, or mimic, sounds that it hears. You can teach a parrot to repeat words.


A peacock.

**Penguins** are birds that cannot fly. They use their wings to swim. Penguins wings work like paddles under the water. The Galápagos penguin lives near the equator, the hottest part of the world. The emperor penguin lives in Antarctica, the coldest part of the world.


A penguin's wings work like paddles in the water.



**Ducks, geese, and swans** float on water. They have broad, flat feet with pieces of tissue, or webs, between their toes. These webbed feet are like paddles that help the birds swim on top of the water.

**Ostrich** are one of a few types of birds that cannot swim or fly. The ostrich is a large bird that lives in Africa. The body of the ostrich is too large for its wings to lift it off the ground. It has big, powerful legs and can run very fast. The rhea in South America and the emu in Australia are like the ostrich.


*An ostrich.*

Getting to know...

## John James Audubon

John James Audubon was born in 1785 and grew up in France. His family sent him to live in the United States when he was eighteen. He lived on a farm in Pennsylvania. Audubon loved nature and art. He decided to draw every type of bird in North America. He drew male and female birds. He drew illustrations showing birds caring for their young and their feeding habits.

Audubon could not find people who were interested in his paintings. So, he took his pictures to England and Scotland. He earned enough money to begin publishing *The Birds of America*. The book had very large pages. It showed a thousand different birds from five hundred species. Audubon also wrote about the behavior of birds.

The Audubon Society was named to honor John James Audubon and works to protect birds, other wildlife, and their habitats.

# Mammals

Mammals are probably the animals you know best. Humans are mammals. So are dogs and cats. Mammals share some similar traits. They are all warm-blooded vertebrates. They have at least some hair or fur on their bodies. Female mammals have special body parts called mammary glands. These glands make milk that baby mammals drink. Almost every mammal gives birth to live offspring. A few types of mammals such as kangaroos have a pouch where the baby continues to grow after it is born. A couple of mammals even lay eggs.

*Newborn piglets feed on their mother.*

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## Land mammals

**Bears** are one type of large mammal. All bears have long fur and strong claws. Bears may eat fruit, insects, fish, and other animals. Sometimes, they stand on their back legs to eat or to scare their enemies. Some bears hibernate. That means that they sleep through the winter when food is hard to find.

**Polar bears** are the biggest bear. They live in arctic areas and have white fur. Polar bears have two types of fur. Thick, woolly fur keeps them warm while guard hairs keep them dry. Polar bears catch fish and hunt seals.

*Polar bears have thick, woolly fur to keep them warm.*





## Cats

Some wild mammals are related to domesticated cats. Cats are one type of mammal that comes in many sizes and colors. Cats hunt other animals and have sharp teeth and claws. Many are good climbers.

**Tigers** are the largest cats. They live in Asia. Most tigers are orange with black stripes. Unlike other cats, tigers like water. They hunt alone rather than in a group.

*Tigers are an endangered species.*

**Lions** have light brown fur. They live in Africa. It is easy to tell if the lion is male because he has long, darker fur around his head called a mane. Lions live in a group called a pride. Usually, only one male lion will be in the pride. The female lions hunt for food for the pride and will hunt in a group.

**Leopards** live in Asia and Africa. They have light brown fur with black spots. A leopard hunts alone and drags its prey into a tree to hide it from other hungry animals.

| Cat | | Details |
|---|---|---|
| Cheetah |  | Habitat: Africa<br>Length: 6-7 feet (1.8-2.15 m)<br>Weight: 100-125 pounds (45-55 kg) |
| Jaguar |  | Habitat: South and Central America<br>Length: 4-6 feet (1.2-1.8m)<br>Weight 79-300 pounds (36-136 kg) |
| Leopard |  | Habitat: Asia and Africa<br>Length: 3.5-5.5 feet (1-1.7 m)<br>Weight: 65-175 pounds (30-80 kg) |
| Lion |  | Habitat: Africa and India<br>Length: 6 feet (1.8 m)<br>Weight: 420 pounds (190 kg) |
| Cougar |  | Habitat: North and South America<br>Length: 6 feet (1.8 m)<br>Weight: 200 pounds (90 kg) |
| Tiger |  | Habitat: Asia<br>Length: 4.5-9 feet (1.4-2.7 m)<br>Weight: 500 pounds (230 kg) |



## Dogs

Some wild mammals are related to domesticated dogs. These mammals are predators that often hunt in groups, called packs.

**Coyotes** look like a small, light brown wolf. They live in North America and may hunt near people's homes. A coyotes howling and other sounds are one of the few wild mammal sounds commonly heard by humans.

*A coyote.*

**Foxes** are smaller than coyotes and have a bushy tail and large ears. Foxes are well adapted to all habitats such as the arctic, deserts, forests, and grasslands.

**Jackals** look like the coyote. They live in Africa and Asia. Jackals usually live alone or in pairs.

*A Black-backed Jackal.*

**Wolves** are larger than most domestic dogs. They may be gray or red. Wolves live in North America, Europe, and Asia.

*A wolf pack.*

| There Are Different Kinds of Foxes | | |
|---|---|---|
| **Arctic Fox.** They live in Arctic regions of Europe, Asia, Iceland, Greenland and North America.<br> | **Desert Fox or Fennec.** Can be found in the Sahara Desert of North Africa.<br> | **Red Fox.** They live in parts of the United States, Canada, Europe, Asia and Australia.<br> |

## Elephants and Rhinos

**Elephants** are the biggest land animals. Adult elephants can weigh six tons (5443 kg) or more. There are different types of elephants in different parts of the world. The African elephant is larger than the Asian or Indian elephant and also has bigger ears.

Male elephants have long teeth called tusks made of ivory. Muscles in an elephant's trunk let it pick up objects and drink water. Elephants eat hundreds of pounds of plants every day.

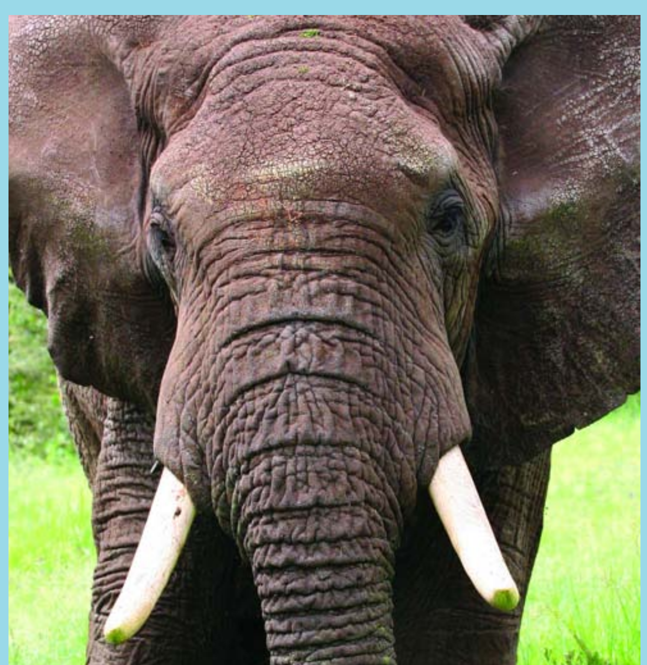

*African elephant.*


*Indian elephant.*

***African elephants have larger ears than Indian elephants.***

### Find out more

Elephants have few natural enemies except man. They are in danger of extinction because of loss of habitat and poaching. Elephants are hunted for their ivory tusks which have been used to make items such as jewelry and piano keys. They are listed as an endangered species. Conservationists are trying to protect the elephant by making laws to ban the sale of ivory.





**Rhinoceros, or rhinos,** are another large mammal from Africa and Asia. They have thick gray skin and little hair, like the elephant. A rhino has one or two horns on its nose.


*Rhinoceros*

## Hoofed mammals

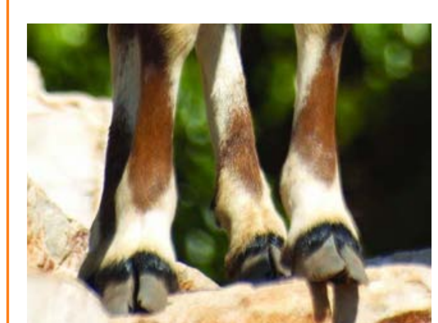
Many mammals have a hard piece on the bottom of each foot called a hoof. They eat plants and often live in groups called herds. Many have horns or antlers on their heads. Some of these mammals are domesticated, such as horses, cows, sheep, goats, and pigs.

Other hoofed mammals live in the wild, such as antelope, bison, deer, giraffe, and zebras.

**Zebras** live in Africa. Zebras are like horses with black-and-white stripes.

**Giraffes** also live in Africa. They have long legs and a very long neck. Giraffes can reach leaves at the tops of trees.

**Camels** live in the deserts of Africa and Asia. They are a large animal that has one or two humps on its back. Camels have one nail and a large, soft pad instead of a hoof. This helps them walk on sand.

| There Are Different Kinds of Hooves | | |
|---|---|---|
| Animals like horses, donkeys, and zebras have one hoof on each foot. | Animals like goats, deer and cows have cloven hooves. They look split. | Camels do not have hooves. Instead they have a two-toed foot with toenails. |
|  |  |  |

## Marsupials

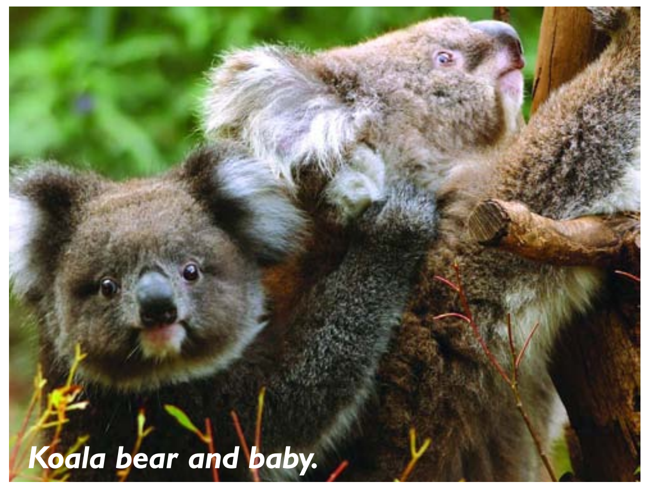
Marsupials are mammals with a pouch. The pouch is where the developing young marsupial lives when it leaves its mother's uterus. In the pouch a baby marsupial finds a nipple where it can drink the milk from its mother. The baby will complete its development in the pouch. It will not leave the pouch until it can survive outside. Most marsupials live in Australia and South America.

**Kangaroos** are the largest marsupials. They have small front legs, large back legs, and a thick tail. The kangaroo uses its back legs to leap high and far. It often stands on its back legs.

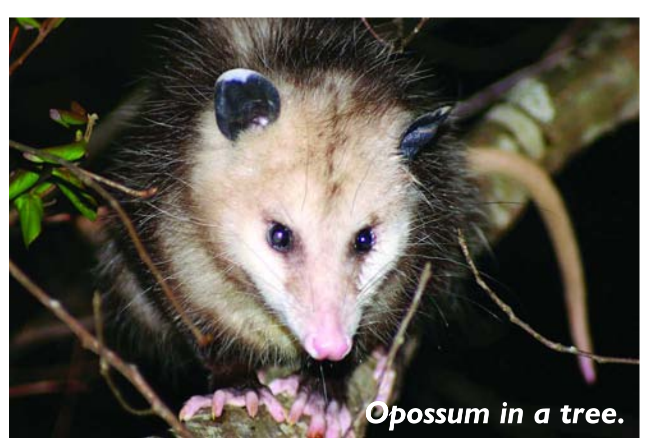
Kangaroos eat plants. A baby kangaroo is called a joey. The joey may ride in its mother's pouch to feed or travel until it is a year old.


*Kangaroo with a baby joey.*

**Koalas** are another marsupial from Australia. They look like a bear. Koalas live in eucalyptus trees and eat the trees leaves and young bark. A female koala carries its baby on its back until the offspring is a year old.


*Koala bear and baby.*

**Opossums** are the only marsupial native to North America. They have a long nose and a tail like a rat. Opossums can hang upside down by their tails. They often live near people and search garbage cans for food. Opossums will eat both plants and animals.


*Opossum in a tree.*

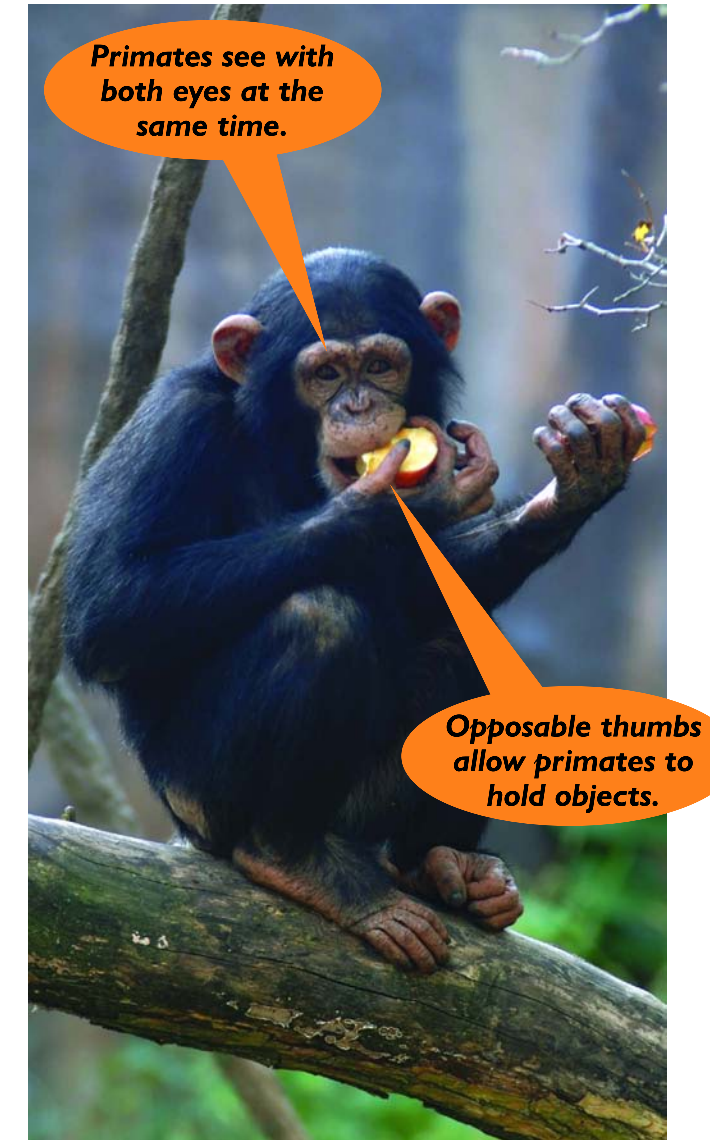


## Primates

Humans belong to the group of mammals called primates. The other primates are apes, monkeys, and lemurs. Primates depend on their eyesight to find food or locate a mate. Their eyes are on the front of their faces. Primates see the world with both eyes at the same time. The image seen by one eye overlaps with the image that the other eye sees. This gives primates a good sense of depth, or how far away something is. Primates can see in color, unlike most other animals.

Primates have bodies that are good for climbing trees. They have long arms and legs. Their thumbs are opposable. This means that the bone of the thumb can turn, or rotate, to touch the other fingers. The hands of primates can hold branches or food.

Primates have nails instead of claws. They have small folds on the palms of their hands and soles of their feet to help them hold objects. In humans, these folds are fingerprints. Lemurs and many monkeys have long tails. Apes and humans do not have tails.




### Words to Know

**domesticate** (duh-MESS-tuh-kate): to tame something so it can live with or be used by humans

**native** (NAY-tiv): an animal or plant that originally lived or grew in a certain place

**poacher** (POHCH-UR): a person who hunts or fishes illegally

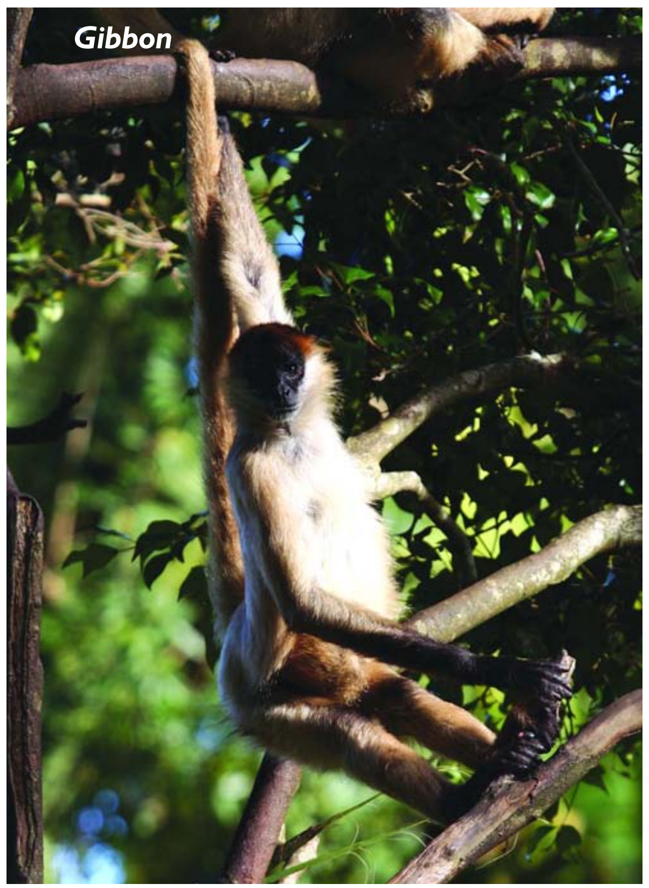
**vertebrate** (VUR-tuh-brate): any animal that has a backbone

**wild** (WILDE): natural or not tamed by humans

## Apes

Apes live in Africa and Asia and on some islands in the Pacific Ocean. They have no tails. Apes include gorillas, chimpanzees, orangutans, gibbons, and siamang.

**Gibbons** are small apes. They have very long arms and swing from tree branches.

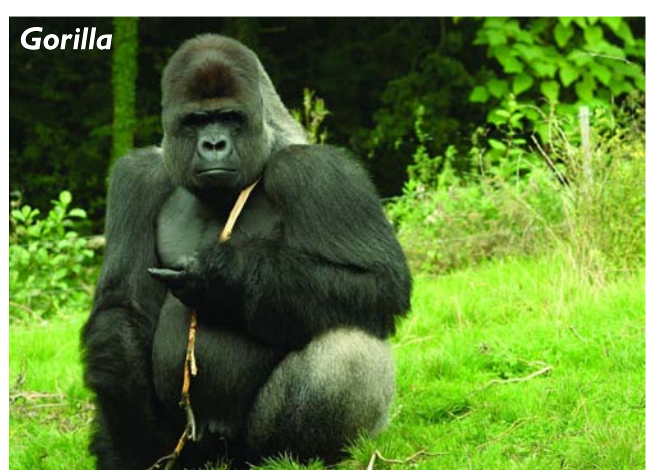

Gibbon

**Chimpanzees** live in Africa. They are smaller than gorillas and have dark fur and skin. Chimpanzees walk on their knuckles like the gorillas, but spend more time in trees.

Chimpanzees may use tools in the wild. They will use a stick to get ants or termites out of a hole or to scare away an unwanted intruder.


*Chimpanzees sometimes use sticks as tools.*

**Gorillas** live in Africa. They are very large and strong. Gorillas have dark fur and skin. They walk on their feet and the knuckles of their hands. They can climb trees, but do not so very often. Gorillas eat mostly plants, but they may also eat meat.


Gorilla



**Orangutans** live on the Pacific islands of Borneo and Sumatra, near Asia. They have brown skin and long red fur. Orangutans climb with their hands and feet. They live in trees and eat plants.


*A pair of orangutans.*

## Lemurs

Lemurs are small primates. They live on the island of Madagascar, near Africa. They have small heads, large eyes, soft fur, and a long bushy tail. Most lemurs eat leaves, fruit, flowers and sometimes insects or small vertebrates. Some scientists put lemurs in their own group because they have some differences from other primates.


*Ruffed Lemurs are just one of many kinds of lemurs.*

## Monkeys

Monkeys are called either New World monkeys or Old World monkeys. New World monkeys live in Central and South America. They live in trees and have long tails. Some use their tails to hang from trees. Howler monkeys can make loud noises. Old World monkeys live in Africa and Asia. They have small tails. The baboon has a long nose, lives on the ground, and eats both plants and animals.


*A Red howler monkey.*

| Primate | | Where They Live |
|---|---|---|
| Chimpanzees |  | Africa |
| Gibbons |  | Tropical rain forests in Southeast Asia |
| Gorillas |  | Africa |
| Orangutans |  | Borneo and Sumatra, near Asia |
| Lemurs |  | Madagascar, near Africa |
| Monkeys (Old World) |  | Africa and Asia |
| Monkeys (New World) |  | South and Central America |



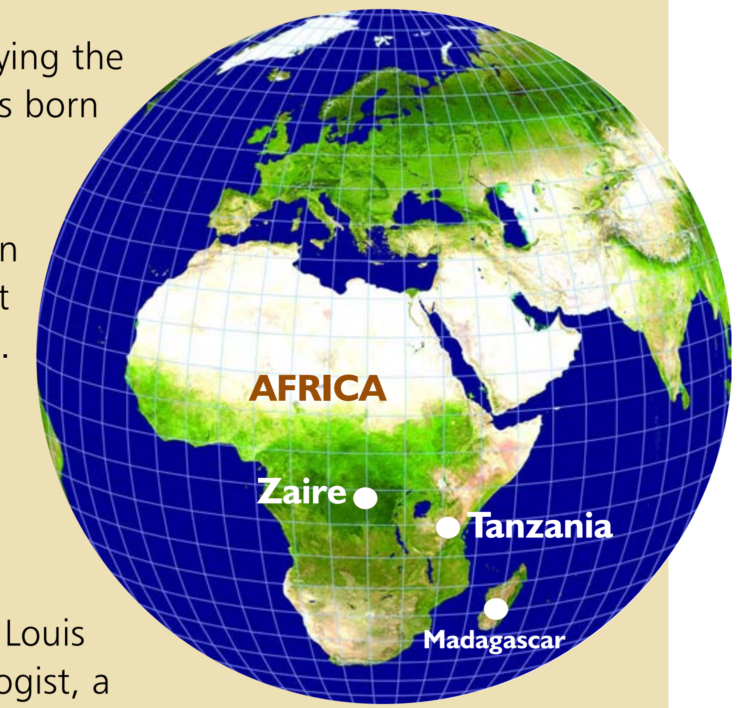
## Getting to know...

Jane Goodall

Dian Fossey

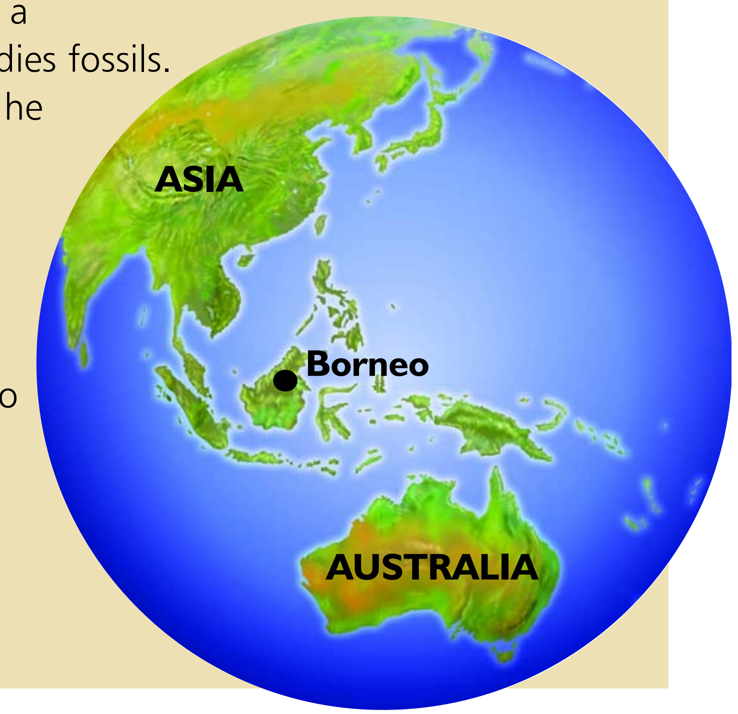
Biruté Galdikas

Three women are famous for studying the behavior of apes. Jane Goodall was born in England in 1934. She went to Tanzania, in Africa, to study chimpanzees. Dian Fossey was born in San Francisco in 1932. She went to Zaire, in Africa, to study gorillas. Biruté Galdikas was born in 1946 and grew up in Canada. She went to the Pacific island of Borneo to study orangutans.




All three women were students of Louis Leakey. He was both an anthropologist, a scientist who studies humans, and a paleontologist, a scientist who studies fossils. He wanted to learn about apes so he could understand humans better.

Goodall, Fossey, and Galdikas lived with the apes and got to know them well. They studied the social system of the animals. They tried to protect the apes from human diseases, the destruction of their habitats, and poachers.



## Rodents

A rodent is a small mammal. All rodents' front teeth continue to grow like your fingernails. They gnaw on food or other things to grind down their front teeth. Rodents often nibble nuts and seeds in small bites.

Rodents that live in the wild include squirrels, gophers, porcupines, chipmunks, and prairie dogs. Many people keep rodents such as mice, rats, guinea pigs, and hamsters as pets. Rodents reproduce frequently and usually have many offspring. Some mammals that are like rodents are rabbits and shrews.

*All rodents have 2 large front teeth and claws on their feet.*

**There Are Different Kinds of Rodents**

| Capybaras are the largest rodent in the world. | Some rodents, like hamsters, make good pets. | A porcupine is a rodent covered in quills. |
|---|---|---|
|  |  |  |



## Water mammals

Some mammals spend most or all of their lives in water. For example, beavers live both on land and in the water while manatees live their whole life in the water.

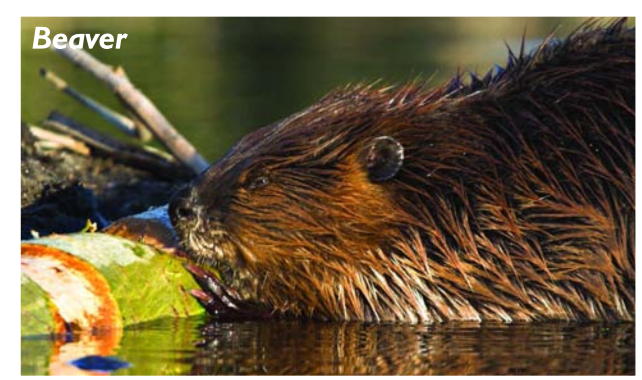
**Hippos**, or hippopotamuses, are a large animal with thick, gray skin like an elephant. Their eyes, ears, and nostrils are located high on their heads so the hippo can stay deep in the water for long periods of time. Hippos do this to stay cool and avoid getting sunburned.

**Otters** are furry mammals that eat fish and mollusks in rivers and the ocean. They float on their backs and break open shells with rocks.

**Beavers** are furry rodents that use branches to make dams across rivers. They build homes that they enter from underwater.

*Hippo*

*In the water, otters lie on their backs and use their stomachs as a table.*



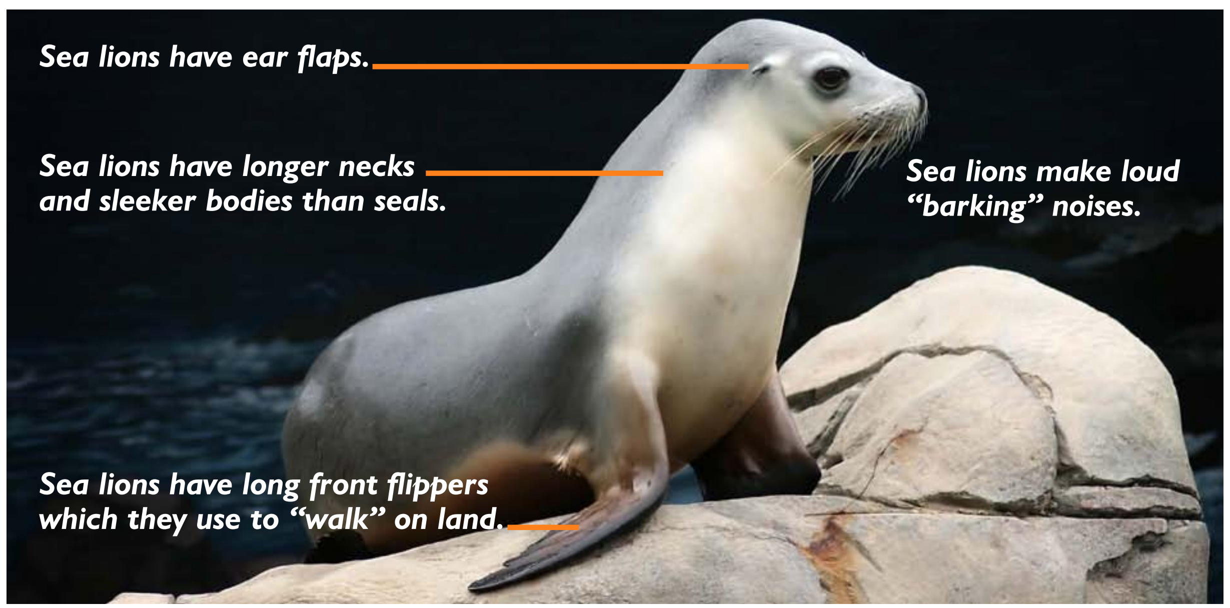
*Beaver*

*A beaver dam.*

**Seals, sea lions and walruses.** Seals, sea lions and walruses have webbed flippers to help them swim in the ocean. They can move on land, but are clumsy and slow. They spend time lying around on beaches or rocks. Seals and sea lions eat fish while walrus eat clams, snails, crabs, and worms. Walruses have long tusks.

*Both male and female walruses have tusks.*

## What's the Difference Between a Sea Lion and a Seal?







**Whales and dolphins.** Whales and dolphins cannot live on land. They live in the ocean and must come to the surface to breathe air. A whale or dolphin breathes through a nostril on its back called a blowhole. The blue whale is the largest animal in the world.

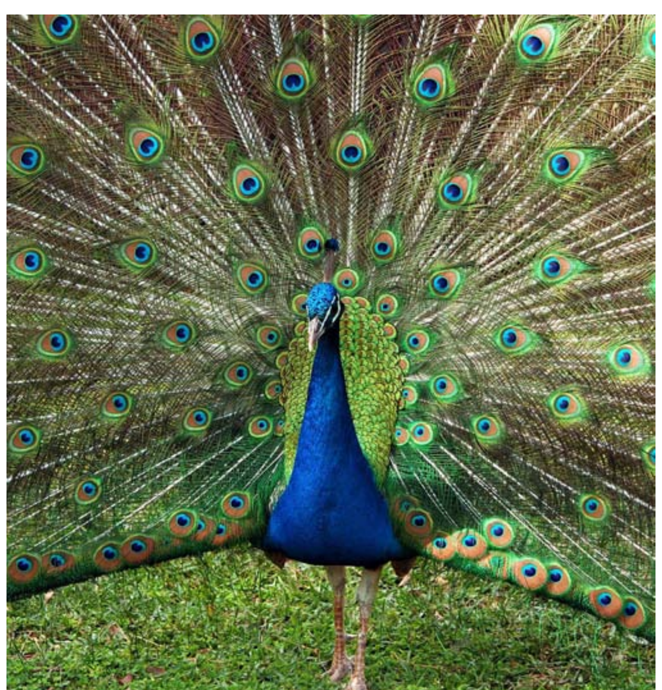
## There Are Different Kinds of Whales and Dolphins

| | | |
|---|---|---|
| Beluga Whale |  | Also known as White Whales. The beluga is able to change the shape of its head by blowing air around its sinuses. Belugas do not have a fin on their back. |
| Blue Whale |  | A Blue Whale's tongue is about the size of an elephant and 50 humans could stand in its mouth. Blue Whales eat krill. They are Baleen Whales. |
| Bottlenose Dolphin |  | Bottlenose Dolphins are the most common and well-known dolphins. They have small, cone-like teeth. They mostly eat small fish. |
| Humpback Whale |  | The humpback's head and lower jaw are covered with knobs, called tubercles. Humpbacks are Baleen Whales. |
| Orca |  | Also known as Killer Whales, Orcas belong to the dolphin family. The Orca's intelligence and trainability have made it popular at theme parks. |
| Southern Right Whale |  | There are four right whale species: North Atlantic Right Whales, North Pacific Right Whales, Southern Right Whales, and Bowhead Whales. |

# Mating and Reproduction in Animals

## Mating

Courtship is the way in which animals find mates. Male birds often have brightly colored feathers that attract the attention of the female. They also may sing to attract a female. Female cats may rub against males to show they are ready to mate. Mammals that are ready to mate are in the estrus phase, or it is sometimes called being in heat. Some animal groups have dominant males and females. They are the strongest or largest. Sometimes, only the dominant male or female will mate.



*Male peacocks have magnificent feathers of many colors.*

Many animals have special behaviors for mating called rituals. Birds often have long courtship rituals. Some of these rituals look strange. They may even seem like a dance. Rituals are a way of creating trust so that the animals will not see each other as a threat. Mating between insects can be dangerous. A female black widow or praying mantis tries to eat the male after mating.

*A Black Widow spider.*

## Reproduction

All species of animals must have offspring in order to survive. Animals give birth to their offspring through reproduction.



Reproduction happens in different ways for different animals. Some make copies of themselves. Some lay eggs. Others have live births. Reproduction is the beginning of the cycle of life.

**Asexual reproduction** is the way many single-celled organisms and other animals have offspring. This means that one organism or animal makes exact copies of itself all by itself. An amoeba splits its nucleus in half. Each half becomes a new amoeba. This is called mitosis. Some animals, like jellyfish, reproduce by breaking off a part of their bodies. This part grows into a whole new jellyfish. This is called regeneration. Many coral plants reproduce by budding. Budding happens when a new animal grows from a parent. Thousands of coral animals live together in colonies.

**Find Out More**

### Starfish Can Regenerate

When some fishermen wanted to get rid of the starfish in their nets, they cut the starfish into pieces and threw them into the sea. To their surprise they had even more starfish. A starfish can regenerate, or grow new tissue. Each piece became a new starfish!

*Coral reefs are made up of thousands of coral animals.*

**Sexual reproduction** is reproduction involving the male and female of a species. Each parent produces special cells called gametes. Female gametes are called ova or eggs. They come from the ovaries. Male gametes are called sperm. They come from the testes. Each gamete contains half the genetic material for a complete animal. Fertilization happens when the male and female gametes join together.

**Words to Know**

**chrysalis** (KRISS-uh-liss): a butterfly at the stage of development between a caterpillar and an adult

**fertilize** (FUR-tuh-lize): to begin reproduction in an egg by causing sperm to join with the egg

**fetus** (FEE-tuhss): a baby or an animal before it is born, at the stage when it is developing in its mother's womb

**gamete** (gam-EET): the male (sperm) or female (egg) reproductive cell of an organism

**larvae** (LAR-vee): insects at the stage of development between the egg and the pupa, when it looks like a worm

**pupa** (PYOO-puh): an insect at the stage of development between a larva and an adult

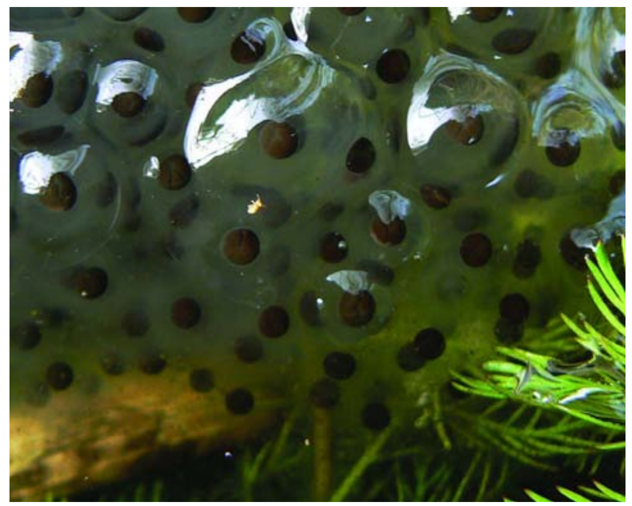
## Bird Reproduction

Birds reproduce by laying eggs with hard shells. The eggs are fertilized in the female's body during mating. The female then lays the eggs in a nest. The mother or father sits on the eggs to keep them warm. This is called incubation. The eggs hatch in two or three weeks. Baby birds, or chicks, are born blind and without feathers. They must be fed and kept safe until they are ready to fly.

***Chicks are born blind and without feathers.***

## Fish Reproduction

Fish and amphibians reproduce by spawning. Spawning occurs when a female releases eggs into the water. A male fertilizes the eggs by covering them with sperm. The eggs of most reptiles are fertilized inside the mother's body. This happens during mating, when the male puts sperm in the female's body. Most reptiles lay soft-shelled eggs on land. Some snakes and lizards have eggs that hatch inside the mother's body.



***Close-up of a frog's eggs.***

Find out more

### Male Seahorses Give Birth

Seahorses are bony fish with heads that look like those of horses. Female seahorses lay eggs inside a pouch on the male's stomach. The male gives birth to young seahorses when the eggs hatch! The father takes care of them after they are born.



## Insect Reproduction

Most female insects lay eggs. Male insects fertilize the eggs. Baby insects are called larvae. Larvae from many insects look like tiny adult insects. Some flying insects larvae do not have wings. They often look like little worms. These larvae must go through metamorphosis, a change in form, before they become adults.

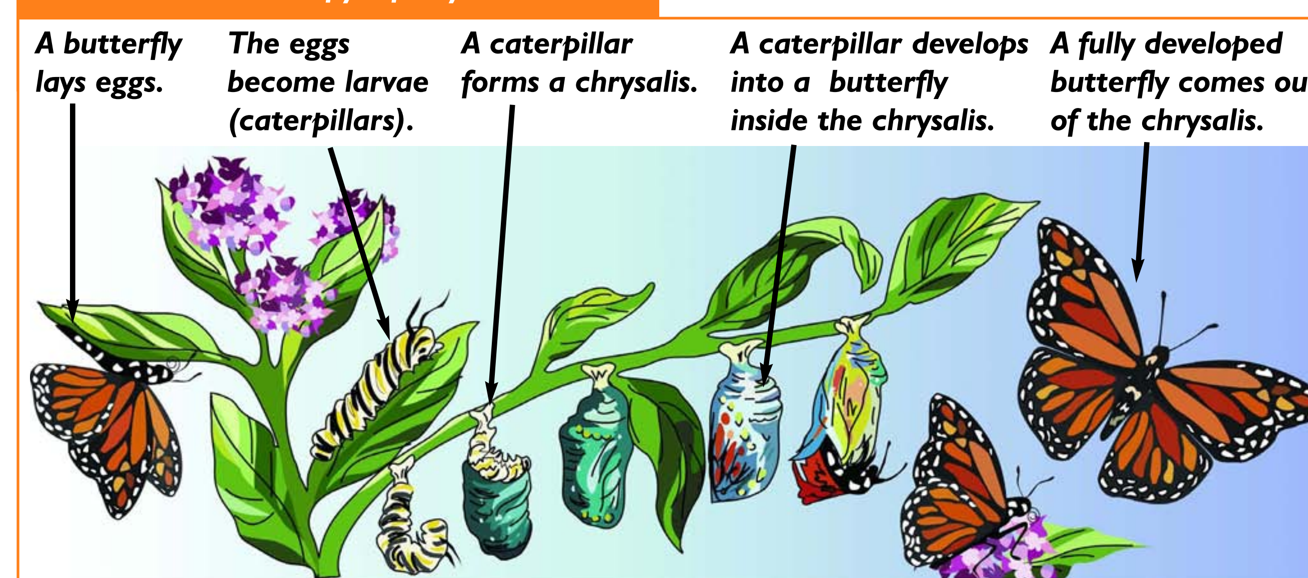
***Caterpillars hatch from butterfly eggs. Through metamorphosis they will become butterflies.***

Find out more

### Metamorphosis

Some animals have babies that look nothing like their parents. Many insects and some amphibians go through a dramatic change in form as they become adults. This change is called metamorphosis. Butterflies and bees go through a complete metamorphosis. Butterflies lay eggs that hatch into larvae called caterpillars. A caterpillar spends its time eating and growing. It enters the pupa stage by forming a chrysalis. The caterpillar develops into an adult butterfly inside the chrysalis case. The metamorphosis is complete when the butterfly comes out of the case.

***The Butterfly Life Cycle***



## Amphibian Reproduction

Frogs go through metamorphosis. The larvae that hatch from frog eggs are called tadpoles. They look like fish because they have gills and a tail that looks like a fin. Tadpoles slowly change into frogs. They grow legs and a mouth after several weeks. Their tails are reabsorbed, or taken back into their bodies. The metamorphosis is done when the tadpole becomes a frog. (See page 19 to see how frog larvae changes into frogs).

## Mammal Reproduction

Most mammals carry their offspring in the mother's body until they can live on their own.

**Marsupials** such as koalas have babies that are not fully developed when they are born. The young marsupial crawls up its mother's fur into a pouch. It grows in the pouch until it can live on its own.

*A koala with her baby.*

**Monotremes** are mammals that lay eggs. The only monotremes are the platypus and the spiny anteater. All other mammals give birth to live young.

**Placentals** are mammals that carry babies in their bodies until they are fully formed. Most mammals are placentals. The developing fetus is connected to the mother through the placenta. The placenta is an organ through which the fetus gets nutrients. The time that the fetus stays inside the mother is called the gestation period. The gestation period for elephants is almost two years. It is less than a month for mice. The gestation period for primates can be as long as nine months.

*A model of a human baby inside its mother.*



## Reptile Reproduction

All reptiles hatch from eggs fertilized inside the female. Most reptiles lay their eggs in nests before the young hatch. Sea turtles lay their fertilized eggs buried in a nest in the sand and leave the eggs unprotected. The newly hatched sea turtles must find their way back to the sea on their own. Pythons lay their fertilized eggs in a nest and protect them from predators.

Some female reptiles such as rattlesnakes carry the eggs inside their bodies. The eggs hatch inside the snake's body and then the mother gives birth to live young. Once the snakes hatch and are born, the young snakes must fend for themselves.

**Different Animals Have Different Gestation Periods**

| | | |
|---|---|---|
| Cat |  | 7–10 week gestation period. Cat babies are called kittens. |
| Dog |  | 7–10 week gestation period. Dog babies are called puppies. |
| Elephant |  | 73–104 week gestation period. Elephant babies are called calves. |
| Human |  | 36–43 week gestation period. Human babies are called infants. |

# Animal Adaptations

Animals have to adapt to the world in which they live in order to survive. Every species of animal has a different way of surviving. Species develop better ways of dealing with their environment over time. Traits that help an animal survive are passed on to the next generation. Traits that are not needed may disappear. After many generations, these changes become adaptations. Adaptations can be both behavioral and physical traits. Physical adaptations might include the shape of a bird's beak, the shape of nose or ears, or even fur color. Behavioral adaptations include special ways animals mate, defend themselves, move around, or get food.

## Behavior

Behavior is what animals do. Some types of behavior are called instincts. Instinct behaviors happen without the animal thinking about it. All animals are born with instincts, like knowing how to eat and sleep. Some behaviors are taught by parents. A female mountain lion may bring home a live rabbit to show her offspring how to hunt. Some behaviors are taught by experience. A dog that is stuck with quills learns not to get too close to a porcupine. Most animals use both instincts and learned behavior to adapt to their world.

***An Arctic fox's fur is white when there is snow on the ground.***

***When the snow melts, the Arctic fox's fur turns dark. This way it blends into its surroundings.***



## Defense Mechanisms

Many animals have defense mechanisms. These are adaptations that help them protect themselves, or defend themselves from predators. Porcupines and hedgehogs have sharp spines called quills on their backs and tails. The quills rattle when they are shaken. This is a warning to their enemies. The porcupine can release quills into the nose or body of a predator if attacked.

***Porcupine quills.***

A skunk raises its striped tail when threatened. If the attacker does not go away the skunk squirts a bad-smelling liquid to make the attacker leave. Squids and octopuses can squirt a dark ink in the water when threatened. The ink hides them so they can escape. A turtle has a hard shell that surrounds its entire body. Only the head and legs stick out. It can quickly pull them inside if attacked.

***A squid.***

Many animals protect themselves simply by the way they look. Some animals try to hide against a background. They hide themselves with colors or patterns that match the world around them. This is called camouflage. The stripes on zebras help them blend into one another when they stand in a herd. This makes it difficult for a predator to pick out a single zebra.

***With so many stripes, it's hard to find one zebra!***

Some insects look like leaves and sticks. Leaf butterflies in southern Asia look exactly like tree leaves until they move. Stick insects look like twigs and branches of plants.

***Stick insects look like part of the plant they hide in.***

Bright colors on animals attract mates and warn predators. Many butterflies have brilliant colors. Their coloring helps males and females find each other for mating. Bright red insects often warn predators that they are poisonous. Red ladybugs taste bad.

***The ladybug's color warns predators not to eat them.***

## Hunting

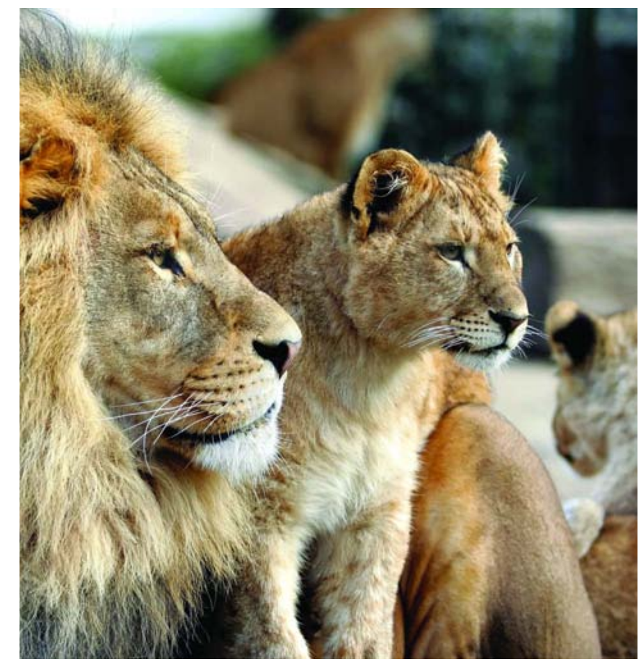
Predators are meat-eating animals that hunt for their food. Many types of animals hunt. Birds hunt for insects to feed themselves and their offspring. Birds of prey hunt small rodents, fish, and other birds.

***Osprey hunt fish.***

***Smaller birds hunt worms and insects.***

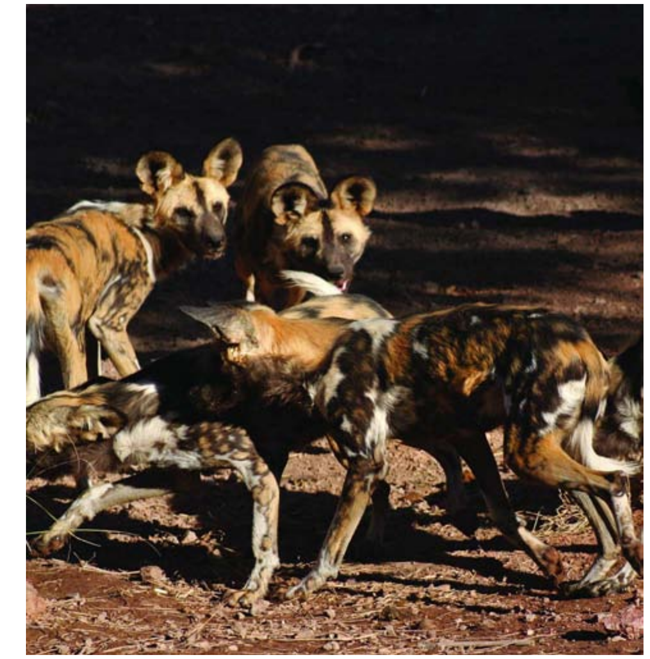


Cats and dogs are the best hunters among land mammals. Cats, like tigers and leopards, usually hunt alone. A cat watches from a hiding place and sneaks up close to its prey. Sometimes, cats hide the dead body, or carcass. They can eat from it for several days. Mothers may bring the carcass back to their offspring. Lions are the only cats that hunt in a group, called a pride.



***Lions hunt in groups called prides.***

Many dogs, like wolves, hunt in a group called a pack. Hunting in a group is a way for predators to work together to catch their prey. The predators will watch for a young or weak animal. As a group they can easily chase an animal that is separated from its herd.



***A pack of African wild dogs.***

Some animals find or steal food killed by other animals. They are called scavengers. Vultures and hyenas are common scavengers in Africa. Vultures are large birds. Hyenas are like dogs. Both vultures and hyenas try to take carcasses away from other animals.

***A vulture.***

## Social Groups

Many animals live in small family groups or larger groups. Even an animal that lives alone may join other animals of its species for mating or migration.

Migration is the movement of large groups of animals from one place to another. They may be looking for food or a warmer climate during the winter. Insects called locusts fly in swarms. Many birds fly south for the winter in groups called flocks.

*Birds fly in flocks when they migrate.*

Other animals live in large groups for food and protection. Ants, bees, and termites are social insects. This means that they live together in colonies and depend on each other for survival. Life in the colony is controlled by the queen. The queen is larger than the other insects and is the only one in the group that lays eggs.

*Some wasps live together in colonies.*

Many hoofed mammals live in groups called herds. Some animals in the herd can eat while other animals watch for predators. The males often fight to choose which one is dominant. The dominant members will get to eat before the other members of the herd.

*Many hoofed animals live in herds for protection.*

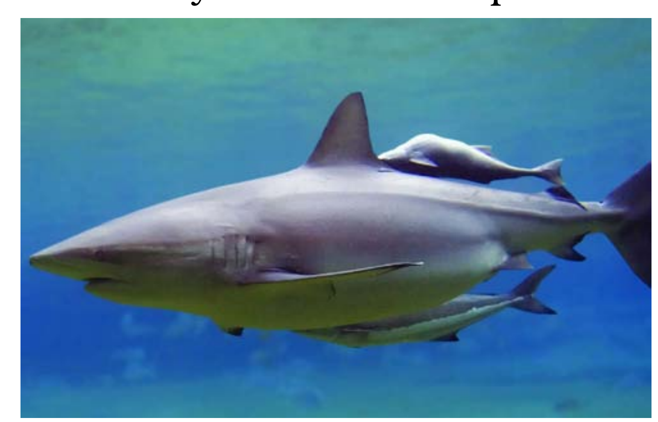


## Symbiosis

Symbiosis is when organisms of different species live together. Many times an animal's survival depends on a symbiotic relationship. Dust mites must eat dead skin that animals shed. They even eat human's dead skin!

### Commensalism

When a symbiotic relationship helps one animal without affecting the other animal it is called commensalism. Remoras are a type of fish that attach themselves to sharks. The remoras get scraps of food and protection from the sharks. The sharks are not affected by this relationship.



*A remora attached to a shark.*

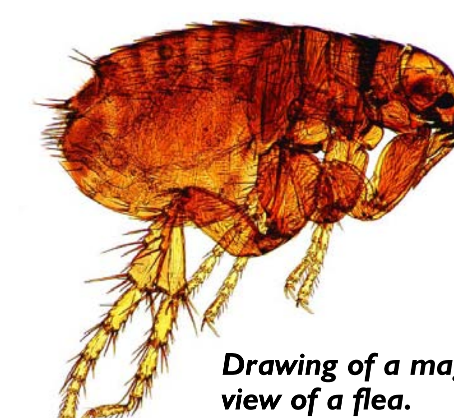
### Mutualism

When a symbiotic relationship helps both animals it is called mutualism. Ants and aphids live together and benefit each other. Aphids make a sweet liquid called honeydew. The ants drink the honeydew and feed it to their larvae. The ants build shelters for the aphids and protect the aphid larvae.

*Ants provide protection and shelter for aphids in return for honeydew.*

### Parasitism

When a symbiotic relationship helps one animal and harms the other animal it is called parasitism. Fleas, ticks, and mites are all parasites that are harmful to their animal host.



*Drawing of a magnified view of a flea.*

# How We Use Animals

Humans use animals for a wide variety of purposes. Animals such as dogs, cats, and hamsters can be family pets. Horse racing and dog shows can provide entertainment for people. Scientists study animals. Some animals are eaten as food. Humans use many different products made from animals. Farmers raise many of these animals.

*Some people enter their pet dogs into dog shows.*

## As Pets

All kinds of animals are kept in homes as pets. Mammals such as dogs and cats are the most common pets. Some people have birds. Snakes and lizards are common reptiles kept as pets. Many people keep different kinds of fish in aquariums in their homes. Other people even keep insects as pets. Ant farms and butterfly gardens are fun to watch and see how those creatures move and change. Many people consider their pets to be an important part of their family.

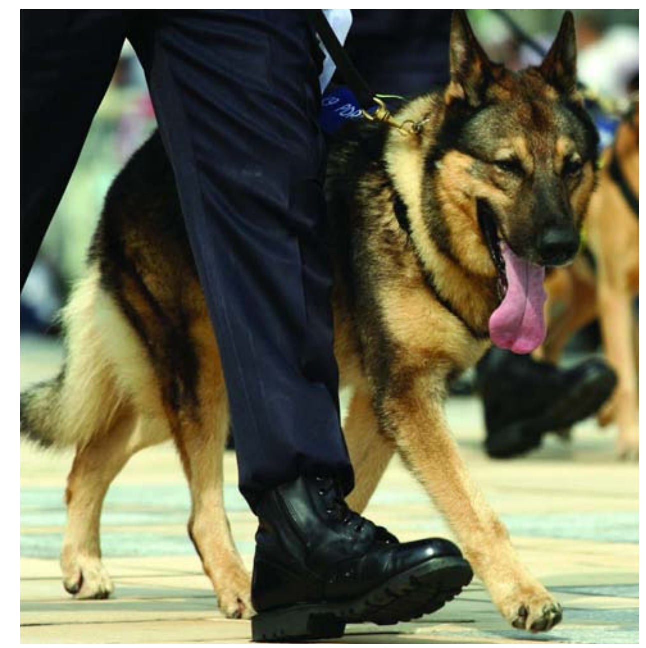
| Number of U.S. Households that Own a Pet (millions) | |
|---|---|
| Bird | 6.4 |
| Cat | 37.7 |
| Dog | 43.5 |
| Equine | 4.2 |
| Freshwater Fish | 13.9 |
| Saltwater Fish | .8 |
| Reptile | 4.4 |
| Small Animal | 5.7 |

| Total Number of Pets Owned in the U.S. (millions) | |
|---|---|
| Bird | 16.6 |
| Cat | 90.5 |
| Dog | 73.9 |
| Freshwater Fish | 139.0 |
| Saltwater Fish | 9.6 |
| Reptile | 11.0 |
| Small Animal | 18.2 |



## In Work and Sport

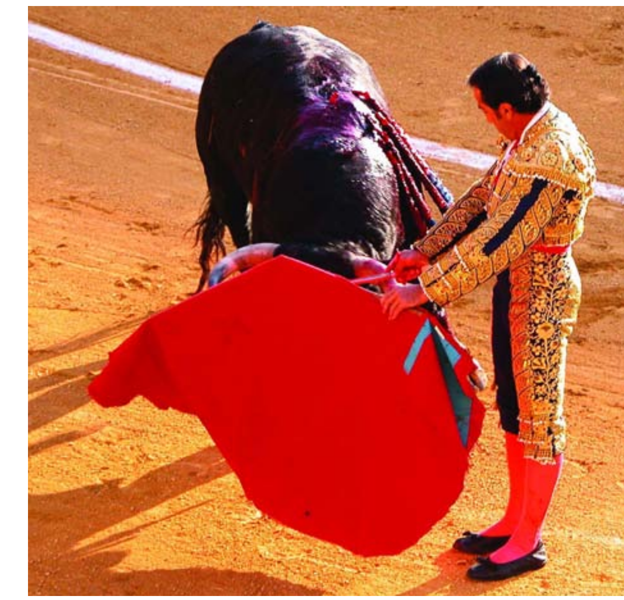
Many animals are working animals. People around the world ride horses, mules, camels, or elephants when they need to go places. Oxen are used to pull plows in fields on farms in many parts of the world. Dogs are used by the police to sniff packages and to track down missing persons and criminals. Rats can be trained to string cables in places that are hard to reach.



*Police dogs are trained to help police.*

Some animals are used in sports. Jockeys ride horses in races. Many people enjoy hunting wild animals such as deer, rabbits, and wild turkeys for sport. Dogs can be used to help hunters kill and fetch their prey.

Matadors, or bullfighters, in Spain and Portugal fight bulls to entertain crowds of people. North America is home to most cowboys who entertain crowds at rodeos.



*Bullfights are held in Portugal and Spain.*

## In Scientific Experiments

Scientists study animals to learn about many different things. Experiments are tests to see if an idea works or not. Scientific experiments are done on animals to find out more about animal behavior. They are also done to test drugs, shampoo, and makeup as well as medical advances for humans that might help to cure a disease.

## For Food

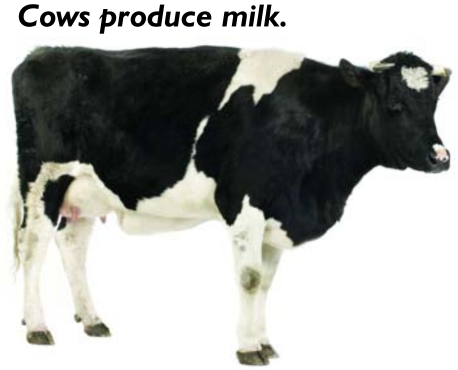
Many animals are eaten as food. Meat from cows is called beef. Meat from a baby cow is called veal. Meat from birds is called poultry. Meat from pigs is called pork. People also eat seafood. Seafood includes all kinds of fish, mollusks, and crustaceans. Mollusks that people eat include squids, octopuses, clams, oysters, and snails. Crustaceans that people eat include lobsters, crabs, shrimp, and crayfish. Some people like to eat sushi, which is usually uncooked seafood.

Other foods that we eat come from or contain animal products. Honey comes from bees. Milk comes from cows and goats. Chickens can lay unfertilized eggs that are eaten. Gelatin comes from animal tissues and is used in several food products, like some jellies and ice creams.

*Bees make honey.*

*Chickens lay eggs.*

*Cows produce milk.*





## Other Animal Products

Animal products are things we use that come from animals. Wool, silk, leather, and the fur from some animals are used to make clothes. Wool is trimmed from sheep. Silk comes from the cocoons of silk worms. Leather comes from the skins of cows and other animals. Animal products are also used in a number of cosmetics. Perfume is sometimes made from the oils of whales.

*Sheep are sheared for their wool.*

## Animal Rights

Many people believe that the use of animals in experiments and in the testing of products is cruel and wrong. They believe that humans should treat animals with respect. They are concerned about the treatment of animals raised to be used for food and to make other animal products. Many animal rights activists believe humans do not need to eat or use animal products. Some people also worry about the methods used for the testing of products on animals. Other groups of people such as The Humane Society work to educate others on how to prevent cruelty to animals.

*Mink is just one animal of many that have been hunted for their fur.*

# Endangered Species

Life on Earth exists in a balance between the environment and the plants and animals that live on it. Throughout history, animals have become extinct when the environment changed. Scientists have discovered and documented many animals that have become extinct by studying fossils. Today, many species of animals are threatened by human activity and environmental changes. Endangered species are animals that are close to becoming extinct.

Many countries are taking steps to protect endangered species. Some countries have banned the sale of endangered animals and animal parts. Some governments have introduced land management programs to protect habitats. The United States has set up National Parks to help preserve many habitats and environments for the future.

## Changes to Habitats

Some animals, such as the panther, are endangered because the places they live, known as habitats, are being destroyed.

Humans destroy many animal habitats as they build more houses and cities. Wetland habitats including lakes, rivers, swamps, and marshes are often affected by development. Many birds, insects, fish, and other animals that make their homes in wetlands die when their food supply is destroyed.

***Deforestation destroys habitats.***

The destruction of forests, or deforestation, throughout the world has also put many animals in danger. In South America, the Amazon Forest is being cut down to make room for farms and to make grasslands for cows. The habitats for many insects, birds, and other animals are being destroyed.

People sometimes release non-native species such as Cuban tree frogs or pythons to a habitat. These new species often destroy the balance of the native animals living in the habitat.



## Pollution

The biggest human created danger that affects the world environment is pollution. Pollution is the poisoning of water, land, or air by chemicals or other things. The pollution of oceans, lakes, rivers, and streams has killed and endangered many animals. The Great Barrier Reef in Australia is home to thousands of animal species. Much of the coral reef has been destroyed by a combination of pollution and too many starfish.

***Fish and coral of the Great Barrier Reef.***

## Hunting and Poaching

Hunting and poaching, or illegal hunting, are threats to many species of mammals. Whales are killed for their oil and meat. Monkeys are taken from forests in Africa and South America for medical research. Elephants and rhinos are killed by poachers for their ivory tusks and horns. Many of these animals have become endangered.

***Zebras are killed for their skins.***

### WORDS TO KNOW

**activist** (AC-tiv-ist): a person who speaks or shows support for a cause

**endangered** (en-DAN-jered): to threaten with extinction

**extinct** (ex-STINGKT): when a type of plant or animal has died out

**pollution** (puh-LOO-shuhn): harmful materials that damage or contaminate the air, water, and soil, such as chemicals, gasoline exhaust, and industrial waste

**preservation** (pres-ur-VA-shuhn): to protect something so that it stays in its original state

**threatened** (THRET-uhnd): animals and plants likely to become endangered in the near future

# People Who Study Animals

There are many things about animals that can be studied. We study their anatomy, their behavior, and how they live in the wild. We also learn more about our own bodies, behavior, and development when we look at other animals. We study how animal life can have an affect on humans and how humans can have an affect on animals lives. We study their place in the classification of living things and the history of evolution.

## Zoology

Zoology is the study of all animals. It is a branch of biology. There are different fields within zoology. They are divided into types of animals that are studied. An entomologist studies insects. A herpetologist studies reptiles and amphibians. An ornithologist studies birds. A marine biologist studies animals that live in the ocean. Ethology is the study of animal behavior.

*Two marine biologists draw blood from a dolphin.*

## Veterinarian

A veterinarian, or vet, is a doctor who keeps animals healthy and cares for sick or injured animals. Most veterinarians treat pets. Some treat farm animals, wild animals, and animals that live in zoos.

*A veterinarian examining a small dog.*

Rourke's World of Science

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Volume 3

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# Table of Contents

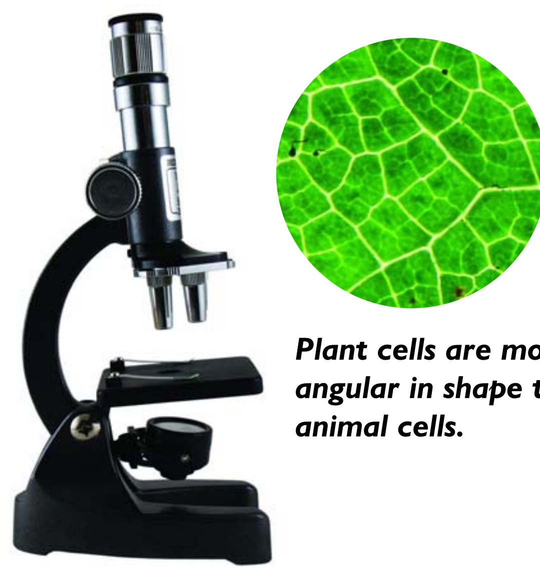
# What Is a Plant?

Plants and animals are living things, or organisms. Plants make it possible for all the other living things to exist on planet Earth. While plants are similar to animals in some ways, they are unlike animals in many more ways. Plants, like animals, are made up of cells.

Most plant cells contain a green pigment, called chlorophyll. Animal cells do not. Chlorophyll makes it possible for most plants to absorb energy from sunlight. Using a cell process called photosynthesis, plants use that energy (along with water and carbon dioxide molecules) to make food substances and release oxygen. Plants provide all the food and oxygen that animals, including people, depend on.

Fungi are not considered to be plants. They have no chlorophyll. They digest dead things and absorb nutrients from them. These saprotrophs are nature's recyclers.

*Plants also need water to carry out photosynthesis.*



*Plant cells are more angular in shape than animal cells.*

*While mushrooms resemble plants, they are actually in the fungi kingdom.*



## The Size of Plants

Unless you use a microscope, some tiny plants, such as some algae, are invisible. Other plants, such as giant Sequoia trees, are hundreds of feet tall. Enormous groves of Aspen trees are hundreds of feet wide.

*Some plants are very small and only seen when magnified.*

*Sequoias can grow up to 379.1 feet (115.5 m) in height and 23 feet (7 m) in diameter at the base.*

## How Plants Live

Many types of plants grow together in forest, grassland, desert, or aquatic ecosystems. Mosses hug the ground in dense mats. Vines climb up and over other plants and objects.

*More than half of the world's plant species live in the rain forest.*

Molds and fungi prefer dark, moist places where there is dead stuff for them to digest and absorb. Soil is loaded with them. So are your sneakers. You may even see them in your refrigerator, on food that has been in there too long.

*Mold is used to produce some of our foods.*

Some aquatic plants live in watery places with their leaves floating on the surface. Desert plants live for long periods without any water at all.

***The lily pad's long stem anchors it to the bottom of the pond.***

Flowering plants are the most common, but many, such as mosses and ferns, do not have flowers. Evergreen trees (pine, spruce, fir, hemlock, and cedar) all have cones instead of flowers.

WORDS TO KNOW

**organism** (OR-guh-niz-uhm): a living plant or animal

**chlorophyll** (KLOR-uh-fil): the green substance in plants that uses light to make food from carbon dioxide and water

**photosynthesis** (foh-toh-SIN-thuh-siss): a chemical process, in green plants that makes food and releases oxygen, from carbon dioxide, water, and sunlight energy

***The seeds of an evergreen tree are produced in its cones.***

Though most plants grow in the wild, people all over the Earth grow and cultivate a large variety of plants. Some are food plants, like rice, wheat, and corn.

***Some of the rice we eat might be grown in this field in Bali, Indonesia.***

We grow other crops for the beauty of their forms and colors of their flowers. We also value plants for the healthful substances they produce, or just the comfort of having them around.



## Classifying the Plant World

There are many organisms on Earth with similar characteristics. The plant kingdom has many divisions. We call each division a phylum. The kingdoms Protista and Fungi also contain organisms with plant-like characteristics, but they are not considered plants. A class is a division of a phylum.

Further division of the plant kingdom follows the groupings of Carolus Linnaeus, used for all organisms. Classes of organisms are divided into groups called orders, followed by families, and finally the genus and species.

The genus and species is the first and last name of an organism. They are Latin names. Every known organism on Earth has a scientific name, in Latin. The Latin name for human is Homo sapiens.

When we think of plants, we often think of plants belonging in the Coniferophyta or the Anthophyta phylums.

### Carolus Linnaeus

Getting to know...

Carl von Linné was born in Sweden in 1707. We know him by his Latin name, Carolus Linnaeus. Linnaeus was interested in nature and plants. He taught himself about biology and botany, the study of plants.

He devised a system to classify all the plants and animals known at that time. He described living things and grouped them by their shared physical characteristics. For instance, he put animals with backbones, or vertebrae, in one group and those without a backbone in another. He put animals that laid eggs in one group and those that had live young in another. Linnaeus gave each group and each kind of living thing a Latin name made up of two descriptive words. Scientists refer to this system as the binomial (two names) system of nomenclature (naming).

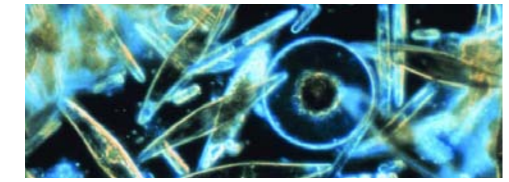
In 1735 he published a series of books, *Systema Naturae*, which described and named all the animals and plants known at that time. Scientists today still use his binomial classification system to organize and understand all living things.

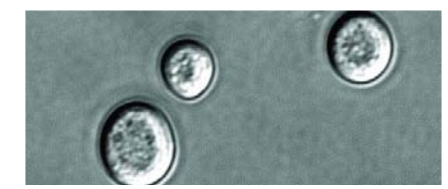
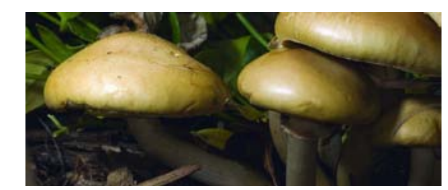
**Coniferophyta** are cone-bearing plants. The cones contain the plants seeds. Some common examples of conifer trees are pines and bald cypress trees. We cut down many conifer trees for lumber.

**Anthophyta** are flowering plants. The two classes of flowering plants are dicotyledoneae (dicots) and monocyotyledoneae (monocots). Dicots are plants with net veined leaves and two-parted seeds. Most broad leaf plants such as magnolias, oaks, and roses are dicots. Monocots are flowering plants with parallel veined leaves and one-part seeds. Common monocots are grasses, lilies, and palms.

| The Plant Kingdom Phylum | | |
|---|---|---|
| Bryophyta |  | Mosses |
| Hepatophyta |  | Liverworts |
| Pteridophyta |  | Ferns |
| Lycopophyta |  | Club moss |
| Coniferophyta |  | Cone-bearing plants |
| Anthophyta, also called angiosperms |  | Flowering plants |



| The Protista Kingdom | | |
|---|---|---|
| Protista |  ***Marine diatoms as seen through a microscope.*** | Algae and Diatoms |

| The Fungi Kingdom Phylum | | |
|---|---|---|
| Zygomycota |  | Black molds |
| Ascomycota |  | Green molds,blue molds, yeasts, mildew |
| Basidiomycota |  | Mushrooms, puffballs |

# The Parts of Plants

## Plant Cells

All living things are made up of small parts called cells. Plant and animal cells are similar. Animal and plant cells have a nucleus that contains genetic substances, such as DNA. Around the nucleus there is jelly-like cytoplasm.

Both plant and animal cells have special structures in their cytoplasm, called organelles.

Mitochondria use nutrients to release energy for the cells. The endoplasmic reticulum is a folded membrane that makes proteins and fat molecules.

A noticeable difference between plant and animal cells is their shape. Plant cells have rigid cell walls around them. This causes plant cells to be rectangular and blocky. The walls are made of a tough material called cellulose.

## Robert Hooke

**Getting to know...**

Robert Hooke was born in England in 1635. He went to Oxford University in 1653. He later became the chief scientist for the famous Royal Society of London, a gathering of the foremost scientists of that time. The society had a meeting every week. Hooke performed three or four new experiments at each meeting.

Hooke was curious about living things. He used an instrument called a microscope to look at objects up close. Hooke looked at insects, plants, hair, and fossils.

He became the first person to see cells when he looked at a piece of bark under his microscope. Hooke made drawings of what he saw. In 1665, he published his studies in a book called *Micrographia*.

*An illustration from Hooke's* **Micrographia**

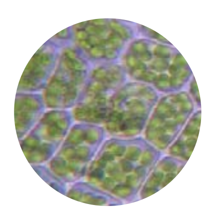
### WORDS TO KNOW

**chloroplast** (KLOR-uh-plast): a plant cell structure that contains the green pigment, chlorophyll

**mitochondria** (mitt-oh-KAHN-dree-uh): a cell structure that takes energy from nutrients and makes it available for other cell processes

**phloem** (FLOW-uhm): tubular cells in plants that carry food from leaves to roots

**xylem** (ZIE-luhm): tubular cells in plants that carry water and nutrients from roots to leaves



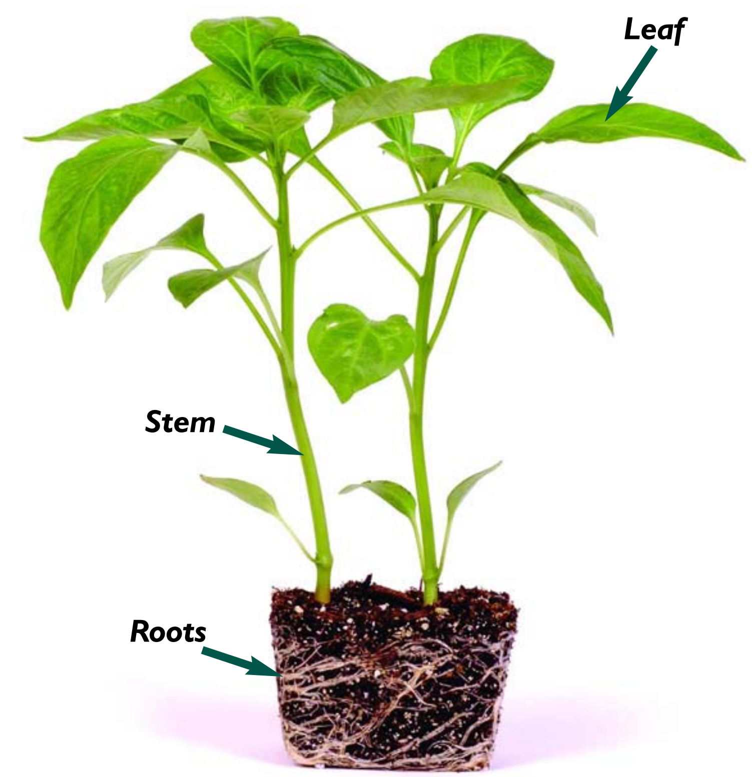
***Magnified plant cells have a blocky appearance.***



# Vegetative Parts

Plants have many parts, or organs. Each plant organ has a particular use, or function. Roots, stems, and leaves are the vegetative organs of plants.

Some organs are underground. Roots absorb water and nutrients from the soil.




Leaves are above ground. They absorb the energy from sunlight and carbon dioxide from the air for photosynthesis.

Stems hold up the leaves. Stems also transport substances between the roots and leaves.

## Roots

Roots are the underground parts of plants. Plants need a large, branching root system to perform several functions. By branching and re-branching, plant roots create many surfaces to absorb with and hang on to the soil.

Plants, such as dandelions, grow long roots called taproots that reach water deep in the ground. Other plants, such as witch grass and black spruce trees, grow and spread their roots near the surface.

### Functions of Roots

- **Roots connect plants to the soil.** Millions of microscopic root hairs cover their growing tips. The root hairs absorb water and nutrients from the soil.
- **Roots anchor, or hold a plant in the ground.** Plants with strong, branched roots will not wash away in a storm.
- **Roots store nutrients.** People eat the roots of many plants such as carrots, turnips, beets, and radishes.

## Stems

The stem of a plant usually grows above the ground surface. Stems can be short, or very long. We find buds, leaves, flowers, fruits, or cones on the stems. Some plants have thorns and tendrils on their stems, too.

When seeds germinate, or sprout, a part called an epicotyl, or leafy shoot, develops into stems and leaves.

Some plants have soft, green stems called herbaceous stems. They usually live for one season. Woody stems are harder and live for many years. Stems may start out as herbaceous and become woody as they grow.

Irises, ferns, and other plants have special underground stems called rhizomes. Tubers are thick underground stems with buds called “eyes”. Potatoes are tubers.

*These iris rhizomes will grow into beautiful plants.*

*Potatoes are structures called tubers.*

*An epicotyl develops into leaves and a stem.*



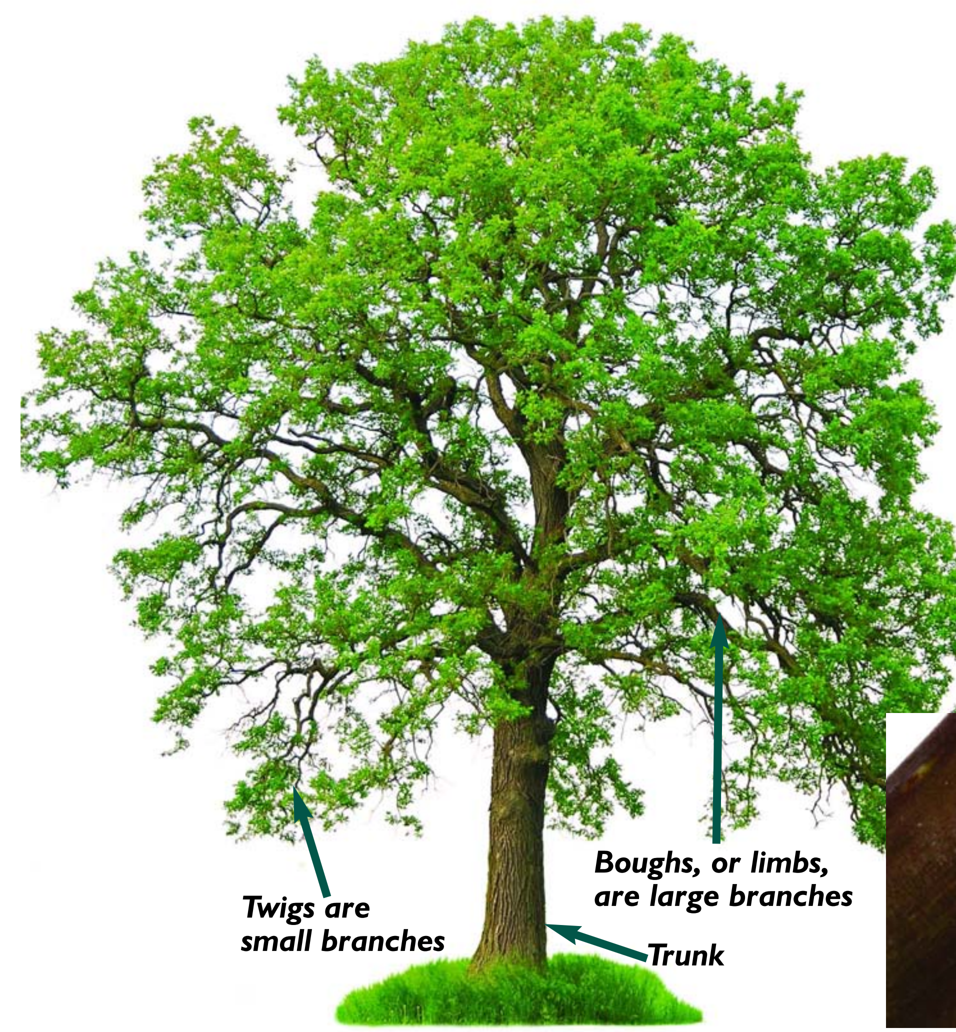
**Branches** form as the stems of trees grow and divide. Twigs are small branches. Boughs or limbs are large branches.

**Trunks** are the large single base of a tree. Tree trunks vary from tree to tree. They may be long and bendy or short and sturdy.

Trunks that grow for many years produce a ring of wood each year called a growth ring. When a tree is cut down, you can count the growth rings in the trunk to figure out the tree’s age.

**Bark** is the hard covering of the trunks and stems of woody plants. It protects the plant from insects and injury. Some desert plants, such as cacti, have chlorophyll in their bark and use it for photosynthesis.

On smooth, young stems you can see tiny dots, called lenticels, which allow air to get into the stems.




*Look closely and you can see the growth rings in this cross-section of a tree trunk.*

*Lenticels allow air to get into the stem.*

### Functions of Stems

- Stems hold up the leaves to get energy from the Sun.
- Stems support the flowers, and the fruits and seeds, that grow from them.
- Stems permit the flow of water and nutrients between roots and leaves.

**Find out more**

Some of the most common desert trees around Tucson, Arizona are Yellow Paloverde trees. Paloverde means "green stick" in Spanish and refers to their distinctive green bark.

Most plants have chlorophyll in their leaves. Paloverde bark is green because it contains the chlorophyll the plant needs for photosynthesis. Three-quarters of the photosynthesis in Yellow Paloverde trees takes place in their green bark instead of in their tiny, rather sparse leaflets.

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## Leaves

Leaves grow from stems and are usually flat, thin, and wide to absorb a lot of sunlight for photosynthesis. Bulbs are underground leaves that store food. Onions and garlic are plants that grow from bulbs. Tulips, daffodils, and gladiolas are flower garden plants that grow from bulbs.

*Did you know that for each leaf, there will be a ring of onion? The larger the leaf, the larger the ring will be.*

**Shapes, Sizes, Colors, and Pigments of Leaves.** There is great variability in the shapes, colors, textures, and size of leaves among plants. They can be needle shaped, rounded, pointy, smooth, or wrinkly.

*It is easy to see the vein pattern on these ivy leaves.*



Palm trees have leaves six feet (1.83 m) long, or bigger. The tiny leaves of duckweed (an aquatic plant) are only about one eighth of an inch (2.5 mm) long.

*This magnified photo gives a close-up view of duckweed leaves.*

● ⟵ *Actual size of duckweed leaves.*

Leaves can be pink, purple, green, and white. But most leaves are green because their cells contain a green substance, or pigment, called chlorophyll, for photosynthesis.

*The same leaf can be different shades of green.*

In the fall you can see other pigments contained in leaves. When cool temperatures and short days cause the breakdown of chlorophyll, the red, yellow, and orange colors become visible. Deciduous trees lose their leaves in the fall.

### Vein Patterns of Leaves

**The parallel pattern** is common among grasses, such as lawn grass, wheat, rice, and corn. Their veins run side-by-side from the base of the leaf to its tip.

**The pinnate pattern** resembles the branching pattern of a Christmas tree. Birch, alder, elm and beech trees have pinnate veins.

**The palmate pattern** of maple trees has several large veins that spread out like your fingers from the palm of your hand.

**Functions of Leaves**

**Absorbing sunlight for photosynthesis is the main function of plant leaves.** The chlorophyll contained in the leaves is vital for photosynthesis. In this process, plants convert light energy to food.

## Reproductive Parts

Plant reproduction results in new generations of plants. Flowers, cones, fruits, and seeds are the reproductive parts, or organs, of plants. Flowers and cones are for making new plants. Fruits and seeds contain the undeveloped baby plants, called embryos. Special cells called spores, eggs, sperms, and pollen are part of the process in different plants, also.

WORDS TO KNOW

**herbaceous** (hur-BAY-shus): non-woody plants

**nutrient** (NOO-tree-ehnt): a necessary substance found in foods

### Spores

Some living things without flowers can use cells called spores to reproduce. These kinds of cells can grow into new plants. Algae, fungi, mosses, and ferns use spores for reproduction. The organisms release huge numbers of spores because most of the spores do not survive long.

Released spores travel by wind and water to spread out away from the parent organisms. Insects and animals can also trigger the release of spores and end up carrying them to other places, too.

*Each of the dots on this leaf contains thousands of spores.*

### Cones

A cone is a special type of reproductive structure with spiraling rows of hard, woody scales. Conifers are trees with cones. Pine, spruce, cedar, cypress, hemlock, fir, and tamarack trees are conifers. The cones on juniper trees and yews resemble berries.

Conifers have two types of cones. Male cones produce pollen grains. Female cones make egg cells. When egg cells are joined with pollen they develop into seeds. The seeds form at the base of each cone scale.



*These female cones are much larger than the male cones from the same evergreen tree.*

### Flowers

Flowers are the reproductive parts, or organs, of most kinds of plants. Flowers produce fruits with seeds in them. New plants grow from the seeds.

Petals and sepals make up the outer part of a flower. Petals are usually soft and brightly colored.

The sepals are greenish scale-like structures, which protect the flower while it is developing.

The male stamens are inside the petals and produce the pollen. The female pistils occupy the center of a flower. Egg cells are produced in the ovary at the base of each pistil. The top of each pistil has a sticky surface area, called the stigma, where pollen grains land.

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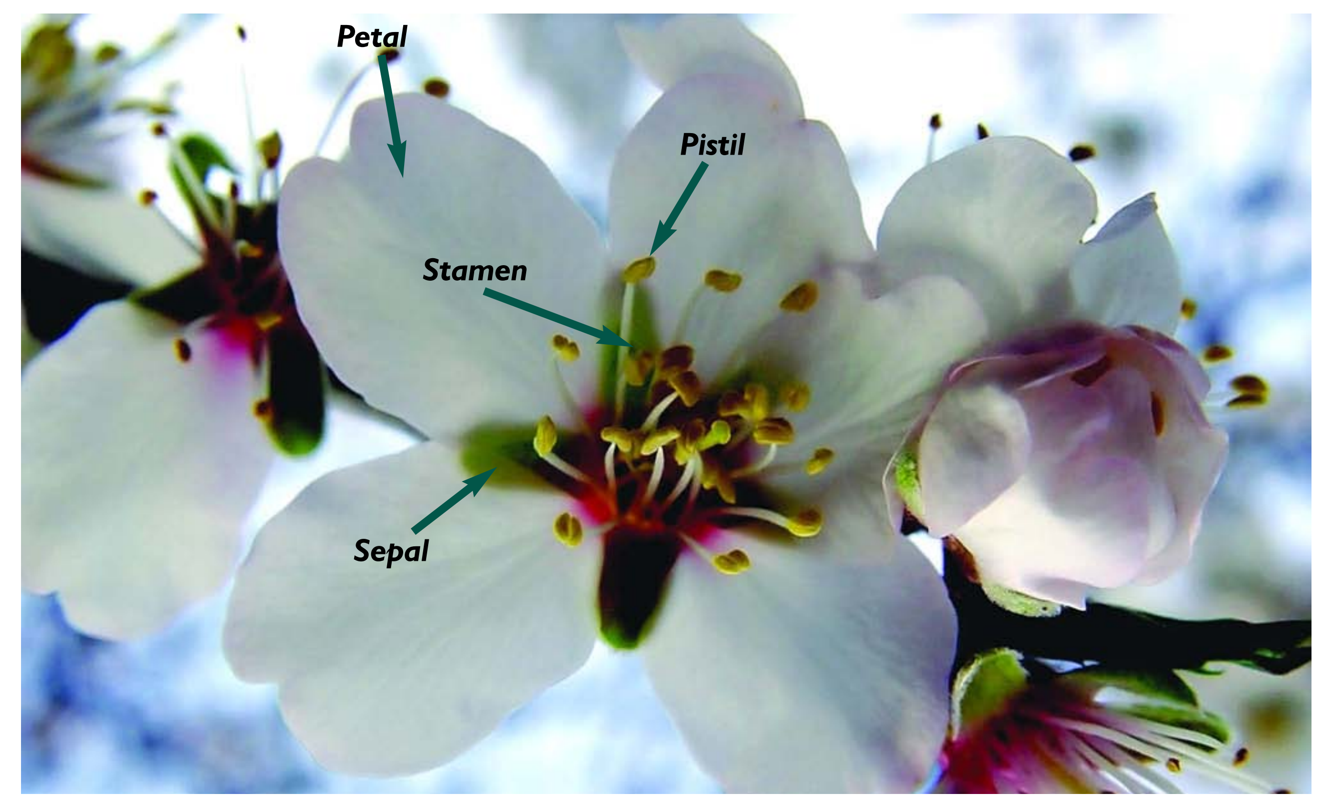

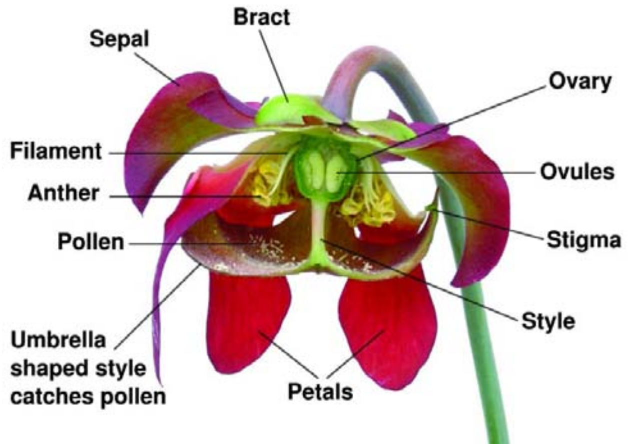


**Shapes, Sizes, Colors, and Pigments of Flowers.** Flowers occur in many colors, forms, and arrangements on plants. Their colors range from shades of red, orange, yellow, blue, purple, and white. Many are multi-colored. Flowers may be cup-shaped, trumpet-like, or starry. Some flowers are tiny, such as forget-me-nots. Sunflowers are enormous in comparison. Do you enjoy the fragrances, or smells, of flowers, such as roses or lilacs?

### Words to Know

**anther** (ANN-thur): the male flower structure that produces pollen cells

**ovary** (OH-vur-ee): the female structure that contains egg cells

**pistil** (PIS-tuhl): the female structure at the center of a flower

**pollen** (PAH-lehn): the male cells of flowering plants

**stamen** (STAY-mehn): the male flower structure that is composed of an anther at the tip of a long, thin filament

The shapes, colors, and fragrances are also very important to the plant because they attract insects, birds, and bats. These animals help to spread pollen from flower to flower.

## Fruit

Fruit is actually the ripened part of the plant ovary that contains seeds. Some fruits are hard and dry. Other kinds are soft, sweet, and juicy. Both kinds protect the seeds inside and help to spread, or disperse them in the environment.

Gourds are tough or hard fruits with shells. They contain seeds and pulpy flesh. Plant relatives of gourds include pumpkins, melons, cucumbers, and squash.

*In the fall, we enjoy many seasonal gourds.*

Edible dry or hard fruits are nuts and beans. Acorns, produced by oak trees, are important wildlife food for bears, deer, squirrels, and birds. Long ago, some Native American Indian people used acorns as food, too.



| Fleshy Fruit | |
|---|---|
| **Drupes:** Some fruits, such as avocados, cherries, plums, and peaches are called drupes and have a hard seed known as a pit. |  |
| **Berries:** Soft, often brightly colored fruits, containing many seeds are berries. Grapes and tomatoes are actually berries. Oranges and other citrus fruits are actually modified berries with a tough skin, or rind. |  |
| **Pomes:** Soft fruits with a papery core and seeds in the middle are pomes. Apples and pears are pomes. |  |
| **Aggregates:** Raspberries and blackberries are aggregate fruits. Aggregates are clusters of tiny drupes. |  |
| **Multiple:** Pineapples and mulberries are multiple fruits. Multiple fruit develops from a cluster of flowers. |  |
| **Accessory:** Strawberries are accessory fruit. Accessory fruit have tiny hard seeds scattered all over their surface. |  |

Sometimes plants produce fruit that have no seeds. These plants cannot reproduce naturally (because they have no seeds). Plant scientists have figured out different ways to reproduce these kinds of fruit.

**Find out more**

Many people prefer eating seedless varieties of fruits such as watermelon, grapes, grapefruit, and oranges. Grafting is one way to reproduce the seedless varieties of fruit trees.

Grafting is the process of taking small stems and buds from a seedless tree and putting them into a cut in the bark of another tree of the same kind that has seeds. The bud or twig is covered with wax and tape to protect it until it begins to grow and the cut heals.

Later, that bud or twig will produce flowers and fruit that are seedless.

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## Seeds

A seed consists of an embryo and a cotyledon. The embryo is a baby plant, and the cotyledon is a stored food structure. The seeds of plants may be as small as dust particles or as big as a coconut. Nuts and grains are seeds. Seeds germinate, or sprout, and grow into new plants.

*Coconuts are large seeds.*

**Gymnosperms,** such as evergreen trees, grow seeds on the cones of the plants.

**Angiosperms,** or flowering plants, produce their seeds within the female ovary of their flowers.

**Two Types of Seeds**

**Monocotyledon seeds** have one cotyledon and come from plants such as corn.

**Dicotyledon seeds** have two cotyledons and come from plants such as beans.

*Comparison of monocot (left) and dicot (right) sprouting.*

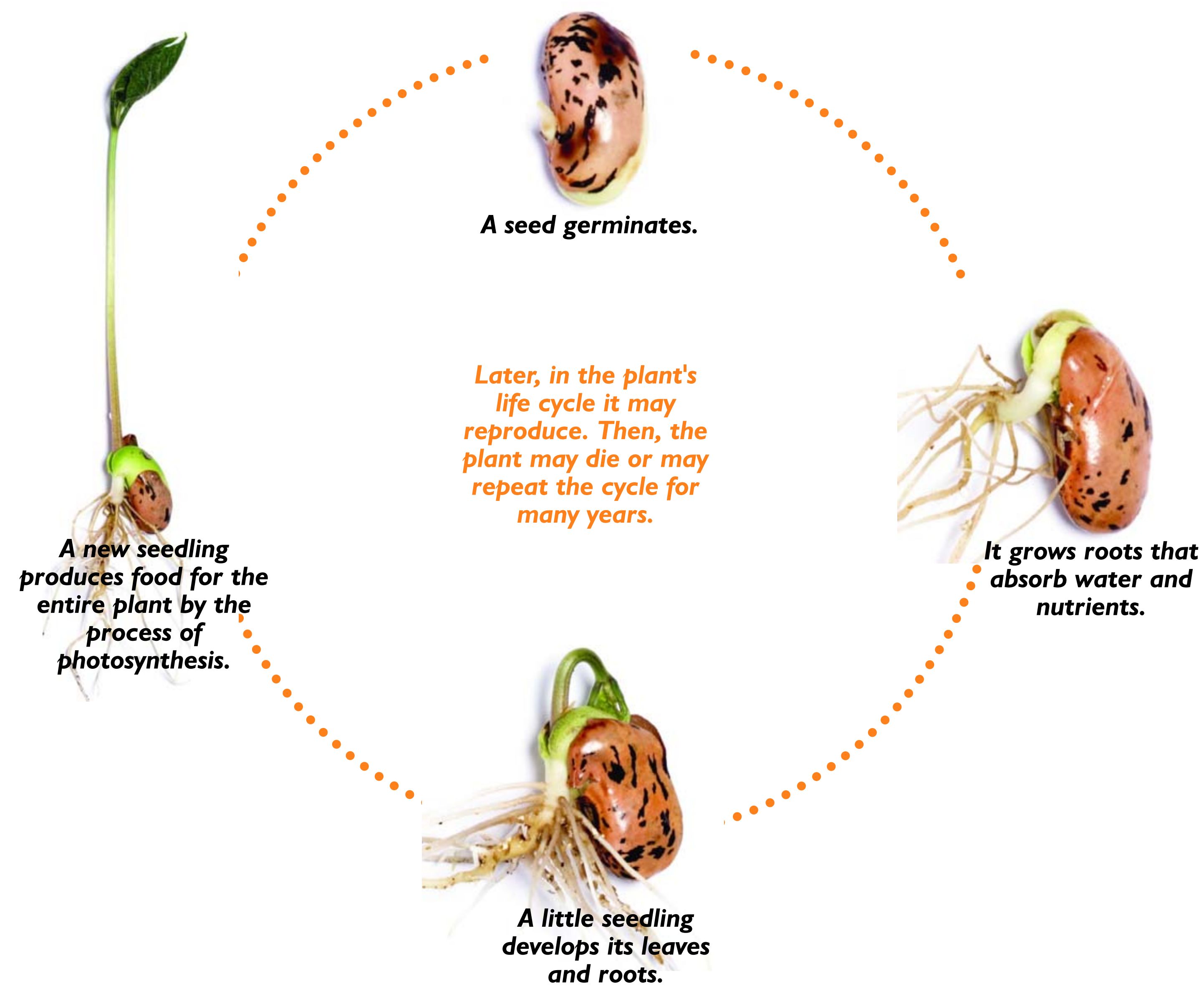


# How Plants Grow

## The Life Cycle of Plants

Plants grow and develop in stages called a life cycle. Most plants begin life as a spore or a seed. Some plants make spores that grow into new plants. Other plants make seeds.

Flowers make seeds from egg cells fertilized by pollen. Wind, water, insects, and animals disperse spores to new places where they can grow.



# Plant Reproduction

All plants must make new plants for their kind to survive. Reproduction is the name of this process.

Plants reproduce in several ways. Fragments, or pieces, of plants can sometimes grow into new plants. Gardeners make cuttings of stems or leaves and put them in containers of water or wet peat moss to grow them. Since this kind of reproduction does not involve male or female cells, we call it asexual reproduction.

*Cut stems will sprout roots when placed in water. This is asexual reproduction.*

Sexual reproduction, among plants, relies on eggs and pollen. Most plants use sexual reproduction and reproduce by making seeds.

## Mosses, Ferns, and Fungi Reproduction

Some plants, such as mosses and ferns, reproduce by releasing spores.

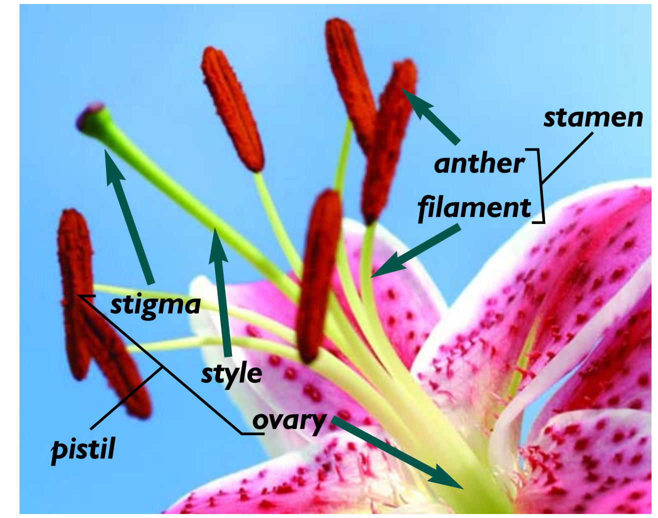
*These fern sporangia will produce spores that wind, water, and animals will carry away.*

Mosses and liverworts can also reproduce with male and female cells called sperm and eggs. Sperm are cells that must swim to the egg, or ovum. A fertilized egg develops into a chamber called a sporangium that grows from the tip of the moss. This sporangium later makes and releases spores that grow into new moss plants. Alternation of generations is reproduction using eggs and sperm, and then spores.

## Flowering Plant Reproduction

Flowering plants use flowers for reproduction. In flowers, anthers on the stamens make the pollen. In cone-bearing plants, a microsporangium makes the pollen.






A pollen grain and an egg cell must combine to produce a seed. In flowering plants, the pollen must get to the top of the pistil of a flower. In cone-bearing plants, pollen enters an egg at a structure called a micropyle.


Pollination is the name of the process by which pollen gets to the egg bearing structure. Wind, water, insects, and animals pollinate flowers.

*A hummingbird pollinating a flower.*

Fertilization is the name of the process that combines eggs and pollen in the ovary of a flower. The fertilized egg, or ovule, then develops into a seed.

**Find out more**

Ears of corn are female flowers. The tassels at the top of the corn plant are the male flowers.

Pollen is shed from the tassels and is carried by the wind to the corn silks at the ends of the ears. Corn silks are long tubes leading to the corn kernels where the egg cells are located.

The pollen cells that land on the silks have to go all the way down the silk tubes to fertilize the eggs.

After fertilization, the egg cells develop into the corn that you love to eat!

### Seed Dispersal Reproduction

When seeds are fully formed they are usually dispersed, or spread out, from the parent plant. The wind carries away some small seeds and seeds with special wing-like structures. Maple tree seeds are winged and flutter to the ground like little helicopters.

*Each maple tree that grows was once a tiny winged seed.*

Seeds, like those of the burdock plant, have hook-like structures and can hitch a ride on an animal by sticking to its fur.

Birds carry seeds and sometimes drop them far away.

**WORDS TO KNOW**

**asexual** (ay-SEX-you-uhl): reproduction without eggs and sperm

**feces** (FE-seez): excrement from bowels

**fertilization** (fur-till-eye-ZAY-shun): the joining, or union of and egg and a sperm cell

**pollination** (pah-luhn-AY-shun): the transfer of pollen from one flower to another

**sexual** (SEX-you-uhl): reproduction with eggs and sperm, or pollen cells

*Some birds carry seeds and drop them far away.*

Animals such as mice and squirrels bury seeds.

*Many squirrels bury seeds.*

Animals eat some seeds and carry them away in their digestive systems. The animals drop the seeds in a new location when they get rid of waste (feces).

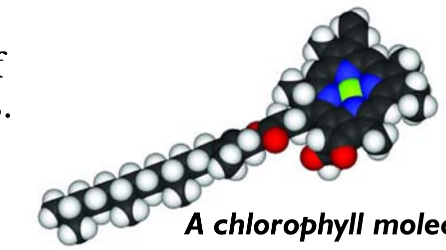
## Photosynthesis

Photosynthesis is the chemical process in plants that feeds all living things on the Earth. Animal life, including people, would be impossible without the food and oxygen produced by plants.



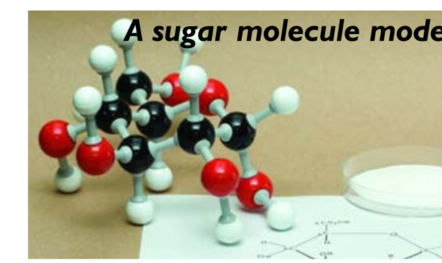
**About Photosynthesis**

Photosynthesis occurs in the green leaves of plants, in cell structures called chloroplasts. Chlorophyll is the sunlight absorbing pigment that powers the process.




Photosynthesis is the process that produces food substances in green plants. Carbon dioxide, from the air and water, and sunlight are all part of the process.

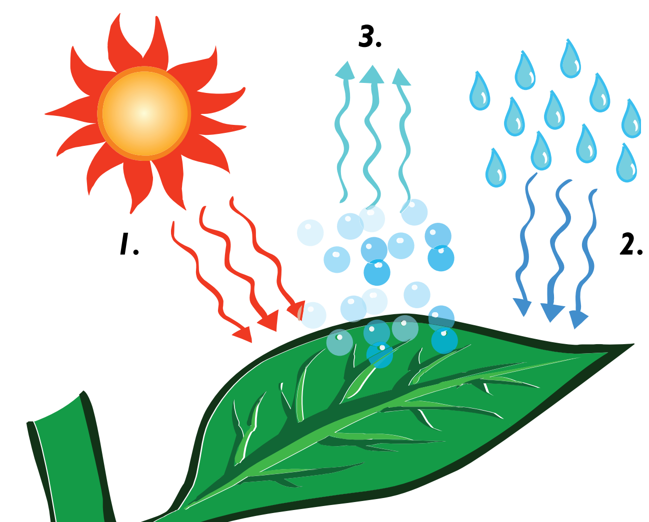
Some carbon, hydrogen, and oxygen atoms combine to make food molecules, such as sugars. The plant releases leftover oxygen molecules into the air.




There are two parts, or stages, in photosynthesis known as the light reaction and dark reaction.

**The Light Reaction** is the first stage and needs sunlight, water, and chlorophyll. During the light reaction water molecules split into hydrogen and oxygen.

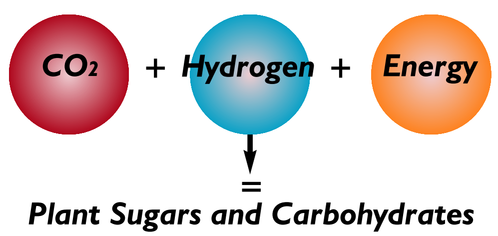
This process depends on the chlorophyll in the plant, which can absorb the sunlight energy needed to split the water. The oxygen is released into the air (that's where we get our oxygen). The second stage of photosynthesis uses the remaining hydrogen and energy.




*The Light Reaction:*
1. *Chlorophyll absorbs energy from the Sun.*
2. *It uses the energy to split water molecules into hydrogen and oxygen.*
3. *The oxygen is released into the air.*

**The Dark Reaction** is the second part of photosynthesis. It needs no sunlight and goes on all of the time. Another name for it is the Calvin Cycle.

This process takes carbon dioxide from the air and combines it with the hydrogen and energy from the light reaction. In this way, plants can make carbohydrates, such as sugars and starches, they need for food. The plant reuses some of the substances produced during the cycle. The cycle repeats as long as the plant lives.




***The Dark Reaction:***

1. ***Carbon dioxide ($CO_2$) from the air is combined with the carbon compound and energy from the light reaction.***
2. ***The plant uses this to make the sugars and carbohydrates it needs to live.***

WORDS TO KNOW

**carbohydrate** (kar-boh-HIGH-drait): a food substance produced by the plant process called photosynthesis

**chlorophyll** (KLOR-uh-fill): a green pigment used by plants to absorb sunlight energy during photosynthesis

**meristem** (MEH-reh-stem): plant cells at the tips of roots and stems, and under the bark, where growth can occur

**The Rate of Photosynthesis**

The rate of photosynthesis speeds up or slows down depending on conditions. The amounts of sunlight, temperature, carbon dioxide, and water affect the rate of photosynthesis. If any of these factors decrease, photosynthesis decreases.

Most regions of the Earth provide just about enough of these factors for plants to grow. In some parts of the world, winter conditions slow, or stop, photosynthesis. The polar ice caps and tops of many mountains are too cold for most plants.

Some deserts, such as the Bonneville Salt Flats, are too hot, dry, and salty for photosynthesis to occur. No plants can live there. In the deepest parts of oceans and very deep lakes, it is too dark for photosynthesis.



Getting to know...

**Karl von Nageli**

Karl von Nageli was born in Switzerland in 1817. He first studied medicine, but became interested in plants and switched his studies to botany, which is the study of plants.

Nageli began to wonder how plants grow and reproduce. After discovering the spores of ferns, he studied mosses, which are simple plants. Nageli also noticed that there are two kinds of tissues in plants. They are structural tissue that has stopped growing and formative tissue that is always growing. He discovered that the formative, or meristem tissues, were located at the growing tips of stems and roots, and under the bark of trees.

Today, wilderness survival trainers know that if you become lost in the woods, you can scrape the meristem tissue from the inside of the bark of some living trees, and survive by eating it. Meristem tissues contain many nutrients, such as proteins and sugars.

# Types of Plants

There are many kinds, shapes, and sizes of plants on Earth. Among them, algae, mosses, liverworts, ferns, and some trees are non-flowering plants. Among the flowering plants are the grasses and other non-woody, herbaceous plants. Shrubs, some vines, and many kinds of trees are woody plants.

***Many different kinds of plants grow in a rain forest, including mosses and ferns.***

### Annual Plants

Annual plants complete their life cycles in one growing season.

*Peas are one kind of annual plant.*

### Perennial Plants

Perennial plants repeat their life cycles and live for many years.

*Day lilies are one kind of perennial plant.*

## Algae

Some algae are part of the Kingdom Protista, and others are part of the Kingdom Eubacteria, and thus are not really plants. We classify common algae by the pigments that they contain. Algae have been around for many years. Fossils show that blue-green algae were among the first living things on Earth.

Algae are made of cells like other plants but have no roots, stems, or flowers. Common green algae live in water or on wet soil, rocks, and other damp surfaces, such as cellar walls, tree bark, and the sides of flowerpots.

*You may also see algae growing on stone steps.*

Algae cells can be like bacteria cells with no nuclei. Other algae are one-celled, such as many of the ocean's plankton. Some plankton are photosynthetic algae, capturing energy from sunlight and converting it into useful food for all sea life.



*Some ice cream contains agar, which comes from red algae.*

When you eat ice cream, you might be eating agar, a jelly-like substance produced by red algae. Agar gives ice cream a smooth texture.

Algae can also cause harm. The rapid growth of blue-green algae in small, polluted lakes can use up so much oxygen that fish suffocate.

*Sometimes algae covers the surface of a lake.*

Lichens are symbionts composed of blue-green algae cells and fungus cells living together. They are grayish-green and you can sometimes find them on apple tree branches and evergreens. Hummingbirds use them to build their tiny nests.

### Different Kinds of Algae

**Spirogyra**, a green algae, lives in groups of cells called colonies.

**Irish Moss** grows on rocks along the shores of the North Atlantic Ocean, and is edible.

**Seaweed and kelp** are brown algae that live in the ocean. Kelp can grow to 100 feet (30.5 m) in length.

**Silica shells** enclose the cells of diatoms.

**Blue-green algae** cells have no nuclei in their cells.

### WORDS to KNOW

**agar** (AH-ger): a jelly-like substance produced by some algae

**diatom** (DYE-uh-tahm): one-celled algae that have shells of silica

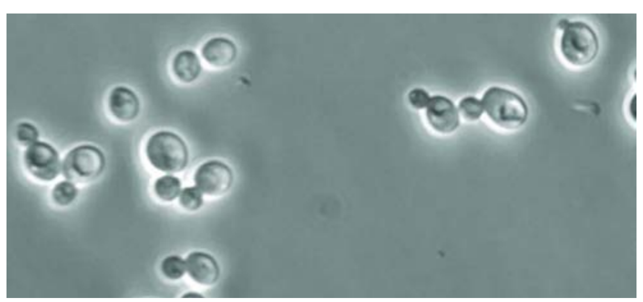
**lichen** (LYE-kuhn): plant composed of a fungus and an algae

**plankton** (PLANK-tuhn): microscopic algae and protozoa that live in the ocean

## Fungi

Fungi resemble plants in some ways. Their cells have walls like plant cells. They reproduce with spores, like mosses, liverworts, and ferns. But, unlike plants, they have no chlorophyll and can't make their own food.

The structure of a fungus consists of tiny thread-like cells that grow in moist, dark places, such as the soil, dead plants and animals, and other organic substances. Some fungi, such as mushrooms, produce a large, visible, spore-bearing structure, but many are microscopic.



*Yeast cells can be seen under a microscope. Yeast is a fungus.*

Fungi get their food by digesting and absorbing dead plant and animal substances. They are decomposers and recyclers of dead things. We call them saprophytes. Common fungi are molds, mildews, yeasts, mushrooms, slime molds, bracket fungi, and puffballs.

### Helpful Fungi

Molds are fungi that sometimes can grow on spoiled foods. Penicillium is a common green mold, which grows on spoiled food.

Penicillium produces a substance, penicillin, which is an antibiotic. Antibiotics kill bacteria and are important to fight against diseases.

Special molds are used to create the flavors of cheese, such as Roquefort and other blue cheeses.



### Helpful Fungi

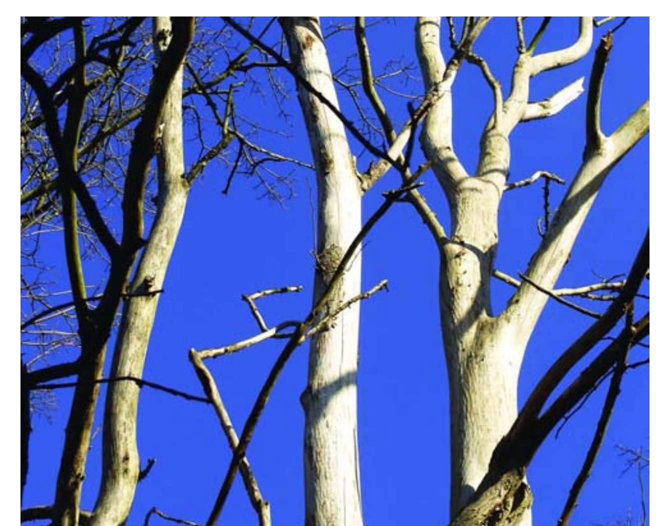
Yeasts are fungi that decompose fruit. They create alcohol and carbon dioxide bubbles when they digest sugars, and are used to make wine and beer. We call this process fermentation.

Yeast also releases carbon dioxide bubbles when placed in bread dough. The dough rises up and becomes light and spongy when baked.

Some yeasts act as germs, or pathogens, creating infection.

### Fungus Diseases

Some fungi cause diseases in plants and animals. Dutch elm disease kills elm trees. Chestnut trees, which were once very common in North America, have almost been eliminated by a blight fungus.



*Dutch elm disease is caused by a fungus.*

Horses and cattle also suffer from a disease called hoof-rot, caused by a fungus.

Wheat, rye, and other grain crops become infected by Ergot fungus. The bread made with flour from ergot-infected grain is toxic, or poisonous, to humans.

*This ergot-infected grain stalk needs to be removed from our food supply.*

### Edible Fungi

Mushrooms are familiar fungi because people eat them in salads, pizza, and other foods. In nature, they grow on organic matter, such as dead leaves, bark, and in rich soils. They have a great variety of colors and shapes, which are of interest to mycologists, who study them.

Many are edible but some are very poisonous. It's best not to eat mushrooms you find growing outside.

**Example of an Edible Mushroom**

**Example of a Poisonous Mushroom**

## Other Fungi

Out in the woods you are likely to see bracket fungi, growing like shelves on dead trees.

*Bracket fungi form spores shaped like wooden clubs.*

Puffballs pop up after a warm rain on lawns. They look like ping pong balls when they are young. If you step on them when they are mature and dried out, they puff out a cloud of spores.

*If you look inside of a puffball, you can see its spores.*

**WORDS TO KNOW**

**decomposer** (dee-cahm-POZ-er): an organism, such as a fungus, that digests dead material and absorbs nutrients to live

**fermentation** (fur-men-TAY-shun): a chemical process used by some bacteria and fungi to digest sugars

**organic** (or-GAN-ick): carbon-containing substance remaining after living thing has died

**Find out more**

**FUNGI CAN BE HUGE**

The largest living things are not plants or animals. They are fungi. Some fungi weigh thousands of pounds. They live underground and cover areas of many square miles.

In the cool, wet, coastal rain forests of the northwestern United States, these fungi destroy large areas of trees.

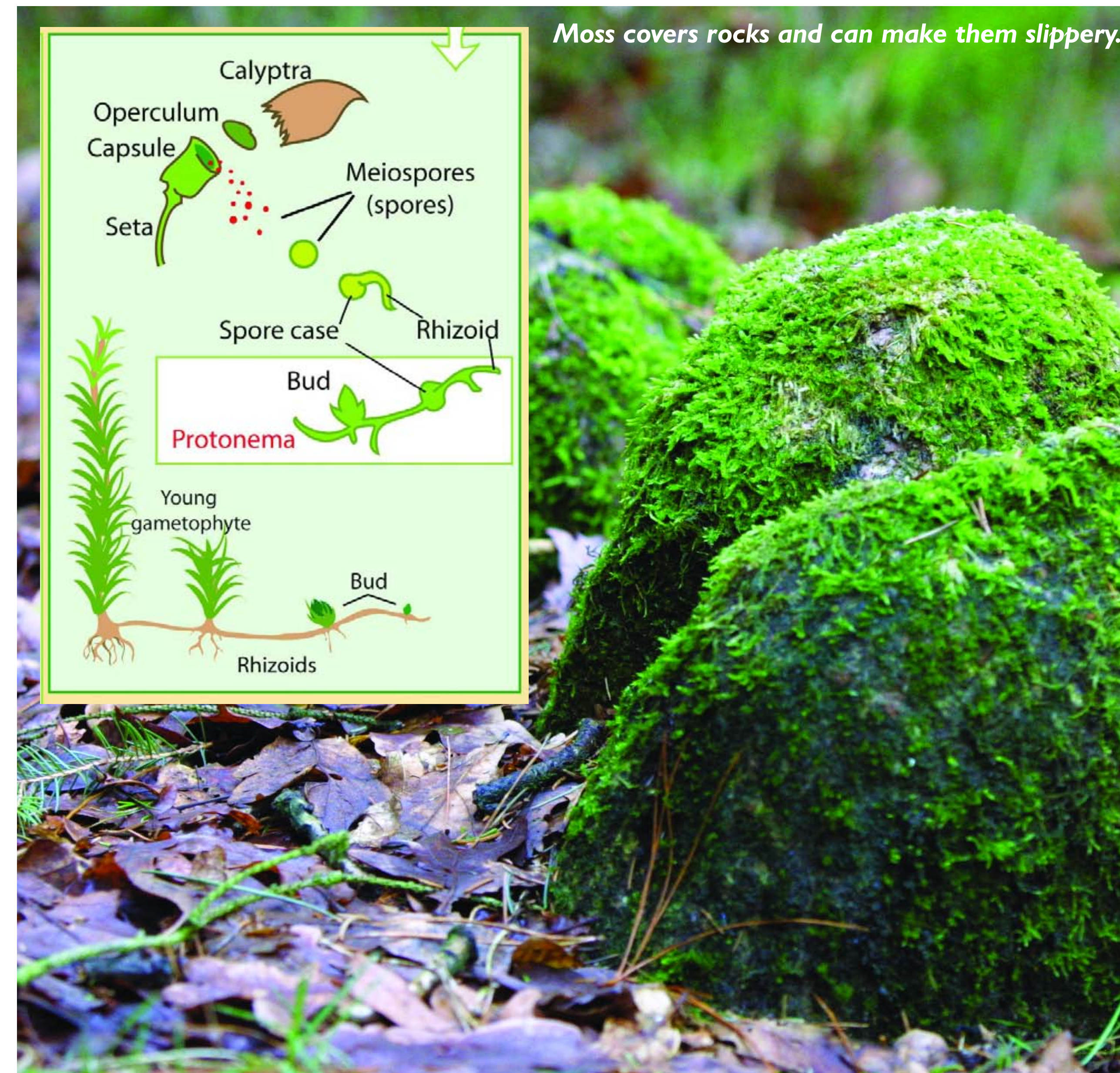


## Mosses and Liverworts

Mosses and liverworts are small, simple, green, flowerless plants. They grow in moist, shady places all over the Earth. They attach themselves to cool and damp surfaces with root-like threads, called rhizoids.

Mosses grow in dense carpets made up of thousands of individuals. Mosses contain chlorophyll and are green.

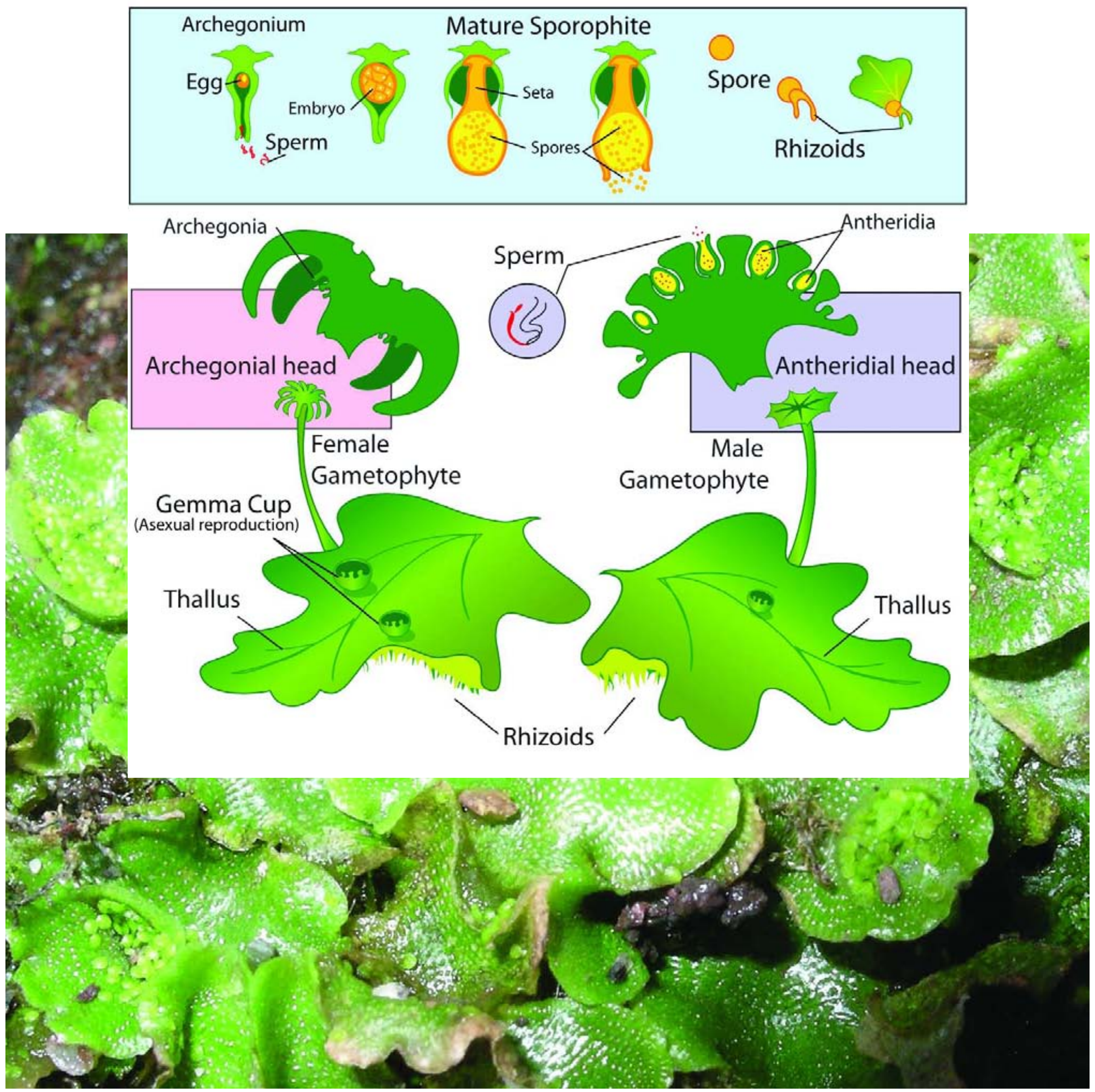
They reproduce by spores released from tiny capsules at the tips of the plant. At another stage they produce eggs and swimming sperm to continue their life cycle.




*Moss covers rocks and can make them slippery.*

Liverworts are like mosses in that they attach themselves by hair-like rhizoids. Unlike mosses, they have no leaves or stems. Their bodies are wide, flat, branching, green ribbons growing on wet rocks and soil near shady, cool woodland streams.

Like mosses, liverworts reproduce with spores and, at another stage, with eggs and sperm during their life cycle. Mosses and liverworts must live in wet places to complete their life cycles.



*Liverworts grow in wet places.*



## Ferns

Ferns have been on Earth for millions of years.

They are flowerless plants. Like mosses and liverworts, they prefer wet and shady places. Most live on the ground but some can live on rocks and tree bark. A few types live in open, sunny places and a few others live completely in water.


*Ferns prefer shady places, like forests.*

Ferns range in size from tiny rock ferns that look like moss, to giant tree ferns, 40 feet (12.2 m) tall.

Fern leaves, called fronds, are leafy. They grow on stems in a branching pattern resembling an evergreen tree. The leaves sprout from underground stems called rhizomes, uncoiling as they grow. In this stage, they look like the curled end of a violin. That is why we call them fiddleheads.


*The fiddlehead on this fern will unroll as the plant matures.*

### Edible Ferns

In Maine and eastern Canada, fiddleheads are springtime delicacies that many people eat. Native American and Canadian Indians taught early white settlers to pick and cook fiddleheads during colonial times.

Ferns also alternate between producing spores and making eggs and sperm to reproduce. Sporangia produce the spores. They look like dots on the underside of fronds. A few types of ferns, called seed ferns, reproduce with seeds produced from pollen and egg cells.

WORDS to know

**fiddlehead** (FID-uhl-head): a coiled, immature fern that resembles the upper end of a violin, or fiddle

**frond** (frahnd): the green leaf-like part of a fern

**rhizoid** (RYE-zoyd): tiny, hair-like structures that hold mosses, ferns, and liverworts to the rocks, logs, or soil that they grow on

## Flowering Plants

Flowering plants outnumber all other kinds of plants. There are over 250,000 species of them on Earth.

They grow wild in deserts, forests, meadows, and on mountains. People cultivate them inside and around their homes.

*Tulips are grown in regions where the winters are cold.*

Flowers that are mostly small and not noticeable are usually wind-pollinated plants. Birds and insects usually have a role in the pollination of flowers that are showy and noticeable. The bird of paradise flower is an unusually shaped flower. It has a perch for birds to sit on and drink the nectar. The pollen collects on the bird's neck and the bird carries the pollen from flower to flower.

*Can you see how the bird of paradise got its name? It looks like a beautiful bird in flight.*

### Simple or Composite

Flowers may be simple or composite.

**Simple Flowers**

A simple flower is a single blossom with one set of sepals, petals, stamens, and pistils.

Lilies, violets, poppies, tulips, and morning glories are simple flowers.

*Tulip*

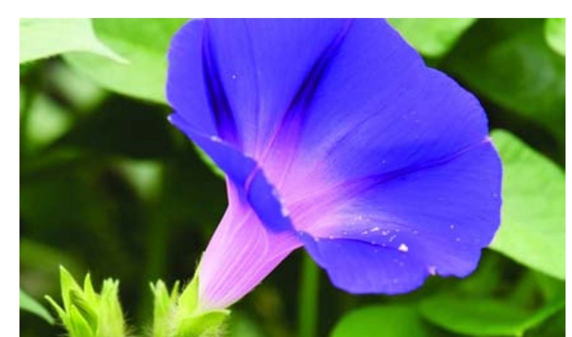


**Composite Flowers**

A composite flower is hundreds of tiny flowers clustered together. Petal-like ray flowers surround a button-like cluster of tiny disk shaped flowers in the center. The disk flowers in the center have multiple stamens and sepals. Daisies, asters, chrysanthemums, and sunflowers are composite flowers.

### Flower Arrangement

Flowers are arranged on plants in various ways. On some, the flower arrangement is in groups, or clusters. Other plants have single flowers.

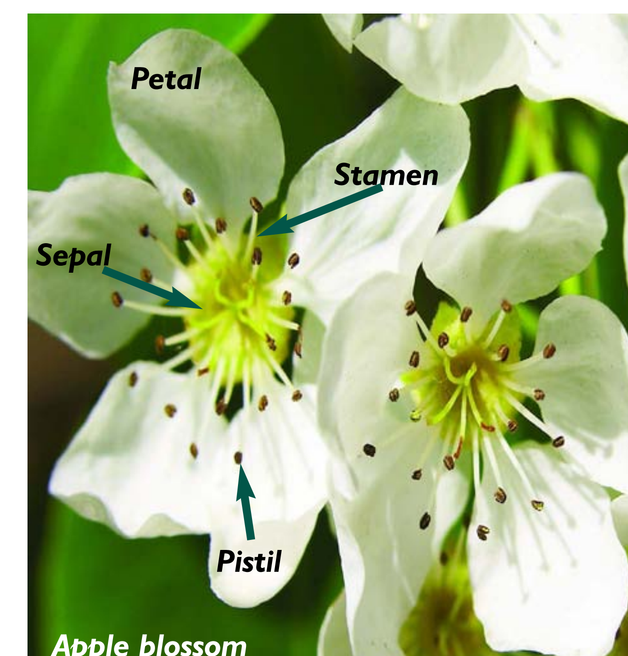


*Morning glories grow single flowers.*

*Lilacs grow clusters of flowers.*

### Complete and Incomplete Flowers

Complete flowers have a set of sepals, petals, stamens, and pistils. Apple and cherry blossoms are complete flowers.




*Apple blossom*

*When the pollen from the stamen fertilizes the ovum in the pistil, an apple will develop.*

Incomplete flowers lack one of the four major parts of a flower. These plants usually rely on the wind to pollinate them. Birch and willow trees have incomplete flowers.

Flowering vines sometimes have separate male and female flowers. Cucumbers, pumpkin, squash, and watermelon plants all have female flowers that develop into vegetable fruits after pollination by separate male flowers.

*Pumpkin plants have female flowers.*

**WORDS to KNOW**

**complete** (kom-PLEET): a complete flower has petals and sepals

**composite** (kom-POZ-itt): a composite flower is made up of ray flowers surrounding a central area of disk flowers

**incomplete** (inn-cuhm-PLEET): flowers that lack one or more of the four main flower parts

**pollinate** (POL-uh-nate): to carry or transfer pollen from the stamen to the pistil of the same flower or another flower

Sometimes the female flowers are on one plant and the male flowers on others.

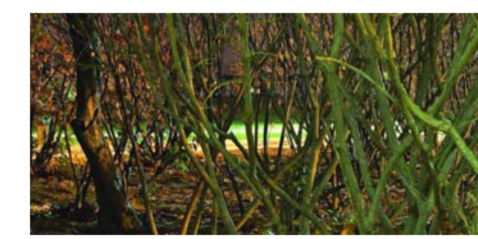
*The flowers of a pussy willow are called catkins. You can see the yellow pollen on the tips of this catkin.*

## Shrubs

Shrubs are woody plants with tree-like branches without a main trunk. The branches grow from the base of the shrub, or from below ground level. Shrubs range from a few inches in height up to 16 feet (4.9 m) tall. Some shrubs are flowering evergreens, such as Rhododendrons.

Shrubs are known by many names, such as scrub, bushes, brush, thickets, and hedges.

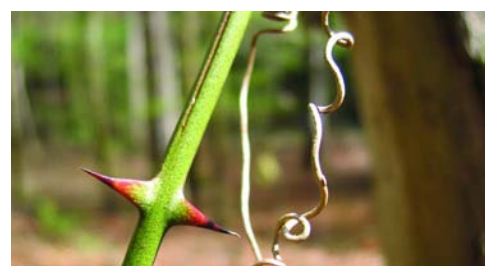


| Shrubs Grow in Many Different Ways | |
|---|---|
| Bushes are low shrubs, such as roses. |  |
| Scrub is used to describe an area with dense or tangled growth of shrubs. |  |
| Wild areas of shrubs are called brush. |  |
| Thickets are wild areas where shrubs grow very close together. |  |
| Hedges are shrubs used as fences or borders around houses, buildings, and parks. When hedges are trimmed, more side branches develop, causing the hedge to thicken. Topiaries are hedges trimmed into shapes of animals or other forms. |  |

## Vines

Vines are plants that climb up other plants or structures. Some vines grow across the ground between different plants. Some vines simply wind around other things to receive the sunlight that they need.

The climbing vines of tropical rain forests grow to the tops of tall trees to get sunlight. Climbing plants use other plants for support because they are not as sturdy or strong.

| Climbing Vines Get Support in Many Ways | |
|---|---|
| Tendrils are little branches that can wrap around the stems of other plants for support. |  |
| Ivy vines grow roots into the surfaces that they hold onto. They have special little pads that can attach them to walls or other surfaces. |  |
| Thorny vines entangle themselves with the supporting plants that they climb on. |  |

Some vines produce edible fruits and vegetables, such as tomatoes, melons, squash, and cucumbers. Other vines have pretty flowers and lots of decorative foliage. Many people enjoy growing these vines for houseplants or in flower gardens.

*Cucumbers grow on vines.*

WORDS TO KNOW

**foliage** (FOH-lee-ij): the leaves of a plant

**rain forest** (RAYN-foh-rest): a lush, moist forest with many kinds of plants and animals

**topiary** (TOH-pee-air-ee): a hedge that is trimmed in the shape of some object or animal

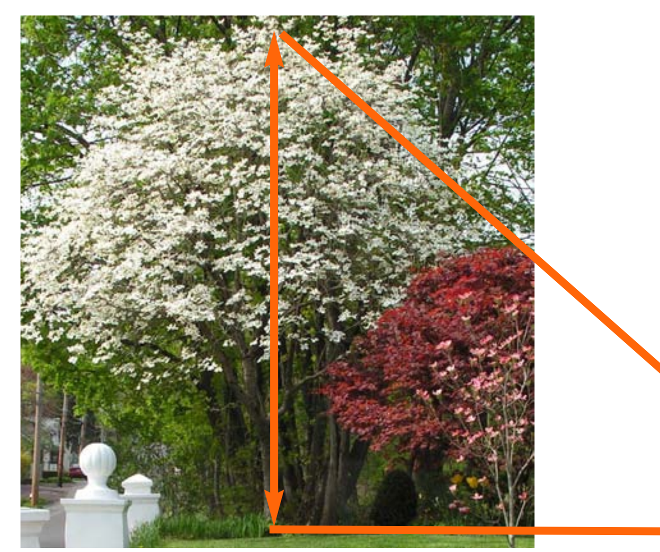


## Trees

Trees grow to various sizes and shapes according to their species. Like people, they grow to a particular size and then stop growing.

*An oak tree can live 200 or more years.*

Small flowering trees, such as dogwoods, grow only 10 to 20 feet (3 to 6 m). The tallest cone-bearing redwood trees are about 367 feet (111.9 m) tall.



*An approximate height comparison of a twenty foot dogwood to a 367 foot redwood.*

People grow some tiny trees, called bonsai, in plant pots and trim them to keep the trees little.

***Bonsai can be created from almost any tree or shrub.***

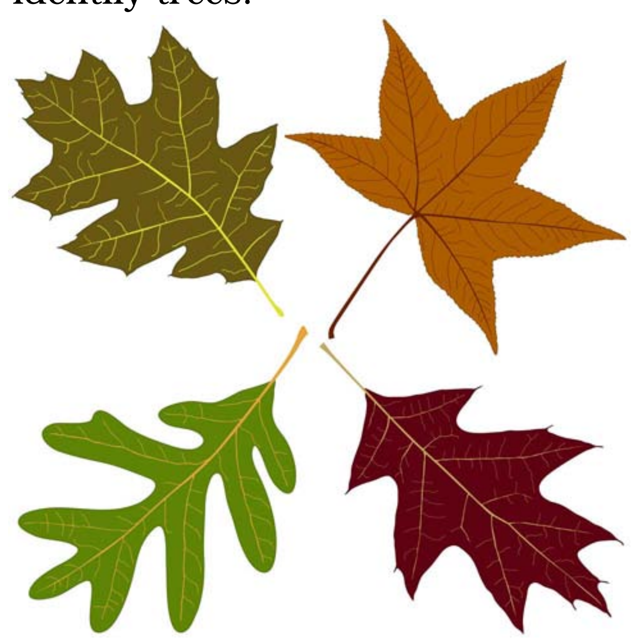
Some large plants, such as bananas, are treelike but are not trees. Their trunks are not woody and are made of leaves tightly rolled. Yuccas are plants with trunks made of tough fibers and leaves that are blade-like. They grow quite tall, but are not trees either.

***Bananas grow in hanging clusters, called hands.***

**Deciduous trees** are trees that shed, or drop their leaves in the fall. The leaves of deciduous trees are usually flat, thin, green leaves. Maple, oak, birch, dogwood, beech, aspen, and many fruit trees are deciduous.

***Deciduous trees lose their leaves in the fall.***

Some trees, such as the red maples, have dark red leaves. Tree leaves vary in size and shape, too. The shapes of the leaves and other characteristics help us identify trees.

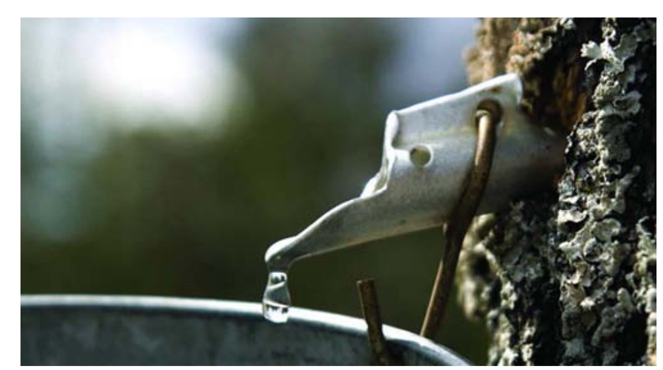




Trees produce lots of oxygen through photosynthesis and provide food for wildlife. Many animals, including birds, feed on the nuts and other fruit produced by trees. Tropical rain forests are particularly productive and support large numbers of animal species.

***Trees provide food and homes for a variety of animals.***

Food products, such as maple syrup, come from deciduous trees. In the spring, the watery sap of maple trees drips from small holes drilled into the trunks. Then we boil down the watery sap to make the sweet syrup.



***Sap is collected in February, March, and April, when freezing nights and warm days aid its flow.***

Citrus trees, such as orange, lemon, and grapefruit, grow in groves in mild climates. Other orchard fruits, including apples, peaches, mangos, cherries, plums, and olives, also grow on trees. Dates and coconuts grow on palm trees. Trees also produce nuts, such as walnuts, pecans, and almonds.

***Trees provide many nutritious fruits and nuts.***

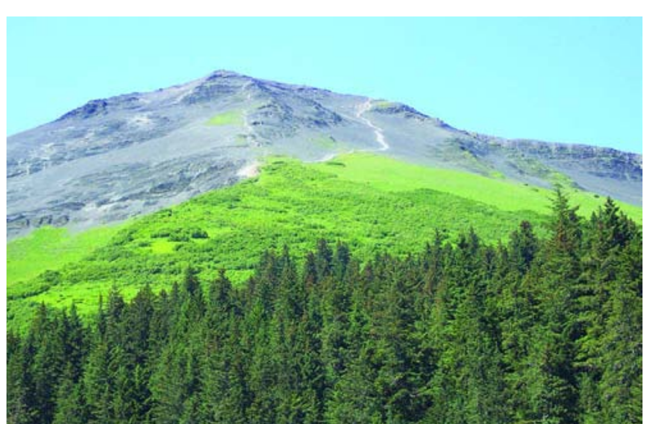
**Evergreen trees** have green leaves all year long. Eucalyptus trees are evergreen trees. They can grow as tall as 300 feet (91 m). The Australian koala is an animal that feeds on eucalyptus leaves and bark.

***Koalas live most of their lives in eucalyptus trees, rarely coming to the ground.***

Palm trees are evergreen trees. They live in warm tropical places. Their large leaves are shaped like fans or feathers. Large ridges on their bark are the scars that form when their leaves break off. Some palms have large, bushy clumps of dead leaves at their tops.

*The coconut palm's leaves can be used to make baskets and thatched roofs.*

Conifers are evergreen trees that bear their seeds on cones. Their leaves are needle-shaped. Conifers grow on mountainsides and in northern forest ecosystems, called Taiga.



*Some conifers are more suited to growing at higher altitudes than other types of trees.*

Conifers grow in both cold and warm climates. Pine, spruce, and fir trees grow in cold, northerly regions of the Earth. Cedar and tamarack grow in cool, northern bogs. Cypress trees grow in warm, watery swamps, such as the Florida Everglades.

*Cypress swamps are found in the southern United States, including the Florida Everglades in the southern tip of Florida.*

Conifers grow with boughs that slant downward. This helps them shed heavy snow in winter. Their needle-shaped leaves resist cold temperatures.

*The conifer's shape helps protect its branches from breaking.*



**Find out more**

The widest trees in the world are banyan trees. They grow in a region called the East Indies. They sprout new shoots from their branches that reach to the ground, take root in the soil, and become new trunks. One tree can create a whole forest!

## Herbs

Herbs are non-woody, or herbaceous, flowering plants. Plants such as tulips, marigolds, asters, and other garden flowers and weeds are herbs.

We call some spices, such as basil, thyme, sage, pepper, and oregano, herbs. Some of them have woody stems, though, and are not really herbs. Herbaceous plants are mostly flowering plants.

Perennial herbs have tops that die at the end of a growing season, but sprout again from the underground roots the following year. The roots are dormant, or inactive, in winter. Some herbs are annuals, which grow from seeds each year and live one growing season.

Culinary herbs are plants that are edible and often used to flavor foods. You may be tasting sweet basil or dill when you eat tomato sauce. Chives are grass-like herbs that taste like onions.


*Chives, spearmint, and sage are some of the culinary herbs that add flavor to our meals.*

**Words to Know**

**deciduous** (di-SIJ-you-uhss): trees that shed their leaves every year

**evergreen** (EV-ur-green): a shrub or tree that has green leaves throughout the year

**botanist** (BOT-uhn-ist): one who studies plants

**culinary** (KUH-lin-airy): having to do with cooking foods

### Various Herbs and Spices and Their Uses

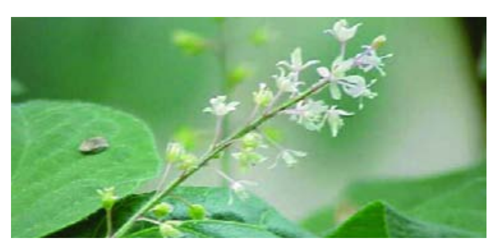
**Bay Leaf**
Fresh or dried bay leaves are used in cooking for their flavor and fragrance. The leaves are not usually eaten, but left to simmer in soups and stews.

**Catnip**
Catnip is named after the effect it has on cats. Cat owners buy catnip to entertain their pet cats. Cats will rub on it, roll over it, paw at it, chew it, and lick it.

**Cinnamon**
Cinnamon is a spice mostly used to flavor desserts, cereals, and hot chocolate. Cinnamon comes from the bark of a small evergreen tree native to Sri Lanka and Southern India.

**Echinacea**
Echinacea is an herb native to prairie habitats in the United States. Some people believe it can boost the body's immune system and ward off infections like the common cold.

**Patchouli**
The oil from a patchouli plant has been used for centuries in perfumes and is grown in the East and West Indies.



**Wasabi**
Wasabi is a member of the cabbage family. Its root is used as a spice and has an extremely strong flavor that can leave a burning sensation on the tongue and in the nasal passages.



We use the leaves of many kinds of herbs to make herbal teas. Some herbal teas help people sleep and some keep them awake. Caffeine is a substance in some teas that keeps people awake.

Some herbs, such as mint or sage, have very pleasant aromas and are used in cooking, aroma therapy, and many other products.

The large roots of some herbs, such as carrots, beets, and radishes, are used as food. Many herbs also contain substances that are useful medicines.

## Grasses

Grasses are flowering plants with tiny flowers, arranged in clusters, on the tips of long stems, or stalks. Grasses are low-growing plants with long, thin leaves. Most have very fine, thin roots that bind them to the soil. Tube-shaped stems hold the narrow leaves, or blades of grass, growing very close together.

The leaves and stems of grasses wither and die at the end of a growing season. Water and nutrients remain in the roots so that the grass can regrow when conditions improve in the springtime. Healthy grasses grow new stems and blades throughout a growing season.

There are many varieties of grass. Corn, rice, wheat, oats, rye, barley and millet are all grasses. The grains from these grasses are used for food, including cereal.

Ordinary grasses, such as Timothy, a common hay plant, usually grow a few feet tall. Hay, or dried grasses, is what many farm animals eat.


*Some grasses are used for landscaping, lawns, and athletic fields.*

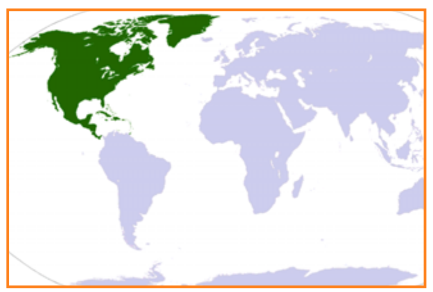
*Bamboo is a type of grass that can grow over 100 feet tall.*

In nature, grasslands are regions that receive too little rainfall to grow trees. Grasses require less water than trees.

**Grasslands of the World**

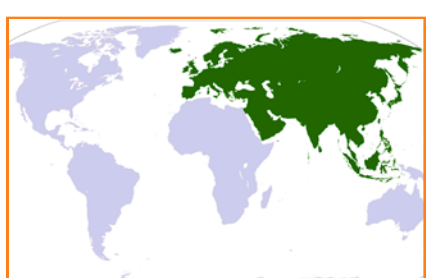
In Africa grasslands are called savannahs.

In North America grasslands are called prairies.



In South America grasslands are called pampas.

In Europe and Asia grasslands are called steppes.





# Plant Movements and Adaptations

## Plant Movements

Plant reactions usually are slower than those of animals. Some plants, such as jewelweed, have seed pods that pop open when touched, flinging their seeds in all directions. Mimosa trees have leaves that wilt and collapse when touched.

Carnivorous bog plants, such as the Venus flytrap, have special leaves that close up on insects when they touch them.

***The speed at which a Venus flytrap closes on its prey depends on the humidity, light, size of the prey, and even the health of the plant.***

### Tropisms

Tropisms are plant growth movements. They help plants grow closer to the things they need and away from things that might harm them.

Have you ever noticed how some plants bend toward light?

Sunflowers move to face the Sun from sunrise until sunset. Light makes some parts of the plant grow faster than others. This bending or growing toward the light is called phototropism.

***The fungus phycomyces exhibits phototropism.***

Plant growth reactions, or tropisms, can be positive or negative. A positive tropism is growth toward something, such as a leaf facing the Sun. A negative tropism is growth away from something, such as a stem growing upward, away from the Earth.

Roots grow toward the Earth, a positive geotropism. Tendrils of a vine touch an object and grow around it, a positive thigmotropism.

Find out more

**AUXINS**

Auxins are chemicals produced by plants that control growth.

A stem grows toward the light because the auxin moves to the shady side of the stem. The cells on the shaded side grow longer, making the stem bend toward the light. This can happen within minutes, or may take hours.

## Plant Adaptations

Plants are threatened by many dangers in their environment. Some plants live in saltwater oceans and must resist salt poisoning. Others live in dry deserts and struggle to get water.

Plants also must compete with other plants for sunlight, water, and soil. Insects and other animals damage them. So plants have developed many adaptations, or changes, to survive all these threats.

WORDS to KNOW

**auxin** (AUX-in): plant substance that may speed up or slow down growth

**carnivorous** (kar-NIV-uhr-uhss): meat eating

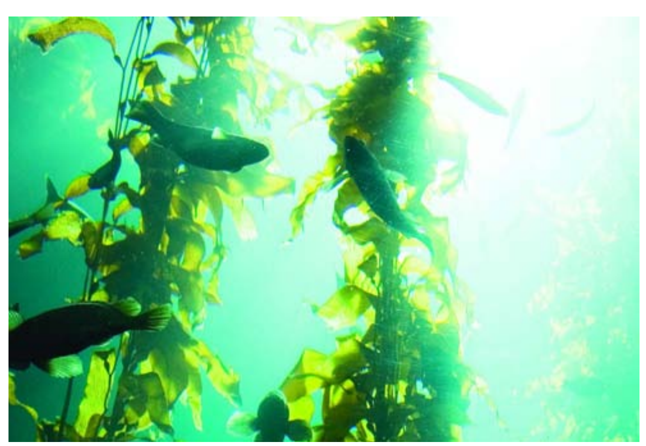
**tropisms** (TROP-izmz): plant growth movements

*Plants are damaged by many creatures.*

### Water Plants

Water plants live in water and have special problems. Saltwater plants must prevent too much salt from killing their cells. Freshwater plants must keep too much water from entering their cells, causing them to burst.

Water lilies use air filled sacs to keep their leaves on the surface helping them get air and sunlight. Giant Amazon water lilies can be 6 feet (almost 2 m) across and can support the weight of large birds.



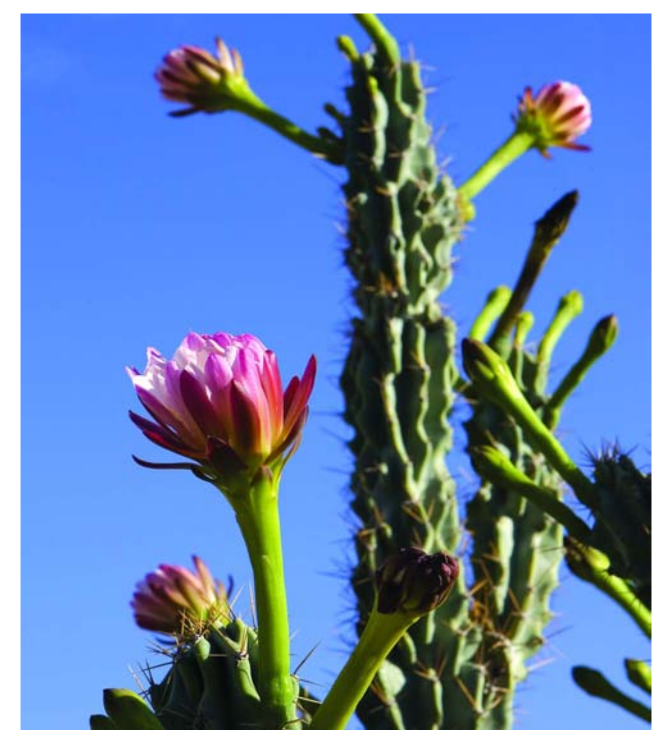
*Kelp beds create an underwater forest off the coast of California.*



### Desert Plants

Desert plants have adapted to live in hot, dry places. They remain dormant for many months, until it rains. They complete their entire life cycle, producing flowers and seeds, in a few weeks or months. Desert plants, such as cacti, adapt to the dryness by being leafless. Leaves have large surfaces that lose a lot of water. Cacti are also succulent plants with fleshy stems that hold in water. After a rain, each cactus rapidly blooms and produces seeds.

Large spines on cacti repel desert herbivores (animals that try to eat them). This keeps animals from biting into the cacti, causing it to lose water. Many other plants, such as rose bushes, have thorns. Thorns protect them from being eaten, too.



*A cactus blooms after a desert rain.*

*Spines keep most animals from biting or eating a cactus.*

### Epiphytes

Epiphytes are plants that grow on trees. Plants must have sunlight. Forests are crowded with trees and other plants that shade the forest floor. Some ferns, mosses, and even small, flowering plants survive by growing on the taller trees to get the light they need. Mistletoe is an epiphyte.

*Mistletoe can be harmful to its host tree, but it helps provide many animals with food and a habitat.*

### PLANTS THAT EAT ANIMALS

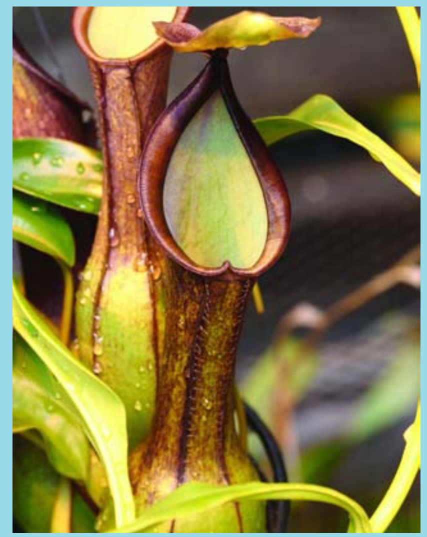
Find out more

Some plants get the nitrogen they need from insects rather than soil. They are carnivorous, or meat-eating. Plants such as Venus flytraps, sundews, and pitcher plants capture flies and other insects and digest them.

Flytraps have leaves that fold together and grasp whatever lands on them. Chemicals called enzymes digest the insect.

*A Venus flytrap*

*A sundew plant*



*A pitcher plant*

### WORDS TO KNOW

**adaptation** (ad-ap-TAY-shuhn): a change that a living thing goes through, so that it fits better into its environment

**desert** (DES-urt): a dry, often sandy area where hardly any plants grow because there is so little rain

**enzyme** (EN-zime): a chemical that causes chemical reactions to occur in living things

**herbivore** (HER-buh vor): a plant-eating organism

**parasite** (PAIR-uh-site): an animal or plant that gets its food by living on or inside another animal or plant

### Parasitic Plants

Parasitic plants do not have chlorophyll. They are parasites on other plants. This means that they take food substances from others by growing into their stems or roots. Beech drops are odd looking little plants that grow attached to the roots of beech trees. They are very pale, almost colorless, because they have no chlorophyll. They absorb the nutrients that they need from the beech roots.

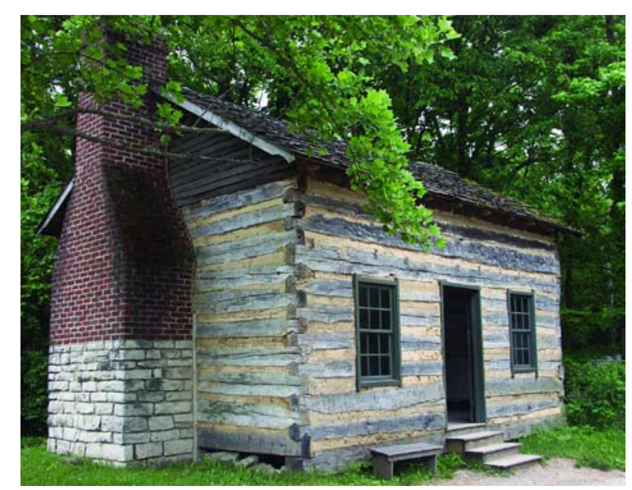


# How We Use Plants

Humans use plants in many ways. We build structures with them. We plant them in and around our homes to enjoy their colors, forms, and fragrance. We study them to learn from them. We eat them and use them to make food products and drinks. We even make our clothes from their fibers. Some of them provide medicines and cosmetics.

## Shelter and Decoration

People have always made homes from plants. Grasses, logs, and bamboo poles have been useful building materials throughout our history.



*This log cabin was made from the wood of nearby trees.*

Axes, handsaws, and eventually sawmills, made it possible to create planks and boards. Today, many people live in houses with wooden frames covered with plywood sheets, wooden shingles, and clapboard siding.

People cut down trees for their wood. People plant trees to decorate, or landscape, yards and parks.

Flowers are pleasant to look at, and fruits and vegetables are delicious to eat. That is why so many of us plant them in our gardens. People even grow houseplants, such as ferns, palms, orchids, and geraniums to brighten up their homes and apartments.

*Gardening can be an enjoyable hobby at any age.*

Many people enjoy taking care of their indoor and outdoor plants, feeding them a mixture of nutrients called fertilizer. They must make sure their plants get enough water and sunlight, too.

## Scientific Exploration With Plants

Scientists find many things that plants and animals have in common by studying and experimenting with them. The way plants and animals inherit and pass down physical traits, or heredity, was discovered in this way.

*A researcher examines the roots of a plant.*

### Cross-Pollination

Plant breeders cross-pollinate plants to improve the next generation of plants. The seeds produced by cross-pollinated plants may have bigger, more colorful flowers. These young plants, called hybrids, may also produce bigger and more nutritious fruit.

Cross-pollinating means that you put the male pollen cells from a plant with a good characteristic on the female pistils of another plant that has a good characteristic. The seeds that are produced from cross-pollination grow up to have both of the good characteristics.

*Cross-pollination can lead to better fruits and vegetables.*

### Plant Genetics

In the 1860s, a man named Gregor Mendel studied and experimented with the colors and shapes of pea plants.

He noticed that certain traits were passed down from plant to plant in certain ways. By counting and using mathematics, he figured out how plants inherited traits and created the science of genetics.

Later, scientists discovered the genes that control the inheritance of traits. Other scientists have figured out the chemical structure of the chemical substances, the DNA, that genes are composed of.



### Barbara McClintock

**Getting to know...**

Barbara McClintock was born in Connecticut in 1902. As a child, she loved nature and spent a lot of time in the countryside.

She studied biology at Cornell University, in New York, and earned a PhD in 1927. Because women at that time were not hired as college professors, she could not find a job at a college. She continued studying genetics, working with Indian corn, or maize, that has seed kernels of many colors.

She discovered genes could move, or "jump", from one chromosome to another, changing their genetics. Other scientists later discovered jumping genes in bacteria, flies, and other animals.

McClintock was awarded the 1983 Nobel Prize in Medicine for her work.

**Find out more**

### THE NOBEL PRIZE

The Nobel Prize is an award that honors men and women... *"who, during the preceding year, shall have conferred the greatest benefit on mankind."*

The Nobel Prize started in 1895 when Alfred Nobel, a Swedish chemist, engineer, innovator, and inventor of dynamite, wrote his last will, leaving much of his wealth to set up the prizes.

Since 1901, the prize has honored men and women for outstanding achievements in physics, chemistry, medicine, literature, economics, and for work in peace.

## Plants as Food

People eat many kinds of plants. We eat all the parts of plants. We eat roots, stems, and leaves…flowers, fruits, and seeds.

A tall, strong grass called sugar cane is the source of most of our sugar. The flavoring cocoa, or chocolate, comes from the ground up beans of cacao plants. Coffee comes from the ground beans of the coffee plant. Agar, a gel, used to thicken ice cream, comes from seaweed (red algae).

*Heavy machines help farmers harvest sugar cane.*

*Each cacao pod can contain 20 to 60 cocoa beans.*

*Coffee plants growing on a plantation.*

*Coffee fruit is red when it's on the plant, but turns brown when roasted.*

### Words to Know

**chromosome** (kroh-muh-sohm): the part of the cell that contains the genes that gives living things their characteristics

**fertilizer** (fur-tuh-lize-ur): a substance, such as animal manure, compost, or a chemical that promotes plant growth

**genetics** (juh-net-iks): the study of the ways that personal characteristics are passed along from one generation to another by genes

| Plants and the Parts That We Eat | |
|---|---|
| **Roots**<br>Roots that we eat include carrots, beets, turnips, parsnips, and radishes. |  |
| **Stems**<br>Stems, such as celery and rhubarb, are tasty and nutritious. |  |
| **Leaves**<br>The leaves of lettuce, cabbage, spinach, collards, chard, and others are common foods, too. |  |
| **Flowers**<br>Flowers, such as broccoli and cauliflower, are good cooked or eaten raw. |  |
| **Fruits**<br>Fruits, including apples, oranges, cherries, grapes, kiwis, and others are sweet and juicy. Vegetable fruits, such as tomatoes, cucumbers, squash, and eggplant add to the variety that is available to people. |  |
| **Seeds**<br>Seeds are eaten by people and make up the bulk of most of our nutrition. Corn, wheat, rice, and all the other grains we make into breads and pastas contain important nutrients. |  |

## George Washington Carver

Getting to know...

George Washington Carver was born to black slave parents in Missouri in the 1860s. His mother was taken away to the South when he was a baby. His mother's former owners raised him and helped him get an education.

A college in Kansas originally accepted Carver but then rejected him when they saw that he was an African American. At a college in Iowa, he studied botany and agriculture, the science of farming.

He went on to teach at the Tuskegee Institute in Alabama. Insects called boll weevils were destroying cotton plants at that time. Carver convinced farmers to grow peanuts instead of cotton.

Carver developed over 300 products made from peanuts. He made inks, dyes, makeup, medicine, glue, soap, and even peanut milk.

## Other Plant Products

Today, plants are used to produce many things. One product is ethanol made from corn and used to fuel engines. Dyes come from plants, as do other chemicals, such as rubber, turpentine, and shellac.

We make clothing from cotton fibers twisted into thread and then woven into cloth. Hemp rope is made of plant fiber.

Milky juices of some tropical trees are the source of natural rubber. The juice, or latex, is cooked and it thickens to become the elastic, or stretchy material we call rubber.

WORDS to KNOW

**agriculture** (AG-ruh-kul-chur): farming

**ethanol** (EH-than-all): an alcohol produced by yeasts from the fermentation of sugar

**gel** (gehl): a thick, jelly-like substance

**latex** (LAY-teks): the milky juice of the rubber tree


*Many newer model cars can run on E-85 ethanol.*



# People Learn From Plants

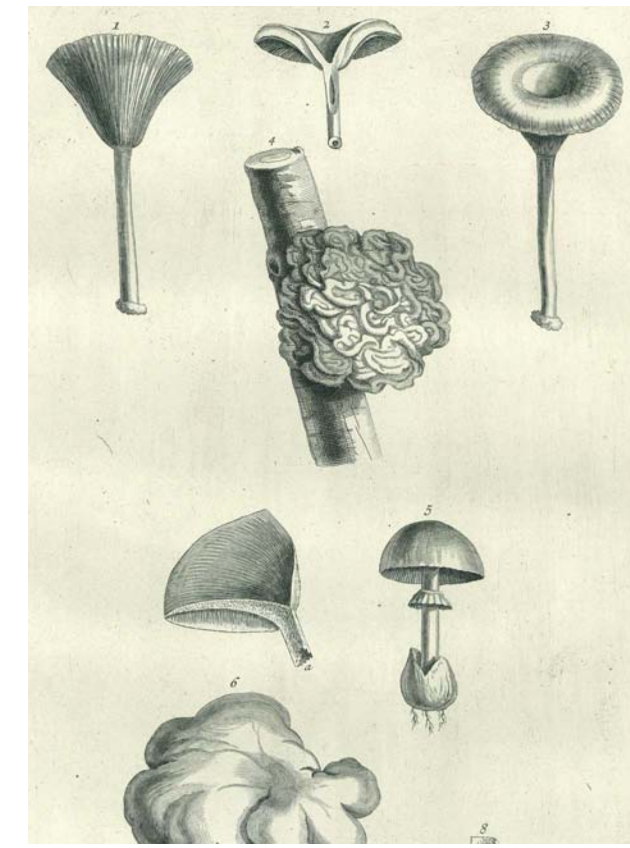
## Why Study Plants?

Knowledge of plants has always been useful to people. Wild fruits, vegetables, and nuts first became food sources thousands of years ago. They still are.

*Plants have always been a food source for humans.*

When people discovered how to grow their own plants, farming began. Edible plant crops made more food available to more people.

People long ago discovered the value of plants in making medicines such as pain killers.



*Plant drawings by Sebastian Vaillant in the 1700s.*

Today we understand and depend on the use of plants and plant products. Plant scientists are discovering more and more about plants.

Young people can learn about plants and, someday, work at interesting and important jobs all over the world.

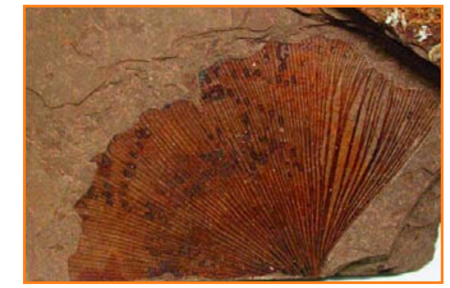
Botany is the branch of biology that studies plants. There are many people who work with plants including botanists, or plant scientists.

**PEOPLE WHO WORK WITH PLANTS**

| | | **Specializes in...** |
|---|---|---|
| Arborist |  | the science of tree growing. |
| Aroma-therapist |  | knowing scents, or smells, of plants that relax, calm, and comfort people. |
| Bryologist |  | studying mosses. |
| Herbalist |  | using herbs to treat illnesses. |
| Horticulturist |  | having knowledge of the varieties of plants used in landscaping and ornamental gardening. |



**PEOPLE WHO WORK WITH PLANTS**

| | | **Specializes in...** |
|---|---|---|
| Paleobotanist |  | studying plant fossils. |
| Phytopathologist |  | studying plant diseases. |
| Pomologist |  | working with orchard plants, such as apple trees and others. |

Plant growers, or farmers, require knowledge of the planting, cultivation, and harvesting of a wide variety of plant crops.

Farmers must learn about farm chemicals, too. Fertilizers and pesticides are important chemicals that farmers use, but they can also be dangerous.

*Farmers examine the health of their crops.*

Agricultural engineers invent machines used in farming and show farmers how to use or repair them.

*An agricultural engineer explains how a farm machine works.*

Other people who study and work with plants include gardeners, who take care of private and public gardens.

*A gardener tends his flowers.*

## WORDS TO KNOW

**ancient** (AYN-shunt): very old

**engineer** (en-juh-NIHR): a person who builds structures

**pesticide** (PESS-tuh-side): a chemical used to kill pests, such as harmful insects

Landscape architects design plans for arranging plants around homes, buildings, parks, and highways.

*Landscapers use grass, herbs, and trees in attractive combinations.*

Florists grow and sell plants and need to know ways of keeping them fresh and healthy.

*Florists sell many different types and arrangements of flowers.*

Rourke's World of Science

# ENCYCLOPEDIA

## Volume 4

# Earth Science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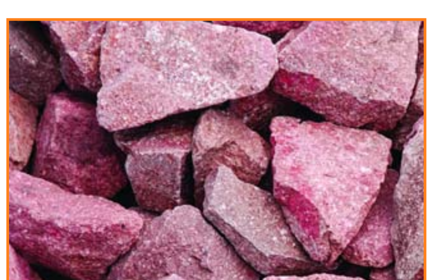
# What Is Earth Science?

As far as we know, Earth is the only place in the solar system that contains all the ingredients (liquid water, chemical building blocks, and an energy source) needed for life. All the living things we know of live on Earth. It is home to plants, animals, and humans. Everything on the planet needs everything else to survive. Earth scientists help us understand and value our unique home.

Earth science is the study of the Earth. It includes how the Earth works and its origin, structure, and physical features. The term Earth science is a general term that includes all the sciences related to the Earth. It might surprise you that sciences like meteorology and oceanography are both Earth sciences.

**EARTH SCIENCES**

| Science | | What Is Studied |
|---|---|---|
| Glaciology |  | Glaciers and ice |
| Geology |  | Solid matter including rocks and minerals |



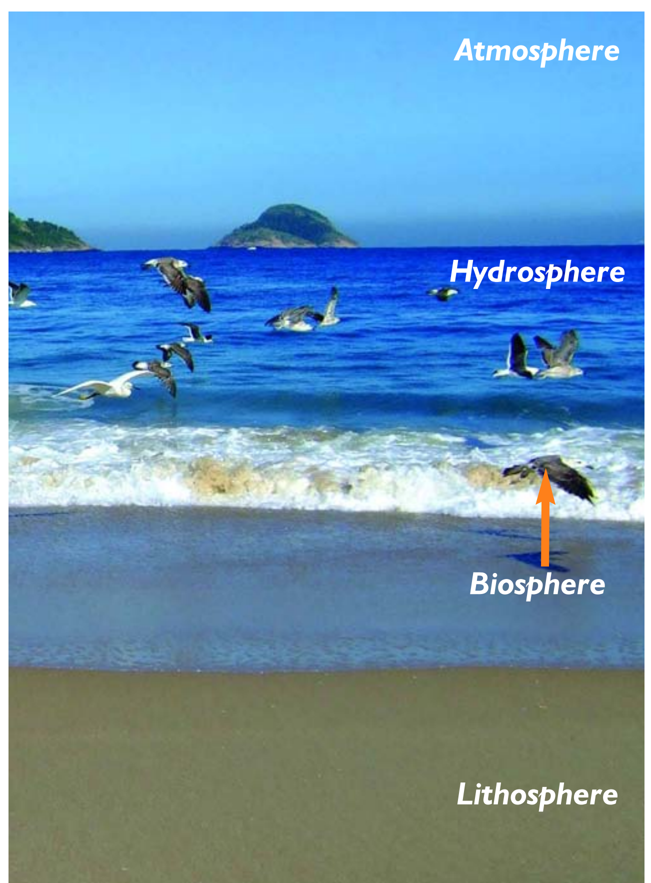
**EARTH SCIENCES**

| Science | | What Is Studied |
|---|---|---|
| Physical Geography |  | Patterns and processes including weathering and erosion |
| Limnology |  | Inland waters including lakes, ponds, rivers, streams, wetlands, and groundwaters |
| Meteorology |  | Atmosphere, including the weather |
| Oceanography |  | Oceans and seas |
| Paleontology |  | Fossils and prehistoric life |

| EARTH SCIENCES | | |
|---|---|---|
| **Science** | | **What Is Studied** |
| Pedology |  | Soil |
| Volcanology |  | Volcanos, lava, and magma |

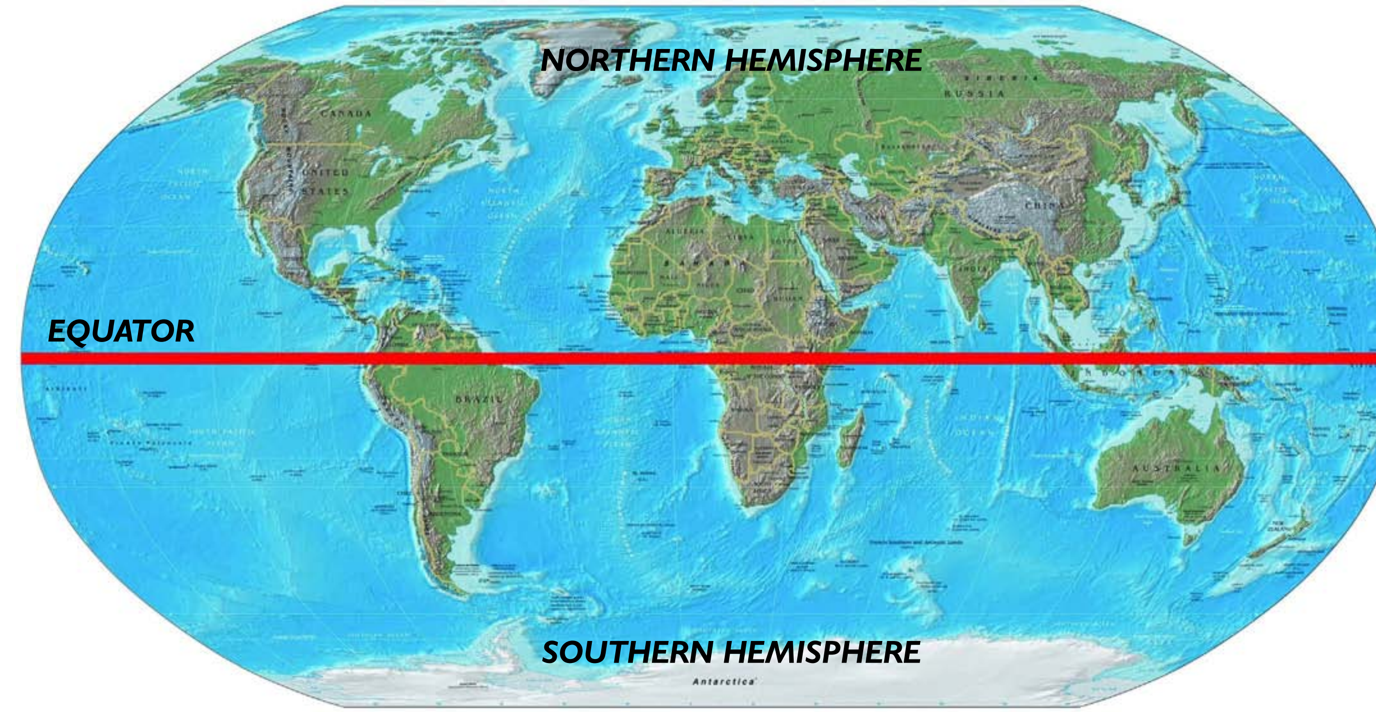
The Earth's shape is almost round like a ball, or sphere. But unlike a ball, the Earth is made of different parts. Scientists call these parts Earth's spheres. The four spheres are the lithosphere, hydrosphere, biosphere, and atmosphere. Hydro means water. Can you guess what part of Earth makes up the hydrosphere? The hydrosphere includes all forms of water under, on, and above Earth.

| Earth's Spheres | |
|---|---|
| **Atmosphere** | = air |
| **Hydrosphere** | = water |
| **Biosphere** | = life |
| **Lithosphere** | = land |




*This photo shows all four Earth spheres.*





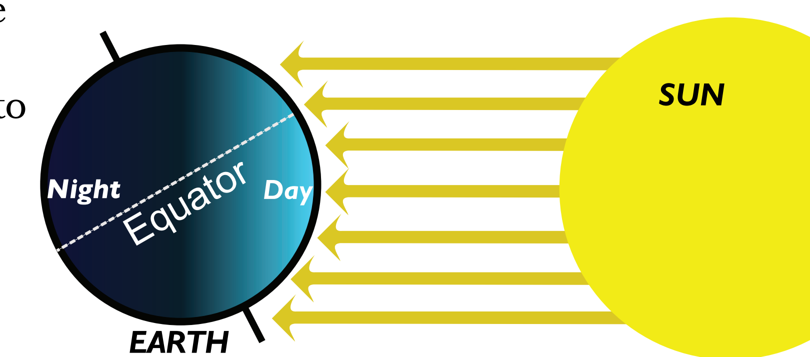

## The Earth's Hemispheres

We call the top half of the Earth the Northern Hemisphere and the bottom half the Southern Hemisphere. The equator is an imaginary line around the middle of Earth's surface separating the Northern Hemisphere from the Southern Hemisphere.

At the top of the Northern Hemisphere is the North Pole. The South Pole is at the bottom of the planet in the Southern Hemisphere. The closer you live to the equator, the warmer your weather. And the further away from the equator you live, the colder your weather is.

Another imaginary line runs through the center of the Earth from the North Pole to the South Pole. We call this line Earth's axis. The axis tilts at 23.45 degrees. Earth rotates around the axis. The tilt of Earth's axis is why our seasons change.

The seasons in the Southern Hemisphere are opposite of the seasons in the Northern Hemisphere. If it is winter in the Northern Hemisphere, it is summer in the Southern Hemisphere.




***In this illustration, the Sun's rays shine more directly on the Southern Hemisphere, causing those below the equator to experience summer.***

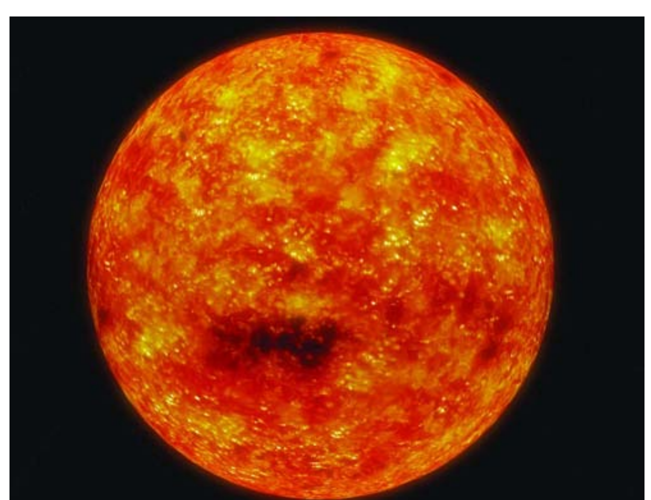
| What Season Is It? | | |
|---|---|---|
| **Months (approximate range)** | **Northern Hemisphere Season** | **Southern Hemisphere Season** |
| December, January, February | Winter | Summer |
| March, April, May | Spring | Fall |
| June, July, August | Summer | Winter |
| September, October, November | Fall | Spring |

**Find out more**

Did you know Earth really isn't a perfect sphere? Earth bulges slightly at the equator making the Earth a geoid. Earth rotates (spins) faster at the equator than at the poles because the poles are closer to Earth's axis. This is what causes the bulge.

## The Origin of Our Planet

Scientists believe the Earth was created over 4.5 billion years ago. It came from a cloud of dust and gas swirling in space. Some of the dust and gas formed the Sun. The rest became planets in the solar system.



*The Sun is the star closest to Earth.*

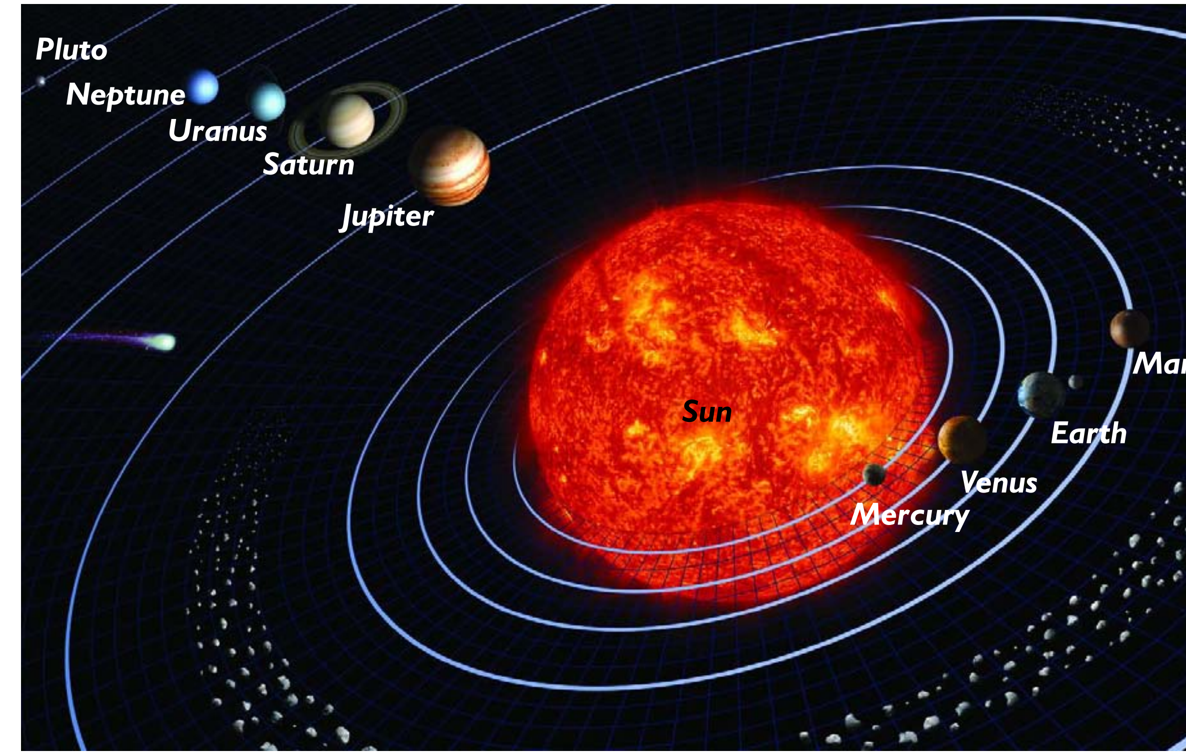
**Words to Know**

**equator** (i-KWAY-tur): an imaginary line around the middle of the Earth

**pole** (pohl): one of the two points that are farthest away from the equator, the North Pole or the South Pole

**sphere** (sfihr): a solid shape like a basketball or globe






*The solar system is composed of eight planets circling the Sun. The asteroid belt can be seen between the orbits of Mars and Jupiter. Pluto, once called the ninth planet, is now considered a dwarf planet.*

The young Earth looked very different than it does today. Intense heat inside the growing planet caused molten, or liquid, rock to form. The hot surface slowly cooled over millions of years. Water vapor and other gases made the atmosphere. Clouds covered the planet. Rain helped cool the hot surface. Cooling rocks slowly began to soak up the falling rain. When the ground could not hold any more water, oceans formed.

The land above the level of the ocean formed continents, and the continents have been moving and changing ever since. Sometimes the continents moved together forming a supercontinent before separating again. Pangaea was the last supercontinent. When Pangaea separated, the continents moved into their current formation.


*The supercontinent Pangaea existed 250 million years ago.*

The continents weren't the only thing changing. The clouds became thinner and sunlight could shine through. Heat and other forces inside the planet continued changing the surface. Ice ages and many living organisms came and went. Over billions of years, the Earth became the way it is today.

***GEOLOGIC TIMELINE***

| | | |
|---|---|---|
| Phanerozoic Eon 543 million years ago to present time | Cenozoic Era 65 million years ago to present time | Quaternary 1.8 million years ago to today |
| | | Tertiary 65 to 1.8 million years ago |
| | Mesozoic Era 248 to 65 million years ago | Cretaceous 144 to 65 million years ago |
| | | Jurassic 206 to 144 million years ago |
| | | Triassic 248 to 206 million years ago |
| | Paleozoic Era 540 to 548 million years ago | Permian 280 to 248 million years ago |
| | | Devonian 408 to 360 million years ago |
| | | Cambrian 540 to 500 million years ago |
| Precambrian Time 4.6 billion years ago to 543 million years ago | Proterozoic Eon 2.5 billion years ago to 540 million years ago | |
| | Archeozic Eon 3.9 billion years ago to 2.5 billion years ago | |
| | Hadean Eon 4.6 billion years ago to 3.9 billion years ago | |

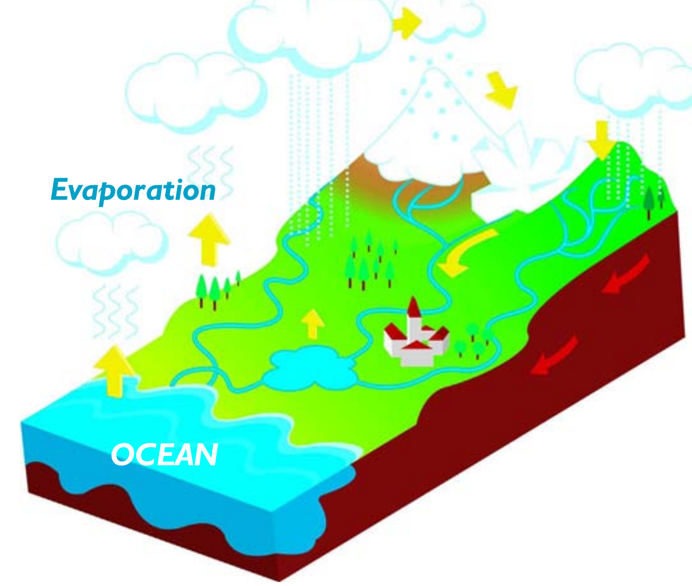
## The Earth Today

From outer space, the Earth looks very blue. That is because water covers most of the planet. Nearly three quarters of the Earth's surface is oceans, seas, lakes, rivers, and other bodies of water. The seven continents cover the rest of the planet.




The ocean is the source of most of the water on the planet. It provides much of the water that makes clouds in the sky. Water rises up into the air when it evaporates. This means that it turns into a mist you cannot see. The water comes back down to the ground as rain. Rain fills the lakes, rivers, and streams on the land. Plants and animals need this water to survive.

***THE WATER CYCLE***




The different environments of Earth support many different plants, animals, and other organisms. Deserts, prairies, forests, and mountains are all types of environments on the land. Oceans, lakes, rivers, and ponds are all types of water environments. Both water and land environments depend on a balance between all the living and nonliving things in the environment. This includes everything from the air and soil to the plants and animals.

***Forests and mountains are types of land environments.***

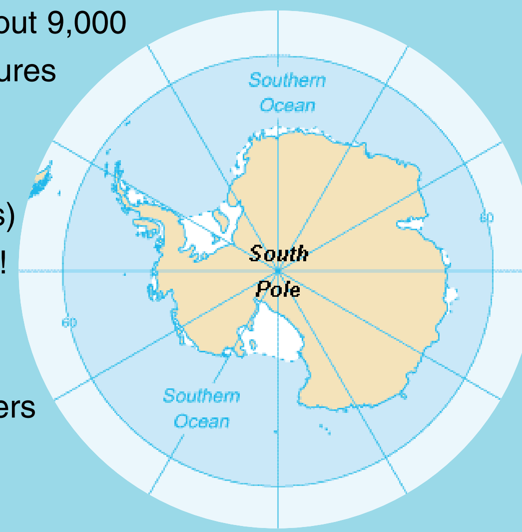
***The ocean is a type of water environment.***

### The North and South Poles

Find out more

Would you like to visit the North Pole? It probably is harder than you think. There is no land at the North Pole, only huge moving sheets of ice in the middle of the Arctic Ocean. An American explorer, Robert E. Peary, is usually credited as being the first person to reach the North Pole on April 6, 1909. Peary, his trusted assistant, Matthew Henson, and four Eskimos traveled over the ice using dogsleds.


Even though the South Pole is on the continent Antarctica, it is still difficult to visit. A polar ice sheet that is about 9,000 feet (2,700 m) thick covers the land. The temperatures in the winter can get down to minus 76 degrees Fahrenheit (-60 degrees Celsius). It warms up to minus 18 degrees Fahrenheit (-28 degrees Celsius) during the summer. Now that's a cold place to visit!




Year round, scientists live and work at the Amundsen-Scott South Pole Station run by the United States. The station, named for polar explorers Roald Amundsen and Robert Scott, is important to research.

***The Amundsen-Scott South Pole Station sits within 330 feet (100 meters) of the Geographic South Pole.***

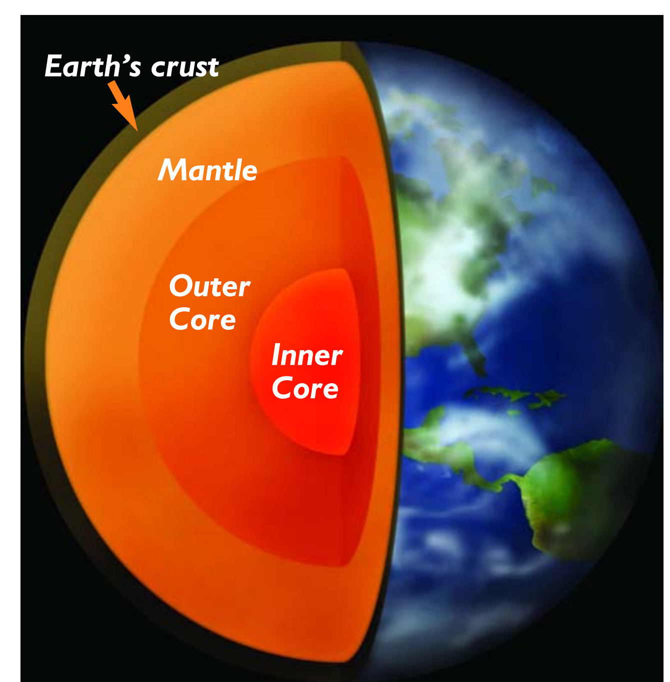


# The Parts of the Earth

When studying the Earth, scientists look at the surface of the Earth and the parts that are above and below it. The atmosphere is a part above the surface while the core is a part below the surface. All of Earth's parts work together to make life possible.

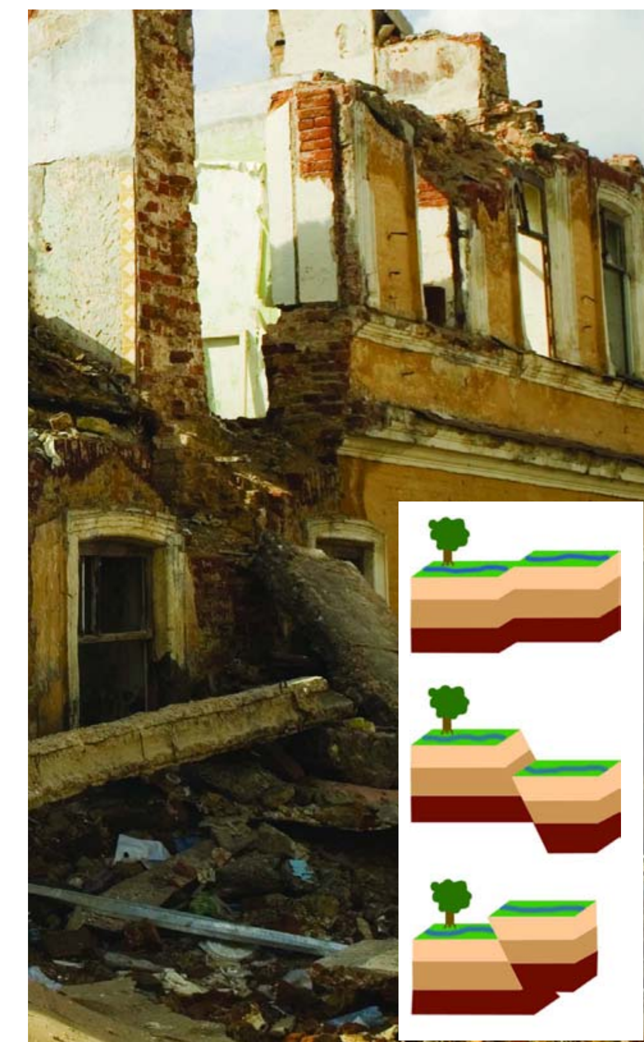
## The Earth's Layers

Earth is a terrestrial planet, meaning that it is mostly made of rock. There are three major layers from the surface of the planet to its center. They are the crust, the mantle, and the core. The force of gravity pulls Earth's layers together.




***The Earth has a solid inner core and a liquid outer core, which is the source of the Earth's magnetic field.***

Studying how an earthquake wave moves is one important way scientists learn about the different materials in the Earth's layers. Scientists estimate that they can detect nearly 500,000 earthquakes each year in the world. Fortunately, only about 100 quakes cause damage on Earth's surface.



***The Earth's layers can move in different ways during an earthquake, causing immense damage.***

## The Crust

The top layer of the Earth is the crust. Just like the crust on a loaf of bread, the Earth's crust covers the entire planet. This top layer is also the thinnest layer of the Earth.

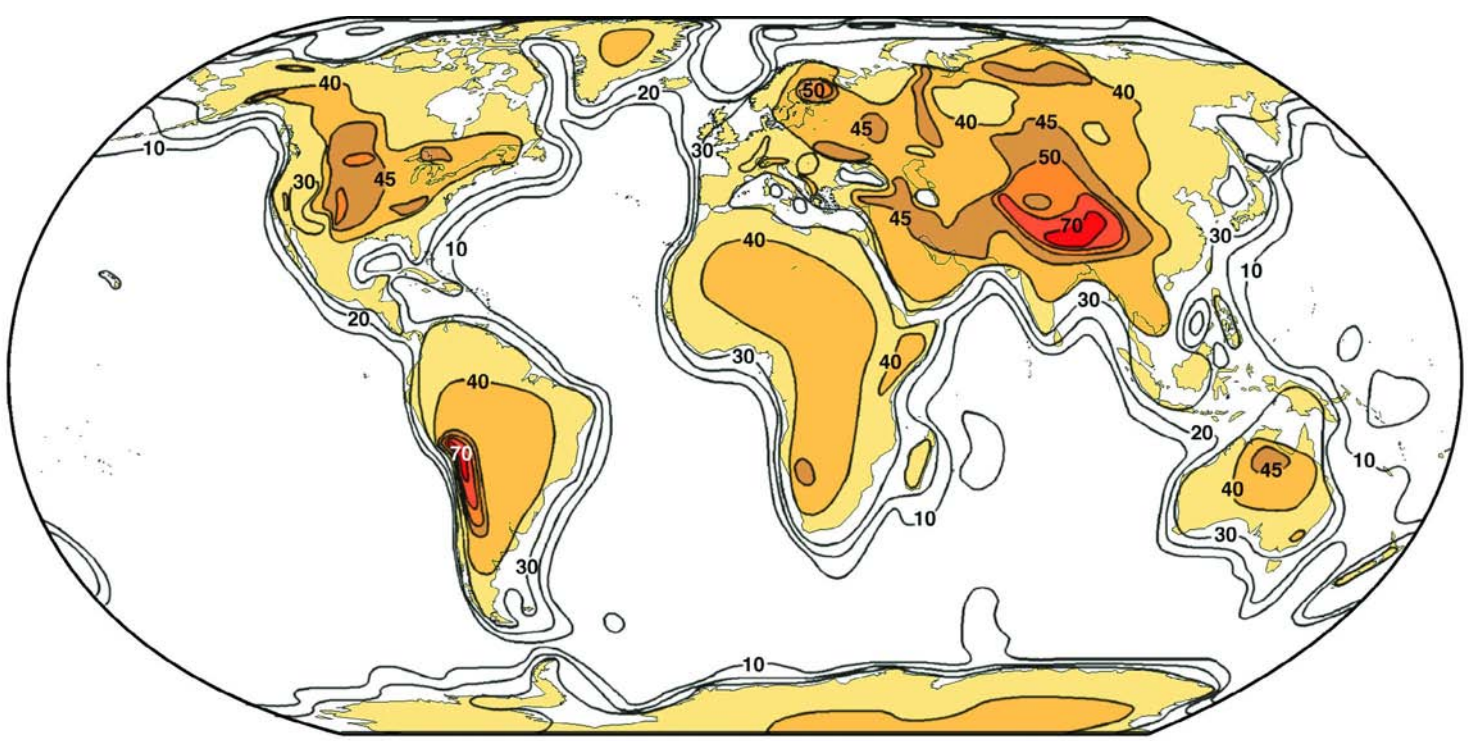
There are two types of crust. Under the oceans, the oceanic crust is 3-6 miles (5-10 km) thick. Below the tallest mountains, the continental crust can be over 40 miles (70 km) thick.

Forty miles sounds thick but if you compared the Earth to an apple, the crust is like the apple's peel. All life on the planet lives in or above the crust.

## The Mantle

Below the crust is the mantle. The mantle is the thickest layer of the Earth. It goes down over 1,800 miles (2,900 km). Most of Earth's rocks are in the mantle. Rocks in the mantle are dense. This means that the rocks are packed closer together than rocks in the crust. They are under the weight of all the rocks on top of them.

The temperature in the mantle is very hot. Some rocks even melt and become molten. This molten rock is called magma. Sometimes magma comes to Earth's surface through volcanos. Lava is magma that has reached the surface of the Earth.



***This map shows the different thicknesses of Earth's crust.***

- land 12-24 mi (20-40 km)
- 24-27 mi (40-27 km)
- 27-30 mi (45-50 km)
- 30-36 mi (50-60 km)
- 36-42 mi (60-70 km)
- 42 mi (70 km)



***Lava oozes from an erupting volcano.***

### Find out more

The deepest man-made hole in the Earth's crust is on the Kola Peninsula in Russia. It is 7.6 miles (12.3 km) deep. Drilling began in 1970 and ended in 1992 because the temperature inside the Earth's crust was getting too hot. There were many different boreholes drilled from the main hole. The deepest borehole was drilled in 1989.

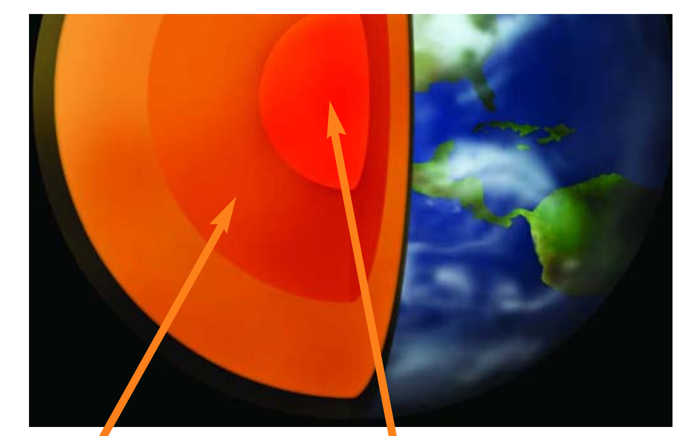
The reason for drilling into the Earth's crust was not for an oil well but for research. Scientists learned new information about the layers of rock in Earth's crust from samples taken from the drill.

## The Core

The middle of the Earth is the core. The core has two different layers. They are the inner core and the outer core.

The outer core is right below the mantle. It is a combination of the metals iron and nickel. There may even be sulfur in the outer core. The outer core is a liquid because it is so hot.

At the very center of the Earth is the inner core. The inner core is made of solid metal. It is also made of iron and nickel and is very hot. It is solid metal because the pressure is so high. If you were able to travel to Earth's core, the high pressure would squeeze you to be about the size of a pea.



***Outer Core***
- *Liquid*
- *Mostly nickel and iron*
- *Temperatures from 4,000 to 9,000 degrees Fahrenheit (2,200-5,000 degrees Celsius)*
- *1,800-3,200 miles (2,897-5,150 km) deep*

***Inner Core***
- *Solid*
- *Mostly nickel and iron*
- *Temperatures reach 9,000 degrees Fahrenheit (5,000 degrees Celsius)*
- *3200-3900 miles (5,150-6,276km) deep*

# Rocks

The Earth's crust is made of rocks. The substances that make up most rocks are minerals. The three basic kinds of rocks are igneous, metamorphic, and sedimentary.

## Igneous Rocks

The most common type of rock is igneous rock. Another name for igneous rocks is fire rocks, because they form when magma cools. Magma is hot liquid rock that comes from the Earth's crust and the mantle.

Igneous rocks can form below Earth's surface or above it. Erupting volcanos bring magma to the surface. We call this magma lava. As the lava cools, it forms igneous rocks.

## Metamorphic Rocks

All metamorphic rocks were once either igneous, sedimentary, or other metamorphic rocks. Heat and pressure caused the rocks to change form. When rocks change from one type of rock into another, they change mineral makeup and texture. The process of rocks "morphing" from one form to another can take thousands of years.

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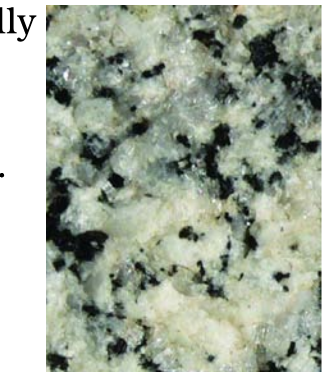
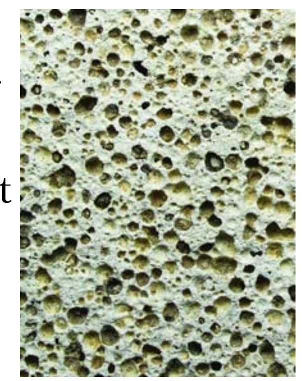
### Igneous Rocks

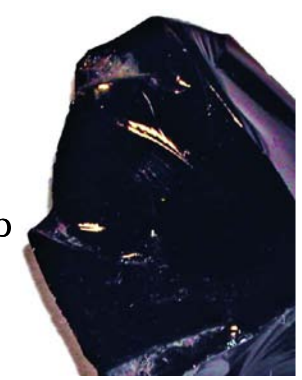
Granite is usually found in large slabs. It is very hard and tough. Its colors range from pink to dark gray or black.



Pumice is very porous, or full of holes. It is usually white, but can be yellow, gray, brown, or dull red.



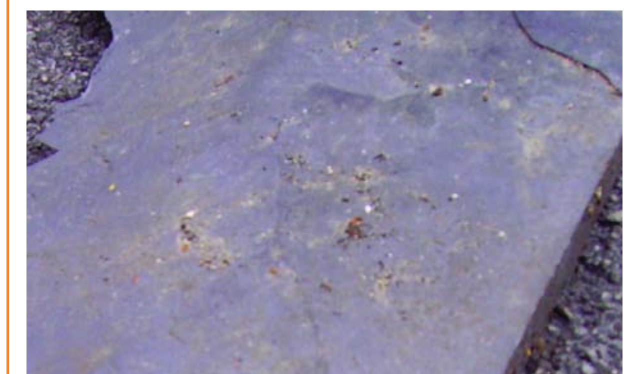
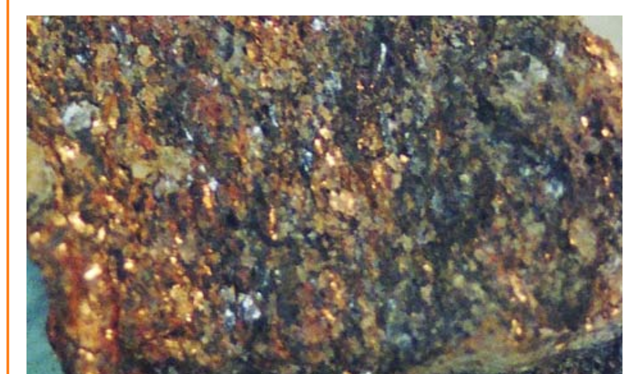
Obsidian is a type of naturally-occurring glass. Its edges can be so thin and sharp that it was used in ancient times for weapons.



Basalt is a common rock — it makes up most of the world's oceanic crust. It is usually dark gray in color.



### Textures of Metamorphic Rocks

| **Foliated Metamorphic Rocks** (Made of many different minerals) | **Non-Foliated Metamorphic Rocks** (Usually made of one mineral) |
|---|---|
|  slate |  marble |
|  schist |  quartzite |
|  gneiss |  serpentinite |

## Sedimentary Rocks

Sedimentary rocks form from sediments, or little bits, of other rocks. Over time, erosion and weathering cause little bits to wear off rocks. Then rain, streams, and rivers carry the little bits of rock until they settle on the bottom of rivers, lakes, seas, or the oceans. The layers of sediment build up on top of one another, pressing the bits of rock together. Slowly these layers turn into rock.

Sedimentary rocks form layers, or strata, in the Earth's crust. Strata near the surface are newer than those further underground. Each layer tells about the Earth's past.

The different strata of sedimentary rock often hold fossils of plants, animals, and other organisms that lived long ago. We usually think of fossils looking like animal bones, shells, or plant leaves. But did you know that even a footprint could become a fossil?

*This fossil, found in Colorado, is a footprint left by a duck-billed dinosaur that lived millions of years ago.*

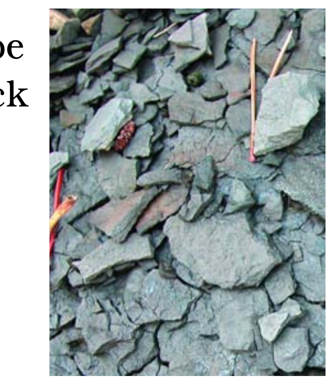


**Sedimentary Rocks**

Limestone is produced from the mineral calcite (calcium carbonate) and sediment.

Most sandstone is composed of quartz and/or feldspar.

Shale rock is a type of sedimentary rock formed from clay.



Gypsum is a soft mineral composed of calcium sulfate dihydrate.

## THE GEOLOGIC TIME SCALE

**Precambrian Era,**
**from 4 billion to 540 million years ago.**

Simple life first appeared, such as bacteria and hard shelled animals.

**Paleozoic Era,**
**from 540 to 250 million years ago.**

The earliest fish, reptiles, and land plants appeared.

**Mesozoic Era,**
**from 250 to 65 million years ago.**

The dinosaurs appeared, and became extinct at the end of the era.

**Cenozoic Era,**
**from 65 million years ago to the present.**

Large mammals and humans evolved.

# The Ocean

In the solar system, Earth is the only planet that has liquid water. Most of this water is in the ocean. The ocean's salty water covers nearly 70 percent of the Earth's surface. The first living things evolved in the ocean. Today, many more plants and animals live in the oceans than on the land.

Not only is the ocean home to lots of plants and animals, it is important to all life on our planet. Nearly 97 percent of the Earths water is in the ocean. The ocean affects the weather and temperature on Earth. In the summer, the ocean cools the land and air. In the winter, it warms them. How the ocean moves also has a big effect on life on land.

WORDS TO KNOW

**dense** (DENSS): crowded, or thick

**erode** (i-RODE): to wear away by water and wind

**geologic** (jee-o-LOJ-ik): having to do with the study of soil and rock

**mineral** (MIN-ur-uhl): a natural substance, such as gold, quartz, or copper, that is not a plant or animal

**pressure** (PRESH-ur): the force produced by pressing on something

**surface** (SUR-fiss): the outside or outermost layer of something

*Ninety-seven percent of the Earth's water is in its salty oceans, but most of the water we use is from freshwater sources.*

## Tides

Tides are the rising and falling of the ocean level near the shore. During high tides, the water level rises. During low tides, the water level falls. The Moon causes most of the tidal movement. The gravity of the Moon pulls the water in the ocean toward it. In most places, there are two high tides and two low tides each day.

*At low tide, the ocean level lowers exposing more beach.*



The Sun also affects the tides. It is larger than the Moon and has more gravity, but because the Sun is farther away, it does not pull on the oceans as strongly as the Moon. When the Sun, Moon, and Earth all line up, the gravitational pulls from the Sun and Moon work together making the tides higher.

Plants and animals near the shore spend their lives adapting to high and low tides. Land at the shores, called coastlines, is built up and torn down by the movement of the ocean tides.

*Tide pools are formed as a high tide comes in over a rocky shore.*

## Waves

The movement of waves also changes the coastlines. Waves break up rocks, coral, and shells into smooth pieces of sand. The waves carry the sand to the land's coastline making beaches.

Many things make waves, including ship's wakes, earthquakes, volcanos, and landslides. But most waves form from winds blowing across the water's surface. Stronger winds make bigger waves. Some strong winds in the middle of the ocean can make waves that hit a beach very far away.

We usually see waves crashing onto a beach, making us think that the water in a wave is moving forward. Waves in deep water are really the forward motion of energy, not the water. The water is only moving up and down.

*Waves erode rock.*

*Waves sculpt sandy beaches.*

Find out more

**Tsunamis**

A tsunami (tsoo-NAH-mee) is a destructive series of waves. Tsunamis are often called tidal waves, but they are not caused by tides. They can be caused by an underwater earthquake or by a volcano erupting beneath the ocean.

These waves can be small, but sometimes they are very large and cause great destruction. They can travel at a speed of almost 500 miles an hour, and reach heights of over 100 feet. Tsunamis are not like hurricanes that meteorologists track, allowing people to get out of harm's way. Tsunamis can arrive on land within fifteen minutes of a quake.

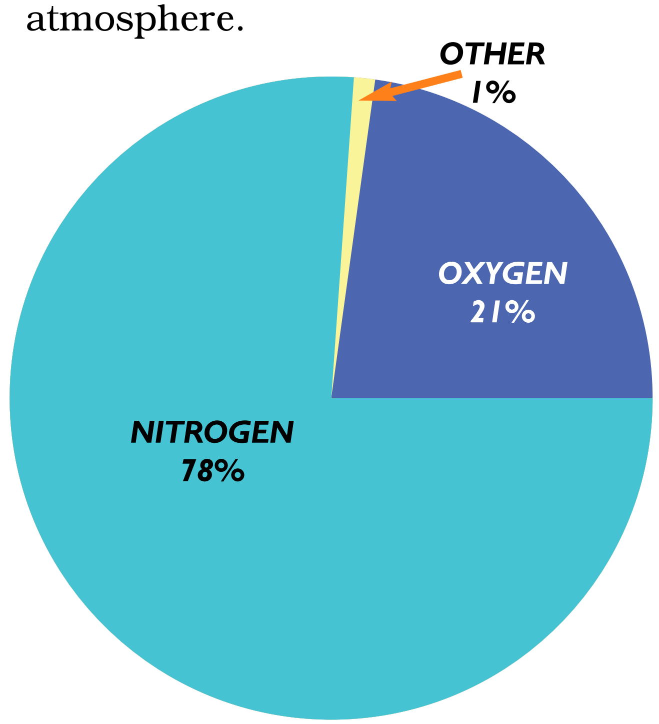
A tsunami caused by an earthquake in the Indian Ocean on December 26, 2004 killed as many as 200,000 people. It was one of the deadliest disasters in modern times. Because of this disaster, scientists are working to create better ways of detecting and warning people of approaching tsunamis.

# The Atmosphere

An atmosphere is the layer of gases that covers the surface of a planet. Earth's atmosphere is about 600 miles (1,000 km) deep. It is very important to all plants and animals. It protects our planet from dangerous radiation from the Sun. It also provides gases that animals need to breathe and that plants need to make food.

## Composition Of The Atmosphere

Earth's atmosphere is made mostly of nitrogen and oxygen, with small amounts of argon, carbon dioxide, hydrogen, methane, and other gases. Ash from volcanos, dust, and small drops of water called vapor are also in the atmosphere.






## The Layers of the Atmosphere

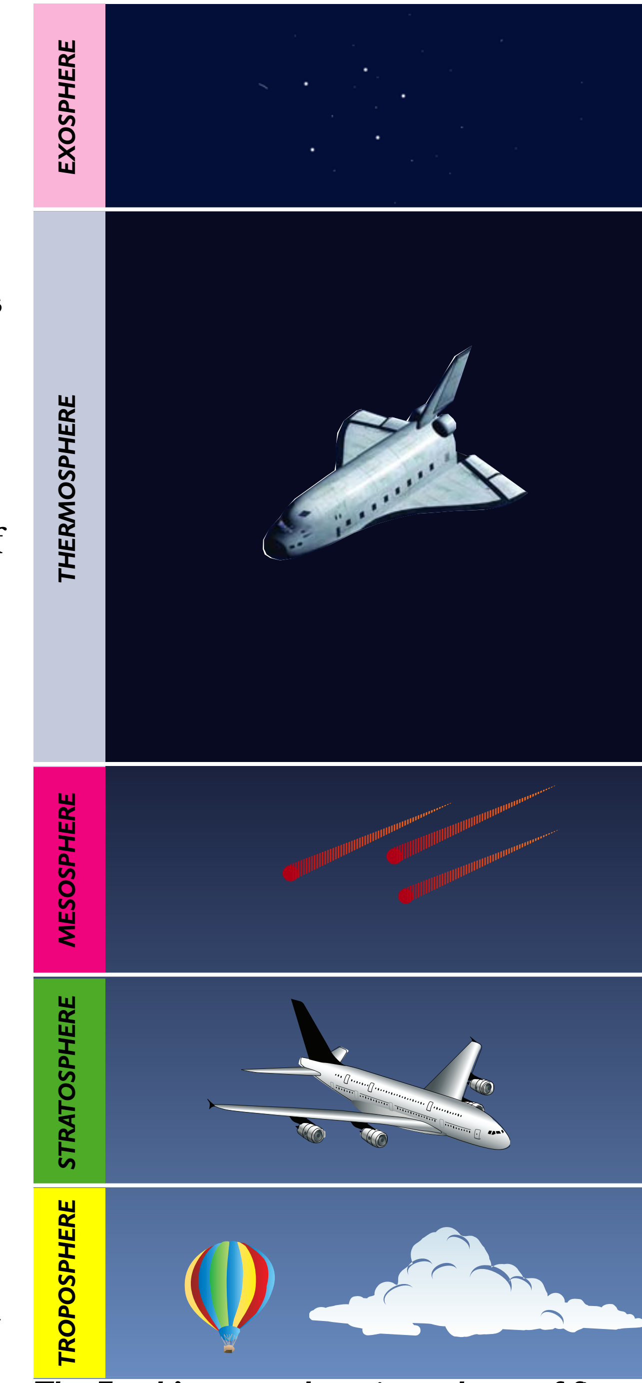
Earth's atmosphere has many different layers. The troposphere is the layer closest to Earth's surface. It is where most changes in the weather happen. Half of the Earth's atmosphere is in the troposphere.

Above the troposphere is the stratosphere. The stratosphere contains the ozone layer. Ozone is a form of oxygen that stops most of the Sun's ultraviolet radiation from reaching the lower part of the atmosphere. If you've flown on a commercial jet, you've probably been in the stratosphere. Pilots like to fly in the stratosphere because it is very clear and calm.

The mesosphere is the next layer up. Meteors burn up as they move through this layer.

Then, on top of the mesosphere, is the thermosphere. Space shuttles orbit the Earth in the thermosphere.

The exosphere is the highest layer in the atmosphere, and it just fades into space. Have you ever wondered why you get more radio stations at night than in the day? Well, thank the exosphere. The exosphere reflects radio waves. The Sun affects the exosphere's height. The changing height of the exosphere increases the range of radio stations after dark.




*The Earth's atmosphere is made up of five distinct layers (not drawn to scale as shown).*

WORDS to Know

**composition** (kom-puh-ZISH-uhn): what something is made of

**radiation** (ray-dee-AY-shuhn): the sending out of rays of light, heat, or particles

**vapor** (VAY-pur): fine particles of mist or steam

# Forces That Shape the Earth

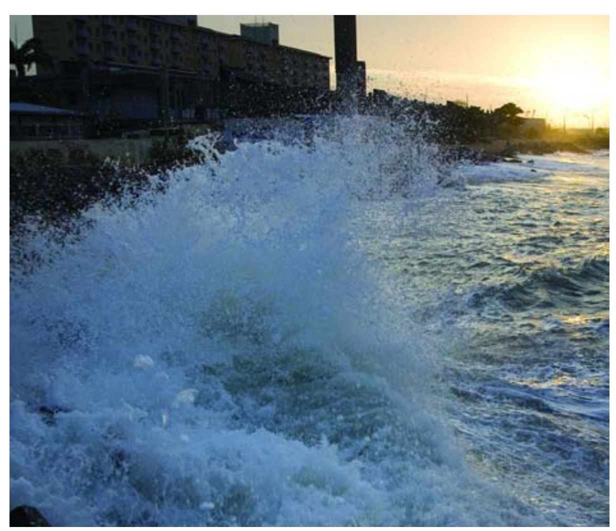
Many forces can form, or shape, the Earth. Some of these forces come from deep within the ground. Volcanos and earthquakes cause major changes to the landscape. Other changes occur because of natural forces on the surface. Water and wind shape the planet every day. Human activity also plays a role in shaping the world.

**Forces That Shape The Earth**

*Volcanos erupt when pressure builds; sending out lava, hot gases, and ash.*

*Sandstorms move huge clouds of sand and dust from place to place.*

*Earthquakes cause cracks that run deep into the Earth's crust.*



*Waves erode rock, sand, and sometimes, man-made structures.*



## Plate Tectonics

It's difficult to imagine entire continents moving, but they do. The Earth's crust is not all one piece. It is broken up into 16 huge pieces and several smaller ones called tectonic plates. These plates make up all the Earth's dry land and the ocean floor.

The tectonic plates move at the rate of about four inches (10 cm) a year. That may not seem like much, but over hundreds of millions of years, the plates have moved long distances. Plate tectonics is the idea that the lithosphere is made of slow moving plates.

Plates come together to form ridges on land and underwater. They form trenches where they separate from one another.

A plate grows bigger on one edge where new igneous rock forms. The other edge of the plate slides under or on top of another plate.


*This map shows the world's tectonic plates. Can you find the continents drawn in lighter colors?*

*Plate tectonics causes earthquakes to shake, volcanos to erupt, mountains to grow, and continents to move.*

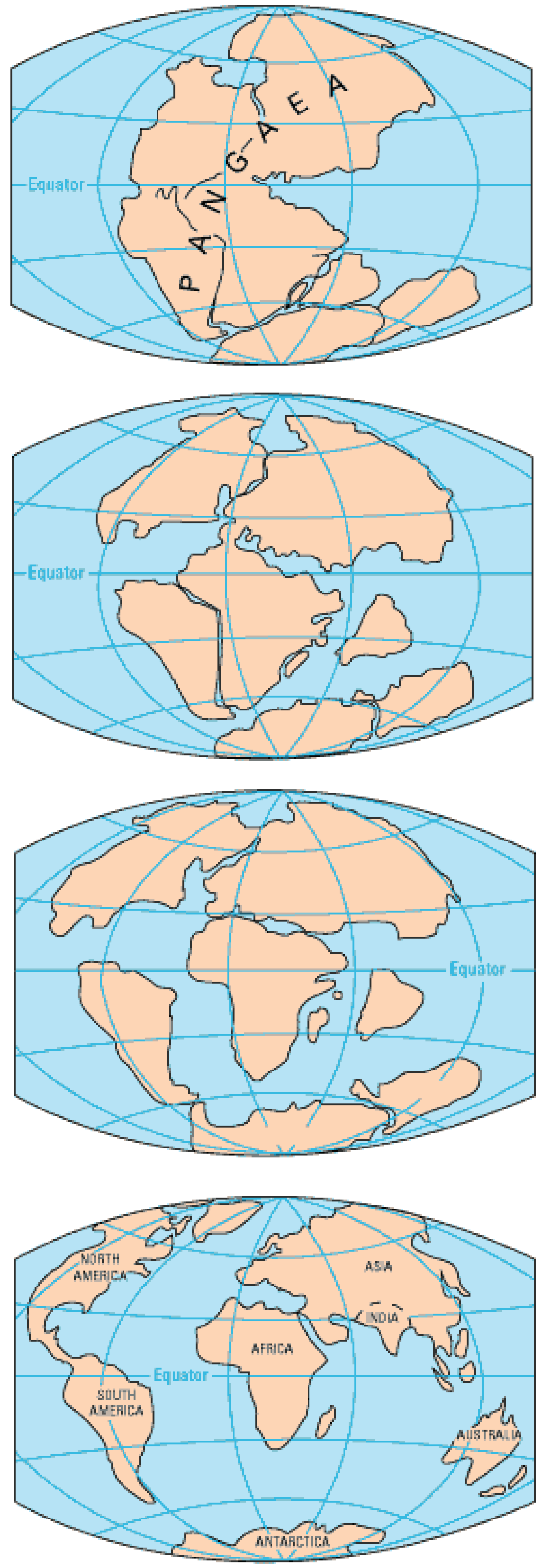
WORDS to know

**continent** (KON-tuh-nuhnt): one of the seven large land masses of the Earth

**ridge** (rij): a narrow, raised strip

**trench** (trench): a long, narrow ditch

## Continental Drift




Throughout Earth's history, the continents have connected and separated. The last time all the continents were connected they made one huge continent, Pangaea. Pangaea means "all lands". Pangaea broke up about 200 million years ago. Its pieces drifted apart over time. They created the continents as we know them today. Continental drift is the process of the continents shifting relative to one another.

Plate tectonics cause the continents to drift. The giant trenches created from this drift are called rift valleys. The plates on which the continents sit spread away from these valleys. The plates move apart as new material from within the Earth comes up.

In some places, an ocean plate will slide below a continental plate. Mountains are often pushed up along the plate that stays on top. The Andes in South America formed this way. Sometimes, two continental plates collide. This causes the plates to crumple and high mountains to form. India collided with Asia and formed the Himalayas.



***The Himalayas contain the three highest mountains on Earth.***

***The Hawaiian Islands are actually mountain tops poking above the waterline.***

There are actually more mountains under the water than there are above the water. Many of these mountains are taller than the ones we see above the water.

Earth's longest mountain range, the Mid-Atlantic Ridge sits in the middle of the Atlantic Ocean between South America and Africa.

Getting to know...

### Alfred Wegener

Alfred Wegener was born in Germany in 1880. He dreamed of exploring Greenland and the Arctic. In school, Wegener studied astronomy, meteorology, and geophysics, the study of the forces that shape the Earth. He fought in World War I and was wounded twice.

Wegener is best known for his ideas about continental drift. He looked at a map of the world and noticed the similar shapes of the coasts of Africa and South America. Wegener suggested that they were once joined and then drifted apart. In 1924, he published his theories in the book *The Origin of Continents and Oceans*. Wegener died in 1930. It was not until the 1960's that discoveries confirmed that continental drift really happens.

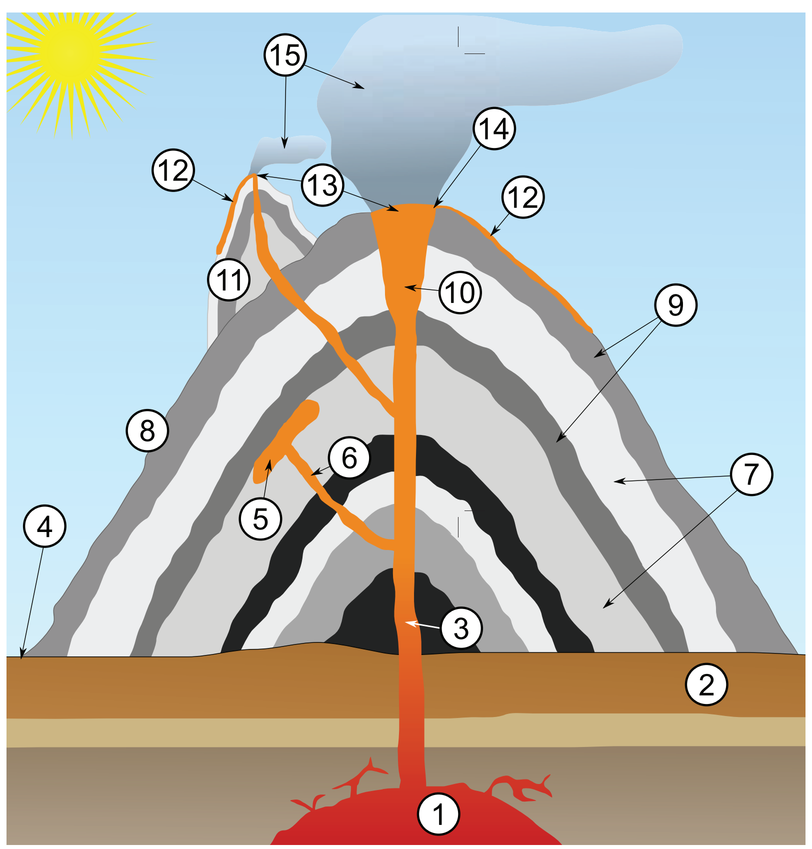
## Volcanos

A volcano is a hole or vent in the Earth where hot rock and gas come out. Magma deep within the Earth puts pressure on weak areas of the crust. The magma melts away rock and creates hot gases. The gas and magma come together many miles underground in the magma chamber. Pressure builds. The volcano erupts when the pressure becomes high enough.

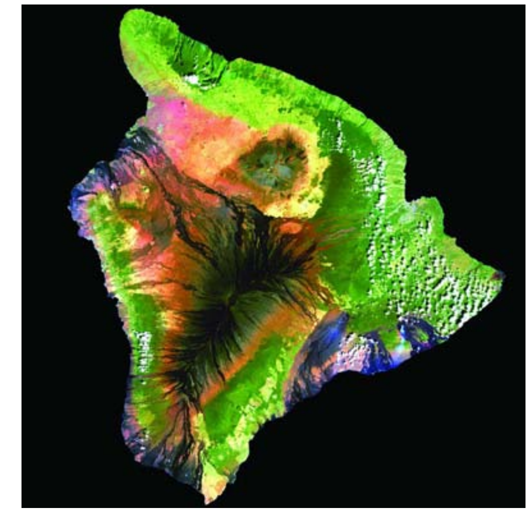
An eruption sends out lava, hot gases, and ash. Lava is magma that reaches the surface. Volcanos erupt in many ways. Some volcanos send out towers of lava and clouds of ash. Other volcanos ooze rivers of lava. Many volcanos explode violently.

Volcanos usually occur on or near the edges of the plates in the crust. They often erupt when the plates move.

Volcanos in the ocean can create islands. The islands of Hawaii formed this way.




1. *Large magma chamber*
2. *Bedrock*
3. *Conduit (pipe)*
4. *Base*
5. *Sill*
6. *Branch pipe*
7. *Layers of ash emitted by the volcano*
8. *Flank*
9. *Layers of lava emitted by the volcano*
10. *Throat*
11. *Parasitic cone*
12. *Lava flow*
13. *Vent*
14. *Crater*
15. *Ash cloud*



Volcanos on land sometimes make mountains. Active volcanos still erupt sometimes. Dormant volcanos have not erupted in a long time, but might. Extinct volcanos will never erupt again.

***The island of Hawaii was created by volcanic eruptions.***

Find out more

### Mount St. Helens

In May of 1980, the volcano Mount St. Helens erupted in Washington State. It had been dormant for over 120 years. For several months, earthquakes shook the mountain. Steam was seen shooting out of the top. Then on May 18, 1980, the north side of the mountain collapsed. Mount St. Helens erupted! Hot magma and ash began gushing out. The eruption lasted nine hours.

Before it was over, lava and ash covered 230 square miles of land. Fifty-seven human lives were lost. The eruption destroyed thousands and thousands of acres of forest. It also killed thousands of forest animals and millions of fish.

***Mount St. Helens before the eruption***

***Mount St. Helens after the eruption***

# Earthquakes

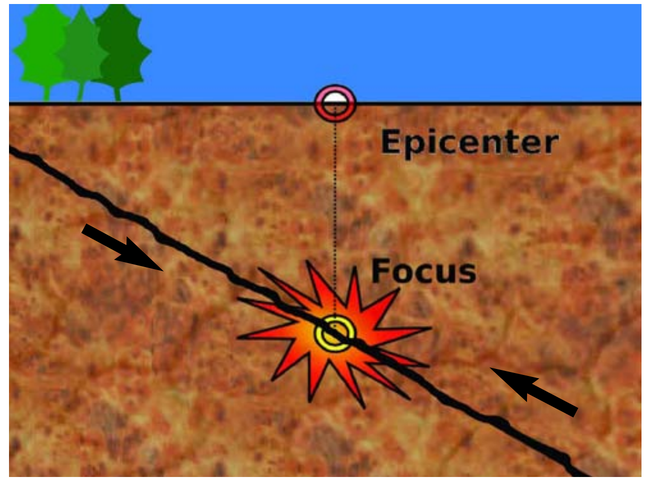
An earthquake is an event that causes the ground to shake. A sudden movement of the Earth's crust causes an earthquake. This releases energy within the ground.

## How Earthquakes Happen

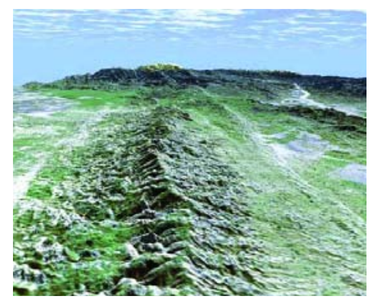
When tectonic plates collide, they can cause the Earth's crust to crack. These cracks, called faults, usually run along the edges of the plates. A few are in the middle of the plates. Most faults run deep into the crust.

The rocks on both sides of the fault fit tightly together. They bend as stress builds up because of continental drift. If the stress gets strong enough, the rocks suddenly snap back into shape. They release shock waves of energy. The shock waves reach the surface of the Earth. The land starts to shake. An earthquake has begun.

The focus of the earthquake is the point where the stress releases. The epicenter is the place on the Earth's surface directly above the focus.




The San Andreas Fault is the best known fault in North America. It runs through California for 800 miles (1,300 km). It was the cause of the Great San Francisco Earthquake of 1906. The earthquake caused massive fires and terrible destruction. It was one of the worst natural disasters ever to hit the United States.



***The San Andreas fault marks a boundary where two tectonic plates meet.***

Many people think of fault lines occurring near the edges of continents. In fact, faults can occur anywhere. If you live in the Southern or Midwestern United States, you might live near the New Madrid Fault Line.

## Measuring Earthquakes

Seismologists, scientists who study earthquakes, have several ways to measure them. If you've heard a news report on an earthquake, you've probably heard of the Richter Scale.



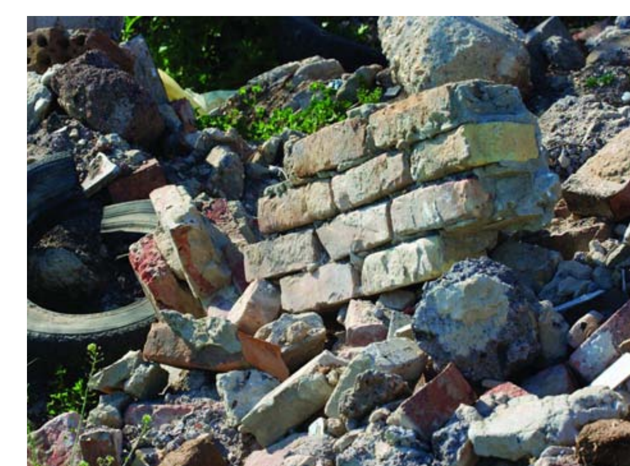
**The Richter Scale** describes the strength, or magnitude, of an earthquake. It is named after American scientist Charles Richter. A machine called a seismograph measures the earthquake's strength.

The Richter Scale ranges from 1 to 10. Each number of the scale stands for a tenfold increase in the strength of an earthquake. An earthquake that registers five on the scale is ten times worse than an earthquake with a magnitude of four.

**Measurements on the Richter Scale**

| Earthquake Magnitude | Effects |
|---|---|
| 1-3 | • Can be recorded on a seismograph, but rarely causes damage<br>• Usually not felt by humans |
| 3-6 | • Can be felt by humans<br>• Damage is usually minor<br>• Some buildings can be affected |
| 6-9+ | • Is felt by humans<br>• Can cause great damage<br>• An earthquake with a magnitude over six can cause damage for 100 miles<br>• Anything greater than eight can cause severe damage over an area of hundreds of miles |

**The Mercalli Scale** measures how much the Earth shakes. It is named after Italian scientist Giuseppe Mercalli. Earthquakes with Mercalli intensity of I (one) are not felt. Special instruments detect them. Those with an intensity of XII (twelve) cause total destruction of cities and change the Earth's surface.



***This once-sturdy structure was completely destroyed by an earthquake.***

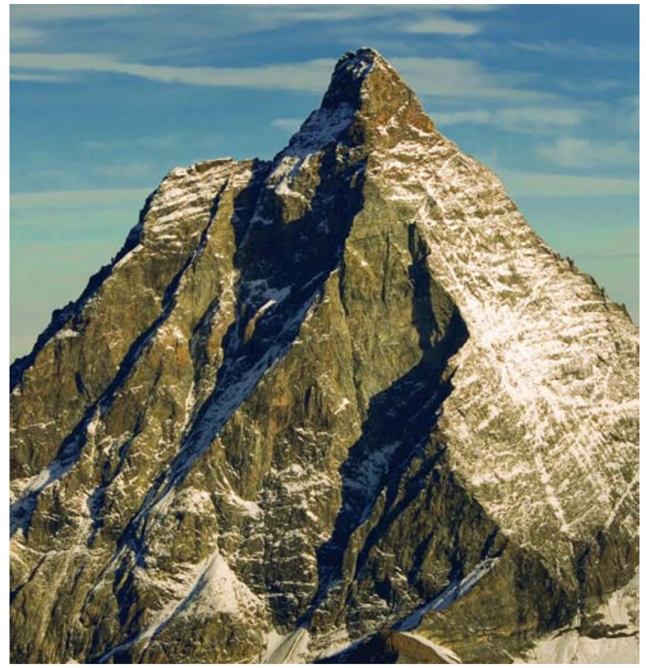
## Glaciers

Glaciers are big sheets of ice. About 75 percent of the worlds fresh water is stored in glaciers. When layer upon layer of snow compresses into ice, glaciers form. Glacier ice is not like the ice that forms in the winter and melts in summer on a lake. The ice from glaciers does not melt away from season to season. Glaciers cover about 10 percent of Earth's land area.

Glacial ice is always moving. It advances, and then retreats. Glaciers begin to move as the ice builds up and becomes denser. Glaciers slowly move down hills and valleys like a river of ice. They can carry huge rocks with them. They often carve deep valleys as they move. Glaciers make mountain peaks and ridges sharper. They also make valley walls steeper. Three glaciers around a mountain in Switzerland created a peak called the Matterhorn.

### Glaciers in the Ice Ages

Glaciers covered more of the Earth at various times in the past. We call these ice ages. The temperature of the planet became much colder during the ice ages.



***The steep faces of the Matterhorn, in Switzerland, make it difficult for much ice and snow to build up.***

During the last ice age, huge glaciers covered about 32 percent of the total land area. Water levels in the oceans dropped over 300 feet (about 100 meters) as glaciers grew. The landscape was changed when the glaciers melted.

### Glaciers Today

Today, many glaciers are small. You may see one in a mountain valley where it stays cold and shady. The largest glaciers are in Antarctica and Greenland. These huge masses of ice are continental glaciers. They are so big that they cool the air and water far away from the glacier.

North America has about 29,000 square miles (75,000



square kilometers) of glaciers. Can you guess what state most of the glaciers are in? If you guessed Alaska, you're right!

***This Alaskan glacier appears blue because the ice absorbs all colors of the visible light spectrum except blue.***

## Erosion

Sunlight, wind, rain, and snow all cause the Earth's surface to change, or break down, over time. We call this erosion.

### Weathering

Weather causes the most erosion. Wind, rain, and frost make many rocks fall apart. Chemical weathering is erosion affecting the chemical structure of things.

### Water Erosion

Water in all forms causes erosion. Ocean waves can erode sand from beaches, create bays, hollow out caves, and change shorelines. Rain often washes away loose topsoil. Rain can sometimes make hillsides very wet and cause landslides. Over time, rivers sometimes wear away rocks and form valleys and canyons. The Grand Canyon formed over millions of years. The sides of the canyon wall show many layers of sedimentary rock.

***A view of the Grand Canyon shows the layers of sedimentary rock.***

**WORDS to KNOW**

**compress** (kuhm-PRESS): to squeeze something so it fits in a smaller space

**landscape** (LAND-skape): a large area of land that you can view from one place

**valley** (val-ee): an area of low ground between two hills or mountains

**bay** (bay): a portion of the ocean that is partly enclosed by land

**canyon** (KAN-yuhn): a narrow, deep river valley with steep sides

**topsoil** (TOP-soil): the top or surface layer of soil

## Wind Erosion

Wind can also change landscapes dramatically. Sand and dust grind down the surfaces of rocks and other objects they blow across. Strong winds can change the shape of piles of sand, called dunes, in deserts and on beaches.

***With very little plant life to help hold the sand in place, these dunes will shift with the wind.***

Find out more

**Caves**

Sometimes, erosion takes place underground. Caves often form because of streams that flow underground. The stream flows just above the water table. The water table is the level at which the ground is made completely wet, or saturated, by water. When the water table goes down, an empty cave, or cavern, is left. Caves are holes that run horizontally underground. The longest cave system is in the United States in Kentucky. Mammoth Cave is 348 miles (560 km) long.

When water drips through the rocks above the cave, mineral deposits form on the cave's roof. They create stalactites that hang down like icicles from the top of the cave. More deposits form as the water drips down to the cave's floor. Eventually, deposits on the floor will form a stalagmite that comes up from the floor of the cave. A column forms when a stalactite and a stalagmite meet.

An easy way to remember the difference between a stalactite and a stalagmite is, a stalactite "holds tight" to a cave's roof so it doesn't fall!

***The inside of a cave shows stalactites and stalagmites.***

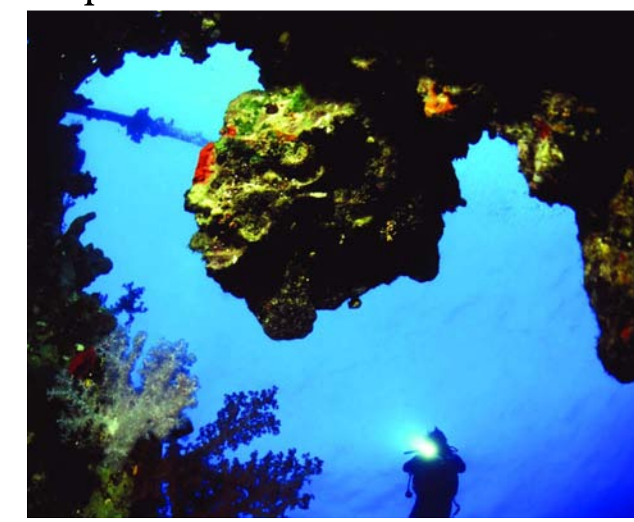


# Human Activities

Natural forces have always shaped the Earth. Only recently in Earth's history have people helped shape it, too.

Humans can change the surface of the Earth in many ways. Mountains are flattened, and valleys are filled in. Sometimes, people dig caves in mountains, called mines, to bring out minerals. Cars, trucks, and trains travel through tunnels in mountains. People may carve mountains into monuments, like Mount Rushmore in South Dakota.

Under the sea, coral reefs form on the wrecks of sunken ships. They provide a new place for sea creatures to live. We construct harbors and walls (breakwaters) by moving piles of dirt and rocks into the ocean. Breakwaters prevent waves from destroying ships.



***Coral reefs grow on sunken ships, creating homes for many fish.***

***The faces of George Washington, Thomas Jefferson, Theodore Roosevelt, and Abraham Lincoln gaze down from Mount Rushmore in South Dakota.***

We dig canals to link two bodies of water. Some canals are small. Other canals, like the Panama Canal, are big enough for huge freighters. The Panama Canal connects the Atlantic Ocean and the Pacific Ocean.

***The Panama Canal, completed in 1914, is 51 miles long.***

We move rivers to provide water to areas that do not have enough. Aqueducts change the flow of the water. The Central Arizona Project (CAP) aqueduct is 336 miles long.

***Arizona residents appreciate the water the CAP aqueduct brings.***

***An aerial photo of the Colorado River also gives a view of the surrounding landscape.***

It brings water from the Colorado River to parts of central and southern Arizona.

Sometimes we build dams across rivers. These dams create lakes and provide energy to communities. Hydroelectric energy is electricity made using the power of water.

***Dams change the landscape and affect the plants and animals that live in the area.***



# Weather

PROJECTS volume 10 4.2

We talk about the weather every day, but what exactly is it? We can define it as the state of the atmosphere. The amount of wind, the temperature, the moisture, and cloudiness are some of the things that make up weather.

***A thunderstorm rolls in over the grasslands.***

Weather affects many things on Earth. Weather extremes usually have a negative effect on people and the environment. Normal weather has a positive effect. Plants and animals need water to survive, but too much water can be a problem. When the usual weather (climate) changes, some plants and animals cannot adapt to the changes and will die off. Weather can be powerful and even dangerous.

## Wind

Wind is moving air. Changes in pressure in the atmosphere create this movement. Temperatures affect pressure. Warm air expands and rises. There is low pressure in areas with warm air. Cold air is heavier. There is high pressure in areas with cold air. A barometer measures air pressure.


***A barometer helps predict changes in the weather.***

### WORDS to Know

**climate** (KLYE-mit): the usual weather in a place

**extreme** (ek-STREEM): one of two ends or opposites, as in wet and dry

**moisture** (MOIST-chyer): the amount of water in the air

**normal** (NOR-muhl): usual or regular

**Find out more**

**Measuring the Wind**

You can measure the speed of the wind and its direction with different weather instruments.

A weather vane usually looks like a rooster. The rooster's head points in the direction the wind is coming from.

A wind sock measures both the speed and direction of the wind. It points the way the wind is blowing. As wind speed increases, the wind sock moves upwards.

An anemometer measures wind speed. Its cups catch the wind and cause the device to spin. The faster it spins, the greater the wind speed.

Winds that blow across deserts are usually warm. Winds that blow across mountains are often cold, especially when there is snow. The wind chill factor is how much colder it feels outside when a cold wind is blowing.

Some winds happen only in smaller areas like cities, towns, canyons, and valleys. These winds are low to the ground. Other winds occur across very large areas like continents and oceans. These winds are higher up in the atmosphere. They move clouds. Jet streams are fast winds high in the sky.

A breeze is a light wind. It may move leaves and flags. A sudden stronger wind is a gust. Strong winds can knock over trees and power lines.

## Clouds

Clouds form when moisture on the Earth's surface evaporates. It rises into the air where it is too cold to stay as mist. The moisture sticks to particles like dust to make drops of water or crystals of ice. Many drops of water form a cloud.

The moisture in the cloud either evaporates or falls back down as precipitation. Mist, rain, hail, snow,



and sleet are all types of precipitation.

Clouds come in many shapes and sizes. Fog is a large cloud that touches the ground. It can be thick and hard to see through. Cloud names come from Latin words that describe how a cloud looks when we're looking up at it.

### Cumulus Clouds

Cumulus means heap. These clouds are tall and puffy like cotton. They can start near the ground and extend far up into the sky.

***Cumulus clouds usually mean fair weather.***

Strong updrafts can change cumulus clouds into thunderclouds. Thunderclouds give off electricity in the form of lightning. A flash of lightning makes the surrounding air expand, which causes a loud sound called thunder. A thundercloud does not always bring rain.

If you visit Florida in the summer months, be prepared for almost daily thunderstorms. Florida has more thunderstorms than any other place in the United States.

***Storm clouds warn of stormy weather on its way.***

### Cirrus Clouds

Cirrus means curl of hair. These clouds are thin and wispy. They are high in the atmosphere. This is the most common type of cloud.

***Cirrus clouds are formed of ice crystals.***

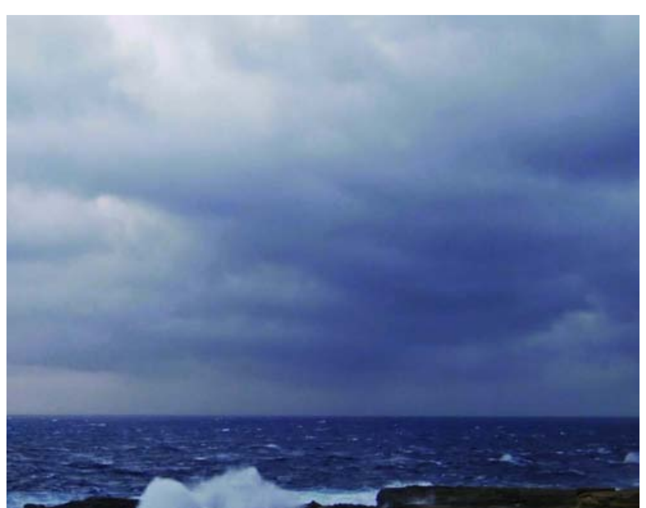
### Stratus Clouds

Stratus means layer. These clouds form a large layer or sheet in the sky. They are usually low in the sky. They rarely bring precipitation.

*Stratus clouds look like a soft blanket covering the sky.*

### Nimbus Clouds

Nimbus means rain. These clouds are dark because they are full of water. Nimbus clouds bring precipitation.



*Nimbus clouds mean rain, snow, hail, or sleet is on its way.*

## Rain

Rain is water that falls from the sky. Rain can be very small drops of water that are almost like mist. It can include some larger drops. We call this sprinkles or drizzle. Showers are short periods of rain that can be heavier. A downpour is a heavy, often sudden rain. A rain storm has heavy rains and, often, strong winds.

*A summer rainstorm is refreshing.*

A thunderstorm also has lightning and thunder. You can tell the distance to a thunderstorm by counting. We see lightning instantly, but the sound of thunder takes several seconds to reach us.

When you are near a thunderstorm, watch for a flash of lightning and count until you hear



thunder. Every five seconds is a mile, and every three seconds is a kilometer.

*Lightning illuminates a stormy sky.*

Heavy rains can cause damage to houses and nature and can hurt people. This is especially true if it rains constantly over a long time or if it rains a lot very quickly. A flood happens when water rises in rivers or lakes and flows over land that is usually dry. The water in a flood can rise slowly or move very fast, like a river.

A flash flood is a flood that happens quickly in a low lying area. The ground cannot absorb the huge amounts of falling rain fast enough. There is little time for warnings. Flash floods can cover houses, wash away roads and bridges, and drown people.

Sometimes, a hillside gets too much rain and cannot soak up any more water. The top layer of soil falls down causing a mudslide.

*A mudslide carries debris to the road below.*

## Snow

Rain often starts out as ice crystals high in the atmosphere. The crystals melt into raindrops if the air on the way down is above freezing. The crystals stay as snow if the air on the way down is below freezing. Snow is falling water in the form of ice flakes.

*Snow falls on a forest of fir trees.*

A lot of snow may fall in an area. Snow can block roads and your door. Being snowed in means you cannot get outside because there is so much snow on the ground.

*A heavy snowfall can make it difficult to get around.*

## Snowflakes

Every snowflake is a little different from the rest. They all have six sides, but some also have needles, stars, or other shapes. Snowflakes all have six sides because of the chemical formula for water ($H_2O$). Larger snowflakes form when the temperature is near freezing. The snowflakes are wet and stick together as they fall through the sky. Smaller snowflakes form when the air is colder.

*Under a microscope's lens, it is easier to see the different shapes snowflakes can form.*

## Sleet and Hail

Sleet is made of frozen raindrops that bounce when they hit the ground. Hail is made of larger frozen raindrops. Hail can fall during thunderstorms. Most pieces of hail are small, but some can be the size of a golf ball or bigger. Large hail can damage crops and even hurt people.

*This golf ball-sized hail fell from thunderclouds.*

Find out more

### Avalanches

Snow builds up in layers on the side of a mountain. Avalanches happen when there is more snow than the slope of the mountain can hold or when one layer of snow slides across the surface of another layer. The snow suddenly slides down causing an avalanche.

An avalanche can bury people. Sometimes this happens to skiers or hikers. Because of this, ski resorts sometimes set off explosives in the mountains to cause small avalanches when no one is around. This prevents snow from building up into a large avalanche when people are on the mountain.



## Tornados

PROJECTS volume 10 4.3

A tornado is a fast moving, violent storm. The wind spins very fast and looks like a funnel. Sometimes people call tornados a twister or whirlwind. Water spouts are tornados occurring over water.

A tornado usually forms inside a thundercloud. Areas of cold air pull in warm, moist air. This makes an area of low pressure. A cloud turns around the low pressure. It makes a spinning cone called a funnel. The funnel usually stays in the air, but it can hit the ground, or touch down, suddenly.

*The tornado is the thin tube reaching from the cloud to the ground.*

Small tornados may break tree branches and street signs. Larger ones can break windows, pull up trees, flip over cars, and knock down walls. The biggest tornados can destroy houses and other buildings. They can kill many people.

Tornados can occur all over the world but most occur in the United States. Tornado Alley, an area from Texas to Nebraska, has had many very destructive tornados. Texas, Florida, and Oklahoma have the most tornados each year. Cold air from the north and warm air from the Gulf of Mexico meet in these places.

*Tornado Alley, circled in white, is an area where tornados frequently occur.*

The Fujita scale rates a tornados force. An F0 is a small gale tornado. An F5 or F6 tornado destroys everything in its path.

Meteorologists have developed tools and warning systems, giving people a chance to get to a safe place. A tornado watch means that weather conditions are right for a tornado to form. A tornado warning means there is immediate danger and you should move to a safe place quickly.

Getting to know...

## Vilhelm Bjerknes

Vilhelm Bjerknes was born in Norway in 1862. He worked with his father, a physicist who studied the motion of fluids called hydrodynamics.

Bjerknes studied the atmosphere and the oceans. His ideas helped start meteorology, the science of the atmosphere and weather. Vilhelm's son, Jacob Bjerknes, became a meteorologist and worked with his father to set up weather stations to collect information. Their results suggested the polar front theory to explain how a cyclone forms. A front is the area between different masses of air. Bjerknes said that cyclones happen where warm and cold fronts meet.

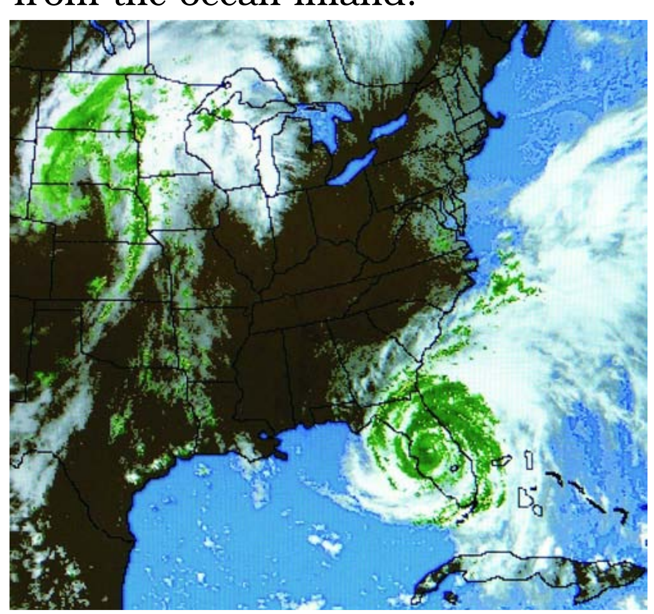
The Bjerknes crater on the moon was named in his honor.

## Hurricanes

Hurricanes and typhoons are both tropical cyclones. Tropical cyclones are powerful storms that form in places near the equator, or the tropics. Whether a tropical cyclone is called a typhoon or hurricane depends on where it is located. A tropical cyclone west of the International Date Line is a typhoon. A tropical cyclone east of the International Date Line is a hurricane.

A tropical cyclone always forms over water. It begins as a tropical depression. Then it becomes a tropical storm spinning around an area of low pressure.

A tropical storm becomes a hurricane when the winds reach high speeds of about 74 miles (119 kilometers) per hour. It usually lasts from five to seven days and slows down when it reaches land. A hurricane often brings rain, lightning, and a storm surge in addition to its strong winds. A storm surge is the water pushed from the ocean inland.



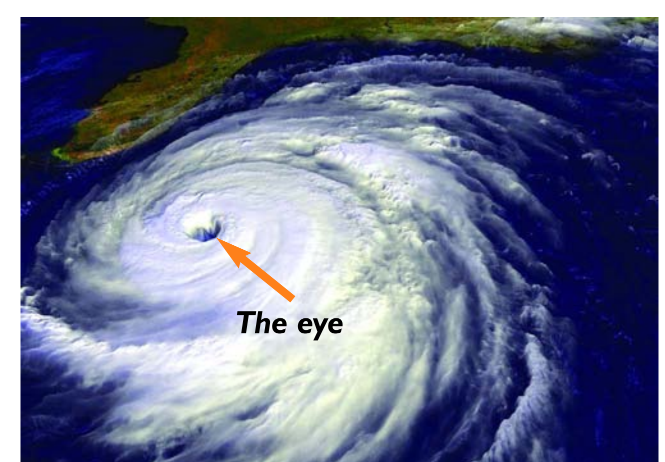
***This large hurricane covers most of the state of Florida.***



**Hurricane Categories**

| Category | Wind speed | Storm surge |
|---|---|---|
| 1 | 74-95 mph (121-153 kph) | 3-5 feet (1-1.7 m) |
| 2 | 96-110 mph (154-178 kph) | 6-8 feet (1.8-2.6 m) |
| 3 | 111-130 mph (178-210 kph) | 9-12 feet (2.7-3.8 m) |
| 4 | 131-155 mph (210-249 kph) | 13-18 feet (3.9-5.6 m) |
| 5 | More than 155 mph (more than 249 kph) | 19 feet or more (more than 5.7 m) |

The center of the hurricane is the eye. Clouds spin around the eye and carry a lot of moisture. Inside the eye of a hurricane, it is strangely calm. There may be sunshine, warmer air, and almost no wind. Some people in the eye of the hurricane think that the storm is over, but the second part will come in a few minutes or hours.




Strong hurricanes can destroy buildings and boats and can kill many people. The worst hurricanes often form in the Atlantic Ocean. They cause a lot of damage on Caribbean islands and in the southern and eastern United States.

***A hurricane completely destroyed this home.***

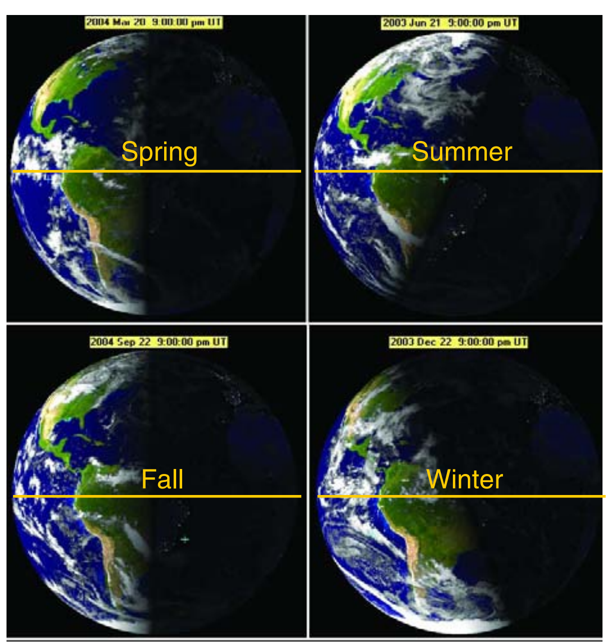
## The Seasons

The earth tilts, or leans, in one direction as it orbits the Sun. It rotates like a spinning top as it moves through space. Half of the Earth tilts toward the Sun. The Northern Hemisphere gets more sunlight when the Earth is on one side of the Sun. There, summer has long days and hot temperatures. Not as much sunlight reaches the Southern Hemisphere.

Half a year later, the Southern Hemisphere receives more sunlight and has warmer weather. At this time, it is winter in the Northern Hemisphere.

The equator receives nearly the same amount of heat from the Sun year round. There are no seasons on the equator. The changes in seasons are greater the farther north or south you get from the equator.

The North and South Poles have only two seasons. The Sun never rises during the middle of winter. The Sun never sets during most of the summer. Much of the United States and southern Canada has four seasons every year.




***Photos from space show the position of Earth in relation to the Sun's light at the start of spring, summer, fall, and winter in the Northern Hemisphere.***

**Weather Forecasting**

"What will the weather be like today?" People want to know if it will be warm or cold, if it will be windy, or if it might rain or snow. The answers help them decide what to wear or whether to go outside at all. A meteorologist is someone who studies the weather and tries to answer these questions. Weather forecasting is the science of predicting what the weather will be like for that day or for the next few days.

Meteorologists measure the air's temperature, pressure, and amount of moisture, or humidity. They measure the direction and speed of the wind. They also watch pictures of the Earth's weather taken by satellites in space. These pictures can follow storms and show where they are going. Meteorologists use all of this information to make a weather report about what will happen.



# Habitats

Life on Earth is delicate. There needs to be a balance between the environment and living things.

A habitat is where certain types of animals and plants usually live. Some habitats are as small as the shade under a rock. Most habitats are larger areas. They may contain many species of plants and animals. Many kinds of plants and animals can only survive in a specific habitat. Look around you. What plants and animals live in your habitat?

## The Ocean

The ocean has many different habitats. Some fish swim down in the deepest parts of the ocean where it is very dark. Other fish spend their lives swimming near the top.

### Tide Pools

Many plants and animals live near the shore in tide pools. When the tide comes in, saltwater pours into the tide pools. When the tide goes out, most of the water leaves, exposing the tide pool to the air.

A tide pool is a very tough environment. Animals living in tide pools must be able to live on land and in water. They must be strong enough to keep from washing out to sea with the tide. They also must adjust to the waves that crash over them. Many of the animals that live there have hard shells to protect them.

***Sea stars cling onto the rocks of a tide pool.***

Some animals that live in tide pools are sea anemones, crabs, mussels, sea stars, snails, sea urchins, and whelks.

### Coral Reefs

Many different creatures live in coral reefs. Coral is not a plant but an animal. Colonies of coral provide homes for many small fish. They swim in and out of the coral to protect themselves from larger fish looking for a meal.

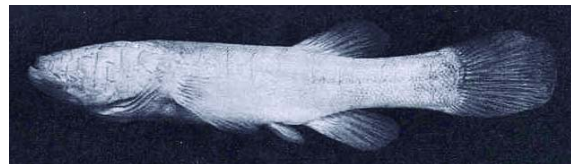
*Many varieties of coral grow in the warm waters of the Great Barrier Reef.*

The Great Barrier Reef off the coast of Northeast Australia is the largest reef system in the world. It is made of nearly 3,000 reefs and 900 islands. The reef system is in the Coral Sea and is more than 1,600 miles (2,600 km) long. Many forms of sea life from the tiniest of fish to large sharks live there.

Many people travel to Australia to visit this natural wonder.

### The Open Ocean

Many sea creatures live in the open ocean. Some live close to the surface because they need sunlight. Seaweed needs light for photosynthesis. Photosynthesis is how plants convert sunlight into food. Seaweed never grows deep where light cannot reach it. Other creatures have adapted to live deep under the sea where there is very little light and enormus pressure. Some deepwater creatures have no eyes.



*Cave fish do not have eyes. They live in darkness so they do not need them.*

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### Jacques Cousteau

**Getting to know...**

Jacques Cousteau was born in France in 1910. He joined the French navy in 1930. Cousteau tested how long he could hold his breath underwater. He wanted to go on long dives. At that time, big diving suits and hoses were used for breathing underwater. They did not work well. Cousteau helped develop the aqua-lung. It was a device for controlling the flow of gases on a small tank of air.

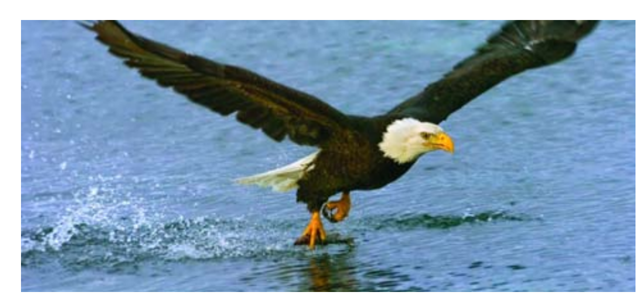
Cousteau studied the world under the ocean. He used a ship called the Calypso as his laboratory. He explored sunken ships on the ocean floor. He filmed sea animals like sharks, whales, dolphins, and turtles. He went more than one mile, or kilometer, down into the ocean.



Some parts of the oceans change temperature. A condition called El Niño is when a large part of the Pacific Ocean off the west coast of South America becomes warmer than usual. A condition called La Niña is when the same part of the Pacific Ocean becomes colder than usual. These changes can affect the weather around the world. Temperature changes can cause some types of fish to die. When this happens, mammals and fish that eat other fish may also die or migrate somewhere else to look for food.

## Lakes and Rivers

Lakes and rivers are areas of freshwater. This means that their water is not salty, like the ocean. Lakes and rivers are not just home to fish living in the water. Many other animals live on the land surrounding the lakes. Water fowl are birds that live near water. Many birds such as bald eagles dive into the water to catch fish.

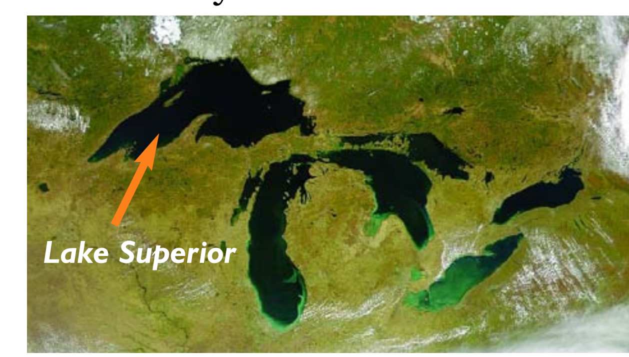


*Bald Eagles are skilled at catching fish.*

### Lakes

A lake is a body of water that is contained within land. Some lakes are very large and deep. For example, the Great Lakes in North America are almost like small oceans. Other lakes are small and shallow.

Different lakes can have very different temperatures. They can have different mixtures of chemicals. These things depend on the surrounding climate and the source of the water that flows into the lake. Lakes getting water from mountain streams of melted snow can be very cold.




*The Great Lakes can be seen from space. Lake Superior, on the far left, is the largest and deepest of the five lakes.*

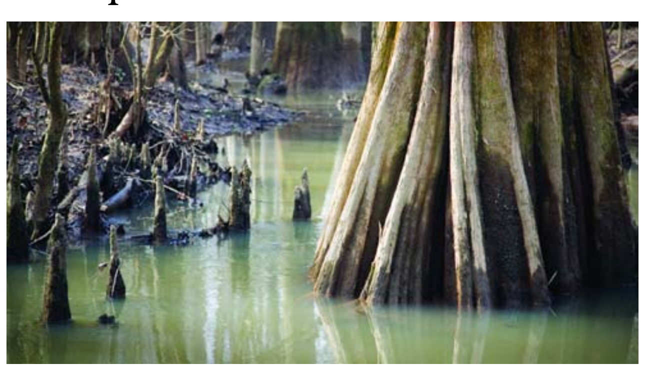
### Rivers

Rivers can be large or small. The Mississippi River in the United States, the Nile in Egypt, and the Amazon in South America are very large, wide rivers. They flow very quickly and have strong currents.

All rivers have a source. It may be a spring, a lake, or even melting glacial water. From its source, a river always flows downhill, ending in another body of water such as a lake or an ocean. Estuaries are the point a river habitat meets with coastal waters. Estuaries tend to be areas teeming with life.


## Swamps and Marshes

Water is always covering the soil of swamps and marshes. Frequent rains or poor drainage causes this to happen. These habitats are very important for the environment. Many types of animals live in swamp and marsh areas.



*Cypress trees have knees that grow up out of the water. The knees help provide oxygen to the tree's roots.*

The blanket of plants growing in them prevents the soil from washing away. The water also makes dead material decay faster and keeps the soil healthy. Another name for these habitats is wetlands. Some wetlands are huge and cover a lot of land, such as the Everglades in Florida.

Swamps and marshes are very muddy. Swamps have more woody plants, while marshes have more grasses.

*The grasses of this marsh provide habitats to many life forms.*

Saltwater fills some marshes. Saltwater marshes are often flooded by the ocean. The plants and animals in them must be able to live in different levels of water and salt. Other marshes have freshwater. Reeds often grow in freshwater marshes.

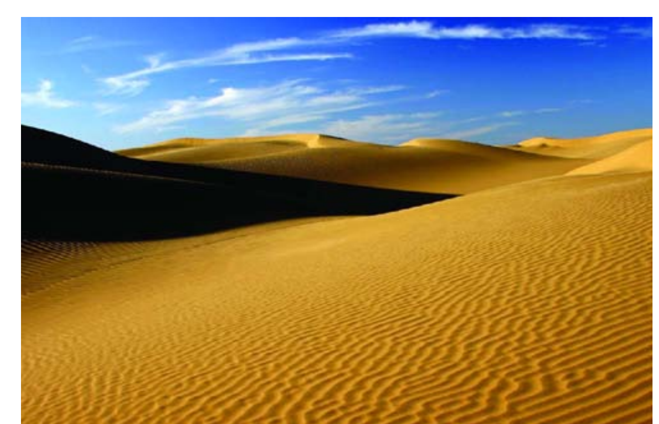
Another type of marsh is a bog. It starts out as a freshwater marsh. Then moving water washes away the nutrients in the soil. The soil left behind contains a lot of acid. Mosses grow well in bogs.



*The soil in bogs has so much plant matter in it that it can be dried and used for fuel.*

## Deserts

Many people think that deserts are dry places where it is always hot and it never rains. A few deserts are like that, but most are not. Deserts often get several inches of rain every year. This rain may fall in only one short period. Some deserts have flash floods when too much rain falls at once. Other deserts have an oasis, an area with more water where trees and other green plants can grow.



*This desert is hot in the daytime and cold at night because there is little moisture in the air to moderate the temperatures.*

*An oasis is a welcome sight to desert travelers.*

Temperatures in deserts can be very hot during the day and very cold at night. The Gobi Desert in eastern Asia can drop 58 degrees Fahrenheit (32 degrees Celsius) in a 24 hour period.

Some deserts have hills or ridges of sand called dunes. These sand dunes are shaped by the wind.

Most deserts are much more than sand. Many plants and animals live in these conditions. Animals like lizards and rabbits dig, or burrow, underground to escape the heat. Other animals only move around at night when it is cooler.

*This lizard has adapted to life in a desert.*

**Find out more**

### THE SAHARA DESERT

The largest desert in the world is the Sahara Desert. It covers most of North Africa. It is about 3000 miles (5000 km) across from east to west. That is about the same size as the United States. It has some of the harshest weather in the world. Daytime temperatures can reach over 130 degrees Fahrenheit (54 degrees Celsius). At night, it can sometimes plunge below freezing.

Despite the difficult climate, the Sahara is home to many wonderful plants and animals. Ostriches, raptors, gazelles, jackals, spotted hyenas, and many other animal species call the Sahara home. It also contains many species of high grasses and trees.

Some plants and animals have ways of keeping water in their bodies. Camels can live a long time without food or water by using the fat stored in the humps on their backs. Plants such as cactus hold extra water in their stems.


*The camel's long, curly eyelashes protect his eyes from the dust and sand of the desert.*

## Prairies

Prairies are vast grassland habitats found on every continent except Antarctica. In Africa, grasslands are called savannas. In Asia, they are called steppes. Prairies look like a sea of grass.

The prairies of North America are low habitats. Very few trees grow there. Most of the plant life is low to the ground. This helps plants survive when there is little water available.

*Strong winds blow across the prairie in both summer and winter.*

Grasses provide food sources for many grazing animals. Huge herds of buffalo once lived on the wild prairies of North America. They ate the grass for food. Because grasses grow from the bottom of their stems, they grow back easily. As the herds moved, they trampled seeds into the ground. Their droppings provided nutrients and fertilizer that encouraged new growth.



Many animals live underground in the prairies. Prairie dogs live in packs and dig burrows underground for shelter and protection. Mice and other rodents also dig tunnels underground. Mice eat the seeds and grass that are all around. Animals like coyotes often eat mice.

Many farm crops grow well in prairies. Giant fields of wheat and corn can stretch out for miles. We use the grains harvested from these fields for food, fuel, and other products.

## Forests

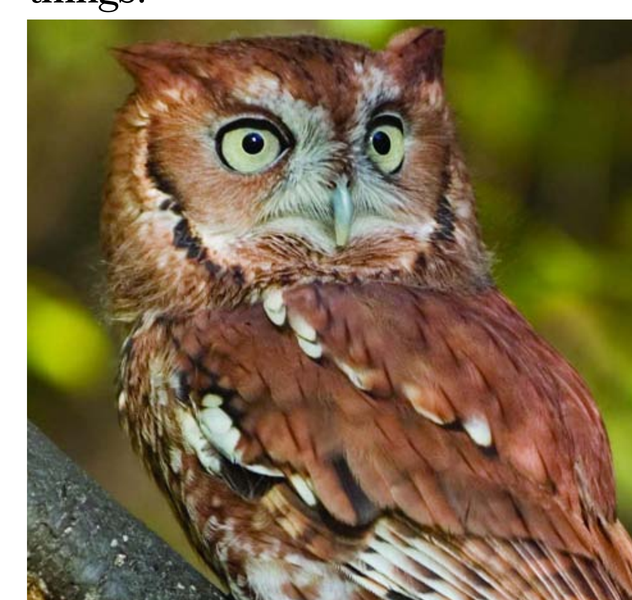
A forest is a habitat with lots of trees. Animals and plants live and grow both on the ground and above it. There are different kinds of forests throughout the world. Rain forests have many trees tightly packed together. Monkeys can live in these trees away from predators.

*The trees of the rain forest provide much of the Earth's oxygen.*

The pine forests in the Pacific Northwest have many trees that need a lot of space to grow. They provide homes for birds of prey like owls. It is easier for birds to hunt animals that live on the ground in forests where the trees are not tightly packed.


*Insects and birds live in healthy trees and in dead and decaying trees in the Pacific Northwest.*

Forests also provide animals with shelter from bad weather. A single tree in a forest can provide a habitat for many other living things.



*Many owls make their home in a forest.*

Birds and squirrels may nest in the trees for protection. Insects might also find a home in the trees. Some birds eat insects. The tree itself can provide food through its fruit and seeds. A tree that falls down can provide a home to many animals on the ground.

Humans often destroy forest habitats. We cut down some forests to make room for farming or construction. Pollution damages other forests. But humans can also help forests. We can recycle things made from trees. We can plant new trees. Reforestation is planting new trees in forests to replace the ones we chopped down. What have you done today to save a tree?

Find out more

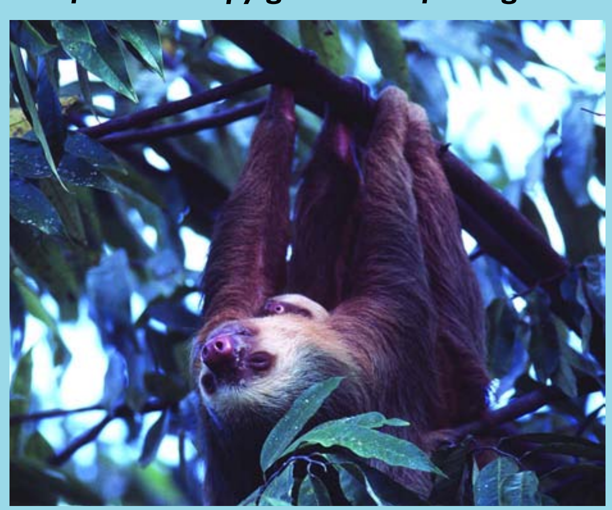
**TROPICAL RAIN FORESTS**

The Earth's tropical areas are around the equator. Tropical areas usually have dense forests that get a lot of rain, called rain forests. These rain forests are very important to the planet. They turn a lot of carbon dioxide in the air into oxygen. They are like giant air filters for the planet.

Trees in the rain forest grow tall. The tops of the trees make up the canopy. Most of the animals in the rain forests live there. The canopy contains a lot of sunlight and food. It is cooler and darker underneath the canopy. Fewer animals live there.

Over half of all the species of plants and animals on Earth live in tropical rain forests. Sloths move very slowly and eat fruit and insects that live on the trees. Snakes like the warm climate of the rain forest. Birds of all different shapes and colors fly above the canopy.

*The forest canopy gets a lot of sunlight.*



*Sloths move so slowly that algae sometimes grows on their fur.*



## Mountains

Mountains are landforms rising above the land around them. Most mountains are very different at the top than at the bottom. The habitats change from top to bottom as well. As you go up a mountain, the temperature gets colder, and the air gets thinner. We identify mountain habitats by zones.

### The Tree Line

Along the base of most mountains are forests. The forests will only grow up a mountain to a certain point. The tree line is the height above which trees will not grow. Other plants grow beyond the tree line. They tend to be small plants that can withstand cold temperatures and high winds.

Tree line zones are not the same for all mountains. Sometimes the tree line zone changes from one side of a mountain to the other.

***Strong winds and the amount of sunlight a mountain receives can affect the height of its tree line.***

Animals living above the tree line tend to be ready for cold weather. Mammals like deer and mountain goats have big hearts and lungs. These help the animals breathe in the high altitude and cold. Many insects survive well in this habitat. Ants and other insects without wings can stay low to the ground to avoid the wind.

***Mountain goats can breathe easily at high altitudes.***

Temperatures are ice-cold on top of a mountain. The point up a mountain where snow stays year round is the snow line. The closer to the equator a mountain is, the higher the snow line will be.

Mountains in the arctic or polar areas of the world are often entirely above the snow line. Very few plants and animals live in this cold region.

# The Environment in Danger

Everything on Earth is connected in some way. Changes on land can affect the air. Changes in the air can affect the water. Damage to one thing always affects something else. It is easy to damage the Earth.

Our planet's population continues to grow. More people means we need to produce more food and build more homes. More people means we need more electricity and fuel. The need for Earth's resources grows.

To meet the needs of a growing population, we often hurt the environment. We have caused the destruction of many habitats. Many species of plants and animals are endangered or extinct.

**WORDS to KNOW**

**arson** (AR-suhn): deliberate lighting of a fire to destroy something

**endangered** (en-DAYN-jurd): put in a dangerous situation; threatened

**extinct** (ek-STINGKT): having died out

**habitat** (HAB-uh-tat): a place or natural condition where a plant or animal lives

**population** (pop-yuh-LAY-shuhn): the total number of people who live in a place

*When we cut down trees, we are destroying important animal habitats.*

## Fires

Fires are one of the ways people might hurt the environment. Fires can burn homes and other buildings. They can burn habitats, too. Forest fires and brush fires destroy trees and other plants. Sometimes these fires start naturally from lightning strikes, but other times it is arson.

*Forest fires destroy habitats, too.*



## Deforestation

People use fires as a way to clear land for agricultural use. We call this deforestation. Humans do the most harm when they burn too much land.

Currently, tropical rain forests are the most endangered forests in the world. Many species of rain forest animal and plant species are endangered because of deforestation.

Trees are important to the environment. They provide food for animals and people. Trees also provide important things such as fuel, paper, wood, and food. Some tree foliage removes pollution from the air. Most importantly, trees affect the climate.

*Scientists believe deforestation in the areas surrounding Kilimanjaro might be the strongest human influence on its glacial ice loss.*

## Smog

Smog is another environmental hazard that comes from human activity. Smog is fog mixed with smoke and other chemicals. It makes the air look brown or dirty. Smog has chemicals that hurt the lungs. It is especially dangerous to people who have trouble breathing.

*Smog makes the air appear dirty and lessens visibility.*

Two kinds of smog can develop. One type of smog forms when people burn fuel that contains the chemical sulfur. Coal-burning electric plants emit sulfur compounds. This smog is common in the eastern United States and Europe.

Another type of smog forms from chemicals released by cars burning gasoline. Sunlight changes these chemicals. Photochemical smog is the result (photo means light). Places with many cars, like cities, have this type of smog.

## F. Sherwood Rowland and Mario Molina

Getting to know...

F. Sherwood Rowland was born in Ohio in 1927. In 1964, he became the head of the new chemistry department at the University of California at Irvine. Rowland began to study chlorofluorocarbons, or CFCs. These chemicals were being used in spray cans, refrigerators, and air conditioners. He wondered what happened to CFCs in the atmosphere.

Mario Molina was born in Mexico in 1943. He joined Rowland's Irvine research team in 1973. Together, they discovered that CFCs break apart and form atoms of chlorine. Chlorine destroys the ozone that protects life on Earth from radiation.

Rowland and Molina helped to create the worldwide ban on CFCs. It is believed that because of their work the hole in the ozone layer is now shrinking. They won the Nobel Prize for their research.

## Acid Rain

Acid rain is rain in which oxides of sulfur and nitrogen mix with the water in the atmosphere. Most acid rain comes from human sources such as car exhausts and manufacturing smoke. Some acid rain comes from natural sources such as the gases released by animals and decaying plants.

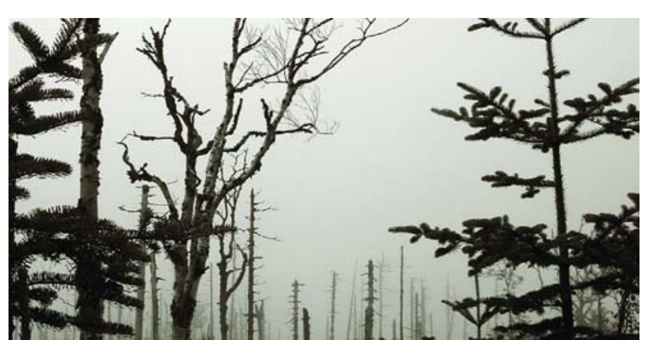
WORDS TO KNOW

**emit** (i-MIT): to release or give off

**hazard** (HAZ-urd): a danger or a risk

Wind can carry these oxides a long way from their source. The acid molecules can travel for hundreds of miles. They can even be carried into other countries. The acids created this way fall back down to Earth when it rains.

Acid rain is more acid than natural rain. It may damage lakes, forests, and soil. Fish die when the water in lakes is too acidic.



*Acid rain damages the leaves and needles of trees.*



Acid rain can also hurt buildings. Statues made of stone can be eaten away by acid rain. The areas with the worst damage have been the eastern United States and the southeastern part of Canada.

*The damage on this building was caused by acid rain.*

## Global Warming

The Earth's climate has varied throughout the planet's history. Geologists and paleontologists have found evidence that Earth has had periods of extreme cooling. We know that during one such period, 1,000,000 B.C. to 10,000 B.C., glaciers covered much of North America.

Scientists have also found evidence that the planet has had periods of significant warming.

Oceans once covered Florida, tropical plants grew within the Arctic circle, and dinosaurs roamed Montana (150 million years ago).

Recently, the Earth's temperature has once more been rising. We can see some of the effects, some of which are undesirable, others helpful.

- Glaciers are melting and shrinking. Potential water sources are lost.

*Grinnell Glacier 1938*

*Grinnell Glacier 2005*

- Some species of plants and animals have become endangered as their habitat changes or is lost.
- Some species of plants and insects have increased their northern ranges. This makes agriculture possible in areas formerly too cold for crops.

## Possible Causes Of Global Warming

Scientists are exploring and debating how much of the overall temperature rise is due to humans and how much from other natural phenomena. Regardless of the answer, everyone agrees we should do what we can reasonably do to lessen our impact during this warming period.

**Scientists are studying:**

- the Sun's activity
- current global warming on Mars
- Earth's weather patterns
- glacial retreat
- ice shelves in the Antarctic
- ocean and sea life populations
- other biological evidence

They are trying to identify the possible causes to the current global warming. They also want to know how much each contributes to the temperature increase.

We know that human activity such as deforestation and the burning of fossil fuels is contributing to the rise in the Earth's temperature.

## Burning Fossil Fuels

People burn fossil fuels to produce electricity and run engines. This produces carbon dioxide.

A small amount of carbon dioxide in the air is normal. (Air is made up of 78 percent nitrogen, 21 percent oxygen, and the rest is carbon dioxide and other gases.) Plants use carbon dioxide to grow and to produce oxygen and animal food. When we burn oil, coal, and wood, we create extra carbon dioxide and other gases. We call these greenhouse gases.

***Some manufacturing plants produce greenhouse gases as a byproduct.***

Greenhouse gases form a layer around the Earth. This layer allows sunlight to pass through to the surface, but it prevents heat from escaping into outer space. Other gases do this too. These include methane and nitrous oxide. These pollutant gases come from cows and other grazing animals, and from agricultural fertilizers.



Scientists believe that increases in the amount of greenhouse gases are contributing to current global warming.

## What People Can Do

Governments, companies, and individuals are taking steps to reduce people's contribution to greenhouse gases.

- Car manufacturers are designing cars that burn fuel more efficiently.
- Engineers are creating biodegradable fuels that do not produce as many pollutants.


- Factories are continuing to find methods of manufacturing that generate fewer $CO_2$ emissions.
- Nuclear plants are being built to replace coal and oil burning electric plants.
- Conservation groups are encouraging people to use less electricity.
- Engineers design appliances that use electricity more efficiently.
- Builders use more efficient insulation.

- Farmers are trying to use less fertilizer.

### Words to Know

**debate:** (di-BATE) to consider or discuss something

**geologist:** (jee-OL-uh-jist) a scientist who studies rocks and the Earth's crust

**glacier:** (GLAY-shur) a huge sheet of ice found in mountain areas and polar regions

**impact:** (im-PAKT) the effect that something has on a thing

**paleontologist:** (pay-lee-uhn-TOL-uh-jist) a scientist who studies fossils

**undesirable:** (uhn-di-ZYE-ruh-buhl) not wanted, not pleasant

# People Who Study the Earth

Throughout history, people have always wanted to understand the planet we live on. They wanted to know why the weather changes from hot to cold and back again. They wanted to know why it rains or snows and what lightning and thunder are. They wanted to know why volcanos erupt and why earthquakes move the ground.

***Volcanologists study volcanos.***

Scientists decided to study nature. Earth science is the study of the Earth and all the forces that can affect it.

## WORDS to KNOW

**pollution** ((puh-LOO-shuhn): harmful materials that damage the air, water, or soil

**resistant** (re-ZIS-tent): having the ability to withstand

**resource** (REE-sorss): something valuable to a place or a person

There are different fields within Earth science. Most Earth scientists spend lots of time out studying the Earth. Many of the things they learn affect our daily lives.

- Meteorologists study the atmosphere. They watch and try to predict the weather.
- Some geologists study the history of the Earth by looking at rocks. Other geologists study natural resources such as ground water, petroleum, and metals; all things we use in our daily lives.
- Seismologists measure earthquakes and study the movement of the continental plates. They sometimes try to predict when future earthquakes will occur. Seismologists also help design and build earthquake resistant structures.
- Ecologists try to understand how living things and their environments affect each other. Environmentalists try to protect the environment from pollution and other dangers.

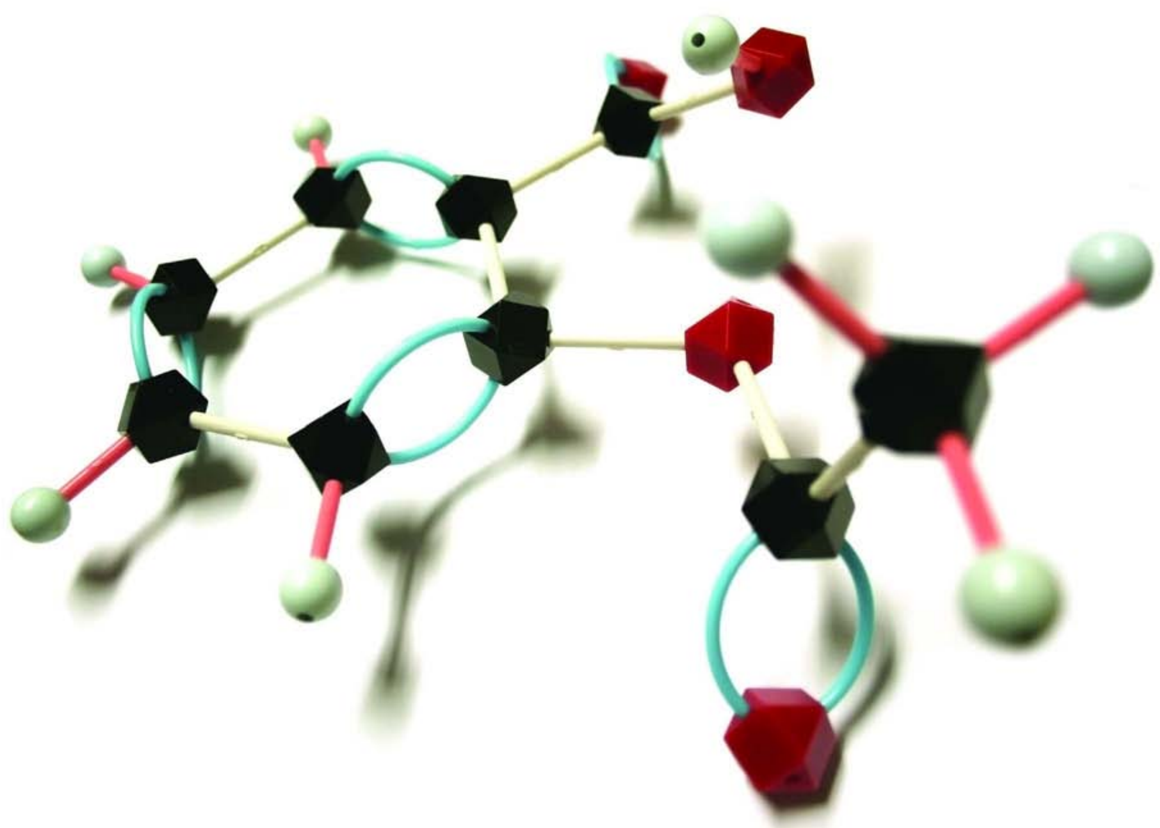
Learning about these things helps people use the resources of the Earth wisely. Human beings must understand that everything they do affects the planet that all living things share.

Rourke's World of Science

# ENCYCLOPEDIA

## Volume 5

# Chemistry



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# Table of Contents

# What Is Chemistry?

Chemistry is the study of substances and the changes that happen to them. Substances are things like food, clothes, and medicine.

Chemistry is very important. Plastic bags and shoes with rubber soles would not exist without chemistry. Fuels for cars, airplanes, and rockets would not exist without chemistry. Chemical reactions, or changes, inside the human body are important. They make it possible for people to think, eat, and breathe. Chemistry is everywhere.

*Chemicals in fertilizer helped these fruits and vegetables grow.*

*Without chemistry, we would not have these clothes to keep us warm.*

*Enzymes in the girls' stomachs will help them digest their food.*

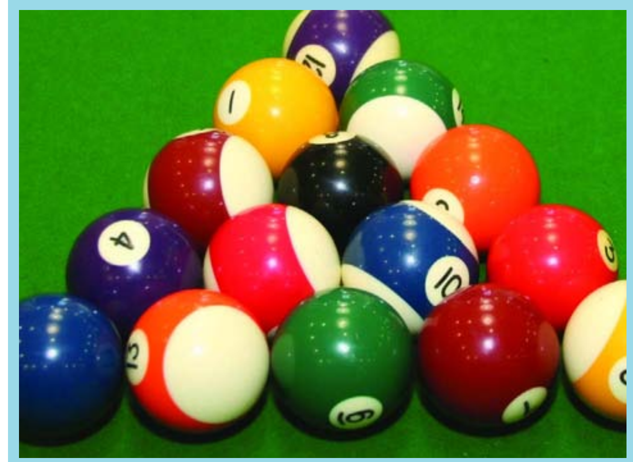
*We know how our medicine works because of chemistry.*



Find out more

**What do elephant tusks and billiard balls have in common?**

Before the invention of plastic, elephant tusks were the main material used to make billiard balls. John Wesley Hyatt invented celluloid, a special kind of plastic, in 1868. Celluloid proved to be the perfect ingredient for creating billiard balls as well as movie film.



## The Scientific Method

Scientists learn about chemistry in three ways. They observe, or watch, substances. They study substances and they do experiments. They try to make substances change and then record what happens. Scientists carefully plan how they learn about chemistry. They often use a system called the scientific method to answer questions they might have.

The scientific method is very important. It allows scientists to learn about how things work. There are four parts to the scientific method:

1. Scientists begin the scientific method by asking a question.
2. They research information about their question, or problem. When gathering information, scientists use observation to watch what they are studying very carefully. They might write down, or record their observations when collecting the information. Scientists call this information data. They also collect data by reading other scientists' books and journal articles. The Internet is another useful tool for gathering information.

*A scientist carefully records data during an experiment.*

3. The third step of the scientific method is making a thoughtful guess, or hypothesis. A hypothesis is an idea or opinion based on some data or observations, but not proven.

*Scientists formed the hypothesis that this fertilizer is what makes the plants grow big and healthy. They will test their hypothesis to see if it is true.*

4. The fourth step of the scientific method is gathering materials and then testing the hypothesis. Scientists, test or try out, their hypotheses in experiments.

*Scientists conduct the same experiment many times to be sure of the results.*

Scientists often do their experiments in a laboratory. A laboratory is a place where scientists conduct experiments and collect data. Controlling conditions in a laboratory is easier than controlling conditions in the real world. For example, temperature levels are able to remain constant in a controlled setting. That would be impossible to do outside of a laboratory.



## HOW DO SCIENTISTS LEARN ABOUT CHEMISTRY?

They observe or watch substances.

They do experiments.

They try to make substances change and then record what happens.

An experiment might show that the hypothesis is not correct. For this reason, scientists always perform tests for one experiment several times. They call these tests trials. In each trial, scientists change only one thing, also known as the variable. New data might cause a scientist to change the hypothesis. Sometimes, a scientist throws away the hypothesis and starts all over. Hypotheses proven true predict how things will work and can be very helpful.

*Chemists made sure this medicine was safe for children.*

### WORDS to Know

**control** (kuhn-TROHL): to make something or someone do what you want

**experiment** (ek-SPER-uh-ment): a scientific test to try out a theory or to see the effect of something

**fuel** (FYOO-uhl): something that is used as a source of heat or energy, such as coal, wood, gasoline, or natural gas

**observation** (ob-zur-VAY-shuhn): the careful watching of someone or something

## Measurement

People can describe the world in many ways. They can say how big something is, how much it weighs, or how hot it feels. They can use measurements to describe these things.

Scientists use the metric system to measure distance and length. They measure distance and length using a metric ruler, tape measure, or other special tools. A meter is a specific unit of measurement. A meter can be broken down into smaller parts called centimeters and millimeters. There are 100 centimeters (cm) in 1 meter (m). There are 1,000 millimeters (mm) in 1 meter. There are 1,000 meters in a kilometer (km).

*Your dad measures your height in the standard unit of inches. Scientists measure height in the metric unit of centimeters.*

| Unit of Measurement | Abbreviation | Things You Might Measure With This Unit |
|---|---|---|
| millimeter | mm | ant, small button, or end of an eraser |
| centimeter | cm | hamster, length of your foot, or the length of a gecko lizard |
| meter | m | distance between your classroom and the lunchroom, or the length of a Komodo dragon or a whale |
| kilometer | km | distance of a marathon or the distance between two cities |



| Unit of Measurement | Abbreviation | Things You Might Measure With This Unit |
|---|---|---|
| kilogram | kg | yourself or a tiger |
| gram | g | a bag of apples or a box of cookies |
| milligram | mg | a paper clip or a baby tooth |

Scientists use grams or milligrams to measure the weight of something. Scales are instruments used to measure weight. Scientists use scales that weigh in kilograms, grams or milligrams.

*This scale measures in the standard unit of pounds or the metric unit of kilograms.*

Find out more

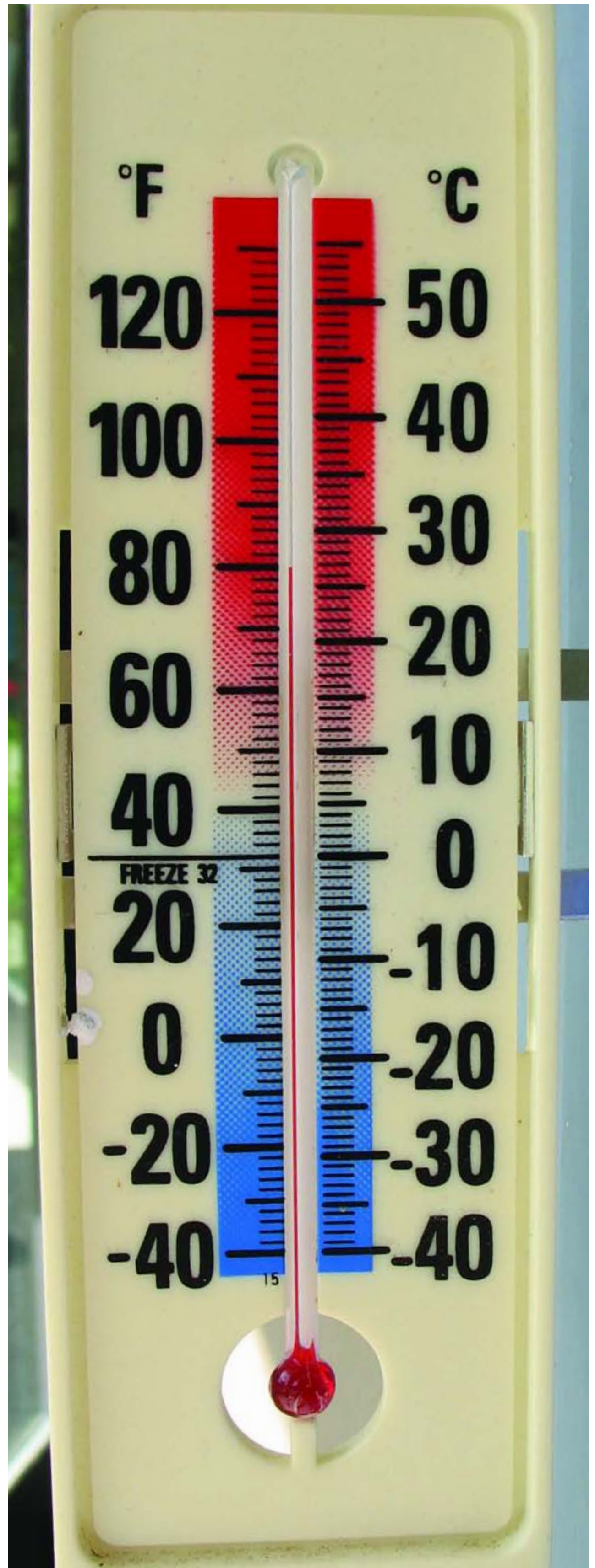
### What's the Difference Between Mass and Weight?

Weight is the measure of how strongly gravity pulls on matter. Mass is the measure of how much matter an object has. If you were to go to the Moon, your weight would change because the pull of gravity on Earth is stronger than on the Moon. Your mass would not change because you would still have the same amount of matter.

Scientists measure temperature using the Celsius temperature scale. The freezing and boiling points of water is the basis for Celsius (°C). Water freezes at 0°C and boils at 100°C. An average room temperature is about 20°C.

Another way of measuring temperature is to use the Kelvin scale. The lowest possible temperature determines the Kelvin (K) scale. This is 0 K or -273°C. Absolute temperatures are temperatures measured in the Kelvin scale.

*Thermometers display temperature using the standard Fahrenheit scale and the metric Celsius scale.*




WORDS to KNOW

**distance** (DISS-tuhnss): the amount of space between two places

**length** (lengkth): the distance from one end of something to the other

**measure** (MEZH-ur): to find out the size, capacity, weight, etc. of something

**metric system** (MET-rik SISS-tim): a system of measurement based on counting by 10's

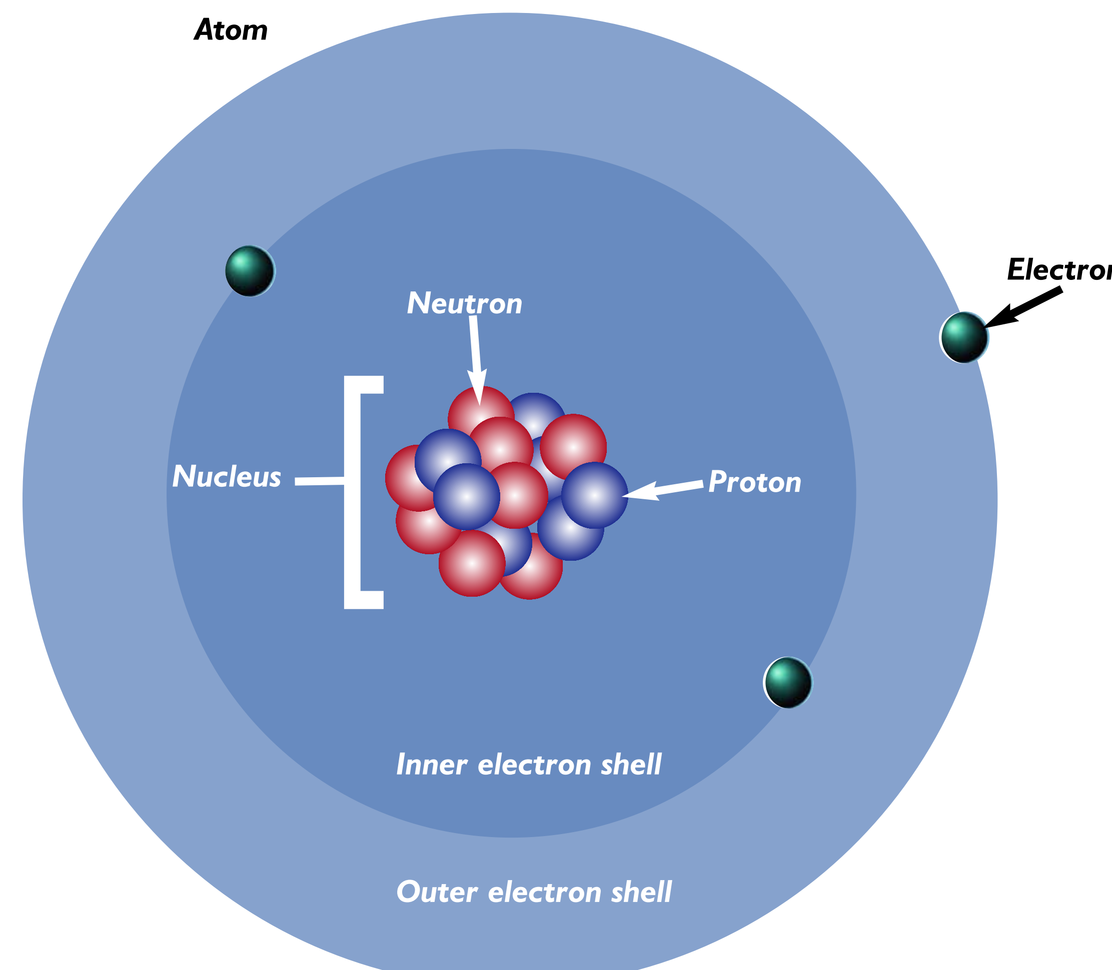
**temperature** (TEM-put-uh-chur): the degree of heat or cold in something



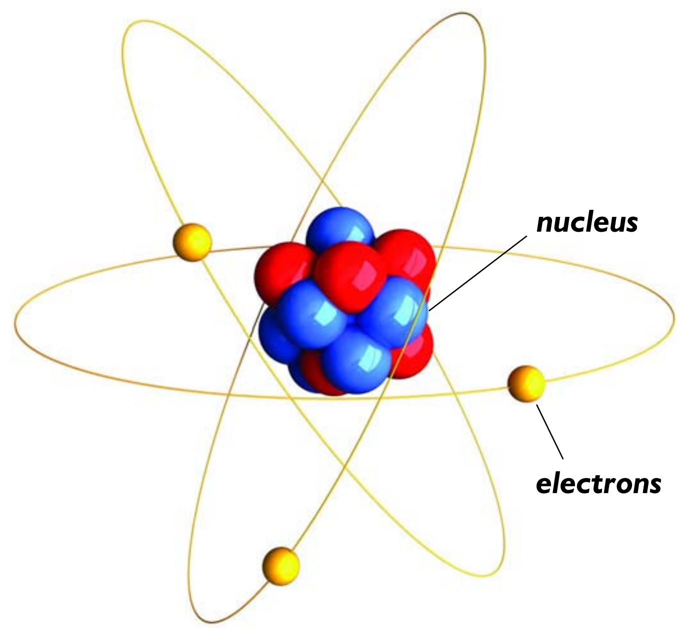
# Atoms and Elements

Atoms are the building blocks of all matter. Atoms are very small. Many atoms put together make up everything in the world. Atoms are so small that you cannot see an individual atom without a special microscope. All atoms are made of the same basic parts. Putting these parts together in different ways, by scientists or in nature, causes the traits of the atom to change.

*Scientists use electron microscopes to give them an idea of what atoms look like.*



## The Parts of an Atom




The parts inside the atom are much smaller than the atom itself. There are two sections in an atom. There is a center section and an outer section.

### Center Section

The center section contains the nucleus. The nucleus is made of two types of particles. We call these particles protons and neutrons. Protons have a positive electrical charge. Neutrons do not have an electrical charge. Scientists say they are neutral. The nucleus of most common atoms is made of the same number of protons and neutrons.

### Outer Section

The outer part of the atom is made of electrons. Electrons are very tiny particles. They move around the nucleus of an atom in special layers called shells. Each shell can have several electrons in it. Many atoms have several electron shells. All electrons have a negative electrical charge. Normal atoms have the same number of electrons and protons. The negative electron and the positive proton attract. This is what holds the atom together.

### Subatomic Particles

Subatomic particles exist inside an atom. Protons, neutrons, and electrons are examples of subatomic particles. Many other subatomic particles exist inside an atom. For example, protons and neutrons are made of tiny particles called quarks. Gluons, even smaller particles, hold quarks together. There are more than 200 other types of subatomic particles.

### Words to Know

**neutral** (NU-trel): neither positive or negative

**particle** (PAR-tuh-kuhl): an extremely small piece or amount of something

**trait** (trate): a quality or characteristic that makes one person or thing different from another

### Niels Bohr

Getting to know...

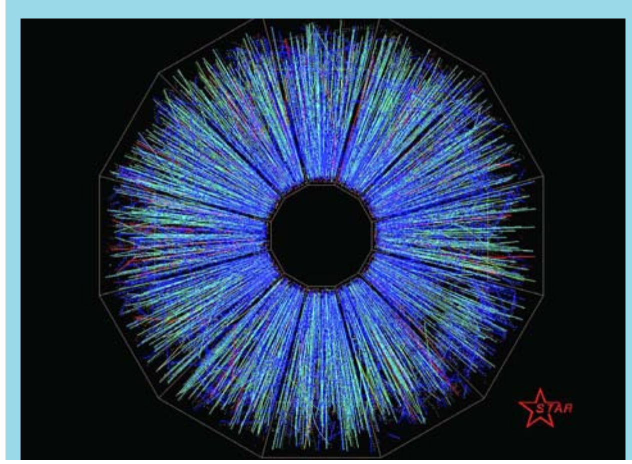
Niels Bohr was born in Denmark in 1885. His father was a professor who invited many important scientists to their home. Bohr studied physics at the University of Copenhagen. Then he went to England to work with the famous physicists J.J. Thomson and Ernest Rutherford.

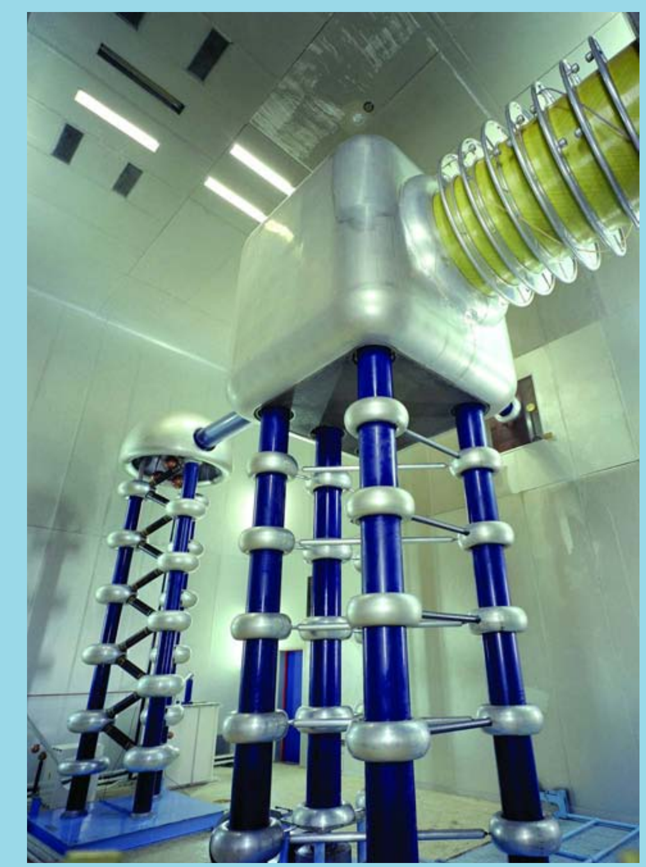
Bohr returned to Denmark and became a professor. He wrote papers in which he described the structure of an atom. Bohr showed that electrons have stable orbits around the nucleus, which allows them to keep spinning. Electrons give off energy only when they jump to a different orbit. In 1922, Bohr won the Nobel Prize for his studies of atoms.

Find out more

### Scientists Can Smash Atoms

Particle accelerators are giant machines used by scientists to discover subatomic particles. These machines move atoms and subatomic particles very fast. Then they smash them together! Special photographs and computer images from the accelerator show the impact. The picture below shows the trails left by particles.





## Elements

An element is a substance made of the same type of atoms. Scientists know of over 100 different elements. Most elements occur naturally. Some are very common. Others are harder to find. Scientists have created a few elements in laboratories.

*Gold and copper are naturally occurring elements.*

### Solid Metals

Most of the elements are solid metals and usually shiny. They can also conduct, or pass on, heat and electricity. Metals are malleable and easily formed into many shapes. Flattened sheets of metal used as prongs in an electrical cord conduct electricity. Pulling metals very thin without breaking them means they are ductile. Wires are an example of ductile metals.

*The prongs on this electrical cord plugs into a wall. It will conduct the electricity to a lamp when switched on.*

### Nonmetals and Semimetals

The rest of the elements are nonmetals or semimetals. Nonmetals are different from metals in many ways. Most nonmetals are gases, like oxygen. Solid nonmetals are hard and brittle, like carbon. They break apart easily. Carbon is used to make some pencil tips. Bromine is the only liquid nonmetal. Semimetals have traits of both metals and nonmetals.



*Helium is lighter than oxygen, allowing these balloons to float.*

### Atomic Number

Elements differ from one another depending on the number of protons each possesses. The number of protons in an element determines the atomic number of the element.

Protons and neutrons have about the same mass. Mass is the amount of physical material in an object. The atomic number determines the organization of all elements in the periodic table of elements. The first element, hydrogen is number one. The last known element, lawrencium, is number 103.

Protons and neutrons make up nearly all of the mass of an atom. The atomic mass of the element is the approximate total number of protons and neutrons in that element. The unit of measurement for atomic mass is the atomic mass unit (AMU).

**Find out more**

How many neutrons are there in Krypton? The atomic number of Krypton is 36. This means there are 36 protons and 36 electrons in its nucleus. To determine the number of neutrons, you must first round the atomic weight. Krypton is about 84 AMU. Subtract the number of protons and that will leave us with the number of neutrons, 48.

36
Kr
krypton
83.80

*Use the table below to help find the number of protons, electrons, and neutrons of any element.*

| | |
|---|---|
| Number of Protons | Atomic Number |
| Number of Electrons | Atomic Number (or Number of Protons) |
| Number of Neutrons | Mass Number (rounded)-Atomic Number |

# The Periodic Table

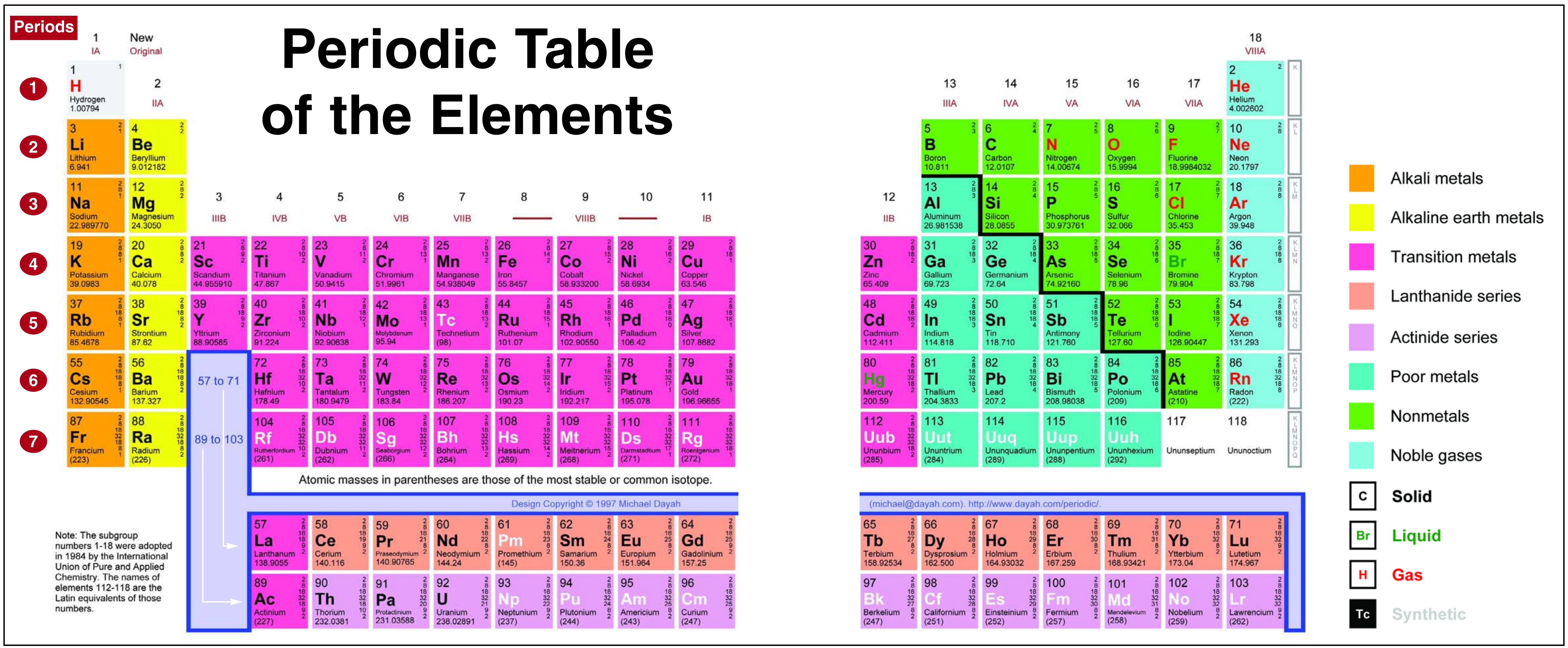
## Symbols

The periodic table lists all known elements. Each element has a special symbol that describes it. Some symbols are the first letter of the element. The first element has the letter H for hydrogen. O is for oxygen. C is for carbon. Most of the elements have a symbol with two letters. Helium has the letters He. Ca is the symbol for Calcium. Bromine is Br. Every element must have a different symbol, so sometimes the symbol is very different from the actual name of the element. Many of these symbols come from Latin words. Gold is Au. Tin is Sn. Silver is Ag.



## Listing Elements

The periodic table lists over 100 elements. The atomic number determines the arrangement of each element. Rows and columns help to organize the elements according to specific properties. A row going across is called a period. The atomic number in each period increases by one with each element as you move left to right across the table. The chemical properties of the elements change slowly as well. Each element contains one more electron and one more proton than the next. Columns, also known as groups, consist of elements that share similar chemical and physical properties.



### Periods

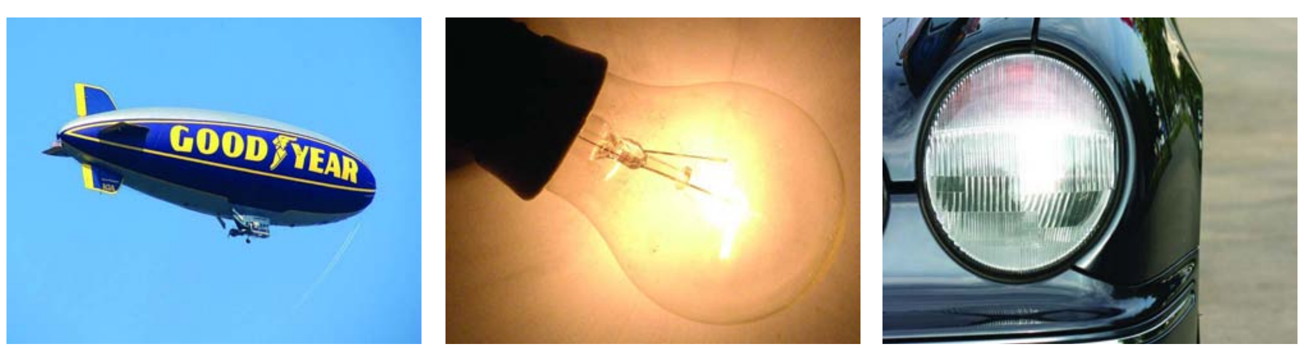
Periods are the rows going across the periodic table of elements. As you move across the rows from left to right, the atomic number increases by one. This means that each element contains one more electron and one more proton than the previous element. The chemical and physical properties gradually change across the row. A new period begins with a drastic difference in properties.

As an example, the first period in the periodic table is very short. It contains only two elements, hydrogen (H) and helium (He). The second period contains eight elements. It begins with lithium (the symbol Li) and ends with neon (Ne). The fifth period also has 18 elements. It starts with rubidium (Rb) and ends with xenon (Xe). See chart on pages 16 and 17. Scientists are still discovering new elements.

### Groups

Elements in the same group have similar properties. Every element in a group has the same number of electrons in its outer electron shell. With the exception of hydrogen, the elements in the first group, called alkali metals, each have only one electron in the outer shell. They are soft metals that react easily with water.

Noble gases are the last group. Helium, neon, argon, krypton, xenon, and radon are all noble gases. Except for helium, they all have eight electrons in their outer shells. They are usually inert elements. This means they do not combine chemically with other elements. In the 1960s, scientists were able to force noble gases to combine with other elements. The gases would otherwise not form a bond.




***Helium is the main element that allows this blimp to defy gravity and stay afloat. Light bulbs stay lit because of argon. Headlights in this new car contain xenon.***



Getting to know...

### Dmitry Mendeleyev

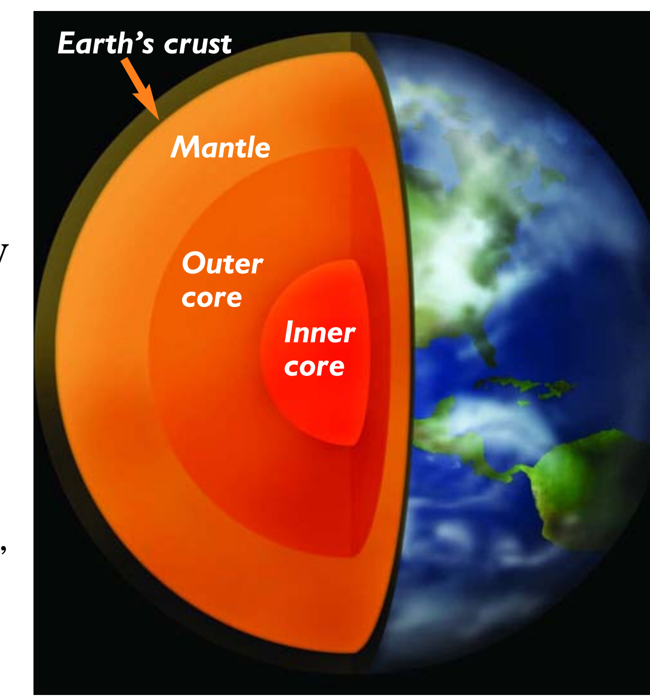
Dmitry Mendeleyev was born in 1834 in the country of Russia. His father became blind. His mother worked in a glass factory to support their fourteen children. In 1849, Mendeleyev left home to become a teacher.

Mendeleyev noticed that some elements have similar properties. He wondered if there was a way to classify elements, or place them into different groups. Using cards, Mendeleyev wrote down the properties of each element. He also wrote down the atomic weight of each element known at the time. He arranged the cards until he saw a pattern. Organizing the elements by their atomic weight allowed Mendeleyev to discover that the properties repeated themselves. Mendeleyev created the periodic table. Later, new elements filled empty spaces left in the table.

## Elements Important to Life

On Earth, there are 92 naturally occurring elements. A few are the building blocks of all life on our planet. Hydrogen and oxygen form water. The atoms of five elements form the majority of the air we breathe. They are nitrogen, oxygen, carbon, hydrogen, and argon.

Elements mixed together form the surface of the Earth. These elements are mainly oxygen (O), silicone (Si), iron (Fe), aluminum (Al), and magnesium (Mg). Many scientists believe that the center, or core, of the Earth is made mainly of two elements. They are iron (Fe) and nickel (Ni).




WORDS to know

**Latin** (LAT-uhn): the language of the ancient Romans

**symbol** (SIM-buhl): a design or object that represents something else

The same elements make up all organic or once living matter on Earth. The elements carbon, hydrogen, nitrogen, and oxygen, make up life on Earth. Plants and animals are exceptions. This is because the organization of the elements is different.

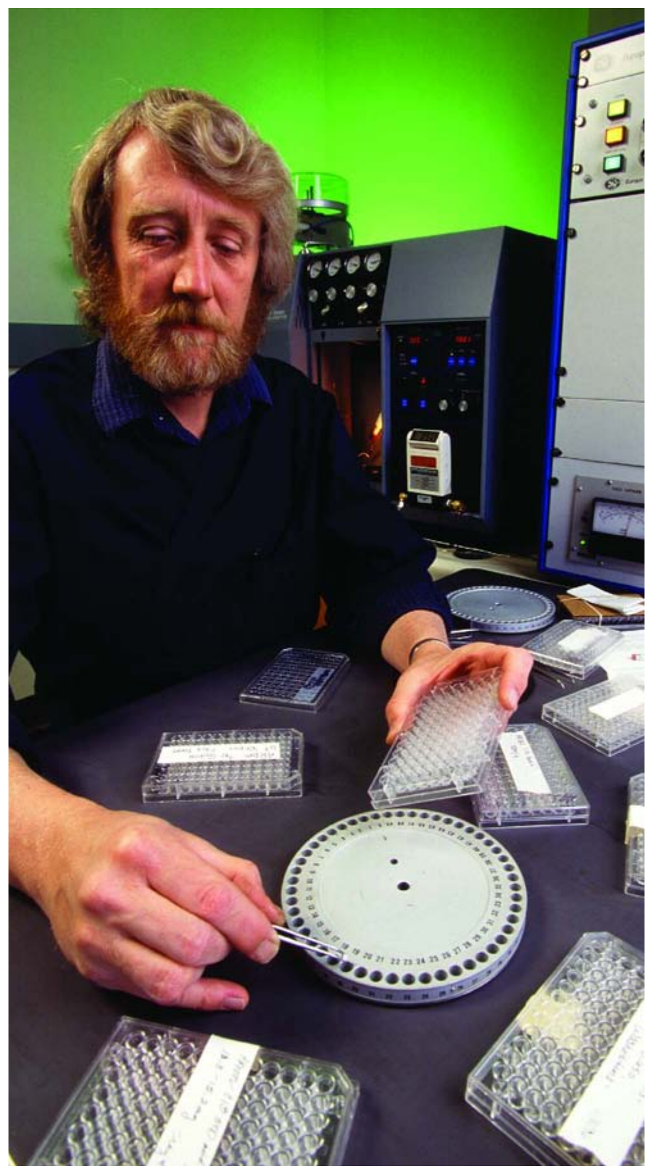
Life first developed when these and other elements came together millions of years ago. These elements exist throughout the universe. We do not know if life exists anywhere else.

## Isotopes and Radioactive Elements

### Isotopes

Sometimes, the nucleus of an atom can have extra neutrons. The normal atom and the one with extra neutrons have the same atomic numbers. This is because they have the same number of protons. They have different masses because of the extra neutrons. Scientists call these atoms isotopes.

All elements have isotopes. Many isotopes occur naturally. Some occur by themselves, like sodium. Other elements in nature are actually mixtures of several isotopes. Oxygen that occurs naturally contains three isotopes of oxygen. It is a mixture containing mostly oxygen with an atomic mass of 16. It also has tiny amounts of oxygen with atomic masses of 17 and 18. Scientists can measure the mass of an atom by using a device called a mass spectrometer.



*Mass spectrometry determines the effects of drugs in the body, identifies illegal steroids in an athlete, and determines the age and origin of once-living material in archeology.*

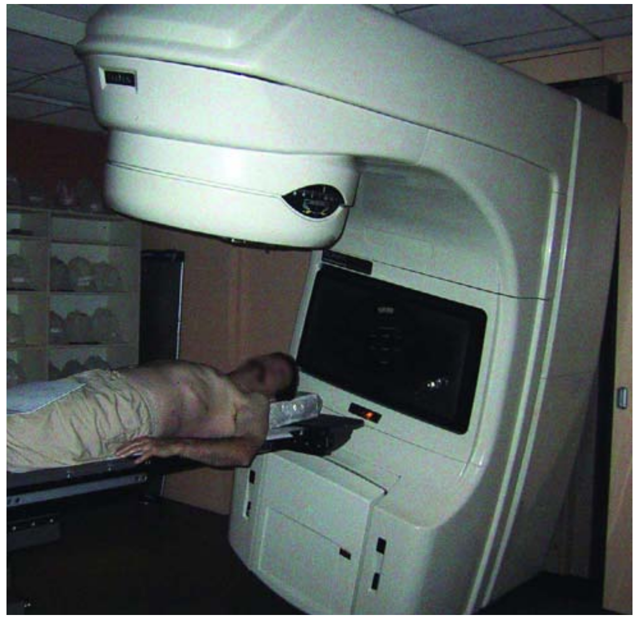


| ISOTOPES AND THEIR USES | |
|---|---|
| **Where They Are Used** | **Reasons for Their Use** |
| Health and Medicine | For diagnosis of heart disease, cancer, and for therapy. Every year more than 30 million medical treatments and over 100 million laboratory tests are completed using isotopes. |
| Environment | For the measurement of air and water pollution and to understand the effects of radioactive waste on the public and environment. |
| Industrial Safety | Used to detect flaws in steel sections used for bridge and jet airliner construction. |
| Consumer Protection and Safety | Used to study the quality of food and its effect on humans. |

### Radioactive Isotopes

Carbon 12 is the most common isotope of carbon. It is stable because it has six neutrons and six protons. It has an atomic mass of 12. Carbon 14 is another isotope of carbon. It has two extra neutrons and an atomic mass of 14. Carbon 14 is an unstable or radioactive isotope of carbon. Some of its neutrons will break down into electrons and protons. Scientists call this radioactive decay. Measurement of radioactive decay is the amount of time that it takes carbon 14 to break down. Half-life is when half the nucleus in a sample of a radioactive isotope breaks down.

A radioactive isotope that is decaying gives off subatomic particles and rays. Scientists call this radiation.



***Radioactive isotopes help determine the health of patients and allow doctors to treat them more effectively.***

For the past century, radioactive isotopes have become a part of our daily lives. We find them in smoke detectors, in the irradiation process that makes food safer, in carbon 14 dating which tells archeologists when an organism died, and often in the field of medicine. Doctors use radioactive isotopes, or tracers to identify diseases and treat them.

Doctors use radioactive isotopes, or tracers to identify diseases and treat them.

Radioactive elements and isotopes can also be harmful. A person exposed to too much radioactivity can develop radiation sickness. Their hair can fall out and they can become very ill. Long-term exposure to radiation can cause cancer and blood diseases.

There are several tools used to detect radioactivity. The most well known tool is the Geiger counter. It will emit loud clicks or move a needle on a screen when encountering radioactive material.

***This man uses a Geiger counter to determine the presence of radioactive materials.***



Find out more

### The Disaster at Chernobyl

On April 26, 1986, one of four nuclear reactors exploded at the Chernobyl power station in Ukraine, a country that used to be a part of the old Soviet Union. The explosion burned for nine days, proving to be the worst nuclear accident in history. The disaster released at least 100 times more radiation than the atom bombs dropped in Nagasaki and Hiroshima. Much of the fallout fell close to Chernobyl, Belarus, Ukraine, and Russia. Many people left the area, but about 5.5 million people continue to live there today.

Every country in the Northern Hemisphere contains soil that has tested positive for traces of radioactive deposits from the Chernobyl disaster. No one knows the final number of people who will die as a result of this accident. Scientists and doctors in the area have seen a drastic increase in thyroid cancer, mainly in people who were children or teens at the time of the accident. Fortunately, survival rates are high in the case of this type of cancer. Today, work continues to keep the Chernobyl plant from crumbling. Wild horses, boar, wolves, and birds have returned to the area and are thriving.

### Marie Curie

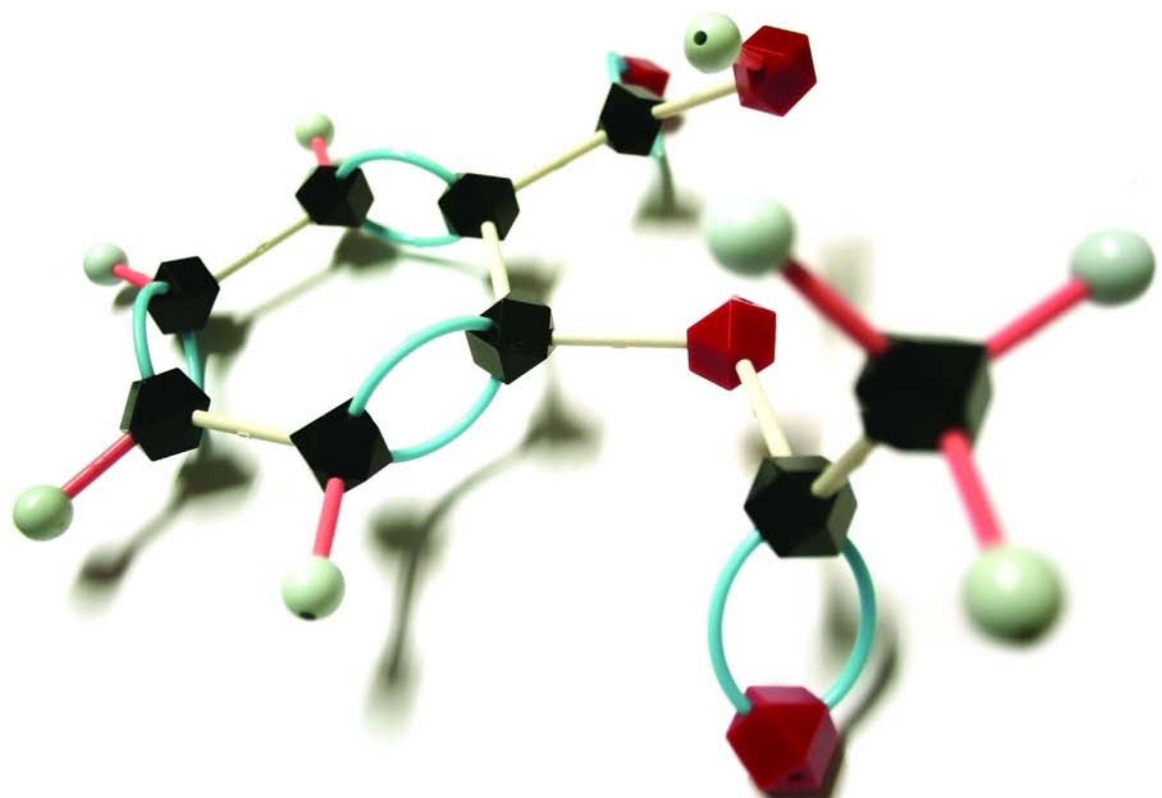
Getting to know...

Marie Curie was born Marya Sklodowska in Poland in 1867. She attended the famous university in Paris called the Sorbonne. She married Pierre Curie in 1895. They studied chemistry together.

Marie and Pierre Curie heard that the element uranium gives off radiation. Uranium comes from an ore, which is a type of rock called pitchblende. They found two other radioactive elements in the pitchblende. They were polonium and radium.

In 1903, the Curies shared the Nobel Prize in Physics for their work with radioactivity. Pierre died in an accident in 1906, and Marie continued her research. She won the 1911 Nobel Prize in Chemistry for discovering polonium and radium. Marie Curie died of a type of cancer called leukemia. Exposure to radioactivity caused her cancer.

# Molecules



*An aspirin model helps us to visualize what the actual molecule might look like.*

Naturally occurring elements are usually a combination of several elements. Some combine with elements just like themselves. Others combine with different elements. Scientists call these combinations of elements molecules. They are made of at least two atoms and are stable. This means they have the same number of protons and neutrons.

A molecule is the smallest form of a substance that can exist on its own. A molecule still has the features of that substance.

Molecules can exist without breaking apart or linking to other atoms.

*There are more molecules in your body than there are stars in the entire universe.*



For some elements, there is no difference between a single atom and a molecule of the elements. For example, an atom of hydrogen is the same as a molecule of hydrogen. All the noble gases can exist as a molecule with a single atom. Noble gases include helium, neon, argon, krypton, xenon, and radon.

## Bonds

A bond is like a link that holds two or more atoms together. There are many different kinds of bonds. Sometimes, atoms share electron pairs with other atoms. Scientists call these bonds covalent bonds.

### Covalent bonds in gases

The atoms that make up common gases naturally occur as molecules. Hydrogen, oxygen, nitrogen, fluorine, and chlorine are gases. Each molecule provides two atoms. For example, two oxygen atoms combined together make up one oxygen molecule. Covalent bonds hold them all together. These elements can only exist as molecules.

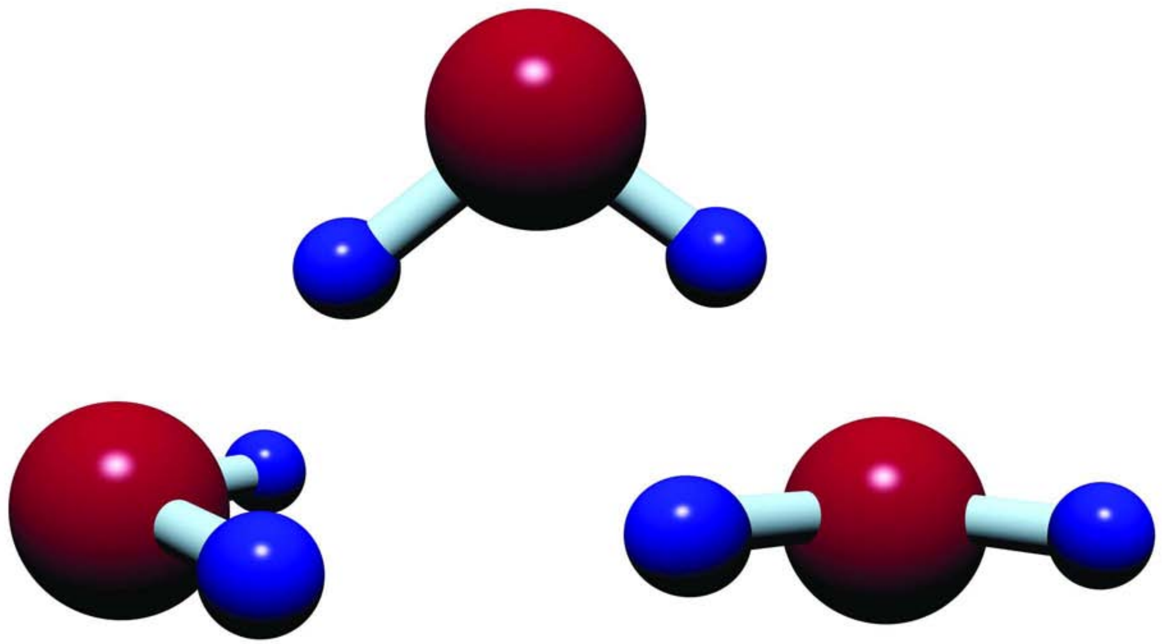
*Some molecules, like oxygen, are very simple in appearance.*

### Ionic bonds

Sometimes, atoms link up with other atoms because they have extra electrons. Sometimes atoms link up with other atoms because they are missing electrons. We call these atoms ions. Ionic bonds hold the atoms together. Salt molecules are formed when sodium (Na) ions and chloride (Cl) ions bond together to make NaCl, or salt.

*Sodium and chloride bond to make common table salt.*

**Types of ions.** Scientists call an ion that is missing an electron or that has an extra proton a cation. An anion has an extra electron or is missing a proton.



*The two blue balls in each model represent hydrogen. The red balls represent oxygen. Each individual model represents one water molecule.*

## Hydrogen Bonds

Two atoms of hydrogen and one atom of oxygen form water. A covalent bond occurs when atoms share electrons with other atoms. Hydrogen bonds hold water together when water is a liquid. These bonds pull the hydrogen atoms of one water molecule close to the oxygen atoms of another water molecule. Hydrogen bonds are what give water such a high boiling point (212˚F or 100˚C).

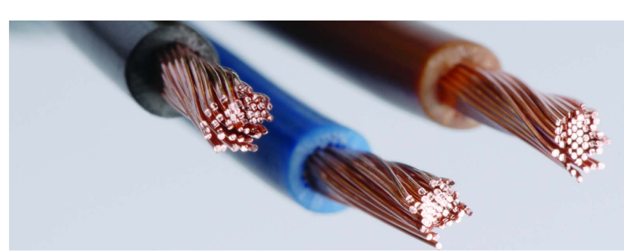
WORDS TO KNOW

**equation** (i-KWAY-zhuhn): a mathematical statement that one set of numbers or values is equal to another set of values or numbers

**stable** (STAY-buhl): firm and steady

## Metallic Bonds

Metallic bonds hold together the atoms that form metal. Loosely attached electrons are in the outer shell of a metal atom. The electrons float around between the individual atoms in a sea of electrons. These electrons keep metal atoms in orderly rows. They fit together and flow easily in a metallic lattice. This allows heat and electricity to flow through the metal. Metallic bonds do not hold the atoms in place. When stretched or bent, atoms can move around. This movement is what enables metalworkers to make wire.



*Wires conduct electricity. They enable us to talk on the phone, or recharge our iPods.*



| Timeline of the Atom Bomb | |
|---|---|
| 1898 | Marie Curie discovers radium and polonium. |
| 1905 | Albert Einstein develops a theory about the relationship between mass and energy. |
| 1911 | C.T.R. Wilson invents the cloud chamber. |
| 1913 | Radiation decay detector developed by Hans Geiger. |
| 1925 | First nuclear reaction captured by a cloud chamber photo. |
| 1935 | Arthur Dempster at the University of Chicago discovers uranium-235 isotope. |
| 1939 | Einstein and several other important scientists send a letter to the President of the United States, Franklin D. Roosevelt, detailing how Germany is developing and planning to use the first atom bomb. |
| 1941 | Japan attacks Pearl Harbor. The U.S. enters World War II. |
| 1942 | The Manhattan Project was established by the President to speed up research of the atom bomb. J. Robert Oppenheimer becomes the director in charge of its creation. Scientists all over the United States begin research and development. |
| July 1945 | The first test of the atom bomb performed in New Mexico displays its unbelievable release of energy. It prompted many involved to sign petitions urging the United States not to use this weapon because of the destruction it can cause. |
| August 6, 1945 | The first uranium bomb dropped on Hiroshima, Japan causes devastating destruction. Sixty-six thousand people die and more than 69,000 people are injured. |
| August 9, 1945 | Three days later, a plutonium bomb devastates Nagasaki. More than 39,000 people died, and 25,000 were injured. |
| August 14, 1945 | Japan offers to surrender. The surrender becomes official on September 2, 1945. |
| 1945-Present | Many innocent people lost their lives in order for a war to end. Since that time, countries developed, threatened to use, and then disarmed themselves of nuclear weapons. It is the fervent wish of many that nuclear weapons become part of history and never used again. |

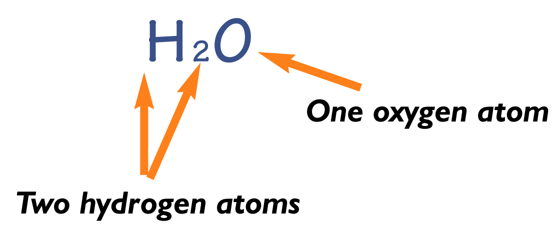
## Chemical Formulas

Scientists can describe a molecule or a compound with a chemical formula. A chemical formula is a written description of all the elements in a substance. Scientists sometimes write out chemical equations to figure out how different chemicals react with one another or to describe a reaction.

| Common Molecules | Chemical Formula |
|---|---|
| Carbon Dioxide | $CO_2$ |
| Ammonia | $NH_3$ |
| Sugar | $C_6H_{12}O_6$ |
| Rubbing Alcohol | $C_3H_7OH$ |

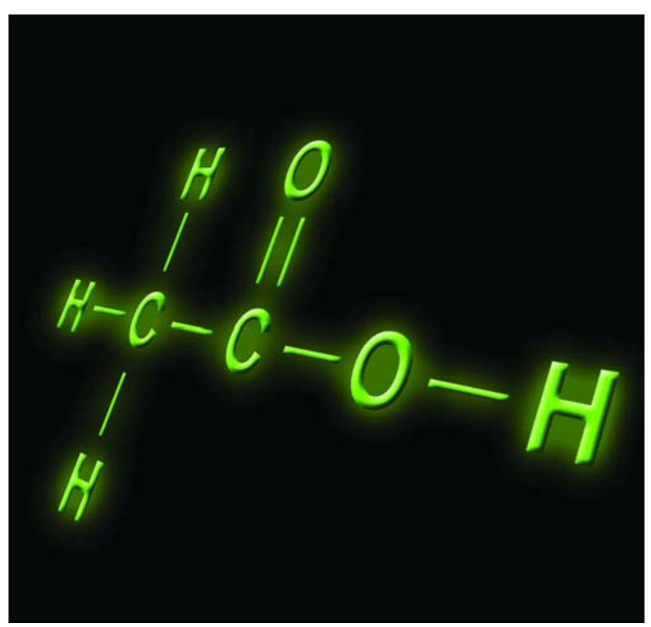
### Molecular Formulas

Molecular formulas describe the exact number of atoms in a molecule. The tiny numbers to the bottom right of an element in a chemical formula stand for the number of atoms in that element. Water is a molecule made from two hydrogen atoms and one oxygen atom. $H_2O$ is the molecular formula for water. The little 2 next to the H means that there are two hydrogen atoms. The O means that there is one atom of oxygen. Big numbers to the left of the atom stand for the number of molecules. Water that is written as $5H_2O$ has 5 molecules of water.




### Structural Formulas

Structural formulas describe the arrangement of atoms within the molecules. A drawing of the formula shows the shape of the molecule.



*A structural formula displays the shape of the molecule similar to an actual model.*



# Matter

Matter is anything that takes up space and has mass. Atoms or parts of atoms form all matter. It is everything from the tiniest electron to the planets and stars.

The molecules of a solid will start to move as they are heated. Most metals in the periodic table are solids at room temperature. Silver bricks are a solid.

## Phases of Matter

Nearly all matter is a solid, a liquid, or a gas. These forms are called phases of matter.

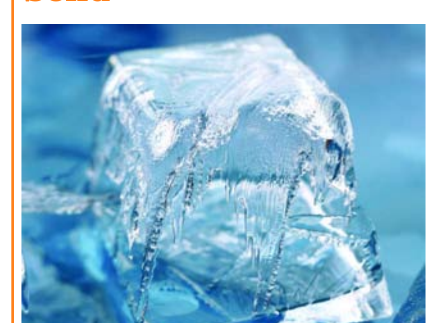
### Solids

Solids have a definite, or fixed, shape and volume. Their shape stays the same and they take up a certain amount of space. They are often very hard, or rigid. The molecules are usually locked in position. Molecules are made of at least two atoms. The colder a solid is, the less the molecules move.

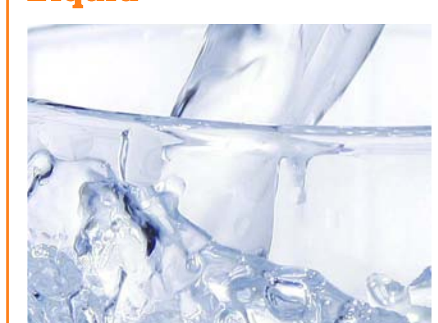
*The desks, chairs, and books are solids in this classroom. They will hold their shape unless physically changed.*

**Water can be in the form of a solid, a liquid, or a gas.**

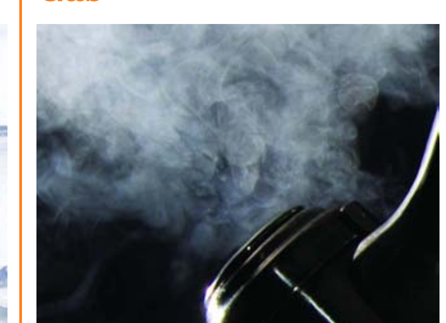
**Solid**



**Liquid**



**Gas**

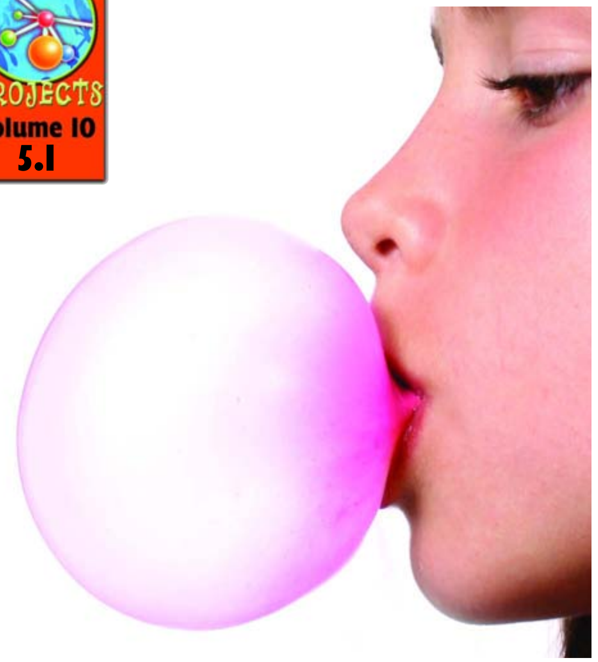


### Liquids

Liquids have a fixed volume but not a fixed shape. The molecules in a liquid vibrate and move around each other easily. This means that they are fluid. Some liquids are thin, like water. It pours quickly. Other liquids are thick, like oil or syrup. They pour more slowly.

*Water is not as thick as oil. The oil will sink to the bottom of the water.*

PROJECTS volume 10 5.1



*The gas in a popped bubble will not keep its shape.*

### Gases

Gases have no fixed shape or volume. Gas fits into a container of almost any size. Gas molecules compress, or push together easily. Solid and liquid molecules do not function in the same way.

Some gases are lighter than air, like helium. An untied balloon filled with helium will float into the sky. Other gases are heavier than air, like carbon dioxide. You breathe out carbon dioxide with the air that leaves your lungs. A balloon filled with this mixture will sink to the floor.

*Tropical rain forests take in carbon dioxide, a gas that we exhale, and changes it into clean air that we can breathe.*



Find out more

**Atoms In Gases**

The atoms in a gas can lose their electrons at really high temperatures. The result is a hot mixture of ions and electrons called plasma. This is another phase of matter. The flames of a fire are plasma. Lightning is plasma that forms when the air is electrically charged. Some scientists consider plasma to be a charged gas and not its own phase of matter.

*Plasma television*

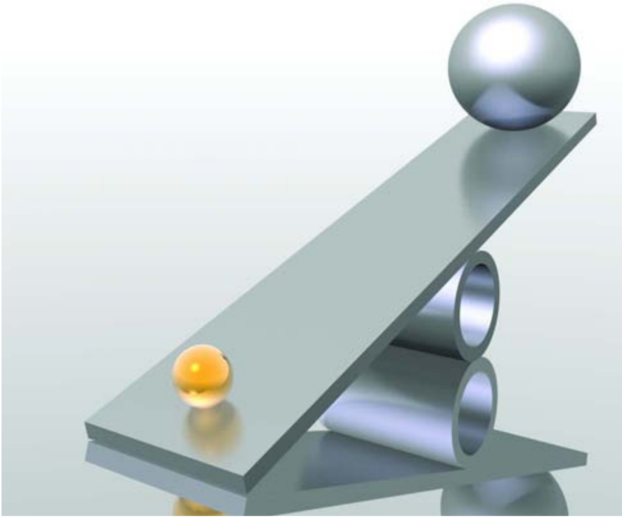
## Properties of Matter

There are many ways to describe matter. Some things are either big or small. Other things might be hard or soft. An object might be light or heavy. A rock might be hot or cold. Some materials stretch into different shapes. Other materials mix easily with water. Still others float on water. All these descriptions tell you about the properties of matter.

*Lava is a very hot liquid until it cools. Then, lava becomes a solid rock.*

### Mass

Mass is the amount of matter in an object or substance. All forms of matter have mass. Solids, gases, and liquids have mass. The more neutrons and protons there are in an atom, the larger its mass will be. An atom of gold has 197 protons and neutrons. An atom of aluminum has only 27 protons and neutrons. This is why gold has a greater mass than aluminum.



*Comparing sizes of objects does not help us to determine mass. This scale shows us that gold has greater mass than aluminum.*

## Weight

Gravity pulls down on mass creating a force called weight. Mass and weight are proportional on the surface of the Earth. This means you double the weight of something if you double the amount of mass. In outer space, an object can be weightless, but still have the same mass. This is because gravity is not pulling on the object. Mass does not change, but weight depends on surrounding forces.

### WORDS to know

**mixture** (MIKS-chur): something consisting of different things mixed together

**properties** (PROP-ur-tee): special qualities or characteristics of something

"I weigh 60 pounds."

"I weigh 10 pounds."

"My weight changed, but my mass didn't change. My body still contains all the same stuff it contained when I was on Earth."



| Planet | Weight (lb) | Weight (kg) |
|---|---|---|
| Mercury | 33 | 15 |
| Venus | 79 | 36 |
| Mars | 33 | 15 |
| Jupiter | 207 | 94 |
| Saturn | 79 | 36 |
| Uranus | 77 | 35 |
| Neptune | 97 | 44 |

*The pull of gravity is different on each of the planets in our solar system. If you weighed 88 lbs (40 kg) on Earth, the table will show you how much you would weigh on the other planets. Your mass would still stay the same.*

## Volume

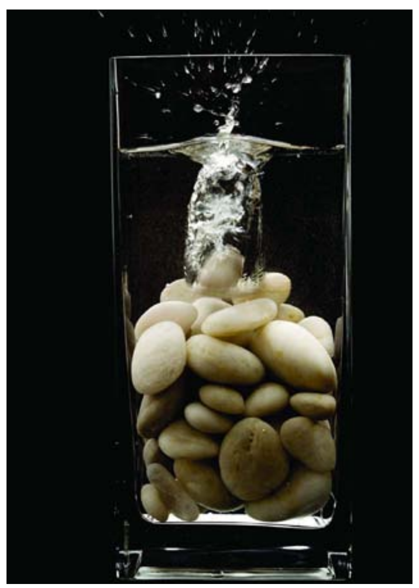
Another way to describe the amount of something is its volume. Volume is the amount of space taken up by matter. An object can have a large mass but take up only a small amount of volume. An object can also have a small mass but take up a lot of volume.

*Scientists measure liquid volume in graduated cylinders that are marked with the units milliliter and liter.*

*The cotton candy's volume is greater than the golf ball. The golf ball's mass is greater than the cotton candy.*

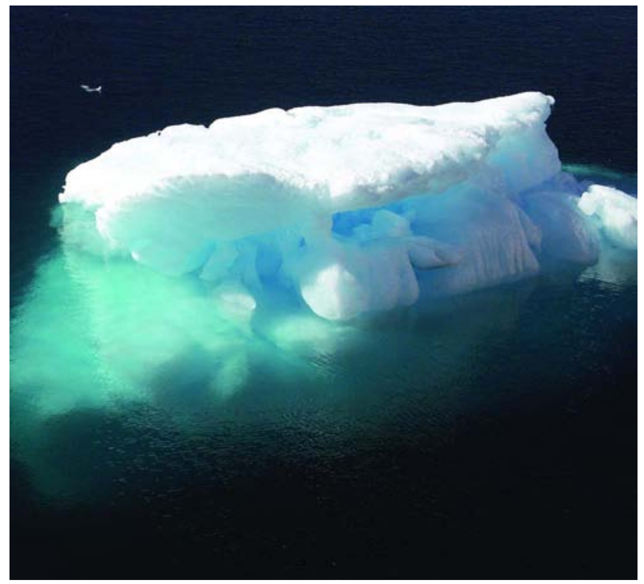
## Density

Density is the amount of mass for a certain volume. A block of iron is heavier than a block of wood that has the same size or volume. Iron is more dense than wood. Gases are not as dense as solids and liquids. Different gases have different densities. Hydrogen and helium are not as dense as oxygen and nitrogen. This is why a helium balloon floats up into the air.



*These rocks are denser than the liquid.*

A solid that is not as dense as a liquid will float on it. A denser solid will sink in it. The buoyancy of an object describes how well it floats on top of a liquid. Cork floats because it is not as dense as water. A boat can float because its shape allows it to contain a lot of air. The air in the boat is less dense than the water beneath the boat. The boat will sink if it fills up with too much water.



*Icebergs float because they are slightly less dense than water. Most of the iceberg is below the surface of the water.*

**Find out more**

Water has the density of 1.0 $g/cm^2$. Saturn's density is .69 $g/cm^2$. If you were to go to Saturn and return with a chunk of the planet, you could throw it in a body of water and watch it float!

*Saturn*



## Conductors of Heat

Heat can be conducted, or passed, through many types of matter. Metals are very good conductors of heat. The energy in heat conducts from one end of a piece of metal to the other end. This is why a metal spoon gets hot when only one end is touching the source of the heat.

*The glowing end of this metal rod shows us its intense heat. Eventually, the heat will transfer along the rod to the other end.*

## Conductors of Electricity

Metals are also good conductors of electricity. Electrons flow easily between the atoms of a metal. An electrical current at one end of a metal wire quickly passes through to the other end.

*The prongs of this plug will conduct electricity to the wires in the cord. The wires will conduct the electricity to the appliance. The plastic covering around the wires allows us to be able to hold the cord without burning our hands.*

**Liquids** can also be good conductors of electricity. This is why it is a bad idea to use an electric device near water. For example, never use a hair dryer near a bathtub filled with water.

*Get out of a pool immediately if you hear thunder or see lightning!*

**Semiconductors.** Other elements can also be good conductors of electricity. Semiconductors can conduct electricity when they are heated. Silicon, when mixed with other elements, is a very good semiconductor.

Most solid materials are poor conductors of electricity. Wood, plastic, and glass are electrical insulators. The plastic covering on wires acts as an insulator. The plastic prevents wires from touching each other and causing electrical problems.

*Semiconductors enable us to use many everyday items, such as a cell phone.*

WORDS TO KNOW

**insulator** (IN-suh-late-ur): a covering which prevents heat or electricity from escaping

Find out more

**Some Metals Are Liquids**

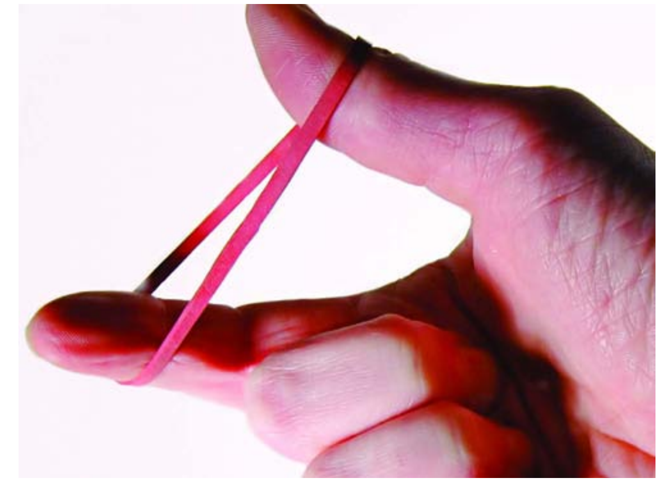
Most people think of metals as hard and strong. Some metals are actually liquids! Mercury is the only metal that is a complete liquid. This happens at room temperature. Thermometers and electrical switches use mercury. Other metals become liquids at higher temperatures.

*Mercury is very poisonous. If a thermometer drops and breaks, stay away from the mercury and wait for an adult to help you.*

## Elasticity

Rubber bands have elasticity. They will snap back into their original shape if you stretch them and then let go. Other things made out of rubber show this same elastic property. A balloon will return to its original shape if you let the air out of it.





*Rubber bands have elasticity. They will snap back to their original shape if you stretch them and let go.*

**Elastic Limit.** Other materials are not as elastic. Metal springs bounce back into shape after being stretched or compressed. An overstretched spring will not return to its exact original shape. The point to which you can stretch a material and still have it bounce back is called the elastic limit. Almost all materials have at least a little bit of elasticity.

*When you chew gum, you are really chewing plastic and rubber with a little bit of flavoring. Gum is not as elastic as a rubber band.*

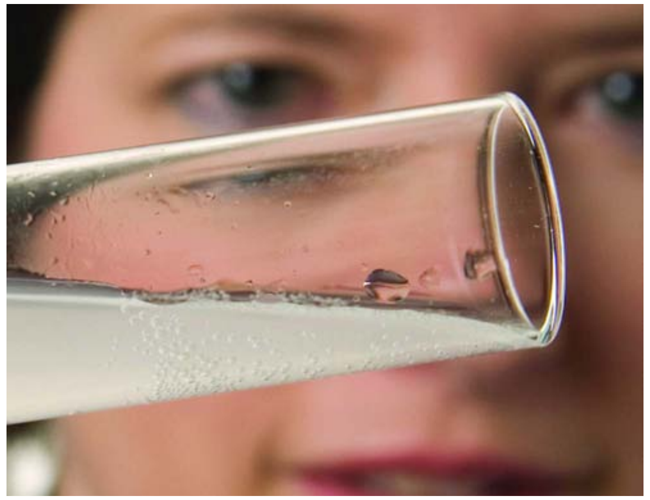
## Solubility

PROJECTS volume 10 5.2

Solubility is the ability to dissolve. A substance dissolves and distributes evenly into another substance. The dissolved substance may be difficult to detect. Sugar dissolves in hot tea. After stirring, it is difficult to see the sugar.

*Sugar dissolves easily in a hot cup of coffee.*

**Changes in Solubility.** Solids, liquids, and gases dissolve into liquids. They form a solution. A solution is a mixture of more than one thing. The solubility of solids and liquids can change. This can happen when the temperature changes. Solubility will increase as the temperature increases. This means that more liquids or solids dissolve at higher temperatures. It will also increase as pressure is increased. The solution is saturated when no more of a substance can be dissolved into it.



*This water is saturated. You can clearly see the crystals of salt that will not dissolve.*

## Changes in Matter

### Boiling Point

*The boiling point of water changes depending on your elevation. The boiling point of water at the highest point in the Rocky Mountains is 194°F (90°C).*

Some phases of matter can change into other phases. This can happen when the conditions are right. A liquid heated enough will change into a gas. Scientists call the temperature at which this begins the boiling point. The boiling point of a liquid will increase as the pressure is increased. At sea level, water boils at 212°F (100°C). Water boils at a lower temperature at higher altitudes. This is because there is less air pressure pushing against the water.

### Evaporation

Water is the most common liquid on the planet. It changes into a gas called water vapor as it is heated. Water is absorbed into the atmosphere through a process called evaporation.

*The water in this puddle will not really disappear. It will evaporate back into the atmosphere.*



### Condensation

Water vapor that cools will turn back into a liquid. Cold metal or glass can help speed up this process. Little drops of water build up on a cold surface as the molecules in the water vapor begin to move more slowly. Condensation is the buildup of little drops of water.

*The cold iced tea caused condensation to form on the outside of this glass.*

### Sublimation

Sublimation occurs when certain solids turn directly into gas. A gas will form if the molecules of a solid move fast enough. Dry ice is frozen carbon dioxide. Dry ice does not change into a liquid before changing into a gas.

*Carbon dioxide freezes at -109° F (-78° C), turning it into dry ice. Dry ice gives the appearance of fog or smoke when exposed to warmer temperatures.*

### Melting Point

Heated enough, a solid will melt into a liquid. The melting point is the temperature at which a solid begins melting. Nearly all metals are solids at room temperature. Hard rocks will melt deep below the surface of the Earth. This is because of high temperatures. Ice cream is solid as long as it is kept cold. It becomes a liquid as it melts.

*Ice cream does not remain a solid for long if left out in the Sun.*

## Freezing Point

The freezing point of a liquid is the temperature at which it becomes a solid. Water will freeze at 0° Celsius or 32° Fahrenheit.

*Many children are elated when a liquid reaches the freezing point!*

### Robert Boyle

Getting to know...

Robert Boyle, the founder of chemistry, was born in Ireland in 1627. His father was one of the richest men in the country of Great Britain. Boyle went to the best schools. He had the money to set up laboratories for his work in science.

Boyle thought about science in a new way. He believed in testing theories. He designed experiments for other scientists to repeat. He wrote down all of his results. He was the first to suggest that certain kinds of matter share similar chemical properties. He noted the difference between atoms and elements.

# Compounds, Acids and Bases, Mixtures, and Solutions

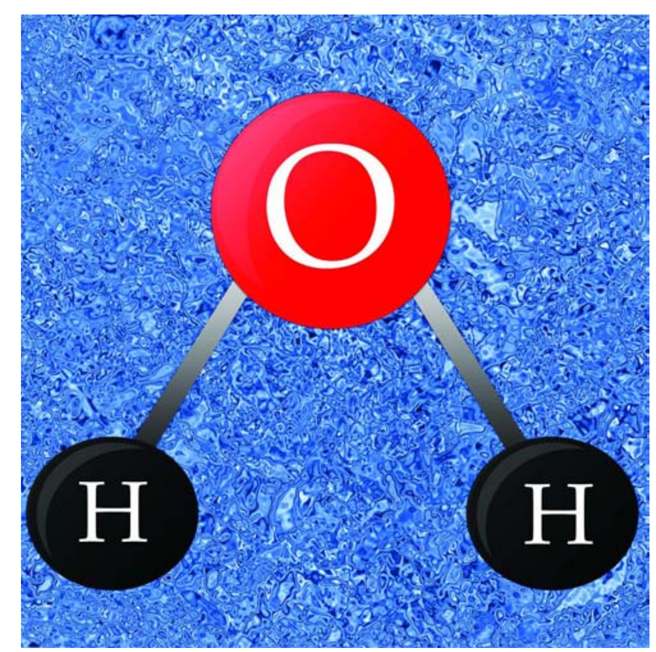
Every material is made of either a pure substance or a combination of substances. A substance is pure if it contains only one type of element. An element is a substance made up of all of the same type of atoms. Oxygen is a pure substance. It only contains oxygen atoms. Elements combine in several ways. Some of these combinations will always stay together while others separate.

*This steel container is rusting. A chemical reaction occurs when the iron from the can meets the oxygen in the air.*



## Compounds

A compound is a combination of two or more elements. These elements exist in the compound in fixed amounts. A chemical reaction occurs during the formation of a compound. The chemical reaction may produce light or heat. It might also produce some other kind of change. Compounds often look very different from the elements from which they came. The elements that make up the compound lose their identity. There is only one way to separate the elements that make a compound. This is with another chemical reaction.




*Hydrogen and oxygen are gases. When they form a compound, their characteristics are very different. Combined, they become a liquid, water.*

## Simple Compounds

Simple compounds are different kinds of combined elements. They combine chemically. Water is the most common compound. It is made of 2 parts of hydrogen (H) and 1 part of oxygen (O). Sugar, alcohol, baking soda, and acids are all different types of compounds. Millions of different compounds exist in nature. Scientists have the ability to form many compounds in laboratories.

### Sir Humphry Davy

Getting to know...

Humphry Davy was born in England in 1778. At sixteen, he worked for a surgeon. At first, Davy wanted to be a doctor. Then he became interested in chemistry. He began to create his own experiments.

Davy suggested that compounds break down into elements. This happens when electricity passes through them. Scientists call this electrolysis. Davy used electrolysis to separate many elements.

He also used it to study a substance called muriatic acid. We now call this hydrochloric acid. Some people thought that all acids contain oxygen. Davy found that muriatic acid has hydrogen and chlorine but no oxygen. He realized that all acids contain hydrogen.

**Find out more**

Fireworks, batteries, and flashbulbs from cameras work because of hydrochloric acid. Your stomach makes its own hydrochloric acid so you can digest your food.

## Acids and Bases

PROJECTS volume 10 5.3

### Acids

An acid is a substance. It gives up hydrogen ions in solutions containing water. Some acids are weak. They contain fewer hydrogen ions. Other acids are strong. They contain more hydrogen ions.


*Battery acid is very strong. Never touch or use a leaky battery.*

### Inorganic Acids

Acids made from minerals are inorganic acids or mineral acids. Minerals are things found in nature. They are not plants or animals. These acids, often used to make commercial products, are liquids. Sulfuric acid is one of the most often used chemicals in the United States. We use it to make gasoline, plastics, and many other products. Some gardeners use fertilizer made from nitric acid and phosphoric acid.

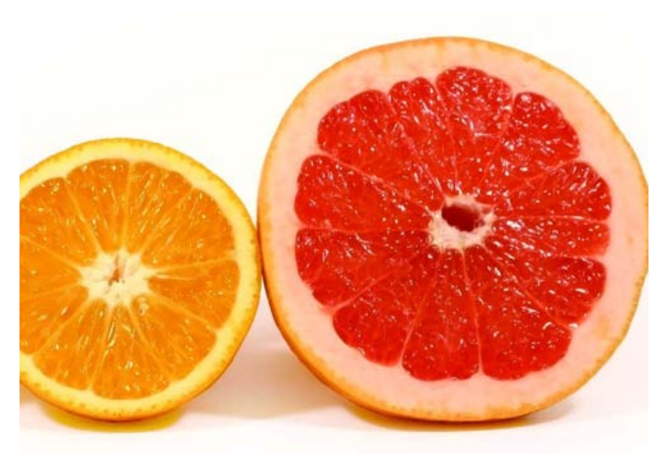
*Fertilizers help gardens grow and stay beautiful.*



### Organic Acids

Humans make an acid in their stomachs called hydrochloric acid. Hydrochloric acid helps digest, or break down, food. Mucus, a thick substance inside the stomach, protects it from hydrochloric acid. Hydrochloric acid can eat through the lining of the stomach. This happens when there is not enough mucus to protect it. People can get a hole in their stomachs called an ulcer.

Some acids are in the foods that people eat. A food that tastes sour probably contains citric acid. Lemons, oranges, and grapefruits all contain citric acid.



*Citric acid crystallized from lemon juice is used in everything from shampoo to photography.*

Sometimes people get sore muscles from a buildup of lactic acid in their muscles. Milk that spoils also makes lactic acid.

Butter that goes bad makes butyric acid. Vinegar contains an acid called acetic acid. We call all of these acids organic acids because they occur naturally.

### Bases

The opposite of an acid is a base. Bases cancel out, or neutralize, an acid. We call bases dissolved in water alkalis. Bases are everywhere.

*Soap is a common base we use everyday.*

**Strong Bases.** Sodium hydroxide is a strong base used to make soap and other cleaning agents. Strong alkalis are often caustic. This means that they can burn skin. They can also dissolve some substances. Some alkalis are even poisonous.

**Weak Bases.** Ammonia, or ammonium hydroxide, is a weak alkali base used in many cleaning and disinfecting products. Foods that contain weak alkalis often taste bitter. So do some things that are not edible. Soap bubbles taste bitter because of the alkalis in them.

*Unsweetened chocolate contains alkalis which causes it to taste bitter.*

Find out more

### pH

People can tell how strong an acid or a base is. They find this by measuring its pH. Acidity is how strong an acid is. Alkalinity is how strong a base is.

The symbol pH stands for "power of hydrogen." It is measured on a scale from 1 to 14. A strong acid might have a pH of 1. Sulfuric acid and hydrochloric acid have a low pH. They can burn through clothes and skin. At the other end of the scale are bases. A pH of 14 means that the solution is a strong base. Strong bases are also dangerous. A neutral solution is neither an acid nor a base. A neutral solution has a pH of 7.

There are many ways to determine the pH of something. Use litmus paper to see if a liquid is an acid or a base. The paper turns red if dipped in an acid. The paper turns blue if dipped in a base. Scientists can measure pH accurately by using a special machine called a pH meter.

It is very important to know what the pH of a substance is. A person can die if the pH of the blood changes even a little. Doctors must make sure that any solutions used to help people are neutral.




## Mixtures

PROJECTS volume 10 5.4

Many things are combinations of substances. A mixture is matter made up of different parts. The parts have different properties. The parts of a mixture can be present in any amount or proportion. No chemical reaction occurs in a mixture. There is no flash of light or heat. Heterogeneous mixtures look like they have different parts. The parts that make up a mixture keep their identities. Heterogeneous mixtures easily separate.

*A salad is an example of a heterogeneous mixture.*

### Making and Separating Mixtures

There are many ways to mix and separate a mixture. Simply dump two materials together to make a mixture. Cement is a mixture made by pouring water into a special kind of sand. Mud is a mixture of dirt and water.

*Cement is a mixture used for sidewalks and streets. There are four essential ingredients in cement: calcium, silicon, aluminum, and iron.*

Sometimes, mixtures form over a very long period of time. Granite is a type of rock that is actually a mixture of three other kinds of rock. It is made of quartz, feldspar, and mica rock.

*It can take millions of years for granite to form.*

Mixtures used in preparing food, such as Italian salad dressing, are often a mixture of oil, vinegar, and spices. The dressing will separate into three layers if you let it sit long enough.

***Shake a bottle of salad dressing before you use it. The greater the density of the liquid, the more it will separate and sink.***

## Solutions

Many types of mixtures do not seem like mixtures at all. They often look like only one substance when they are actually two or more. We call these mixtures solutions, or homogeneous mixtures.

Solids combined with liquids form some solutions. A mixture of sugar and water can make a solution called sugar water. The sugar disappears, or dissolves into the water. Sugar water tastes sweet even though the sugar is dissolved. When the water evaporates, the sugar remains. Then the water will have changed into a gas and you will only be able to see the sugar.

***Hot chocolate is a delicious solution on a cold winter day.***

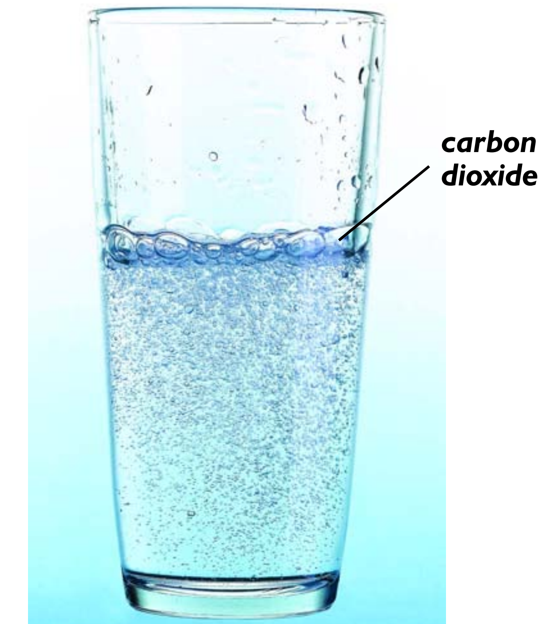


### Making and Separating Solutions

Two liquids combined form a solution. Alcohol dissolved into water is a solution. Evaporation separates the solution. Alcohol will evaporate first. This is because it has a lower boiling point than water.

Gold and silver become liquids if they become hot enough. Liquid gold and silver separate when heated. The gold will settle to the bottom because it is heavier than silver.

A gas and a liquid can also make a solution. Carbon dioxide mixed with water makes a solution called soda water. When soda water separates, carbon dioxide bubbles rise out of the liquid. Pressure releases from the can or bottle of soda.




Find Out More

### Air

Do you wonder what is in the air that you breathe? Air is actually a mixture of gases. It is mostly a solution of nitrogen and oxygen gases. There are other gases in air such as carbon dioxide and water vapor. Other gases are in the air because of natural and human activity.

Volcanos send sulfur dioxide and carbon monoxide into the air. Forest fires also add carbon monoxide. Tiny living creatures remove some of these poisonous gases from the air. Human activity adds many different gases into the air. Exhaust from cars and factories create harmful carbon monoxide. Smog forms when sunlight reacts with carbon monoxide and other gases in the air. High levels of smog can cause health problems in humans.

Humans and animals change the air around them. They do this when they breathe. They breathe in the oxygen and nitrogen. They breathe out a new mixture of air containing carbon dioxide. Plants use carbon dioxide during the process of making food called photosynthesis. One product of photosynthesis is oxygen.

***We can help our environment and ourselves by reducing the number of cars on the road. We should walk, ride a bike, take a train, take a bus, or carpool whenever possible.***

# Reactions

## Chemical Reactions

A chemical reaction occurs when chemicals combine and change. Reactions are constantly taking place. Many occur in nature. Some reactions take place inside animals and plants. The food that humans and other animals eat digests as a series of chemical reactions. Photosynthesis is a series of chemical reactions in plants. This is how plants make food.

***Photosynthesis, a chemical reaction powered by the Sun, changes carbon dioxide and water into oxygen and sugar.***

Other chemical reactions caused by humans take place every day in factories. Chemical reactions take place above the surface of the Earth. Some of these reactions protect the Earth from harmful things. Chemical reactions make all life possible.

### Combining Chemicals

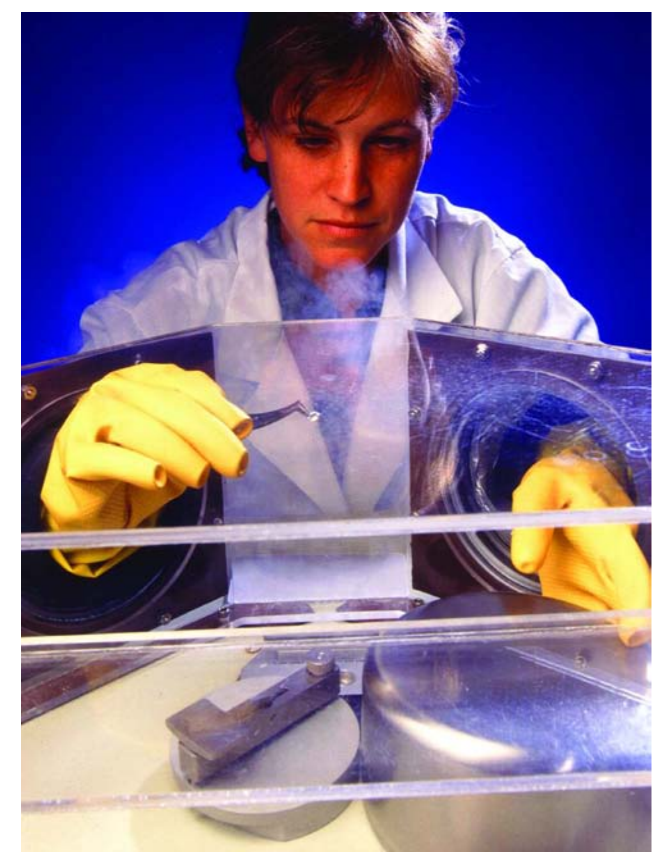
**Reactants and Products.** There are many different ways that chemicals combine, or react. A chemical reaction occurs when one substance is broken apart and then put together as a new substance. Reactants are the starting substances. Scientists call the new substances products. Atoms and molecules rearrange during a chemical reaction, but do not disappear or change. Reactions speed up when special chemicals are used. Reactions also release some form of energy.

***The head of a match contains sulfur, glass powder, and an oxidizing agent. Friction from striking the match creates enough heat to cause a chemical reaction, and fire.***



## Making and Breaking Bonds

All chemical reactions involve making and breaking bonds between atoms. Every time a chemical reaction takes place, chemical bonds pull apart and come back together. Energy is required for bonds to break. This energy can take many forms. Some chemical reactions take place when there is heat or light. Other reactions need electricity to get started.



***Scientists use this device to measure the heat of reactions. Scientists like you can also use a styrofoam cup and get similar results!***

### Mass

All chemical reactions conserve mass. This means that the amount of atoms at the beginning of a reaction is the same as the amount of atoms at the end of a reaction. The atoms just move places. The number of atoms is the same on both sides of a chemical equation.

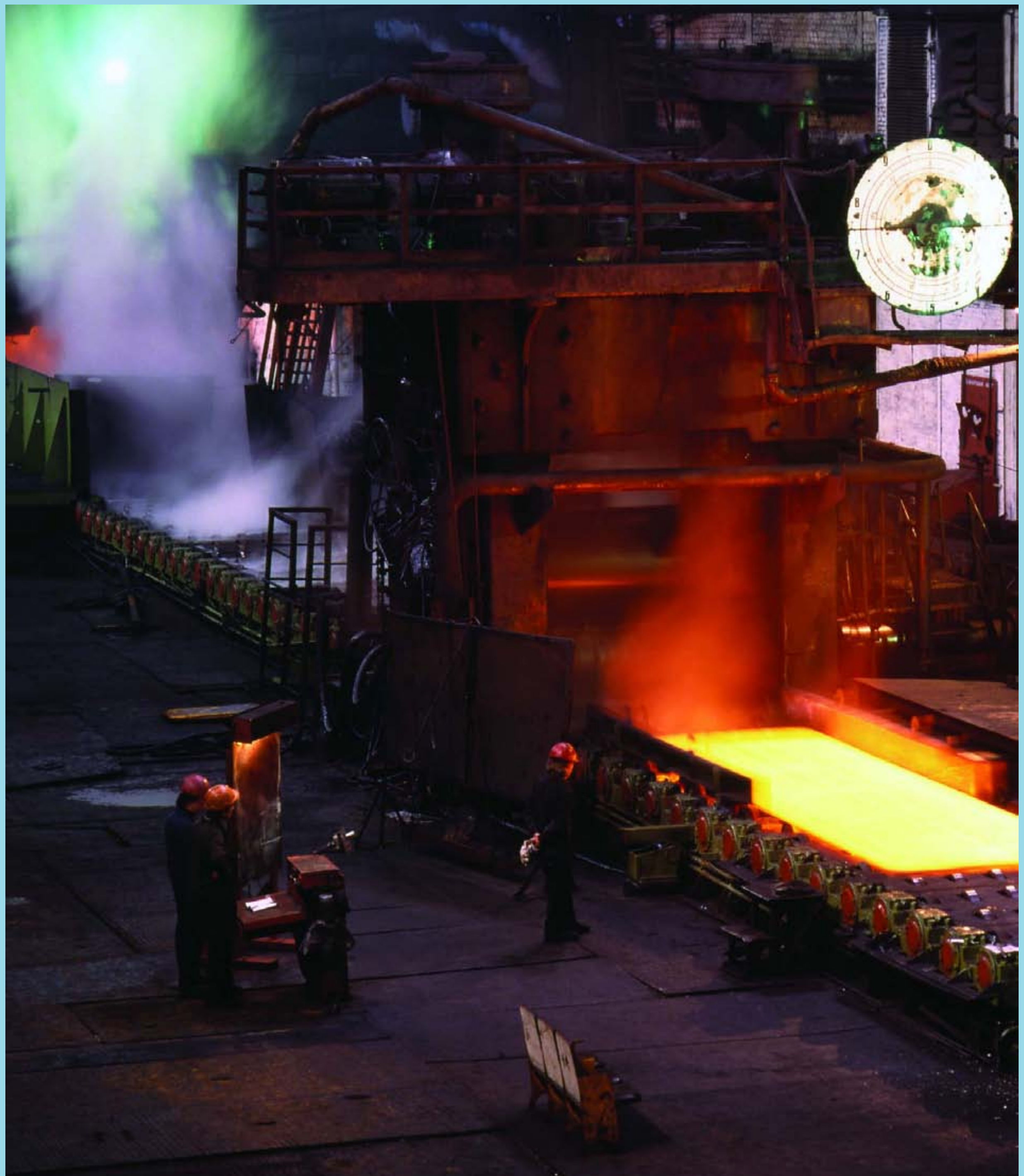
## Catalysts

A catalyst is a chemical that changes the speed of a reaction, but does not change in the reaction. Some catalysts are a single substance. Other catalysts are a combination of many substances. Catalysts do not start reactions. Most catalysts speed up reactions. Inhibitors are catalysts that slow down reactions. Some inhibitors cause other catalysts to stop working.

Catalysts help do many different things. They can allow reactions to happen at lower temperatures. Some catalysts help bring reactants close together. In manufacturing, they help to produce gasoline, rubber, and medicine. Catalysts remain at the end of a reaction, making them reusable. This helps save companies money.

**Find out more**

Companies keep their catalysts a secret. If two companies are producing the same product and one has a better catalyst, that company will be more successful. The company can produce more of that product faster and for a cheaper price.





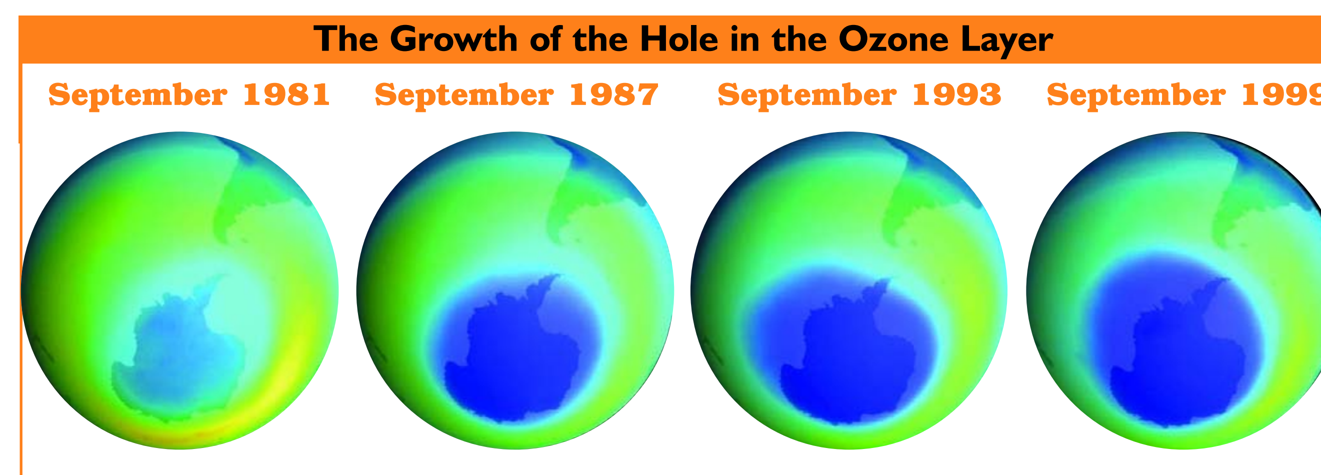
## Helpful Catalysts

Enzymes are catalysts made by living cells. They help speed up chemical reactions in the human body. Each enzyme will work in only one type of reaction. Enzymes help digest food in the body. They help do this in only a few hours. Digestion would take several weeks without enzymes.

*Thankfully, enzymes speed up the digestion process!*

## Harmful Catalysts

Catalysts in the Earth's atmosphere are causing troubles. They are causing the ozone layer to break down. Ozone protects the Earth from harmful ultraviolet rays from the Sun. Chlorine is a catalyst in the upper atmosphere. The chlorine comes from chlorofluorocarbons, or CFCs, released into the atmosphere. Chlorine allows ozone to break down into oxygen. The chlorine remains and keeps destroying ozone. This has caused a hole in the ozone layer. Governments around the world have banned the production of CFCs. This hole in the ozone now appears to be shrinking. We must continue to protect the ozone layer by reducing pollution around the world. Some scientists believe the ozone layer could return to normal levels by 2075.



## Oxidation and Reduction

Whenever a molecule takes up oxygen, something else has to give up oxygen. An oxidized substance combines with oxygen or loses hydrogen. We call the substance that loses oxygen or gains hydrogen reduced. Oxidation and reduction always go together. They can also take place between the electrons of two atoms. Scientists call this an electron transfer. Photsynthesis occurs because of electron transfers. Atoms that lose electrons oxidize. Atoms that gain electrons reduce.

Find out more

### Some Metals Turn to Dust

Air and water can eat away iron and steel! Oxygen binds to iron molecules to make iron oxide. Layer by layer, the metal changes to a red powder called rust. When painted, rusting slows on cars, bicycles, and tricycles.



### Food

Many different kinds of chemical processes use oxidation and reduction. Food that gets old oxidizes and goes bad. Keeping food refrigerated slows down the rate of oxidation. Humans and animals also rely on this reaction. The food people and animals eat is oxidized in the cells. This helps give the body energy.

***Cows graze all day to give them energy and help their bodies make milk.***

### Germs

A weak solution of hydrogen peroxide is a common reducing agent. The chemical formula for hydrogen peroxide is $H_2O_2$. When reduced, it becomes water and oxygen. A solution of hydrogen peroxide kills germs. Bleach sometimes contains stronger solutions of hydrogen peroxide. Bleaching is a process that removes color from cotton and wool. Bleach makes clothes whiter. It also kills germs.

***Bleach whitened these socks and removed germs and bacteria.***

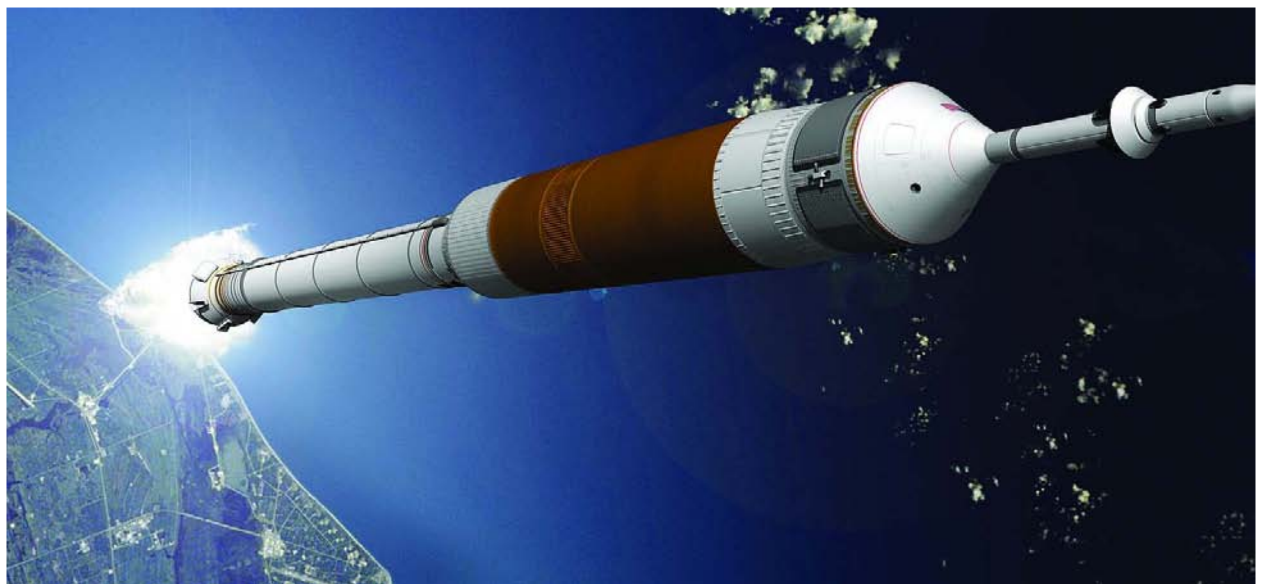
### Fires

Fires are common oxidation reactions. Fire consumes a lot of oxygen. This is because the material that is burning oxidizes at a very fast rate. Flames erupt because the reaction energy is so intense. Fires need oxygen, heat, and fuel. Materials cannot burn when there is no oxygen.

***Water takes heat from fire when turning into steam. It also cuts the supply of oxygen to the fire so it will go out more quickly.***

### Combustion

Combustion is a form of burning. Combustion helps to drive motors, propel airplanes, and launch rockets. Rockets in outer space carry oxygen in their fuel. They need the oxygen for combustion to take place. Gasoline engines are sometimes called combustion engines. Gasoline burns inside the engine. The oxidation reaction releases energy that makes the car move.



***On March 16, 1926, Dr. Robert Goddard launched the first rocket into the atmosphere. Today, rockets launched into outer space are a common occurrence.***

Getting to know...

### Antoine-Laurent Lavoisier

Antoine-Laurent Lavoisier was born in France in 1743. His father and grandfather were lawyers, so he became a lawyer too. However, Lavoisier was more interested in science.

Lavoisier wanted to make chemistry a separate science. He began to experiment with combustion. Some scientists believed that burning released a material called phlogiston. Lavoisier discovered that phlogiston does not exist. He also showed that air and water are compounds. He proved that many elements occur in different phases, as solids, liquids, or gases. Lavoisier came up with the names "oxygen" and "hydrogen."



## Releasing Energy

### Exothermic Reactions

The temperature of chemicals changes as they react with each other. Heat releases or is absorbed into the compound during a chemical reaction. The compound becomes warm or hot when heat releases. Scientists call this an exothermic reaction. Most of the chemical reactions that occur in nature are slow exothermic reactions. They take place so slowly that it is difficult to notice the release of heat. Exothermic reactions are often easy to see when fuels burn. Energy releases from oxidation that occurs while fuel is burning. This is why fires are so hot.

***An exothermic reaction occurs when vinegar removes the coating from a steel wool pad. When the steel meets oxygen, oxidation occurs, releasing heat.***

### Endothermic Reactions

Reacting chemicals become cooler when heat is absorbed. Scientists call this an endothermic reaction. Photosynthesis is one of the few natural endothermic reactions. Photosynthesis occurs when plants convert or change sunlight, carbon dioxide, and water into oxygen and food. Plants actually get a little bit cooler during photosynthesis.

Cold packs, used by doctors and athletes, lower the temperature of an injury. A cold pack contains two chemicals. The chemicals react with each other when they are mixed. The endothermic reaction absorbs heat from the injured part of the body. It helps to cool the body down.

***Athletes use cold packs that do not have to be frozen. To get the pack to be cold, the athlete smashes the pack on a hard surface. The chemicals inside the pack mix together, causing them to become very cold.***

# Explosions

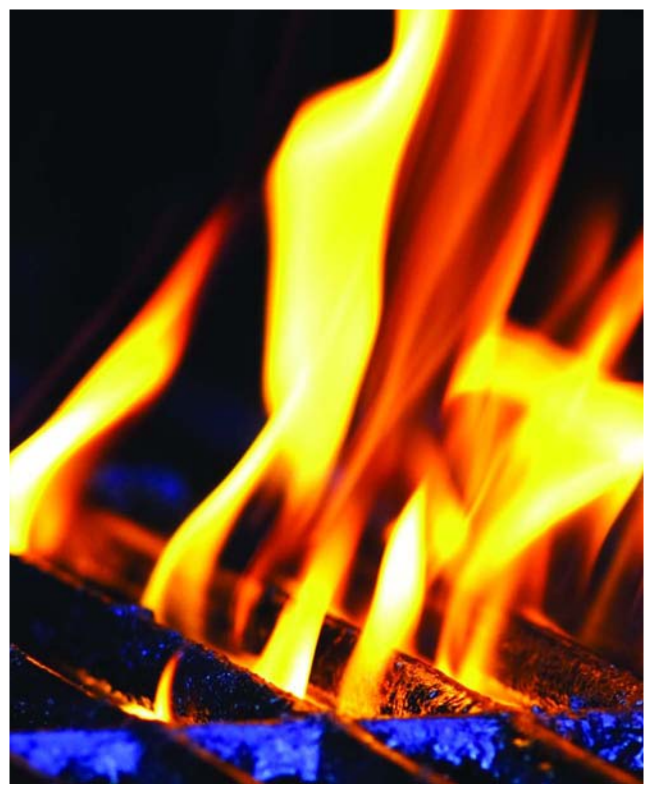
## Exothermic Reactions

A chemical reaction might blow up, or explode. This happens when it releases a lot of energy all at once. Explosions are very fast exothermic reactions. These reactions can happen in many different ways.

*Huge explosions occur under unsafe conditions.*

## Explosive Oxidation

Explosions on the Earth often take place when there are combustible materials around. These materials bond easily with oxygen. They can catch on fire. Sometimes, we call this reaction an explosive oxidation. Gases like hydrogen and propane explode if they mix with oxygen and then encounter a flame. Some liquids can explode if they become a gas, called vapor. Vapors allow molecules to bond with oxygen much more easily. Gasoline vapors can explode if a spark ignites gasoline fumes.



*We create small explosions when we light a gas grill.*

Other explosions do not need oxygen from the air. Explosive materials often contain chemicals that provide their own oxygen. Gunpowder is a mixture of potassium nitrate, sulfur and



other chemicals. Potassium nitrate ($KNO_3$) contains lots of oxygen. Gunpowder burns by getting its oxygen from potassium nitrate, not the air. Dynamite is an explosive made from tightly packed gunpowder. When dynamite ignites, it makes a very powerful explosion. Fireworks also use various amounts of gunpowder and other chemicals. These mixtures make the variety of colors and explosions seen in fireworks displays.

**Joseph Black**

Getting to know...

Joseph Black was born in 1728 in France. His father was from the country of Ireland. He sent Black there for his education. Black then went to college in the country of Scotland. He lived there the rest of his life.

Black, known for his study of heat, showed that different substances need more or less heating time to reach the same temperature. He also noticed that phase changes (solid, liquid, gas) gain or lose heat.

Find out more

**The First Fireworks**

More than 2,000 years ago, a Chinese cook accidentally combined potassium nitrate, sulfur, and charcoal. The combination ignited and exploded, creating the first firecracker. The Chinese explode the "huo-yao," or fire chemicals, during celebrations such as religious holidays and weddings. Many believed that the loud noise scared away evil spirits. Today, people around the world use firecrackers as symbols of joy during holidays and events.

Find out more

**Fermentation**

Fruit starts to smell funny as it gets too ripe. There is a change going on inside the rotting fruit. It is a chemical reaction. Small organisms or living things, called microbes change the sugars in the fruit. They change them into carbon dioxide and either water or alcohol. Scientists call this chemical process fermentation.

Fermentation without the presence of oxygen produces alcohol and carbon dioxide. Sugar is broken down into alcohol and carbon dioxide. This happens with the help of an enzyme from the microbes. The enzyme makes a chemical reaction happen.

Humans use fermentation to make other kinds of foods and medicines. Bread would not exist without yeast. Yeast is a microbe, or living thing. Yeast converts the sugars in wheat grains into carbon dioxide and water. The gas causes the bread to rise and to look like a sponge. The yeast dies as the bread is cooked. Humans also use a fermentation process to make penicillin and other medicines.

Many types of fermented foods can make people sick. E. coli are bacteria that cause raw meat to ferment. Eating undercooked meat with E. coli in it can make a person very ill.

*Yeast*

*Dough rising*

*Bread*

***Archeologists discovered that people started to bake bread using yeast in 4,000 B.C. Before that, bread was usually flat.***



# People Who Study Chemistry

Hundreds of years ago, people called alchemists used chemical reactions. They used them to make medicines and combine metals. Some of them thought they could create gold from other metals. Some of them thought they could make people live forever. Unfortunately, they were wrong. Today, we know a lot more about how things really work.

## Types of Chemists

Chemistry is the study of how chemicals react with one another and the products they make.

Chemists are people who study chemistry. There are many different kinds of chemists.

Chemistry makes life possible. Everything from the tiniest atoms, to the blood in our bodies, to the shoes on our feet is the result of chemical reactions. People will keep learning about chemistry and how it affects our lives.

### Gerhard Ertl

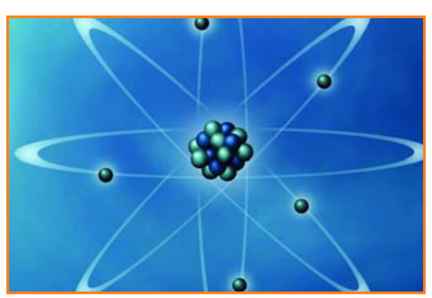
Getting to know...

In 1901, the first Nobel prizes, named for Alfred Nobel, a wealthy industrialist, recognized achievers in the fields of literature, chemistry, medicine, physics, and peace. Every year, outstanding people from all over the world, continue to receive this prestigious award.

On October 10, 2007, Gerhard Ertl of Germany received an amazing 71st birthday present, the Nobel Prize in Chemistry. His research in answering questions such as why iron rusts, how fuel cells function, and how catalysts work, helps to explain the reasons behind Earth's damaged ozone layer. Ertl's prize includes a gold medal, a diploma, and 10 million krona (Swedish) or about $1.5 million (U.S.).

***Chemistry is used to make video games!***

## THERE ARE MANY PROFESSIONS THAT USE CHEMISTRY

| Profession | | What They Involve |
|---|---|---|
| Analytic chemists |  | using computers to study chemical reactions. |
| Biochemists |  | studying the chemistry of living things like the human body. |
| Chemical engineer |  | converting basic raw materials into a variety of products. |
| Geochemist |  | studying the chemical composition of the Earth and other planets. |
| Nuclear chemists |  | studying the atom and its parts. |



| Profession | | What They Involve |
|---|---|---|
| Organic chemists |  | studying molecules and compounds that contain carbon. These compounds include everything from fuels like gasoline to foods like candy. |
| Pharmacists |  | using their knowledge of chemistry to sell drugs and medicines. |
| Physical chemists |  | studying reactions and conduct many experiments. |
| Pyrotechnicians |  | making things explode for special effects and fireworks displays. |
| Toxicologist |   | studying the adverse effects of chemicals on living organisms. |

## Types of Chemists

We do not hear much about women in science, but without their contributions, the world would be a very different place. This timeline highlights a few of the thousands of women who have contributed enormously to the study of chemistry.

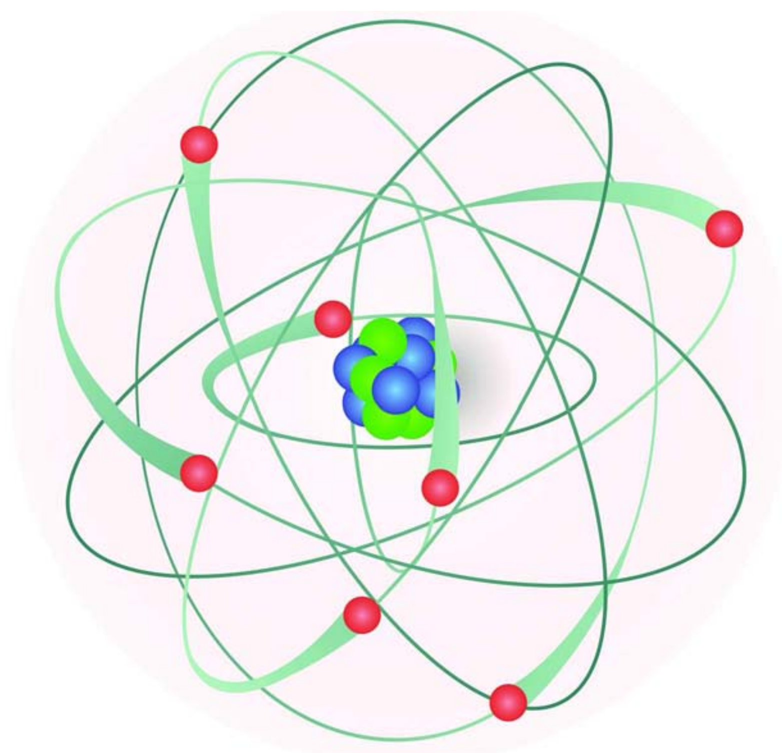
| Women In Chemistry | |
|---|---|
| 1842-1911  | Ellen Swallow Richards: First female to study at MIT. She pioneered the study of Home Economics. |
| 1867-1934  | Marie Curie: Discovered radium. |
| 1896-1957  | Gerty Cori: Her work in biochemistry made a great impact on research in diabetes. She was the first American woman to win the Nobel Prize in science. |
| 1897-1956  | Irene Joliot Curie: Won a Nobel Prize for chemistry for her work with radioactive elements. |
| 1910-1994  | Dorothy Crowfoot Hodgkin: Won the 1964 Nobel Prize in chemistry for her work on vitamin B12. |
| 1920-2007 | Katsuko Saruhashi conducted some of the first radioactive research showing how the effects of fallout can impact the entire Earth, not just the immediate area. She also studied acid rain and its effects. |

Rourke's World of Science

# ENCYCLOPEDIA

## Volume 6

# Physics



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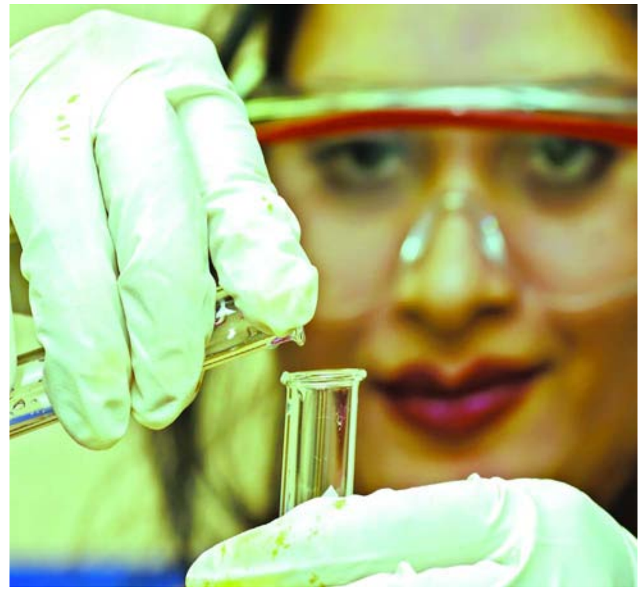
# Table of Contents

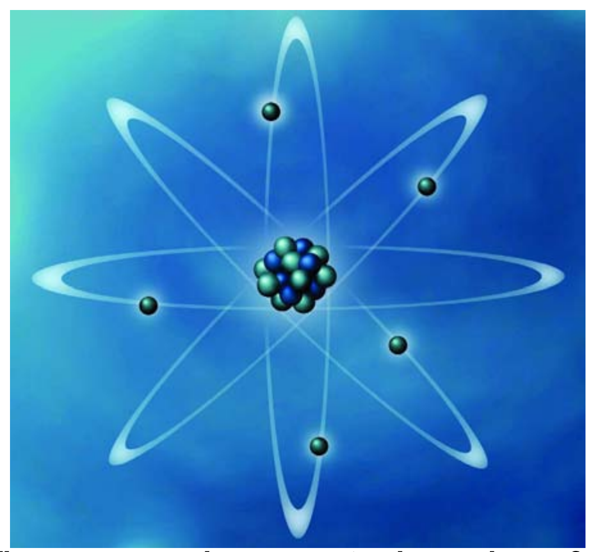
# What Is Physics?

Physics is the science of how the universe works. It is a science based on experiments, observation, and measurement. Experiments involve making things change. Observation is when scientists watch what they are studying very carefully. Measurement is describing things by their weight, size, or temperature.

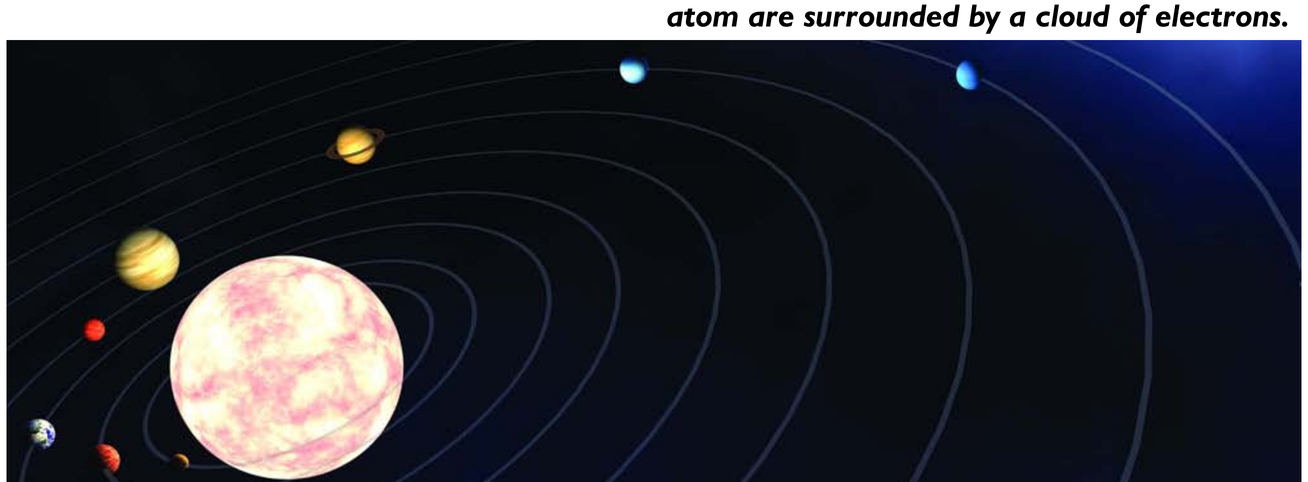
Physics looks at how tiny atoms are put together. Atoms are tiny particles that make up everything in the universe. Physics looks at how huge planets and stars move. It helps scientists understand the way matter acts. Matter includes the solids, liquids, and gases in the universe. Physics also helps scientists understand how energy acts.



*A physicist uses precise measurements.*



*The protons and neutrons in the nucleus of an atom are surrounded by a cloud of electrons.*



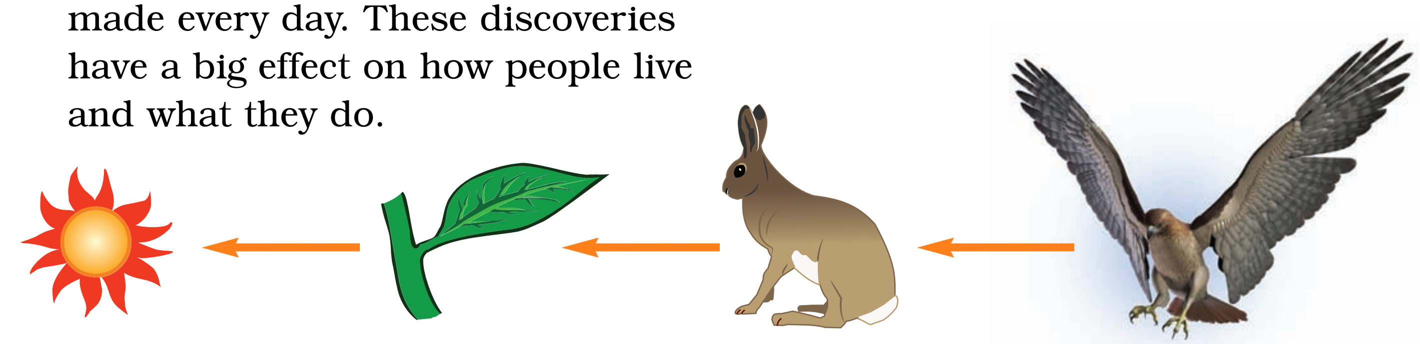
*Astrophysicists are physicists who study the stars and planets.*



## Energy

Energy is everywhere. Energy is the ability to do work. It takes on many different forms. Energy is stored inside atoms. Light and sound are forms of energy. One way or another, everything is energy. People who study physics study how energy is used. They study how energy changes.

Scientists are constantly improving the understanding of the basic, or fundamental, laws of nature. New discoveries are being made every day. These discoveries have a big effect on how people live and what they do.



*Plants get their energy from the Sun. Animals get their energy from plants or from eating other animals.*

## Mass, Length, and Time

The laws of physics can be described in simple terms. These terms explain the way the universe works. Scientists use units of measurement to describe what they do. This is done so that all scientists can understand each other's results. The three fundamental units of measurement they use are mass, length, and time.

| Mass, Length, and Time | |
|---|---|
| **Mass** | measures the amount of material in an object |
| **Length** | measures how long something is |
| **Time** | measures how long changes take |

### Words to Know

**atom** (AT-uhm): very small part of an element

**energy** (EN-ur-jee): the ability to do work

**experiment** (ek-SPER-uh-ment): trying to make substances change and recording what happens

**matter** (MAT-ur): anything that takes up space and has mass (size)

**measurement** (MEZH-ur-ment): saying how big something is, how much it weighs, or how hot it is

**observation** (ob-zur-VAY-shuhn): when scientists watch what they are studying very carefully and write down what they see

**physics** (FIZ-iks): the study of matter and energy

In physics, the International System of Units is used to measure things. This system is based on the metric system. The metric system uses specific units of measurement. The International System Unit of mass is the kilogram. The basic unit of length is the meter. The basic unit of time is the second. Scientists can describe almost everything by using these units in different combinations.

| International System of Units | |
|---|---|
| **Kilogram (kg)** | used to measure mass |
| **Meter (m)** | used to measure length |
| **Second (s)** | used to measure time |

**Words to Know**

**International System of Units** (in-tur-NASH-uh-nuhl, SISS-tuhm, YOO-nitz): a standard way of measuring something

**force** (forss): what causes something to change its speed or it's direction of movement

**mass** (mass): the amount of material in an object

**metric system** (MET-rik, SISS-tuhm): a system of measurement based on tens that uses basic units such as the meter, liter, and gram

**motion:** (MOH-shuhn): when something is moving

# Motion and Force

## Motion

Everything is in motion. Both small things and big things move. People and animals move about on the surface of the Earth. The Earth itself rotates (turns) and moves in an orbit (circles) around the Sun. The largest view that we can have is to look at the entire universe.

Scientists often choose a certain point of view, or frame of reference, when studying physics. This allows them to study specific actions in the universe.

*This river is in motion.*

## Force

Forces are at work everywhere. A force is anything that affects the movement or shape of an object. Objects can be so small that you cannot see them with the naked eye. They can be bigger than planets and stars. Some forces pull objects together. Other forces push objects apart. Forces also affect people.

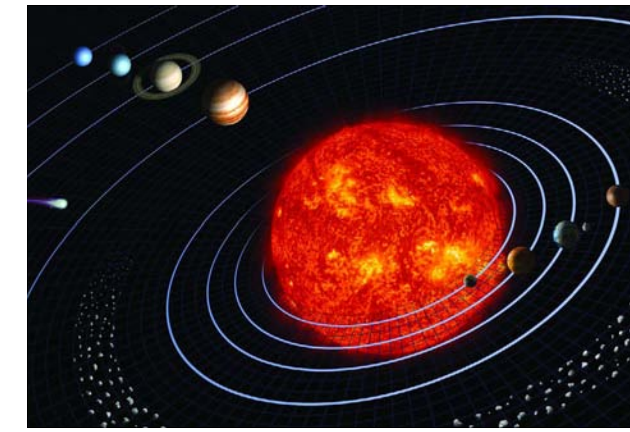


## The Four Fundamental Forces

There are four basic, or fundamental, forces in nature. They are the gravitational force, the electromagnetic force, the strong nuclear force, and the weak nuclear force. These forces pass through us and exist within us. They hold everything together. All forces in nature are related to one of the four fundamental forces. Each of these forces serves a different purpose.

### Gravitational Force

The gravitational force is the force of attraction, or pulling together. It is powerful enough to hold the Earth in its orbit around the Sun. Still, it is the weakest of the four fundamental forces. The gravitational force of the Earth is often called gravity. Gravity keeps things on the surface of the Earth from flying off into space. It keeps the ground on the Earth and your feet on the ground. Everything that has mass has gravity. In deep space, the force of gravity is very weak. This is because objects with mass are so far apart.



*Gravitational force keeps the planets in orbit around the Sun.*

*Gravity pulls this diver into the water.*

## Electromagnetic Force

The electromagnetic force is either an attraction, pulling toward, or a repulsion, pushing away. The electromagnetic force occurs in many forms. Except for gravity, most of the forces in nature are caused by electromagnetic forces.


*Small pieces of iron are attracted to the magnet.*

### Words to Know

**electromagnetic force** (i-lek-tro-mag-NET-ik, forss): a combination of electrical and magnetic forces that attract (push towards) or repel (push away)

**escape velocity** (ess-KAPE, vuh-LOSS-uh-tee): how fast something needs to travel to leave the Earth's gravity

**gravity** (GRAV-uh-tee): a force that pulls things toward Earth

**nucleus** (NOO-klee-uhss): center section of an atom made of protons and neutrons

**radioactive decay** (ray-dee-oh-AK-tiv, di-KAY): when the center of an atom breaks apart

**subatomic particles** (suhb-a-TOM-ik, PART-tuh-kuhls): the smaller parts of an atom including the protons, neutrons, and electrons

## Strong Nuclear Force

The strong nuclear force is the strongest of the fundamental forces. It only works within atoms. The strong nuclear force keeps the nucleus (center) of an atom from coming apart. It is like a glue holding the subatomic particles (or smaller parts of the atom) together. The strong nuclear force gets weaker the further the particles are from the center of the atom.

## Weak Nuclear Force

The weak nuclear force causes the nuclei (centers) of some atoms to break apart. These atoms are radioactive, or unstable. They give off tiny particles over time. These are called beta particles. The weak nuclear force causes the subatomic structure, or smaller parts of some atoms, to change. This process is called radioactive decay. The weak nuclear force does not happen in all nuclei.

# Velocity and Acceleration

The speed of an object is called velocity. The velocity of an object is how fast it is moving at a point in time. Velocity is measured in distance traveled per unit of time. For example, cars may drive 62



miles per hour (100 kilometers per hour). Most people can walk at a speed of 2 miles per hour (3 kilometers per hour) and run at a speed of 17 miles per hour (27 kilometers per hour). They can only run this fast for a short time. Scientists often measure velocity in kilometers per second (km/s).

## Escape Velocity

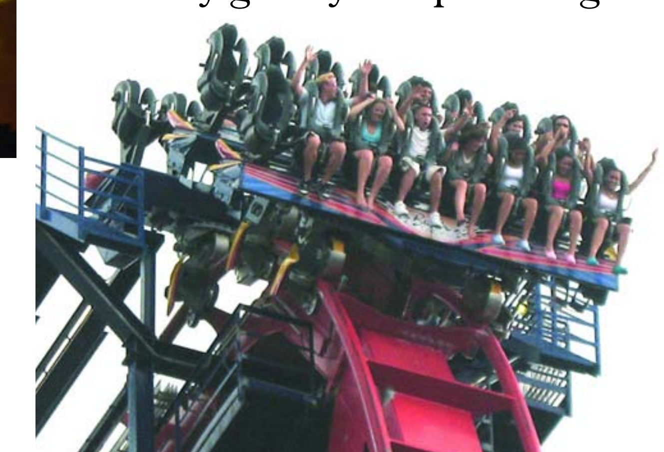
In outer space, velocity is measured in a specific way. It is measured by how fast something is moving away from or toward the Earth. An object must travel a certain speed to escape the gravitational force (pull) of a planet or a moon. This is called the

*The Space Shuttle launches into the night sky.*

escape velocity. This speed depends on the mass of the planet or moon. It also depends on the distance of the object from the center of the planet or moon. The escape velocity from the surface of the Earth is about 6.6 miles (11 kilometers) per second. This is almost 25,000 miles per hour (about 40,000 kilometers per hour).

## Acceleration

Acceleration is a change in velocity (speed) over a certain time. In physics, anything that is speeding up is accelerating. The speed of a car changes when it starts to move. The car is accelerating. When it slows down, it is decelerating (also called negative acceleration). A dropped object accelerates as it falls. This acceleration is caused by gravity. Gravity keeps things on the surface of the Earth from flying off into space. The acceleration caused by the gravity of the Earth is sometimes called g. At the surface of the Earth, the acceleration caused by gravity is equal to 1g.



*SheiKra, a roller coaster in Florida, pulls 4g.*

PROJECTS volume 10 6.1

# Newton's Three Laws of Motion

All objects follow certain rules. These rules are called laws because they apply to everything everywhere. Isaac Newton discovered the three laws of motion. These laws help scientists understand how objects move.

*Newton's first law states that an object will stay still unless something pushes or pulls it.*

## First Law of Motion

Newton's first law of motion is sometimes called the law of inertia. It says that an object that is not moving will stay still. It will stay still unless something pushes or pulls it. It also says that an object that is in motion will keep moving. The object will travel in a straight line at a constant speed. Its movement will only change if it is affected by a force. On the Earth, gravity is a big force that affects objects. Without gravity, all objects would stay still or keep traveling in a straight line. The Moon would fly off its orbit if the Earth's gravity did not pull on it. It is easier to see the law of inertia in outer space. A tool released by an astronaut floats away until it bumps into something.

## Second Law of Motion

The second law of motion says that acceleration is caused by a force acting on an object. The acceleration (increased speed) of an object depends on the amount of the force acting on it. It also depends on the mass of the object. Light objects, like pens and pencils, are easy to pick up. They require very little effort, or force, to lift. Heavy objects, like a refrigerator, require a lot of force to move.

*The second law of motion says that acceleration is caused by a force acting on an object.*



### Sir Isaac Newton

Getting to know...

Isaac Newton was born in the country of England in 1642. At first, he was not a great student and ran the family farm. He began to show genius when he returned to school.

Newton went to Cambridge University. In 1665, Cambridge was closed because of a deadly disease called the plague. Newton went home for a year to think about science. During this time, he discovered the law of gravity and the three laws of motion. He also discovered a type of mathematics called calculus. He invented the reflecting telescope. He learned about optics, the science of light.

Newton was elected to the famous Royal Society of London. He entered politics and was elected to Parliament. Newton was made a knight in 1705.

One way of writing the second law of motion is to say that force (F) is equal to mass (m) times acceleration (a).

$$F = ma$$

*Newton's second law is usually written F=ma.*

## Third Law of Motion

Newton's third law of motion says that every action causes a reaction that is equal and opposite. A cup on a table pushes down on the table with the force of gravity. The table pushes up with an equal force to keep the cup from moving. A person pulling on a rope is using force on the rope. This is called the action force. The rope uses the opposite force on the person. This is called the reaction force.

*You experience Newton's third law when you play tug of war.*

### Words to Know

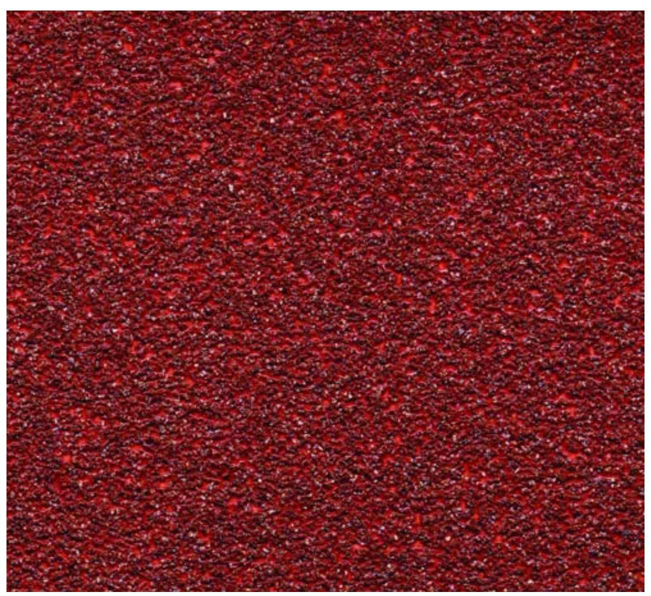
**action force** (AKT-shuhn, forss): the force that is acting on something, for example someone pulling on a rope

**inertia** (in-UR-shuh): an object at rest will stay at rest and an object in motion will stay in motion, unless acted on by an outside force

**reaction force** (ree-AK-shuhn, forss): a force that reacts against a force being put on it

## Friction

Friction is the force that slows objects down when they rub against each other. Friction holds objects in place until the forces acting on them become bigger than the force of friction. Friction depends on the mass and the types of surfaces being rubbed. Different materials cause different amounts of friction. Rubbing sandpaper on wood causes a lot of friction.



***Rough surfaces create more friction.***

### Wind Resistance

Friction keeps people from sliding around when they walk. The gases in air cause friction on moving objects. Air molecules, or the small parts of air, cause wind resistance when they bump against objects. Airplanes and cars have smooth surfaces to decrease (slow down) wind resistance. The brakes on cars and bicycles use friction to slow the cars and bicycles down. Spaceships returning to Earth are slowed down by the friction between the atmosphere and the moving spaceship. This type of friction is called drag. It causes the outside of the spaceship to get very hot.


***Heat-resistant tiles protect the space shuttle during re-entry.***

**Find out more**

**Friction Slows Down Spaceships**

Spaceships must travel very fast to reach other planets like Mars and Jupiter. They need to slow down when they get there. One way they slow down is by flying through the upper atmosphere of the planet. Using friction to slow down a spaceship is called aerobraking.



Friction often causes heat. It causes your hands to get warm when you rub them together. Friction from air resistance makes meteorites (rock or metal from space) get very hot. They burn up in a bright streak across the sky.

## Circular Motion

Anything that spins or goes around in a circle is experiencing circular motion. Wheels and tops spin. Windmills and merry-go-rounds go around in circles. Many forces influence objects in circular motion. Every part of the spinning object experiences inertia and wants to fly off in a straight line.

One force pulls the object toward the center of the circle. This is called centripetal force. It causes the object to change direction constantly and travel in a circle. Another force is directed out from the circle. This is called centrifugal force.

### Centripetal Force

Satellites in space experience circular motion. Gravity is the centripetal force that keeps the satellite in a circular orbit. Momentum keeps it moving forward in the orbit. The inertia of the satellite as it moves forward keeps it from falling back to Earth.

A ball on a string can be swung around in a circle. The pull of the string on the ball is the centripetal force. The force on the string becomes stronger as the ball moves faster and faster.

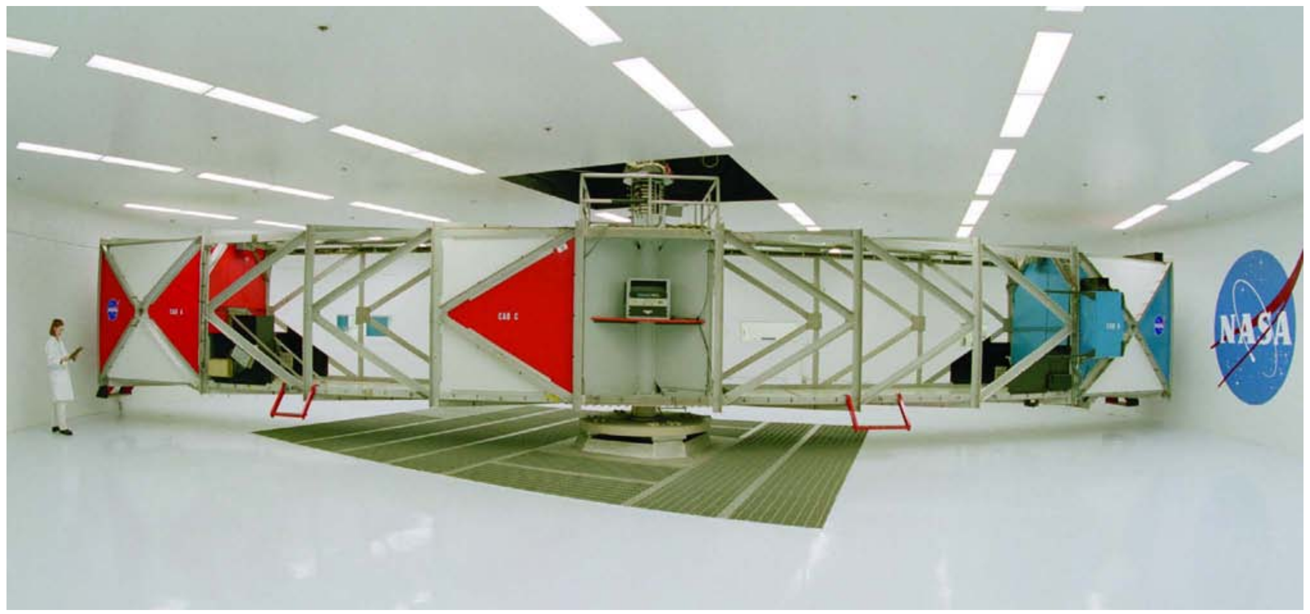
**Find out more**

**Centripetal Acceleration Spins Ice Skaters**

Ice skaters experience circular motion when they spin! They can spin very fast by pulling their arms in tight. This increases their centripetal acceleration. They slow down if they stretch their arms out. This causes their centripetal acceleration to decrease.

## Centrifugal Force

Centrifugal forces on the ball as it travels in a circle keep the string tight. The string will break if the centrifugal force becomes too strong. Then, inertia will cause the ball to fly off in a straight line from the circle.




*NASA uses a 20g centrifuge to test the reactions of pilots and astronauts to acceleration above those experienced in the Earth's gravity.*


*Chemists use a centrifuge to separate parts of a liquid.*

### WORDS TO KNOW

**atmosphere** (AT-muhss-fihr): the gases around a planet

**centrifugal force** (sen-TRIF-yuh-guhl, forss): a force that pushes you away from the center

**centripetal force** (sen-TRIP-uh-tuhl, forss): a force that pulls you toward the center

**drag** (drag): slowing something down

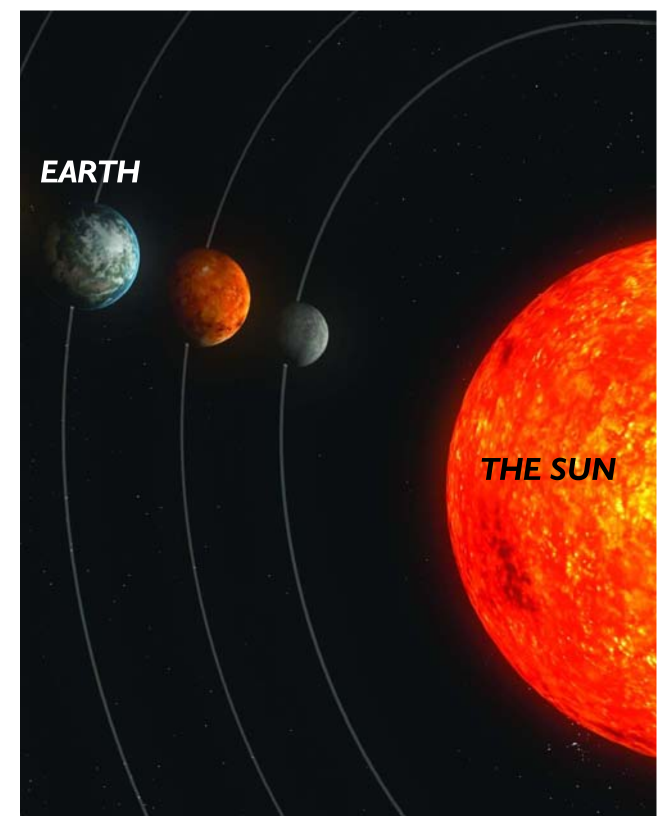
**friction** (FRIK-shuhn): when things rub against each other, it causes them to slow down

**wind resistance** (wind ri-ZISS-tuhnss): a force that pushes against another object



# Gravity

Gravity is a force that pulls objects or masses together. Everything that has mass also has gravity. Gravity keeps the Earth in orbit around the Sun. It also holds the Moon in orbit around the Earth. The Earth is a strong gravitational source because it has a very high mass. A falling object is pulled toward the ground by the Earth's gravity.




*The Sun's gravity keeps the planets in their orbits.*

## Free Fall

An object dropped near the Earth's surface accelerates downward. Its acceleration rate is about 32 feet (9.8 meters) per second for every second that it falls. It is easier to say that the acceleration caused by gravity on Earth is 1g. The mass of the falling object does not matter. All objects fall at the same rate when there is no air resistance to slow them down. This fall is sometimes called free fall. A grape and a watermelon fall at the same rate when they are dropped together from a height. They will smash into the ground at the same time.

*Despite their size and weight, a melon and a grape will fall at the same speed.*

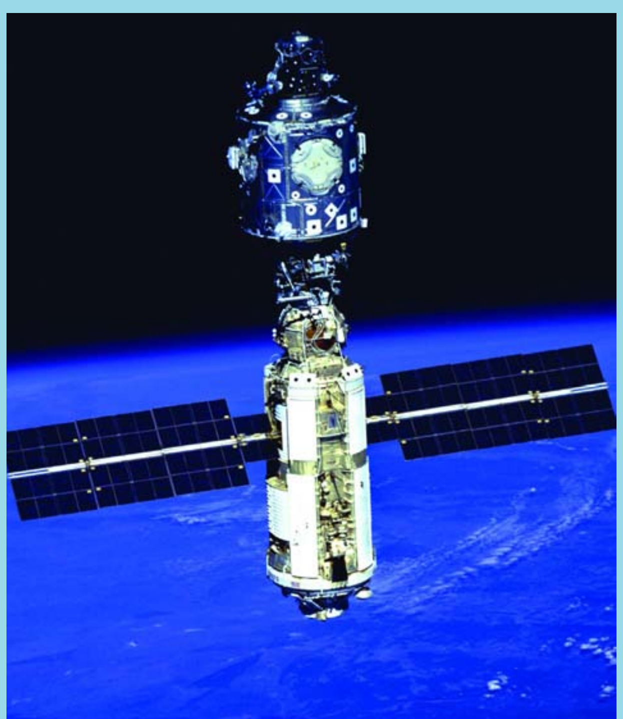
## Weight

Gravity gives a person weight. Mass and weight are different. Mass is the amount of material in an object. Weight is the force of gravity on an object's mass. People weigh a lot less on the Moon than they weigh on the Earth. The gravity on the Moon is about one-sixth as strong as the gravity on Earth. The force of gravity is stronger when the mass of the object is greater.

Find out more

**Gravity Is Still Felt in Space**

A space station orbiting the Earth has some microgravity, or a very tiny amount of gravity. It is traveling fast enough, and is far enough away from the Earth, to orbit (circle) and be in a constant free fall. The Earth's gravity is pulling on the space station, but the space station's forward speed is keeping it from falling back to Earth.



### Newton's Universal Law of Gravity

The gravitational attraction between two objects depends on two things. They are the mass of the objects and the distance between them. Isaac Newton suggested that every particle (tiny piece) in the universe attracts every other particle. The force of this attraction decreases as the distance between objects increases.

The Moon has a gravitational effect on the Earth even though it is far away. The ocean on the side nearest the Moon is pulled toward it. This creates tides. The Earth is also pulled toward the Moon. The ocean tides change as the Moon orbits (circles) the Earth. The gravitational force of the Sun also affects the tides. Twice each month, the Sun and Moon are in line with each other. The gravitational effects of the Sun and Moon together cause very high tides.

*The Moon's gravitational pull causes two high tides and two low tides every day.*



# Energy

## Work

Physics is the study of force and energy. Energy is changed from one form to another when a force acts on an object. This change is sometimes called work. Energy is the ability to do work.

*We enjoy many delicious foods with the help of our teeth.*

## Simple Machines

Simple machines are simple tools that make work easier. We have some simple machines built in our bodies. Do you remember when you were missing your two front teeth? Without your built in simple machines (teeth), it's more work to bite and chew. Teeth are simple machines called a wedge. Other simple machines are inclined planes, wheels, pulleys, levers, and screws.

Throughout history people have used different types of simple machines to make their work easier. Think about how early hunters put sharp wedge shapes at the end of a stick to create a weapon.

*This stone-tipped spear would be helpful to an early hunter.*

| Common Simple Machines | |
|---|---|
| **Simple Machine** | **Example** |
| inclined plane |  |
| lever |  |
| pulley |  |
| wheel |  |
| wedge |  |
| screw |  |



A simple machine has very few parts. Some simple machines, such as pulleys, have moving parts. Other simple machines, for example inclined planes, have no moving parts. All compound, or complex, machines are made by putting simple machines together.


*The bicycle is a complex machine that contains many simple machines.*

In physics, scientists define work as how a force acts on an object to move it. Another way to write this definition is with a formula.

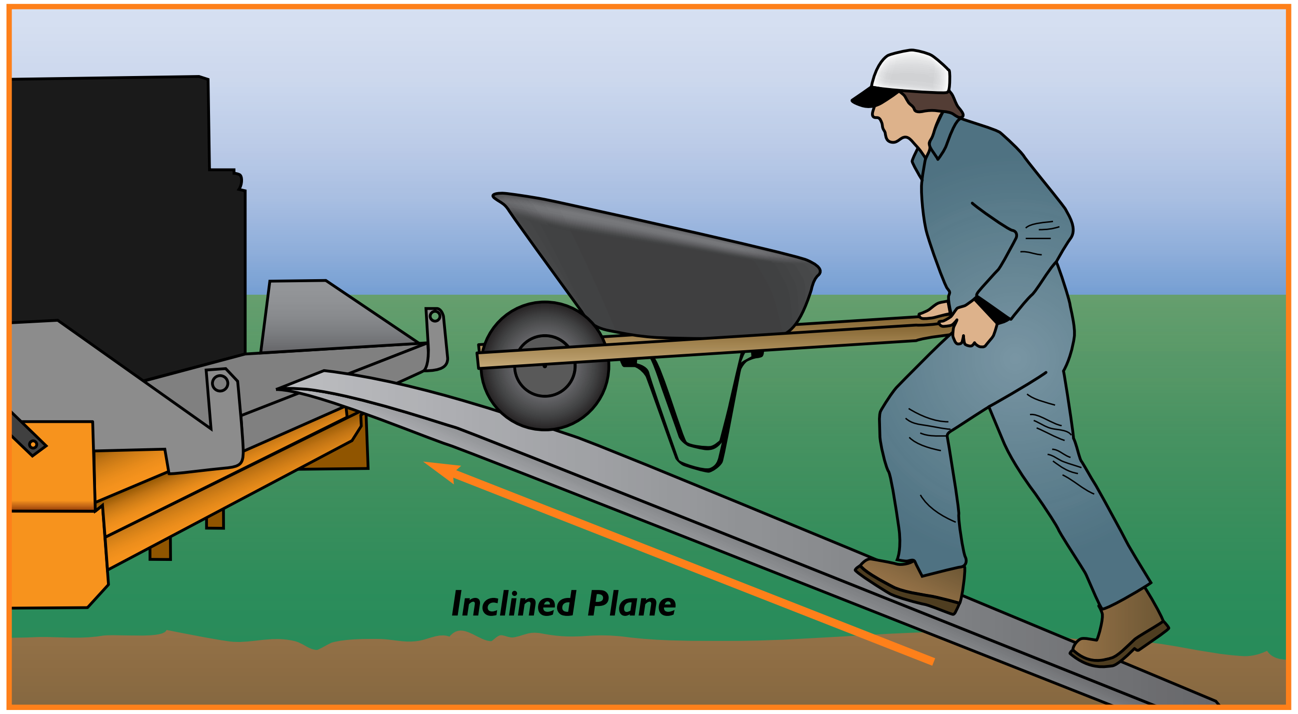
## Force x Distance = Work

The amount of work needed for any job is the same. An example of a delivery driver is an easy way to understand how this formula works. If the driver uses a short ramp, the distance he moves is also short. But a short ramp is steep so the driver would need to use a lot of force to push a big box up a short ramp.

If the driver uses a long ramp, the distance he pushes the big box is farther. But the long ramp is not as steep as the short ramp so the driver would use less force to push the big box up a long ramp.

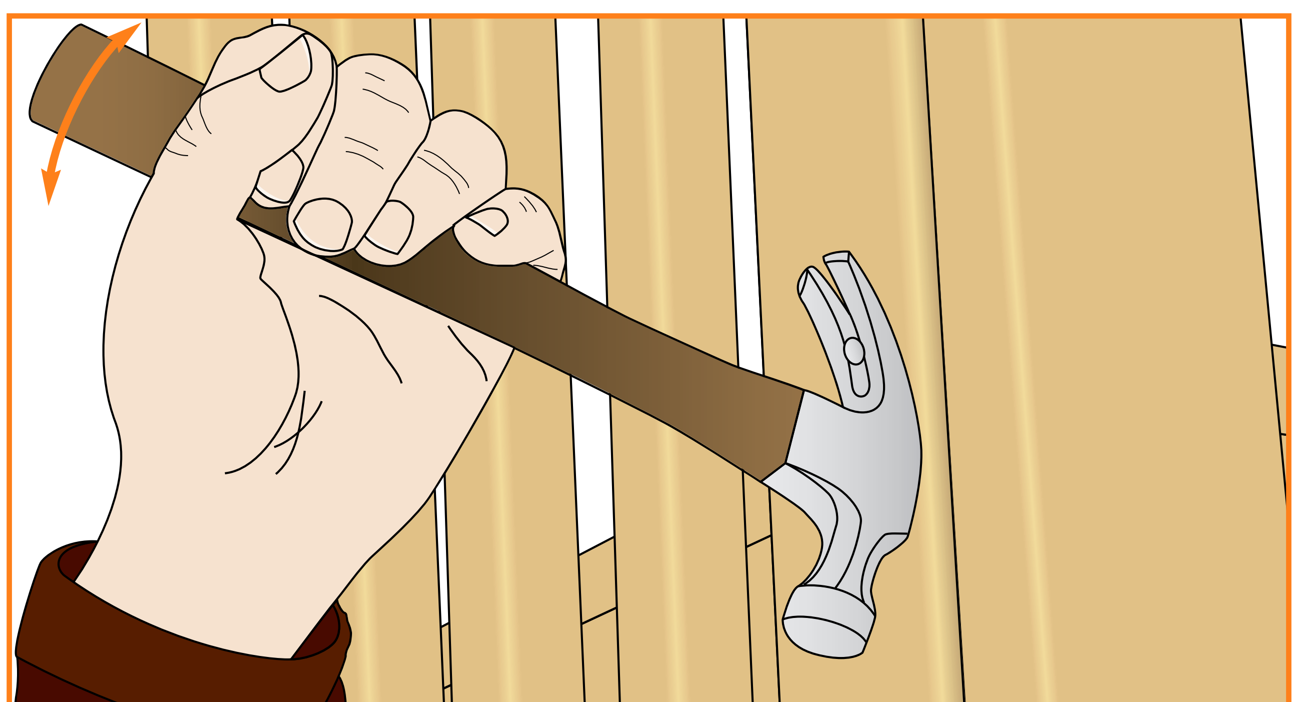
*The first ramp is longer, but its slope is gentler. The second ramp is shorter, but its slope is steep. Both jobs take the same amount of work to complete.*

## Inclined Plane



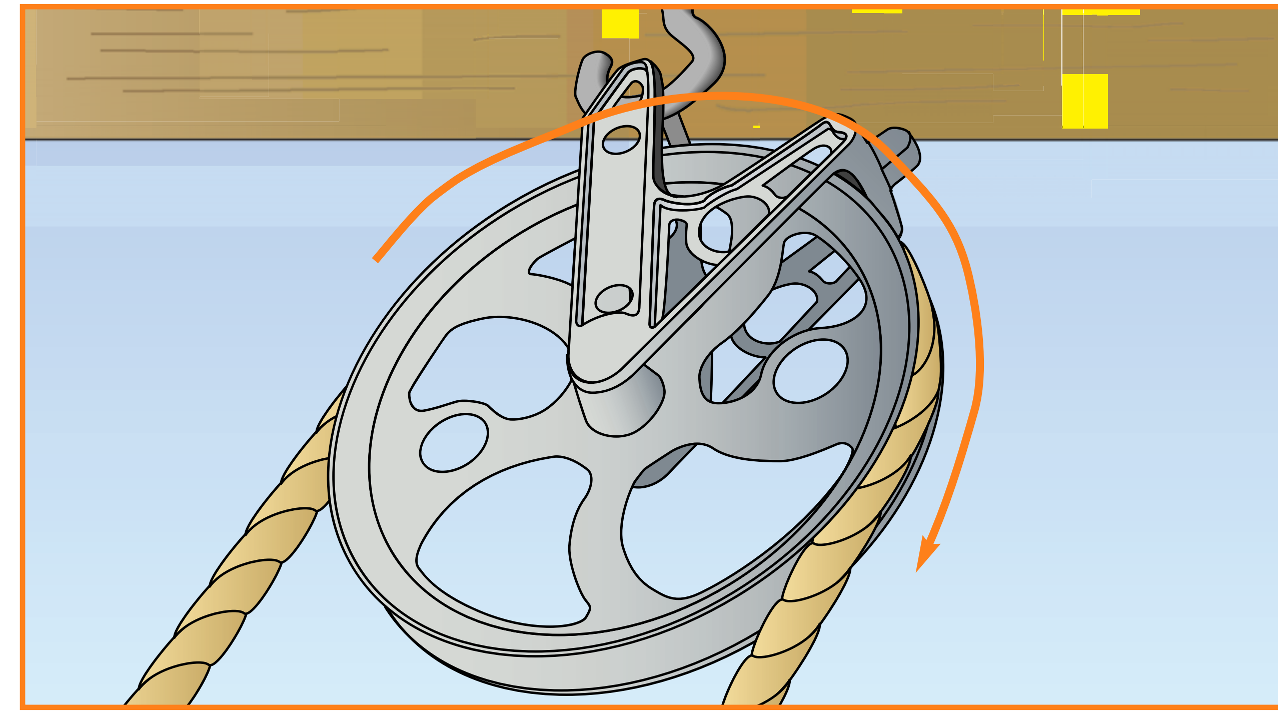

*It would be very difficult to lift the wheelbarrow into the truck.*

## Lever



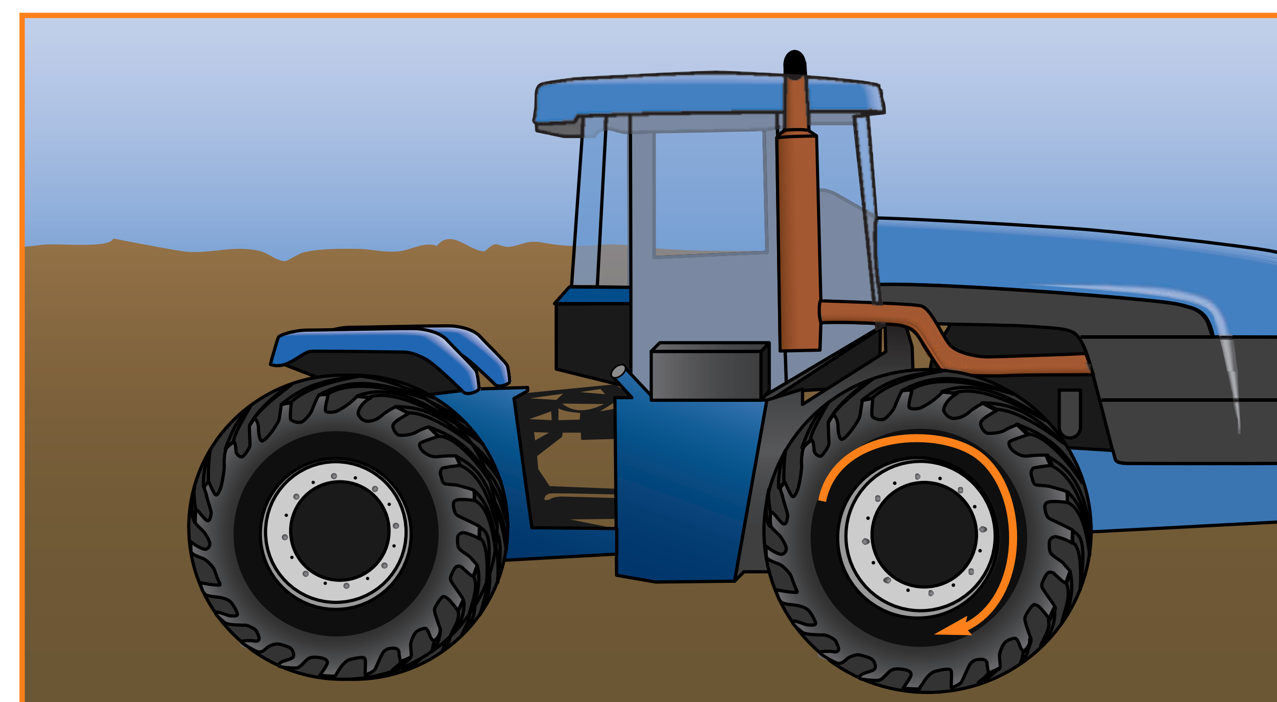
*Have you ever used your fingers to pull a nail from a piece of wood? The lever makes the job much easier.*

## Pulley



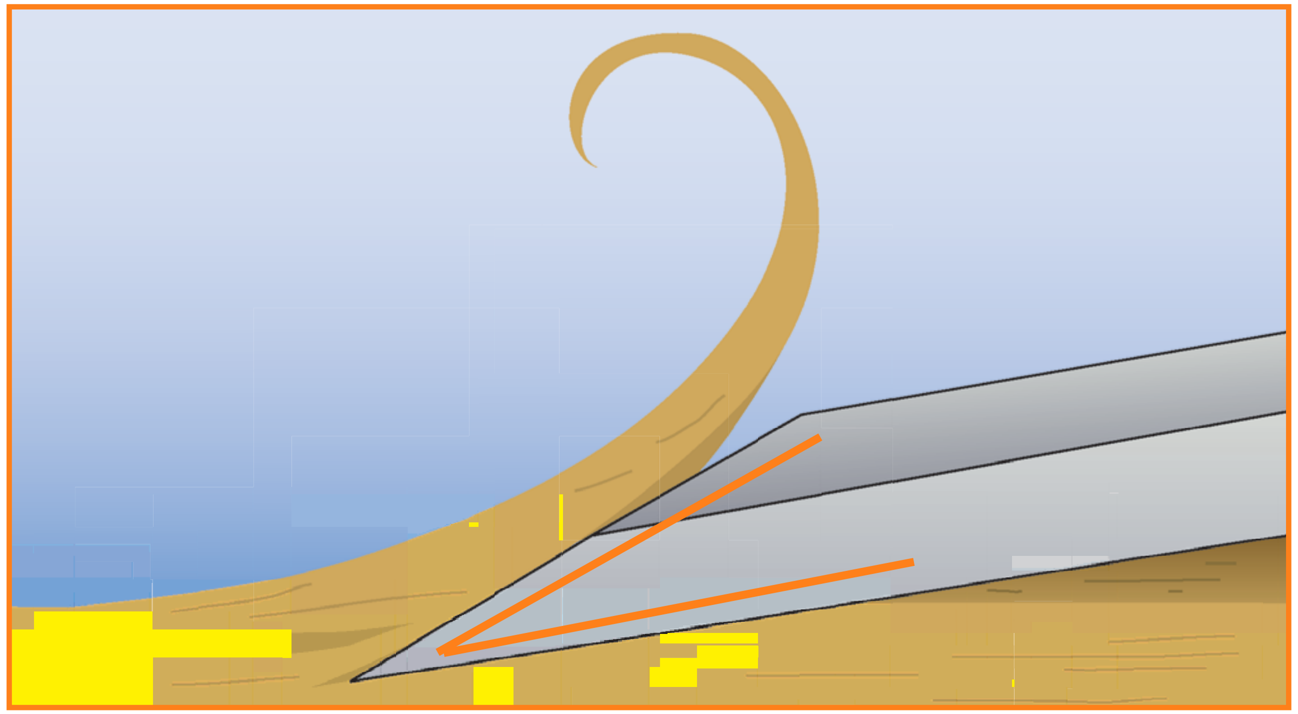
*A pulley makes it easier to lift heavy objects. Adding more pulleys makes the heavy object seem even lighter.*

## Wheel



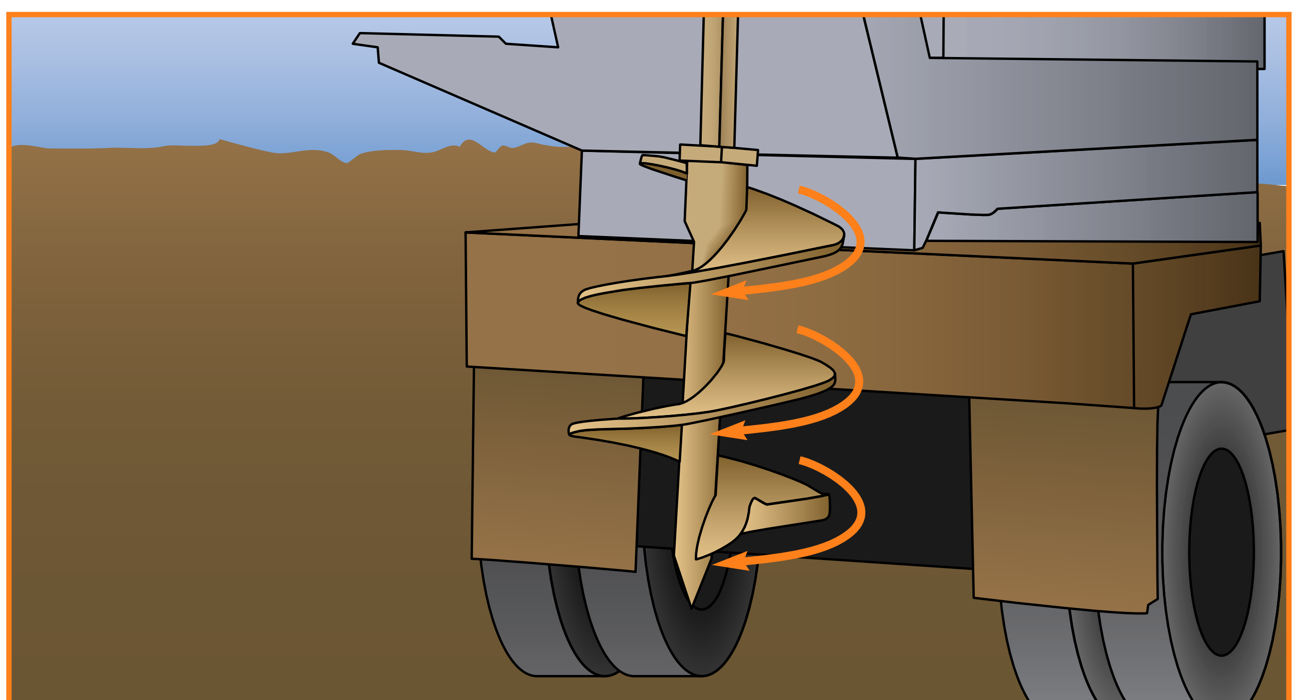
*It's hard to imagine life without the wheel.*

## Wedge



*Wedges such as axes, knives, and scissors make it easier to separate or split objects.*

## Screw



*A screw can drill a hole in something, or it can be used to hold two things tightly together.*

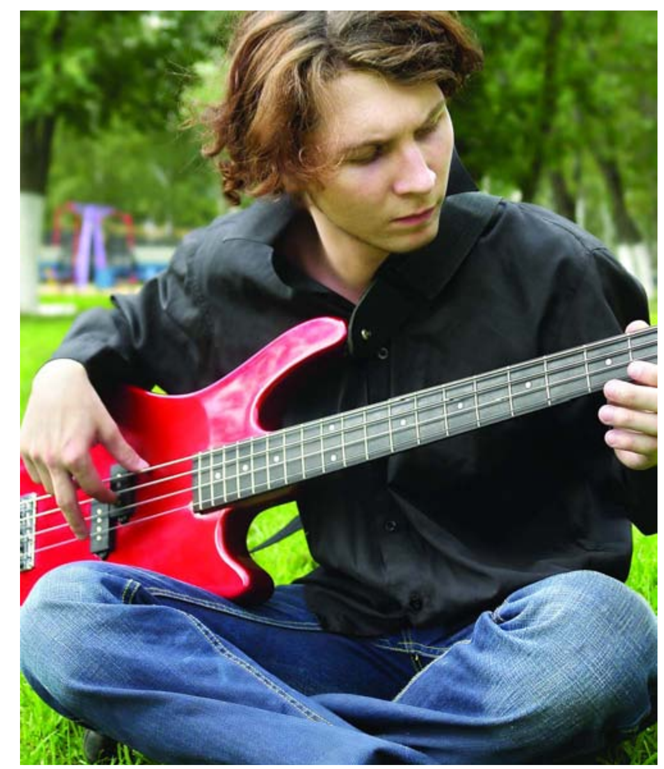


## Forms of Energy

Energy comes in many different forms. You may see and hear energy in the form of light and sound every day.

Every moving object has energy. Even objects that are standing still have energy. Wood put in a fireplace has energy. Some of that energy is released as flames when the wood burns. In fact, everything is a form of energy—even you.

*Every color and shade is a form of light energy.*



*Every noise is a form of sound energy.*

## Conservation of Energy

Energy can never be created or destroyed. It can only be converted, or changed, into another form. This principle is known as the conservation of energy. The various forms of energy include mechanical energy, electromagnetic energy, chemical energy, heat energy, and nuclear energy.

**WORDS to know**

**distance** (DISS-tuhnss): the amount of space from one place to another

**machine** (muh-SHEEN): a device or tool that uses energy to make work easier

**work** (wurk): a force acting on an object to move it across a distance

All forms of energy are related to one another. Energy can be transformed from one form into another. The total amount of energy stays the same. The electric energy in a battery can be converted into mechanical energy in a motor.

*The potential energy in the battery becomes kinetic energy when the toy is turned on.*

## Potential and Kinetic Energy

### Potential Energy

There are many ways to describe energy. Physicists often describe energy in two ways. Energy can be stored up, waiting to be released. This is called potential energy. A ball sitting on the top of a hill has potential energy. A rocket waiting to be launched has potential energy stored up in its fuel.

### Kinetic Energy

The ball releases energy when it rolls down the hill. This energy in action is called kinetic energy. The rocket has kinetic energy when its engines ignite and lift it into space. An object has more kinetic energy the faster it moves.

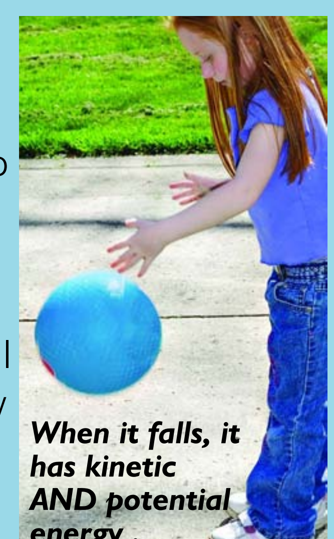
Find out more

**Example of Kinetic and Potential Energy**

A bouncing ball has both kinetic and potential energy. The ball has only potential energy before it is dropped. It has both kinetic and potential energy as it falls. The ball has only kinetic energy when it hits the floor. It gains potential energy again as it bounces back up.

Each bounce converts energy to heat, sound, and fast movements called vibrations. Eventually, the ball will lose its energy and stop bouncing.

*Before it is dropped, the ball has potential energy.*



*When it falls, it has kinetic AND potential energy .*



**There Are Many Sources of Energy**

Energy comes from many different sources. Solar energy is energy from the Sun. The Sun provides the Earth with a lot of energy every day. Wind is a form of energy caused by changes in air temperature. Tides in the ocean contain energy as they rise and fall. Water in rivers and lakes also contains energy.

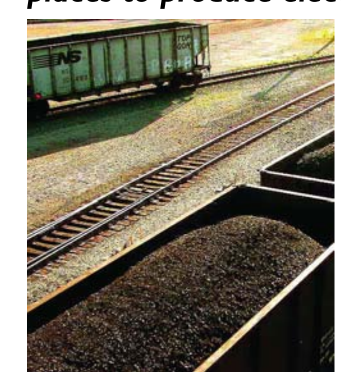
### Geothermal Energy

Other forms of energy include geothermal energy from the Earth itself. Heat rises from deep inside the Earth. It escapes through cracks in the crust. Geysers and hot springs are sources of geothermal energy. Volcanos and earthquakes are also forms of energy.

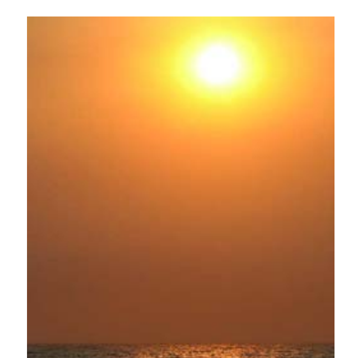
*Geothermal energy is now being used in some places to produce electricity.*

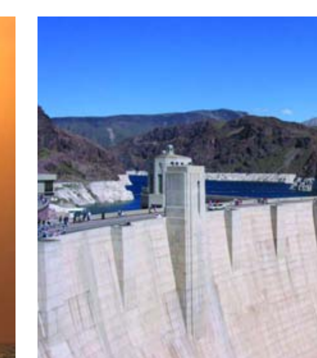
### Renewable and nonrenewable energy sources

Humans use oil and coal from the Earth's crust. Coal and oil supplies will eventually run out. They are nonrenewable energy sources. Other energy sources are renewable. They will never run out. Solar energy is a renewable energy source. Water can be used as a renewable energy source too. Dams are built on rivers to capture hydroelectric power, or power from running water.




*Coal and oil are nonrenewable energy sources.*





*Solar power and water power are renewable energy sources.*

## Momentum and Collisions

Momentum is another word for inertia. All moving objects have momentum. They keep moving until some force stops them or changes their direction. Momentum is a form of energy. The momentum of an object depends on its mass (size) and velocity (speed).

### Conservation of Momentum

A collision happens when two objects hit each other. A moving object that collides with another object passes on its momentum. The momentum of the two objects stays the same, or constant. When no other forces are affecting the objects, this is called conservation of momentum.

**Words to Know**

**conservation of energy** (kon-sur-VAY-shuhn, EN-ur-jee): energy can be changed into another form, but cannot be created or destroyed

**kinetic energy** (ki-NET-ik, EN-ur-jee): energy caused by movement

**momentum** (moh-MEN-tuhm): the force of something when it is moving

**potential energy** (puh-TEN-shuhl, EN-ur-jee): stored energy

*Faster speeds produce a greater impact when two cars collide.*

Conservation of momentum is used in the game of pool. The white ball, or cue ball, transfers its momentum when it hits another ball. This ball moves away at a similar speed as the cue ball. Rockets that travel into outer space use conservation of momentum. The rocket gains momentum from the force, or thrust, pushed out of its engine. The thrust goes one way, and the rocket goes the other way.

*The larger and heavier a rocket is, the more thrust it will need to lift off.*



# Electricity and Magnetism

Electricity and magnetism are everywhere. Electricity is a form of energy. Magnetism is also a form of energy. They make it possible for televisions, computers, and many other electronic devices to exist. Medicine uses them to help treat illnesses in humans and animals.

*Magnetism stores the data in a computer even when it is turned off.*

Electric motors use magnetism to convert electricity into motion. Generators use magnetism to create electricity. Electric forces exist in nature too. They determine phases of matter. For example, electric forces let solids be solids and liquids be liquids.

## Electric Charges

The electromagnetic force between particles is one of the basic forces of nature. An electric charge occurs when an atom has too many or not enough electrons. An electron is a particle that moves around the center of an atom. Materials can become electrically charged, or electrified, in many different ways.

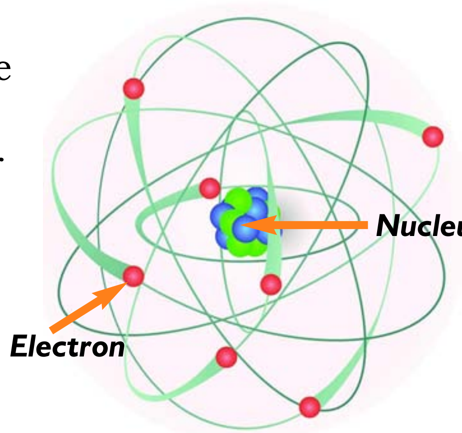
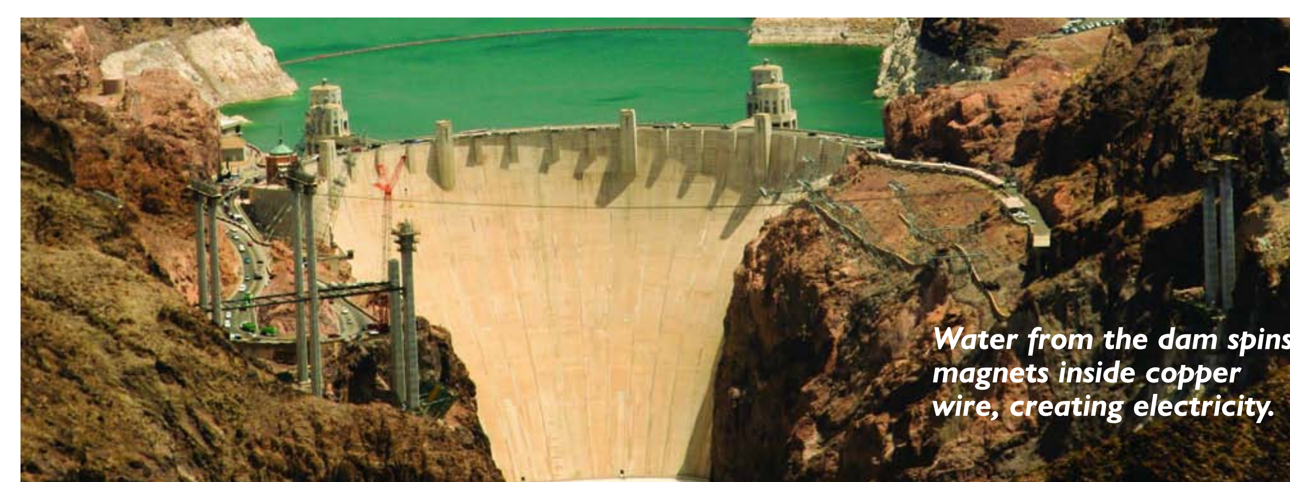



*Illustration of a Atom*



*Water from the dam spins magnets inside copper wire, creating electricity.*

## Benjamin Franklin

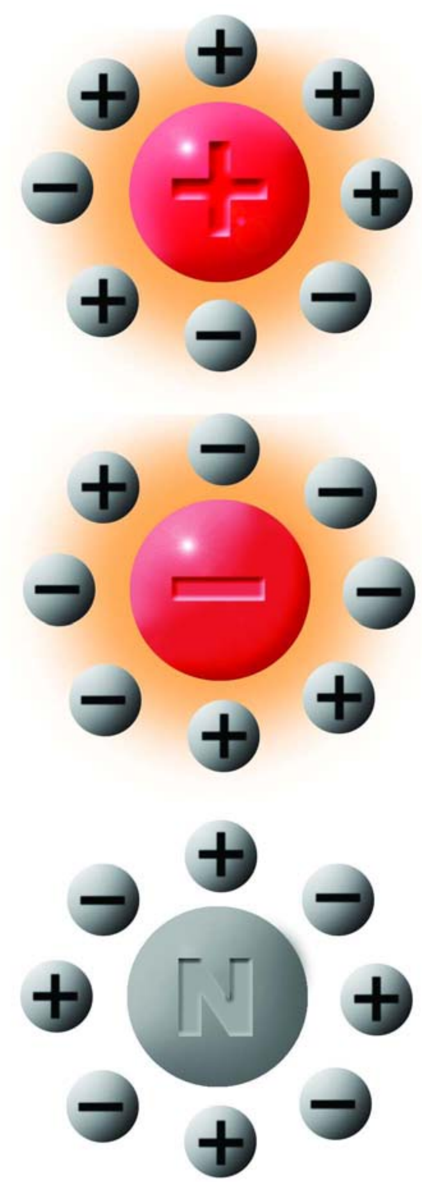
**Getting to know...**

Benjamin Franklin was born in the city of Boston in 1706. He went to school for only two years. Franklin made candles for his father and worked in a printing shop with his brother. He made money in business in the city of Philadelphia. Franklin invented a wood-burning stove, bifocal glasses, the postal system, and the first public library in America.

Franklin performed many experiments. He was interested in electricity. He thought that objects are positive, negative, or neutral. Franklin flew a kite during a thunderstorm to test his theory. (This is a very dangerous experiment!) He tied a metal key to the string. The key touched a Leiden jar, which stores electric charges. Franklin also invented the lightning rod. This metal pole attracts lightning and keeps it from hitting buildings.

## Positive and Negative Charges

There are two different kinds of charged particles, negative and positive. A negative charge comes from electrons. A material that has extra electrons is negatively charged. A positive charge comes from protons. A proton is a particle found in the center section of an atom. A material that loses electrons is positively charged. There are more protons in the material than there are electrons. A neutral atom has the same number of protons and electrons.




***You can find out if an atom is positive, negative, or neutral by comparing the number of protons and electrons it contains.***



Rubbing a balloon on hair will make the hair stand up. The balloon has picked up a negative electric charge from the hair. The hair will have a positive electric charge. Hair is attracted to the balloon because charges that are opposite attract each other. Two negatively charged balloons will move away from each other. Charges that are the same push away, or repel, one another.

## Static Electricity

Electricity that does not flow is called static electricity. Friction between different materials can build up static electricity. Running a comb through hair will charge the comb with static electricity. Then the comb can pick up little pieces of paper. An inflated balloon rubbed on wool will stick to the wall or ceiling of a room.

You can electrify your body with static electricity by rubbing your shoes on a wool rug. The static charge is removed, or discharged, when you sneak up on your friends and zap them. Under the right conditions, you can even see a spark!

**Find out more**

It is easier to build up static electricity in the wintertime because there is less humidity in the air. When you come in from the cold and take off your hat, your hair becomes electrically charged and stands up. This is because electrons moved from your hair to your hat when you pulled off your hat.

The hairs on your head are all now positively charged. We know that charges that are the same push away from each other, and that's just what the hairs on your head are doing, giving you a hair raising new look!

**Words to know**

**electron** ( i-LEK-tron): a particle that moves around the nucleus (center part) of an atom

**negative charge** (NEG-uh-tive, charj): one of the two kinds of charges, positive and negative, that go in opposite directions in an electrical current

**positive charge** (POZ-uh-tive, charj): one of the two kinds of charges, positive and negative, that go in opposite directions in an electrical current

**static electricity** (STAT-ik, i-lek-TRISS-uh-tee): electricity that builds up on an object and does not flow

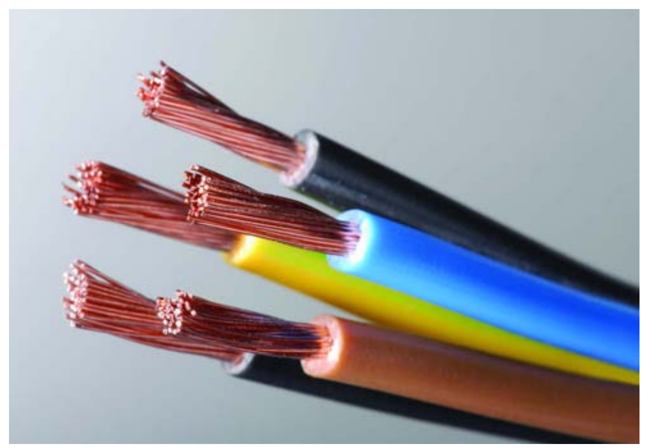
### Conservation of Electric Charges

Electric charge is conserved. This means that an electric charge cannot be created or destroyed. An object can become electrified. This is because the electric charge is transferred from one object to another. One object gains some negative charge. The other object gains the same amount of positive charge.

## Current

### Circuits

Electricity that flows, or moves, is called electric current. An electric current is usually made of a stream of electrons. The electrons are moving from one place to another. A circuit is the complete path of an electric current. A simple circuit looks like a loop. Metal wires are often used to conduct, or pass on, electric current. Electrons flow easily through metals. Copper is a metal that can be stretched into wires. It is a good conductor of electricity. This is because electrons flow easily through it. Copper wires are used to conduct electricity in houses and other buildings.



*Copper wire is used in many electronics and telecommunications products.*

### Amps

The amount of electric current flowing through a material is measured in units called amps. Wires can handle only a certain amount of electricity.

### Fuse

The thicker the wire, the more electricity can flow through it. A wire will heat up if too much electricity flows through it. Sometimes, wires get so hot that they melt the insulation protecting them. This can start a fire. A fuse is used to limit the amount of current flowing through wires. The fuse stops the flow of electricity. It does this if the number of amps, or amount of current, gets too high. The fuse breaks in order to protect wires that cannot handle higher currents.

*It is much easier to replace a blown fuse than to repair fire damage or replace damaged electronics.*

*Circuit breakers protect electrical circuits from damage.*

### What Provides Current

Many different things provide current. Batteries store chemical energy. Solar panels convert sunlight into electricity. Even the forces inside of an atom can be used to produce energy.

**Words to Know**

**circuit** (SUR-kit): a group of electronic parts that are connected and make a circle

**conductor** (kuhn-DUK-tur): matter that allows heat to pass through it

**fuse** (fyooz): a device that stops electricity flowing when there is too much current

**volt** (vohlt): a unit used to measure the electrical force in a battery

**Find out more**

**Batteries**

Batteries are used to store energy in the form of chemical energy. The chemical energy is stored in a battery cell. Each battery cell has two ends, the positive and the negative end. The chemicals inside a battery are called electrolytes.

A chemical reaction happens inside the battery. A chemical reaction is when chemicals combine and change. The chemical reaction makes electrons flow from the positive end to the negative end. Different chemicals can provide different amounts of electricity.

Electrical force is often measured in volts (V). A volt is the force that makes electrons flow around a circuit. Flashlights and radios often use 1.5 volt batteries. Some batteries can be recharged, or charged again, when they run out of power.

Batteries are used as power for many different electronic devices. Tiny batteries are used in watches. Portable computers often use rechargeable batteries. Cars have big rechargeable batteries to start their engines. Some cars even run completely on batteries. They are called electric cars.

# Magnetism

Magnetism is an invisible force that brings some materials together or pushes them away from each other. It can also attract or repel other materials. It is usually found in materials containing iron. A magnet is usually made out of iron. Magnets can attract or repel other magnets. They can also attract pieces of iron that are not magnetic. These pieces of iron will become temporarily magnetized, or made into magnets.

***Iron filings become temporarily magnetized when they touch other iron filings that are in contact with the magnet.***

## Poles

Every magnet has two ends called poles. These poles are called north and south. Poles behave like electrical charges in many ways. Different poles attract each other. North poles are attracted to south poles. South poles are attracted to north poles. Poles that have the same charge repel each other. South repels south, and north repels north.

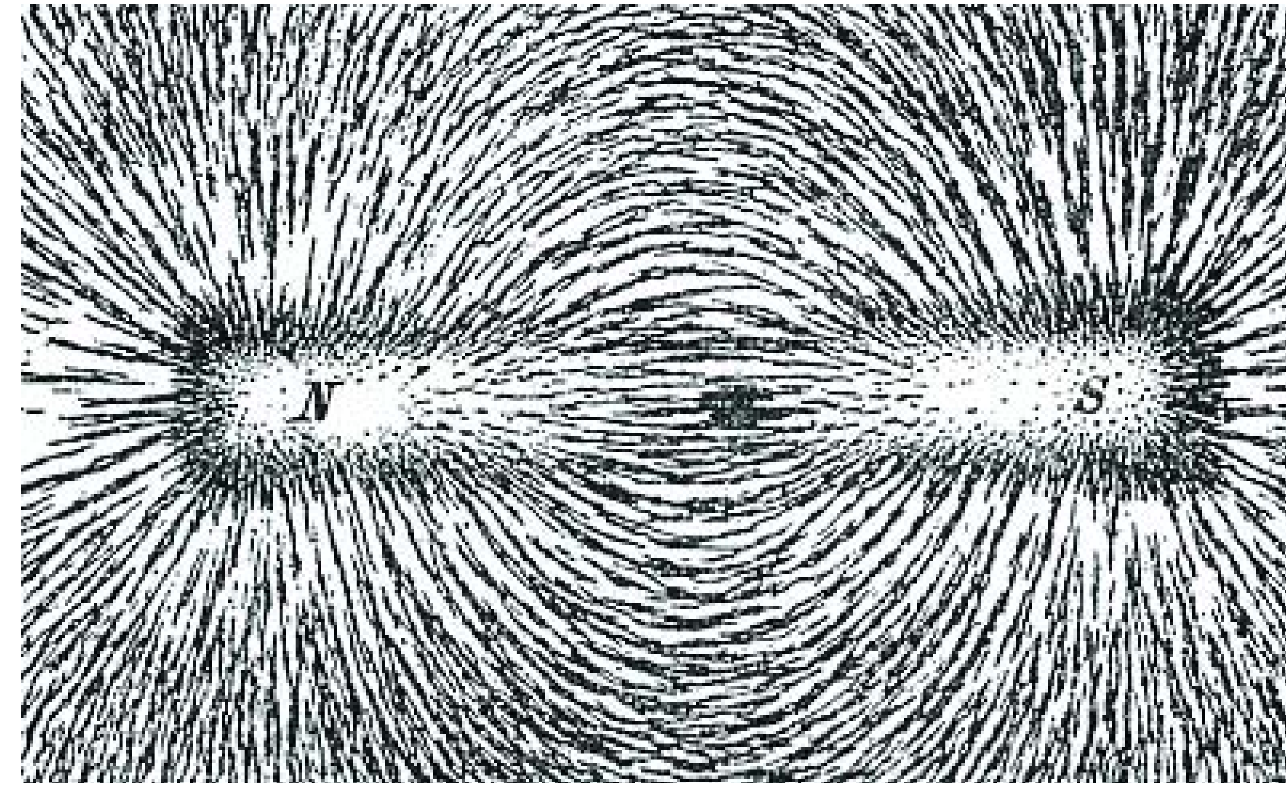

***Like poles repel each other, but in this position they can lie side by side.***

Magnetic poles are also different than electrical charges. Magnetic poles cannot be separated from each other. It does not matter how many pieces you cut a magnet into. Each piece will always have a north pole and a south pole.

## Magnetic Field

All magnets produce a magnetic field. This is the area around the magnet where the magnetic force can be felt. Magnetic fields travel from the magnet's north pole to its south pole.






***Placing iron filings on a piece of paper covering a bar magnet shows the magnetic field.***

Find out more

### Make Your Own Magnet

Hold a pair of scissors in one hand. Hold a magnet in your other hand. Rub one end of the magnet along the metal scissors. Lift the magnet and repeat the same movement as before. Continue for 10-12 strokes. Remember to always lift the magnet between strokes, and always use the same end of the magnet. Now your scissors should act like a magnet. Experiment to see how many household items you can pick up.

## Electromagnet

Magnets can be created with electricity. Every electric current can make a magnetic field. Current flowing through a wire creates a magnetic field around the wire. This can be seen with a compass. Put a compass needle close to an electric wire. The needle will change the direction it is pointing.

Wire that carries a current can be wrapped around a piece of iron to make a powerful magnet. It is called an electromagnet. Magnets can also be used to produce electricity. A magnet that is moved close to a wire can create an electric current in the wire.

*Maglev trains use magnetic levitation.*

## Using Magnets

Magnets are used everywhere. Electromagnets can pick up heavy objects. They are also used in speakers to make sound. Magnets and electromagnets help electric motors spin. Magnetic disks are used to store information for computers.

Videotapes and audiotapes record pictures and sound with electromagnets. Scientists use magnetic fields to study and control subatomic particles, or the smaller particles in atoms.

### Words to Know

**electromagnet** (i-lek-tro-MAG-nit): a magnet made by an electric current

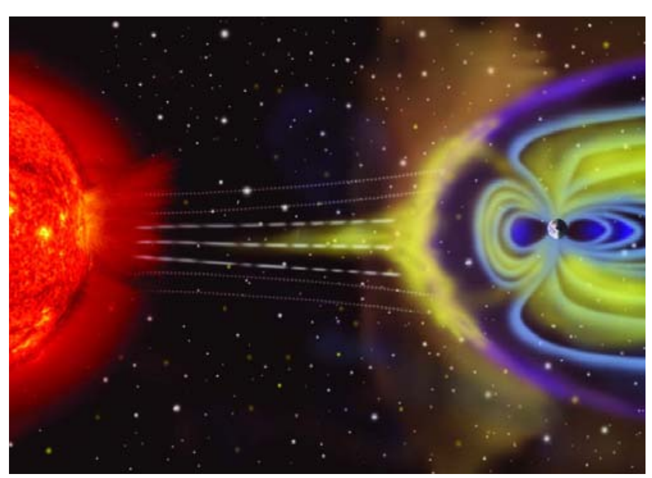
**magnet** (MAG-nit): a metal object that pulls iron or steel toward it

**pole** (pohl): the north or south end of a magnet

*Magnetic discs are used inside computers.*

## Earth

Earth itself is a giant magnet. Like any magnet, the Earth has a magnetic field. The direction of Earth's magnetic field can be seen with a compass. The compass needle always points toward the north magnetic pole. Earth's magnetic field protects the planet. It protects it from charged particles thrown out by the Sun. These charged particles are called solar wind. Some other planets have magnetic fields too.



*The magnetosphere shields the surface of the Earth from the charged particles of the solar wind.*

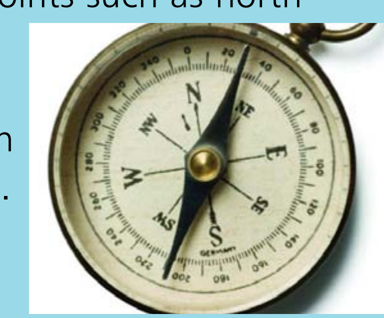


### Find out more: Compasses

Have you ever gone for a hike in the woods and lost your sense of direction? You might think you came one way, but as you backtrack, you find yourself in unfamiliar territory and wondering which way to go. Maps are helpful for showing a route, but if we don't know east from west, our map isn't going to be very useful. Knowing that the Sun rises in the east isn't much help at noon, when it is directly overhead.

There is a tool that can help us find our way. It is the compass. A compass uses a magnetic needle that spins freely on a post, or pivot point. The needle spins so that one end is always pointing to the Earth's magnetic north pole. We can use the markings on our compass to find our way in any direction.

A compass has four main points: north, south, east, and west. These are the cardinal points. Between these points lie northwest, northeast, southwest, and southeast. Even more detailed are points such as north-northeast, halfway between north and northeast.



### Getting to know... James Clerk Maxwell

James Clerk Maxwell was born in the country of Scotland in 1831. His mother taught him at home, but she died when Maxwell was eight years old. He was sent to school and did well in mathematics. Maxwell decided to study physics. He went to Cambridge University.

Maxwell began to perform experiments with electricity and magnetism. Physicists wondered how electric charges traveled across space. They wondered how they influenced other charges. They found that charges create electric fields. They found that magnets create magnetic fields.

Maxwell joined these fields into a single electromagnetic field. He used mathematical equations now called Maxwell's equations. He showed that electromagnetic energy moves as waves. A wave is energy that moves through air or water. The speed of these waves is the speed of light. Maxwell found that light is made of electromagnetic waves.

# Heat

Heat is a form of energy. It is created when molecules (small pieces) in an object move around. The study of heat and how it is used is called thermodynamics. Heat is very important to life on Earth. The Sun warms our planet and helps create weather. Heat from our bodies helps them work properly.

## Temperature

Temperature is how hot or cold something is. The temperature of an object tells us how fast the molecules in the object are moving. Different materials behave in different ways depending on their temperature.

A temperature scale is a system for measuring how hot or cold something is. There are three common temperature scales: Kelvin, Celsius, and Fahrenheit. In the United States, the Fahrenheit scale is used to describe how hot or cold the weather is.

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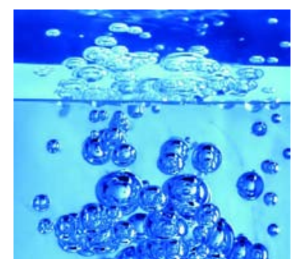
### Temperature Scales

**Fahrenheit Scale**

In the United States, temperature is measured in degrees fahrenheit. Water freezes into ice at 32 degrees Fahrenheit (32°F). Water boils at 212 °F.



**Celsius Scale**

Temperature is often measured using the Celsius scale. Celsius (°C) is based on the freezing point and boiling point of water. Water freezes at 0°C, or 0 degrees Celsius. Water boils at 100°C. An average room temperature is about 20°C.

**Kelvin Scale**

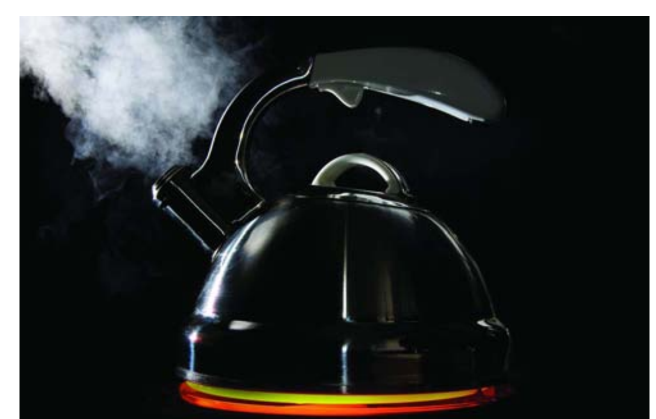
Another way of measuring temperature is to use the Kelvin scale. The Kelvin (K) scale begins at the lowest possible temperature. This is 0 K, or -273°C. Temperatures measured with the Kelvin scale are called absolute temperatures.



| | Kelvin | Celsius | Fahrenheit |
|---|---|---|---|
| Absolute zero (precisely, by definition) | 0 K | -273.15°C | -459.67°F |
| Melting point of ice | 273.15 K | 0°C | 32°F |
| Water's boiling point | 373.1339 K | 100°C | 212°F |

## Expansion and Contraction

Most things expand, or get bigger, as they get hotter. Most materials contract, or get smaller, as they get colder. The molecules (small pieces) that make up material move faster as they get hotter. They take up more space as they move more quickly. A solid that is heated enough will become a liquid. A liquid that is heated enough will boil. It then turns into a gas, or vapor.



*When water boils and becomes steam, it escapes from the kettle.*

### Rates of Expansion and Contraction

Different materials expand and contract at different rates. Solids and liquids expand only a little bit when they are heated. The expansion and contraction of some rocks makes them crack. This happens when the temperature gets really cold. Many paved streets and sidewalks crack. This happens as they are exposed to temperature changes over time.

### Heat

Gases expand a lot when they are heated. Heated air is used to fill hot-air balloons. Hot air rises because it is less dense (lighter) than cooler air. It takes up more space because there is more space between the molecules. This allows the balloon to rise into the sky.

*Hot air balloonists control their height by adding hot air to the balloon, or by releasing it.*

Find out more

### Thermometers

There are many ways to tell how warm or cold it is outside. Humans get goose bumps on their skin when it is really cold. A more accurate way to measure temperature is to use a thermometer. Thermometers are used to measure the temperature of many different things.

Some thermometers are used to control, or regulate, temperature. They are called thermostats. Thermostats in car engines turn on a cooling fan when the engine gets too hot. Other thermostats regulate the temperature of refrigerators and air conditioners. Heaters have thermostats that tell them when to turn on.

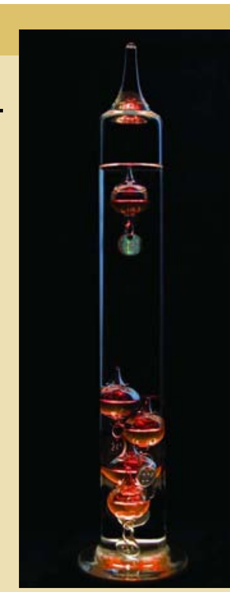
The metal mercury is used in many thermostats. The mercury is kept inside a sealed glass tube. The metal will expand or contract as the temperature changes. Warmer temperatures cause the mercury to expand and rise in the tube. Colder temperatures cause it to contract and fall in the tube. People can use mercury thermometers to measure body temperature. Digital thermometers use electronic parts to measure temperature. People can also use a digital thermometer to measure body temperature. Different types of digital thermometers can be placed in the ear or under the tongue.

Getting to know...

### Galileo Galilei

Galileo Galilei was born in Italy in 1564. He was an Italian physicist, mathematician, astronomer, and philosopher.

One of Galileo's inventions was the thermoscope. With a thermoscope the temperature is read using the engraved metal disc on each bulb. If there are some bulbs at the top and some at the bottom, but one floating in the gap, then the one floating in the gap tells the temperature. If there is no bulb in the gap then you take the temperature of the bulb at the bottom of the gap, add it to the temperature of the bulb at the top of the gap, and divide the result by two.



### Measuring Temperature

**1597** Galileo Galilei invents the thermoscope.

**1612** Santorio Santorio applies a scale to an air thermoscope and thus is thought to be the inventor of the thermometer as a temperature measuring device.

**1654** Grand Duke of Tuscany, Ferdinand II (1610-1670) makes the sealer liquid-in-glass thermometer. His thermometer has an alcohol filling. Although this is a significant development, his thermometer is inaccurate and there is no standardized scale in use.

**1714** Gabriel Fahrenheit (1686-1736) makes the first thermometer using mercury. The more predictable expansion of mercury, combined with improved glassworking techniques, leads to a much more accurate thermometer. The Fahrenheit scale is still in use today.

**1742**
The Swedish scientist Anders Celsius (1701-1744) devises a thermometer scale dividing the freezing and boiling points of water into 100 degrees.
The Celsius Scale is still in use today.

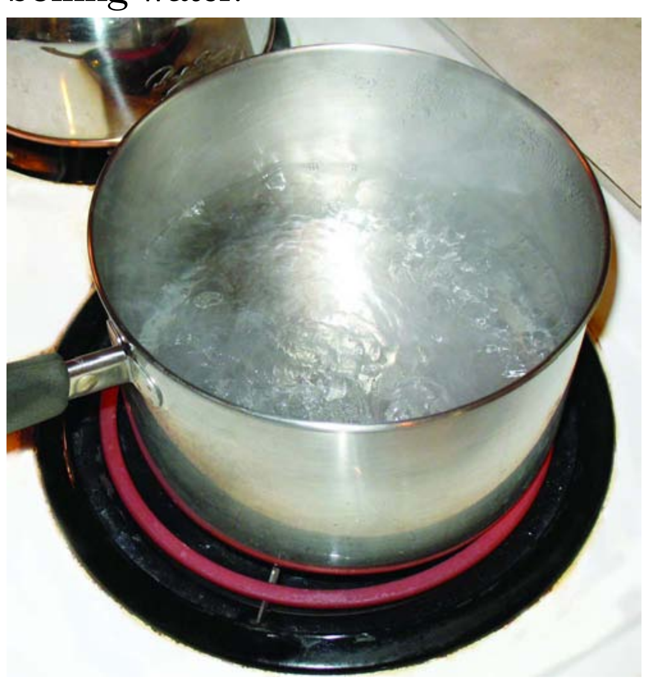
**1848** Lord Kelvin of Scotland (1824 - 1907) proposes the absolute temperature scale, or Kelvin scale. The kelvin (K) is the current standard unit of temperature measurement.

## How Heat Works

Heat is the energy that an object has because the molecules (small pieces) inside it are moving. Heat flows from materials that are hot to materials that are cool. The heat will flow until both materials are the same temperature. The three ways that heat can travel are convection, conduction, and radiation.

### Convection

Convection is how heat moves through liquids and gases. Water will slowly start to boil as it is heated. The convection currents of vibrating water molecules cause the violent movement we see in the boiling water.



***We see convection in the boiling water, and know to keep our hands away from the hot metal pot.***

### Conduction

Conduction is how heat moves through solids. Molecules start to vibrate as they are heated. As they vibrate faster, the molecules next to them start vibrating. This vibration conducts the heat energy through the material. A metal spoon dipped in hot water will get hot at the other end because heat energy was conducted through the spoon.

***The handle of this ceramic mug will not conduct as much heat as the metal spoon.***

### Radiation

Radiation is how heat moves through empty space. It travels by electromagnetic waves. Energy from the Sun reaches the Earth in this way. All objects emit, or give off, radiation in the form of heat.



An object will emit more radiation the hotter it becomes. A fire feels warmer as you get close to it.

***A red-hot iron rod will transfer heat to the surrounding environment through radiation.***

## The Uses of Heat

Humans use heat in a lot of ways. Car engines use heat from the burning of fuel. The heat energy is converted to a force. The force pushes pistons in the engine up and down. The pistons provide power so that the car can move.

Refrigerators use the laws of thermodynamics when they cool your food. The first law of thermodynamics says that when something is made cold, something else becomes hot. This is why the back of a refrigerator feels warm.

***Insulation and thermodynamics work together to keep your food cool.***

### Insulation

Insulation helps prevent heat from shifting. People wear thick clothes in the winter to keep their bodies warm. The clothes act as insulation that prevents heat from leaving the body.

**WORDS to KNOW**

**conduction** (kuhn-DUHKT-shuhn): how heat moves through solids

**convection** (kuhn-VEK-shuhn): how heat moves through liquids and gases

**insulation** (in-suh-LA-shuhn): material that keeps heat in or out

**radiation** (ray-dee-AY-shuhn): how heat moves through empty space

*The jacket's insulation helps this girl retain body heat.*

Ice chests use insulation to prevent heat on the outside from getting inside. This allows cold food and ice to stay cold.

*A well-insulated cooler will keep drinks cold on the hottest of days.*

Homebuilders use insulation in the attics and walls of homes so that the homes will stay warm in winter and cool in summer.

**Find out more**

You can test how well different materials act as insulators or conductors. Gather some cooking utensils, like wooden and metal spoons, from the kitchen. Place the utensils in a bowl or pan. Add enough ice to fill the bowl or pan about halfway. After a few moments, touch the handles of the utensils.

What do you notice about the temperature of each? Did some materials conduct cold better than others? Compare the temperature of the metal spoon to the wooden. Which is a better insulator? Why do cooks use wooden spoons when they stir boiling liquids?

**Superconductivity Moves Energy Fast**

Some materials take on special characteristics when they get really cold. They become superconductors. This is because they have very little resistance to electric current. Superconductors can be used to move energy inside computers very fast. They are also used to make some materials float!



# Waves, Sound, and Light

Light and sound are two of the most important forms of energy to humans. People see light and hear sound. Light from the Sun makes life on Earth possible. Sound is one of the most important ways that animals and humans communicate. Both sound and light travel as waves. Light also behaves like a particle. One of the things physicists study is the way light and sound work.

## Waves and Sound

### Waves

It is easy to make waves. Drop a stone in a pool of water. Waves of water will form as circles around where the stone fell in.

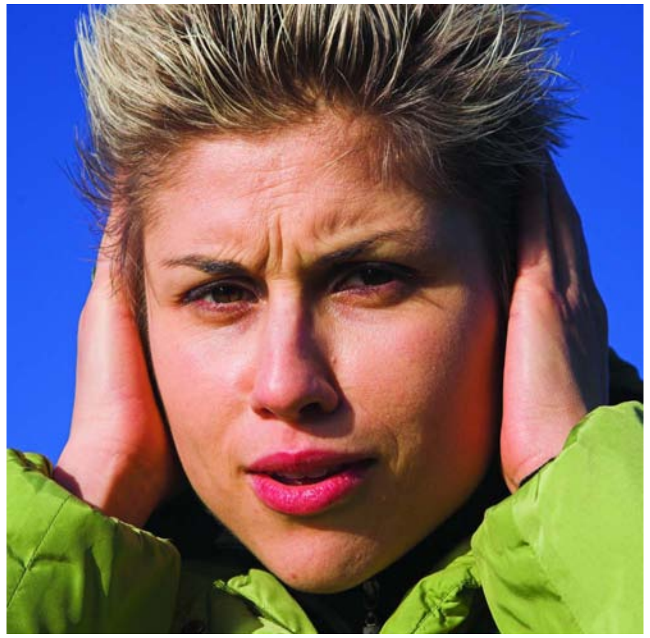
*Waves of water travel in all directions from the source.*

The high points of a wave are called crests. The low points of a wave are called depressions. The distance between the crests is the wavelength. How fast the waves move is their speed. How many waves pass a certain point in a second is called frequency. The frequency is higher when the waves are closer together.

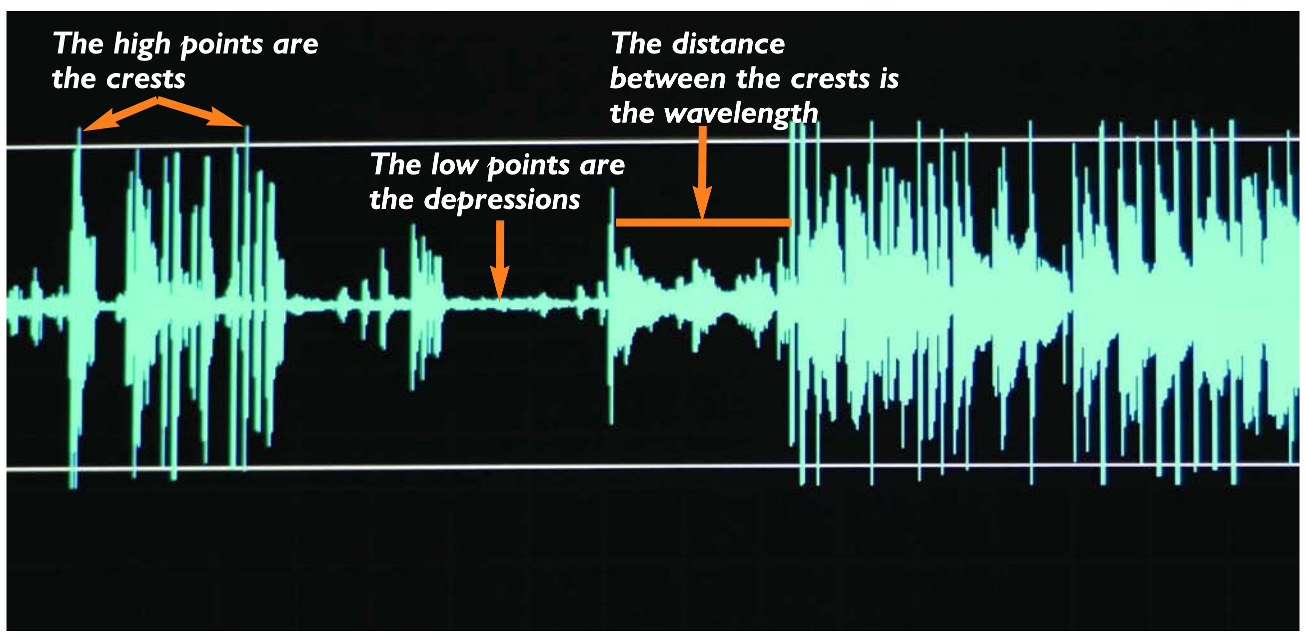
The amplitude is how tall the waves are. Sound waves can have different frequencies and amplitudes. High-pitched noises and sounds have high frequencies. Whistles have high–pitched sounds. The deep noises and sounds that come from drums have low frequencies.

### Sounds

Sounds travel by moving molecules of air like a wave. Sound waves behave like water waves. But they move in all directions. Have you ever felt a really loud sound? The force that you are feeling is sound waves moving through air. More air is moved when the sound is louder. A louder sound or noise has a higher amplitude.


*Very loud sounds can damage your eardrums.*

Sound waves can travel in many different materials. The speed of sound depends on the material it is traveling through. Sound can move faster through denser materials, but it may not travel very far. The energy from the sound wave can be absorbed into the material. This is why it is difficult to talk through a brick wall. The speed of sound through air depends on the air's temperature. At a temperature of 68°F (20°C), sound travels 1,130 feet (343 meters) per second.



*Sound Waves*

WORDS to Know

**amplitude** (AM-pluh-tood): how tall waves are

**frequency** (FREE-kwuhn-see): the number of times something moves in a second

We measure the intensity of sounds in decibels. The same sound will not seem to have the same loudness to all people, though. Age affects the human ear's response to a sound. Your grandparents do not hear like they used to. The same intensity sound would not seem to have the same loudness to them as it would to you.



**Intensities Of Common Sounds Measured In Decibels**

| Source | Intensity Level |
|---|---|
| Rustling leaves | 10 dB |
| Whisper | 20 dB |
| Normal conversation | 60 dB |
| Busy street traffic | 70 dB |
| Vacuum cleaner | 80 dB |
| Large orchestra | 98 dB |
| Front rows of a rock concert | 110 dB |
| Threshold of pain | 130 dB |
| Military jet takeoff | 140 dB |
| Instant perforation of eardrum | 160 dB |


*A lawnmower's intensity level is abut 90dB.*

# The Nature of Light

## Speed of Light

Light is a form of electro-magnetic energy. The light from a flashlight seems to shine instantly. However, it takes time for light to travel from the flashlight to where it is shining. Light moves very fast. The speed of light is about 186,000 miles (300,000 kilometers) per second. This is called the universal speed limit, because nothing yet discovered can go faster than the speed of light.


*Photons shine in a beam of light from the flashlight.*

## Particles and Waves

Scientists have studied light for many years. A long time ago, they thought that light was made up of tiny particles. Other scientists thought that light behaved like a wave of energy.

Today, scientists believe that light behaves both like a particle and like a wave.

### Particles

Particles of light energy are called photons. Photons come from anything that produces light. Stars, like the Sun, make a lot of photons. When objects block photons coming from the Sun, they make shadows.

*It's smart to take a break from the strong rays of the summer Sun.*

### WORDS to KNOW

**electromagnetic spectrum** (i-lek-tro-mag-NET-ik, SPEK-truhm): all the forms of energy that travel as a wave

**light** (lite): a form of energy

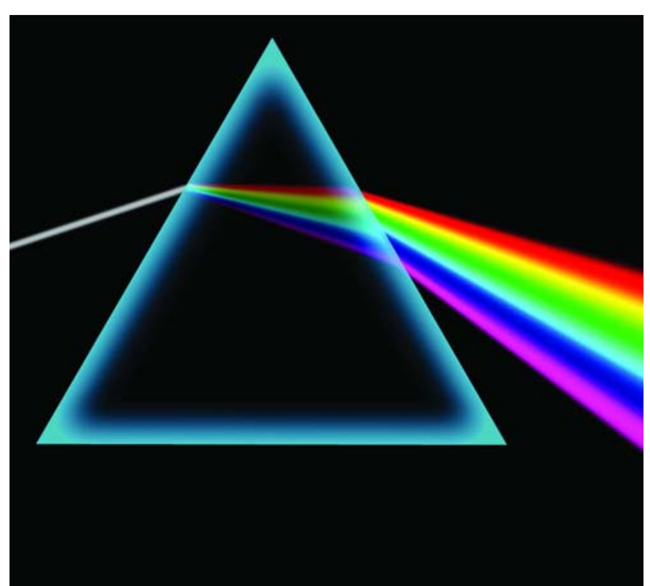
**microwaves** (MYE-kroh-waves): waves that can go through a solid object

**photons** (FOH-tons): particles or small pieces of light energy

**visible spectrum** (VIZ-uh-buhl, SPEK-truhm): the colors you can see; the colors of the rainbow (red, orange, yellow, green, blue, indigo, and violet)

Other physical processes on the Earth can produce light. Chemical reactions from fires release energy as light. Light bulbs of all kinds also produce light.

**Waves** also play a part. Light acts like a wave. Some forms of light are easy to see. The light that humans can see is called visible light. All visible light makes up the visible spectrum. This spectrum includes all the colors of the rainbow. The order of the colors in the visible spectrum is red, orange, yellow, green, blue, indigo (red-blue), and violet (purple). Other forms of electromagnetic energy are invisible. Light energy above the violet end of the spectrum is called ultraviolet light. Light energy below the red end of the spectrum is called infrared light.



*All the colors of the rainbow appear in the visible spectrum.*



### Other Energy That Can Travel As A Wave

Visible light is just one part of the electromagnetic spectrum. The electromagnetic spectrum includes all forms of energy that can travel as a wave.

**Radio Waves**

Radio waves are part of the electromagnetic spectrum. These are the waves received by radios, televisions, and cellular phones.

**Microwaves**

Microwave ovens use waves called microwaves to heat food. The wavelength of microwaves is just right to cause water molecules to vibrate. Vibrating makes the water molecules give off heat. Any food containing water gets hotter in a microwave oven.

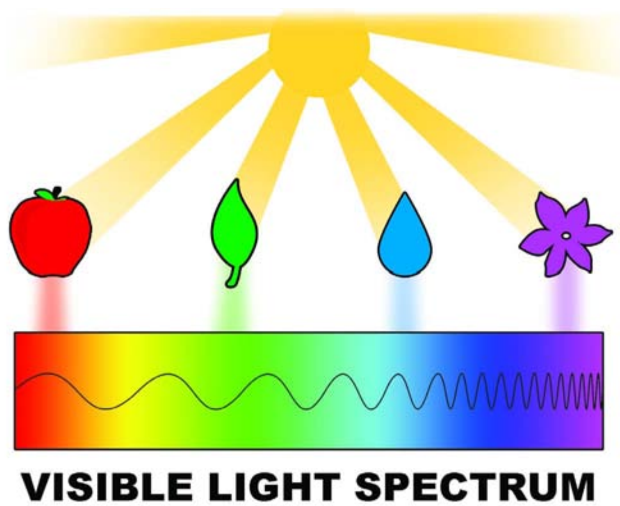

### Getting to know... Christiaan Huygens

Christiaan Huygens was born in the Netherlands in 1629. Huygens and his brother built a powerful telescope. He used it to study the planet Saturn. He discovered Titan, one of Saturn's moons. He discovered the rings around Saturn. Christiaan studied the motion of a pendulum and created a pendulum clock.

Huygens suggested the wave theory of light. He thought that light moves in waves that make more waves. They were like ripples of water. He assumed that space was filled with something for light waves to move through. This substance was called ether. Two hundred years passed before scientists realized that ether does not exist.

## Where Light Comes From

Electrons orbiting an atom in an electron shell have potential energy. An electron that drops down to a lower orbit changes potential energy into a photon of light. The frequency of light depends on the energy level. The frequency is high when the energy level of the orbit from which the electron came is high.




*Red light has a longer wavelength than green, blue, or violet.*

### Types of Light

Many kinds of chemical reactions release energy. A chemical reaction happens when chemicals combine and change. Reactions of different materials produce different kinds of energy. Scientists can tell what something is made of from the wavelengths of light that come from the material when it is burned. Gases give off specific wavelengths of light when they are electrified. Materials that are heated also give off light. When the wire in a light bulb gets very hot, it begins to glow.

*An electric current passes through the filament in this light bulb and causes it to glow.*

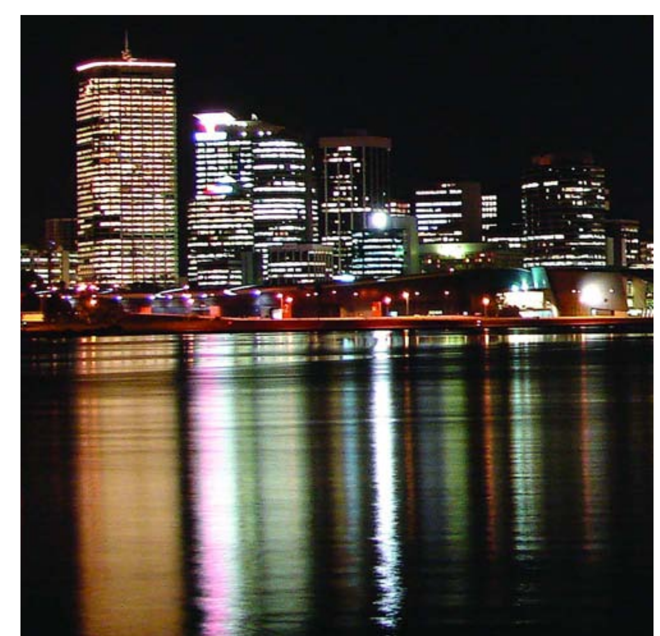
## Reflection and Refraction

### Reflection

PROJECTS volume 10 6.3

Light normally travels in a straight line. Light that meets an object will change direction. It will bounce or bend depending on what it hits. Light that bounces off a surface is reflected. Light is reflected like a ball bouncing off a hard floor.

Smooth surfaces, such as mirrors, reflect a lot of light and give sharp, clear reflections. Bumpy or rough surfaces give fuzzy, or diffuse, reflections. A dull object that is polished becomes smoother and better able to reflect light.



*The smooth surface of the water reflects the city's buildings.*



### Max Planck

Getting to know...

Max Planck was born in the country of Germany in 1858. He attended the University of Berlin and was inspired by his physics professors. Planck became a professor himself after college.

Planck began to work on the problem of blackbody radiation. A blackbody is any object that takes in, or absorbs, all light that hits it. A blackbody then gives off, or radiates, light at all frequencies or wavelengths. Planck found a formula that explained all his experiments. For his formula, energy had to be given off in chunks that he called quanta. Quanta depend on frequency and a number called Planck's constant. His idea of quanta of energy helped create the field of quantum mechanics. Planck was awarded the Nobel Prize in1918.

Find out more

### THE NOBEL PRIZE

The Nobel Prize is an award that honors men and women "... *who, during the preceding year, shall have conferred the greatest benefit on mankind.*"

The Nobel Prize started in 1895 when Alfred Nobel, a Swedish chemist, engineer, innovator, and inventor of dynamite, wrote his last will, leaving much of his wealth to set up the prizes.

Since 1901, the prize has honored men and women for outstanding achievements in physics, chemistry, medicine, literature, economics, and for work in peace. Many of the scientists and doctors who contributed to the advancement of scientific and medical knowledge won the coveted Nobel Prize for their work.

## Refraction

Light travels at different speeds through different materials. Light moves slower in water than in air. Its path is bent, or refracted, when light passes from one substance into another one. Refracted light makes a straight stick look bent when part of it is in water.

*You might think this pencil has been broken into two pieces!*

### WORDS TO KNOW

**lens** (lenz): a curved piece of glass or plastic

**prism** (PRIZ-uhm): a plastic or glass shape that separates light into the colors of the spectrum

**reflect** (ri –FLEKT): when light bounces or bends off a surface

**refract** (ri-FRAKT): when light is bent as it passes through different materials

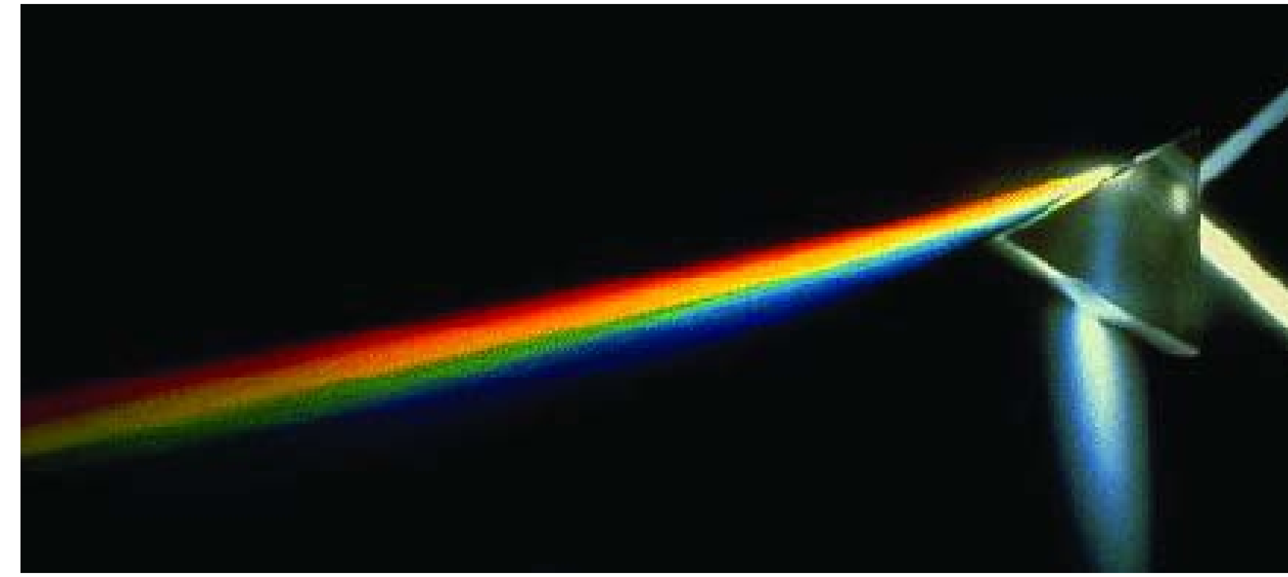
## Lens

A piece of glass shaped to bend light into an image is called a lens. Some lenses magnify things, or make them look closer. Some lenses reduce things, or make them look farther away. Lenses are used in eyeglasses to help people see. Other lenses are used to magnify tiny images in microscopes. Refracting telescopes use lenses to magnify things that are far away.

PROJECTS volume 10 6.4

*The lenses in telescopes and microscopes allow us to see things we could never see before; constellations from far away and tiny cells invisible to the naked eye.*





*A prism can separate all the visible colors of light found in sunlight.*

## Prism

Sometimes, light waves separate into different colors. A prism can separate sunlight into the colors of the spectrum. A prism is a specially shaped piece of glass or plastic. It can separate colors because different wavelengths of light travel at different speeds. Because they travel at different speeds they are bent by different amounts as they pass through the prism.

*Even the tiny ridges in a CD can act as a prism.*

### Find out more: Rainbows Show the Spectrum

Rainbows form when sunlight is refracted through drops of water in the air. The light splits into the seven colors of the visible spectrum: red, orange, yellow, green, blue, indigo, and violet. Rainbows can only be seen when the Sun is shining from behind you!

# Nuclear Energy

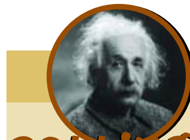
The protons and neutrons of an atom release nuclear energy when they break apart. Every atom contains a lot of energy. The forces that hold the atom together are the strongest forces that scientists know of.

In 1905, Albert Einstein showed that mass can be converted, or changed, into energy. He used mathematics to do this. The reaction can be written as $E=mc^2$. The E means energy. The m means mass. The $c^2$ means the speed of light squared, or multiplied by itself.

$$E = mc^2$$

*$E=mc^2$ is a very big number.*

A little bit of mass has a lot of energy. Some of the mass of the starting material is converted into energy in a nuclear reaction. Atoms that are split, or fused together, may weigh less than when they started. The mass that disappeared has been converted into energy.



## Albert Einstein

**Getting to know...**

Albert Einstein was born in the country of Germany in 1879. Einstein worked as a clerk in a patent office. He thought about physics and how the universe works. In 1905, he published a paper on the special theory of relativity. This theory changed how scientists looked at space and time.

Einstein continued to study space and time. In 1916, he published papers on the general theory of relativity. This theory showed that space, time, and gravity are all related. His theory was proved correct during an eclipse of the Sun in 1919. He was awarded the Nobel Prize in Physics in 1921.

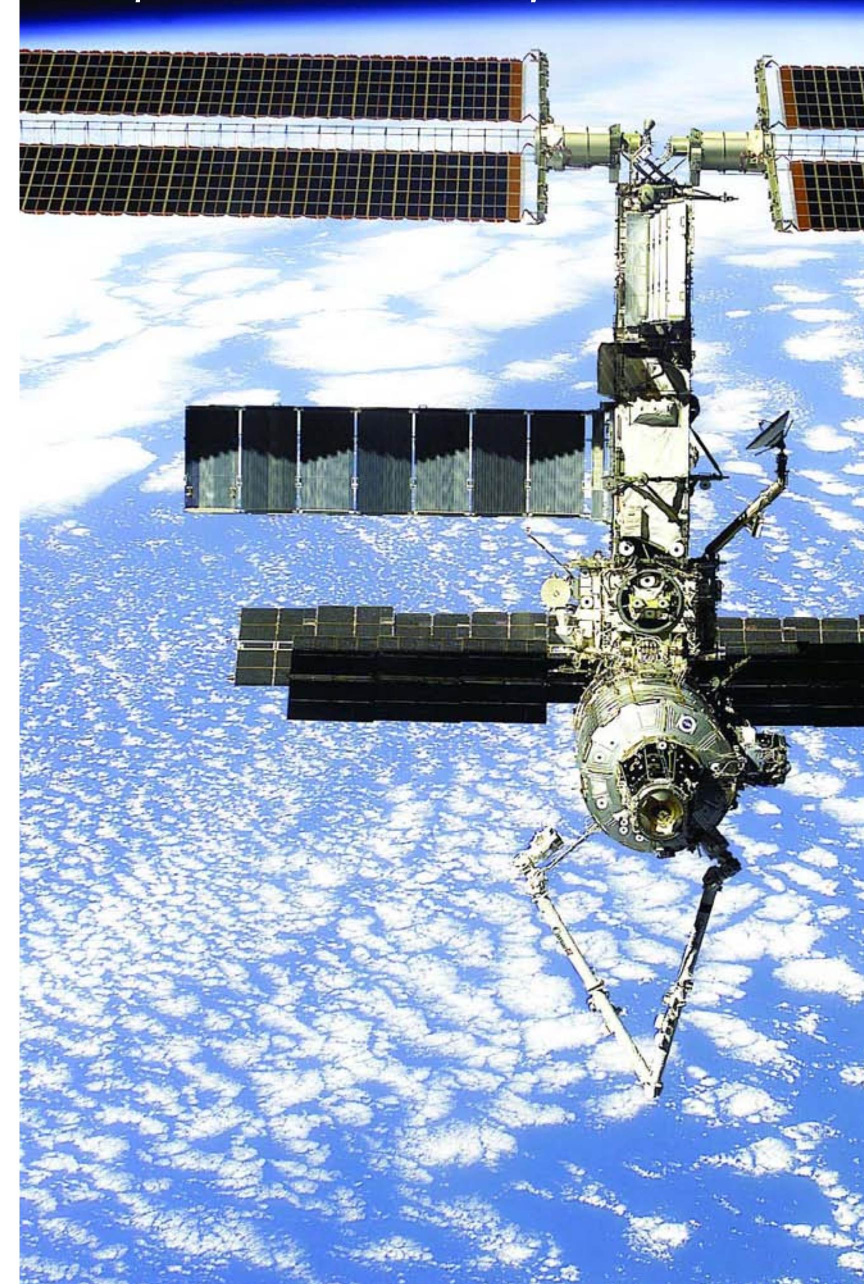
In 1933, Einstein moved to the United States to escape the Nazi persecution of Jewish people. He became a professor at Princeton University. Einstein continued to study physics and to work for world peace.



## Uses of Nuclear Energy

Nuclear energy is what powers the Sun and all the stars in the sky. Nuclear reactions are used to produce energy in nuclear power plants. Space probes (unmanned vehicles) that travel far away from the Sun sometimes use nuclear energy as their power source. Nuclear energy can also be used to create gigantic explosions. These explosions can destroy entire cities and kill millions of people.

*The space station collects and uses solar energy, which comes from the nuclear reactions of the Sun.*



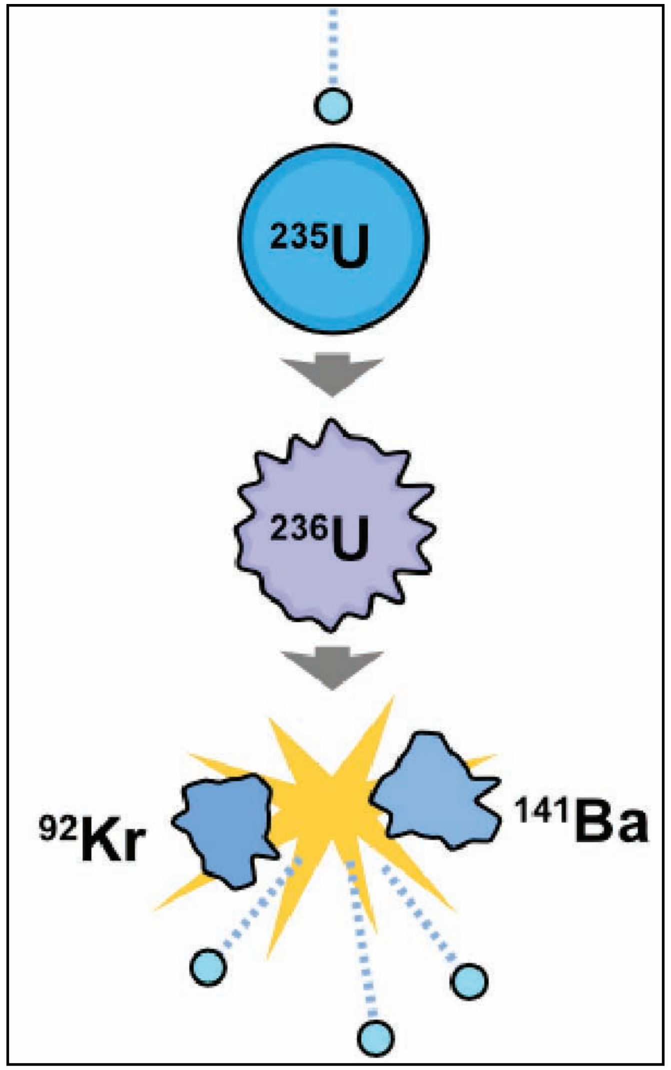
*Galileo and Cassini are powered by their own mini nuclear power plants.*

*The Galileo spacecraft was launched in 1989 to explore Jupiter and its moons.*

*Cassini studies the planet Saturn and its moons.*

# Fission and Fusion

Nuclear energy can come from two basic types of reactions. Fission happens when the nucleus of an atom is split to form two smaller atoms. Fusion happens when the protons and neutrons of two atoms combine to form a new atom.




*Simple diagram of nuclear fission in three steps:*

*1. A neutron is about to collide with the nucleus of a U-235 atom.*

*2. The neutron has been absorbed and briefly turned the nucleus into an unstable U-236 atom.*

*3. The U-236 atom has fissioned, resulting in two fission fragments (Ba-141 and Kr-92), three neutrons, and the release of a relatively large amount of binding energy.*

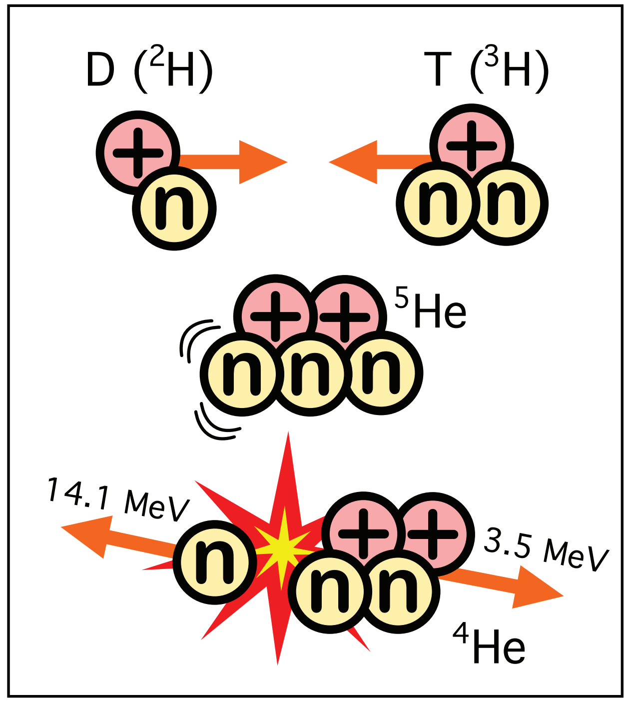



*Diagram illustrating deuterium-tritium fusion in three steps:*

*1. The D and T accelerate towards each other at thermonuclear speeds.*

*2. This creates an unstable He-5 nucleus.*

*3. The end result is the ejection of a neutron and repulsion of the He-4 nucleus.*

## Chain Reaction

Fission reactions begin when a neutron moving very fast collides into the nucleus (center) of an unstable atom. An unstable atom can be broken apart. This reaction requires a lot of energy at the beginning. The collision with the neutron causes the atom to break apart. Neutrons from the split atom cause other atoms to split if the reaction is not controlled. This is called a chain reaction.



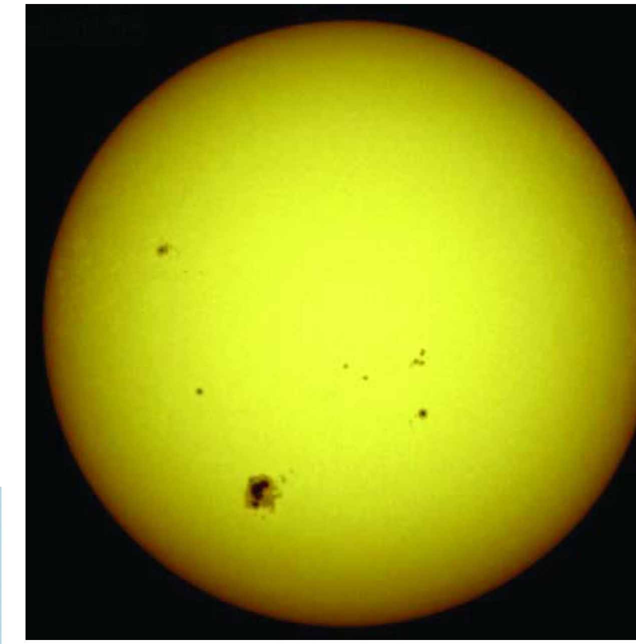
## Fission Reactions

Humans use fission reactions inside nuclear power plants. They use it to make nuclear energy.

*Water cools in giant towers at the nuclear power plant so it can be used again and again.*

## Fusion Reactions

Fusion reactions also require a lot of energy at the beginning. Even more energy is released when fusion takes place. The Sun's energy is released when fusion takes place. The Sun produces most of its light and energy from nuclear reactions.



*Nuclear fusion reactions in the Sun produce solar energy.*

*Solar panels convert the Sun's energy into electricity.*

WORDS to KNOW

**chain reaction** (chayn, ree-AK-shuhn): when a change keeps happening over and over again until it is controlled

**fission** (FISH-uhn): when an atom is split into two smaller atoms

**fusion** (FYOO-zhuhn): when parts of two atoms join together to make a new atom

**nuclear energy** (NOO-klee-ur, EN-ur-jee): energy made when an atom breaks apart

## Lise Meitner

**Getting to know...**

Lise Meitner was born in the country of Austria in 1878. She earned a Ph.D. in experimental physics. Meitner moved to Berlin, Germany, and met many famous physicists. She studied radioactivity with Otto Hahn.

In the 1930s, Adolf Hitler and the Nazi Party came into power in Germany and then Austria. They wanted to get rid of the Jewish people. Meitner was Jewish, and she had to escape to Sweden in 1938.

Back in Germany, Hahn and Fritz Strassman were hitting uranium with neutrons. They did not understand why they got barium, a lighter element. Meitner realized that the uranium atoms were being split. She also knew that energy was being released. This process is now called fission. Hahn was given the Nobel Prize in 1944 for their work, but Meitner was not.

**Find out more**

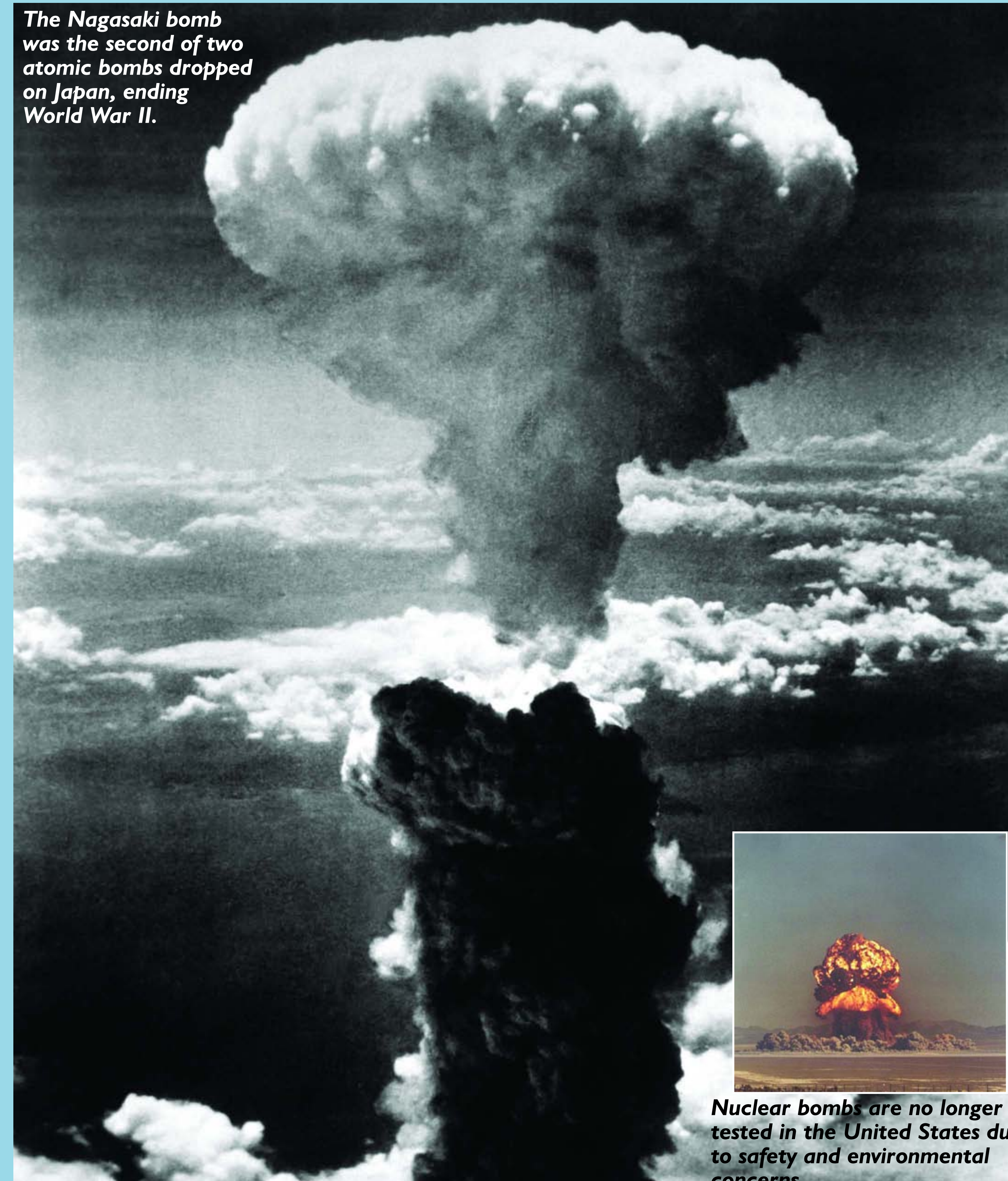
## The Atomic Bomb

One of the scariest and most powerful weapons in the world is the atomic bomb. In 1945, the United States dropped two atomic bombs on Japan to end World War II. The weapons completely destroyed the cities of Hiroshima and Nagasaki. Thousands of people were killed or seriously hurt by the explosions. Many other people became very sick from the radioactive particles called fallout.

Atomic bombs are also called nuclear weapons. They are made from specially produced uranium and plutonium. When enough uranium or plutonium is brought together it can reach a critical mass. A critical mass means it has enough mass (material) to produce a chain reaction. A chain reaction will take place if the critical mass is hit with neutrons. The chain reaction will lead to a nuclear explosion. Nuclear explosions are very powerful.

Nuclear weapons are tested deep underground. This is so the radiation does not make people sick. Computers are also used to test, or model, nuclear explosions.

Most nuclear weapons are used in missiles. These weapons are meant to deter other countries, or keep them from attacking. Many people think that nuclear weapons should not exist. Governments around the world are working together to get rid of nuclear weapons.



*The Nagasaki bomb was the second of two atomic bombs dropped on Japan, ending World War II.*

*Nuclear bombs are no longer tested in the United States due to safety and environmental concerns.*

## Electricity Through Nuclear Power

In the United States, more than 100 nuclear reactors work to make our electricity. About one-fifth of the electricity we use comes from nuclear power.

### Physics and Technology

*At the power plant, a fission reaction splits uranium atoms. The fission reaction releases energy to heat water. The boiling water produces steam. The steam turns huge turbines. The turbines send power to generators that make our electricity.*

*Before electricity leaves the power plant, it travels to the transmission substation. The substation uses transformers to change the voltage of the power. Then it sends the power out along high-voltage transmission lines.*

*When the power reaches a substation, transformers are used to lower its voltage. Then the power is sent off in many different directions. After passing through more transformers, the electricity makes it to our homes. Finally, it travels through wires to our outlets, where we can plug in our favorite toys, radios, and video game systems.*



Find out more

### Nuclear Medicine

Many doctors use nuclear medicine to diagnose and treat patients. Nuclear medicine is used in many areas of medicine including oncology (cancer), cardiology (heart), neurology (brain), and pediatrics (children).

One form of nuclear medicine is positron emission tomography, or PET scans. PET scans are unique because they give doctors information about the structure and function of the patient's body. Many other scans, such as MRIs (magnetic resonance imaging), only give doctors information on structure.

When a person has a PET scan, he is injected with a drug that contains very small amounts of radioactive materials (radiopharmaceuticals). The PET scanner measures the signals given off by the radioactive materials. The doctor uses the result to diagnose diseases, such as cancer, in patients.

Doctors use other types of radiopharmaceuticals to treat diseases. One common use for radiopharmaceuticals is in the treatment of enlarged thyroid glands, or goiters.

One big benefit of nuclear medicine to the patient is that diagnosis and treatment are painless.

*A PET scan gives the doctor information that will help diagnose and treat this patient.*

# People Who Study Physics

Physics is about how things work. People who study physics are called physicists. They learn about light and sound. They learn about electricity and magnetism. They learn about force and energy. They learn about how everything works, from the tiniest atom to the vastness of space.

Physicists study many different areas of physics.

There is atomic physics. This is the study of atoms. There is nuclear physics. This is the study of the nucleus or the center of atoms. There is particle physics. This is the study of the individual particles or parts of atoms. There is solid state physics. This is the study of how atoms are combined together to make a solid object.

All physicists use mathematics to help figure out how things work. Maybe you can be a physicist too.

## Women in Physics

**Marie Curie (1867 – 1934) and Irène Joliot-Curie (1897 – 1956)**

Marie Curie and her daughter, Irène Joliot-Curie, are both Nobel Prize winning scientists. Marie was the first woman to win a Nobel Prize. During World War I, Marie and her daughter worked together to treat wounded soldiers with radium emanation (radon).

**1903 Nobel Prize in Physics** – Marie Curie and her husband Pierre Curie were awarded the Nobel Prize for research on the radiation phenomena.

**1911 Nobel Prize in Chemistry** – Marie Curie received a second Nobel Prize for her work in radioactivity.

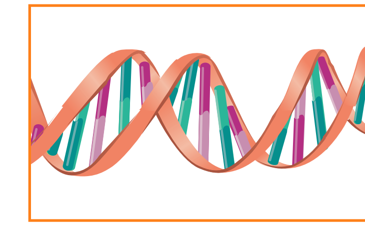
**1935 Nobel Prize in Chemistry** - One year after the death of her mother, Irène Joliot-Curie and her husband Frédéric Joliot shared the Nobel Prize for the discovery of artificial radioactivity.



## Women in Physics

**Rosalind Franklin (1920 – 1958)**

Rosalind Franklin is known for her contributions to the double helix model of the DNA molecule.



**Lisa Meitner (1878 – 1968)**

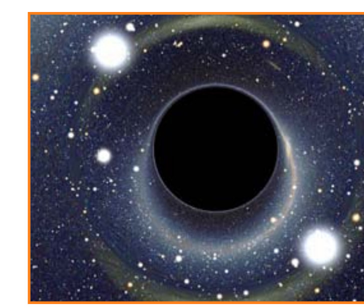
Lisa Meitner was the first scientist to discover nuclear fission. Although her work led to the eventual development of nuclear weapons, Meitner did not want to have any part in creating such a destructive weapon.

**Chien-Shiung Wu (1912 – 1997)**

Chien-Shiung Wu was a nuclear physicist. She was the first woman to teach Physics at Princeton University, where she earned an honorary doctorate. She later taught at Columbia University. She was the first woman president of the American Physical Society.

**Renata Kallosh (1943 - )**

Renata Kallosh is a physics professor at Stanford University in California. Among other things, she is working on the quantum theory of black holes.



**Euphemia Lofton Haynes (1890 – 1980)**

Euphemia Lofton Haynes was the first African-American woman to earn a Ph.D. (doctorates degree) in Mathematics. She was a prominent educator in the Washington D.C. area throughout her life.

## Technology From Physics


plasma televisions


computers


mp3 players


cell phones


fiber optics


microwaves


radios


world wide web

Rourke's World of Science

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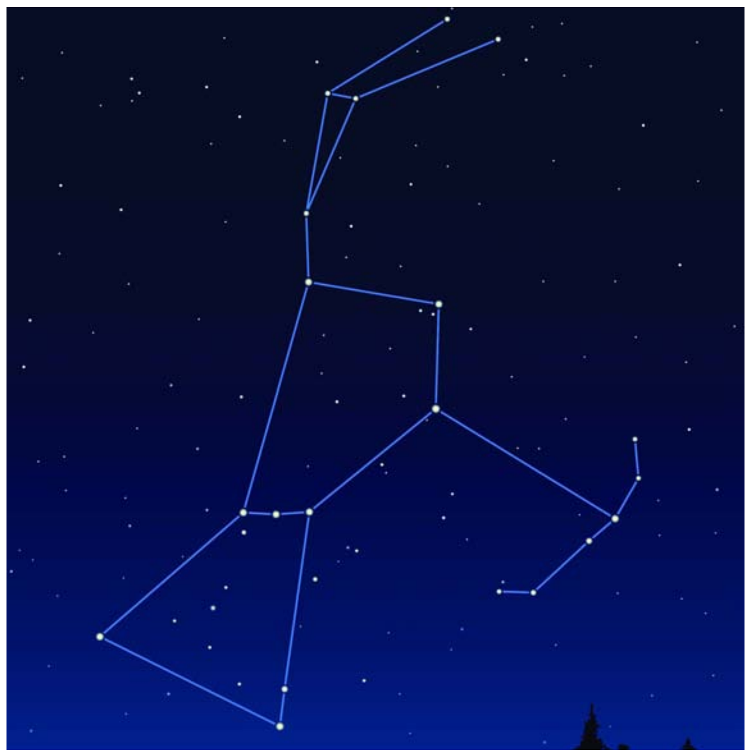
Volume 7

# Astronomy and Space



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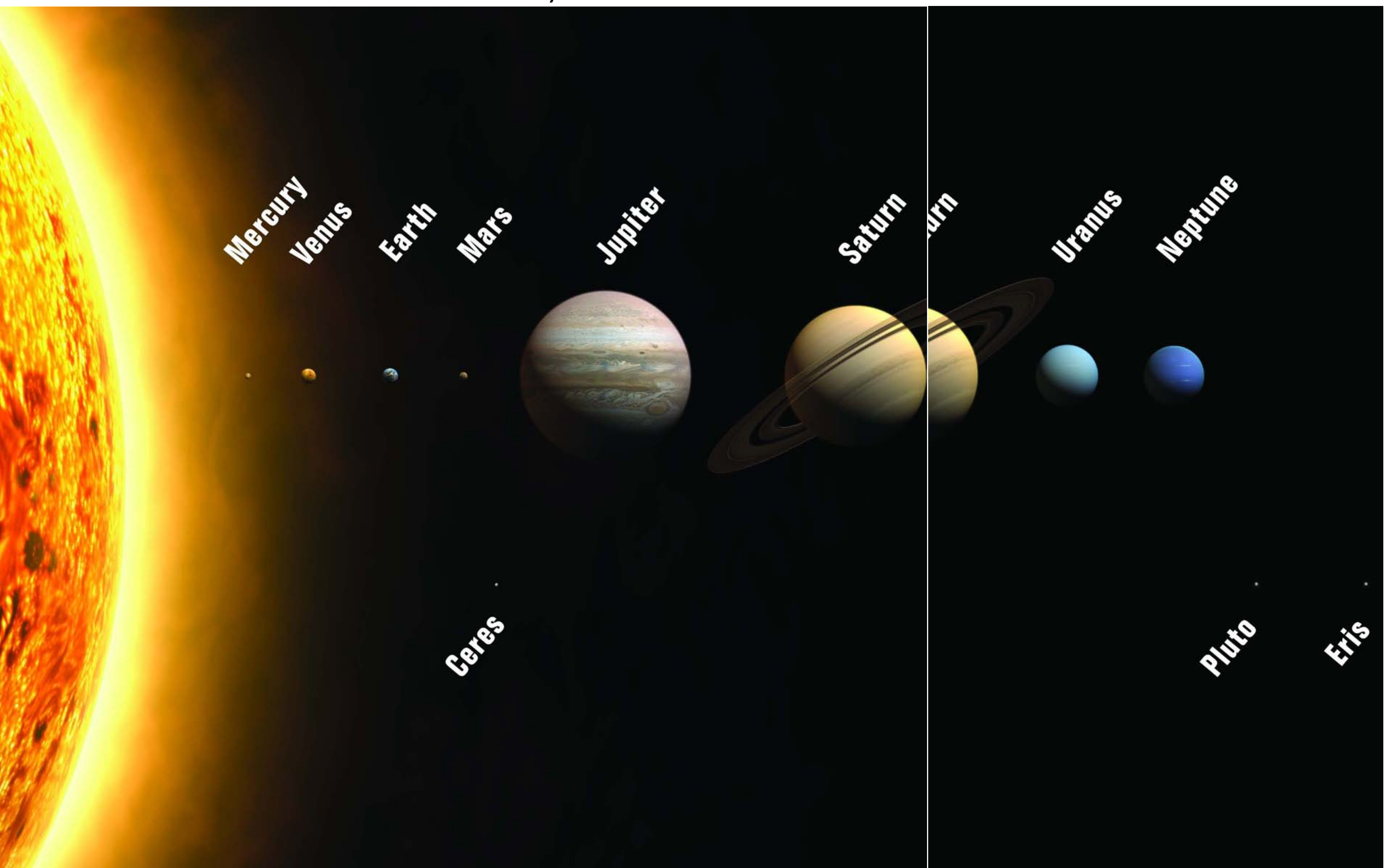
# Table of Contents

# What Is Astronomy?

Have you ever looked up in the sky and wondered what life would be like if you lived on Mars? Astronomy is the study of the universe, or outer space, and can help you find the answer to your question.

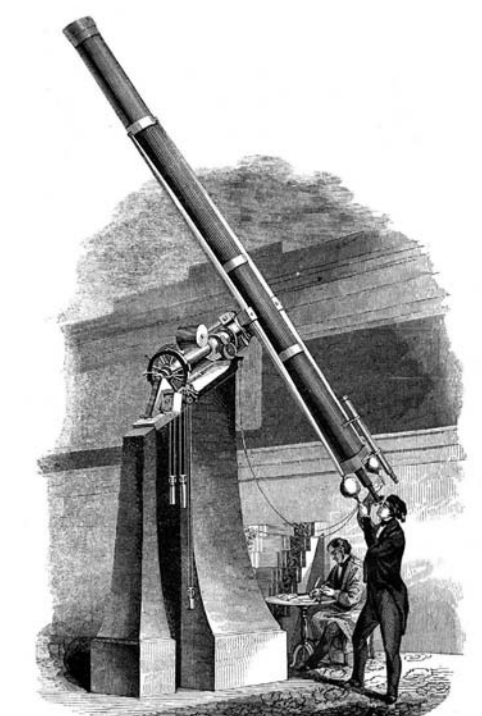
*The Solar System*




Astronomers study all of the objects in the sky outside Earth's atmosphere. Some of the things they study are the Sun, moons, stars, planets, galaxies, asteroids, and comets. New technologies such as the Hubble Space Telescope help astronomers make new discoveries about outer space.

***A star photographed by the Hubble Space Telescope. Dust particles can be seen swirling around the star.***

The science of astronomy is very old. Throughout Earth's history, people have been curious about what they saw in the sky. Different ideas developed about how the universe worked.



***This drawing shows an 1848 telescope.***

## Key Events in the Early History of Astronomy

| | |
|---|---|
| **280 B.C.** | Aristarchus thinks the Earth revolves around the Sun. He provides the first estimation of Earth-Sun distance. |
| **130 B.C.** | Hipparchus develops the first accurate star map and star catalogue with over 850 of the brightest stars. |
| **45 B.C.** | The Julian calendar, a purely solar calendar, is introduced to the Roman Empire. |
| **140 A.D.** | Ptolemy suggests the geocentric theory of the universe in his famous work, Mathematike Syntaxis. |
| **1054 A.D.** | Chinese astronomers observe a supernova in Taurus. |
| **1259 A.D.** | An observatory was built for the famous Persian astronomer, Nasir al-Din al-Tusi. |
| **1543 A.D.** | Copernicus publishes his heliocentric theory of the universe. |
| **1582 A.D.** | Pope Gregory XIII introduces the Gregorian calendar. |
| **1603 A.D.** | Johann Bayer introduces his Bayer designation of stars, assigning Greek letters to stars, still in use today. |
| **1608 A.D.** | Hans Lippershey, a Dutch spectacles maker invents the telescope. |
| **1609 A.D.** | Galileo uses a telescope for astronomical purposes. |
| **1656 A.D.** | Christian Huygens discovers Saturn's rings and Titan, the fourth satellite of Saturn. |
| **1659 A.D.** | Huygens notes markings on Mars. |
| **1666 A.D.** | Martian polar ice caps are noted by Cassini. |
| **1668 A.D.** | The first reflecting telescope was built by Newton. |
| **1675 A.D.** | While in Paris, Danish astronomer Ole Romer measures the speed of light. |
| **1675 A.D.** | Cassini discovers that Saturn's rings are split into two parts, the gap is called the "Cassini Division". |
| **1687 A.D.** | Newton publishes his theory of gravity. This is viewed as the start of Modern Astronomy. |
| **1705 A.D.** | England Halley correctly predicts the return of a comet (Halley's comet) in 1758. |
| **1758 A.D.** | Johann Palitzsch observes Halley's comet as predicted by Halley in 1705. |
| **1781 A.D.** | Herschel discovers the planet Uranus. |
| **1781 A.D.** | Messier discovers galaxies, nebula and star clusters while looking for comets. |
| **1801 A.D.** | Piazzi discovers the first asteroid, Ceres. |
| **1840 A.D.** | J. W. Draper takes first pictures of the Moon. |
| **1846 A.D.** | Johann Galle observes and discovers Neptune. |
| **1877 A.D.** | Asaph Hall discovers Phobos and Deimos, the moons of Mars. |
| **1877 A.D.** | Schiaparelli observes the canals on Mars. |
| **1878 A.D.** | The Great Red Spot on Jupiter becomes prominent. |
| **1905 A.D.** | Albert Einstein introduces his special Theory of Relativity. |
| **1914 A.D.** | Robert Goddard begins practical rocketry. |
| **1916 A.D.** | Albert Einstein introduces his general Theory of Relativity. |



| | |
|---|---|
| **1923 A.D.** | Hubble shows that galaxies exist outside the Milky Way galaxy. |
| **1930 A.D.** | Clyde Tombaugh discovers Pluto. |
| **1931 A.D.** | Karl Jansky discovers cosmic radio waves. |
| **1937 A.D.** | The first radio telescope is built by Grote Reber. |
| **1957 A.D.** | Sputnik, the first manmade object to orbit the Earth, is launched by the Russians. |
| **1958 A.D.** | Explorer 1 is launched. This was the first U.S. satellite to orbit the Earth. |
| **1960 A.D.** | The field of archeoastronomy expands in England. |
| **1961 A.D.** | Yuri Gagarin becomes the first man in space. |
| **1962 A.D.** | John Glenn becomes the first American man to orbit Earth. |
| **1966 A.D.** | The first non crash landings on the Moon are by Luna 9 (Russian) and Surveyor I (U.S.A.). |
| **1969 A.D.** | Armstrong and Aldrin walk on the Moon as part of the Apollo 11 mission. |
| **1970 A.D.** | The Russian Venera 7 becomes the first spacecraft to land softly on the surface of Venus. |
| **1972 A.D.** | The U.S. launches Pioneer 10, the first satellite destined for Jupiter. |
| **1974 A.D.** | The U.S. Mariner 10 probe transmits the first image of Mercury. |
| **1976 A.D.** | The U.S. Viking probes land on Mars. |
| **1977 A.D.** | The rings of Uranus are discovered. |
| **1978 A.D.** | Charon, the moon of Pluto, is discovered by James Christy and Robert Harrington. |
| **1980 A.D.** | Voyager 1 sends back to Earth the first images of Saturn and its rings. |
| **1986 A.D.** | Voyager 2 closes in on Uranus. |
| **1986 A.D.** | The Space Shuttle Challenger breaks apart after launch. |
| **1990 A.D.** | The Hubble Space Telescope is put into orbit from space shuttle Discovery. |
| **1992 A.D.** | The Vatican, under Pope John Paul II, announces that the Catholic Church erred in condemning Galileo's work that proved that the work of Copernicus was valid, mainly that the planets circle the Sun and not the Earth. |
| **1994 A.D.** | The Comet Shoemaker Levy crashes into Jupiter. |
| **1995 A.D.** | The Galileo space probe reaches Jupiter. |
| **1996 A.D.** | The Comet Hyakutake is discovered by Yuji Hyakutake. |
| **1997 A.D.** | The Mars Pathfinder lands on the Red Planet. |
| **1997 A.D.** | Cassini begins its journey to Saturn. |
| **1998 A.D.** | The Lunar Prospector reaches the Moon. |
| **1998 A.D.** | Construction begins on the International Space Station. |
| **1998 A.D.** | The Galileo space probe discovers the origin of Jupiter's Rings. |
| **1998 A.D.** | John Glenn returns to space after 36 years. |
| **1999 A.D.** | Scientists discover the real Hubble Constant. |
| **1999 A.D.** | Chandra X-ray Observatory is put into orbit. Col. Eileen Collins becomes the first woman shuttle commander. |
| **1999 A.D.** | NASA loses the Mars Climate Orbiter and the Mars Polar Lander. |
| **2000 A.D.** | The space shuttle Endeavor makes a detailed, global map of Earth. |
| **2000 A.D.** | The NEAR spacecraft reaches asteroid Eros. |
| **2000 A.D.** | New evidence is found for water on Mars. |

# Views of the Universe

Long ago, before the invention of the telescope, people had a much different idea of what the universe was like. The two major views of the universe through the course of history are the geocentric view and the heliocentric view.

## The Geocentric View

In 140 A.D. a Greek astronomer named Ptolemy wrote that the Earth was the center of the universe. He thought all the stars, the Sun, and the Moon revolved around it. This made sense because that is how things looked in the sky from Earth. We call Ptolemy's theory the geocentric view. It is derived from *geo* (Earth) and centric (center). Astronomers believed the geocentric view for 1,500 years until 1543.

***Claudius Ptolemaeus, is known in English as Ptolemy.***

## The Heliocentric View

About 500 years ago, Copernicus found that the Earth and other planets revolve around the Sun. His theory was published in1543. We call Copernicus's theory the heliocentric view because *helios* means sun. Astronomers still base their understanding of the Solar System on Copernicus's heliocentric view.

### Nicolaus Copernicus

Getting to know...

Nicolaus Copernicus was born in 1473 in what is now Poland. His father died when Copernicus was only ten. His uncle, a Catholic bishop, raised him. In 1491, he became interested in studying the skies. He collected many books on astronomy and studied with famous astronomers.

In 1513, Copernicus built an observatory. He realized that Earth and the other planets revolve around the Sun. This is the heliocentric view. Many people did not believe him. The Catholic Church banned his ideas for the next three hundred years.

We call Copernicus the father of modern astronomy even though Greek, Indian, and Muslim astronomers before him believed that the Sun was the center of the solar system as well.



We now know that our solar system is part of a bigger universe, or cosmos. The size of the universe is unimaginable. It includes all the matter, energy, and space in all the galaxies.

# How People Used the Skies

People have always found the skies fascinating. They found the skies helpful, too. They developed calendars based on the Moon and Sun. They used the stars and midday Sun to navigate.

## The Lunar Calendar

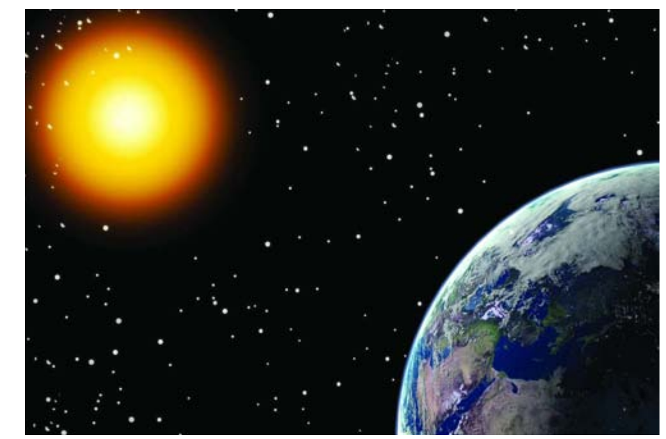
Early on people noticed that there were 29 1/2 days between two full Moons. They created a 354 day calendar. Based on the phases of the Moon, they divided the calendar into12 lunar months.

***The lunar calendar is based on the phases of the Moon.***

Today, the Islamic calendar is still a purely lunar calendar. It has twelve months based on the Moon's movements.

## The Solar Calendar

Later calendars used the movements of the Sun rather than the Moon. The ancient Egyptians created the first 365 day solar calendar. The ancient Romans made adjustments and added one extra day every four years. Do you know what we call these longer years? Yes, they are leap years.



***Based on the heliocentric view, the Earth revolves around the Sun.***

### Words to Know

**observatory** (uhb-ZUR-vuh-tor-ee): a building that has telescopes and other instruments astronomers use to study the sky

**revolve** (ri-VOLV): to orbit around an object

**theory** (THIHR-ee): an idea that explains how or why something happens

**universe** (YOO-nuh-vurss): everything that is in space including the Earth, stars, and planets

## The Gregorian Calendar

Even with the improvements, the calendars being used were still not quite right. In 1582, Pope Gregory XIII (the 13th) corrected the problems. He ordered that three leap years should be skipped every 400 years. We use the Gregorian calendar today, named for Pope Gregory. It is the most widely used calendar in the world.

## The Days of the Week

You may wonder why there are seven days in a week. No one seems to agree on any single reason for a seven day week. But they do agree on the origins of each day's name.

In English, three days (Saturday, Sunday, and Monday) are named for objects in the solar system. The other four days (Tuesday, Wednesday, Thursday, and Friday) are named for Norse gods. See the chart below.

## Navigation

Ancient people learned to navigate by using the Sun and stars. Using the stars and Sun people could find their north-south position when crossing deserts and seas where there were no landmarks to guide them.

During the day, the Sun's movement in the sky guided them. At night, they used a star called Polaris, or the North Star.

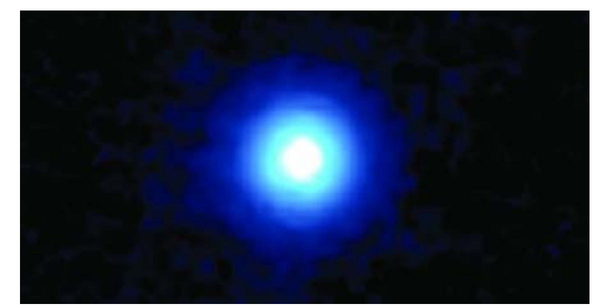
*All stars are fixed in a set position in the sky relative to each other. It is the movement of the Earth that makes the stars and the Sun appear to move across the sky.*

| Named After | Originally | Now |
|---|---|---|
| The Sun | Sun's Day | Sunday |
| The Moon | Moon's Day | Monday |
| Tiw, Norse God of war | Tiw's Day | Tuesday |
| Woden, German for Odin, chief Norse god | Woden's Day | Wednesday |
| Thor, Norse god of thunder | Thor's Day | Thursday |
| Frigg, the Norse goddess of love | Frigg's Day | Friday |
| Saturn | Saturn's Day | Saturday |

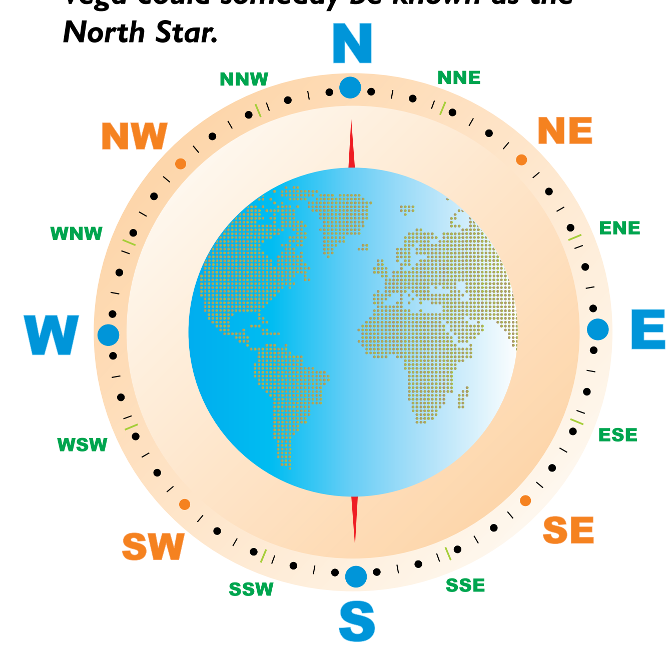


Polaris is always due north. Earth's North Pole points to Polaris. Over the next 13,000 years, Earth's North Pole will slowly shift to point to a star called Vega.

*Polaris, is also known as the North Star.*



*Vega could someday be known as the North Star.*




*Earth's North Pole points to Polaris, but is slowly moving and will eventually point to Vega.*

Over time, people developed different tools to make navigation using the Sun and stars easier.

*The compass is one of the most important navigational tools ever invented.*


Many of the tools were difficult to use and caused blindness. People had to look directly into the Sun to use the tools properly. In 1595, John Davis invented the back-staff. It prevented blindness because the user stood with his back to the Sun.

### WORDS to KNOW

**lunar** (LOO-nur): to do with the moon

**navigate** (NAV-uh-gate): to travel using maps, compasses, or the stars to guide you

**solar** (SOH-lur): to do with the Sun

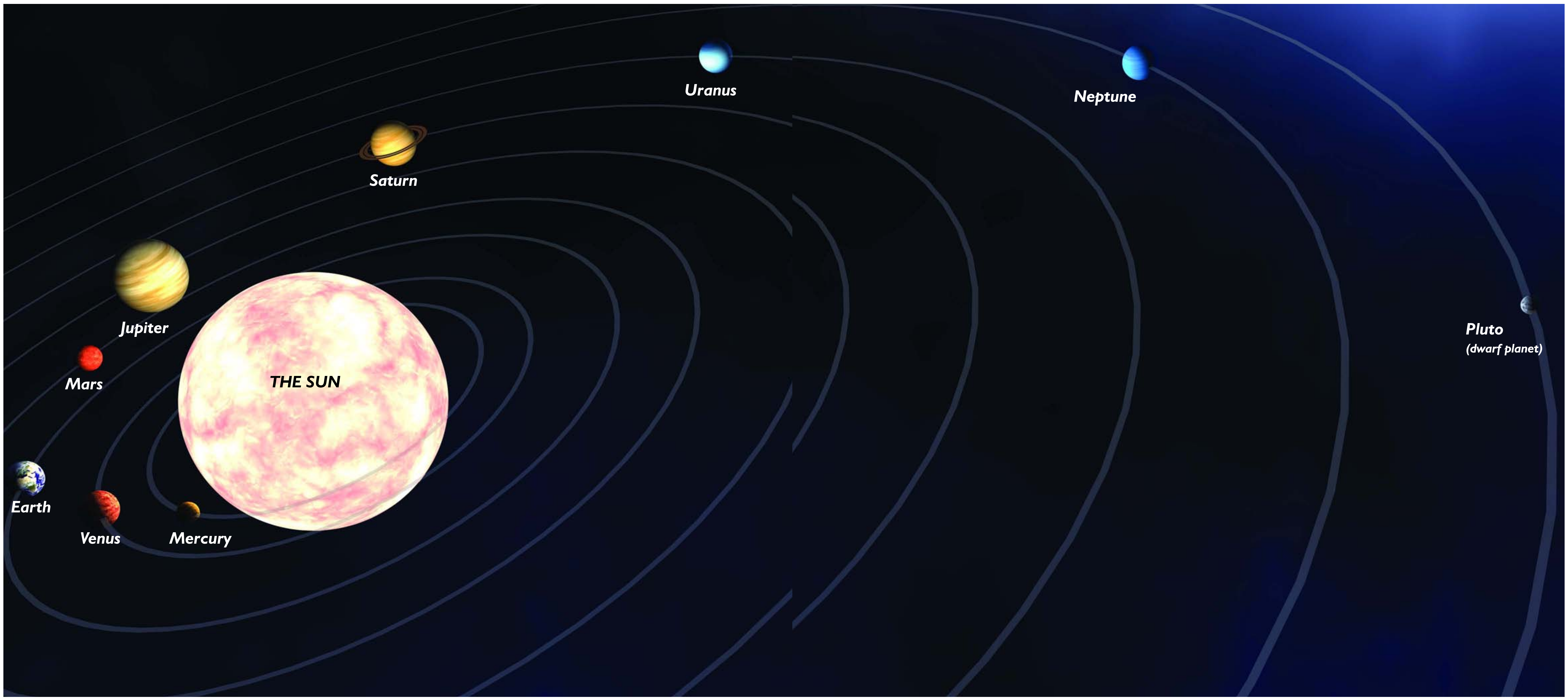
# The Solar System

A solar system is a group of planets and one or more stars. Our solar system has just one gigantic star, the Sun. It also has eight planets and three dwarf planets. Many planets have their own moons. There are also thousands of asteroids, meteoroids, and comets.



Gravity from our huge Sun holds the solar system together. Planets, asteroids, and comets revolve around (orbit), the Sun. moons orbit some of the planets.

A year for a planet is the amount of time it takes the planet to make one complete revolution around the Sun. The planets also rotate on an axis. One day on a planet is the time it takes for the planet to make one complete rotation (360 degrees) on its axis. It takes Earth about 24 hours to complete one rotation.



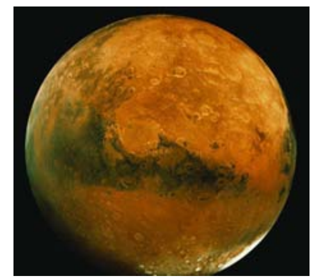
### Inner Planets

There are inner and outer planets. Mercury, Venus, Earth, and Mars are the inner planets. They orbit close to the Sun. The inner planets are very rocky. They are smaller than the outer planets. An asteroid belt separates the inner planets from the outer planets.


Mercury

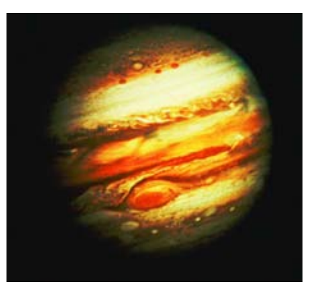

Venus


Earth

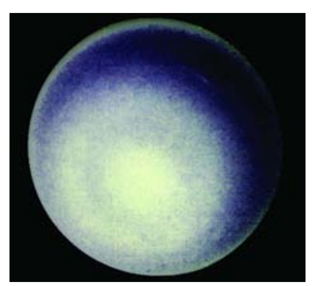

Mars

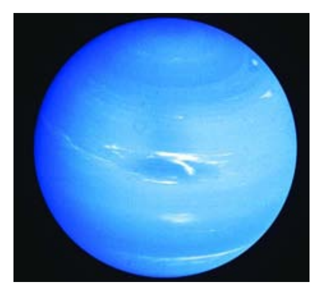
### Outer Planets

Jupiter, Saturn, Uranus, and Neptune are the outer planets. They orbit far from the Sun. The outer planets are all much larger than the inner planets. We call the outer planets the gas giants because they are made mostly from gasses.


Jupiter


Saturn

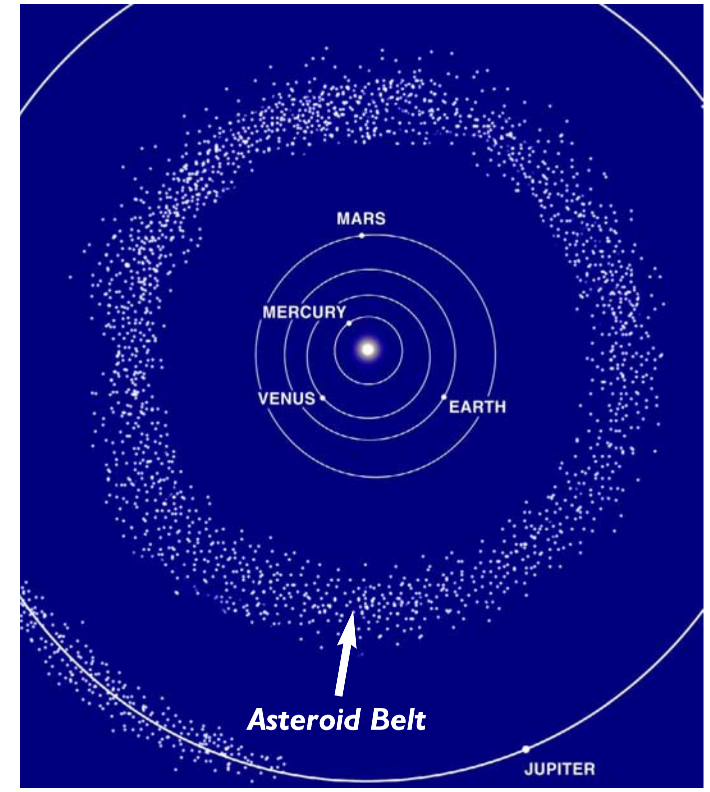

Uranus


Neptune

Are you wondering about Pluto? In the past, we thought Pluto was a planet but astronomers now classify it as one of the dwarf planets. The other dwarf planets are Ceres and Eris. Ceres and Eris are both large asteroids. Astronomers discovered Eris in 2005. Eris is larger than Pluto and is even farther away from the Sun.


*Pluto and its moons.*

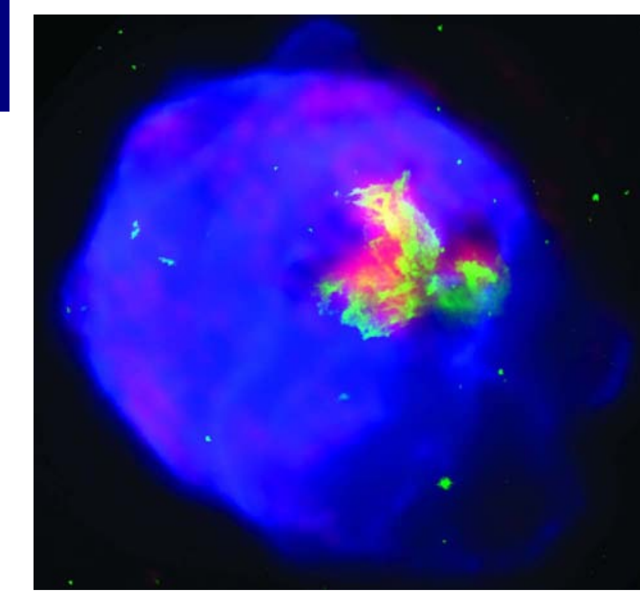





## The Origins of Our Solar System

Where did the solar system come from? Many astronomers believe it began as a cloud of dust and gas. Nearly 5 billion years ago, a nearby star may have exploded. The explosion caused the cloud to collapse and spin into a disk. Gravity made the dust and gas pull together into the center of the disk. The force of gravity caused great heat and pressure. Nuclear reactions occurred. These reactions caused the Sun to shine for the first time.


*The solar system may have been created from a cloud of gas and dust.*


*A supernova is a particular type of exploding star. The core of the star collapses and releases a tremendous amount of energy into space.*

The rest of the solar system also came from that cloud. The dust and gas formed into hot clumps. The clumps began orbiting the Sun. As they grew bigger, they became planets and moons.

Many planets and moons still have scars from the formation of the early solar system. Impact craters are holes in the ground that form when material from space slams into a planet, or sometimes even a moon.

*The Barringer Crater is a gigantic hole in the middle of the Arizona desert that formed when a meteor crashed to Earth.*

All elements that make up the Sun and planets came from the ancient dust and gas. This includes all the plants and animals on the Earth. Scientists believe that even the atoms that make up your body are as old as the stars.

### WORDS to know

**atom** (AT-uhm): the smallest part of an element

**axis** (AK-siss): the imaginary line going through the middle of a planet or other object that it rotates around

**nuclear** (NOO-klee-ur): to do with the energy created by splitting atoms

**revolve** (ri-VOLV): one object moves around or orbits another object

**rotate** (ROH-tate): an object turning around and around its center point or axis

## The Sun

Even though it is 93 million miles away, the Sun is the nearest star to Earth. In comparison to other stars, the Sun is a medium sized star. All stars, including the Sun, are balls of exploding gas. You might think of stars as having points like the ones we draw but stars are shaped more like a ball (sphere).

*The Sun heats the land, ocean, and air.*

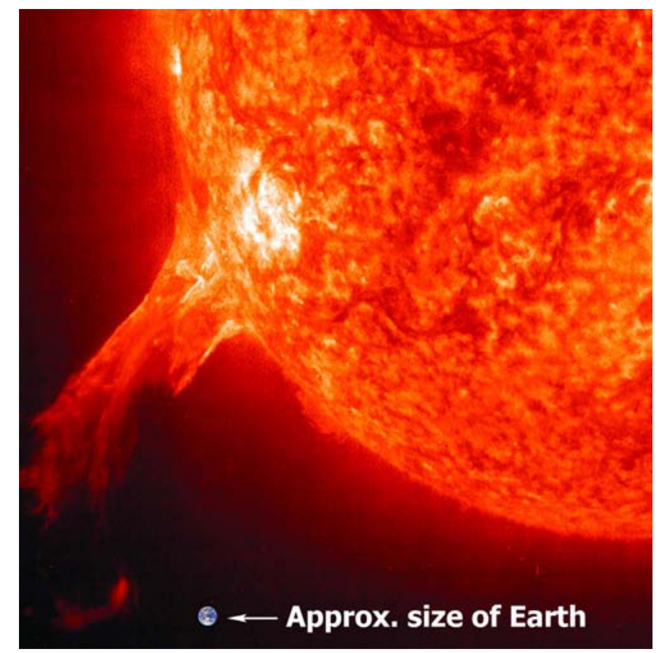
The Sun is the center of our solar system. Another name for the Sun is Sol.

Most of the light and heat on Earth comes from the Sun. Without that heat source, life on Earth could not exist. Scientists believe that eventually changes in the Sun will make life on Earth, as we now know it, impossible.



### Size

Compared to the Earth, the Sun is huge. It is the largest object in our solar system. The Sun's diameter is over 864,432 miles (1,392,000 kilometers). That is nearly 109 Earths across. It would take 1,300,000 Earths to fill up the Sun.




*If the Sun was the size of a basketball, the Earth would be about 1/16 of an inch (2.2 millimeters).*

Because it is so huge, the Sun exerts a lot of gravity. This force holds the planets in orbit.

### The Sun's Core

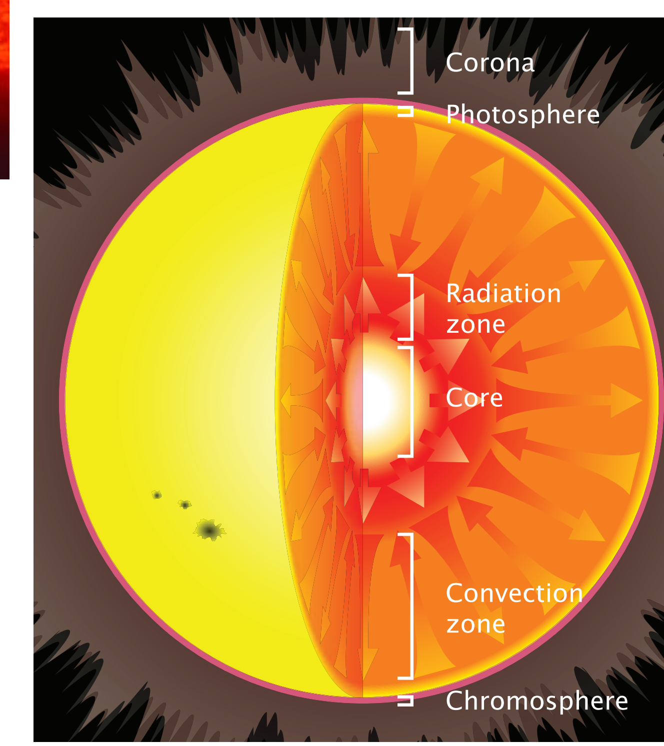
The center (core), of the Sun creates solar energy. In the core, temperatures and pressures are very high. This makes nuclear reactions occur. It takes a million years for energy made in the core to reach the surface. The Sun releases its energy as heat and light.

### The Sun's Outer Layers

The photosphere is the top layer of the Sun's surface. This is where we find sunspots. Sunspots appear as dark green areas in the photosphere. Solar flares come from the sunspots. These bright arcs of hot gas can interfere with radio communications on Earth.

The chromosphere is above the photosphere. Light and solar flares pass through the chromosphere on their way out into space.

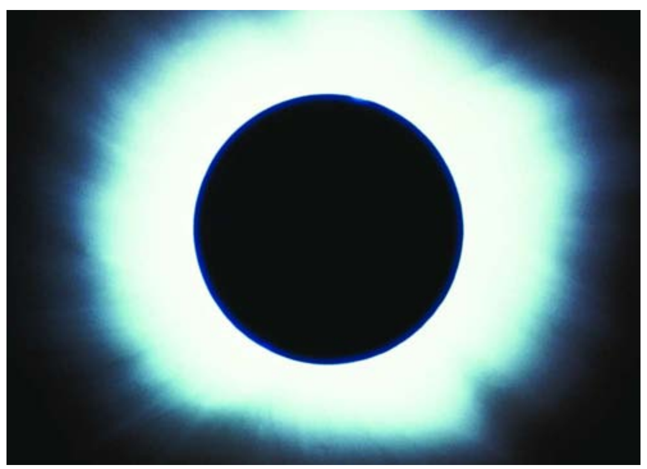
The corona is the outermost part of the Sun's atmosphere.




*The core temperature of the Sun is over 27 million degrees Fahrenheit (15 million degrees Celsius).*

During a solar eclipse, the corona is the part of the Sun that is seen shining around the Moon. A solar eclipse occurs when the Earth's Moon blocks out most of the light from the Sun.

Many people are tempted to look directly at the Sun during an eclipse. This is very dangerous. Even if you don't feel pain in your eyes, looking directly at the Sun can cause permanent eye damage or blindness.



*Welding goggles are the best eye protection for looking at an eclipse of the Sun.*

**WORDS TO KNOW**

**atmosphere** (AT-muhss-fihr): the mixture of gasses that surround a planet

**diameter** (dye-AM-uh-tur): a line going straight through the center of a circle, from one side to the other

**elliptical** (i-LIP-tik-uhl): having an oval shape

**gravity** (GRAV-uh-tee): the force of attraction of an object

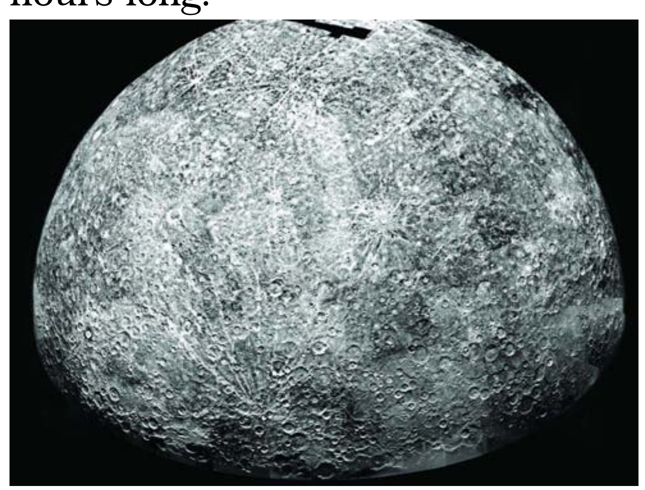
**sphere** (sfihr): a symmetrical geometric shape like a ball, all points on the shape are the same distance from the center

## Mercury

PROJECTS volume 10 7.3

Mercury is the closest planet to the Sun. It is a small planet, just a little bigger than Earth's Moon. Mercury has a diameter of about 3,029 miles (4,878 kilometers). It revolves, or orbits, around the Sun once every 88 Earth days. It has an elliptical orbit. An elliptical orbit is like a stretched out circle (oval shape). Its average distance from the Sun is about 36 million miles (58 kilometers).

Days are very long on Mercury. This is because the planet has a very slow spin. Mercury rotates once every 59 Earth days. One day on Mercury would be 1,416 hours long!



*The first telescopic observations of Mercury were made by Galileo in the late 17th century.*

### Temperature

Temperatures get very hot during the daytime. Surface



temperatures can reach over 752 degrees Fahrenheit (400 degrees Celsius). At night it gets very cold. It can reach below -279.4 degrees Fahrenheit (-173 degrees Celsius). Mercury has some of the highest and lowest temperatures in the solar system.

### Atmosphere

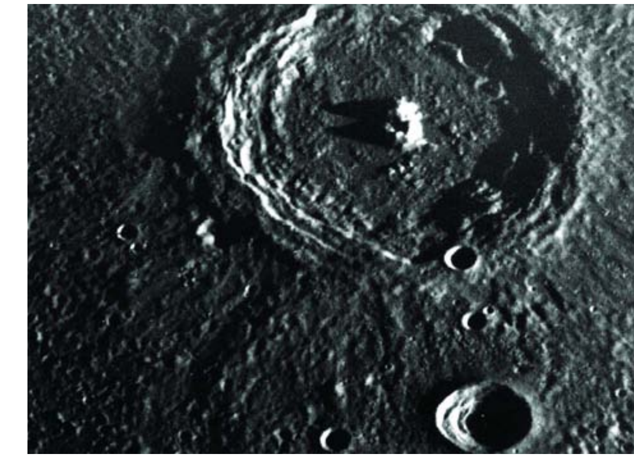
There is almost no atmosphere on Mercury. Because of the heat, any gasses on Mercury would burn up.

### Moons

Mercury has no moons.

### Special Features

The surface of Mercury is hard and rocky. Impact craters cover the surface. Mercury's craters formed a long time ago during the early history of the solar system.



*The craters on Mercury were formed when asteroids and comets struck the surface of the planet.*

Some craters are small. Others are very large.

Mercury has cliffs up to 1.8 miles (3 kilometers) high and hundreds of miles long.

### Exploration

The first spacecraft to visit Mercury was Mariner 10, in 1974. It took photographs of the planet. It found that Mercury has a weak magnetic field.

| Planet | Rotation on axis | Orbit around the Sun | Distance from the Sun | Number of moons |
|---|---|---|---|---|
| Earth | 24 hours | 365 Earth days | 93 million miles (149.6 million km) | 1 |
| Mercury | 1,416 hours | 88 Earth days | 36 million miles (58 million km) | 0 |

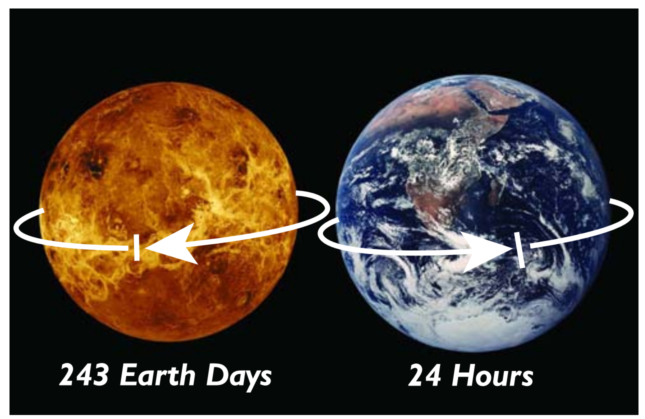
## Venus

Venus is the second planet from the Sun. Because it is so close to Earth, you can often see Venus in the sky at dusk or dawn, without the use of a telescope.

Sometimes we call Venus our sister planet because it is a lot like Earth. It is about the same size as Earth. Both planets have a near circular orbit around the Sun. A lack of craters shows that both planets formed about the same time.

*Venus and Earth are sometimes called sister planets.*

Although they are alike in many ways, Venus and Earth are different in some very important ways. Venus rotates in the opposite direction as Earth. Its spin is retrograde. That means it spins backward from the rotation of Earth and the other planets. On Venus, the Sun rises in the west and sets in the east. Venus rotates much slower than Earth. It takes about 243 Earth days for Venus to rotate one time. Another difference is that Venus has a very weak magnetic field.




*Venus has the slowest rotation period of all the major planets.*

The diameter of Venus is 7,516 miles (12,103 kilometers). Its average distance from the Sun is about 67 million miles (108 million kilometers). It takes Venus 225 Earth days to orbit the Sun. It might be a little confusing to live on Venus because one planetary year is shorter than one planetary day!

### Temperature

The surface of Venus is very hot. Temperatures on the surface can reach 880 degrees Fahrenheit (470 degrees Celsius) making it the hottest planet. Venus is far too hot to support life.

### Words to Know

**inactive** (in-AK-tiv): a volcano that is not currently active or erupting

**probe** (PROHB): a tool or robotic spacecraft used to explore something



### Atmosphere

The atmosphere of Venus is mostly carbon dioxide. Because the carbon dioxide is so thick, the pressure on Venus is 90 times that of Earth. The clouds in the upper atmosphere are made of tiny drops of sulfuric acid. The sulfuric acid forms thick clouds that reflect the Sun's rays making Venus shine brightly like a star.

*The clouds on Venus reflect the light from the Sun making the planet seem to shine like a star.*

### Moons

Venus has no moons.

### Special Features

The surface of Venus is rocky. It has many inactive volcanos. There are also many mountains, some of which are higher than the mountains on Earth.

### Exploration

The first spacecraft to successfully orbit Venus was Mariner 2, in 1962. Since then, many other spacecraft have flown by, orbited, or landed on its surface. The Magellan probe has provided maps of Venus.

| Planet | Planetary Day (rotation on axis) | Planetary Year (revolution around Sun) | Distance from the Sun | Number of moons |
|---|---|---|---|---|
| Earth | 24 hours | 365 Earth days | 93 million miles (149.6 million km) | 1 |
| Venus | 5,832 hours | 225 Earth days | 67.2 million miles (108.2 million km) | 0 |

## Earth

Earth, our home, is the third planet from the Sun. It is the only planet we know of that contains life. The diameter of the Earth is about 7,920 miles (12,754 kilometers). The Earth rotates one time every 24 hours. A planetary day on Earth is 24 hours. Earth's planetary year is about 365 days. It takes the Earth 1 year to revolve, or orbit, the Sun.

Earth's average distance from the Sun is about 93 million miles (150 million kilometers). We call this distance 1 astronomical unit, or AU. We sometimes measure distances to other planets in astronomical units.

### Temperature

The coldest parts of Earth can reach -129 degrees Fahrenheit (-90 degrees Celsius). The hottest parts can reach 136 degrees Fahrenheit (58 degrees Celsius). Most life on Earth will survive in places with temperatures somewhere in between.

WORDS TO KNOW

**environment** (en-VYE-ruhn-muhnt): the natural world of the land, sea, and air

**mission** (MISH-uhn): a group of people sent on a special assignment or job

**radiation** (ray-dee-AY-shuhn): the sending out of heat or light

*The lowest recorded temperature in Antarctica was -129 degrees Fahrenheit (-89 degrees Celsius) recorded in 1983.*

*The hottest temperature ever recorded in the United States was in Death Valley, California. (shown above) The 134 degrees Fahrenheit (57 Degrees Celsius) temperature was just 2 degrees Fahrenheit (1 degree Celsius) cooler than the hottest in the world. It was recorded in El Azizia, Libya.*

### Atmosphere

The Earth's atmosphere is made mainly of nitrogen and oxygen. Our atmosphere has more oxygen than any other planet's atmosphere. When people talk about the air, they are really talking about the atmosphere. It is the perfect mix of gasses to support life.

The atmosphere keeps temperatures from getting too high or too low to support life. It also helps keep out harmful radiation from the Sun.



*A view from space shows the Earth's land and water.*

### Special Features

The Earth is the only planet with lots of water. Water covers two thirds (2/3) of the Earth. The amount of water on Earth stays about the same. Other planets may have only tiny amounts of ice or steam. Without water, there would be no life on Earth.

*The oceans of the Earth are all connected and take up about 70% of the Earth's surface.*

The Earth orbits the Sun in a near perfect circle. This helps keep temperatures from getting too high or too low. About 1.5 million types of animals and plants live in this perfect environment.

### Exploration

Even though we live on Earth and explore it every day, there are things about Earth that we can learn from space. Space exploration began by looking at our own planet.

In 1957, Sputnik was the first spacecraft to orbit the Earth. Since then, thousands of spacecraft have studied the Earth from space. Today satellites send information back to Earth that can help us in our daily lives. Meteorologists, more often called weather forecasters, use information from satellites to study and predict the weather.

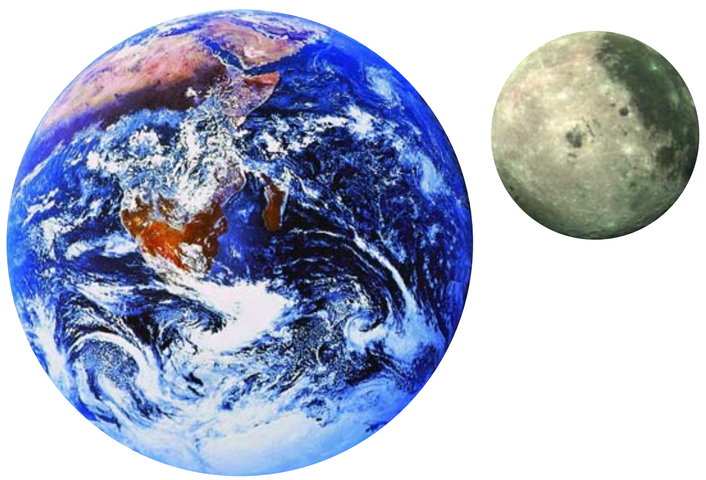
In 1969, the Apollo 11 spacecraft was the first manned mission to the Moon. It carried astronauts Michael Collins, Edwin "Buzz" Aldrin, and Neil Armstrong. Collins orbited the Moon during Armstrong and Aldrin's historic Moon walk.

*Astronaut Buzz Aldrin photographed by Neil Armstrong during the first Moon landing.*

## Earth's Moon

The Earth has one Moon. It is about 240,000 miles (384,000 kilometers) from Earth. Its diameter is about 2,159 miles (3,476 kilometers). The Moon is about one fourth (1/4) as big as the Earth.

The force of gravity ties the Moon to the Earth. The Moon revolves around (orbits), the Earth once every 27.3 days. It also takes the Moon 27.3 days to rotate one time. This means that the same side of the Moon always faces the Earth. Astronauts orbiting the Moon are the only humans to see the other side of the Moon in person. We only know what it looks like from photographs.



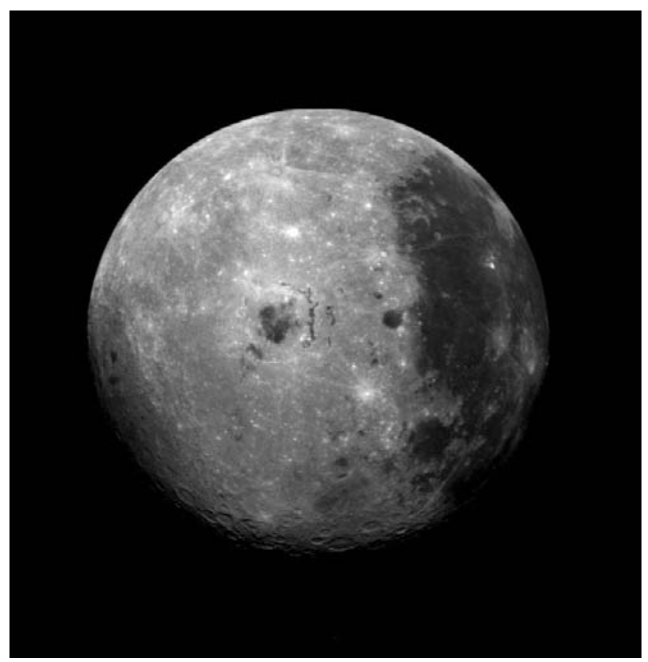
*The Moon is smaller than Earth which means the Moon's gravity is one-sixth of the Earth's gravity.*

Find out more

**There's Water on the Moon**

Millions of tons of ice are inside some of the craters on the Moon's poles. In the future, space missions might use the water for fuel, or to support life. Would you like to live in a space station on the Moon?

High tides are caused by the gravitational pull of the Moon and the Sun. The pull stretches the Earth's oceans into an ellipse with Earth in the center. The oceans of the Earth seem to bulge out to make the oval shape. Areas on the Earth near the bulge will experience a high tide. The high tide moves from west to east as the Earth rotates. High tides occur twice a day. This is because the water on the opposite side of the Earth from the Moon also bulges.

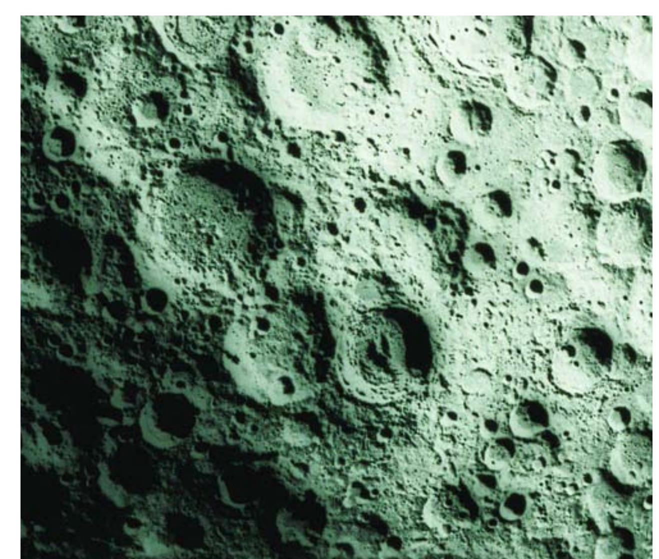


*In 1968, the Apollo 8 mission took three astronauts to the far side of the Moon. They described its appearance as the color of dirty beach sand.*



*The Earth rotates much faster than the Moon moves in its orbit which creates two high tides per day.*

Craters (holes), cover the Moon. Meteorites striking the surface of the Moon created these bowl-shaped holes.

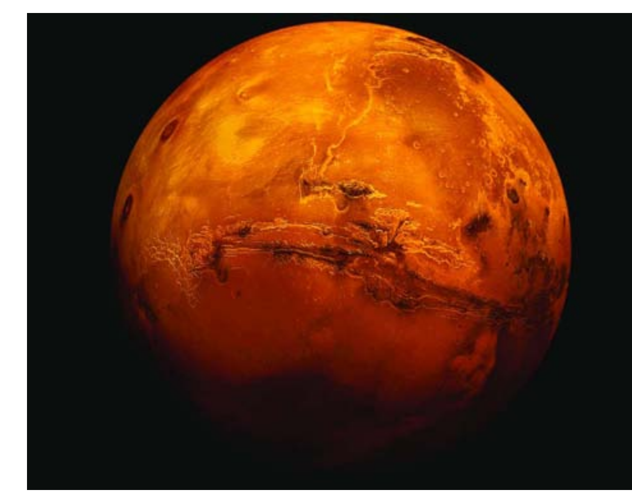


*Craters are formed by an asteroid, meteor, or comet crashing into the surface of the Moon. Most of the craters on the Moon are circular.*

## Mars

Mars is the fourth planet from the Sun. Sometimes we call it the Red Planet because of its red coloring. Mars looks red because of the pinkish color of its rocks, soil, and sky.

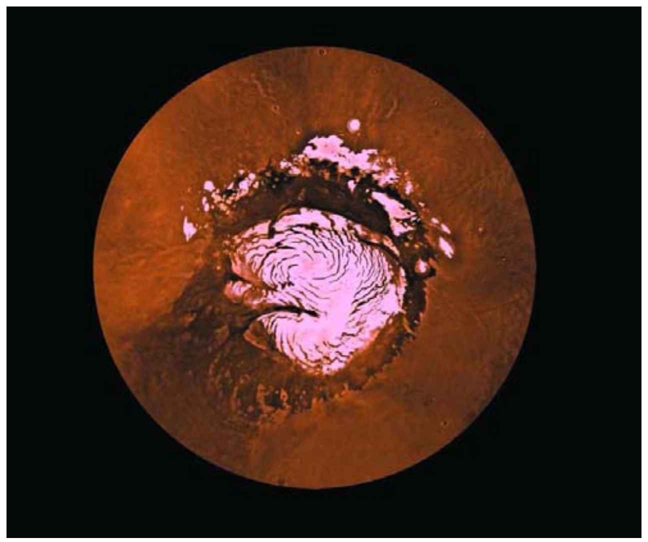
Mars is about half the size of Earth. It has a diameter of 4,219 miles (6,794 kilometers). Its average distance from the Sun is about 142 million miles (228 million kilometers). Mars orbits the Sun once every 687 Earth days. You can see Mars without a telescope. It appears as a bright red object in the night sky.



*Mars is called the Red Planet.*

Mars is more like Earth than any other planet. The length of a day on Mars is almost 24 Earth hours. Like Earth, Mars has polar ice caps.

During the winter on Mars, one of the poles is covered in snow and ice. At the same time, it is summer in the other hemisphere of the planet. When one ice cap gets bigger, the other ice cap gets smaller.



*The polar ice caps on Mars are made of frozen carbon dioxide and water.*

## Temperature

It is always cold on Mars. The highest temperature is about 32 degrees Fahrenheit (0 degrees Celsius). But Mars can get much colder than freezing. It can get as cold as -200 degrees Fahrenheit (-144 degrees Celsius).

Mars has an elliptical orbit. As it orbits, the planet gets colder as it travels farther away from the Sun.

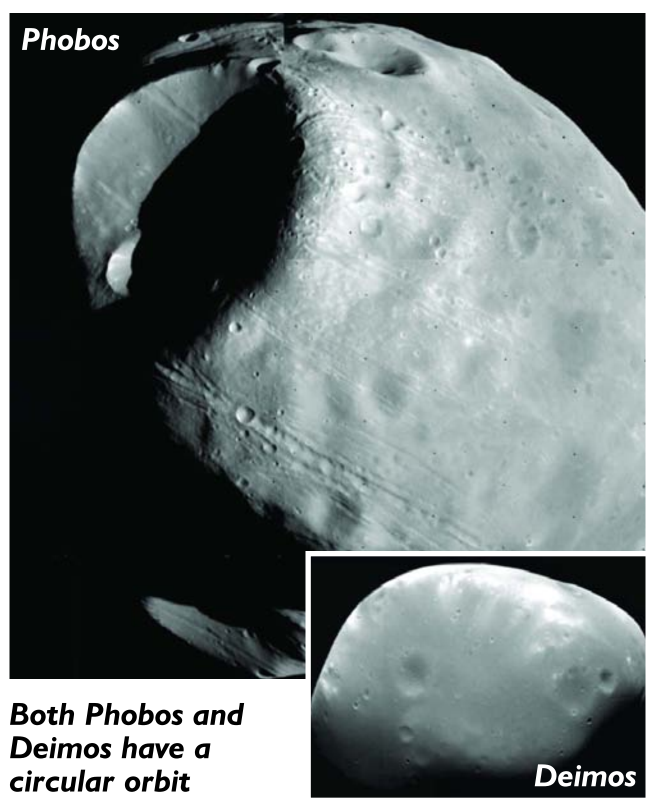
## Atmosphere

The atmosphere of Mars is 95% carbon dioxide. The atmosphere is very thin. Humans would not be able to breathe the air on Mars. The surface of Mars is also very dry. Sometimes, giant dust storms cover the entire planet.

If you lived on Mars, the sky would not look blue like the sky on Earth does. It would be reddish orange in color.

## Moons

Mars has two moons named Phobos and Deimos. They are both odd shaped and were probably asteroids at one time. Phobos is about twice as large as Deimos, but both are tiny compared to Earth's Moon. Phobos is only 17 miles (27 kilometers across).



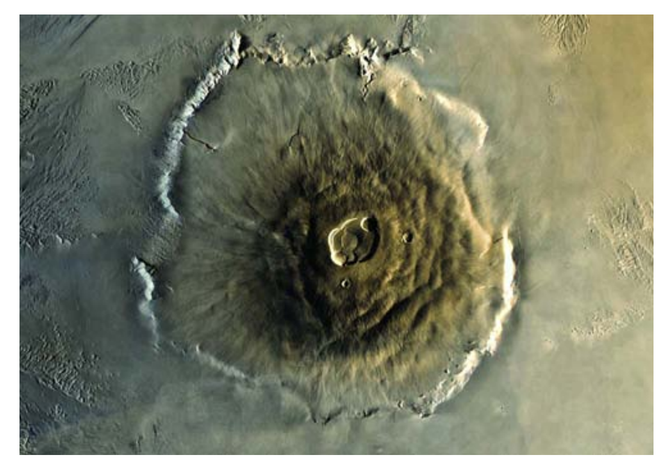

*Both Phobos and Deimos have a circular orbit around Mars.*



| Planet | Planetary Day (rotation on axis) | Planetary Year (revolution around Sun) | Distance from the Sun | Number of moons |
|---|---|---|---|---|
| Earth | 24 hours | 365 Earth days | 93 million miles (149.6 million km) | 1 |
| Mars | 24.6 hours | 687 Earth days | 141.6 million miles (227.9 million km) | 2 |

## Special Features

There are many volcanos on the surface of Mars. Most of them are in the northern regions of the planet. The biggest volcano is Olympus Mons. It is the largest volcano in the solar system. It is 342 miles (550 kilometers) wide and 17 miles (27 kilometers) high.



*Olympus Mons is the tallest known volcano and mountain in our solar system.*

Scientists believe that water once existed on the surface of Mars. A huge canyon called the Valles Marinares is evidence of water in Mar's past. It is over 5 miles (8 kilometers) long. Dried up flood plains and riverbeds also cover parts of the surface.

## Exploration

The first probe to go to Mars was Mariner 4, in 1965. Since then, many other spacecraft have visited the planet. Viking 1 and 2 were the first to land on the surface.

### Words to Know

**canyon** (KAN-yuhn): a narrow, deep river valley

**flood plain** (fluhd plane): an area of low land near a stream or river that easily floods

**hemisphere** (HEM-uhss-fihr): one half of a sphere such as the Earth or a planet

**ice cap** (eyess kap): a mound of ice that covers an area of land

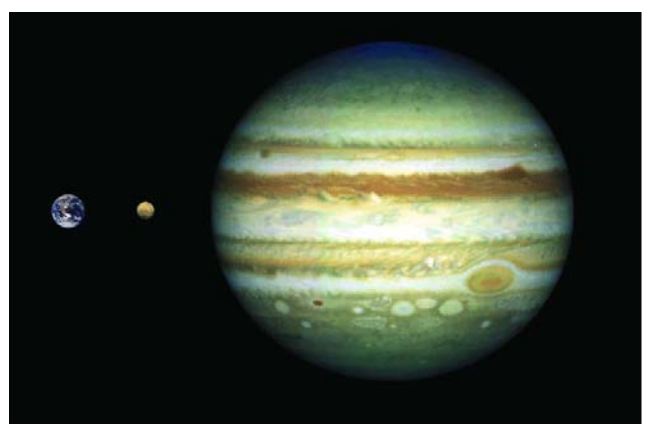
# Jupiter

Jupiter is the fifth planet from the Sun. It is the largest of all the planets in the solar system. It is also the first of the gas giants, or outer planets. All the outer planets are huge balls of gas. The other gas giants are Saturn, Uranus, and Neptune.

*Jupiter is the largest planet in the solar system.*

Jupiter is a huge planet. It has a diameter of over 88,679 miles (142,000 kilometers). Jupiter is 11 times larger than Earth. This giant planet also has a great mass. Jupiter has much more mass (matter) than all the other planets put together. If Jupiter were 13 times bigger, it would be classified as a star called a brown dwarf instead of a planet. That would make it another star in the solar system.

Jupiter takes more than 11 Earth years to orbit once around the Sun. The distance from the Sun to Jupiter is over 5 astronomical units or five times the distance of the Sun to the Earth. Jupiter spins very fast. It takes a little less than 10 Earth hours for Jupiter to rotate once.



*Many space probes have explored Jupiter. The piano-sized space probe New Horizons came within 1.4 million miles (2.3 million meters) of Jupiter on February 28, 2007.*

WORDS to KNOW

**mass** (mass): the amount of physical matter that an object contains

**pressure** (PRESH-ur): the force of one object pushing on another

**satellite** (SAT-uh-lite): a moon or other heavenly body that revolves around, or orbits, a larger heavenly body

## Temperature

You might think Jupiter would be a frozen planet because it is so far away from the Sun but it's not. Jupiter's core is very hot. It can reach temperatures of 43,000 degrees Fahrenheit (24,000 degrees Celsius). In contrast, Jupiter's atmosphere is cold. The clouds average -193 degrees Fahrenheit (-125 degrees Celsius).



## Atmosphere

The atmosphere of Jupiter is very deep. It is made mostly of hydrogen and helium. Layers of clouds cover the planet. These layers are thin bands made of hydrogen sulfide, ammonia, and water vapor. Clouds near the top of the atmosphere move very quickly. As bands pass each other, they sometimes create a storm. Giant lightning bolts come from the clouds during a storm.

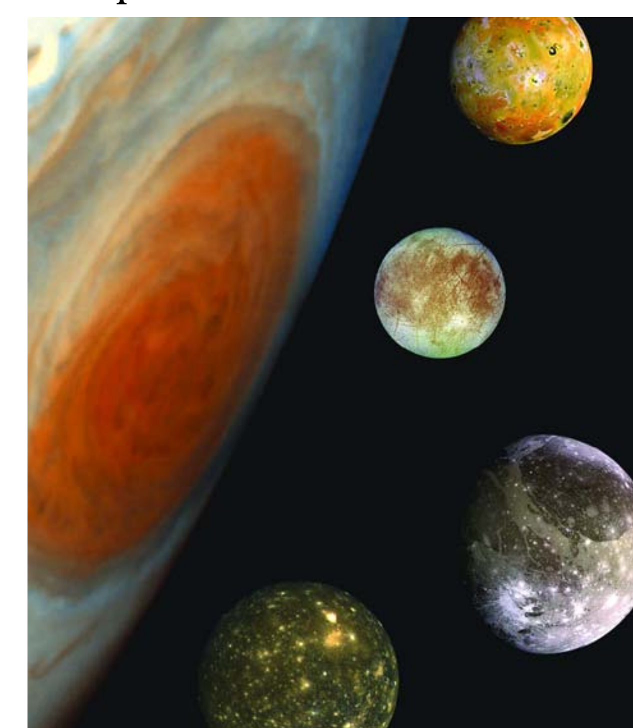
*Jupiter is covered with thick clouds that move quickly and may cause storms when they meet.*

A thin ring of dust orbits the planet far above the clouds. We cannot see the ring from Earth because it is so faint.

Jupiter creates a huge and powerful magnetic field that surrounds the planet and its moons. It is unlikely that there will ever be a manned space mission to Jupiter. The pressure on Jupiter is so great that it turns gas into liquid. That is enough pressure to crush a spaceship!

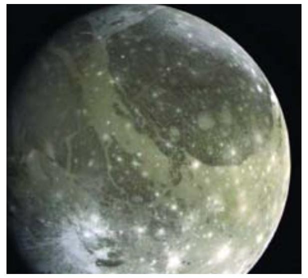
## Moons

Jupiter has sixty-three known moons. That is the highest number of moons identified for any planet. Four of these moons are very large. Galileo discovered them in 1610. We know them as the Galilean satellites. They are named Ganymede, Callisto, Io, and Europa.

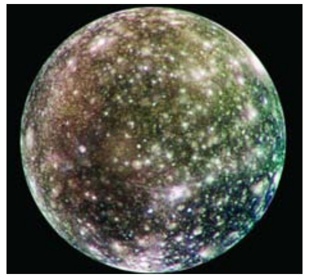


*One of Jupiter's moons, Ganymede, has a diameter greater than the planet Mercury.*

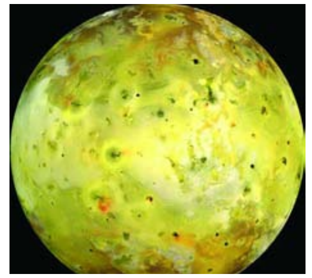
**Jupiter's Four Largest Moons**



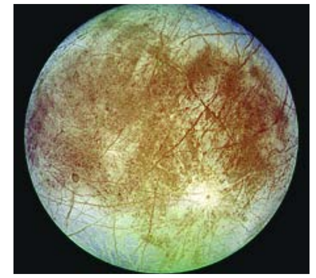
Ganymede is the largest moon in the solar system. Its diameter is 3,280 miles (5,262 km).



Callisto is covered in ancient craters. It is about the same size as Mercury.



Io is about the size of Earth's Moon. It has a violent surface with active volcanos.



Europa is the smallest of the four large moons. It has a smooth and icy surface. It is possible that below the ice there is a layer of liquid water.

The other moons of Jupiter are much smaller. Many of them are recent discoveries. Astronomers discovered more than half of Jupiter's moons after 1999.

### Special Features

There is a "Great Red Spot" on Jupiter. This spot is actually a giant storm. It is red from the gases that swirl within it. The spot has existed for hundreds of years. The storm is wider than three Earths!

*The Great Red Spot on Jupiter can be seen with an Earth based telescope.*

### Exploration

The first spacecraft to visit Jupiter was Pioneer 10 in 1972. Since then, Voyager 1 and 2 have flown past the planet. The Galileo

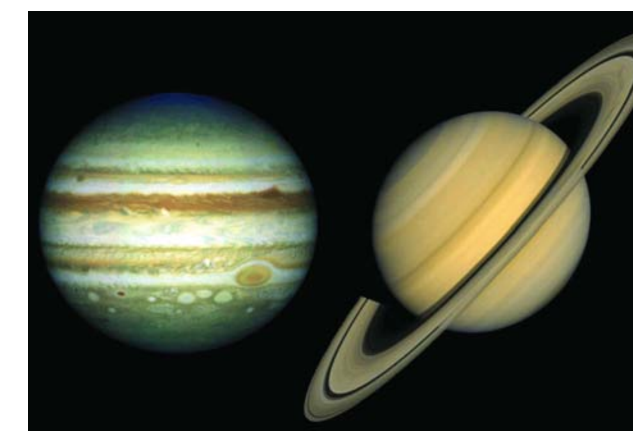


| Planet | Planetary Day (rotation on axis) | Planetary Year (revolution around Sun) | Distance from the Sun | Number of moons |
|---|---|---|---|---|
| Earth | 24 hours | 365 Earth days | 93 million miles (149.6 million km) | 1 |
| Jupiter | 9.8 hours | about 12 Earth years | 483.6 million miles (778.3 million km) | 63 (to date) |

probe began to orbit Jupiter in 1996. It studied Jupiter and its moons. We learned from data sent back to Earth from the Galileo probe that the winds are stronger on Jupiter than the winds on Earth.

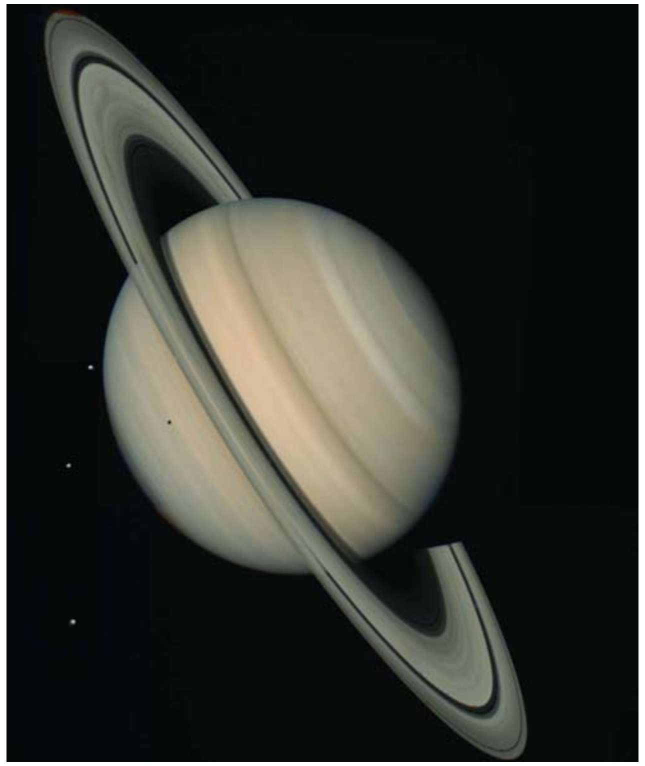
## Saturn

Saturn is the sixth planet from the Sun. It is the second largest planet in the solar system. Saturn is one of the four gas giant planets. It is the farthest planet that we can see without the help of a telescope. Saturn is a lot like its neighbor planet, Jupiter. Both planets are made mostly of gases and neither one has a solid surface.



*Saturn's atmosphere exhibits a banded pattern similar to Jupiter. Saturn's bands are much less visible than Jupiter's.*

Saturn has a diameter of about 74,085 miles (119,300 kilometers). It is nine times wider than the Earth. Saturn takes over 29 Earth years to revolve around (orbit), the Sun. Saturn's shape is like a ball squeezed flat on the top and bottom. Saturn spins very fast causing the flattened shape. It takes just over 10 Earth hours for the planet to rotate once.



*Saturn spins very fast causing it to appear flat on the top and bottom.*

## Temperature

The average temperature on the surface of Saturn is very cold. It is about -290 degrees Fahrenheit (-179 degrees Celsius).

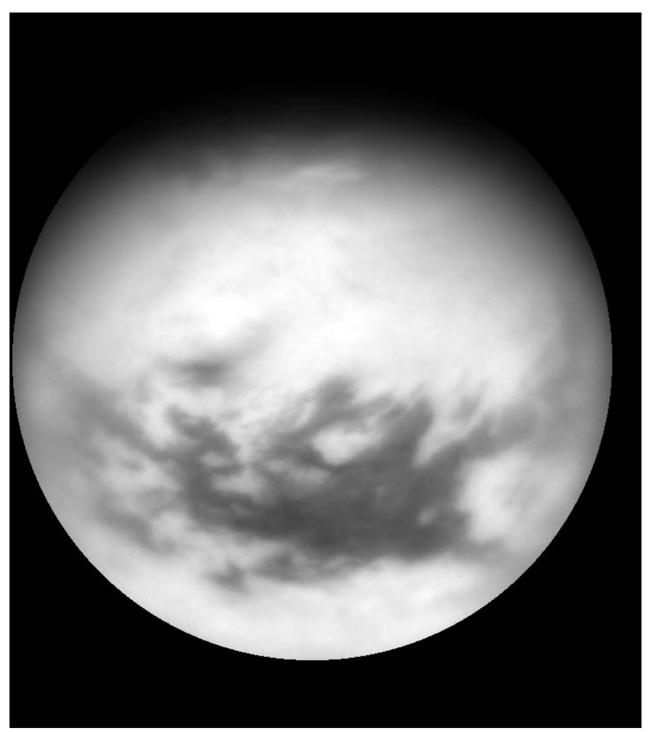
## Atmosphere

The atmosphere on Saturn is mostly hydrogen. There are also small amounts of helium and methane.

Strong winds blow across the surface of Saturn. These winds move very fast. Its clouds can move at about 1,100 miles per hour (1,800 kilometers per hour). There are wide bands of clouds. These clouds contain storms like those on Jupiter. A layer of haze covers the upper atmosphere. This haze makes Saturn look yellow.

## Moons

At least 56 moons orbit Saturn. Some are a few kilometers across. Others are the size of small planets. Titan is the largest moon of Saturn. It has a thick atmosphere covered in a brownish orange haze. Probes have detected nitrogen and methane on Titan. Many of Saturn's other moons have icy surfaces covered with craters. Some scientists believe that the moons of Saturn and Jupiter are where we might find evidence of simple life forms.



*Titan is the largest moon of Saturn.*

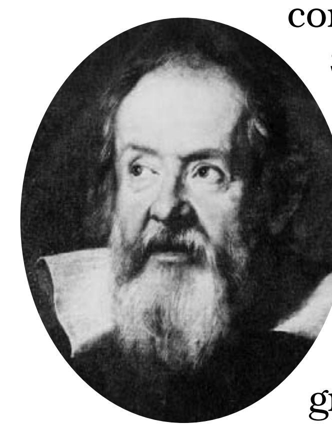


| Planet | Planetary Day (rotation on axis) | Planetary Year (revolution around Sun) | Distance from the Sun | Number of moons |
|---|---|---|---|---|
| Earth | 24 hours | 365 Earth days | 93 million miles (149.6 million km) | 1 |
| Saturn | 10.2 hours | about 29 Earth years | 886.7 million miles (1,427 million km) | 56 (to date) |

## Special Features

Many people call Saturn the jewel of the solar system or the ringed planet because of its giant, beautiful rings. Galileo discovered the rings in the 17th century.

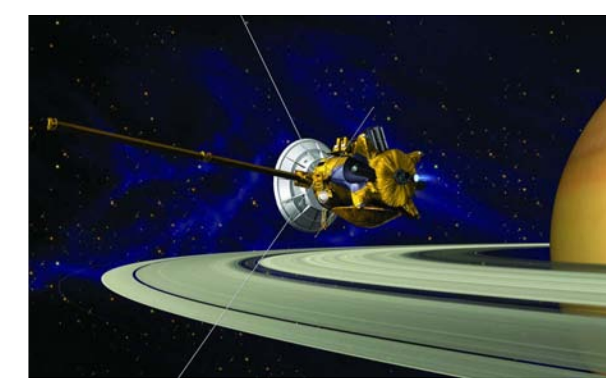
From Earth, we can see only three big rings. Saturn actually has thousands of small rings called ringlets. The rings are made mostly of ice particles, but also contain dust and rocks. Some particles are as small as dust. Others are the size of a house. Saturn's rings are about .6 miles (one kilometer) thick. The gravitational pull of Saturn's moons gives the rings their shape.



*Galileo Galilei*

## Exploration

The first spacecraft to visit Saturn was Pioneer 11, in 1979. Since then, Voyager 1 and 2 have flown past and studied the planet. In 2004, the Cassini space probe landed on the surface of Saturn's moon, Titan.



*The Cassini space probe landed on Titan.*

WORDS to KNOW

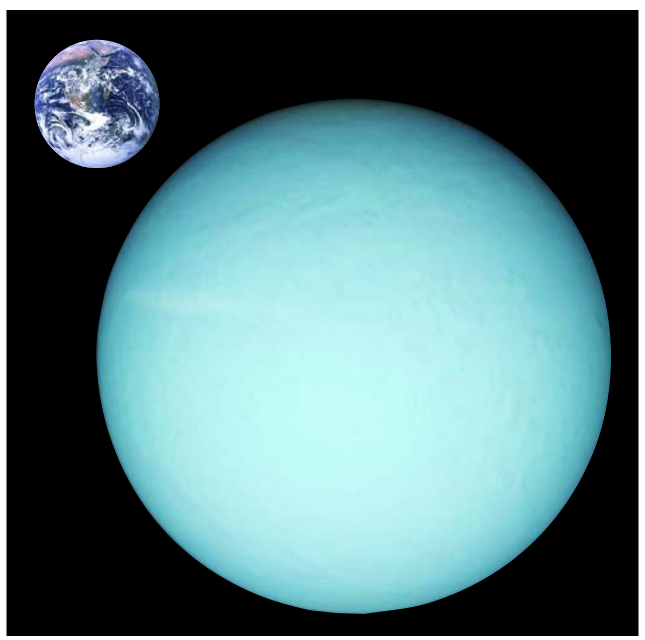
**band** (band): a narrow ring of material that goes around something

**haze** (hayz): smoke, dust, or moisture in the air that prevents you from seeing very far

# Uranus

Uranus is the seventh planet from the Sun. It is the third largest planet in the solar system. Like Jupiter and Saturn, it is one of the gas giants.

The diameter of Uranus is 32,168 miles (51,800 kilometers). It takes Uranus 84 Earth years to orbit the Sun. The planet rotates once every 17 Earth hours.



***The size of Uranus is roughly 14.5 times that of the Earth.***

Uranus does not spin around the Sun like the other planets. It is tipped on its side and rolls around the Sun like a barrel. We can't be sure, but scientists think Uranus is tipped because it was hit by a small planet or comet.

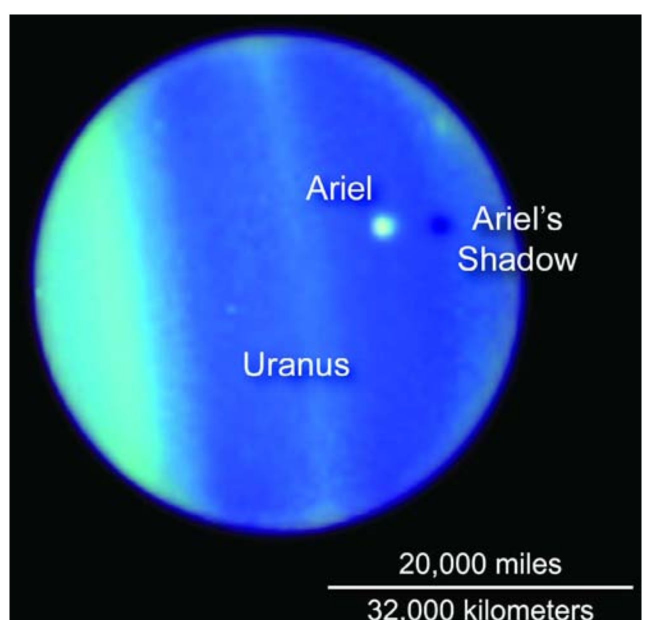
## Temperature

Because it is so far from the Sun, Uranus is very cold. The average temperature is about -355 degrees Fahrenheit (-215 degrees Celsius). Scientists do think that there is a layer of very hot water, ammonia, and methane on Uranus.

Like Earth, Uranus experiences changing seasons. Because Uranus is titled on its side, a season lasts a very long time. One season on Uranus can last more than 20 years!

## Atmosphere

The atmosphere on Uranus is made mostly of hydrogen, helium, and methane. Methane gives Uranus its blue-green color. Wind speeds on Uranus are much slower than on Saturn and Jupiter.




***The methane in the atmosphere gives Uranus its blue-green color.***



## Moons

Uranus has at least 27 moons. Most of them are very small. The five large moons are mostly made of rock and ice. Miranda is the most unusual moon orbiting Uranus. It looks like a combination of many different pieces. Scientists think it may have been shattered as many as five times. The surface has craters and deep grooves unlike any other moon.


***The moons of Uranus are the least massive of all the gas giants.***

## Special Features

In 1977, scientists discovered Uranus' 11 rings. Scientists observed a star blinking on and off as it passed behind the planet. The blinking was caused by the rings blocking the starlight. Pictures taken in 1986 from the Voyager 2 space probe showed that Uranus' rings are made mostly of dark dust.

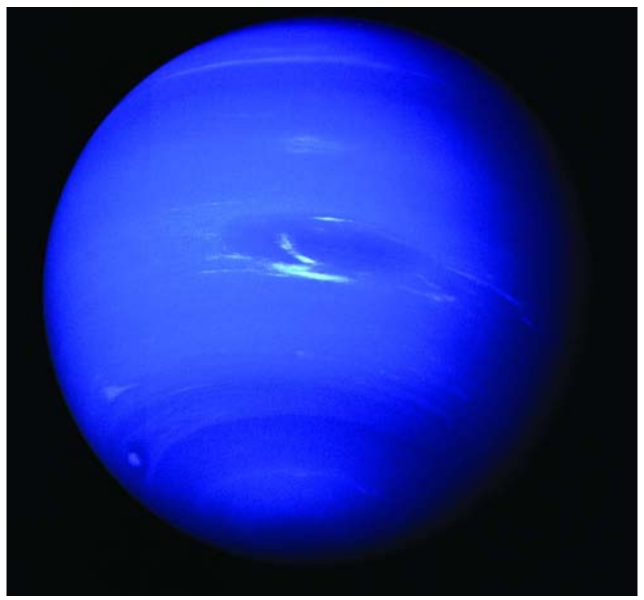
## Exploration

Even though the Voyager 2 space probe launched in 1977, it did not reach Uranus until 1986. This was the first space probe to reach this distant planet. Since that time, we have learned more about Uranus from the Hubble Space Telescope.

| Planet | Planetary Day (rotation on axis) | Planetary Year (revolution around Sun) | Distance from the Sun | Number of moons |
|---|---|---|---|---|
| Earth | 24 hours | 365 Earth days | 93 million miles (149.6 million km) | 1 |
| Uranus | 17.9 hours | 84 Earth years | 1,784 million miles (2,871 million km) | 27 (to date) |

# Neptune

Neptune is the eighth planet from the Sun. It is the smallest gas giant in the solar system. Neptune has a diameter of 30,740 miles (49,500 kilometers).



*Neptune is the smallest of all the gas giants.*

Neptune is very far away from the Sun. Its average distance from the Sun is 2.8 billion miles (4.5 billion kilometers). It orbits the Sun once every 165 Earth years. In 2011, Neptune will complete its first orbit around the Sun since scientists discovered it in 1846. A day on Neptune is just over 16 Earth hours.

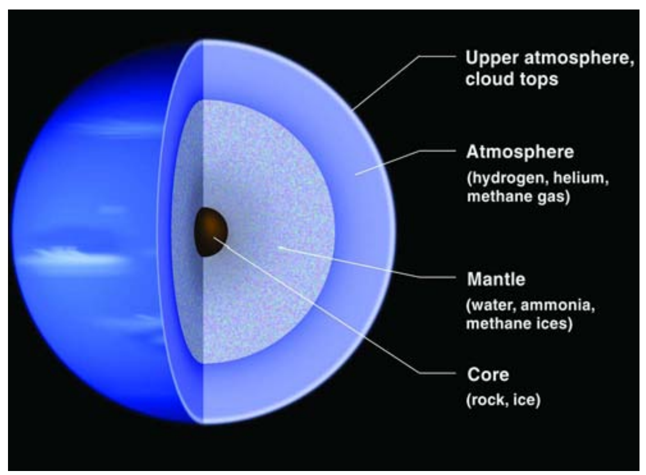
If you want to see Neptune from Earth, you must use a telescope. Even with a telescope, Neptune can be hard to see. It looks like a very small bluish ball.

## Temperature

Neptune has recorded some of the coldest temperatures in the solar system. It has an average temperature of -355 degrees Fahrenheit (-214 degrees Celsius).

## Atmosphere

The atmosphere on Neptune is made of hydrogen, helium, and methane. The methane in the upper layers gives the planet its blue color.

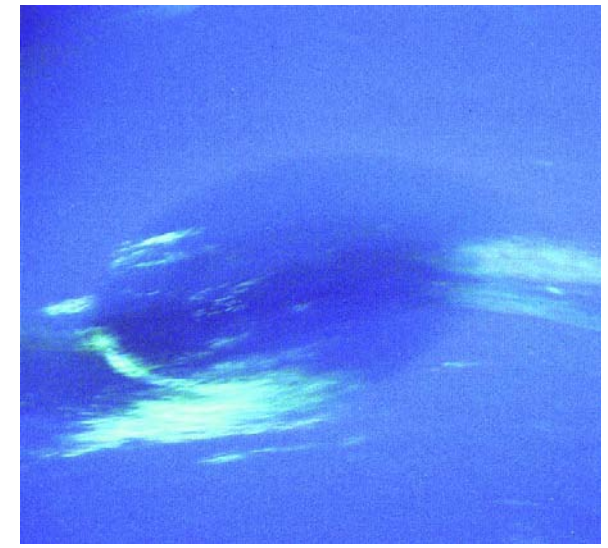



*The layers of Neptune are very similar to those of Uranus.*

A good nickname for Neptune would be the windy planet. The strong wind rips through the atmosphere at 1,200 miles per hour (2,000 kilometers per hour). These winds are the strongest of any planet in the solar system. Thin white clouds move around the upper atmosphere. A giant storm, the Great Dark Spot continues to



move across the surface. The storm is about the size of the Earth.



*The Great Dark Spot of Neptune is a storm similar to the Great Red Spot of Jupiter.*

## Moons

At least thirteen moons orbit Neptune. Triton is the largest moon. It orbits in the opposite direction of Neptune's other moons. This is a retrograde orbit. Triton has a thin atmosphere. The surface temperature of Triton is the coldest of any known moon or planet in the solar system. The other moons of Neptune are much smaller than Triton.

## Special Features

Neptune has rings like the other gas giants, Jupiter, Saturn, and Uranus. There are four rings in all. They are very faint and difficult to see.

## Exploration

Neptune was the first planet identified by using mathematical predictions rather than by observation. Neptune was not actually seen until 1846, by astronomers J.G. Galle and Heinrich Louis d'Arrest.

In 1989, Voyager 2 became the first space probe to visit Neptune giving us our first chance to learn more about this distant planet.

| Planet | Planetary Day (rotation on axis) | Planetary Year (revolution around Sun) | Distance from the Sun | Number of moons |
|---|---|---|---|---|
| Earth | 24 hours | 365 Earth days | 93 million miles (149.6 million km) | 1 |
| Neptune | 19.1 hours | 165 Earth years | 2,794.4 million miles (4,497.1 million km) | 13 (to date) |

# Pluto and the Dwarf Planets

## Pluto

In 1930, when astronomer Clyde Tombaugh discovered Pluto, he identified it as a very small planet. Astronomers classified Pluto as a planet for 76 years. Then on August 24, 2006, the International Astronomical Union (IAU) changed Pluto's label from a planet to a dwarf planet.

Scientists reclassified Pluto as a dwarf planet because there are other objects in its orbital path. Two other dwarf planets are Ceres and Eris.

Pluto's diameter is smaller than the Earth's Moon. It has an elliptical orbit. Pluto's distance from the Sun ranges between 2.7 and 4.6 billion miles (4.4 and 7.4 billion kilometers). From 1979 to 1999, Pluto was closer to the Sun than Neptune. It takes Pluto 249 Earth years to orbit the Sun once. Pluto orbits in what we call the Kuiper Belt.

## Pluto's Moons

Pluto has three moons. They are Charon, Nix, and Hydra.

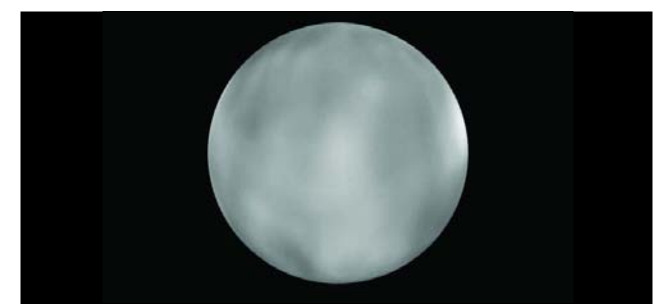
| A Planet | A Dwarf Planet | Small Solar-System Bodies |
|---|---|---|
| • is in an orbit around the Sun<br>• is big enough for gravity to squash it into a round ball<br>• has cleared other things out of its orbital path | • is in an orbit around the Sun<br>• is big enough for gravity to squash it into a round ball<br>• has not cleared other things such as ice out of its orbital path<br>• is not a satellite | • are all other objects except for satellites orbiting the Sun |



## Ceres

Ceres is the smallest dwarf planet. It is about the same size as Texas. It is the only dwarf planet in the main asteroid belt. Unlike most objects in the belt, Ceres is a sphere.

Scientists discovered Ceres in 1801. They first thought it was a planet, but then changed the classification to an asteroid. For another 150 years, scientists considered Ceres to be the largest identified asteroid. In 2006, scientists upgraded Ceres to be a dwarf planet.



*Ceres is the smallest dwarf planet in the solar system.*

## Eris

Although Eris is called a dwarf planet, it is the ninth largest object orbiting the Sun. It is just slightly larger than Pluto. It has its own moon, Dysnomia. Scientists discovered Eris in 2005. Some astronomers initially called it the tenth planet. However, based on the definition developed by the IAU, it is recognized as a dwarf planet along with Pluto and Ceres.

Eris is located in the outer regions of the Kuiper Belt, which is a band of small bodies orbiting the Sun beyond Neptune.

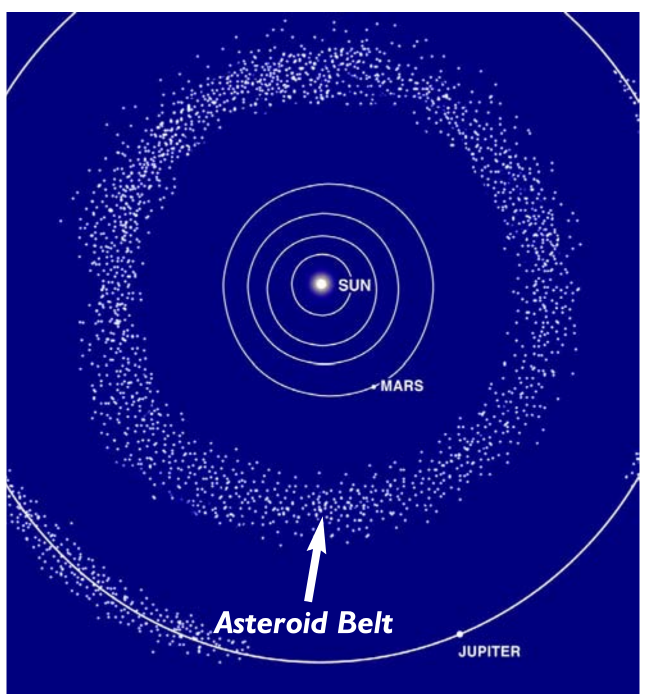
*Eris was first identified as the tenth planet. It was later recognized as one of the three dwarf planets.*

| Dwarf Planet | Diameter | Location | Number of moons |
|---|---|---|---|
| Pluto | 1,143 miles (2,274 kilometers) | Kuiper Belt | 3 (to date) |
| Ceres | 590 miles (950 kilometers) | Asteriod Belt | 0 |
| Eris | 1,489 miles (2,397 kilometers) | Kuiper Belt | 1 |

# Asteroids, Meteoroids, and Comets

## Asteroids

Asteroids are objects that orbit the Sun. They might also be called planetoids, minor planets or small solar system bodies.They are usually made of rock or iron, similar to the makeup of the four inner planets. Asteroids come in many different sizes and shapes. Some are large, but others are as small as pebbles. Most are in the asteroid belt between the orbits of Mars and Jupiter.




Most scientists think asteroids are pieces of material left over from the formation of the solar system. Asteroids could be material that never formed into a planet.

*Ada's Moon*

*Some asteroids even have moons. In 1993, the space probe Galileo found a moon orbiting the asteroid Ida.*

## Meteoroids

Meteoroids are large sand to boulder size pieces of debris in the solar system. Many meteoroids form when asteroids break apart. A meteoroid that hits the Earth's atmosphere usually burns up in a streak of light. This visible streak of light is a meteor. People sometimes call a meteor a shooting star. A meteorite is a meteor that strikes the Earth.

## Comets

A ball of ice and dust particles that orbits the Sun is a comet. A comet is like a giant, dirty



*A falling star or shooting star is actually a meteor.*

*Most comets are too faint to be visible without the aid of a telescope.*

snowball. The orbit of a comet is constantly changing. Sometimes, a comet orbits close to the Sun and then will be thrown far out into space. Most comets are too faint to be seen without a telescope. We can see comets only when they are heated and illuminated as they near the Sun. As the comet gets closer to the Sun, the nucleus (center) of the comet begins to melt. The melting particles following behind the comet are its tail. The tail can extend for millions of miles or kilometers away from the Sun.

Between 1995 and 1997 the Comet Hale-Bopp was the clearest comet people on Earth had seen for over 100 years. It was so bright it could be seen without using a telescope. Unless you plan to live a very long time, you will not see Hale-Bopp again. Hale-Bopp won't be visible again from Earth for about 2,380 years!

Find out more

### Halley's Comet

Perhaps the most famous comet of all is Halley's Comet. It was named after Edmond Halley, an astronomer and mathematician. Halley correctly predicted in 1705 that a certain comet would return in 1758.

Halley's Comet is visible every 75-76 years. The last time it was visible from Earth was 1986. Scientists predict Halley's Comet will be visible again in the year 2061. How old will you be the next time Halley's Comet passes near the Earth?

Because it looks like a huge fireball in the sky, many people used to think that Halley's Comet was a sign of bad luck. Some people even thought it was the end of the world!

PROJECTS volume 10 7.4

# Stars

On a clear night, you can see thousands of stars shining in the sky. From Earth, they seem to be small points of light. Yet many of them are larger than our Sun. There are far more stars in space than you can see with the naked eye. There are so many that you could never count them all. Our Sun is a medium sized star. It is one of the billions of stars in space.

*Stars have been important for celestial navigation, orientation, and even for religious practices.*

## What Is a Star?

Stars are huge balls of spinning hot gas. Hydrogen and helium make up most stars including our Sun. There are many different types of stars. Stars can differ in size, color, and brightness.

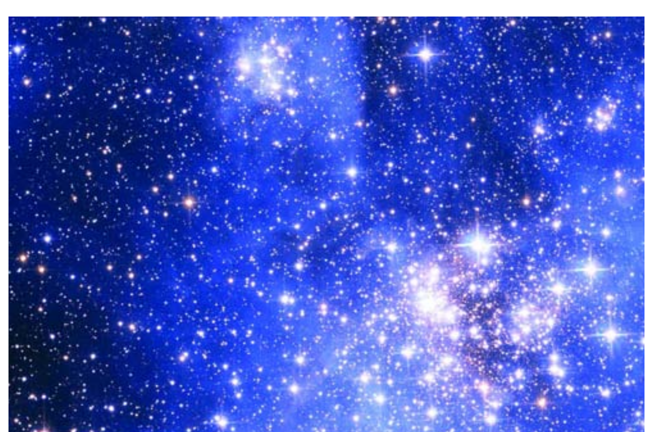
### Constellations

Thousands of years ago, people saw shapes of animals and people in the stars. We call these groups of stars constellations because they form a pattern when viewed from Earth. Today, constellations describe the positions of stars. People have divided the stars into 88 constellations as a way to identify and locate stars.

### Magnitude

As you look into the night sky, you will see that some stars seem brighter than others. We call the brightness of a star its magnitude. Scientists give stars numbers to show how bright they are. Dim stars get high numbers. Bright stars get low numbers. Some stars are so bright their magnitudes are negative numbers.

If a star has a magnitude of six or less, we can see it from Earth without a telescope.



*The apparent brightness of a star is measured by its magnitude.*



**Well Known Constellations**

**ORION.** This constellation looks like a hunter with his bow drawn.

**THE BIG DIPPER.** Many people think the Big Dipper is a constellation, but it is not. It is a group of stars in the constellation Ursa Major.

**URSA MAJOR.** Also known as the Great Bear. If you look closely, you can see that the tail of the bear is made from the same star pattern as the Big Dipper.

**GEMINI.** These stars look like twins holding hands.

## Distance between Stars

The stars look very close together as we view them from Earth. In fact, stars are very far apart. We measure a star's distance from Earth in light years. One light year stands for how far light can travel in a year. One light year is equal to about 5.9 trillion miles (9.5 trillion kilometers).

The closest star to Earth is the Sun. It is 93 million miles away. The next closest star is Proxima Centauri. It is about 4.2 light years away from Earth. That is about 25 trillion miles (40 trillion kilometers) away!

# Types Of Stars

Stars come in many different sizes and colors. We call big stars giants and small stars dwarfs. Astronomers give each star a letter that describes the size, color, and temperature of the star. The types of stars are O, B, A, F, G, K, and M. Type O stars are big and hot. Type M stars are much smaller and cooler.

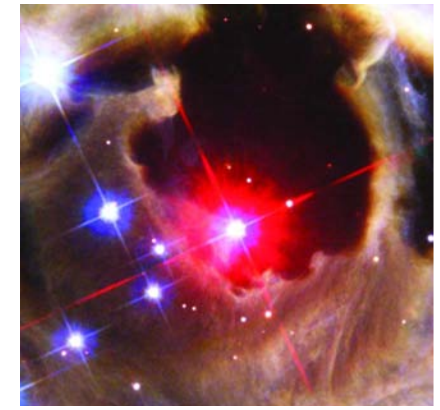
Blue giants are Type O stars. They are very bright and blue in color. Red dwarf stars are Type M and live long lives. Our own Sun is a Type G, or yellow, star. All these types of stars are identified as main sequence stars. All main sequence stars are in a stable time of their lives.

***Stars in green are visible without the use of a telescope.***

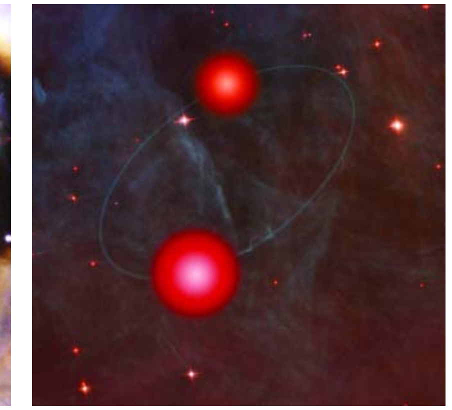
**The Ten Closest Stars Outside Our Solar System**

| Star Name | Distance from Earth (in light years) | Magnitude (lower numbers are brighter) |
|---|---|---|
| Proxima Centauri | 4.2 | 11 |
| Alpha Centauri A | 4.3 | -0.01 |
| Alpha Centauri B | 4.3 | 1.3 |
| Barnard's Star | 5.9 | 9.5 |
| Wolf 359 | 7.7 | 13.5 |
| Lalande 21185 | 8.2 | 7.5 |
| Sirius A | 8.6 | -1.5 |
| Sirius B | 8.6 | 8.4 |
| Luyten A | 8.7 | 12.5 |
| Luyten B | 8.7 | 13 |





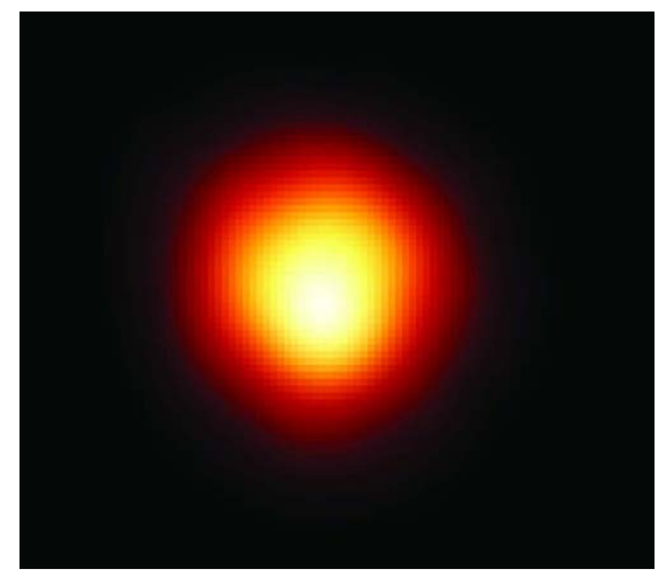
*A red giant*



*A brown dwarf*

*A white dwarf*

Supergiants are the largest stars in the sky. The largest supergiants are the red supergiants. They appear very bright because they are so big. The star Betelgeuse is a red supergiant over 800 times bigger than the Sun.



***Betelgeuse is the second brightest star in the constellation Orion.***

It might surprise you to know that the supergiants have a shorter life span than smaller stars. Their size makes them hotter than other stars making them burn out faster.

**Getting to know...**

### Cecilia Payne-Gaposchkin

Cecilia Payne-Gaposchkin was born in England in 1900. Because girls were not taught science in school, she taught herself. Payne attended Cambridge University. She moved to the United States to work at the Harvard Observatory and to teach at the university. She was called an assistant because women could not join the faculty.

Payne-Gaposchkin studied the spectra of stars. She realized that all stars are made mostly of hydrogen and helium. She discovered that the variation among stars comes from different temperatures, not different elements. The light from each element creates a unique set of colored lines called spectra.

# The Life Cycle of a Star

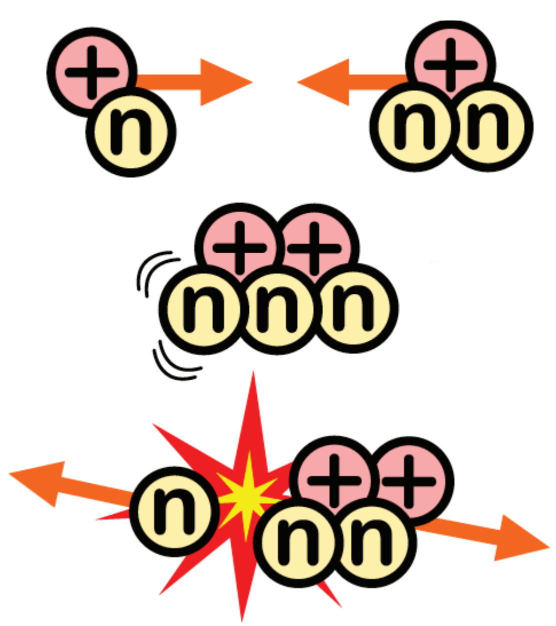
Stars do not live forever. They are born, shine for a period of time, and then eventually go out.

## Birth of a Star

A cloud of dust and gas, called a nebula, begins to form in outer space. Over time, the cloud becomes so massive that gravity makes it collapse in on itself. When it does, it becomes a star.

## Life of a Star

A star spends most of its life in a stage called main sequence. During this stage, a star gives off energy and light from nuclear fusion. It will shine energy into space.



*Nuclear fusion is the process where multiple atomic particles join together to form a heavier nucleus. It is accompanied by the release of energy.*

### Nebulas

**Cat's Eye Nebula**

**Veil Nebula**

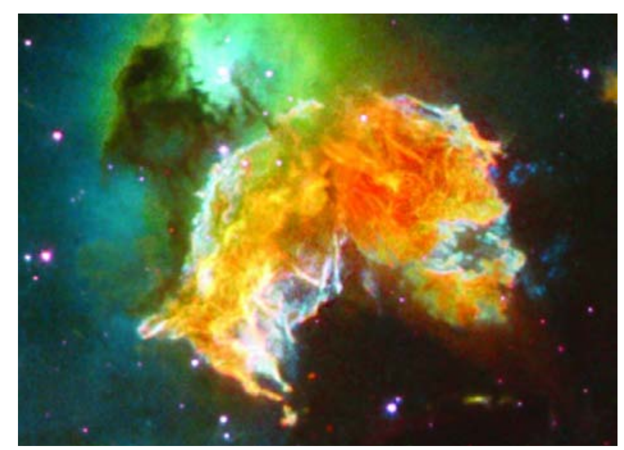
**Helix Nebula**



## Death of a Star

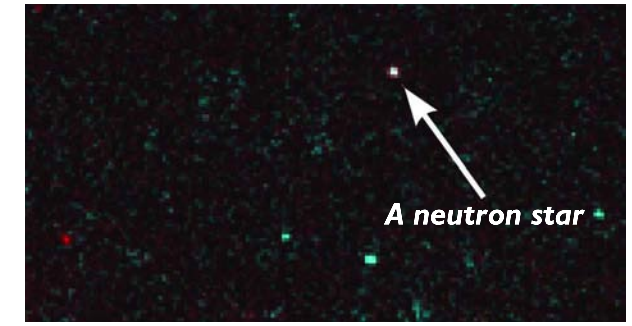
Stars like our Sun have a predictable life cycle. Over time, our Sun will burn up most of its hydrogen. It will cool a little and start to shrink. It will then start to use helium as fuel and grow into a red giant. Eventually the Sun will swallow up Mercury and Venus. Once the Sun uses up the helium fuel, it will shrink into a tiny white dwarf star. The Sun will then completely cool and stop shining. Don't worry, this won't happen for another five billion years or so!

A dying star that has a core with two to three times more mass than our Sun will eventually collapse in on itself. The material of the star collapses so quickly that it creates an explosion called a supernova. From the Earth, supernovas look like bright lights in the night sky.



*A supernova is an explosion of a dying star.*

A supernova may leave behind a neutron star. In a neutron star, all the material is pressed into a dense ball only a few miles or kilometers across.




Neutron stars sometimes give off light at regular intervals as they spin. We call these stars pulsars.

Nebulas may form from the particles given off by the stars collapse. Over time, these nebulas can form into new stars.

A dying star that has a core greater than three times the mass of our Sun will collapse into a black hole. The gravity of a black hole is so strong that even light can't escape. It looks black because no light gets out. Most scientists believe that a few black holes have been detected orbiting distant stars. They suck in material from the star and then throw it out into space at a rate near the speed of light.

### WORDS to KNOW

**dense** (denss): crowded or thick

**nuclear fusion** (NOO-klee-ur FYOO-zhuhn): the release of energy when atoms are combined, or fused, together

# Galaxies

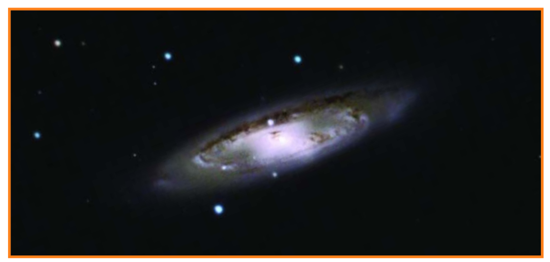
A galaxy is a system of dust, gas, and stars that collects over a very large area. Gravity binds the objects in a galaxy together. Within each galaxy are billions of stars.

## Types of Galaxies

The four basic shapes of galaxies are elliptical, spiral, barred spiral, and irregular. Elliptical galaxies are the most common type. Spiral galaxies, barred spiral galaxies, and irregular galaxies are less common.

**Galaxy Shapes**

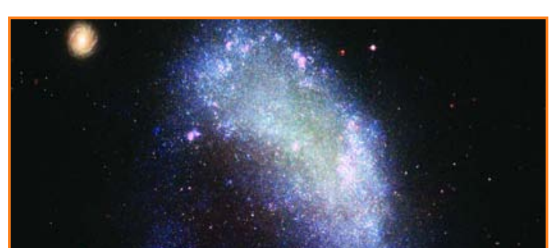
**Elliptical galaxies** usually contain many old stars. Often, these stars are red giants and are near the ends of their lives. Some elliptical galaxies are shaped like spheres, while others are shaped like footballs.



**Spiral galaxies** have gigantic arms of stars that spread out, or radiate, from a center filled with stars. The bright stars in the center are red giants. Most of the bright stars in the arms are hot, young blue stars. All the stars in a spiral galaxy orbit the center.

**Barred Spiral galaxies** have two spiral arms connected by a bar of stars in the center.

**Irregular galaxies** look like a cloud of stars. They have odd shapes unlike elliptical and spiral galaxies.





Scientists believe that stars in a galaxy will group, or cluster, together in two different ways.

| | Open Clusters (Galactic Clusters) | Globular Clusters |
|---|---|---|
| Number of stars | From a few stars up to thousands of stars | Thousands to millions of stars |
| Gravitational bind | Loosely pulled together | Tightly pulled together |
| Age | Less than a few hundred million years old | 10 to 16 billion years old |
| When viewed from Earth | Individual stars can be seen and look bright | Individual stars can be seen and look dim |

## The Milky Way

*A galaxy may contain star systems and interstellar clouds and may have different shapes.*

Our galaxy, the Milky Way, is one of many galaxies in a large group of galaxies called the Local Group. Some scientists think the Milky Way is a spiral galaxy, while others think it is a barred spiral galaxy.

Many stars group together near the center of the galaxy. Giant arms of stars spread out from the center. The Sun is one of billions of stars in the Milky Way. Our solar system is nestled in one of the spiral arms about 32,000 light years away from the center.

The Milky Way is over 140,000 light-years across. It is also nearly 2,000 light-years thick. It will take our solar system nearly 230 million years to complete one orbit of the galaxy's core.

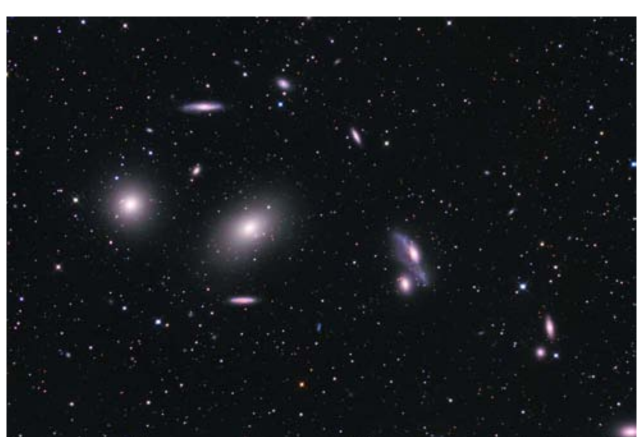
*The Milky Way as seen from Death Valley. The best time of year to view the Milky Way from the Northern Hemisphere is between July and September.*

If you look at the sky on a very clear night, you may be able to see the light of a billion distant stars in a milky path. This path of light is our galaxy.

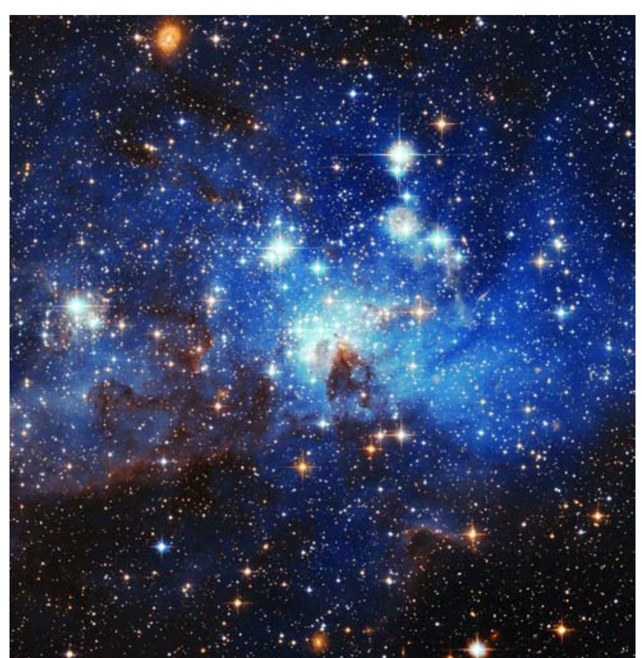
## Other Galaxies

Billions of galaxies fill the void of outer space. Many of these galaxies are grouped together. The Milky Way belongs to a cluster of galaxies known as the Local Group. It contains about 21 galaxies. The Local Group is part of a large supercluster of galaxies called the Virgo Supercluster.

The Milky Way has two irregular companion galaxies called the Small Magellanic Cloud and the Large Magellanic Cloud.

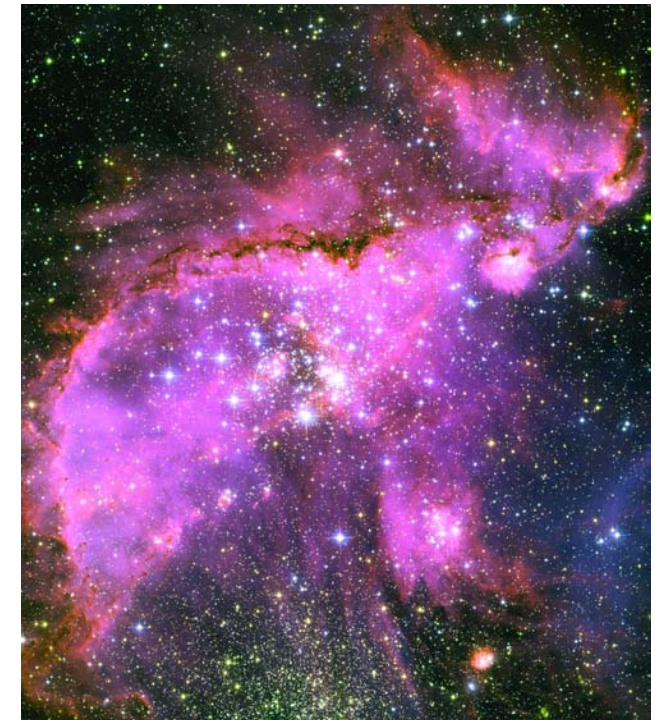


*The Milky Way and Andromeda galaxies are part of the Virgo Supercluster.*



*The Large Magellanic Cloud is a dwarf galaxy that orbits the Milky Way.*



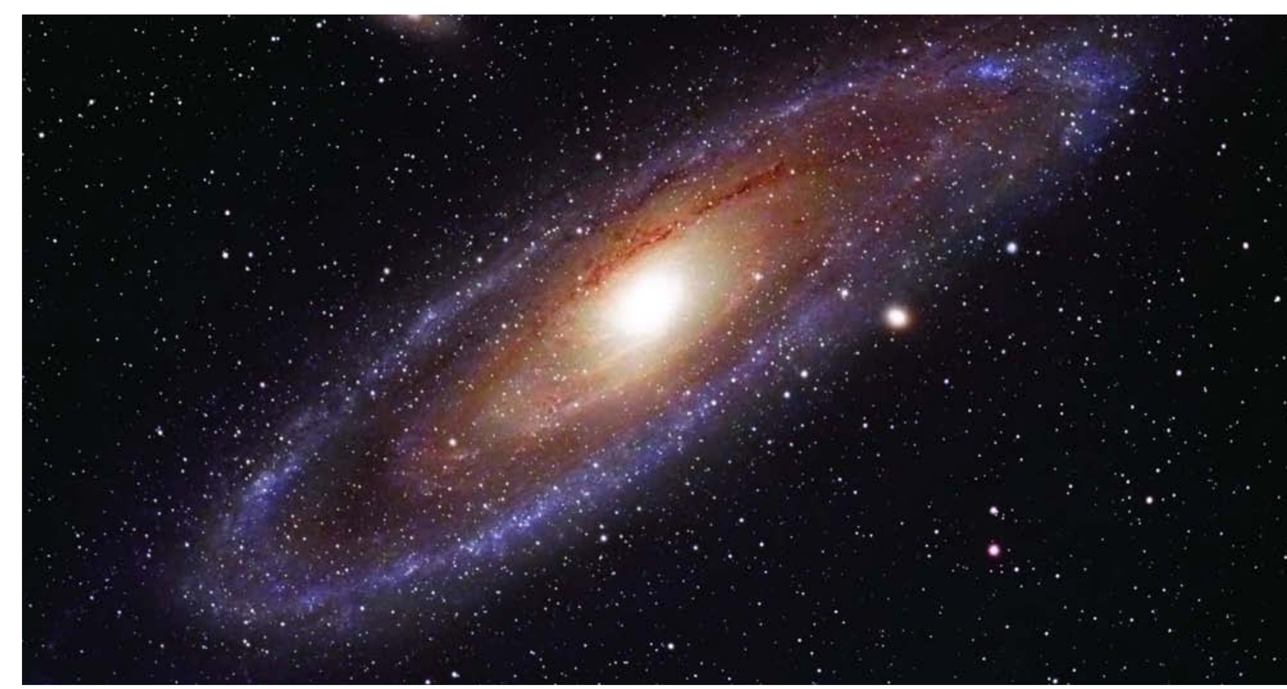


*The Small Magellanic Cloud is a galaxy that belongs to the Local Group along with the Milky Way.*


**Galaxies Can Collide**

Sometimes, the huge gravity created by galaxies can make them collide, or hit each other! Their stars do not actually bump into each other, but the particles in their gas clouds do collide. These collisions may cause many new stars to form.

The Andromeda galaxy is the closest spiral galaxy to the Milky Way. You can see the Andromeda galaxy on a very clear night as a fuzzy spot in the sky.



*The Andromeda galaxy is a spiral galaxy about 2.5 million light years away.*

# The Universe

The universe is everything. It contains all galaxies, stars, planets, and matter that have ever existed or ever will exist. Everything you can possibly think of is part of the universe. The cosmos is another word for universe.

It is impossible to imagine the size of the universe. Think of words like huge, gigantic, enormous, and vast. The universe is bigger than all those words put together!

The Earth is a tiny planet orbiting one of 400 billion stars in our galaxy. There are over 100 billion galaxies.

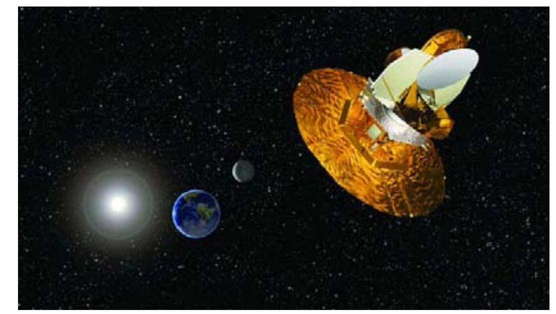
We are only beginning to understand how the universe works. Scientists still have more questions about the universe. There are many more questions than there are answers. We don't know exactly how galaxies form and where stars originate. Theories about the universe are constantly being developed and tested. This is the nature of science. How we look at the universe will change as technological advances reveal more of the universe's secrets.

*The universe contains all the galaxies, stars, planets, and types of matter. The universe continues to expand.*



## Origins of the Universe

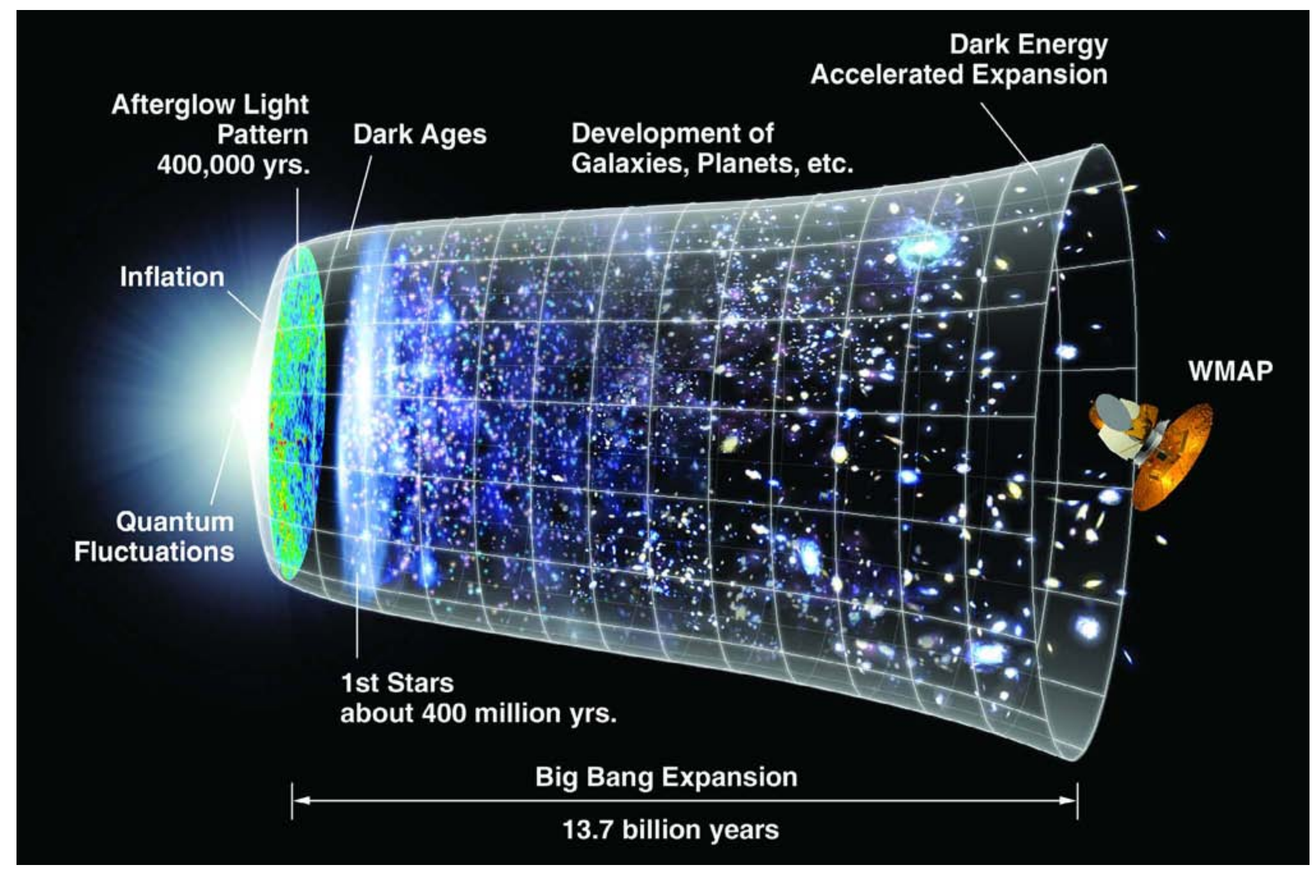
Many scientists believe that the universe is between 15 and 20 billion years old. They believe this because nearly all the galaxies in the universe are traveling away from one another. Scientists can measure the rate at which the galaxies are moving apart.



*Satellites in space help collect data for scientists.*

### The Big Bang Theory

Many scientists think that everything in the early universe was packed tightly into a single point. There were no galaxies, stars, or planets. Space, as we know it, did not exist. This single point was super hot and thick. Then this single point exploded. Scientists call this the Big Bang. Because of this huge explosion, the universe began to expand. This created matter, energy, space, and time.




*A graphical representation of the expansion of the universe, courtesy of NASA (WMAP stands for Wilkinson Microwave Anisotropy Probe).*

The Big Bang is a theory based on the motion of galaxies and many mathematical calculations. Scientists still measure cosmic background radiation that came from the Big Bang.

There are over 100 billion galaxies in the visible universe. Most of these galaxies belong to clusters and superclusters. These superclusters are groups of galaxies that are drawn together in groups. They stretch out across the universe and may span several hundred million light years. The patterns of these superclusters can tell scientists a lot about the early history of the universe.

Find out more

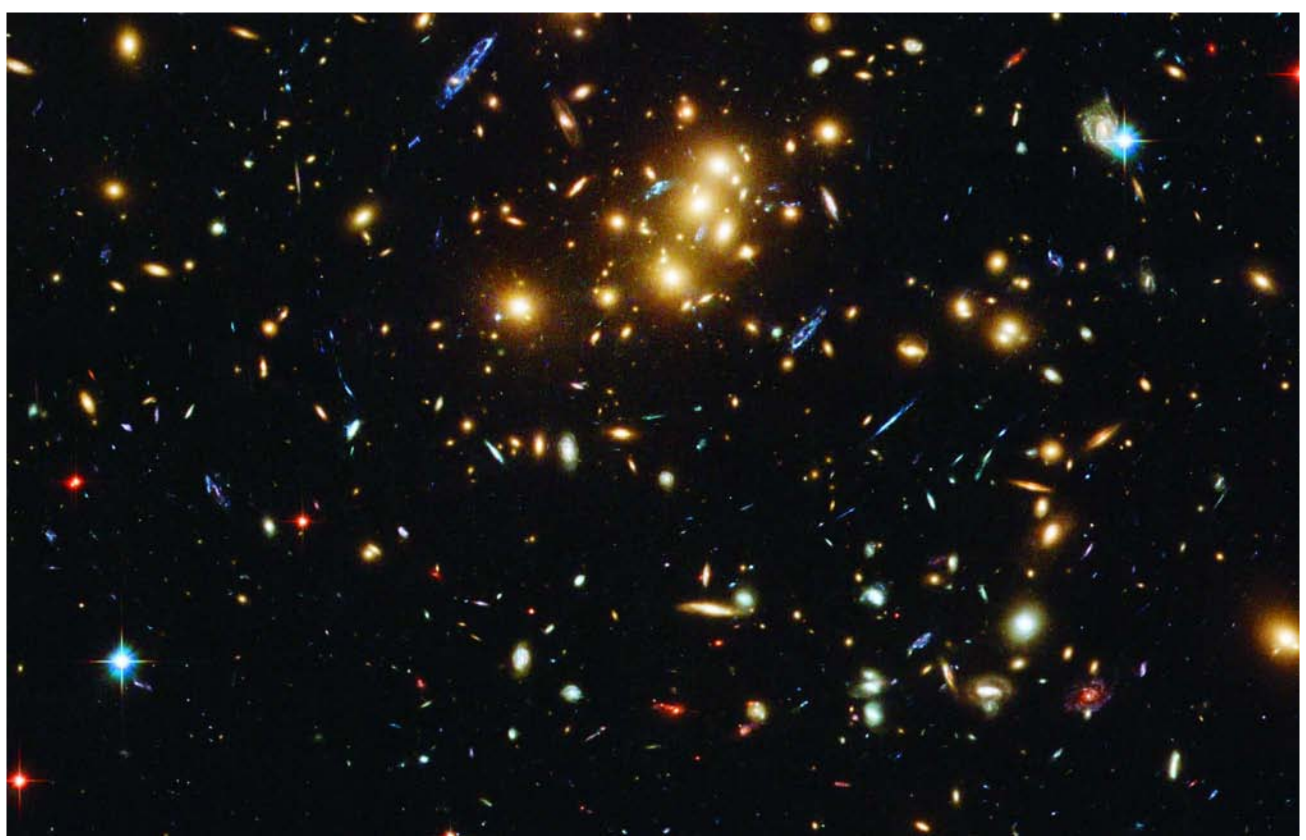
**Dark Matter**

Much of the universe is not visible even with the assistance of telescopes. Mathematical formulas and calculations help scientists figure out what is in outer space.

Astronomers have measured the amount of mass needed to hold galaxies together and to explain their motion through space. The number that they have calculated is far greater than the amount of material that has been observed. This "missing" mass is sometimes called dark matter.

Intergalactic space is the space between galaxies. It might contain a lot of dark matter. This matter may take the form of dust, cold gas, dead stars, or black holes. Maybe dark matter is something else. We don't know for sure.

Over the centuries, people have wondered why the night sky is not lit up with light from the billions of stars in the Milky Way and other galaxies. One explanation is that dark matter is common throughout the universe. It might block some of the light from distant stars and galaxies. We know that there are giant dark clouds around the Milky Way. Some light from distant stars cannot reach Earth because of these dark clouds.



***The Local Supercluster contains our galaxy the Milky Way.***



## Possible Ends of the Universe

Have you ever wondered if the universe will come to an end? If so, how do you think it will end? Scientists have several theories. The most common theories are the Open Universe Theory and the Closed Universe Theory.

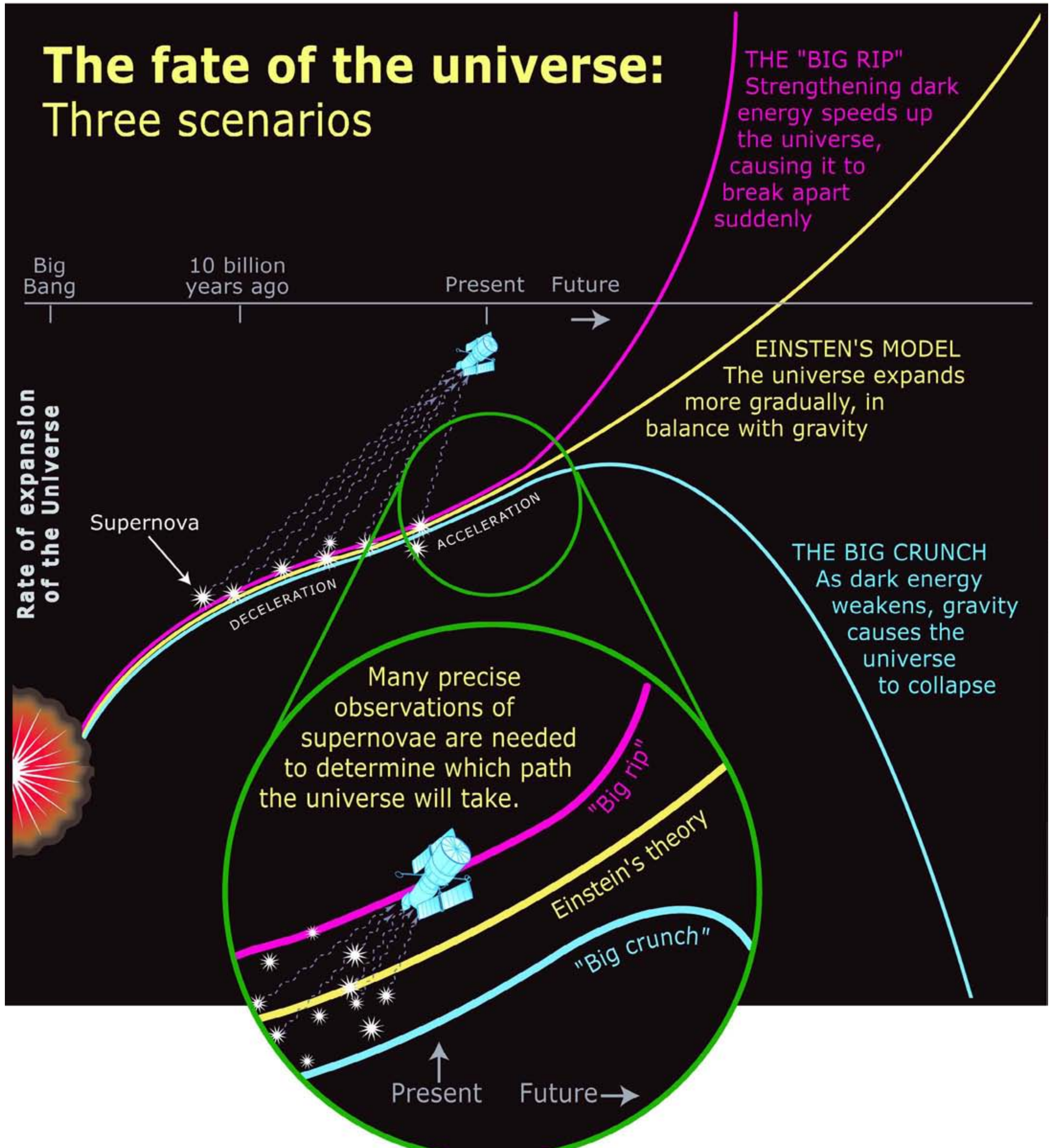
### The Open Universe Theory

Some scientists think that the universe will continue to grow, or expand, forever. They believe that the galaxies will continue to move away from each other. At some point, the continuous growth will use up all of the energy in the universe. When this happens, scientists believe the universe will end by getting too hot, too cold (the Big Freeze), or ripping apart (the Big Rip). Scientists call this the Open Universe Theory.

### The Closed Universe Theory

Other scientists believe that the universe will stop expanding. They think that the gravity from all the galaxies combined with all the material in the universe will begin to pull the universe back together. The universe will start to shrink, or contract. Eventually, all the energy, matter, space, and time will come together, or collapse, in the Big Crunch. After the Big Crunch, another explosion might begin a new universe. Scientists call this the Closed Universe Theory.

So who is right? Is the universe open or closed? It all depends on how much matter is in the universe. Current measurements still allow for both possibilities but most data suggests the universe will not collapse.




*There are many theories about how the universe will end.*



**Stephen Hawking**

**Getting to know...**

Stephen Hawking was born in England in 1942. In 1963, Hawking was diagnosed with amyotrophic lateral sclerosis. This fatal disease destroys the spinal cord and weakens the muscles. Hawking did not let this disease deter him from his passion for mathematics and physics.

Hawking earned a Ph.D. at Cambridge University. He began to study black holes. He found that they leak some radiation, which makes them become smaller. A black hole explodes if it gets too small, much like the Big Bang that started the universe.

Then in 1985, Hawking lost the ability to speak and began to use a computer voice. He became more famous after publishing *A Brief History of Time* in 1988. This book explains the origin of the universe to the public.

In 2005 at the age of 63, Hawking along with fellow physicist Leonard Mlodinow published *A Briefer History of Time*. This book seemed to be easier to read than the first book and this second version of the book provided more current and updated information.

# Space Exploration

Humans have always had a need to explore. In ancient times, people could study only the places where they lived. They could only wonder about the rest of the world and what might exist in the universe.

Over the years, new technologies developed. With improved modes of transportation, we could explore more of the Earth. Today, with advanced mathematics, telescopes, unmanned spacecraft, and manned spacecraft, we have more options for exploring the universe.

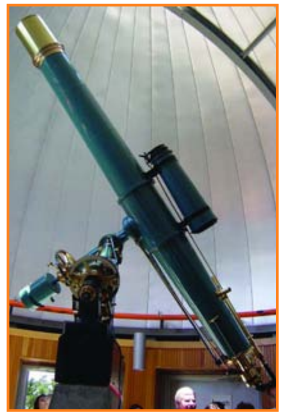
## Telescopes

One of the first tools that helped scientists study the sky was the telescope. There are many different types of telescopes, but all telescopes have one thing in common. They help us study things that are far away.

*A refractor telescope*

## Telescopes Used For Astronomy

**Optical telescopes** gather light to create images. These telescopes are used for astronomy. If you look at a tree through an optical telescope it will appear upside down.



**X-ray and gamma-ray telescopes** can be difficult to use. They are usually used on satellites or high-flying balloons.


*The Gamma-ray Large Area Space Telescope, or GLAST.*

**Radio telescopes** gather very quiet sounds from space using large dishes and antennas.

**Space telescopes** are out in space. Space telescopes can see things and hear things that are too far away or blocked from the view of telescopes on Earth.

## Space Probes

A space probe is an unmanned spacecraft that collects information about outer space. The 1950s marked the beginning of the use of space probes to study the Earth, its Moon, the other planets, and the universe. They can be as small as a coffee can or bigger than a bus. Some probes send pictures back to Earth. Others provide different kinds of information. For example, a probe may explore the surface of a moon or planet.

The earliest probes simply orbited the Earth or the Moon. Later probes explored other planets.



Getting to know...

## Edwin Powell Hubble

Edwin Powell Hubble was born in Missouri in 1889. His family moved to Chicago in 1898. In high school, Hubble earned good grades but excelled in sports. After high school, he studied astronomy and mathematics at the University of Chicago. Hubble studied law, coached basketball, and taught physics and Spanish. Then he decided to pursue astronomy as a career.

Hubble worked at Yerkes Observatory in Wisconsin. It had a 40-inch refracting telescope, the largest in the world at that time. Hubble also used its 24-inch reflecting telescope to study nebulas.

In 1919, he went to Mount Wilson Observatory in California. It had a new 100-inch reflecting telescope. Using this telescope, Hubble proved the existence of other galaxies. He also introduced the classification system for galaxies. In 1929, he formulated Hubble's Law, which helped astronomers figure out the age of the universe and prove that the universe was expanding.

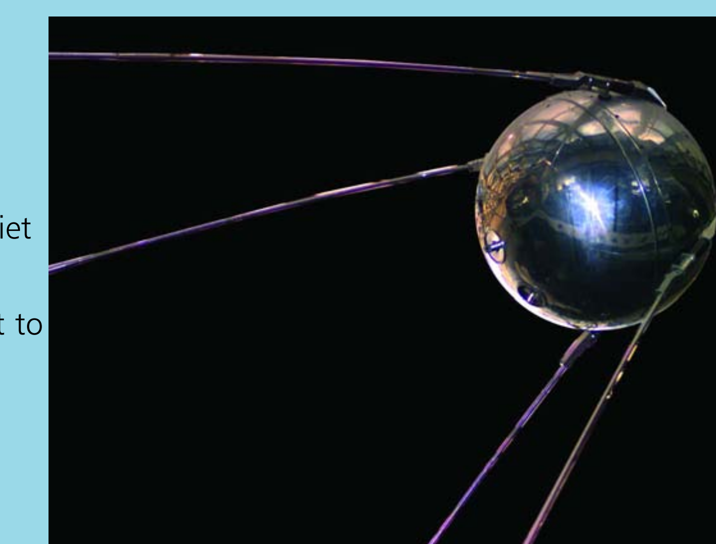
Hubble helped design the 200-inch reflecting telescope at Mount Palomar Observatory, in California. He died in 1953. The Hubble Space Telescope is named in his honor.

Find out more

### The Sputnik Program

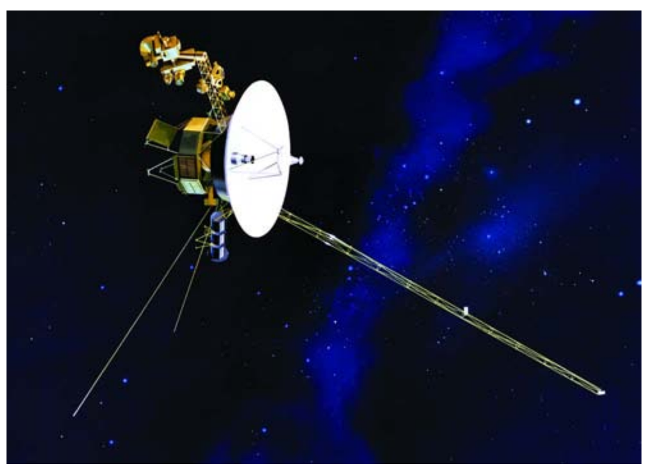
The Sputnik program was a series of unmanned space missions launched by the Soviet Union in the late 1950s. It included Sputnik 1, the first manmade object to orbit Earth.

*1957, the Russian spacecraft called Sputnik 1 was the first manmade object ever to reach outer space.*



Some probes just take pictures as they pass by planets. Others orbit planets and study them in more detail. Scientists drop probes into the atmospheres of other planets. A few probes even land on the surface of the planets and moons they are studying.

The Americans launched Voyager 1 and Voyager 2 in 1977. Voyager 1 is the first probe ever to leave the solar system. It is the manmade object that has traveled the farthest away from Earth. Thirty years after launching, Voyager 1 and Voyager 2 continue to explore the deepest parts of the universe. Scientists with NASA's Deep Space Network communicate with the probes daily.



*Voyager I.*

The Mars Pathfinder was launched on December 4, 1996 by NASA aboard a Delta II. After a 7-month voyage, it landed on Mars on July 4, 1997. The lander opened, exposing the rover, called *Sojourner,* that was used for many different experiments on the Martian surface.

## Humans in Space

Space has fascinated humans for centuries. Since the early 1960's, humans have traveled into orbit around the Earth. By 1969, humans had walked on the Moon.

Astronauts and cosmonauts are men and women who travel into space. Many astronauts travel into the local space around the Earth. Some stay for a few days. Others remain in space for several months.

Launched in 1973, Skylab was the first American space station. In 1986 the Russians launched the space station Mir. Initially, satellites and rockets were launched to transport astronauts and supplies to the space stations. Now we use space shuttles.

Today many countries work together to man, build, and maintain the International Space Station (ISS).



| A History of Manned Spaceflight | |
|---|---|
| **April 12, 1961** | Yuri Gagarin becomes the first human in space aboard Vostok 1. |
| **May 5, 1961** | Alan Shepard Jr. becomes the first American in space aboard Freedom 7. |
| **February 20, 1962** | John Glenn becomes the first American to orbit the Earth aboard Friendship 7. |
| **June 16, 1963** | Valentina Tereshkova becomes the first woman in space aboard Vostok 6. |
| **July 20, 1969** | Neil Armstrong and Buzz Aldrin become the first humans to land and walk on the Moon. |

| A History of the United States Space Shuttle Program | |
|---|---|
| **April 12, 1982** | John Young and Robert Crippin are pilots of Columbia, the first space shuttle. |
| **June 18, 1983** | Sally Ride became the first American woman in outer space, aboard the space shuttle Challenger. |
| **August 30, 1983** | Guion S. Bluford became the first African-American astronaut in outer space. |
| **January 28, 1986** | The space shuttle Challenger was destroyed after launch. All the astronauts, including teacher Christa McAuliffe, were killed. |
| **September 29, 1988** | Discovery is the first space shuttle launched after the Challenger disaster. |
| **February 1, 2003** | The space shuttle Columbia broke apart when it re-entered Earth's atmosphere, killing all the astronauts. |
| **July 26, 2005** | Eileen Collins commands the first space shuttle mission since the Columbia disaster. |
| **August 8, 2007** | Teacher and astronaut, Barbara Morgan, is the first teacher in space aboard the space shuttle Endeavour. |

The ISS has been home to many different astronauts and cosmonauts from around the world since November 2, 2000.

Space is not an easy place for humans to live. There is no air. Humans must stay inside spaceships or special space suits. This protects them from the harsh conditions of outer space. People are also weightless in outer space. This poses challenges to human health.

The conditions of space are unique. People can perform laboratory experiments and study things that are difficult or impossible to study on Earth.

# People Who Study Space

Astronomers are people who study the sky. They make a career out of studying the sky. Amateur astronomers look at planets, stars, and galaxies as a hobby.

Astrophysics deals with the behavior and physical properties of all the objects in space.

Cosmology studies the origin and structure of the universe itself.

Scientists who study the sky use mathematics to predict the paths of planets, asteroids, and comets. Advanced forms of mathematics like chaos theory are used to describe the motions of galaxies and to explain the origins of the universe.

Astronauts who travel into space have backgrounds in physics, chemistry, medicine, and engineering. Mechanical engineers and electrical engineers design and build spaceships, probes, and space stations. People in all different fields of science study space and our place within it. Someday you may work in space, discover new information about the universe, or develop technology to be able to live on another planet!

**Words to Know**

**chemistry** (KEM-is-tree): the scientific study of substances

**physics** (FIZ-iks): the science that deals with matter and energy

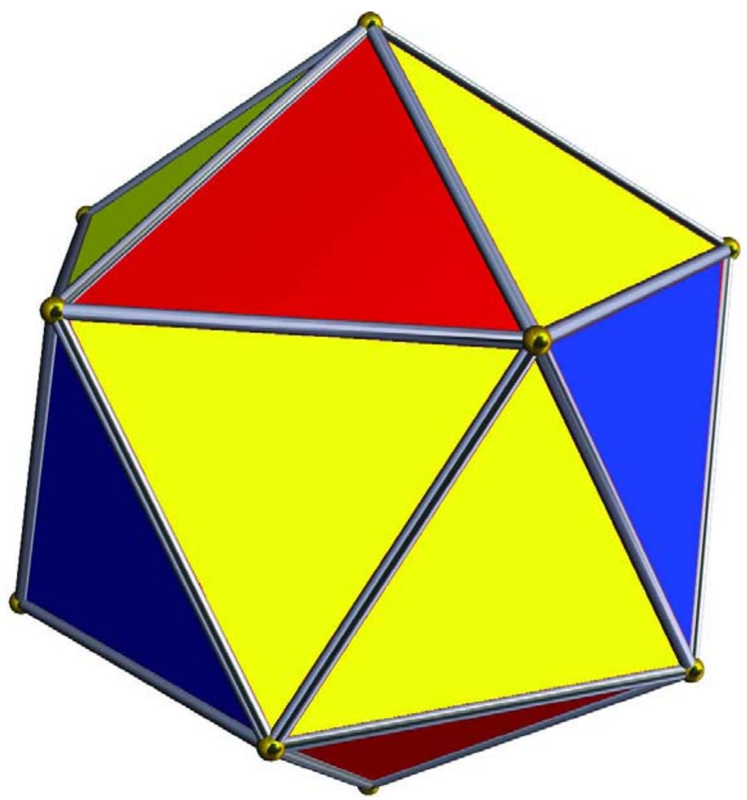
**properties** (PROP-ur-teez): special qualities or characteristics

Rourke's World of Science

# ENCYCLOPEDIA

## Volume 8

# Mathematics



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# Table of Contents

# What Is Mathematics?

When you think of mathematics, you probably don't think of science. But mathematics is a science. Mathematics is the study of numbers, shapes, change, quantities, and patterns. It also looks at the relationships between them. Math is a short way of saying mathematics.

Not only is mathematics a science, all other scientists use math in their work. Can you think of how a chemist, biologist, or astronomer might use math?

**HOW SCIENTISTS USE MATH**

| **Scientists** | | |
|---|---|---|
| Biologists |  | use math to compare microscopic objects sizes and shapes. |
| Chemists |  | use math to measure chemicals for solutions. |
| Meteorologists |  | use math to predict weather patterns. |
| Physicists |  | use math to estimate lasers power. |



**Timeline of Mathematics 70,000 to 300 BC**

| | |
|---|---|
| 70,000 BC | South Africa - ochre rocks adorned with scratched geometric patterns |
| 35,000 BC to 20,000 BC | Africa and France - earliest known prehistoric attempts to quantify time |
| 20,000 BC | Nile Valley - the Ishango Bone is possibly the earliest reference to prime numbers and Egyptian multiplication |
| 3400 BC | Mesopotamia - the Sumerians invent the first numeral system, and a system of weights and measures |
| 3100 BC | Egypt - earliest known decimal system allows indefinite counting by way of introducing new symbols |
| 2800 BC | Indus Valley Civilization on the Indian subcontinent - earliest use of decimal ratios in a uniform system of ancient weights and measures |
| 2700 BC | Egypt - precision surveying |
| 2600 BC | Indus Valley Civilization - objects, streets, pavements, houses, and multi-storied buildings are constructed at perfect right angles |
| 1000 BC | Egypt - use of common fraction by Egyptians |
| 400 BC | India - mathematicians write a mathematical text which classifies all numbers into three sets: enumerable, innumerable, and infinite |
| 300 BC | Egypt - Euclid proves the infinitude of prime numbers and presents the Euclidean algorithm |
| 300 BC | Mesopotamia - the Babylonians invent the earliest calculator, the abacus |
| 300 BC | India - mathematician Pingala writes the "*Chhandah Shastra*", which contains the first Indian use of zero as a digit (indicated by a dot) and also presents a description of a binary numeral system, along with the first use of Fibonacci numbers and Pascal's triangle |

| Timeline of Mathematics 260 BC to AD1100s | |
|---|---|
| 250 BC | Mexico - the Olmecs people were using a true zero (a shell glyph) several centuries before Ptolemy |
| 240 BC | Greece - Eratosthenes uses his sieve algorithm to quickly isolate prime numbers |
| 140 BC | Greece - Hipparchus develops the bases of trigonometry |
| 50 BC | India - Indian numerals, the first positional notation base-10 numeral system, begins developing in India |
| AD 250 | Greece - Diophantus uses symbols for unknown numbers in terms of the syncopated algebra |
| AD 300 | India - the earliest known use of zero as a decimal digit is introduced by Indian mathematicians |
| AD 700s | India - Shridhara gives the rule for finding the volume of a sphere and also the formula for solving quadratic equations |
| AD 750 | Europe - Al-Khawarizmi is considered father of modern algebra since he was the first to bring Indian mathematics to Europe |
| AD 1030 | Iran - Ali Ahmad Nasawi divides hours into 60 minutes and minutes into 60 seconds |
| AD 1100s | India - Indian numerals were modified by Arab mathematicians to form the modern Hindu-Arabic numeral system (used universally in the modern world) |
| AD 1100s | Europe - the Hindu-Arabic numeral system reaches Europe through the Arabs |

Like any science, mathematics must show us things we didn't know. Proofs and theorems are the basis for math. A proof is a mathematical argument that convinces others to believe it is true.

A theorem is a mathematical statement supported by one or more proofs. Mathematicians can prove that theorems are true. There are many proofs and theorems in math.

Mathematics uses reasoning and logic to solve problems. In math, you solve a problem by thinking. Other sciences rely on experiments to solve a problem.



It might seem like mathematicians already have solved all the math problems in the world because most of the math you do in school has a right and wrong answer. But mathematics is always growing. As we learn new things and create new technologies, mathematicians have new problems to solve.

## How We Use Mathematics

People use mathematics every day. At home, we prepare food using math to measure ingredients. It helps us decide what size we need to cut the boards for a tree house. We can keep to a budget using math. You use mathematics when you count, play games, or share a plate of cookies with your friends.

*Many studies have found playing chess improves math skills.*

We use math outside the home, too. It helps us figure out how much of a tip to leave at a restaurant. We can find out how long a car trip will take us. Math can help you decide how much money you will have for snacks after buying a movie ticket.


*You use math when paying a bill at a restaurant.*

Many jobs involve math as well. The people who build homes use mathematics to make sure the walls don't collapse.

WORDS to KNOW

**logic** (LOJ-ik): thoughtful and accurate reasoning or thinking

**quantity** (KWAHN-tuh-tee): an amount or number

**science** (SYE-uhnss): studying nature and the physical world by testing, experimenting, and measuring

A hairstylist uses math to measure the chemicals to color hair. Businesses use mathematics when dealing with money. Stores add up our bills using math.

Math is also the basic tool used by scientists and engineers. They use it to describe the universe and everything within it.

Math isn't just for school. Math is everywhere and we use it every day!

## Number Systems

Humans have used numbers for a very long time. Throughout the history of man, every culture used some form of mathematics. The numbers that we use today have been around for thousands of years.

### The Base Ten System

Today, we use a base ten number system. The digits used in base ten are 0, 1, 2, 3, 4, 5, 6, 7, 8, 9. Using those 10 digits, we can make any number in the system.

The base ten system was probably created because we have ten fingers to count on. There are other bases as well. Some bases use more than ten numbers. Some use fewer.

What numbers can you make with these digits?

| Digits | Whole Numbers |
|---|---|
| 5, 7 | 57<br>75 |
| 1, 3, 9 | 139<br>193<br>319<br>391<br>913<br>931 |

### The Base Two System (Binary Numbers)

In the base two system, only two digits are used. They are 0 and 1. Most computers use the binary system. Binary numbers are base two because all numbers can be made using zero or one.

Let's look at how the base ten numbers look in binary. Can you figure out the pattern?

| The Base Ten Digits | In Base Two There Would Be... |
|---|---|
| 0 | 0000 |
| 1 | 0001 |
| 2 | 0010 |
| 3 | 0011 |
| 4 | 0100 |
| 5 | 0101 |
| 6 | 0110 |
| 7 | 0111 |
| 8 | 1000 |
| 9 | 1001 |

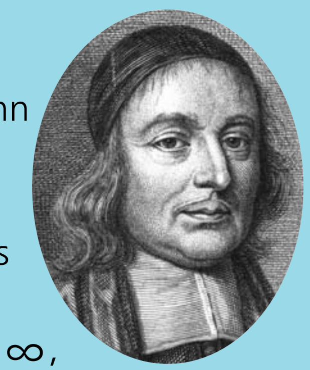


Base two is difficult for humans to use. Larger numbers get very large. The number 100 in base two is 1100100!

**Find Out More**

**The Biggest Number is Infinity**

Infinity is used to describe a number that goes on forever. You can never reach infinity no matter how high or low you count!



In 1665, mathematician John Wallis created a symbol for infinity and we still use his symbol today. The symbol for infinity, $\infty$, looks like a sideways 8.

### Roman Numerals

In ancient Rome, people wrote numbers differently. They used Roman numerals. Roman numerals may look neat, but they are hard to use in mathematics.

*This clock shows that it is ten minutes to one.*

| Roman Numerals | Arabic Numerals |
|---|---|
| I | 1 |
| II | 2 |
| III | 3 |
| IV | 4 |
| V | 5 |
| VI | 6 |
| VII | 7 |
| VIII | 8 |
| IX | 9 |
| X | 10 |
| L | 50 |
| C | 100 |
| D | 500 |
| M | 1000 |

### Arabic Numerals

Today, we use Arabic numerals. The digits 0, 1, 2, 3, 4, 5, 6, 7, 8, 9 are all Arabic numerals. These numerals were developed in the Middle East thousands of years ago.

**Words to Know**

**digit** (DIJ-it): any Arabic numerals from 1 to 9, and sometimes 0

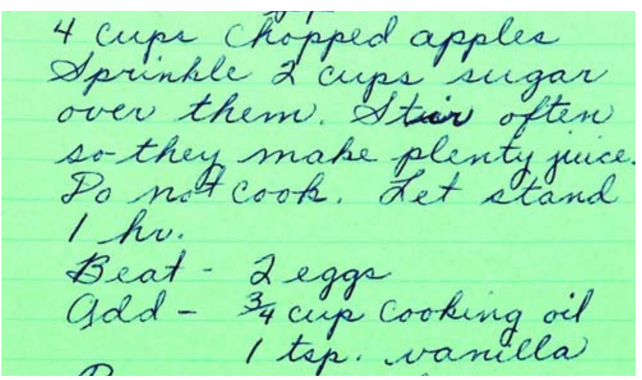
**number** (NUHM-bur): a word or symbol used for counting and for adding and subtracting

**numeral** (NOO-mur-uhl): the symbol that represents a number, such as 4 or IV

# Numbers

Numbers are everywhere. We use numbers to tell time. They help us count money. We measure food with them. We use numbers in everything we do. Numbers are an important form of communication. Every language on the planet has some form of number system. Look around and see all the numbers in your world.


*The Federal Reserve prints a serial number on each bill printed. There are a maximum of 832 bills with the same serial number. Serial numbers help prevent counterfeiting.*



*We use numbers in recipes.*

*Digital clocks display the correct time.*

There are many different types of numbers. The most common are whole numbers. Whole numbers are the ones we use for counting. They are numbers like 1, 4, 15, 27, and 42. They are also called natural or positive numbers. A positive number is greater than zero.

Sometimes numbers are negative. This means that they are less than zero. A negative number looks like a whole number with a minus sign (-) in front of it.

Integers are all the natural numbers, the negative numbers, and zero combined.




In mathematics, we put numbers together in different combinations using different functions. This helps make new numbers. These new numbers give people important information. Math begins with simple counting. Then comes addition, subtraction, multiplication, and division. Arithmetic is another name for these four operations. There are also other ways to use numbers.

| | |
|---|---|
| ***Addition*** | $2 + 2 = 4$ |
| ***Subtraction*** | $4 - 2 = 2$ |
| ***Multiplication*** | $3 \times 3 = 9$ |
| ***Division*** | $8 \div 4 = 2$ |

**Find out more**

**Zero Means Nothing**

The number zero actually means there is no number! It is used as a place holder when other numbers are not being used. In the number 205 the zero holds the "tens place". If we left out the zero we'd have 25. Would you rather get $205 or $25 for your birthday?

The ancient Greeks and Romans did not have a zero in their numbers. This made it difficult for them to write down mathematical problems.

## Counting

The simplest way of using numbers is to count them. Counting from 1 to 10 is easy. You can use your ten fingers. One hand can count to 5 by putting up one finger at a time. The other hand can count from 6 to 10 by putting up the rest of the fingers. This is why many number systems are based on 10.


*We can also use our fingers to perform simple addition and subtraction problems.*

Often people have to count in their heads without using their fingers. This is a very important skill. People who can count in their heads can learn how to do all kinds of mathematics easily. Sometimes, people count on paper by making tally marks. We can also use a device called a counter. Often, computers and calculators are used to count for us.

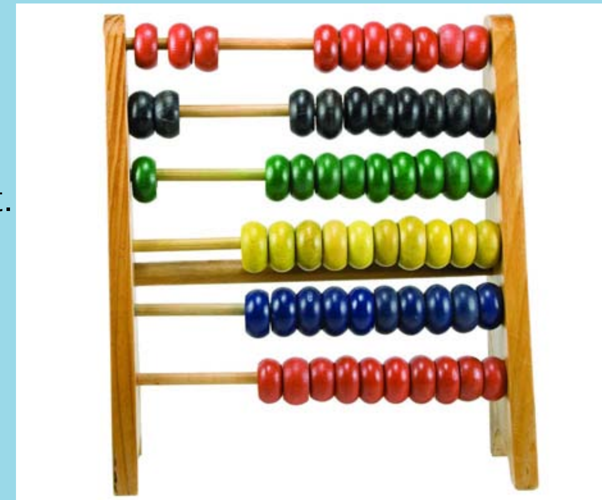

*Tally marks*

Find out more

### You Can Do Math with Beads

Ancient Greeks invented the first calculator. The abacus is a device with beads strung on wires or bars. People can learn to do math very quickly with it. Using an abacus, you can do addition, subtraction, multiplication, and division.

If you travel around the world, you will probably see someone using an abacus in the marketplaces where they sell the goods they make or food they grow in their gardens.



Just about every language on Earth uses the Arabic numbers 0 though 9. Every language has different words for these numbers. Some of the words look the same but sound very different.

| | French | Spanish | Japanese | Chinese |
|---|---|---|---|---|
| 0 | zéro (ZAY-roh) | cero (SHE-roh) | zero (zeh-doh) | ling (ling) |
| 1 | un (uhn) | uno (OO-noh) | ichi (ee-chee) | yi (ee) |
| 2 | deux (dyew) | dos (dose) | ni (nee) | er (ar) |
| 3 | trois (twah) | tres (trace) | san (sahn) | san (sahn) |
| 4 | quatre (kat) | cuatro (KWAH-troh) | shi (shee) | si (ss) |
| 5 | cinq (sank) | cinco (SEEN-koh) | go (goh) | wu (ooh) |
| 6 | six (seece) | seis (sace) | doku (doh-koo) | liu (lyo) |
| 7 | sept (set) | siete (see-EH-tay) | shichi (shee-chee) | qi (chee) |
| 8 | huit (weet) | ocho (OH-cho) | hachi (hah-chee) | ba (bah) |
| 9 | neuf (nuhf) | nueve (NWEH-vay) | ku (koo) | jiu (jyo) |
| 10 | dix (deece) | diez (DEE-ehs) | ju (joo) | shi (shh) |



Getting to know...

### Leonardo Fibonacci

Leonardo Fibonacci was born in Italy around 1170. He was from the town of Pisa and is sometimes called Leonardo of Pisa or Leonardo Pisano. In his time, people in Europe still used Roman numerals. He learned to speak and read Arabic in Algeria. Fibonacci realized it was easier to use Arabic numerals for multiplication and division. He wrote a book about solving math problems using Arabic numerals.

Fibonacci found a way to solve equations with two unknown quantities. He also noticed that a series of numbers in which each number is the sum of the two preceding numbers like 0, 1, 1, 2, 3, 5, 8, 13…has many interesting properties. This is now called a Fibonacci series.

## Addition

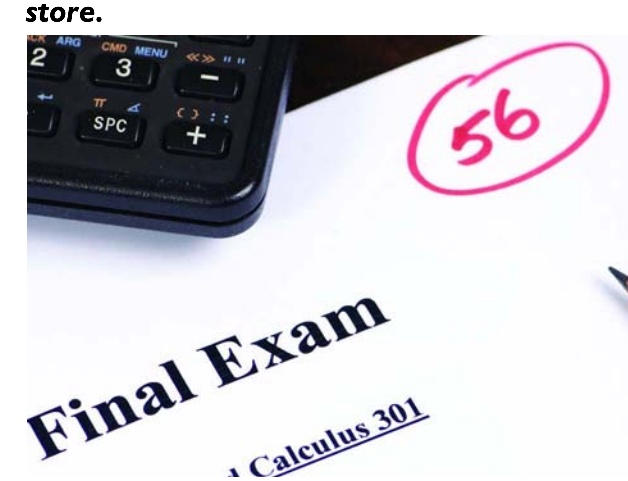
One way of putting numbers together is to add them. Addition is the combining of numbers to make a new number. We can add two or more numbers together.

People use addition all the time. We can add the prices of items we buy to find the total. We can add the points on a test to see the score.

### Terms Used in Addition

Addends are the numbers that we add together. The sum is the total of all the added numbers.


*We add prices together to get a total at the store.*




*The teacher added the points together for a final score.*

### Symbols Used in Addition

The plus sign (+) is used to show when numbers should be added. The equal sign (=) is used to separate the two equal sides of a mathematical statement.

plus sign → +, equal sign → =

$$8 + 8 = 16$$

addends: 8, 8; the sum: 16

**Adding from Left to Right.** Adding numbers from left to right is useful for small numbers.

$$6 + 6 = 12$$

**Adding by Going Down.** It is often easier to add bigger numbers on paper by going down.

A line called a bar replaces the equal sign to separate the sum from the numbers being added.

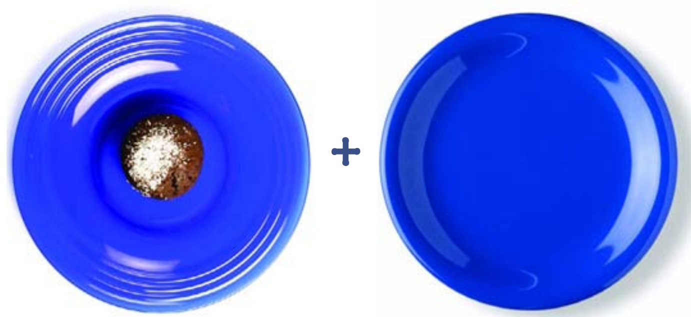
$$\begin{array}{r} 54 \\ +\ 34 \\ \hline 88 \end{array}$$

plus sign: +; addends: 54, 34; bar: the line; the sum: 88

**Adding Zero.** If you add zero to a number, the number does not change.

$$6 + 0 = 6$$

$$12 + 0 = 12$$



1 muffin plus 0 muffins equals 1 muffin

### Addition is Commutative

In addition, you can reverse the numbers you add and the sum will not change. We call this the commutative property.

$$102 + 103 = 205$$

$$103 + 102 = 205$$

## Subtraction

The opposite of addition is subtraction. Addition puts numbers together, but subtraction takes one number away from the other. In subtraction, you find the difference between two numbers. We can subtract two or more numbers from each other.

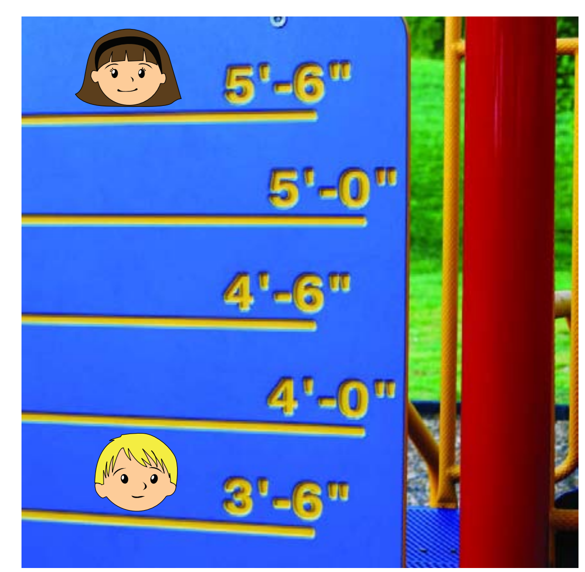


People use subtraction all the time in their lives. We can subtract to find out how much money we will have left after we buy something. We can also find out how much time we have left to complete a task with subtraction.

*This woman is checking how much time she has left before the game is over.*

### Terms Used in Subtraction

In subtraction, we make a new number. The new number is the difference between the numbers.




*If one child is 5'6" and another child is 3'6", you can subtract the two measurements and discover the difference in their heights is two feet.*

### Symbols Used in Subtraction

The minus sign (-) is used to show when numbers should be subtracted. The equal sign (=) is used to separate the two equal sides of a mathematical statement.

minus sign → -, equal sign → =

$$8 - 2 = 6$$

minuend: 8; subtrahend: 2; the difference: 6

**Subtracting from Left to Right.** Subtracting numbers from left to right is useful for subtracting small numbers.

$$7 - 3 = 4$$

**Subtracting by Going Down.** It is often easier to subtract bigger numbers on paper by going down.

We use a bar instead of the equal sign to separate the difference from the big numbers being subtracted.

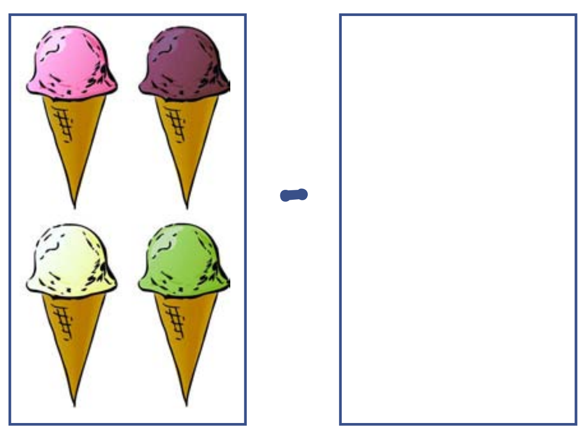
$$\begin{array}{r} 3942 \\ -\ 2934 \\ \hline 1008 \end{array}$$

minus sign: -; bar: the line

**Subtracting Zero.** If you subtract zero from a number, the number does not change.

$$6 - 0 = 6$$

$$12 - 0 = 12$$



4 ice creams minus 0 ice creams equals 4 ice creams

## Subtraction is Not Commutative

If you reverse the numbers in a subtraction problem, you will usually get the wrong answer. Subtraction does not have commutative properties.

$$5 - 3 = 2$$

$$3 - 5 = -2$$

# Multiplication

Sometimes, numbers are added to themselves many times, over and over. A simple way of describing this is multiplication.

For example, you can add the number 6 four times, like this:

$$6 + 6 + 6 + 6 = 24$$

In this problem, the number 6 appears four times. Instead of adding, you can multiply four times six and get the same answer:

$$4 \times 6 = 24$$

Find out more

**Arrays**

Drawing an array is a way to create a picture of the relationship between addition and multiplication.

*There are five rows with four cars in each. You can write the equation 5 x 4 instead of 4 + 4 + 4 + 4 + 4. The answer is still 20.*

## Terms Used in Multiplication

When we multiply two or more numbers together, we call the answer the product.

$3 \times 2 = 6$ ← ***the product***



## Symbols Used in Multiplication

Several different symbols indicate we should use multiplication to solve a math problem. In beginning math, we usually use the times symbol (x) to show that numbers are going to be multiplied. Sometimes a dot (•) or an asterisk (*) is used in between numbers that are being multiplied. If you see an equation with parenthesis around groups of numbers, that also means to multiply.

$$(3+2)(6+2) = 40$$

$$5 \times 8 = 40$$

The equal sign (=) is used to separate the two equal sides of a mathematical statement.

**Multiplying Across.** For smaller numbers, you can multiply on a line going across. You can use the x, the dot, or the asterisk to show multiplication.

$$4 \times 9 = 36$$

$$4 \bullet 9 = 36$$

$$4 * 9 = 36$$

The product of 4 times 9 is 36.

**Multiplying by Going Down.** It is often easier to multiply bigger numbers on paper by going down.

$$\begin{array}{r} 24 \\ \times \quad 5 \\ \hline 120 \end{array}$$

***bar*** → (the line); 120 ← ***the product***

The bar is used instead of the equal sign when multiplying this way. The product, or answer, is below the bar.

**Multiplying by Zero.** Math is not magical. If you multiply a number by zero, the product is always zero.

$$4 \times 0 = 0$$

$$20 \times 0 = 0$$

$$1000 \times 0 = 0$$

## Multiplication is Commutative

You can reverse the numbers you are multiplying. The product will be the same.

$$4 \times 6 = 24$$

$$6 \times 4 = 24$$

Find out more

### The Multiplication Table

A multiplication table shows how we multiply the numbers 1 through 10. It's helpful to have a multiplication table around when you are memorizing your multiplication facts.

| X | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| 2 | 2 | 4 | 6 | 8 | 10 | 12 | 14 | 16 | 18 | 20 | 22 | 24 |
| 3 | 3 | 6 | 9 | 12 | 15 | 18 | 21 | 24 | 27 | 30 | 33 | 36 |
| 4 | 4 | 8 | 12 | 16 | 20 | 24 | 28 | 32 | 36 | 40 | 44 | 48 |
| 5 | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 | 60 |
| 6 | 6 | 12 | 18 | 24 | 30 | 36 | 42 | 48 | 54 | 60 | 66 | 72 |
| 7 | 7 | 14 | 21 | 28 | 35 | 42 | 49 | 56 | 63 | 70 | 77 | 84 |
| 8 | 8 | 16 | 24 | 32 | 40 | 48 | 56 | 64 | 72 | 80 | 88 | 96 |
| 9 | 9 | 18 | 27 | 36 | 45 | 54 | 63 | 72 | 81 | 90 | 99 | 108 |
| 10 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 | 110 | 120 |
| 11 | 11 | 22 | 33 | 44 | 55 | 66 | 77 | 88 | 99 | 110 | 121 | 132 |
| 12 | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 |



There are a few ways to use a multiplication table.

- Pick the two numbers you want to multiply
- Find the first number in the top orange row
- Find the second number in the orange column on the left
- Move down the column from the number on the top and across the row from the number on the left
- The solution is the number where they meet

| X | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| 2 | 2 | 4 | 6 | 8 | 10 | 12 | 14 | 16 | 18 | 20 | 22 | 24 |
| 3 | 3 | 6 | 9 | 12 | 15 | 18 | 21 | 24 | 27 | 30 | 33 | 36 |
| 4 | 4 | 8 | 12 | 16 | 20 | 24 | 28 | 32 | 36 | 40 | 44 | 48 |
| 5 | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 | 60 |
| 6 | 6 | 12 | 18 | 24 | 30 | 36 | 42 | 48 | 54 | 60 | 66 | 72 |
| 7 | 7 | 14 | 21 | 28 | 35 | 42 | 49 | 56 | 63 | 70 | 77 | 84 |
| 8 | 8 | 16 | 24 | 32 | 40 | 48 | 56 | 64 | 72 | 80 | 88 | 96 |
| 9 | 9 | 18 | 27 | 36 | 45 | 54 | 63 | 72 | 81 | 90 | 99 | 108 |
| 10 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 | 110 | 120 |
| 11 | 11 | 22 | 33 | 44 | 55 | 66 | 77 | 88 | 99 | 110 | 121 | 132 |
| 12 | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 |

$5 \times 5 = 25$

Another way to use the table is to move down one column or across one row to see the products of one number. Most people memorize these columns or rows.

## Division

PROJECTS volume 10 8.1

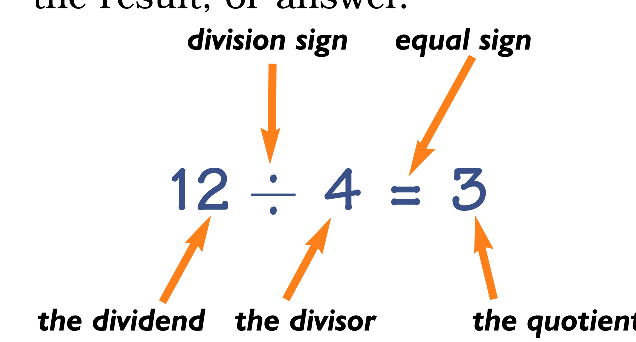
Numbers are broken into equal pieces when they are divided. Division tells us how many of one number it takes to equal another number.

We use division in everyday life. We often divide up our time to see how long we can spend on activities. We divide treats to make sure everyone has an equal amount.

*If four people were to divide this pizza to share, each person would get an equal amount. Eight divided by 4 is 2. You can write the problem this way: $8 \div 4 = 2$.*

### Terms Used in Division

In division, each number has a name. The number that we are dividing is called the dividend. The number that we are using to divide is called the divisor. The quotient is the result, or answer.



When one number is divided by another, the dividend is equal to the quotient itself times the divisor. In this way, division is the opposite of multiplication.

$$3 \times 5 = 15$$

$$15 \div 3 = 5$$

### Symbols Used in Division

There are several different symbols used to let you know you need to use division to solve a math equation.

One way to divide numbers is on a line from left to right using the division symbol (÷).

$$12 \div 3 = 4$$

A slash (/) can also be used to show division.

$$12 \,/\, 3 = 4$$

Another way of writing a division problem is to use a corner-like symbol ($\overline{)\phantom{0}}$). The divisor goes outside the symbol on the left. The dividend goes inside the symbol and the answer, or quotient, is written on top of the symbol.

$$\begin{array}{r} 4 \\ 3\overline{)12} \end{array}$$

### Dividing by Zero

If you divide a number by zero, the quotient is always zero.

$$12 \div 0 = 0$$

$$7 \div 0 = 0$$

### Division is Not Commutative

You can't reverse the numbers you are dividing. The quotient will usually not be the same.

$$15 \div 5 = 3$$

$$5 \div 15 = .333$$

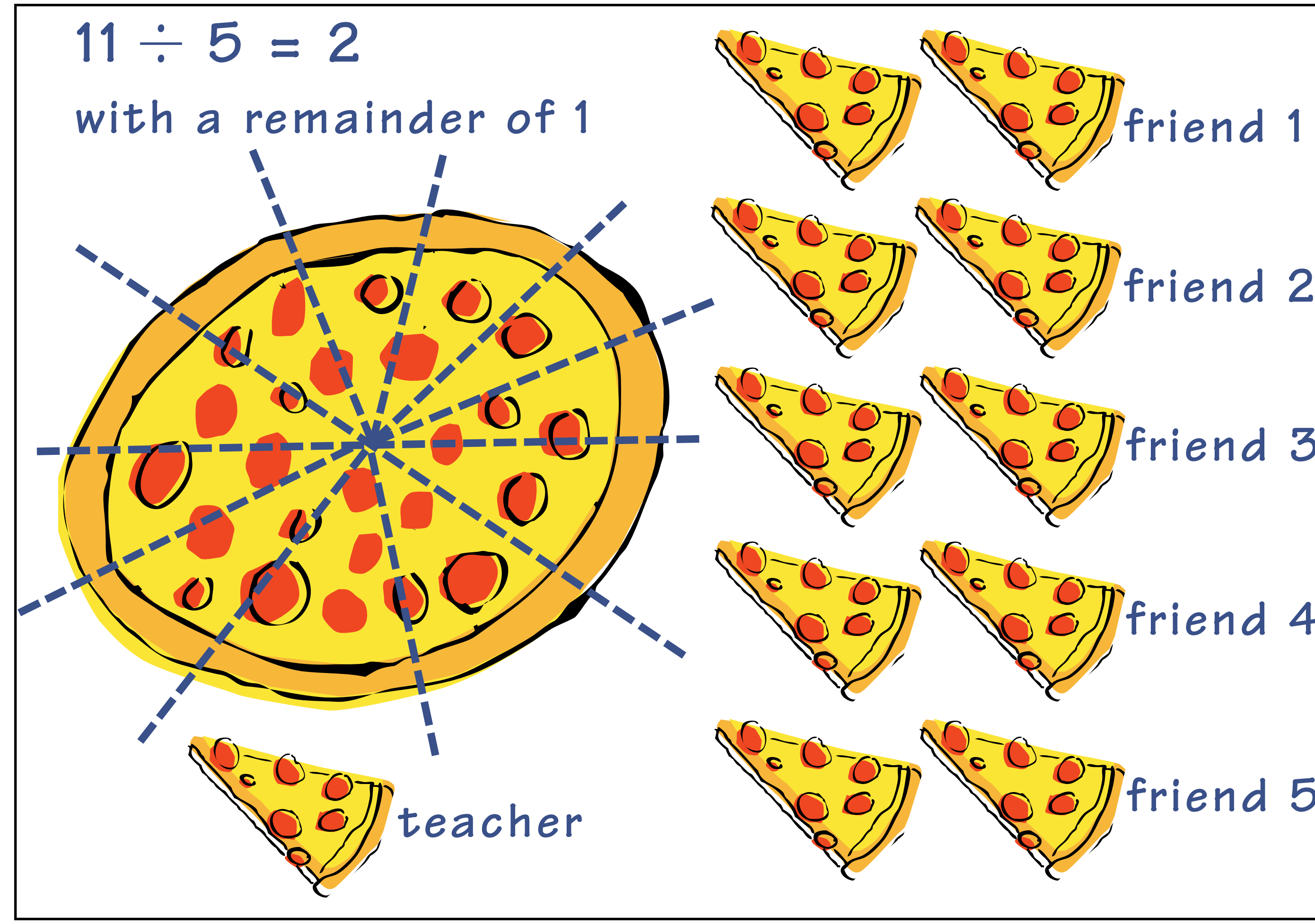
### Remainders

Sometimes numbers cannot be divided evenly. The quotient is not a whole number. When this happens, there is a remainder. The remainder is the number left over after the dividend has been evenly divided.

For example, If you have a pizza cut into 11 pieces and you want to share it equally with 5 friends, each friend will get 2 pieces of pizza and you'll have one piece left over for your teacher.

$$\begin{array}{r} 2r1 \\ 5\overline{)11} \\ -10 \\ \hline 1 \end{array}$$






### Long Division

In more advanced division, there is not a traditional remainder. Instead, long division is used to calculate exact quotients by extending the answer using decimals or fractions.

**Step 1.**
**Divide 7 by 6**

$$\begin{array}{r} 1\phantom{5} \\ 6\overline{)75} \end{array}$$

**Step 2.**
**Then multiply 6 times 1 and subtract answer from 7**

$$\begin{array}{l} \phantom{6)}1 \\ 6\overline{)75.0} \\ \phantom{6)}-6 \\ \hline \phantom{6)}1 \end{array}$$

**Step 3.**
**Now bring down the 5 and divide 15 by 6**

$$\begin{array}{l} \phantom{6)}1 \\ 6\overline{)75.0} \\ \phantom{6)}-6\downarrow \\ \hline \phantom{6)}15 \end{array}$$

**Step 4.**
**Redo all steps until you get to zero**

$$\begin{array}{r} 12.5 \\ 6\overline{)75.0} \\ -6\phantom{5.0} \\ \hline 15\phantom{.0} \\ -12\phantom{.0} \\ \hline 30 \\ 30 \\ \hline 0 \end{array}$$

# Sets

We think of a set as a group of things that go together. A chess set has many different pieces. Some are black and some are white. Some are large and some are small. Some pieces are shaped like horses, and some like castles. Yet, they are all part of the same set.

***All pieces in this game are part of the same chess set.***

In mathematics, a set is a collection of numbers or things that are grouped together. Each item in a set is called an element, or member, of that set. Sets often have something in common.

Set theory is the study of possible sets and it is the basis of most math. You may not talk about set theory but much of the math that you do each day in school is using set theory. Mathematicians use brackets { } to show what is in a set.

This is the set of even numbers from two to ten.

{2, 4, 6, 8, 10}

This is the set of whole numbers that are greater than nine.

{10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23...}

Getting to know...

**Georg Cantor**

Georg Cantor was born March 3, 1845. He is best known as the creator of set theory, which has become a foundational theory in mathematics. In 1904, the Royal Society of London awarded Cantor its Sylvester Medal. Georg Cantor died in 1918.



## Finite Sets

When something is finite, it has a limit or an end. The set {2, 4, 6, 8, 10} is a finite set. It contains only five items. If it is possible to count the number of items in a set, it is a finite set.

## Infinite Sets

When something is infinite, it has no limit or end. For example, the set of whole numbers is infinite. No matter how large a number is, you can always make it larger by adding 1 to it. The set of whole numbers has no end.

It would be impossible to write an infinite set. You could never stop writing! So, we show that a set is infinite by using dots.

{1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11...}

***The three dots show that the numbers would go on to infinity.***

## Subsets and Supersets

In a subset, all the elements of the set are part of a superset. A superset can have many different subsets.

The set of odd whole numbers is a superset.

{1, 3, 5, 7, 9, 11, 13, 15, 17, 19, 21, 23, 25, 27, 29, 31...}

Some possible subsets of the set of odd whole numbers are:

- The set of odd whole numbers from 1 through 5

  {1,3,5}

- The set of odd whole numbers less than 10

  {1,3,5,7,9}

- The set of odd whole numbers greater than 15 and less than 31

  {17, 19, 21, 23, 25, 27, 29}

**Find out more**

### Naming Sets

Sets are often named by using capital letters. We might name two sets like this:

A={5,10,15,20,25,30}    B={10,20,30}

Naming sets makes them easier to talk about. We can say that "Set B is a subset of Set A" or that "Set A is a superset of Set B".

Instead of writing all of that, we can also use symbols. The symbol $\subseteq$ stands for subset. So instead of writing "Set B is a subset of Set A", we can write "B $\subseteq$ A".

### Empty Sets

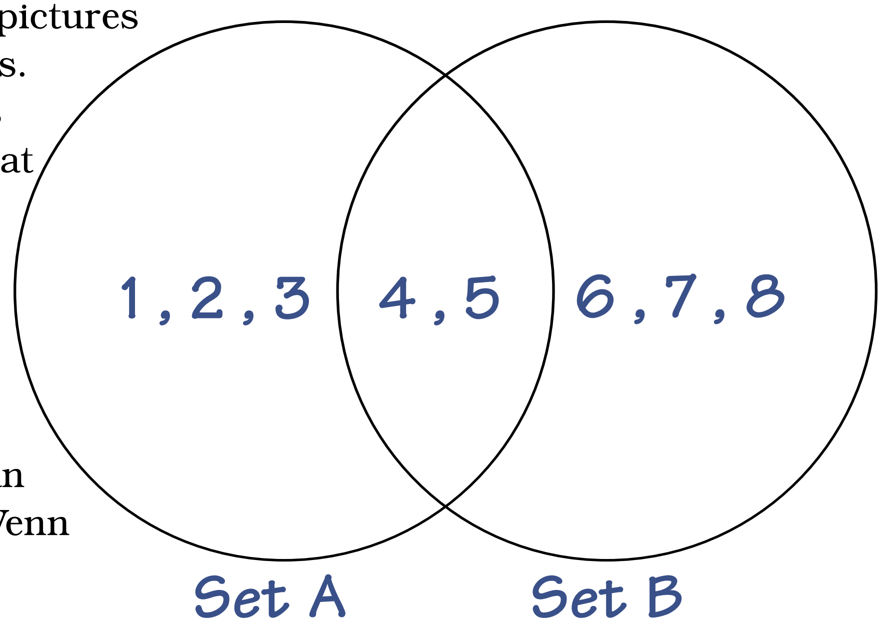
There is a special set called an empty set, or null set. An empty set contains no elements. We show it by using empty brackets { }, or by using the symbol ø. The empty set is a subset of all other sets.

## Venn Diagrams

We can use pictures to help us understand sets. These pictures are called Venn diagrams. They show relationships between sets. Let's look at these two sets:

A={1,2,3,4,5} and
B={4,5,6,7,8}

Both sets contain the numbers 4 and 5. We can show this easily with a Venn diagram.






### Intersection of Sets

The place where the circles overlap is called the intersection of the two sets. The numbers 4 and 5 are there because they are parts of both sets. We use the symbol $\cap$ to show where the circles intersect.

### Union of Sets

The union of sets is all the elements of both sets. In the previous Venn diagram, the union of A and B would be {1,2,3,4,5,6,7,8}. We use the symbol $\cup$ to show a union. We would write that as A $\cup$ B.

**Find out more**

### Using Venn Diagrams to Compare and Contrast

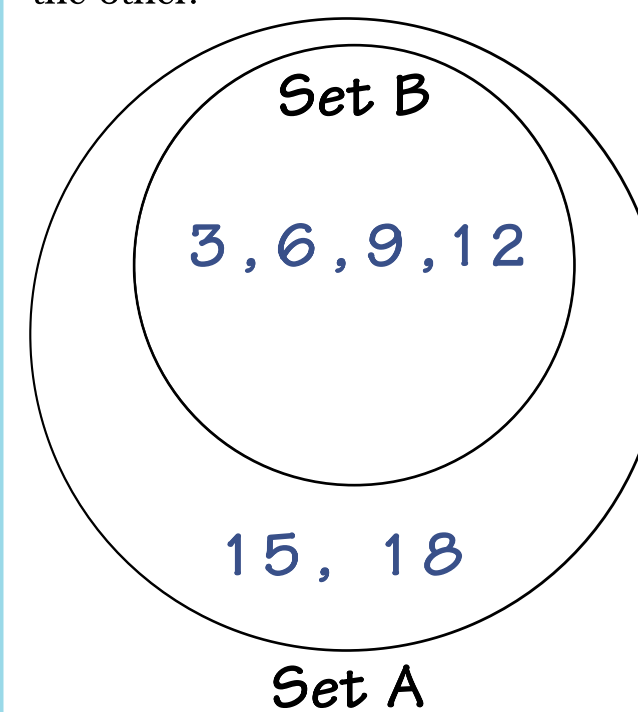
Venn diagrams can be used in subjects besides math to show how things are the same (compare) and how they are different (contrast). For example, in reading you can show how two characters are alike and different. In science, you can compare different species. In social studies, you can use a Venn diagram to compare and contrast two countries. There's no end to how you can use Venn diagrams!


### Showing Subsets and Supersets

It's easy to show subsets and supersets using Venn diagrams. Let's use these sets:

A={3,6,9,12,15,18} and
B={3,6,9,12}

A is the superset and B is the subset. To show this in a Venn diagram, just put one circle inside the other.



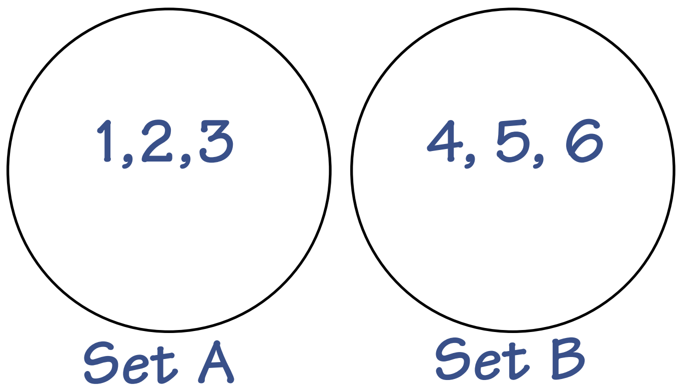

### Showing Disjoint Sets

Sets are called disjoint when they have none of the same elements. Let's use these sets:

A={1,2,3} and B={4,5,6}

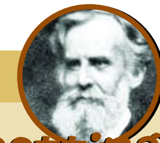
We would show this on a Venn

diagram by drawing two circles that do not intersect.




The only subset of these sets is the empty set { }.

$$A \cap B = \varnothing$$



Getting to know...

### John Venn

John Venn was born in 1834 in Hull, England. He was educated in London and went to college at Cambridge University. He later became a teacher there.

Venn became interested in logic and wrote several books on the subject. In 1881, he published a book called *Symbolic Logic*, which explained the Venn diagrams that he is now famous for. This work made him a very well known scholar. He worked on improving his diagrams over the years. He died in 1923 at the age of 88.

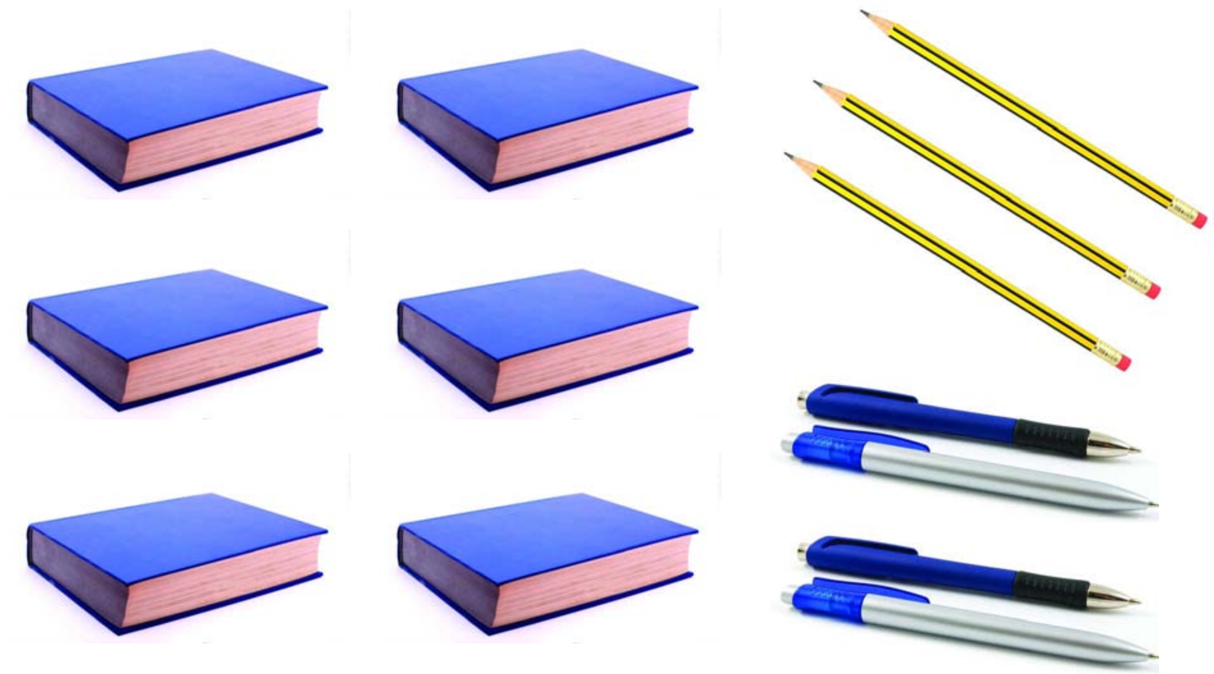
## Ratios

Ratios are comparisons between numbers. We usually show this relationship by using the colon symbol ( : ). For example, most people have ten fingers. Suppose you show your hands like this:



Out of a total of ten fingers, only five are showing. This ratio can be shown as 5:10. To read this ratio you would say "a ratio of 5 to 10." The comparison is between the total number of fingers showing and the total number of fingers.

Suppose you opened up your book bag. Inside are 6 books, 3 pencils, and 4 pens. The ratio of books to pens is 6:4. The ratio of pencils to the total number of items is the bag is 3:13.



*CAPTION*

Find out more

### Television Ratios

On televisions, all screens used to be a ratio of 4:3. That meant for every 4 inches of width, the screen was 3 inches high. Today, many televisions and computer monitors come in a ratio of 16:9. For every 16 inches wide the screen is, it is 9 inches high. This is wider than the old 4:3 standard. Because of this, TVs with a 16:9 ratio are called widescreen.

## Proportions

Proportions are comparisons between two ratios. It is a statement that the ratios are equal. Proportions use an equal sign. They look like this:

$$\frac{2}{3} = \frac{6}{9}$$

To show whether proportions are equal, we cross multiply.

$$\frac{2}{4} = \frac{8}{16}$$

$$8 \times 4 = 32$$

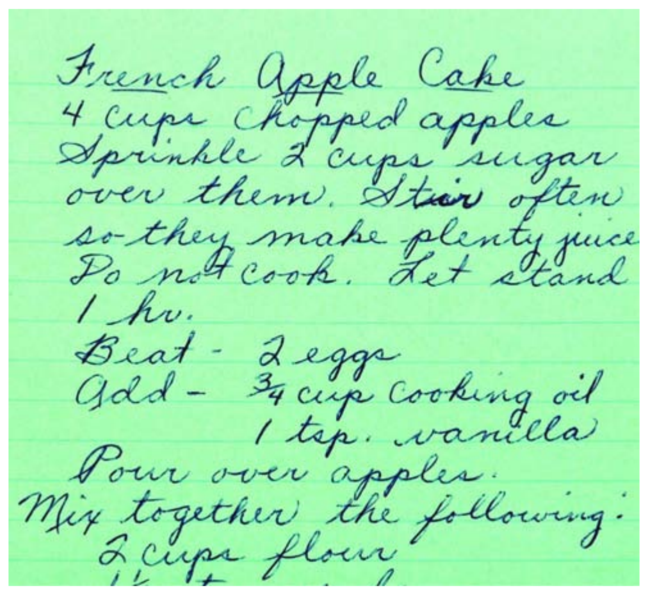
$$2 \times 16 = 32$$

When we cross multiply, the product of each equation is 32. When the products are the same, the proportions are equal.

If you took at test with ten questions, each correct answer might be worth 10 points. The ratio would be 1:10. If you got 7 questions right, your score would be a 70. The proportion would look like this:

$$\frac{1}{10} = \frac{7}{70}$$

Imagine baking a cake. The cake is made up of ingredients. You might use flour, sugar, and butter. These ingredients have to be mixed together in certain amounts, or proportion. If you use the wrong proportion of ingredients your cake will be ruined. The proper ratio of ingredients will make a great cake. Proportions are very important.

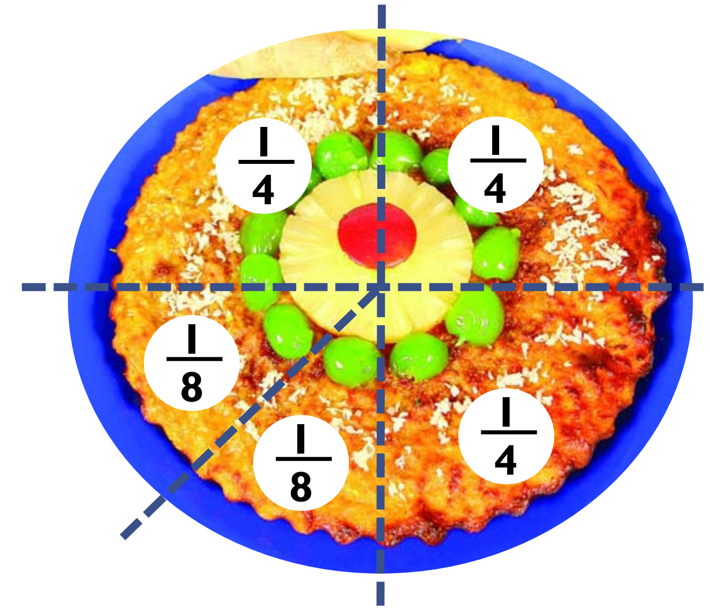

French Apple Cake
4 cups chopped apples
Sprinkle 2 cups sugar
over them. Stir often
so they make plenty juice
Do not cook. Let stand
1 hr.
Beat - 2 eggs
Add - 3/4 cup cooking oil
1 tsp. vanilla
Pour over apples.
Mix together the following:
2 cups flour

*If followed carefully, the recipe will produce a delicious treat!*

## Fractions

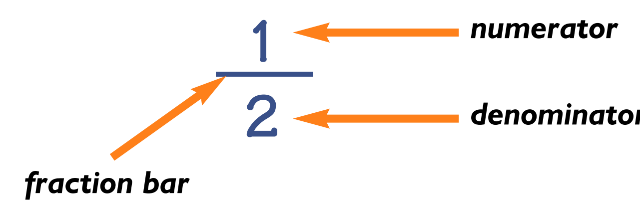
One way of describing a ratio is with fractions. A fraction is used to show the ratio between two numbers. It can also show a piece, or portion, of a number.






### Parts of a Fraction

The top part of a fraction is called the numerator. The bottom part of a fraction is called the denominator. The line between them is called the fraction bar.

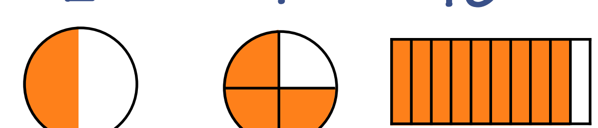


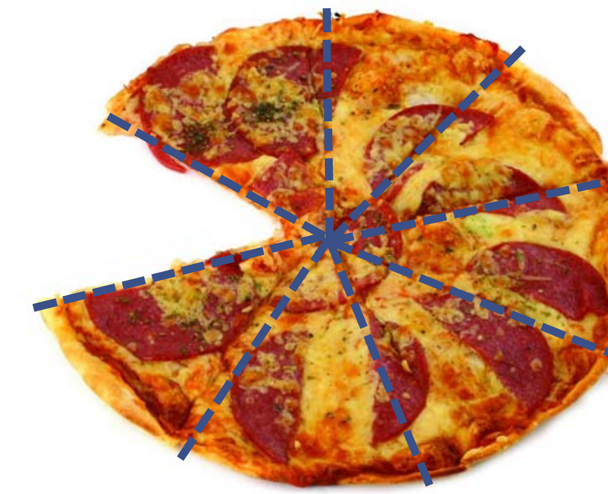

### Types of Fractions

There are many different types of fractions.

In a proper fraction, the numerator is a smaller number than the denominator. These fractions equal an amount that is less than 1 whole.

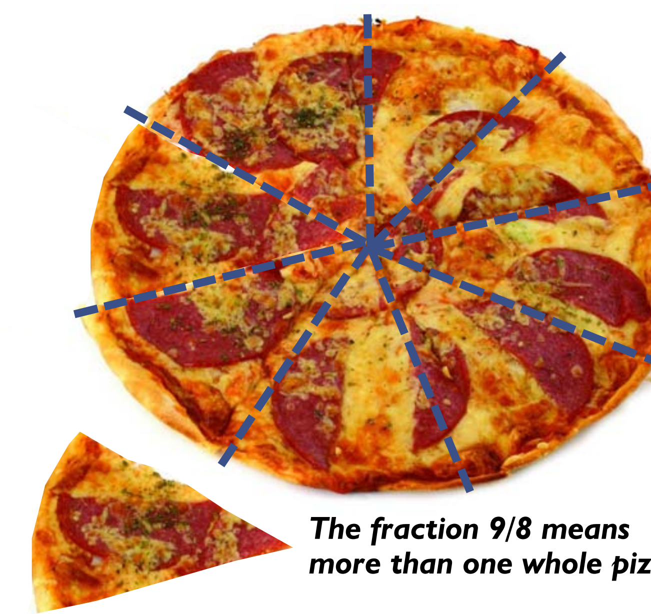
$$\frac{1}{2} \qquad \frac{3}{4} \qquad \frac{9}{10}$$





***The fraction 7/8 means less than one whole pizza.***

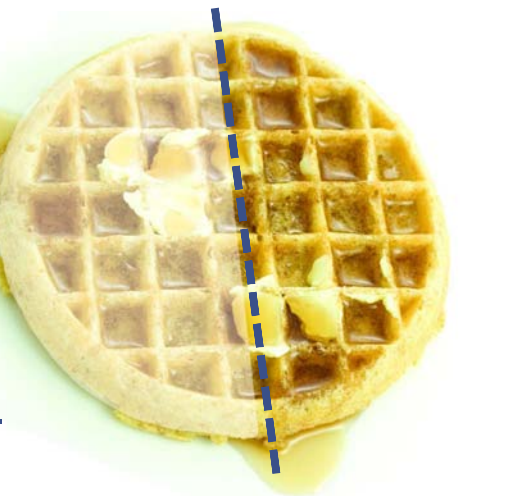
In an improper fraction the numerator is a larger number than the denominator. These fractions equal a number greater than 1 whole.



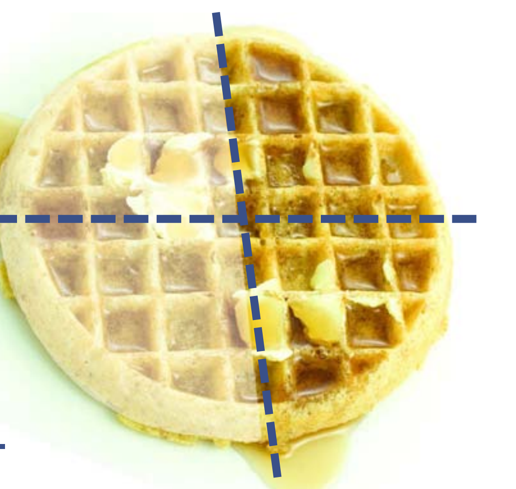
***The fraction 9/8 means more than one whole pizza.***

## Equivalent Fractions

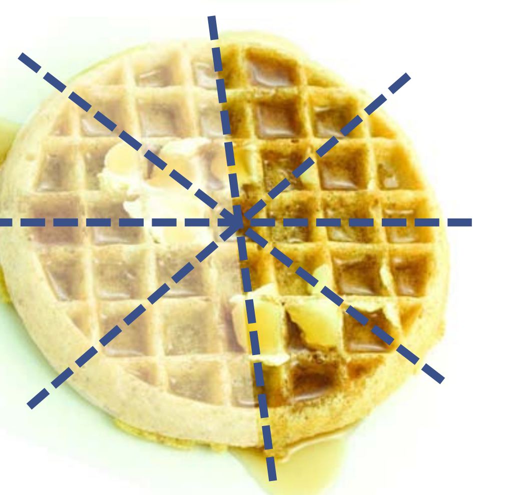
If fractions have the same ratio, they are equivalent. Look at the waffle photos.



$\frac{1}{2}$



$\frac{2}{4}$



$\frac{4}{8}$

$$\frac{1}{2} = \frac{2}{4} = \frac{4}{8}$$

*These fractions are all equal to half the waffle.*

You can find equivalent fractions yourself. Multiply the numerator and denominator by the same number.

$$\frac{1}{2} \times \frac{2}{2} = \frac{2}{4}$$

$$\frac{1}{2} \times \frac{4}{4} = \frac{4}{8}$$

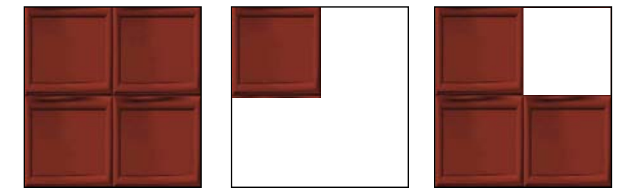
## Adding and Subtracting Fractions

To add or subtract fractions, they must have the same denominator. If they do, just add or subtract the numerators.

$$\frac{1}{5} + \frac{2}{5} = \frac{3}{5}$$

$$\frac{5}{7} - \frac{2}{7} = \frac{3}{7}$$





$$\frac{4}{4} - \frac{1}{4} = \frac{3}{4}$$

Improper fractions can be made into a separate whole number followed by a proper fraction. These are called mixed fractions. You can change an improper fraction into a mixed fraction by dividing the denominator into the numerator.

$$\frac{5}{2} = 2\frac{1}{2}$$

*Five apple halves make two and a half apples.*

## Finding a Common Denominator

You can't add or subtract fractions unless they have the same denominator. If their denominators are different, you must find a common denominator for them.

A common denominator for the fraction 2/3 and 1/2 must be found in order to add or subtract them. To find a common denominator, list the multiples of 3 and the multiples of 2. Some of your numbers will appear in both lists. One common denominator is 6.

2 4 (6) 8 10

3 (6) 9 12 15

An equivalent fraction for 2/3 is 4/6. An equivalent fraction for 1/2 is 3/6. Now, these fractions can be added.

$$\frac{3}{6} + \frac{2}{6} = \frac{5}{6}$$

These fractions can also be subtracted.

$$\frac{3}{6} - \frac{2}{6} = \frac{1}{6}$$

### Multiplying Fractions

When you multiply fractions, just multiply straight across. Multiply the numerators. Then multiply the denominators. The result is your new fraction.

$$\frac{5}{7} \times \frac{2}{3} = \frac{5 \times 2}{7 \times 3} = \frac{10}{21}$$

You can also multiply whole numbers and fractions. Just put a 1 under the whole number to make it a fraction, and multiply.

$$2 \times \frac{3}{7} = \frac{2}{1} \times \frac{3}{7} = \frac{6}{7}$$

### Dividing Fractions

It's almost as easy to divide fractions as it is to multiply them. Just take the second fraction (the one after the division symbol), flip it upside down, and then multiply. That "flipped" fraction is called a reciprocal.

Take a problem like 1/8 ÷ 1/3. Multiply 1/8 by the reciprocal of 1/3, or 3/1.

$$\frac{1}{8} \div \frac{1}{3} = \frac{1 \times 3}{8 \times 1} = \frac{3}{8}$$

You can also divide whole numbers and fractions. Just put a 1 under the whole number to make it a fraction, and divide by flipping the fraction and multiplying.

$$5 \div \frac{1}{4} =$$

$$\frac{5}{1} \div \frac{1}{4} =$$

$$\frac{5 \times 4}{1 \times 1} = \frac{20}{1}$$

$$= 20$$

## Decimals

### What is a Decimal?

A number can be divided forever. It can be divided into smaller and smaller parts. One way to show these small parts is with a fraction. Another way is with a point called a decimal. A decimal point exists after every whole number, even if it is not written there.

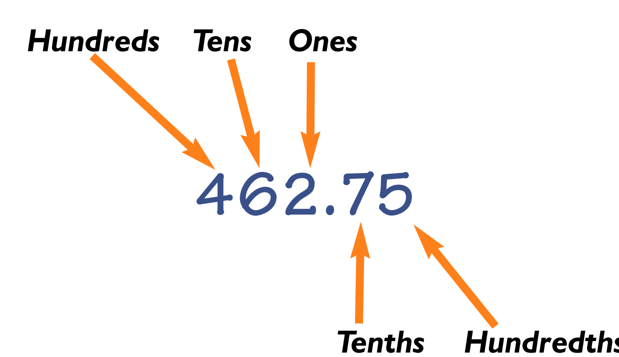
$$3 = 3.$$
$$415 = 415.$$



The fraction 1/2 is equal to 0.5. Decimals can be very important in calculating money, scientific numbers, and test grades. Another way of writing 50 cents is to write $0.50.

### How Decimals Work

Any numbers to the left of a decimal point are whole numbers. Any numbers to the right of a decimal point show a fraction of a whole number. The places have different names as you move to the left or the right of the decimal point. To the left are the ones, tens, hundreds, thousands, ten thousands, and so on. To the right are the tenths, hundredths, thousandths, ten thousandths, and so on. We write 4 hundreds, 6 tens, 2 ones, 7 tenths, and 5 hundredths as 462.75.




### Terminating and Repeating Decimals

Some decimals just end. They have a specific number of decimal places. These are called terminating decimals. An example is 462.75. It ends after the 5. Sometimes a decimal never ends. The final number is repeated over and over in a regular pattern. This is called a repeating decimal. The fraction 1/3 is equal to 0.33333.... The dots show that the 3 repeats forever. You can also write a bar over the repeating part. If you write 0.3 and draw a line over the 3, you show that the 3 repeats forever.

$$0.333... = 0.\overline{3}$$

### Rounding Off Decimals

Sometimes, a calculation can lead to a decimal that never ends and never repeats. You can't write a decimal that never ends. Instead, you can round it off. A number is rounded up if the next decimal is 5 or greater. The number stays the same if the next decimal is 4 or less. The number 0.0236 can be rounded up to 0.024. Money is usually rounded off to the nearest penny.

### Find out more: Percentages

The word "percentage" means "per 100." A percentage is the ratio of a number per 100. The percent symbol (%) shows that a number is a percentage. Twenty-five percent can be written as 25% and is equal to the ratio 25/100. An equivalent fraction to 25/100 is 1/4, or one-fourth.

It is easy to write percentages with decimals. Just move the decimal point two places to the left. Twenty-five percent can also be written as the decimal 0.25. One hundred percent is simply equal to the number 1.

Percentages are used in many different areas. A store may have a sale where everything is 10% off. This means that 10 cents will be deducted for every dollar spent. People often leave a tip of 15% when they eat at a restaurant. This means that they will leave 15 cents for every dollar that the food cost them. Use the example below to practice calculating a tip. Cost of dinner: $20. Tip: 15%

$$20 \times 0.15 = 3$$

The tip would be $3. The total bill would be $23.

Taxes are also measured in percentages.

Grades in school are sometimes measured in percentages. Scoring 100% on a test means you got all the answers right!

# Statistics

Mathematics can be used to predict things. We can figure out when things may happen. This type of mathematics is called statistics.

Statistics can be used to calculate many things. You can figure out the odds of winning the lottery. You might find the number of kids who like to eat strawberry ice cream.


***The odds of winning most state lotteries are more than 18 million to one. If you save one dollar a month for the next 20 years you will have saved $240. However, your account will be worth about $465 because of the interest you collect.***

Statistics are used everywhere. All the sciences use them. Sports teams use statistics to see how each player is doing. Teachers and schools use statistics to analyze how well students are learning. You may use statistics when you figure out how long it takes to do your homework.



## Averages

One form of statistics is called averages. To find an average, add up a group of numbers. Then divide the sum by the amount of numbers. We can figure out the average test scores in a school by adding up all the scores and then dividing that total by the number of people who took the test.

An average is sometimes called the mean. This is not the same as the median. In a list where all the numbers are written in order from lowest to highest, the median is the middle number. On the list, the median has as many numbers lower than itself as it has numbers higher than itself. The median and the mean are usually different numbers.

| Student | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Score | 20 | 30 | 35 | 40 | 45 |

$$20 + 30 + 35 + 40 + 45 = 170 \div 5 = 34$$

median (35) — 34 is the average test score — mean (34)

### Find out more: Baseball Stats

Baseball fans love to keep track of how baseball players are doing. Managers, coaches, and fans all use statistics, or stats. You can find these stats in the sports section of your newspaper. Some baseball stats are simple totals of home runs, stolen bases, and runs batted in, or RBIs. Other stats are ratios or percentages. A pitcher has an earned run average, or ERA. This is the average number of runs that the pitcher gives up in nine innings.

A batting average tells how well a baseball player hits. It is calculated using the number of times the player has come to bat and the number of times he has gotten a hit. A player who hits safely every time would be hitting 1.000. We would say, "He is batting a thousand." Most hitters have a batting average between .200 (two hundred) and .300 (three hundred). This means that they get 2 or 3 hits for every 10 times they come to bat. Great hitters have a batting average of over .300. In baseball, a player who gets out 7 out of 10 at bats is considered a good hitter.

## Probability

Probability tells us how likely something is to happen. It is sometimes called chance. Another name for probability is odds.

Probability can be measured in the real world. Start flipping a coin in the air. Flip it 100 times. The odds are that it will land on heads about 50 times, and tails about 50 times. The chances are equal. We call this a 50-50 chance.

You can figure out the chance of just about anything. Rolling a 6-sided die will give you a 1 in 6 chance of rolling a 5. If you do this thousands of times, the odds remain the same. The average ratio of rolling a 5 will be 1 in 6, or 1/6. The chances of rolling two 5's in a row are much smaller.

*Playing games with dice make them exciting because you are never sure what number you will role.*

Find out more

**The Lottery Has Bad Odds**

In a lottery, people pick numbers they hope will match the official numbers chosen. The more numbers you can pick from, the lower the probability that the numbers will match. Most people who play do not win. You have a better chance of being struck by lightning than of winning millions of dollars in a lottery!



# Algebra

Figuring out a math problem when you know all the numbers is usually easy. But what if one of the numbers is unknown? The problem would be more difficult. You would need to use algebra to figure it out. Algebra is the branch of mathematics that deals with unknown quantities. The principles of algebra are used to describe everything from exchanges of money to lines on a graph. Algebra uses all the rules of arithmetic. It also creates new rules.

## Variables

In algebra, an unknown number is called a variable. We use letters to stand for the unknown numbers. Often, variables are letters such as a, b, and c or x, y, and z. Variables can stand for many different values or a range of values.

Variables can be used to solve problems even if all the values are not known. Imagine that a passenger freight train is 200 meters long. If the freight train is 30 meters less than twice the length of a passenger train, how long is the passenger train?

*You can use algebra to determine the length of this train.*

You can write this word problem as an equation. Let the variable x represent the length of the passenger train.

Twice the length of the passenger train would be 2x, or two times x. The length of the freight train is 30 meters less than that.

$$200 = 2X - 30$$

To solve this equation, the x must be by itself. To do this, add 30 to both sides of the equation.

$$30+200=2X-30+30$$

or

$$230=2X$$

Then divide both sides of the equation by 2.

$$230 \div 2=2X\div 2$$

or

$$115 = X$$

The passenger train is 115 meters long.

# Exponents

Mathematicians often multiply numbers by themselves. An easy way to show this is to use an exponent. An exponent is a little number written above and to the right of a number or variable. It tells how many times the number or variable should be multiplied by itself. For example:

$$5^3 = 5 \times 5 \times 5 = 125$$

Numbers or variables with an exponent of 2 are called squared numbers. We say the variable $x^2$ as "x squared". It is the same as x times x. Numbers or variables with an exponent of 3 are called cubed. We say the variable $y^3$ as "y cubed". It is the same as y times y times y.

Exponents are sometimes called the powers of a variable. We would say $5^3$ as "5 to the third power".

Find out more

### Scientific Notation

Many numbers are either really big or really small. One way to show these numbers is to simply write out all that make them up. You can also show big numbers or numbers much less than 1 by using scientific notation. Scientific notation is a way of writing a number as the product of a number between 1 and 10 multiplied by the number 10 raised to a power. The number is big when the exponent on the 10 is positive. The number is very small when the exponent on the 10 is negative.

It is usually easier to show very big or very small numbers using scientific notation than it is to write out the entire number. The average distance from the Earth to the Sun is about 149,000,000,000 meters. It is much easier to write that distance from the Earth to the Sun as $1.49 \times 10^{11}$ meters. The mass of a single neutron inside of an atom is really, really small. Written out, it would be 0.00000000000000000000000000167 kilograms. In scientific notation, this number is written $1.67 \times 10^{-27}$ kilograms, with a minus sign next to the exponent.



# Roots

The root is a number multiplied by itself. When a number is squared, it is multiplied by itself. An example would be 3 x 3. In this example, the root number is 3. The number 3 squared, or 3 x 3, is equal to 9.

## Square Root

The square root shows what quantity multiplied by itself will be equal to a specific number. For example, the square root of 25 is 5, because 5 x 5 =25.

The symbol for a square root ($\sqrt{\ }$) goes around the number. Since the square root of 25 is 5, we would write it like this:

$$\sqrt{25}=5$$

## Cube Root

The cube root shows what quantity multiplied by itself twice will be equal to a specific number. The cube root of 8 is 2, or

$$\sqrt[3]{8}=2$$

because

$$8 = 2 \times 2 \times 2$$

Roots are the opposite of exponents. The square root of the square of any number is equal to that number. The square root of $x^2 = x$.

## Real Numbers and Imaginary Numbers

In general, two different types of numbers are the result of roots. Most of the numbers we use every day are called real numbers. The square root of a positive number will give a real number. Sometimes, mathematics can be used to make imaginary numbers. The square root of a negative number will give an imaginary number. We do not use imaginary numbers to count objects or measure distance. They are part of a complex number system that aid in understanding of things that are described by ordinary numbers. When determining the strength of an electromagnetic field, scientists use imaginary numbers.

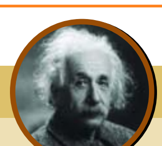
## How to Find Square Roots

Calculators and computers are often used to find the square roots of numbers. The square root of a number may result in a number with many decimal points.

### Roots

You can also find root numbers, square roots, squares and cubes using a chart like the one below. Because some square roots have many numbers to the right of the decimal, they are rounded here to the nearest thousandth.

| Root Number | Squared | Cubed | Square Root |
|---|---|---|---|
| 1 | 1 | 1 | 1.000 |
| 2 | 4 | 8 | 1.414 |
| 3 | 9 | 27 | 1.732 |
| 4 | 15 | 64 | 2.000 |
| 5 | 25 | 125 | 2.236 |
| 6 | 36 | 216 | 2.449 |
| 7 | 49 | 343 | 2.646 |
| 8 | 64 | 512 | 2.828 |
| 9 | 81 | 729 | 3.000 |
| 10 | 100 | 1000 | 3.162 |
| 11 | 121 | 1331 | 3.317 |
| 12 | 144 | 1728 | 3.464 |
| 13 | 169 | 2197 | 3.606 |
| 14 | 196 | 2744 | 3.742 |
| 15 | 225 | 3375 | 3.873 |
| 16 | 256 | 4096 | 4.000 |
| 17 | 289 | 4913 | 4.123 |
| 18 | 324 | 5832 | 4.243 |
| 19 | 361 | 6859 | 4.359 |
| 20 | 400 | 8000 | 4.472 |



### Albert Einstein

Getting to know...

Albert Einstein was born in 1879 in Germany. He is considered one of the great thinkers of all time. People even use the word "Einstein" to mean a genius!

One of Einstein's greatest contributions was a famous equation, $E=MC^2$. This equation shows the relationship between mass and energy.



## Equations

An equation is a statement in mathematics that two things are equal. An equation always has two sides that are separated by an equal sign. Equations can be very simple, such as:

$$2 + 2 = 4$$

The amounts on both sides of the equal sign are the same.

### Equations with Variables

A more complex equation may have a variable in it:

$$9 + X = 15$$

Equations may have many variables in them.

### Polynomial Equations

An algebraic expression with two or more powers of a variable or variables is called a polynomial equation. An example of a polynomial equation is

$$y = 3X^3 + 5X^2 - 6$$

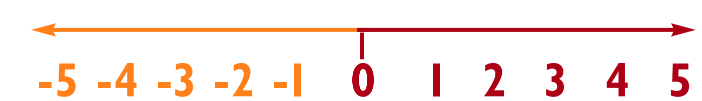
### Solving Equations

The trick to solving the equation is to get the variable by itself and away from all the other numbers. Arithmetic is often used to solve equations. Whatever is done to one side of an equation has to be done to the other side.

## Coordinates and Grids

### Number Lines

Number lines are pictures in which numbers are shown along marks on a line. Some number lines have both positive and negative numbers on them with the number 0 in the middle. The 0 on a number line is known as the origin. They are called real number lines. Numbers can be plotted, or drawn, along the number line. We call the points on a number line coordinates.



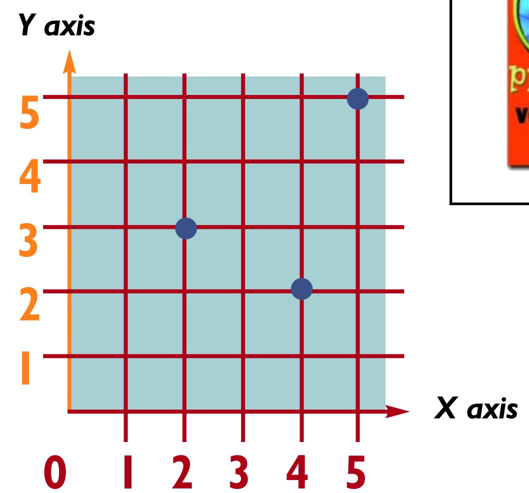

### Coordinate Grids

Sometimes, two real number lines are put together. This is called a coordinate grid. The number line going from left to right is called the x-axis. The line going up and down is called the y-axis. The two lines cross where the zero is located on each line. This is called the origin. This sort of grid is sometimes called a coordinate plane.

## Graphing Coordinates

***Coordinates name a point on a graph. When writing coordinates, use the x-axis coordinate first, followed by the y-axis coordinate.***

***Point A: (2, 3)***
***Point B: (4, 2)***
***Point C: (5, 5)***




PROJECTS volume 10 8.4

### Coordinates

Numbers called coordinates can be shown on the plane. The process of drawing the position of numbers is called graphing. Coordinates in a plane are often represented by the variables x and y. A point on the plane can be written with the coordinates (x,y). Numbers can be put in place of the variables. Then, a dot is drawn on the graph where those two coordinates meet. A line can be drawn between two points that are graphed. Algebraic equations can also be graphed.

### Words to Know

**axis** (AK-siss): a line at the side or bottom of a graph

**grid** (grid): a set of straight lines that cross each other to form a regular pattern of squares

**plane** (plane): a flat surface

### Emmy Noether

**Getting to know...**

Emmy Noether was born in Germany in 1882. She studied to be a teacher but then turned to mathematics. Women could not enroll at German universities. Noether was allowed to attend classes and earned a Ph.D. She worked at the local university without pay because she was a woman. The famous mathematician David Hilbert invited her to the University of Göttingen. Noether taught classes listed under Hilbert's name.

Noether made contributions to the field of abstract algebra. She also worked on the mathematics behind Albert Einstein's theory of relativity. In 1933, the Nazis took power in Germany and Noether was fired because she was Jewish. She moved to the United States but soon died following an operation.



# Geometry

Geometry is the branch of mathematics that studies objects in a defined space. Geometry is all about shapes and how to describe them.

Geometry studies mathematical designs. They are all around us. Lines, triangles, squares, rectangles, circles, and ellipses are found everywhere in nature. The shape of a snail shell is spiral. Lines are everywhere you look.

*A snail shell is an example of a Fibonacci Spiral. It follows the Fibonacci numbers or pattern. The pattern continues by adding the two previous numbers to get the next number in the sequence 0, 1, 1, 2, 3, 5, 8, 13....*

## Basic Geometry

Basic geometry deals with two-dimensional shapes. Anything that is flat is a two-dimensional surface. In geometry, this kind of surface is called a plane.

## Advanced Geometry

More advanced geometry involves three-dimensional shapes. These shapes are objects that exist in space. Three-dimensional objects can be made by rotating or combining two-dimensional objects. The world around you is three-dimensional. But many things in the world can be viewed more easily by looking at them in two dimensions.

*Sphere*

*Cube*

*Pyramid*

*Cylinder*

### Words to Know

**dimension** (duh-MEN-shuhn): the dimensions of an object are the measurements of its length, width, and height

**ellipse** (i-LIPS): an oval shape

**rotate** (ROH-tate): to turn around and around like a wheel

Getting to know...

## Euclid

Euclid was probably born in Greece between 335 and 300 BC. He attended a famous school called the Academy. Ptolemy, the ruler of Egypt, invited Euclid to teach at the Museum of Alexandria. Euclid created his own school of mathematics and wrote mathematical papers.

His most important book was called *The Elements*. It arranged the principles of geometry in a logical way. Euclid was so important that all ideas in geometry different from his are called non-Euclidean.

## Lines

### Lines

A line is said to be infinite, or without end. It stretches forever in both directions. A point is an exact location on a line. There are an infinite number of points on any line. We name a line by naming any of its two points.


***There are two points on this line, point x and point y.***

### Rays

A ray is a line that starts at one point. It then goes on forever in one direction. It is named for its endpoint and one other point found on the ray.


***We would call the beginning of the ray point A.***

### Line Segments

A line segment is part of a line. It starts at one point and ends at another point. It is named for its two endpoints.


***This line segment is known as line segment AB.***

### Parallel Lines

Two straight lines put side by side can be parallel. Parallel lines always remain the same distance apart from each other. The lines could go on forever and never cross.



***As long as the two lines could never meet, they will be considered parallel.***

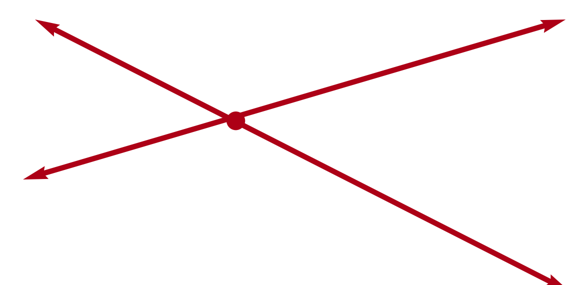




***Train tracks must remain parallel for the train to move.***

### Intersecting Lines

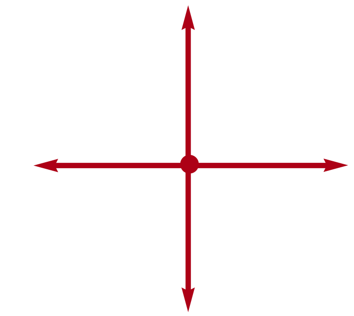
Lines that cross are said to intersect each other. They intersect at one common point, forming four angles. Intersecting lines cannot be parallel. Lines that look like they are very close to each other form two very small angles and two very wide angles where they intersect.



***These two intersecting lines form four angles, two obtuse angles greater than 90°, and two acute angles, less than 90°.***

### Perpendicular Lines

Lines that make a perfect cross are said to be perpendicular. Perpendicular lines are the opposite of parallel lines. They form four right angles when they cross.



***These two intersecting lines form four angles. All are right angles, or exactly 90°. These lines are perpendicular to one another.***

## Angles

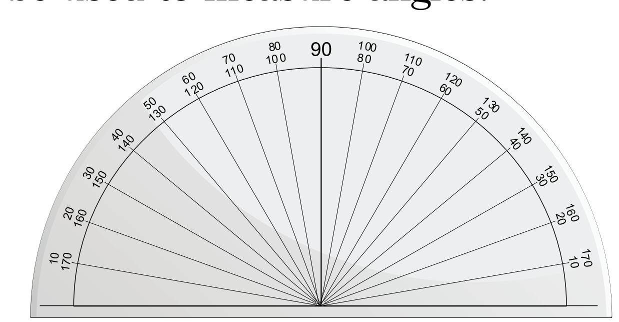
An angle is formed when two lines meet each other at a point. The point where the two lines meet is the vertex of the angle.

### Measuring Angles

The common unit of measure for an angle is called degree. The degree symbol (°) always follows a number.

A line with one end held in place can be rotated a total of 360° around. A whole circle has 360° in it. You have rotated 360° when you spin completely around. Half of a circle has 180° in it.

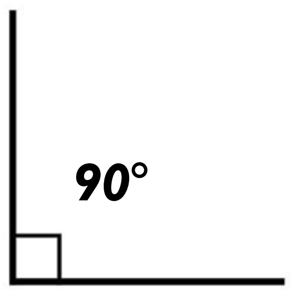
A device called a protractor can be used to measure angles.



***A protractor***

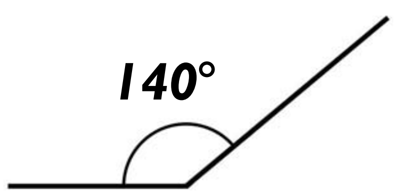
## Right Angles

Perpendicular lines have an angle of 90°. This is often called a right angle.



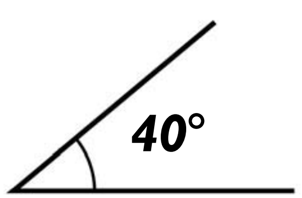

## Obtuse Angles

Angles greater than 90° are called obtuse angles.



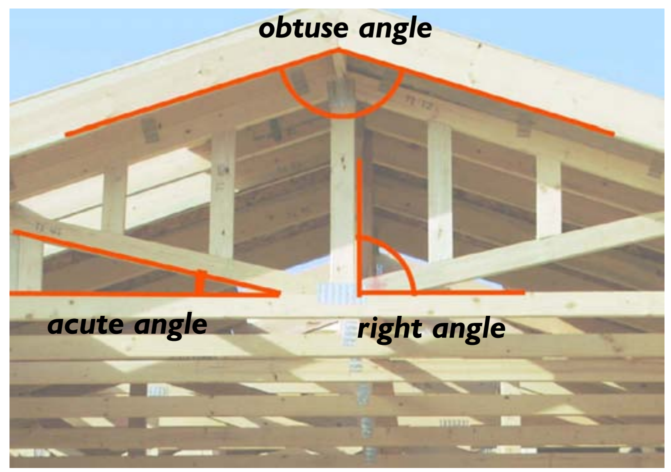

## Acute Angles

Angles smaller than 90° are called acute angles.




## How We Use Angles

Angles are very important in many different fields. Houses are built using very precise angles. Most houses have walls that are perpendicular to the floor. The roofs of some houses rise up at an angle to help water and snow run off. Angles are important in art and many of the sciences.



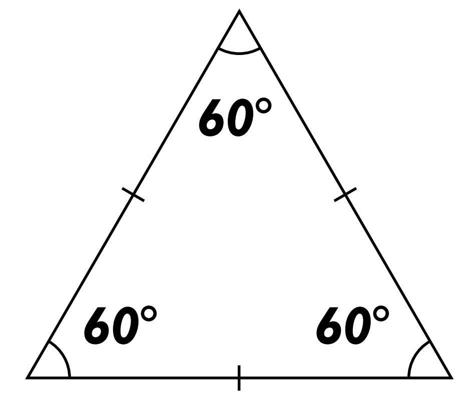

# Triangles

Triangles are shapes that have three sides and three angles. The word “triangle” even means “three angles.” The sum of all the angles in a triangle is always 180°. There are several different types of triangles.

## Equilateral Triangles

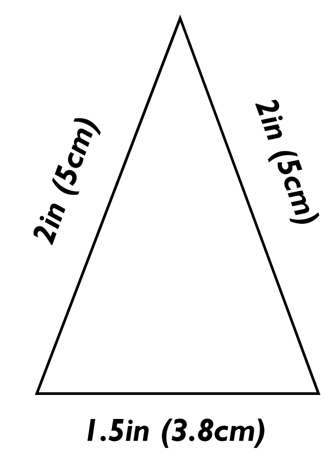
A triangle whose sides are all the same length is called an equilateral triangle. All three of its angles are 60°.





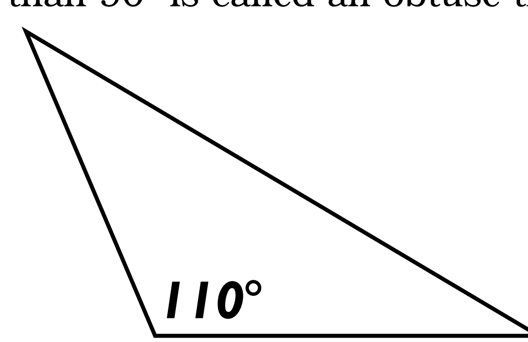

## Isosceles Triangles

A triangle with two sides that are the same length is called an isosceles triangle.



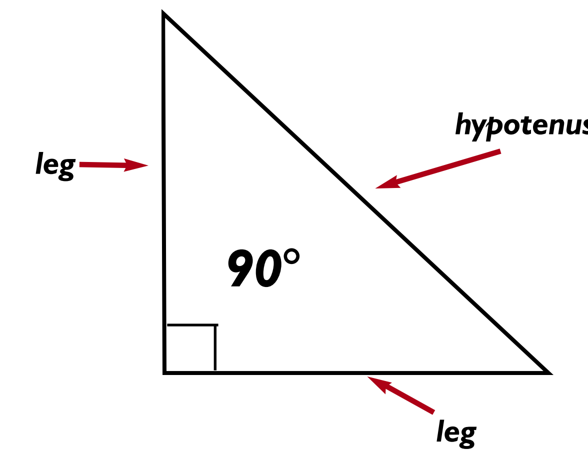

## Obtuse Triangles

A triangle with one angle bigger than 90° is called an obtuse triangle.




## Right Triangles

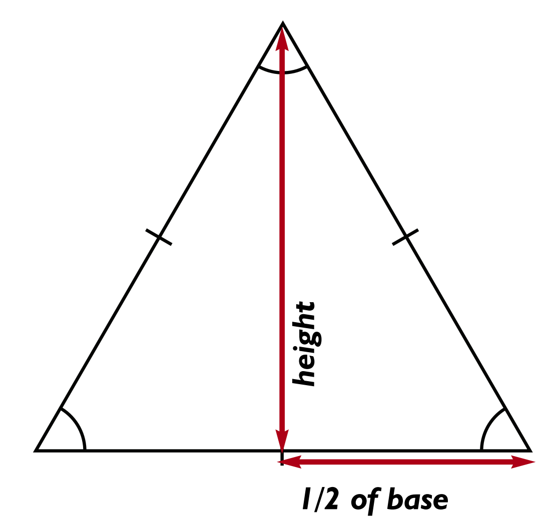
A right triangle has a 90° angle in it. The short sides of a right triangle are called legs. The long side that is opposite the right angle is called the hypotenuse.




## The Area of a Triangle

The area, or space inside, of a triangle is 1/2 of the total base width times the total height. The formula looks like this:

$$A = \frac{1}{2} B*H$$



Find out more

### The Pythagorean Theorem

Right triangles have many special properties. Thousands of years ago, people figured out that the squares of the sides of any right triangle are related to each other. The sum of the squares of the legs of a right triangle is equal to the square of its hypotenuse. This is called the Pythagorean Theorem.

The Pythagorean Theorem is often written as an equation:

$$a^2 = b^2 = c^2$$

In this equation, a and b are the lengths of the two legs of the triangle and c is the length of the hypotenuse. The length of one side of a right triangle can be figured out using basic algebra if the other two sides are known.

*Pythagoras* was a mathematician from ancient Greece. The Pythagorean Theorem is named after him because he was the first person to prove the theorem. Ancient Egyptians used the theorem to help them build the Great Pyramids. People use the Pythagorean Theorem today to figure out distances between points.

### Pyramids

A three-dimensional object with a single base and sides made out of triangles is a pyramid.

***Ancient Egyptians built pyramids using the Pythagorean Theorem.***

### Trigonometry

There is a form of mathematics called trigonometry. It uses the properties of triangles to solve mathematical problems. Trigonometry can be used to figure out angles. Much of trigonometry involves measurements using right triangles.

## Rectangles and Squares

### Rectangles

Rectangles are shapes that have four sides and four right angles.



The opposite sides of a rectangle are always parallel to each other.

***The two longer sides are parallel and the two shorter sides are parallel.***

Some rectangles are long and thin. Others are short and squat.

### Carl Friedrich Gauss

Getting to know...

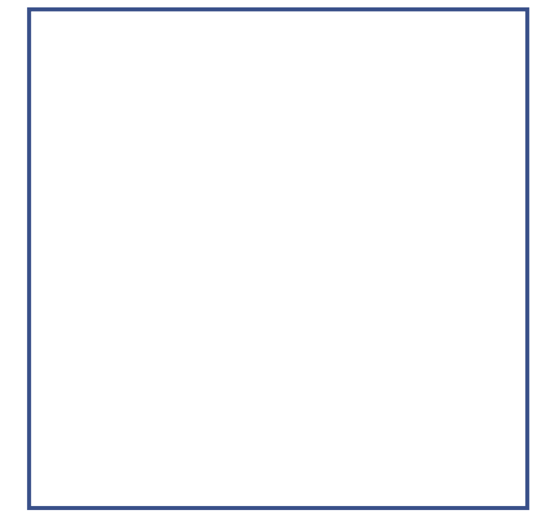
Carl Friedrich Gauss was born in 1777 in what is now Germany. He was a child prodigy. This means that he showed great talent at a very young age. His family was poor, but a rich Duke supported him. Gauss became a professor of astronomy when the Duke died in a battle.

Gauss loved mathematics. He discovered how to build a polygon with seventeen sides. He found a general rule for which polygons could be made and how to build them. Gauss wrote a book on number theory that made him famous. He also revolutionized mathematics with his work in geometry and algebra. He helped build the foundations for statistics. Gauss was called the Prince of Mathematics.

Doors and windows often have rectangular shapes. The area of a rectangle can be found by multiplying the width times the height.

### Squares

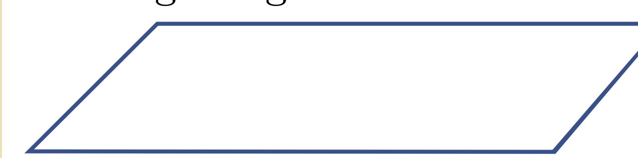
Squares are rectangles whose sides are all the same length.



***All four sides are equal in length and form right angles.***

### Parallelograms

Both rectangles and squares are special types of parallelograms. Parallelograms are four-sided shapes that have two pairs of parallel sides. They do not always have right angles.



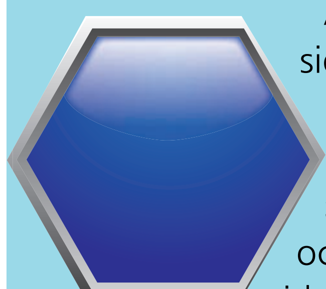
***The longer sides are parallel and the shorter sides are parallel as well. The longer and shorter sides are not perpendicular because they do not form a right angle when they meet.***

Find out more

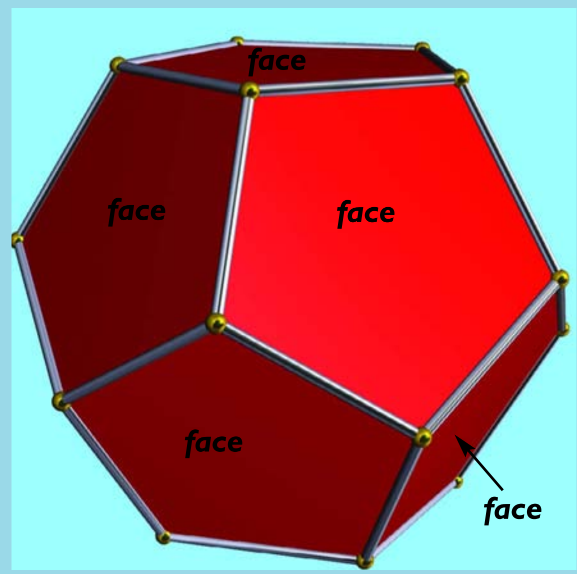
## Polygons and Polyhedrons

A polygon is a two-dimensional shape made of straight lines. Usually, the word "polygon" refers to shapes with sides that are equal in length. The names of different polygons use special prefixes to tell you how many sides they have. A pentagon has five sides and five angles. The headquarters of the U.S. Department of Defense got the name Pentagon because the building has five sides.

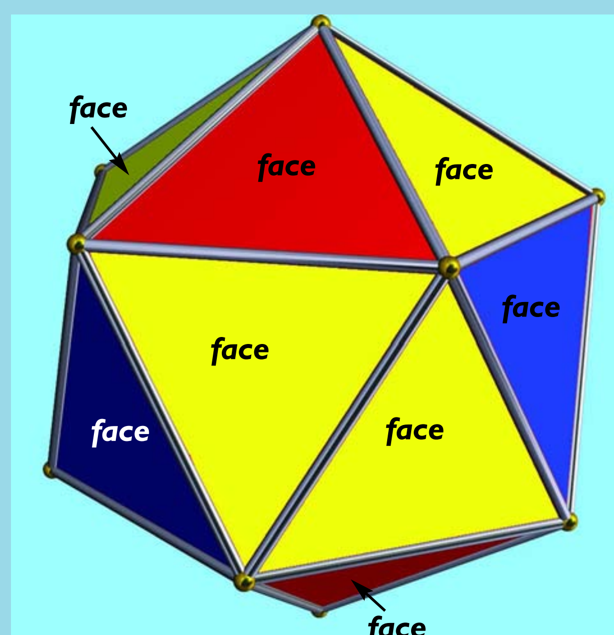
A hexagon has six sides and six angles. A heptagon has seven sides and seven angles. An octagon has eight sides and eight angles. A stop sign is an octagon. A nonagon has nine sides and nine angles. A decagon has ten sides and ten angles.



A polyhedron is a three-dimensional solid made of two-dimensional planes. The names of different polyhedrons tell you how many faces they have. The ancient Greeks found five polyhedrons that have all sides, angles, and faces equal. They called them regular solids or Platonic solids. The tetrahedron has four faces. The cube has six faces. The octahedron has eight faces. The dodecahedron has twelve faces. The icosahedron has twenty faces.



*An dodecahedron*

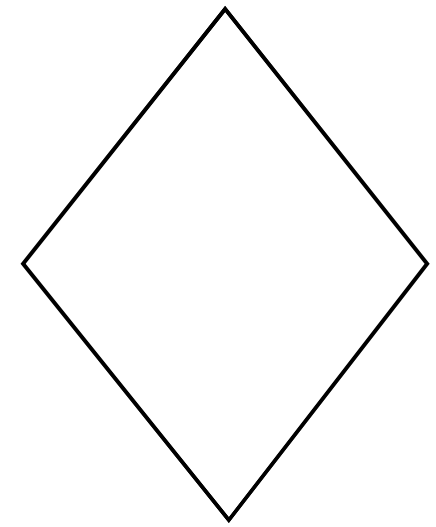


*An icosahedron*



### Rhombuses

A rhombus has equal sides like a square but is tilted so that is does not have right angles.

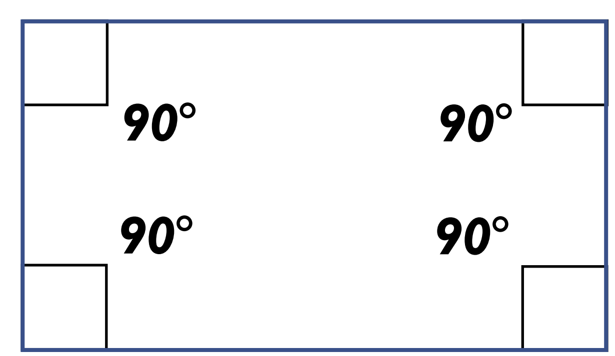


***Sometimes, we use the word diamond when referring to a rhombus.***

### Quadrilaterals

All four-sided shapes made up of straight lines are called quadrilaterals. These include the parallelogram, the rhombus, the square, the rectangle, and the trapezoid.

The sum of all the angles in a quadrilateral is always 360°.



***90° + 90° + 90° + 90° = 360°***

### Cubes

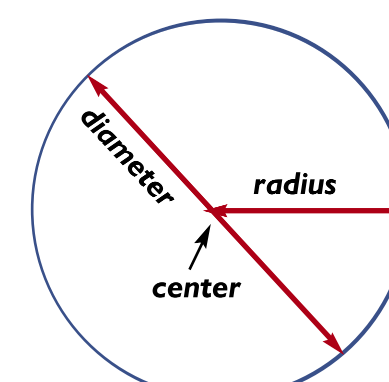
A three-dimensional shape that is made out of six squares is called a cube.

## Circles

A circle is a shape made by drawing a curve completely around a point. Everywhere on the curve is the same distance from the point.

### Diameter and Radius

The distance all the way across the center of a circle is called the diameter. The distance from the center to the edge is the radius.



## Circumference

The distance all the way around a circle is called the circumference.

## Pi

The ratio of the circumference to the diameter of a circle is a special number known as pi. This number is the same for every circle. Pi is equal to the never ending decimal number 3.141596…. It is usually rounded off to 3.14. It is often written as the Greek symbol $\pi$.

**Finding the Circumference of a Circle.** The circumference of a circle is equal to the diameter times $\pi$. Since the diameter is twice the radius, the circumference is equal to 2 times the radius multiplied by $\pi$. The equation to find the circumference of a circle is:

$$c=2\pi r$$

In this equation, c stands for circumference and r stands for radius. A circle with a radius of 3 centimeters has a circumference equal to $2 \times \pi \times 3$. This number is equal to:

$$2 \times 3.14 \times 3$$

or

**18.84 centimeters**

### Archimedes

Getting to know…

The ancient Greek scientist, Archimedes was born in Syracuse, Sicily. His exact birth year is uncertain but was around 287 BC. He probably studied at the Library and Museum of Alexandria.

Archimedes was one of the greatest mathematicians in history. He calculated the value of the number pi ($\pi$). He also found the volume and surface area of a sphere. Archimedes invented many military machines and a water pump called Archimedes' screw. He is famous for shouting "Eureka!" (which means "I have found it!") when he discovered the idea of buoyancy while he was taking a bath.

**Finding the Area of a Circle.** The area of a circle is equal to $\pi$ times the radius squared. The equation to find the area of a circle is:

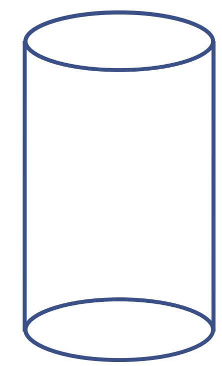
$$A=\pi r^2$$

In this equation, A stands for area and r stands for radius. A circle with a radius of 2 centimeters has an area equal to $\pi \times 2^2$. This number is equal to $3.14 \times 4$, or 12.56 square centimeters ($cm^2$).

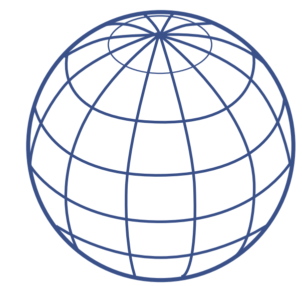


## Circles in Three Dimensions

A circle in three dimensions makes a ball, or sphere. Circles can also form a tube called a cylinder. How many spheres and cylinders can you find in your classroom or your home? Do you think you'd find more cylinders or more spheres in your kitchen?



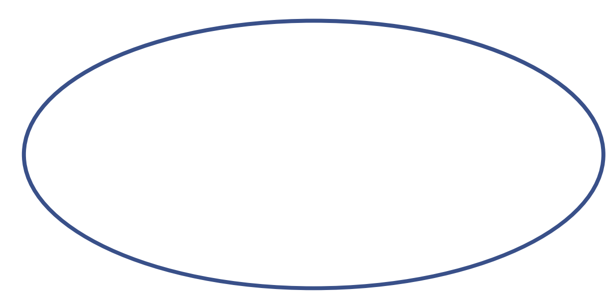
*A cylinder*



*A sphere*

## Ellipses

An ellipse is an oval. Ellipses do not have a constant radius. Instead, they have two foci (fixed points). The sum of the distance to each focus is the same for every point on an ellipse.

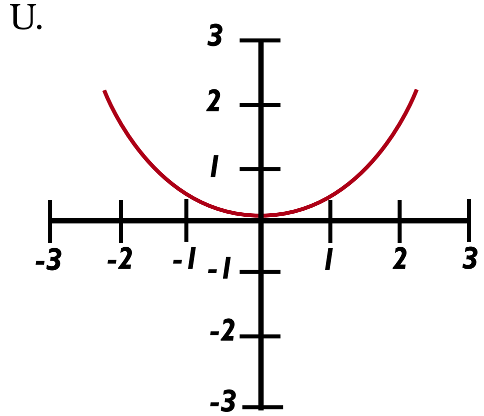


*An ellipses*

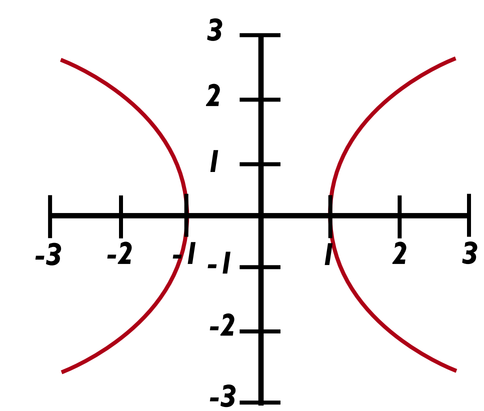
# Curves

Sometimes, it is easier to understand an equation when it is represented by a picture. Algebraic equations can be charted on a graph to make geometric curves with many different shapes. Describing algebraic equations with geometric curves is called analytic geometry.

The graph of the equation $y = x^2$ is a parabola. It has a shape like a U.

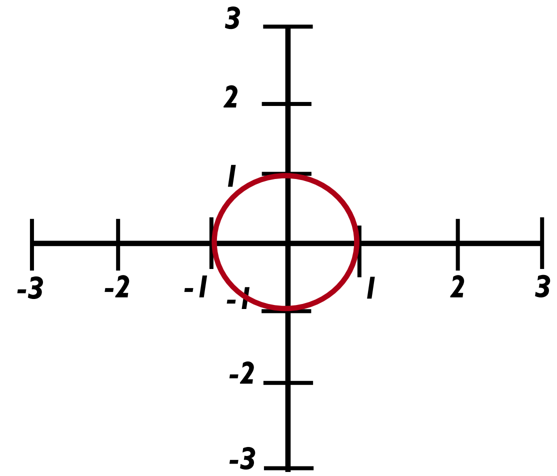



The graph of the equation $x^2 - y^2 = 1$ is a hyperbola.



The graph of the equation $x^2 + y^2 = 1$ is a circle with a radius of 1.

Many other geometric shapes can be made by graphing equations.




# Measurement

Have you ever stood on a scale to weigh yourself? Can you estimate how tall you are?

When we measure things, we can figure out its weight, its length, or how much of something it can hold. We can measure time with a clock. We can tell the temperature by reading a thermometer.

If you live in the United States, you probably use the customary (Imperial) system of measurement. When you use words like inches and feet, quarts and gallons, and ounces and pounds, you are using the customary system.

Most countries use the metric system for measurement. Multiples of ten are the base of the metric system. When you want to change from one unit of length to another, you can simply multiply or divide by 10, 100, or 1000 to form a larger or smaller number. If you use words like meter, liter, and gram, you are using the metric system.

***Doctors and scientists use the metric system of measurement.***



## Length

Length tells us how long something is from one end to the other. We measure how far we can jump or throw a ball, and we measure how far it is from one city to another.


***We would measure the distance this boy threw the ball in feet or meters.***

In the customary system, long distances are measured in miles, and smaller things are measured in inches, feet, and yards. If you want to measure something smaller than an inch, you would measure it to the nearest half inch, quarter inch, or eighth of an inch.

In the metric system, long distances are measured in kilometers. Smaller things are usually measured in meters, centimeters, and millimeters.

| Customary | Metric |
|---|---|
| 1 ft = 12 in | 1 cm = 10 mm |
| 1 yd = 3 ft | 1 dm = 10 cm |
| 1 mile = 5280 ft | 1 meter = 10 dm |
| 1 mile = 1760 yds | 1 km = 1000 m |

If you live in the United States, you would probably say that this plant is 3 inches tall.

A friend who lives in another country would measure the plant in centimeters. To describe your plant to your friend, you would have to convert inches to centimeters.

1 inch = 2.54 centimeters

3 inches = 3 x 2.54 cm, which equals 7.62 cm.

Your friend, who uses the metric system, can picture your plant more easily when you tell him that it is 7.62 centimeters tall.

Other lengths can be converted from one system to another by multiplying.

| Customary to Metric: |
|---|
| 1 inch = 2.54 cm |
| 1 yard = 0.9 meters |
| 1 mile = 1.6 kilometers |

| Metric to Customary: |
|---|
| 1 cm = 0.4 inches |
| 1 meter = 3.3 feet |
| 1 km = 0.6 miles |

## Mass and Weight

When we talk about how heavy something is, we usually use the word weight. Scientists like to use the term mass instead of weight. Mass is a measure of the amount of matter something contains. It is measured with the metric unit of grams, usually on a balance. Your mass will not change, even if you travel to the Moon.

Weight is the measure of the amount of gravity pulling on an object. Your weight would change when you travel to the Moon, because the pull of gravity is not as strong .

"I weigh 60 pounds."

"I weigh 10 pounds."

"My weight changed, but my mass didn't change. My body still contains all the same stuff it contained when I was on Earth."



An object's mass doesn't change when its location changes. That's why scientists and mathematicians use the term mass instead of weight. On Earth, your mass and weight are considered to be about the same.

### Measuring Weight

We can use a scale to measure the weight of an object. When you were a baby, you were probably weighed on a special scale that held you while you were weighed. As you got older, you could stand on the tall scale in the doctor's office. At home, you might have a small bathroom scale. If not, you might use the big one at the grocery store where you shop. These scales tell us how many pounds or kilograms we weigh.

In the customary system, we measure weight in ounces, pounds, and tons. Look around your kitchen, and you will find many foods in small jars and boxes that are measured in ounces. Heavier items, such as sugar and flour, are sold by the pound. A large bag of sugar weighs 5 pounds.

You won't find any food sold by the ton. You'd never be able to carry it home! One ton is the same as 2000 pounds (907 kg).

In the metric system, mass is

*This scale is used to measure the weight of fruits and vegetables in a grocery store.*

measured in grams, milligrams, and kilograms. One paperclip weighs about 1 gram (.04 oz). A U.S. nickel weighs 5 grams (.18 oz). A kilogram is much heavier. One thousand grams equal 1 kilogram. We use kilograms when we weigh large objects such as pianos and people. To measure very small amounts, we use milligrams. A milligram is 1/1000 of a gram.

| Customary | Metric |
|---|---|
| 1 pound = 16 ounces | 1 g = 1000 mg |
| 1 ton = 2000 pounds | 1 kg = 1000 g |

Look at the food in your kitchen. Many of the packages show both metric and customary weights.

Your 5 pound bag of sugar is 2.26 kilograms. A small bottle of spice weighs 25 grams (0.9 ounces). Sixteen ounces of rice is 454 grams. You can convert from one system to another by multiplying.

| Customary to Metric: |
|---|
| 1 ounce = 28 grams<br>A cookie weighs three ounces. How many grams is that?<br>3 X 28 = 84<br>The cookie weighs about 84 grams. |
| 1 pound = .45 kilograms<br>A box of candy weighs two pounds. How many kilograms is that?<br>2 X .45 = .9<br>The box of candy weighs about .9 kilograms |

| Metric to Customary: |
|---|
| 1 gram = 0.035 ounces<br>A soda weighs about 453 grams. How many ounces is that?<br>453 X .035 = 16<br>The soda weighs about 16 ounces. |
| 1 pound = .45 kilograms<br>A box of candy weighs two pounds. How many kilograms is that?<br>2 X .45 = .9<br>The box of candy weighs about .9 kilograms |

## Volume

When we measure volume, we are finding out how much something will hold. If you are buying orange soda for a group, you might buy it in a 2 liter bottle. A smaller bottle or can might contain 12 to 16 ounces.

*One gallon of liquid is the same as four quarts of liquid.*

In the customary system, volume is measured in cups, pints, quarts, and gallons. A family that drinks a lot of milk would buy it by the gallon.

Many recipes use one or two cups of milk. For smaller amounts, you can measure fractions of one cup, such as 1/4, 1/3, or 1/2 cup of the liquid. In a recipe, you would also use your measuring cups for dry ingredients such as flour and sugar.

Sometimes you only want to add a little bit of something to a recipe. You can measure smaller amounts with a set of measuring spoons. If you want to add a very little amount of salt to a recipe, you would use the smallest measuring spoon, 1/8 of a teaspoon. Measuring spoons include many sizes. The largest of all, the tablespoon, is equal to 3 teaspoons.




*One tablespoon is equal to three teaspoons.*

*Measuring cups often show both metric and customary units of measurement.*

The metric system measures volume in milliliters and liters. One liter (1 l) is very close to the quart used in the United States. You can find 1 liter bottles of soda and water on the grocery store shelves. You are probably more familiar with 2 liter (2 l) bottles of soda. Two 2 liter bottles are just a little more than one gallon in the U.S. customary system.

Measuring spoons are used for smaller volumes. In a set of metric measuring spoons the smallest measures 1 milliliter (1 ml), and the largest measures 25 milliliters (25 ml).

| Customary | Metric |
|---|---|
| 1 pint = 16 ounces | 1 l = 1,000 ml |
| 1 pint = 2 cups | |
| 1 quart = 2 pints | |
| 1 gallon = 4 quarts | |

Sometimes we want to use a recipe from another country. A measuring cup that shows cups and milliliters makes things easier. But what if we do not have one? It is helpful to be able to convert liters to cups on our own. We can convert from one system to another by multiplying.

| Customary to Metric: |
|---|
| 1 cup = 0.24 liters |
| 1 quart = 0.95 liters |
| 1 gallon = 3.79 liters |

| Metric to Customary: |
|---|
| 1 liter = 4.2 cups |
| 1 liter = 1.1 quarts |
| 1 liter = 0.26 gallons |

Find out more

### The Metric System

Numbers in the metric conversion chart are powers of ten (10, 100, 1000). There is only one unit for length (the meter), one for mass (the gram), and one for volume (the liter). The metric system was developed in the late 1700s to make it easier to understand and convert from one measurement to another.

We know that 1 meter equals 100 centimeters. How many centimeters are there in 5 meters? Just multiply. 1m = 100 cm, so 5 m = 5 x 100 cm, or 500 cm.

The prefixes used for measurement are the same for meters, liters, and grams. The meter is the basic unit of length. The prefix kilo- means 1000. So, a kilometer is 1000 meters. A kiloliter is 1000 liters, and a kilogram is 1000 grams.

meter (m), liter (l), gram (g)
milli- (m) 1/1000
centi- (c) 1/100
deci- (d) 1/10
deca (da) 10
hecto (h) 100
kilo (k) 1000

There is a relationship between the different units. The metric system was designed so that 1 $cm^3$ = 1 ml. One ml of water weighs 1 gram. One liter of water weighs 1 kilogram.

## Time

How long can you hold your breath? When will dinner be ready? How long until my plant produces watermelons? Time is measured in many ways. We divide a minute into 60 seconds, and count how long we can hold our breath. We set the kitchen timer for 8 minutes to prepare our favorite pasta, but the roast in the oven will bake for at least an hour. It will take days for a plant to grow from a seed, and months until it produces fruit.

Time is a way for us to measure the span between events. We can keep track of time by watching the seasons of the year, noting the rising and setting of the Sun, keeping track on a calender by reading the time on a clock.

| Time Conversions |
|---|
| 60 seconds = 1 minute |
| 60 minutes = 1 hour |
| 24 hours = 1 day |
| 7 days = 1 week |
| 4 weeks = 1 month (approximately) |
| 12 months = 1 year |
| 365 days = 1 year |

Most months last for 30 or 31 days. February is the only month that is exactly four weeks long. But that changes every fourth year. In a leap year, we add a day to February, giving it 29 days in all. This changes the year from 365 to 366 days. We do this because it takes a little more than 365 days for the Earth to orbit the Sun. It really takes 365 days, plus about 6 hours. If we didn't adjust the calendar every four years, our seasons would become confused.

When we want to know the exact time, we use clocks. Digital clocks show the time in numerals. Analog clocks show the time with hour and minute hands on a numbered circular face. The minute hand makes a complete circle every hour, while the hour hand moves slowly from one number to the next. Some analog clocks have a second hand, which circles the clock every minute.



Find out more

### A.M. and P.M.

Suppose you receive a note from a friend asking you to call him at 8:00 the next day. Would you call at 8:00 in the morning or 8:00 in the evening? To be clear, your friend should have added A.M. or P.M. to his note. A.M. (from the Latin ante meridiem) means before noon, and P.M. (from the Latin post meridiem) means after noon.
If your friend had asked you to call at 8:00 A.M., you would know he wanted you to call him in the morning.

## Temperature

Many decisions we make every day depend on temperature. Our summer clothes are very different from our winter clothes. We plan our activities based on the temperature. Meat is cooked to a certain temperature before we serve it for dinner. Temperature is the degree of heat or cold in something.

We measure temperature with a thermometer. Some thermometers measure the air temperature, others are used in baking. When we are not feeling well, there are different types of thermometers for measuring body temperature.

In the United States, temperature is measured on the Fahrenheit scale. The Celsius scale is used by all scientists and in most other countries.

| Temperature Scales |
|---|
| **Fahrenheit Scale** |
| Water freezes into ice at 32° F |
| Water boils at 212° F |
| **Celsius Scale** |
| Water freezes into ice at 0° C |
| Water boils at 100° C |

To convert Fahrenheit temperatures to Celsius, subtract 32 from the Fahrenheit temperature, then multiply by 5/9. A cool fall day might be 59° Fahrenheit or 15° Celsius.

# Advanced Math

Some math problems can't be solved with arithmetic. Even algebra and geometry alone can't solve them. Scientists have looked for other types of mathematics to help them solve these problems.

Advanced math can help. Some types of advanced math help us understand our own world. Sometimes, they help us understand the universe. Math can be used to see the universe in new ways.

All the rules of basic mathematics apply to the more advanced forms of mathematics. In this way, the language of mathematics is consistent.

## Calculus

Finding the area of a square is easy. A square doesn't get larger or smaller. But some things do change. Calculus helps us to figure out how physical quantities change.

Calculus was created in the seventeenth century by Isaac Newton and Gottfried Wilhelm Leibniz. They developed it to solve mathematical problems that regular algebra and geometry could not solve.

Many discoveries were made with calculus. It is the main mathematical language used in science and technology. It was used to define many of the basic principles of physics. Engineers use calculus to show how something works without having to build it.

## Chaos Theory

Many things in nature seem like they are random. Blades of grass blowing in the wind or the shapes of rain clouds are tricky to show using ordinary math. These types of movements and shapes are not entirely random. A branch of mathematics that can explain these things is called chaos theory. This is the study of results that seem unpredictable given some sort of starting point.

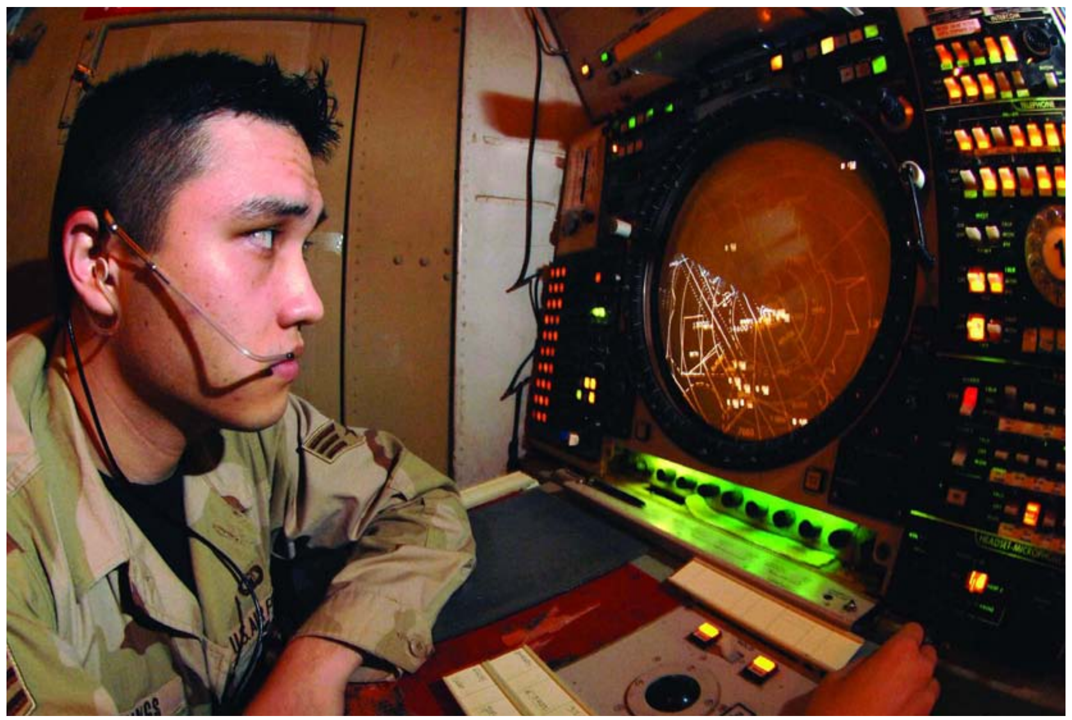
***Chaos theory, discovered in 1961 by a meteorologist named Edward Lorenz, explains how even the smallest change to the initial conditions of a system can drastically change its behavior forever.***

Rourke's World of Science

# ENCYCLOPEDIA

## Volume 9

# Technology



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# Table of Contents

# What Is Technology?

Science is the search for knowledge. Scientists look at the world. They observe how things work and develop ideas about ways to make them work better. Sometimes they try to test an idea to explain how something works. Scientists perform experiments to find out how things work. The knowledge that they discover is useful for many things. It can help to build new machines. It can help scientists to develop new medicines or cure a disease. Technology is the use of scientific knowledge to create new things.

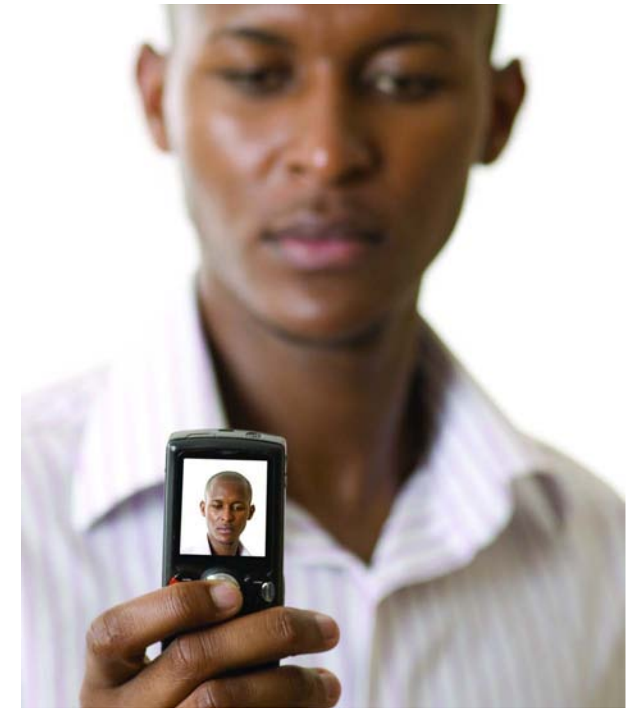
*Scientists must often wear protective clothing.*

## Inventors

An inventor is a person who creates a new idea or device to perform a task. An invention is the new technology created. An inventor with a new idea or design for an invention may decide to have the idea protected. The idea gets protection from the law in a paper called a patent. A patent prevents other people from making, using, or selling the new idea without permission from the inventor. Some inventions are simply a better way of doing or building something. They may improve an existing technology. Other inventions are much more complicated.


*In the 1800s, telephones had a crank to ring the operator for assistance to make a call.*





*Cell phones, a new invention in the 1950s, were used only for telephone calls.*

Today's technology has been in the process of development for thousands of years. New inventions are constantly changing how people work and play. They change how people think and live. The future will bring even more changes. This will happen as we continue to learn about the world.

# Agriculture

Thousands of years ago, humans relied on hunting, fishing, and gathering to provide food for their families. They looked to find edible plants for food. Soon people realized they could grow these plants. They also found they could make clothing out of plant fibers, or threads. People used cotton and flax to make clothing. This was the beginning of farming. People had to learn how to prepare, or cultivate the soil for planting crops. They learned how to breed, or grow plants. They learned how to process, or change plants to grow what they wanted. Agriculture is the science of growing crops. Agriculture has used advancements in technology to improve the methods for growing and harvesting crops.

*Wheel rakes attach to tractors and sweep cut grain crops into piles. Often farmers use other equipment to make the piles into bails.*

## Farm Equipment

A farmer plants crops in shallow trenches. Sowing the seeds is another way to describe the process of planting. Furrows are shallow trenches that look like narrow grooves in the ground. The farmer turns over the dirt to mix nutrients into the soil. Plants need nutrients to stay healthy. Farmers also turn the ground in order to loosen the soil and give seeds room to grow.

*Farmers plow in a straight line wherever possible.*

One invention designed to break up soil is the plow. A plow is a piece of metal shaped liked a V in the front. It digs furrows when dragged along the ground. A farmer pushes the plow from behind or pulls it from the front. He may also use an animal like a horse or an ox to push or pull the plow. A tractor is used to pull many farming machines. Tractors are a type of vehicle which has large wheels to keep it from sinking in mud.

*A horse pulling a plow makes a single furrow.*

*A tractor pulling a plow makes many furrows.*



### Sickles and Reapers

Farmers need to harvest the crops, or cut them down and gather the useable portions after they have grown to full size. People can cut crops by hand. One invention they can use to make the job easier is a sickle. A sickle is a tool with a sharp curved blade. Harvesting with a sickle is hard work and takes a long time. The reaper is another invention. This is a machine that cuts wheat and other grains using many blades. It works much faster than a sickle.

*Another name for a sickle is a scythe.*

*Reapers (threshing machines) can cut a lot of grain in a short time.*

### Cotton Gin

Following the harvest, there is sometimes more work to do. Farmers must process some crops before they are used. For example, cotton grows in balls with many small seeds. The cotton fibers must be unwound and someone must remove all the seeds. People then make thread from the cotton. A worker will weave the thread into fabric for clothes.

*A cotton boll holds the ripe balls of cotton.*

*Commercial looms weave lots of cloth at one time.*

## Eli Whitney

Getting to know...

Eli Whitney was born in Westborough, Massachusetts, on December 8, 1765.

Whitney worked as a farm laborer and schoolteacher to save money to attend Yale University. In 1793, Eli Whitney learned of the problems with processing cotton and developed a machine that would use a comb and roller to make the work much easier. He invented the cotton gin. His invention made it easier and quicker to separate the cotton fibers from the seeds. Eli ran into many problems with his request for a patent, but it finally received approval by the court in 1807.

# Chemicals

### Fertilizers

Fertilizers are substances that add nutrients to the soil to help plants grow. Natural fertilizers have been used for centuries. They include manure, or the excrement of animals. They also include guano, which is made of bird and bat droppings.

Compost is a mixture of decaying plant material, and people use it as a fertilizer. Some farmers use chemical fertilizers to help their crops grow. Chemicals are things which may be found in nature or created in a laboratory.


***Liquid fertilizer is sometimes added to the soil.***

Find out more

**Compost**

Compost is one of nature's best mulches and is a great soil fertilizer. Did you know you can make your own compost? You can make it without spending any money and it will make your garden or the plants in your yard grow strong and healthy without the help of chemicals from the store. You can use yard cuttings, fruit rinds, vegetable peelings, and even tea bags to begin your compost. There are many conservation groups and websites that can help you to get started.



### Protecting Plants

Some farmers use poisons to protect their crops from weeds and insects. Herbicides are chemicals that destroy unwanted plants. Many people spray herbicides to kill weeds. Pesticides are chemicals that kill insects. An aphid is a type of insect that will eat the leaves of a farmer's crops. Other types of insects that can destroy plants are locusts and weevils. Farmers will spray pesticides to prevent these insects from destroying their crops.

***Airplanes and helicopters are both used for crop dusting large areas with pesticides.***

### Organic Farming

Organic farming is a natural way of farming. It is the practice of raising plants, especially fruits and vegetables, without the use of synthetic pesticides. Many people believe using harsh chemicals on plants or produce can be harmful to the health of the humans who regularly use the foods which have been exposed to chemicals. Organic farmers use only things naturally occurring in nature, such as manure to help plants grow. Organic farming does not use chemical fertilizers, herbicides, or pesticides.

***Organic vegetable gardens can produce delicious nutritious food.***

WORDS TO KNOW

**fertilizer** (FUR-tul-ahy-zer): any substance used to increase the ability of the soil to promote plant growth

**organic** (or-GAN-ik): a substance, especially a fertilizer or pesticide, of animal or vegetable origin

**synthetic** (sin-THET-ik): something that is man-made

## Rachel Carson

**Getting to know...**

Rachel Carson was born in Pennsylvania in 1907. She always loved nature and writing. Carson studied biology, the science of life, in college. Then she studied marine zoology in graduate school. This is the study of sea animals. Carson wrote three popular books about the ocean and the creatures in it.

Carson then turned her attention to the land. A friend of hers noticed that many of the birds on her property died rather suddenly. This happened after the spraying of pesticides in the area. Carson studied the impact of the pesticide DDT. She found that the poison contaminated or dirtied the soil and water. It also killed birds. Carson wrote about what she discovered in1962. She called her book *Silent Spring*. Her warnings made people think about the negative effect technology can have on the environment.

# Transportation

People and things have always had the need to move or be moved from one place to another. People have always looked for more comfortable or quicker ways to travel. Transportation is a way people and things move from one place to another. Different environments require different methods of transportation.



***Engineers study traffic patterns, structures, materials, and techniques to help them design safe and efficient roads.***

People have invented machines, called vehicles or crafts, to travel. Some vehicles travel on the ground, like a train. Some vehicles travel on top of the water, like a jet ski. Some even help people to travel under the water, like a submarine. People use other types of crafts to travel in the air. A hot air balloon is an interesting way to travel through the sky.

Crafts such as rockets can help people to travel into space. Over the centuries, inventors designed machines or improved ways of traveling to move people faster and faster.

## Timeline of Transportation After 1600

**1662** - ***Blaise Pascal invented a horse-drawn public bus.***

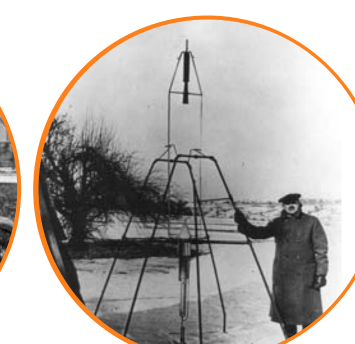
**1783** - ***Joseph Montgolfier and Étienne Montgolfier launched the first hot air balloons.***

**1814** - ***George Stephenson built the first practical steam powered railroad locomotive.***

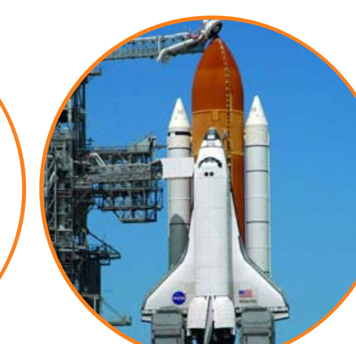
**1900** - ***Ferdinand von Zeppelin built the first successful airship.***

**1903** - ***Orville Wright and Wilbur Wright flew the first motor-driven airplane.***

**1908** - ***Henry Ford developed the assembly line method of automobile manufacturing.***



**1926** - ***Robert Goddard launched the first liquid-fueled rocket.***



**1981** - ***John W. Young and Robert L. Crippen were the first astronauts to fly in a space shuttle mission.***

## Ships and Boats

One of the earliest ways to transport people and things was by traveling in the water. Boats are small crafts generally used for a special purpose like fishing. Ships are larger crafts that might use sails or an engine to propel them through the water. They may travel on rivers, lakes, or oceans.

### Boats With Paddles

People use flat wooden boards called paddles to row small boats. An oar is another name for a paddle. A raft is a simple boat with a flat bottom. We can make a raft using tree trunks or logs. Sometimes, flat pieces of wood called planks are bound together to make a raft. Some rafts are made of rubber or a plastic called vinyl. These rafts are often inflatable.

A canoe is a small boat. It has curved sides and a pointed bottom. Early Native Americans made canoes out of tree trunks.

WORDS TO KNOW

**inflatable** (in-FLEY-tuh-buhl): an object that can be filled with air

**planks** (plangks): a piece of lumber that is cut thicker than a board

**vinyl** (VAYHN l): a type of plastic

***Canoes were made and used for early transportation.***

***Large ships are able to move many people and things at the same time.***

They hollowed out the trunk and used a paddle to move from place to place. Today, an artificial substance, made by man, called fiberglass is a popular material for building a canoe.

A kayak is a sleeker version of a canoe with one or two small holes. The holes are where people sit. A rider may attach a watertight skin or enclosure to prevent water from getting in the boat. The boat can turn all the way over without

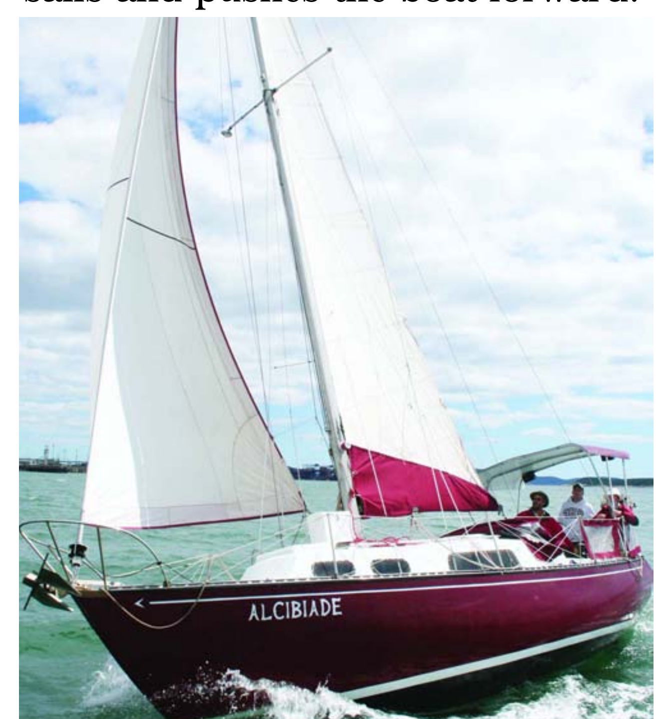


sinking. Some people compete in kayak races. The Olympics have had a kayak event since 1936.

***Kayaks were originally used by hunters in subarctic regions.***

### Boats With Sails or Motors

Other boats and ships use different types of power. A sailboat uses pieces of canvas or other fabrics called sails. Wind fills the sails and pushes the boat forward.




***Sailboats have the right-of-way over motorboats because the sailboats must rely on the wind to move them.***

Ancient Egyptians used sailboats to move the stones for the Great Pyramids from Aswan to Giza. Pilgrims traveled from England on a large sailboat called the Mayflower to reach America in 1620.

A motorboat uses an electric motor and propellers. Propellers are turning metal blades that help the vessel to move through the water. A speedboat is a small, but very fast motorboat. Speedboats pull water skiers, help the Coast Guard or marine patrol on rescue missions, or might even compete in a race.

***Motorboat drivers and passengers should learn and follow the rules of boating.***


***A steamboat driven by a large, single paddle wheel at the stern is called a stern-wheeler.***

## Larger Boats and Ships

Most large ships are made of metals like iron or steel. They use giant propellers powered by engines to move through the water. A steamboat is a large boat with paddles. A steam-powered engine turns the paddles to move the boat.

The biggest ships are tankers and aircraft carriers. Oil tankers can carry millions of barrels of oil inside huge cargo areas. Designers built tankers to travel long distances and other than oil, they may transport water, chemicals, or liquefied natural gas.

Aircraft carriers are long, flat warships designed to act as a floating airbase. Planes take off and land on the runways on the top of the ship.

***When an oil tanker collides with another ship or an iceberg, it may spill oil into the sea. This creates an oil slick (a film of oil floating on the water).***

***The Navy is the branch of the United States military whose pilots land on aircraft carriers.***



A submarine is a metal ship that can travel underwater. A submarine can be small enough to carry one or two people and remain underwater for a few hours. They can also be very large, have a crew of over eighty people and remain underwater for a few months.

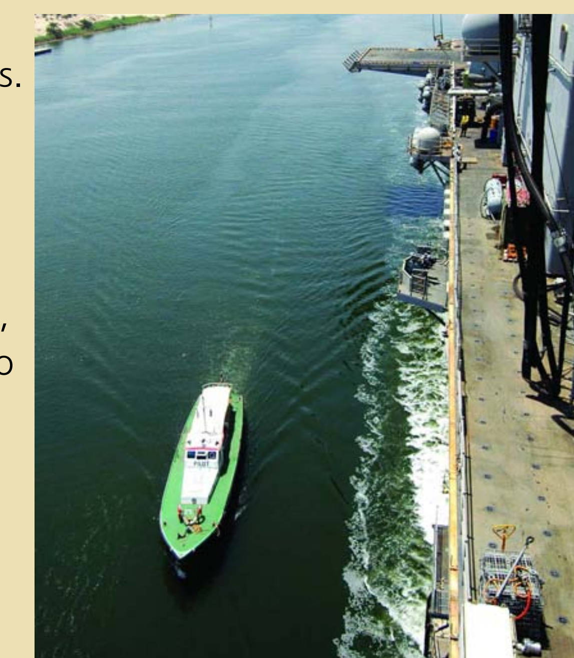
***When a submarine is docked in port, much of the ship remains underwater.***

### Robert Fulton

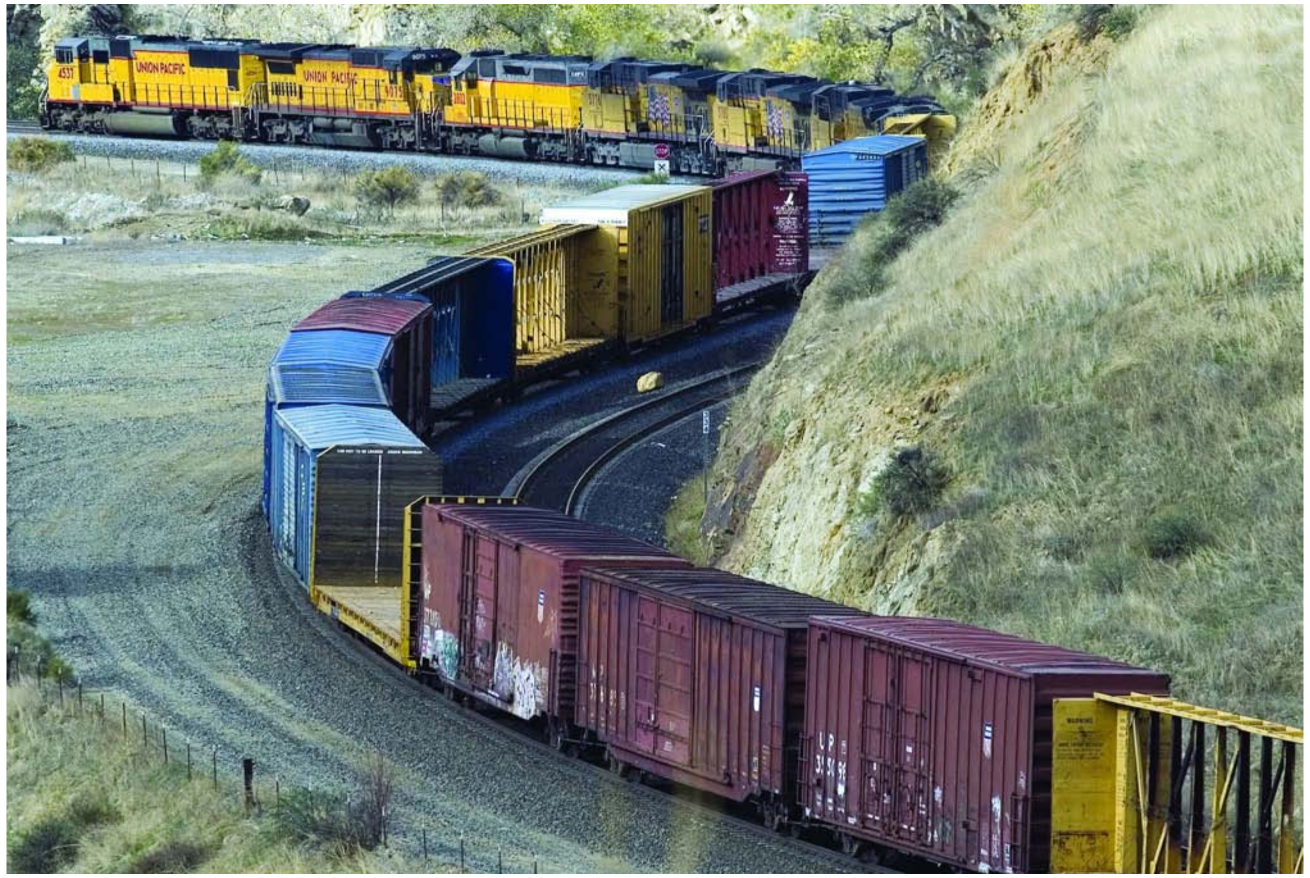
Getting to know...

Robert Fulton was born in Pennsylvania in 1765. His father died when Fulton was only nine. Fulton worked as a portrait painter. He did not have much success. Then he decided to study engineering, using science to solve problems. He patented a method for building canals. Canals are man-made waterways.

Fulton moved to the country of France. At that time France was at war with the country of England. He designed a boat that could travel underwater. He thought its purpose could be to attach a mine or torpedo to enemy ships. In 1800, Fulton built the Nautilus, the first submarine. He also became famous for turning the steamboat into a commercial success. Although other inventors worked to develop steamships, his improvements allowed steamboats to carry more people and cargo. Carrying passengers and materials on rivers became much faster and safer.



## Trains



***When a freight train pulls a heavy load up hills, it may be pulled by several engines (locomotives) hooked together.***

A train is a vehicle that runs on tracks, or rails. Passenger trains may have many compartments for people to travel from one place to another. Freight trains carry cargo, or things. Different cars transport different types of items. Refrigerator cars transport food. Container cars need a crane to lift cargo in or out of the car. Tanker cars transport different types of liquids.

### Light Rail

People sometimes use the term light rail to talk about trains that run on city streets. A trolley, also called a streetcar, is one type of light rail transportation. Horses pulled the first streetcars. Modern streetcars usually get their power from electricity. Electricity makes things run.

A subway is a light rail system of cars. A subway runs on the street and in underground tunnels. Many large cities have a network of subway tunnels.




***In cities, trolley cars are good transportation for short distances.***

***Subways are an efficient method of moving large numbers of people quickly in many of the large cities of the world.***

### Big Trains

Big trains have wheels that run on railroad tracks. They travel long distances between cities and towns. The first car on a train is the locomotive. The locomotive powers the train. The first trains used steams engines. Today, most trains get power from using gasoline or electricity.

High-speed rail trains are electric trains that run faster than a regular train, sometimes called a bullet train. These high speed rail systems also transport people in Germany, Korea, and Spain. The first countries to build and use the bullet train are the countries of France and Japan.

The monorail is another type of train. Most monorail systems run on a single rail. Some monorails are suspended. The train cars actually hang from the track.

***Bullet trains move quietly and quickly.***

***The word monorail means one rail.***

Getting to know...

## Granville T. Woods

Granville T. Woods was an African American inventor. He was born in Ohio in 1856. He left school when he was ten years old so he could work. Woods continued his education at night school. He had many jobs. He worked in a machine shop and on the railroad. He worked in a factory and on a steamship, then he started his own electronics business.

Woods became a successful inventor. He invented a telegraph system. It let trains and railroad stations send warnings and other messages. He also developed trolley cars. They ran using overhead power lines. Woods invented the telegraphony. This is a combination of a telegraph and a telephone. The operator could send messages verbally or by Morse code.

*A telegraphone*

## Motor Vehicles

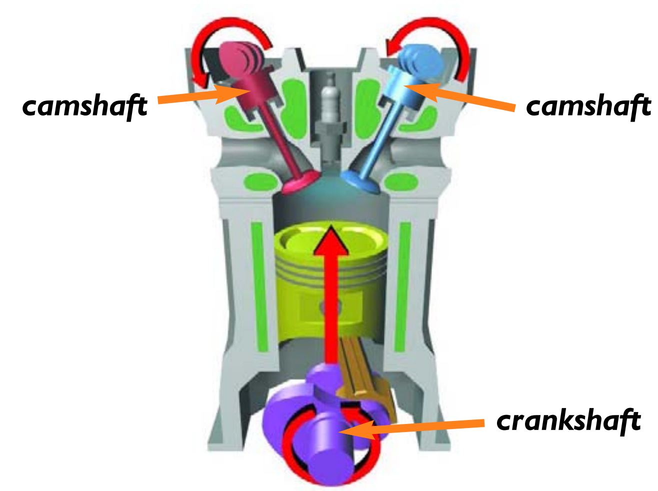
People drive and are passengers in motor vehicles in most places of the world. Motor vehicles have wheels and a motor. They can be driven on many different land surfaces. Cars, buses, and trucks allow people and things to travel to certain places. They can travel where boats and trains cannot go.

*A sedan is sometimes called a family car.*



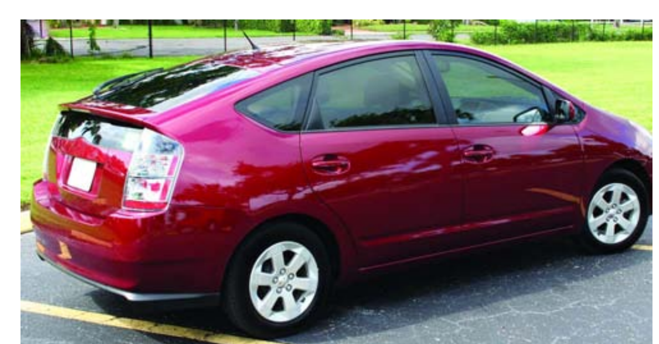
### Cars

Cars are vehicles used by people to get from one place to another. Combustion engines are often the power source for cars. This type of engine burns gasoline or diesel fuel to run. Some people are concerned that combustion engines are contributing to pollution in the air.




*A four-stroke engine*

Inventors are developing other types of power systems to make cars run. Electric cars have electric motors that run on batteries. Some cars use hydrogen to provide power. A hybrid car uses a combustion engine and battery power to make the car work.



*Hybrids look like standard automobiles.*

Cars come in a variety of sizes. A limousine is a long car. It has space for many passengers and has a chauffeur to drive the vehicle. A microcar, also called a bubble car, is very popular in countries outside of the United States. Auto makers designed the microcar to use less gas. It is also economical because a small amount of material is necessary to build the car.

*Limousines are often referred to as limos.*

**Words to Know**

**chauffeur** (SHOH-fur): a person employed to drive a private automobile or limousine for the owner

**combustion** (kuhm-BUHS-chuhn): burning, the process of combining fuel with oxygen to produce heat

**gasoline** (GAS-uh-leen): a flammable liquid mixture of hydrocarbons obtained from petroleum, which is used as a fuel for combustion engines

Some people like to drive a sports car. It can go fast. The fastest cars are race cars. Some cars have special features. A convertible is a car with a fabric top that folds back. Instead of fabric, some convertibles have a hard top that the owner can remove.

### Buses

Buses are bigger than cars. A bus has a long body with several rows of seats or benches for passengers. Buses usually operate on a schedule. A school bus carries children to and from school. A passenger bus can carry people long distances. They travel between different cities and towns. A tour bus carries tourists or people on vacation. Some people charter, or rent, a bus for special purposes.

*The stop sign which a school bus driver activates is a warning to drivers to stop for school children.*

### Trucks

Vehicle engineers designed trucks to carry materials of all kinds. Pickup trucks are a bit bigger than cars. They have a flat bed behind the passenger compartment. They can carry many things in the flat bed. Large trucks transport different kinds of heavier materials or equipment. They carry things to places where trains and boats cannot travel. An 18-wheeler is a very big truck. It has 18 separate wheels.

*Sometimes, pickup trucks are used as emergency vehicles.*



*It is wise to leave extreme space between your car and an 18-wheeler so the truck driver can see your car in his rear-view mirrors.*

## Aircraft

### Hot Air Balloons, Blimps and Dirigibles

Aircraft are vehicles or machines that let people travel through the air. The first type of air transportation was the hot air balloon. It is the oldest successful human carrying technology for flight. It floats using a large bag of silk or nylon filled with heated air. People travel in a wicker basket called a gondola, that hangs underneath.

A blimp or dirigible is like a balloon. The gas helium fills up the balloon to help it float. It has a motor to push it forward. This type of craft was very popular before 1940.

*The first hot air balloon flight carrying humans was on November 21, 1783 in Paris, France.*


*Advertising blimps are sometimes equipped with television cameras when flying over an athletic field.*

As technology for airplanes improved, people stopped using blimps to travel. Today, advertisers use blimps to market their products. Some companies offer sightseeing tours in a blimp.

## Airplanes, Gliders, Helicopters

An airplane is an aircraft that flies using wings and an engine. The Wright brothers receive credit for the invention of the first airplane in 1903. Airplanes can be small and carry only one or two people. Commercial airplanes can be large and carry many passengers a long distance in a short amount of time. Most airplanes take off on a long road called a runway. Air lifts the airplane up. This happens as the air passes over and under the wings. A small airplane gets its power from propellers. Propellers are on the outside. A motor makes the propellers turn. Most larger airplanes have jet engines. This type of engine has many turning blades inside. They move air much faster than ordinary propellers.

*Some jet airplanes are so huge that large trucks and small airplanes can be carried inside them.*

Jet airplanes use turbines to make them move faster. The military uses supersonic aircraft, such as fighters or bombers, to move quickly with a great amount of power. A fighter jet is a small military airplane that can go very fast.

*Military airplanes are not painted such bright colors as passenger airplanes.*

The Concorde is one of the only supersonic planes used as a commercial airplane. It carried passengers from Europe to America in less than half the time it took for a regular airplane to fly the same distance. The Concorde was very expensive to fly. Due to rising costs, the Concorde was retired from use. The last Concorde flight was on October 24, 2003.



*You are not likely to see a Concorde in flight anywhere.*

A glider has a similar shape to an airplane. It uses only the wind for power. The military may use gliders to deliver troops. Gliders are very quiet because they don't have an engine. Some people participate in glider competitions.

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*Gliders have no propellers or jet engines.*

A helicopter is an aircraft with a large propeller on top. It can rise into the air, or take off, straight up. A helicopter can take off without using a runway.

*Helicopters may land on a hospital roof helipad with emergency patients.*

*Military helicopters can deliver personnel and supplies to places where there are no runways.*

### Words to Know

**commercial** (kuh-MUR-shuhl): transporting passengers or cargo for profit

**supersonic** (soo-per-SON-ik): traveling through air faster than the speed of sound

**turbines** (TUR-bine): a machine that uses steam, water, or gas to create energy and is often used in jet engines

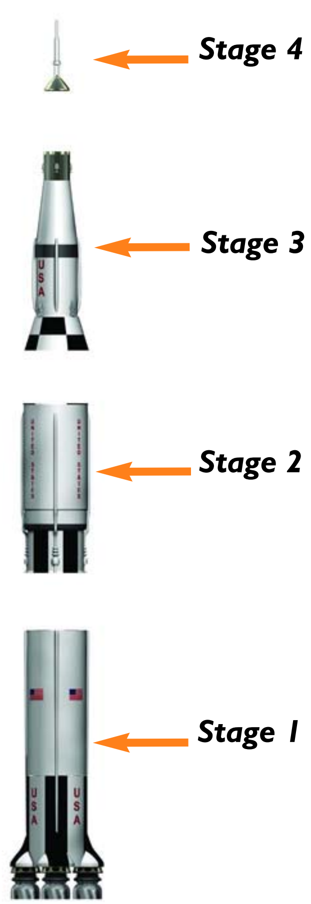
## Rockets

A rocket is a vehicle that travels into the air at a very high speed. It burns fuel to make thrust. Thrust pushes, or propels, the rocket upward. A rocket engine ejects the thrust out of the bottom of the rocket. A lot of energy is required to propel a rocket into space. Energy is necessary to make things happen. Astronauts and cosmonauts are people who travel into space using rockets. Rockets also lift satellites into orbit. Satellites study the Earth and other objects in the universe.

*People must be far away from the base of a rocket at the time of blastoff.*

### Rocket Design and Travel

Multiple sections or stages make up the design of most rockets. Each stage contains its own fuel supply and rocket engine. When its fuel is used up, a rocket is released. This lightens the weight of the rocket. It allows it to travel faster. A rocket needs to travel at least 17,700 miles per hour, (28,500 kilometers) to make it out of the atmosphere into space. This speed is the escape velocity. The part of the rocket that actually reaches space is often called a spacecraft.

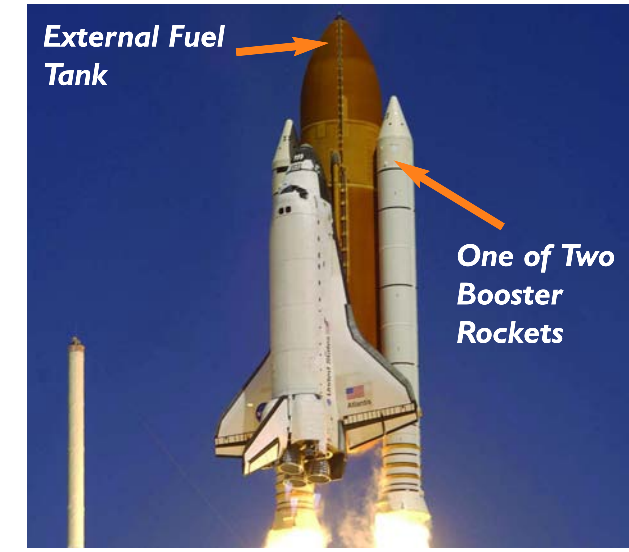



*Stage 4 of a rocket is called the payload.*



### Booster rockets

Some rockets get extra thrust from booster rockets. The scientists usually attach the boosters to the side of the main rocket. The space shuttle is both a rocket and an airplane. It takes off like a rocket. It releases two booster rockets. As the rocket uses up its fuel, it will also release an external fuel tank. The space shuttle lands like an airplane when it returns to Earth.

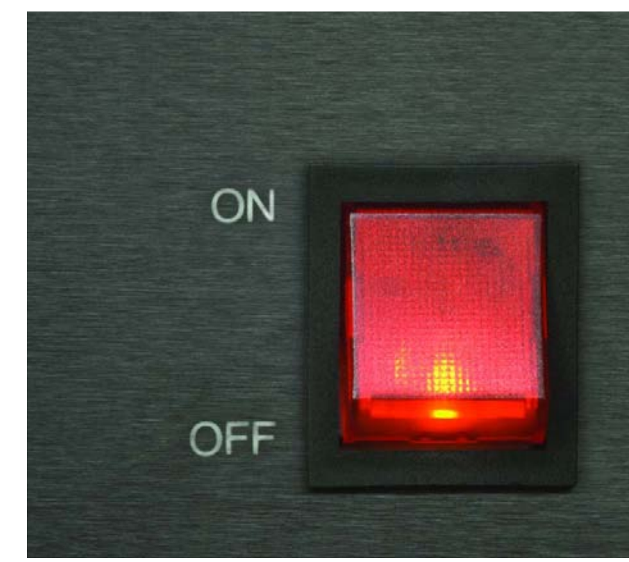



*A space shuttle is also called a spaceship.*

# Electronics

## Currents

Much of modern technology is the development of a variety of tiny electronic devices. Electronics is the study of devices used to control electric current. A current is moving electricity, usually conducted, or moved, in a wire. Different things can happen to currents. Some electronic parts switch the current on and off. Other components make the current larger or smaller.




*A toggle switch is used to turn the current on and off.*

### Types of Currents

There are two different types of electronic current. Direct current, or DC, flows down a wire in only one direction. It remains constant. Direct currents make computers and electronic clocks work properly.

*When your computer is plugged into the AC outlet, a built-in power adapter charges the AC to DC.*

Alternating current, or AC, moves first in one direction and then in the opposite direction. AC is the type of current that delivers electricity to homes and businesses. Frequency is how many times the current changes direction each second.

*Sound systems and TVs operate on alternating current.*

Electronic devices are things that use electricity to work. Computers, televisions, radios and video games use electricity. Can you think of other things that use electricity?

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## Circuits

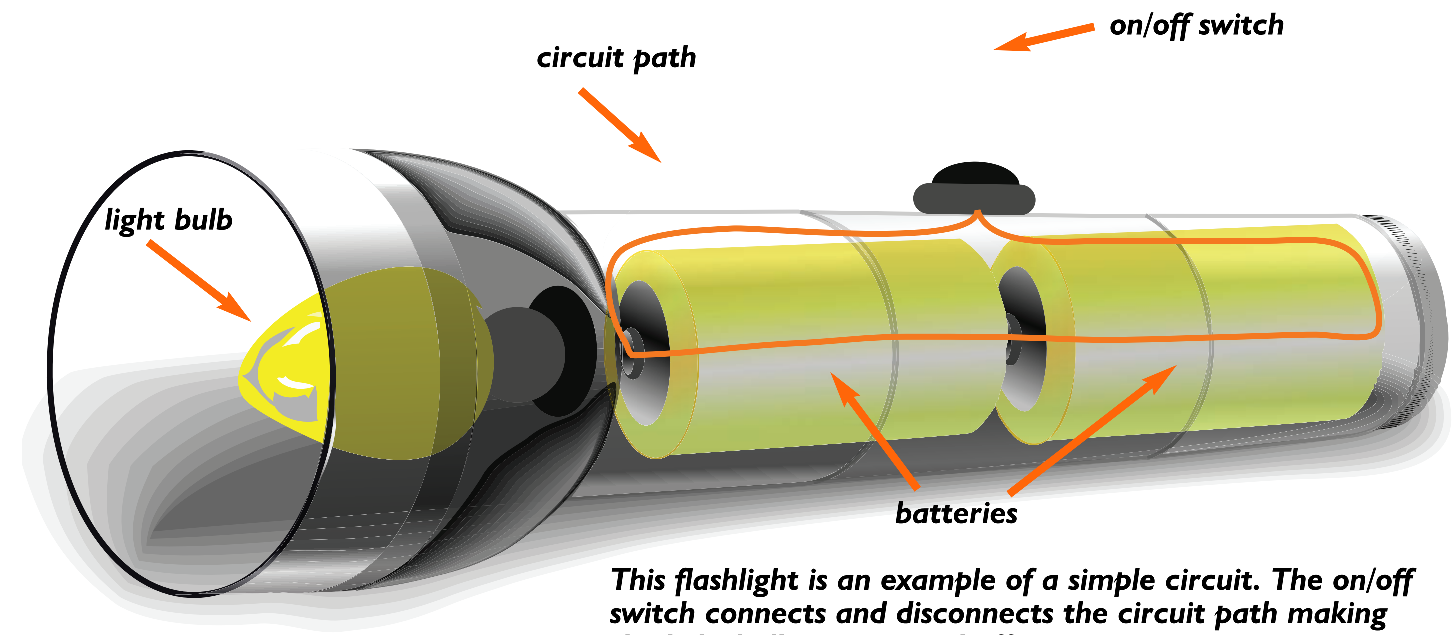
### Electronic Circuit Components

A circuit is a group of electronic components or parts. Electronic circuits are made of parts that are connected. There are several types of electronic parts. Batteries store chemical energy. This can be converted or changed into electrical energy. Resistors control the current. Transistors make the current stronger, or amplify it. Capacitors store energy.

*Batteries have a positive (+) end and a negative (-) end.*

Devices like motors and light bulbs convert, or change, energy. Electronic circuits use these






*This flashlight is an example of a simple circuit. The on/off switch connects and disconnects the circuit path making the light bulb turn on and off.*

components in different combinations to perform different tasks. Circuits come in many sizes. Some are big. Others are tiny. These components form a complete path for the electric current. The current starts and ends in the same place. A very simple circuit forms a complete loop like a rubber band.

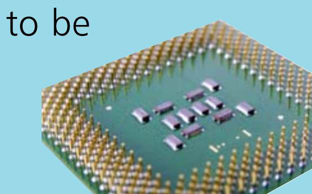
### Simple Circuits

Electronic circuits can be as simple as turning on a light bulb. The components of a flashlight are a battery, a switch, wires, and a light bulb. When the switch turns "on" the circuit completes its path. Electricity can flow. It flows from the battery, through the light bulb, and back to the other end of the battery. The filament, or wire, inside the light bulb heats up. The filament becomes so hot that it emits, or gives off, light. In this circuit, some of the chemical energy from the battery is converted. It changes into light energy.

Find out more

**A Circuit Can Fit on a Tiny Chip**

Sometimes, complicated circuits can be a few millimeters, or a fraction of an inch long! They are integrated circuits. These circuits are found on microchips. Microchips allow some electronic devices to be very small. Cell phones have microchips.



## Nikola Tesla

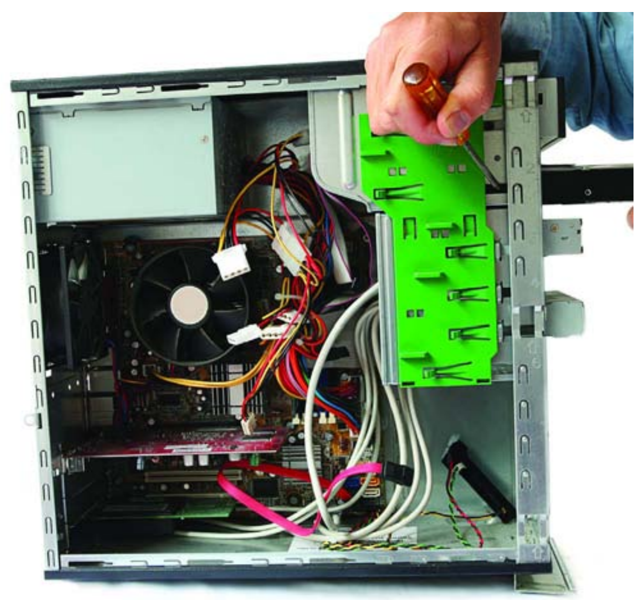
Getting to know...

Nikola Tesla was born in Croatia in 1856. His father was a clergyman and his mother was an inventor. His mother had a great influence on his life. Tesla loved solving problems in science and mathematics. He came to the United States in 1884. He became Thomas Edison's assistant. He disagreed with Edison about the best form of electric current.

Tesla developed a form of electricity called alternating current, or AC. He designed electronic components. They allowed power to travel over long distances. He also discovered medical uses for electricity. Tesla invented other electronic devices and developed the basic principles for many more. Many of his inventions were not valued during his life. Only after his death did Tesla get the praise he deserved.

### Complex Circuits

Many circuits are complex as we see in a powerful computer. Computers use many combinations of different types of components. These components often combine together on a circuit board. Some of the components used in computers include processor chips, RAM, and ROM.

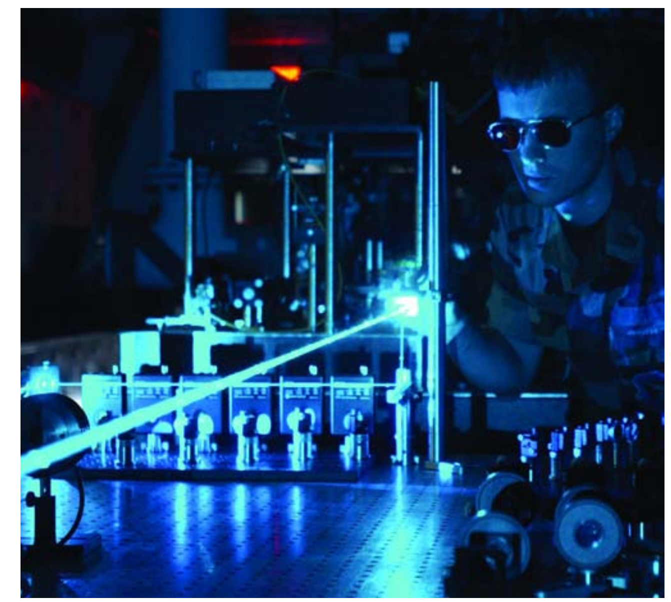


## Lasers

Lasers are devices that make an intense, narrow, and single-colored beam of light. The word "laser" stands for "light amplification by the stimulated emission of radiation." Scientists introduced the first laser in 1960. Many lasers consist of a tube that contains gas. Scientists use different types of gases to make different colors of light. The light happens when the gases become active or energized. The gases usually gain energy when combined with electricity.



Helium-neon lasers create a red light. Argon lasers can produce blue and green light. Helium, neon and argon are gases. Lasers range in size from microscopic to the size of a football field.



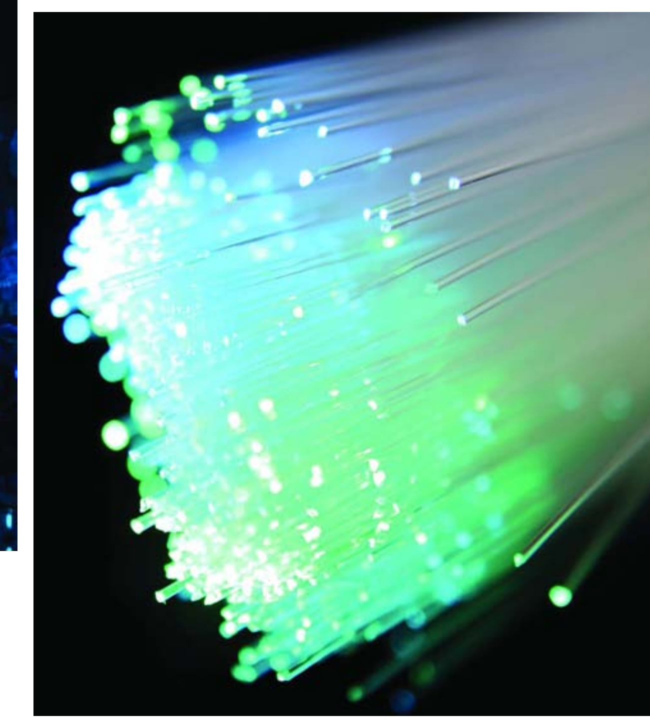
*Laser beams shine in a straight line.*

### Seeing Lasers

You cannot see some lasers unless they reflect off of a surface. Other lasers are easier to see. High-powered lasers cause particles in the air to light up. Usually, a laser beam is visible when it passes through dust or smoke.

### Using Lasers

There are a lot of different uses for lasers. Some people use a laser as a pointer. They shine a little dot on a wall far away. This is especially helpful to teachers. Some people use other kinds of lasers to transmit or send computer information very quickly. They do this through fiber optic cables. They are very thin groups of glass or plastic.



*Fiber optic cables carry computer information sent with lasers.*

Laser printers and compact disc players are common products that use lasers. A bar code scanner in the grocery store uses a laser to read the code. Doctors use medical lasers in surgery. Surgeons use laser technology to remove unwanted tissue in the body. A doctor can make a precise incision using a laser.

For example, lasers are common for eye specialists to perform eye surgeries. Industrial lasers cut steel and other materials. Engineers often use lasers to measure distances or to mark a straight line.

*Lasers enable doctors to perform some surgeries without making any incisions.*

Find out more

### Holograms

#### Seeing holograms without lasers

A hologram is a three-dimensional image. Sometimes, you can see a hologram without a laser. You can see these three-dimensional images with natural light. You can see holograms on most credit cards. Credit card companies use holograms to prevent people from making copies of the card. The hologram appears to move and change colors as you move the card.


*Holograms are used on many banknotes.*

#### Seeing Holograms with Lasers

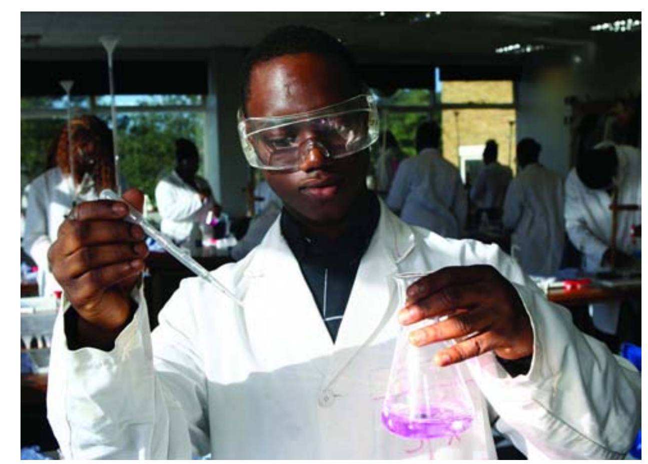
People use lasers to make holograms. A laser beam splits into two separate beams. One of the beams reflects off an object onto a photographic surface, or plate. The other beam shines directly onto the photographic plate. It does not reflect off the object. This is the reference beam. The two beams combine to make light and dark areas on the photographic plate. Scientists call them interference patterns. These patterns make a three-dimensional image when lit with the same type of laser light.

There are many other types of holograms. Medical professionals use holograms. One day, computers may use holographic memory.



# Medicine

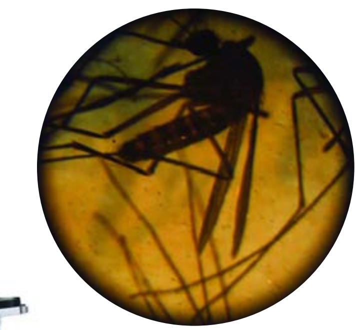
Medicine is the science of keeping the human body healthy. It includes treating people when they get sick. Doctors need technology to help them with a diagnosis, or finding out what is wrong with a person. They need technology to create medications to help sick people feel better. They need technology to perform operations. Operations can help doctors to cure or treat a disease within the body.



*Medical professionals can tell much about us be examining samples of our body fluids.*

## Microscopes

A microscope is a device used to make something look bigger. Scientists use microscopes in medicine to study cells for signs of disease. Cells are the building blocks of life. A specimen is the sample of cells that a researcher will study. The specimen is generally too small for the eye to see without assistance from some type of technology. A scientist might stain, or color, the specimen to make its parts easier to identify.



*A microscope is many times more powerful than a magnifying glass.*

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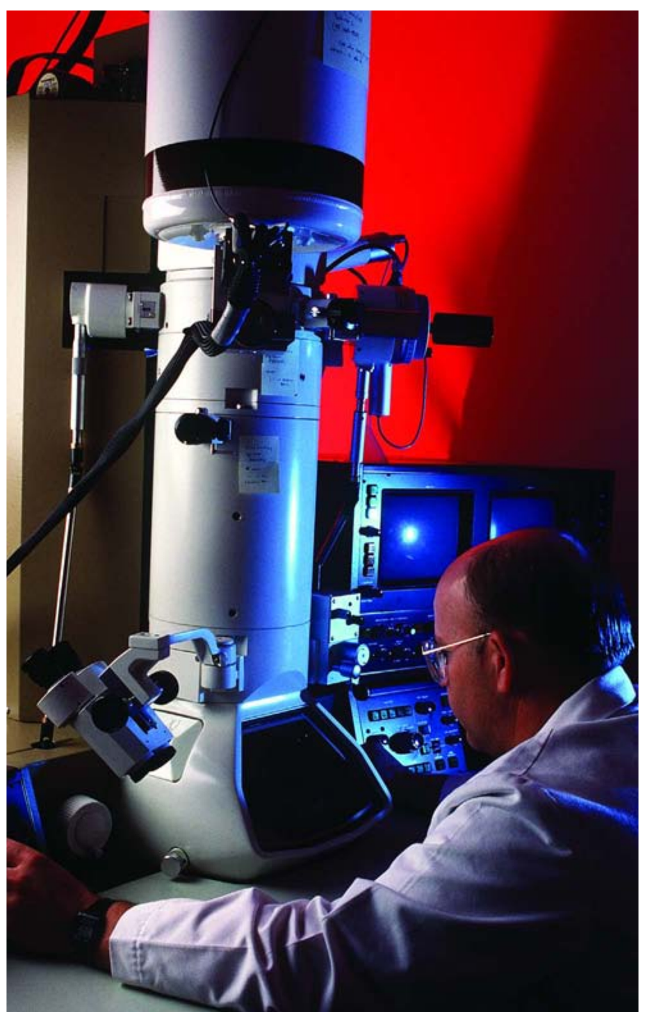
### Compound Light Microscope

The most common type of microscope is the compound light microscope. When you use this microscope, a scientist presses the specimen between two glass slides. A scientist then places it on an area called the platform. A bright light shines below the platform. The image of the specimen is magnified by several glass lenses.

## Electron Microscope

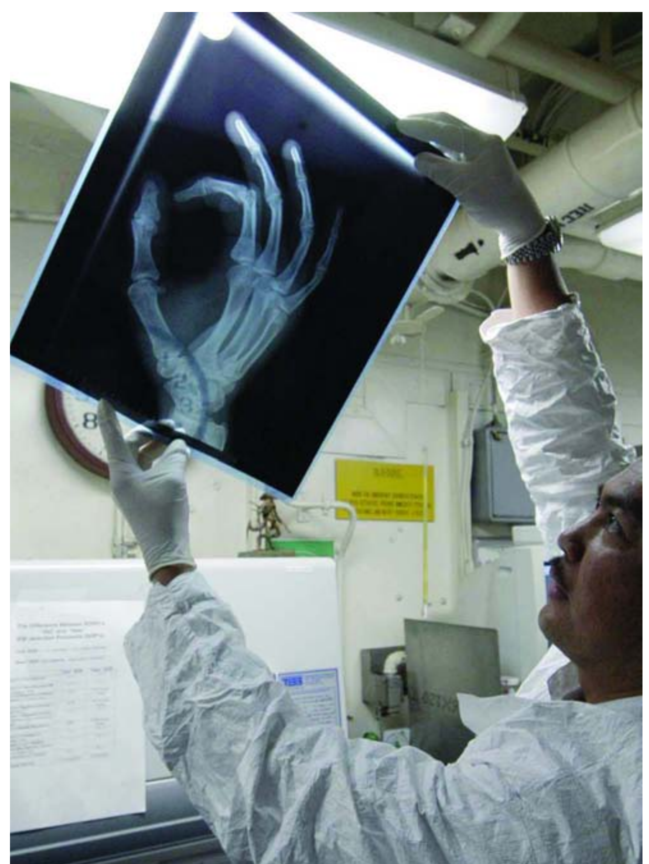
An electron microscope can magnify very small things. Instead of using waves of light, it uses waves of electrons. An electron is a small particle. You cannot see electrons with just your eye. The waves of electrons light up a specimen. Electron microscopes can show viruses and other things that are invisible to the eye. They can also show things that are invisible to light microscopes.



*Electron microscopes are much larger and stronger than light microscopes.*

# Imaging

Doctors often need to know what the body looks like on the inside. Imaging is a way to take pictures of bones and organs, such as the heart. A simple imaging technology is the X-ray. X-rays are a type of radiation. Exposure to the rays in large amounts can damage tissues. Doctors use small amounts for diagnosis. An X-ray is like a photograph. X-rays allow doctors to see cavities in teeth. They allow them to see fractures in bones, or fluid in the lungs.

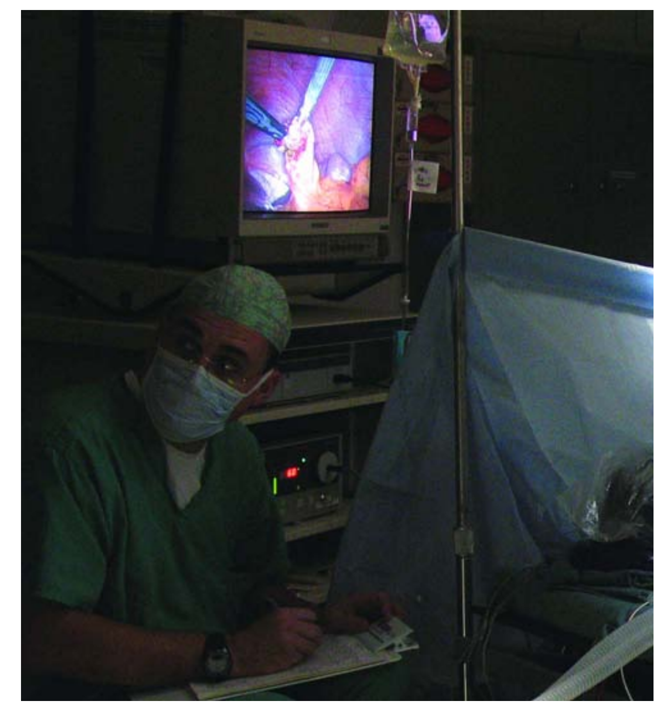


*By comparing x-rays taken at different times, a doctor can tell how a body is changing.*



## Fluoroscopy

Fluoroscopy uses X-rays to show movement inside the body. It also uses a television type screen. It can show what happens when you swallow or when your heart beats. Surgeons use fluoroscopy during surgery if they need to have a consistent picture of what is happening in the body while the patient is on the operating table.



*A fluoroscope helps a surgeon know what is happening inside your body.*

## Other Types of Imaging

Computed tomography scanning, or a CAT scan, creates millions of pictures. A computer puts these pictures together to make one image.

Magnetic resonance imaging, or MRI, uses magnetic fields. A powerful magnet produces small pulses of energy. A computer uses these pulses to create a picture. Doctors use MRI to see soft tissues like the brain.

*During medical tests using an imaging machine, you must lay very still.*

Ultrasound imaging produces images with sound waves. It can show the movement of blood in an unborn baby.


*Your first official photograph might be via ultrasound before you are born.*

## Surgery

Many doctors recommend surgery to treat or cure a disease or other problem inside the body. Surgery usually involves cutting into the skin and other tissues. For hundreds of years, a sharp knife called a scalpel was the tool doctors used. Today, advances in technology have created other ways to operate.

***Surgery is performed in a cool, sterile room with very bright lights.***

**WORDS TO KNOW**

**abdomen** (AB-duh-men): the part of the body containing the stomach and intestines

**incision** (in-SIZH-uhn): the act of cutting into the body for surgical purposes

**surgical instruments** (SUR-ji-kuhl IN-stre-ment): tools used for scientific or medical purposes

### Using An Endoscope

An endoscope is a fiber-optic tube inserted into the body. Fiber – optics are very thin groups of glass or plastic fibers. The fiber-optics send pictures to a screen so that the doctor can see what is happening inside the patient's body. Doctors see inside organs, such as the heart, and even what is happening inside blood vessels. Blood vessels carry blood around the body.

Laparoscopy is the use of an endoscope in the abdomen. The doctor attaches surgical instruments to the tube to perform the operation. This means that the incision into the skin can be much smaller.

### Microsurgery

Surgeons often make incisions using lasers. In microsurgery, the surgeon uses a microscope and tiny instruments to repair tissue and cut away diseased tissue. Doctors use microsurgery to reattach a severed (cutoff) body part. For example, doctors will sew arms, legs, toes and fingers back on during microsurgery.



# Communications

Humans communicate with each other in many different ways. The simplest forms of communication involve talking out loud, using hand signs, and writing down messages. Technology is used to increase the number of ways people can communicate. People have invented devices and systems that allow individuals to talk to each other when they are not together. Communications technology is an important part of both today's and tomorrow's society.

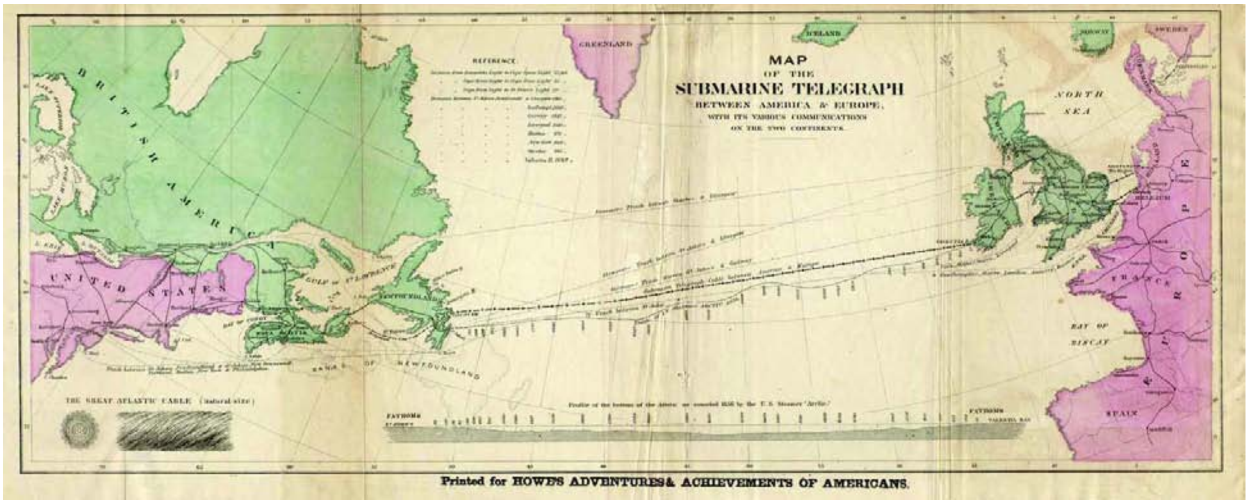
## Telegraphs

People often need to communicate with each other over very long distances. One way people do this is to send electrical signals along a wire. The telegraph was one of the first devices that could do this. Telegraphs are relatively simple devices. Pushing down on a telegraph lever causes electric current to flow. This current travels very fast through a wire. At the other end of the wire is a telegraph receiver. Each pulse of current causes a special magnet, an electromagnet, to turn on. A clicker makes dots and dashes on a strip of paper when this magnet is on. People sometimes call this strip of paper a ticker tape.

Workers laid very long telegraph cables all the way across North America. This transcontinental

***There is a charge for each word used in a telegram.***

telegraph allowed people to communicate from New York to San Francisco. They were able to send messages across the country. Workers laid a metal cable across the floor of the Atlantic Ocean from the state of New York to the country of England. It went to the city of London. This was the transatlantic telegraph.



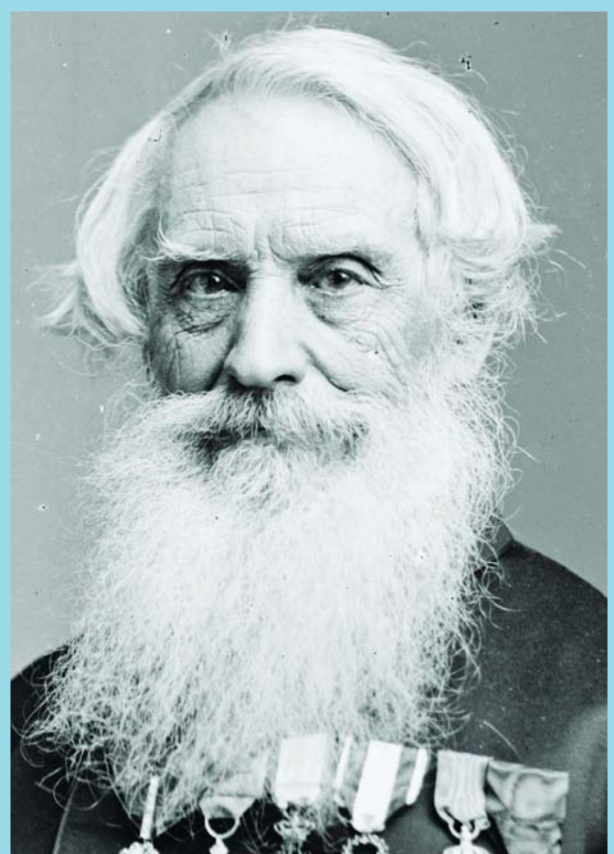

***This old map shows the transatlantic telegraph line placement.***

There are also wireless telegraph systems. A wireless telegraph system allows people to send signals through the air.

### Find out more

**Morse Code**

Sending messages over a telegraph line is not like talking on a telephone. You can make only long or short sounds, not words. A special code is needed that will be understood by the person sending and receiving the message. Samuel F. B. Morse created a list of sound patterns for letters and numbers. The name of this code is Morse code. A short tap on the telegraph makes a short sound called a dot. A longer tap makes a longer sound called a dash. People send a word or words using the dot-and-dash patterns for each letter, with short pauses between letters and longer pauses between words.



***Samuel F. B. Morse***



## Telephones

People use telephones every day to talk with each other. A telephone is a device that converts or changes sound into an electrical signal. Another telephone far away can hear this signal. Telephones come in many shapes and sizes. The microphone is the part of the phone that people talk into. The microphone converts sound into electrical signals. It makes the sound louder. The receiver is the part of the phone that allows people to listen. The receiver converts electrical signals back into sound.

***Telephones make it easy to keep in touch with people.***

Morse code was once very important when ships used the telegraph for communication. The universal or worldwide signal for a ship in trouble is SOS. This stands for "Save our ship." In Morse code, SOS is ••• ---- •••. People can also use flashes of light to send messages in Morse code. Many people in the military still learn Morse code.

Morse code

| | | | |
|---|---|---|---|
| A | •– | S | ••• |
| B | –••• | T | – |
| C | –•–• | U | ••– |
| D | –•• | V | •••– |
| E | • | W | •–– |
| F | ••–• | X | –••– |
| G | ––• | Y | –•–– |
| H | •••• | Z | ––•• |
| I | •• | 0 | ––––– |
| J | •––– | 1 | •–––– |
| K | –•– | 2 | ••––– |
| L | •–•• | 3 | •••–– |
| M | –– | 4 | ••••– |
| N | –• | 5 | ••••• |
| O | ––– | 6 | –•••• |
| P | •––• | 7 | ––••• |
| Q | ––•– | 8 | –––•• |
| R | •–• | 9 | ––––• |

## Types of Phones

There are several ways you can make a telephone call. A rotary telephone has a wheel, or dial, with numbers on it. The rotary phone makes a different pulse, or clicking sound, for each number dialed. A touch-tone telephone has a keypad with numbers on it. Touch-tone phones send out different combinations of tones, or noises, for each number that is pressed.

## How Telephones Work

Telephone companies normally connect telephones to each other by a series of devices such as fiber-optic cables and copper wires. All these devices make up a telephone network. The network allows you to make a phone call to any other telephone line. Every phone line has a different telephone number.

*Telephone companies are responsible for the telephone network. Individuals are responsible for the lines and equipment in their homes.*

*Rotary phones, and some touch-tone phones, must be used where they are plugged into a phone jack.*

People often have one telephone number in their home. The same line can connect several telephones to the same line. They will share the same telephone number.

## Cordless Telephones

Many people have cordless telephones in their homes. They use radio waves to communicate with a base. The base connects to a phone line.

*Cordless phones allow people to move around the house while talking.*

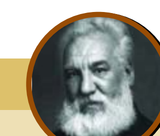


People may hook up a telephone answering machine to their telephone line. The answering machine will make a recording of a phone call if nobody answers the phone.

## Cellular Telephones

Some people carry cellular telephones with them wherever they go. Cellular phones are little telephones. They have powerful transmitters in them. They connect to other phones through a system of antennas called the cellular network. Cellular phones work as long as they are close to a cellular antenna. People have to recharge cellular phones when the battery gets low.

*Cell phones can be used almost anywhere now. In some countries there are more cell phones than people.*



Getting to know...

### Alexander Graham Bell

Alexander Graham Bell was born in the country of Scotland in 1847. His father and his grandfather were well-known speech teachers. Bell taught music and speech to children. In 1871, he moved to the United States and lived in the city of Boston. He moved there to teach deaf children how to speak.

Bell figured out how to send several telegraph messages over a wire at the same time. The telephone is Bell's most famous invention. A telephone changes a voice into an electrical signal. It then transmits it along a wire. It changes it back into sound at the receiver. He founded the Bell Telephone Company in 1877. Bell made the first telephone call from New York City to the city of Chicago.

*Graham Bell's original phone*

## Copiers and Fax Machines

### Photocopiers

Photocopiers are devices that can make a duplicate, or copy, of an image. There are many different types of copiers. Traditional photocopiers use a black powder called toner. The machine uses toner to make a copy of the original image. The toner transfers from an image roller onto paper that is electrically charged. The machine then melts the toner into places by hot fuser rollers. The toner should not rub off when it comes out of the copier.

*Many copiers can make black and white copies as well as color copies.*

### Scanner

Other types of copiers use different methods for copying an image. A device called a scanner is often used. A scanner converts an image into computer data. The computer is able to store or print out the information.

*Scanners can be small desktop devices or large freestanding machines.*

### Facsimile (fax) Machines

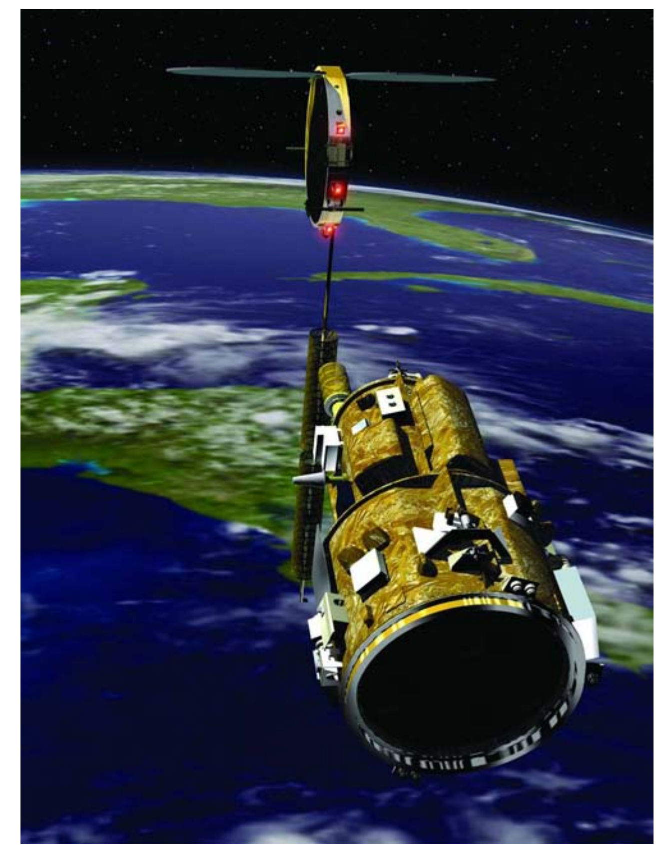
Facsimile or fax machines are copier-like devices. They send written and printed material to another fax machine using telephone lines. They often have a built-in scanner. It changes the image into data that transmits over a phone line. A fax machine receiving a call from another fax machine changes the data back into a printed image. Many people use the term fax to describe the image sent by a fax machine. Sometimes, people use computers to send faxes. They can send and receive a fax without using a single sheet of paper.

*Since the 1980s, fax machines have been an essential tool for most businesses.*



## Satellites

Communications on Earth often depend on technological devices in space. Satellites are anything that orbit around a planet. The Moon is Earth's only natural satellite. Humans have sent up hundreds of man-made satellites. They orbit around the planet Earth.



*The three main types of satellite orbits are polar, Sun synchronous, and geostationary.*

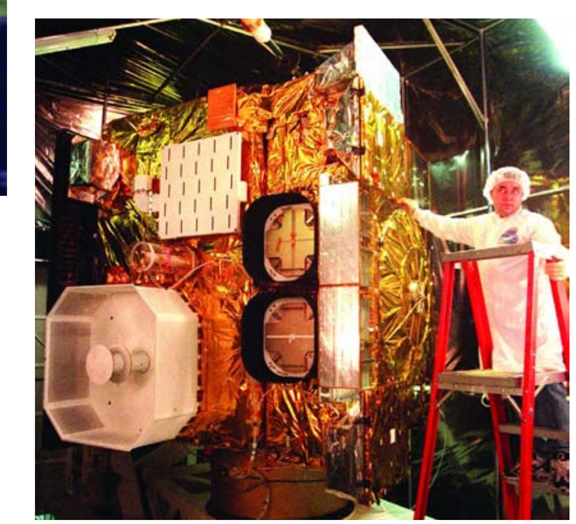
### Communications Satellites

Some companies use satellites for telephone communication. They allow people to place phone calls instantly to any telephone on the planet. Communications satellites have other uses. They can receive and transmit radio and television signals, allowing people to watch and listen to events as they happen around the world.

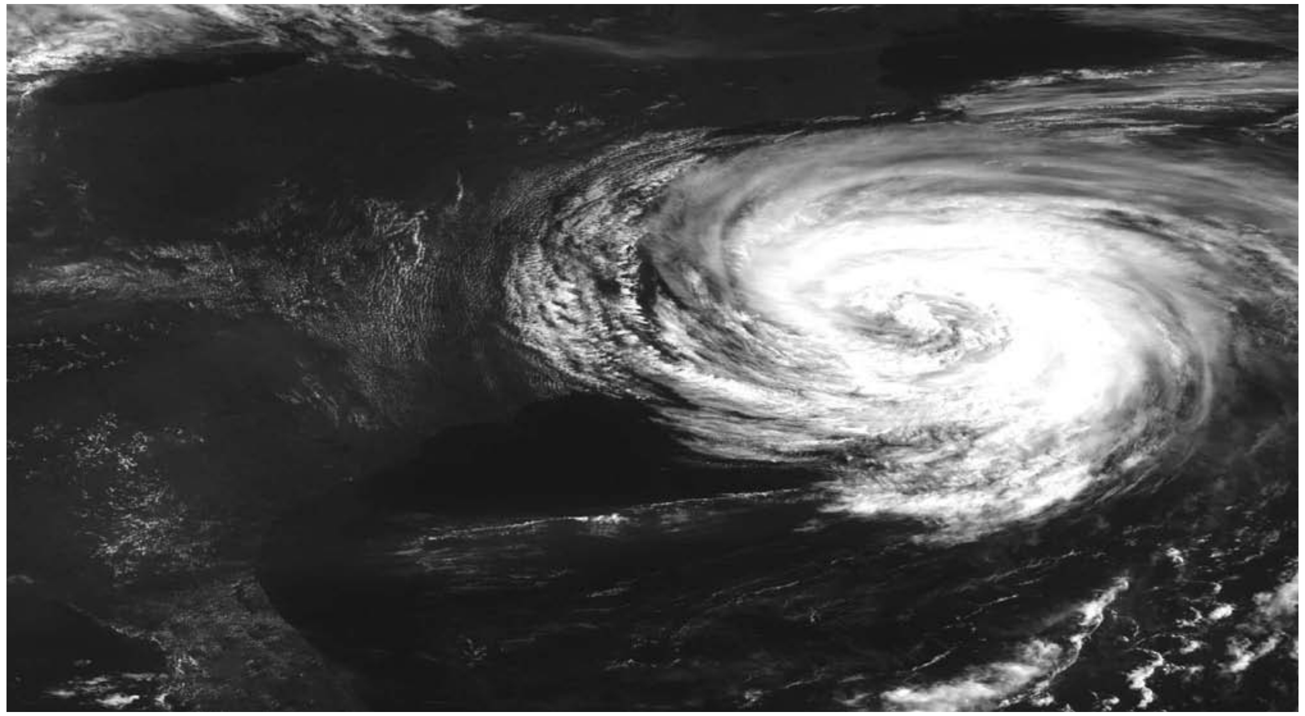
Communications satellites often have a geostationary orbit. This means that they stay over the same spot above Earth as it spins. Some people and companies have satellite dish antennas. These antennas allow them to receive satellite signals.

### Weather Satellites

Scientists use other satellites to study the Earth. Weather satellites send images of clouds and storms covering the planet. These satellites often move about the Earth in a polar orbit. This type of orbit allows them to view the entire planet as it spins.



*Most weather satellites have a lifetime of about seven years.*



*An image from the GOES-9 weather satellite shows Hurricane Felix.*

The weather is predicted using images from weather satellites. Often you will see satellite images on the weather and news channels on television.

### Military satellites

The military sometimes uses satellites to spy on other countries. The satellites carry powerful telescopes. Telescopes are devices that magnify distant objects which people can not see with just their eyes. These telescopes can take detailed images of the Earth's surface. Other satellites with telescopes study the planets and stars.

*The Earth looks like a big ball when seen from space.*



Find out more

## Radar and Sonar

### Radar

Some people can measure distance using radio waves. Radio waves travel well above ground. Some of the waves bounce back when they hit an object. This causes an echo. Radar is an electronic device that listens to echoes. Radar can find the distance to an object by measuring the time it takes to receive the echo.

The word "radar" stands for "radio detection and ranging." Radar is useful to keep airplanes from crashing into one another. Police officers use radar to measure the speed of moving cars. Space probes, which are unmanned vehicles, sometimes use radar to map the surfaces of other planets.

### Sonar

Sound waves travel well underwater. Like radio waves, sound waves create echoes. This happens when they come in contact with an object. Sonar is a device that listens to the echoes of the sound waves. The word "sonar" stands for "sound navigation and ranging."

Like radar, sonar measures the time it takes to receive the echo of a sound. Then it calculates the distance to the object. Submarines use sonar to "see" underwater. Sometimes, people use sonar to find fish underwater. Oceanographers use sonar to map the ocean floor.

# Entertainment

Many of the ways people have fun involve the use of technology. Entertainment includes listening to music on stereos, radios, or MP3 players. It includes watching television, taking photographs, and going to the movies. All these activities depend on technology. Stereos, radios, and televisions have electronic parts. Many cameras have mechanical parts. Video and computer games, movies, and music all require technology.

## Stereos

People use a stereo to listen to music and other sounds. Technicians make stereos using specific electronic components. These components amplify sounds (make them louder). Other devices or components allow stereos to play compact discs and MP3s. They allow them to play records and tapes. Some stereos can take up an entire room. Other stereos are small. Portable stereos run on batteries. People can take portable stereos outdoors. Many people have stereos built into their cars. MP3 players are small portable devices that can fit in a pocket. They can hold hundreds, or even thousands of songs.

### Frequencies

Sound travels on sound waves. A sound wave has a frequency. The frequency is the number of times something moves in a second. A higher frequency sound has a high pitched sound like a whistle. A lower frequency sound has a low pitched sound like a drum. The amplifier is the main part of a stereo. It has different controls for changing the quality of how we hear the sound. The volume control adjusts how loud or soft the sound is. Bass controls make the low frequencies of sound louder or softer. Treble controls make the high frequencies louder or softer. Some stereos have equalizers that can control many different frequencies. Balance controls make the sound louder or softer in the left or right speakers. People use a fader to make the front or back speakers louder or softer.

### Stereo System

A stereo system has many components. It needs to have a tuner to operate the radio and an amplifier to increase the volume. A stereo needs speakers in order for the stereo system to make sound. A tweeter is a speaker which produces high frequency sounds and the woofer provides the bass. Speakers often come in pairs to provide stereo sound. Stereo sound is sound from two sides at once. When sound comes from all sides, it is called surround sound. A compact disc player is a regular feature in modern stereo systems. A compact disc player plays compact discs, (CDs). Some stereo systems have auxiliary inputs to be able to use MP3 players or access satellite radio.

**THE HISTORY OF MUSIC RECORDING TECHNOLOGY**

**Phonographs or gramophones** *were the most common devices for playing recorded sound from the 1870s through the 1980s. Its design changed numerous times during that period.*

**Phonograph records** *began replacing the phonograph cylinders in the early 1900s. Phonographs are often called records, LPs, or 45s.*

**Stereo 8**, *also known as 8-tracks, were created in 1964. They are a form of endless loop tapes.*

**Cassette tapes** *were a primary form of sound recordings between the 1960s and early 2000s. Cassettes made it easier for people to make recordings at home.*

**Compact discs**, *or CDs, have been used since the early 1980s. They are still popular today.*

**MP3 players** *are digital audio players (DAP). These small devices are unique because they can store and play music.*

***Some people enjoy arranging all of their stereo equipment in plain sight. Others prefer placing their equipment in a cabinet.***

Sometimes, people listen to stereos using small speakers on their ears called headphones.

***Headphones make it possible to listen to recordings or radio without disturbing others.***

## Radio

Radio waves are a form of energy that travels through the air all around you. This type of energy is electromagnetic energy. These waves (signals) can carry sound, pictures, and other information over long distances. Radios are a type of device that uses radio waves. People often listen to the radio for news, information, music, and other entertainment. People like to use portable radios because of their small size. Many people have radios in their stereo systems at home or in their cars. The latest technology is satellite radio. It is a digital radio signal broadcast by a communications satellite.



### Getting to know... Guglielmo Marconi

Guglielmo Marconi was born in Italy in 1874. He studied two types of science, physics and chemistry. Marconi read about Heinrich Hertz's transmission of electromagnetic waves across a room. Marconi realized that these radio waves could send messages through the air. They could do this without using wires. He performed experiments in his attic.

In 1896, Marconi obtained a patent for his invention of the radio. He also added a telegraph key that used Morse code. Marconi sent messages across the English Channel to France. The English Channel is part of the Atlantic Ocean. He showed how ships could use radio waves to communicate with other ships. They could also use them to communicate with people on the shore. Marconi found ways to increase the distance that radio waves could travel. Soon, he transmitted signals from England to Canada and Australia.

### Radio Stations

Everything you hear on the radio comes from radio stations. A radio station broadcasts or sends music and other programs to a transmitting antenna. The antenna is high on a mountain, building, or tower. The antenna transmits the radio waves into the surrounding area. Small antennas in radios convert or change the radio waves into electric signals. When the electronic signals are amplified it produces sound. Different radio stations broadcast on different frequencies. You can tune into different stations on the radio to listen to different types of programs or music.

***Towers with antennas for transmitting electronic signals can be found in many countries of the world.***

### How Radio Waves are Transmitted

Radio stations can transmit radio waves in several ways. AM radio stands for amplitude modulation. This means that the strength of the radio wave is varied. FM radio stands for frequency modulation. This means that the frequency of the radio wave is varied. The short-wave is another type of radio wave. Short-wave radio can transmit over very long distances. Satellite radio is a new form of radio. This signal can cover a large geographic area.

## Television

The first televisions had black and white pictures and you could only use them to watch shows broadcasted from television stations.

Television, or TV, is a source of both information and entertainment. Television stations can broadcast pre-recorded programs or live events as they are happening. Some live broadcasts, such as newscasts, are produced in a studio. Other live broadcasts, like sporting events, are done away from a studio. They rely on a mobile studio and satellites.

*Satellite trucks are mobile TV studios.*

### How Televisions Work

Televisions receive signals and then reproduce the signals into pictures and sounds. Televisions must have a screen for us to view the image and speakers for us to hear the sound.

Today, televisions are either analog or digital. Radio waves can carry both analog and digital television signals. Three different ways televisions receive signals are through the air, cables, and satellites.

### Analog Televisions

Analog televisions use a cathode ray tube (CRT) to convert the pictures broadcast from a TV station into the image we see on the screen.

The CRT uses beams of electrons to produce an image. Electrons are very small particles that you cannot see. The electrons light up red, green, and blue dots inside the screen. Electromagnets control the electronic beams and allow them to make a picture on the screen.

On February 17, 2009, all television stations in the United States will stop broadcasting analog signals.

### Digital Televisions

Digital televisions (DTVs) have many advantages over analog televisions. Digital signals are electrical signals and can be compressed. Compressed digital signals can carry lots more information than analog signals. Digital televisions do not use a cathode ray tube to convert the signal into pictures. This makes the flat screen TV possible.

Another benefit of DTVs is that they can both receive and send signals. This makes it possible for you to send a message through your television to select a movie or show you want to watch. Many companies call this feature "on demand viewing."

Digital televisions also have better picture quality than analog TVs. People refer to digital televisions as HDTV (high definition televisions). Not all digital televisions are HDTVs. HDTV is the highest resolution level currently available for digital televisions.

*Digital technology led to the development of flat screen TVs.*

### Devices Connected to Television Sets

Today, televisions have many different functions.

| DEVICE FUNCTIONS | |
|---|---|
| **Video Cassette Recorder (VCR):** plays and records programs |  |
| **Digital Video Disc(DVD):** plays programs |  |
| **Digital Video Recorder (DVR):** plays and records programs |  |
| **Game Consoles:** plays video games |  |
| **Surround Sound:** high quality audio system |  |

WORDS to KNOW

**frequency** (free-kwen-see): In radio or electricity, the number of waves or vibrations per second

**transmitted** (trans-mit-ted): to send forward, to pass on or communicate

**varied** (vair-eed): changed or altered

# Cameras

People use cameras to record images (pictures) of people, places, and things. Some cameras take single still pictures showing one moment in time. Other cameras take several pictures together (movies) that record several moments together.

All cameras work by using a lens to focus light onto a surface. Some cameras capture the image on film while others capture the image digitally.

## Still Cameras

Today, most still cameras have many automatic features and record the images digitally rather than on film. Some of the automatic features that make taking pictures a snap are auto flash and auto focus.

When the light comes through the camera lens, a sensor in the camera turns the light into electrons. The camera reads the electrons and creates the image out of tiny pixels. A pixel, or picture element, is one point in an image. Many pixels make up each image.

PROJECTS volume 10 9.4

Most digital camera sensors are a charge couple device (CCD). A few cameras use a complementary metal oxide semiconductor (CMOS).


In the past, when all cameras captured images on film, it could take several hours or days to develop the film and see your pictures. Digital still cameras have taken away the wait. You can take a picture and then view, print, or e-mail it almost instantly.

Find out more

### Film

Film cameras take photographs when an image remains focused on the film for a certain amount of time. This is the exposure. The aperture controls the amount of light that can come in. Exposure times are longer when there is not much light or the aperture is small.

Once exposed film is removed from the camera, it is then developed. Developed film is called negatives. We can print pictures from the negatives.



## Video Cameras

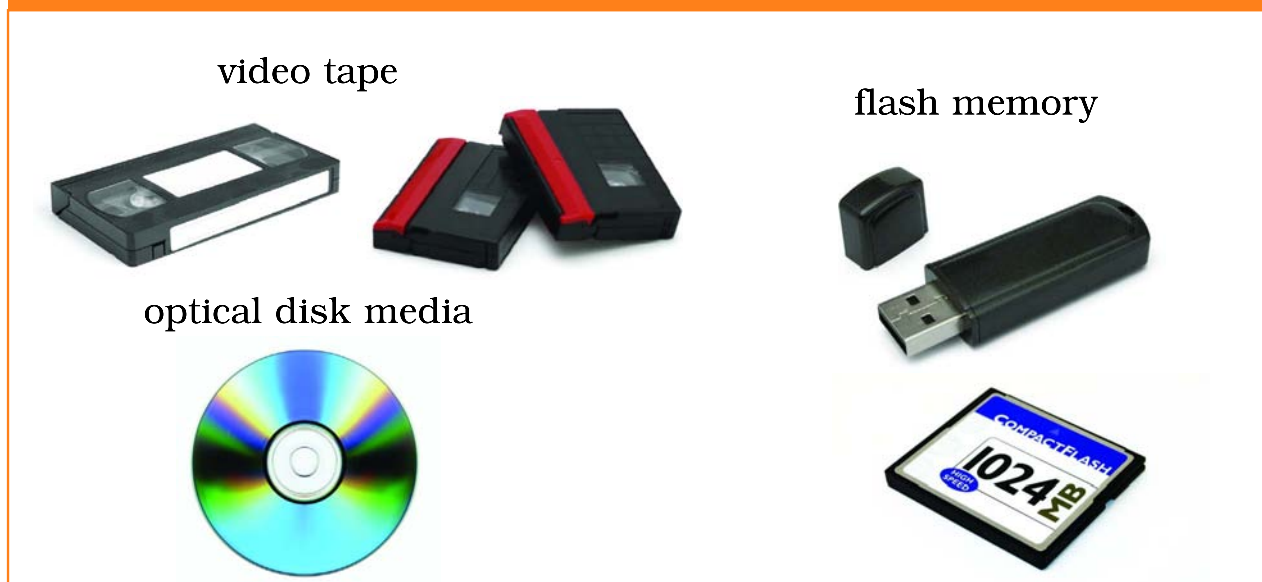
Video cameras, or camcorders, take motion and record pictures. They are both a camera and VCR.

*Sony made the first video camera for home use in 1983. These video cameras were much bigger than the camera the girl is using in this picture.*

*A few digital still cameras can also take short movies. Many people use the digital camera in their cell phone to take short movies.*

Video cameras or television cameras use lenses to focus light. An electronic sensor converts the light to images. The camera records the pictures and then stores them on videotape, optical disk media, hard disk, or flash memory. You probably have home movies taken with a video camera that you view on your TV or computer.

**VIDEO STORAGE DEVICES**



## Motion Picture Cameras

Motion picture cameras take pictures one right after the other. The pictures are recorded on film at a rate of about 24 pictures, or frames, per second. This allows movements to appear smooth and lifelike when someone watches the film.

Movie producers usually use several different cameras to shoot a movie. The film from all of the cameras is then edited (put together) to create one film. Movie theaters use projectors to show motion pictures on a screen.


*Cameras like this one are used to make movies.*

Getting to know...

### Thomas Alva Edison

Thomas Alva Edison was born in Ohio in 1847. As a boy, he worked at a railroad station selling newspapers and candy. Edison found a job as a telegraph operator. Then he decided to become an inventor. In 1876, he opened a research laboratory in Menlo Park, New Jersey.

Edison improved many existing devices, like the telegraph. Edison invented the phonograph. This is a device for recording sound as grooves on a spinning cylinder. This invention made him famous. People called him the 'Wizard of Menlo Park." He developed a motion-picture camera. It could record and play back visual images. People most often recognize the name Edison for his electric lighting system. He did not invent the light bulb, but he improved it.



# Computers

A computer is an electronic device that stores data, or information. It also retrieves and processes or sorts information. People can program a computer to help complete many different tasks. Computers use a combination of hardware and software.

**The hardware** is all the electronic components that make up a computer. For example, a mouse is hardware.

**Software** is the instructions that tell a computer what to do. Sometimes, people use the term program to describe these instructions.


*If your computer seems to be working slowly, you may need to buy more RAM to put in your computer.*

## Central Processing Unit

All computers use a central processing unit, or CPU, to process information. A CPU is made of thousands of tiny electronic circuits. The CPU processes instructions and then sends out a result.

Many computers have ROM chips that provide instructions to the CPU. ROM stands for read only memory. Many computers also have RAM chips that store information. RAM stands for random access memory.

Programs stored in RAM can also send instructions to the CPU. Other data can be stored in RAM temporarily. A computer loses all the information stored in RAM when someone turns the machine off. Most personal computers have more RAM memory than ROM memory.


*ATM machines give people access to their bank accounts 24 hours a day.*

## Dedicated Computers

Some computers do only one thing. This type of computer is a dedicated computer. Automatic teller machines, or ATMs, contain dedicated computers. These computers let people check their bank accounts and withdraw money.

## Computers in Our Everyday Lives

Computers are all around you. Small computers may tell you when an oven is hot. Computers in cars help engines run smoother. They also tell the driver when there is a problem. Many televisions use computers to change channels, or to turn them on and off. Some toys have computers that allow them to talk or make noises. Computers are an essential part of modern technology.

## Personal Computers

A personal computer, or PC, is a computer that can perform many different functions. People use personal computers at home, in school, and for business.

***Business people often use handheld computers to keep track of appointments and read e-mails when they are away from the office.***

Personal computers have many components or parts. Electronic circuits inside a PC process information. PCs also perform calculations, such as adding or dividing. All personal computers need a CPU, ROM, and RAM. Many other peripheral devices can connect to a PC.

Most personal computers have a few USB (Universal Serial Bus) ports that let you plug in peripheral devices. For example, many digital cameras and printers connect to your PC through a USB port.

## Drives

Computers use hard disk drives, or hard drives, to store software and data. They also use hard



***In most libraries, people use computers to see if the book they are looking for is available.***

drives to retrieve information. Most hard drives have hard disks inside the central processing unit that are permanent. That means you can not remove the hard drive without taking the computer apart. Some hard drives have removable hard disks.

***Flash drives plug into your computer through a USB port.***

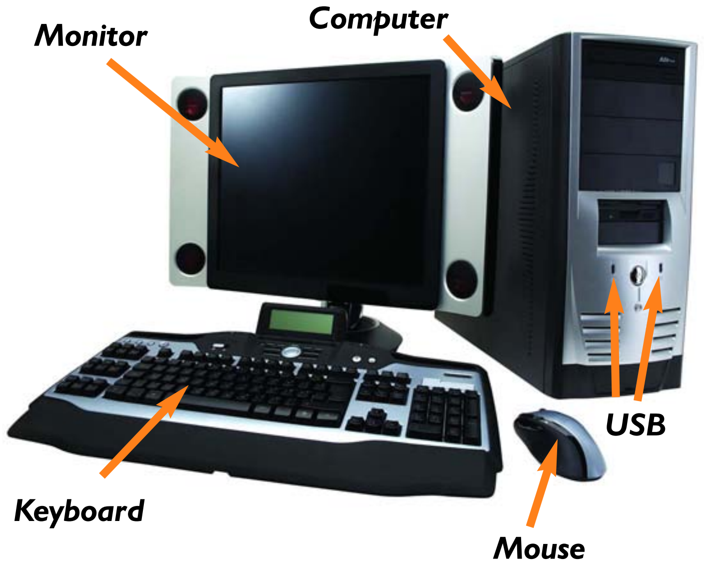
Most personal computers have a CD or DVD drive that can read and write onto CDs or DVDs. Flash drives are smaller than hard disks. They are about the size of your thumb. They can not store as much information. Both hard drives and flash drives store information by magnetizing tiny parts of a disk. When you magnetize something it acts like a magnet and attracts iron or steel. Information can be lost if a magnet comes too close to the disk.

### CD-ROM Drives

CD-ROM drives use a laser to read information on special compact discs called CD-ROMs. A CD-ROM can contain a lot of information. You are not able to erase the data on a CD-ROM.

## Monitor, Keyboard, and Mouse

A monitor is a screen like a television. It shows the information that the computer is processing. People use a keyboard to type information into a computer. Most keyboards have the entire alphabet and numbers zero through nine. They also have several other keys for symbols and special functions. You can use a mouse to select information on the screen. The mouse moves a symbol on the screen called a cursor.




## Printers

People use a printer to make a printout, or paper copy of information displayed on the monitor. There are many different

*Today, many people connect their computer to their printers using Wi-Fi.*

kinds of printers. Some print in black and white. Others print in color. Ink-jet printers and dot matrix printers print with ink. Laser printers use toner to make an image on paper. Toner is like powder.

## Network

A network is a way to link together many computers. A network allows different computers to share information with each other. Many computers on the same network can share the same printer.

People use a device called a router to connect their network. Networks can be connected through the router with cables or with Wi-Fi.

**Find out more**

**Computers Get Sick Too**

Sometimes, computers have bugs in their programs. Bugs are errors in a computer program. Something called a virus can infect a computer. Viruses are little programs that cause big problems in other programs. Bugs and viruses cause computers to crash, or stop working.

## The Internet

The Internet is an electronic communications network that connects millions of computers around the world. It allows people to share information between computers and communicate with people through their computers. Most people connect their personal computers to the Internet. The connection can be a physical connection using phone lines or cable lines or it can be a wireless connection (Wi-Fi).



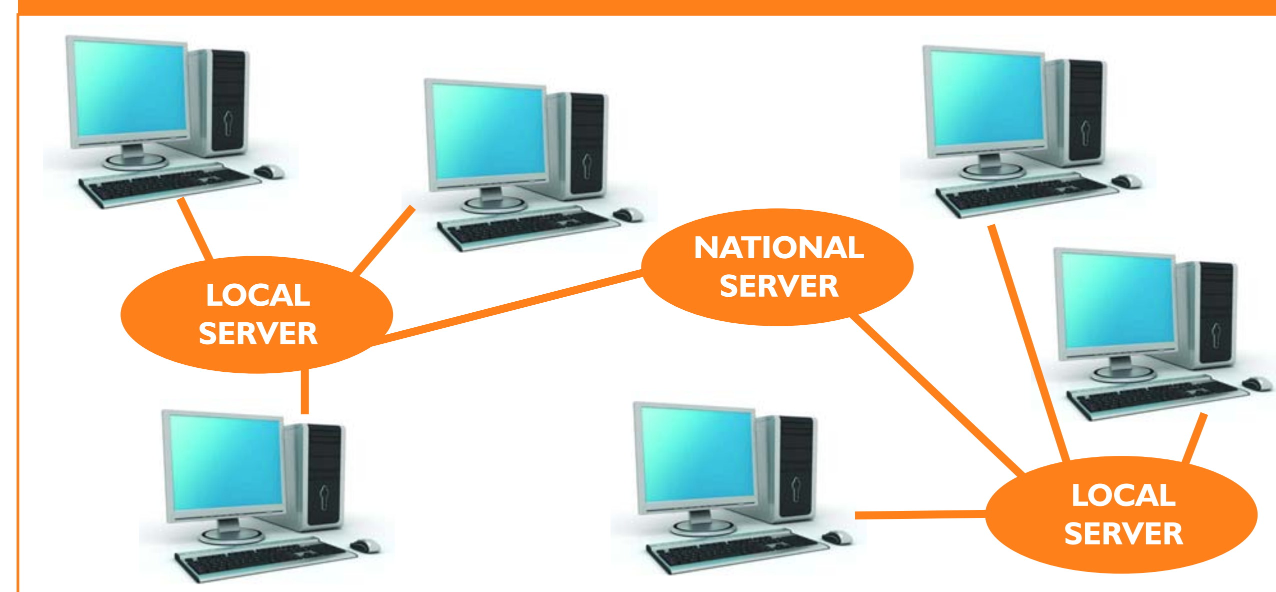
**Getting to know...**

### Steve Jobs

Steve Jobs was born in San Francisco, California in 1955. When he was young he worked for a company called Atari. This company made video games. When Jobs was only 21, he formed the Apple Computer Company. He worked with Steve Wozniak. The company built personal computers. It helped to make the personal computer very popular. Jobs was one of the first inventors to introduce a computer that used a mouse. This was in the early 1980s. This helped to make personal computers easier to use by the average person.

For a short time, Steve Jobs left Apple Computer Company. Jobs then went back to work for Apple. He is now the CEO. Under his leadership Apple has recently made the MP3 player popular. Two of their MP3 products are the iPod and iTunes.

**HOW A COMPUTER CONNECTS TO THE INTERNET**



## INTERNET BASED TECHNOLOGIES

**E-mail** (electronic message) is a way to send and receive messages electronically. The messages are saved and can be read whenever the recipient wants to read them.

**IM** (instant messaging) is like a conversation between two people using text. The communication is in real-time.

**Videoconferencing** is a way for people in different locations to meet and talk using video and audio.

**VoIP** (Voice over Internet Protocol) is a way to carry voice conversations over the internet. VoIP uses phones that look like traditional telephones.

**Web** (World Wide Web) is a part of the Internet. A person uses a web browser to see interlinked and hypertext documents.

**Wi-Fi** (Wireless Fidelity) is the common term for wireless local area networks. Wi-Fi is used for Internet access as well as many other things such as gaming and television.



Find out more

### Calculators

Calculators are small general purpose computers that can do calculations. The basic functions of a calculator are addition, subtraction, multiplication, and division. After you type in your mathematical problem, the calculator displays an answer almost instantly.

Scientific calculators can perform more complex calculations. They have extra function keys for doing simple algebra and geometry. Some people program scientific calculators to solve mathematical equations. These equations have many calculation steps.

## Robots

Robots are devices that perform specific tasks. For example, robots can put parts in a car. People use computer programs to control robots. The programs tell them what to do. Sometimes, people can control a robot directly. They use a remote control to make the robot work.

***Robots used to build cars still require people to program and maintain them.***

### What Robots Can Do

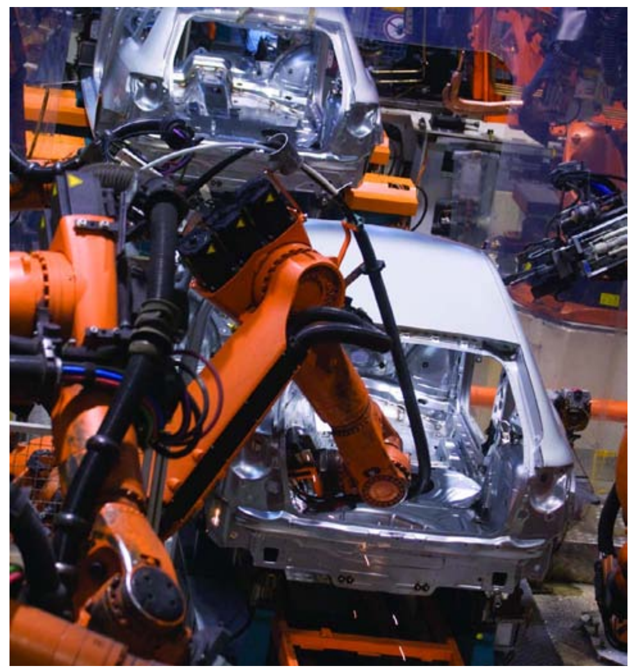
People use robots to help build things. These robots perform the same tasks over and over. Sometimes they do jobs that are too complicated or hard for humans to do. Computers control the movements of these robots.

Some robots do jobs that are too boring for people. Other robots perform tasks that are too dangerous for people to do. For example, they may search for bombs. Robots also go places and do things that humans cannot. For example, robots explore the surfaces of other planets.

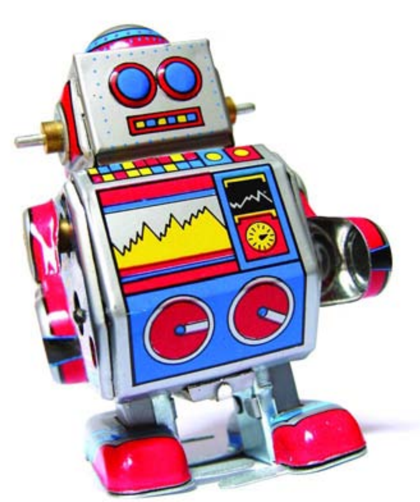
*The Mars Rover Robot has helped us learn more about planet Mars.*

### Robot Parts

Robots have various parts that help them do their jobs. Robots may have attachments or parts that anchor them to the ground or they may roll around on wheels. Some robots have mechanical arms to pick things up. Despite what you may see in movies, most robots look more like machines than people.



*Almost all cars are made using robots.*



*Toys can also be robotic.*



# People Who Use Technology

What did you do today? Did you talk on the telephone? Did you ride in a car or on a bus? Did you use a computer or turn on a light? If you did any of these things, you used technology.

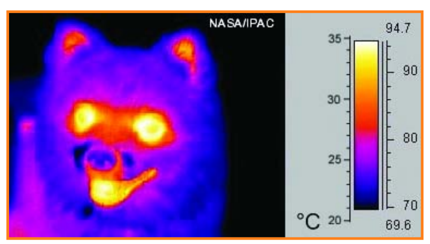
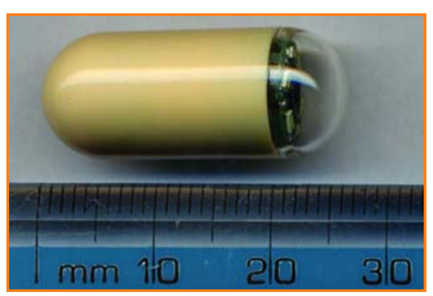
Almost everybody uses some form of technology at work, home, or school. Computer programmers use computer technology to write a computer program. People may write letters using a computer program called a word processor. Many people work in the entertainment industry. Camera operators use television and motion-picture cameras. They use them to make TV shows and movies. Disc jockeys, or DJs, play records and CDs on the radio.

Scientists use all sorts of technology to study the Earth and the Universe. Businesses often have telephones, fax machines, and computers. Graphic designers use desktop publishing programs to create books and magazines. Doctors frequently use medical technology. They use it to treat injuries, illnesses, and diseases such as cancer. Pilots fly airplanes and helicopters. Who knows what jobs will be created by new technologies in the future!

**OTHER AMAZING TECHNOLOGY**

| **Technology** | | **Used For** |
|---|---|---|
| Global Positioning System (GPS) |  | GPS is used by the military to navigate and coordinate the movement of troops and supplies. Civilians use them as navigation tools in their cars. |
| Imax film (short for Image Maximum) |  | Imax film can display images of far greater size and resolution than conventional film display systems. A standard IMAX screen is 72.6 feet (22m) wide and 52.8 feet (16.1m) long. |

## OTHER AMAZING TECHNOLOGY

| Technology | | Used For |
|---|---|---|
| Night vision device (NVD) |  | NVD allows images to be produced in levels of light approaching total darkness. They are most often used by the military and law enforcement agencies. |
| Remotely operated underwater vehicles (ROVs) |  | ROVs are used by the navy to perform deep-sea rescue operations and recover objects from the ocean floor, and by the science community to study the ocean. |
| Thermography, thermal imaging, or thermal video |   | When viewed by a thermographic camera, warm objects stand out well against cooler backgrounds. They are used by security and military people. Firefighters use it to see through smoke. |
| Video Pill |   | Video pills are cameras the size and shape of a pill. Patients swallow the video pill then a doctor can look at their gastrointestinal tract. |
| Virtual reality (VR) |  | VR allows a person to interact with a computer-simulated environment, either through the use of standard input devices such as a keyboard and mouse, or through multimodal devices such as a wired glove. |

Rourke's World of Science

# ENCYCLOPEDIA

## Volume 10

# Research Projects/Cumulative Index & Glossary

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# Table of Contents

# Science Investigations and Projects Overview

The investigations in this book will help you understand some of the ways that science works. You can do the activities at home or with your classmates at school. You will need some everyday items that you probably have at home or can find in your school classroom.

All scientists use the metric system when gathering and recording data. If possible, you should use metric measurements when gathering and recording data. If you do not have access to metric measurement instruments, you can use an Internet online conversion website to change your customary measurements to metric.

## Scientific Process Elements

The investigations in this book focus on some of the things scientists do:

- observe and describe
- experiment or test
- change a variable in an experiment
- collect data (count, measure, conduct timed tests or trials)
- record and analyze data
- draw conclusions
- present data graphically

## How to Do the Investigations

**Before you begin:**

- Read the entire project.
- Think about where you will perform your investigation. Will your project be messy? Choose a spot where clean-up will be easy.
- Gather all your materials together.
- Plan your time. Once you start, will you have time to finish?
- Plan for safety. If you will be using a sharp knife or boiling water, ask an adult to help.

## Performing the investigation

1. Read the directions carefully one more time.
2. Perform the task.
3. Keep a log book for notes and for recording data.
4. Record any questions you think of as you do the investigation.
5. Write a few sentences about conclusions you formed by doing the investigation.



# Heart Rate Project

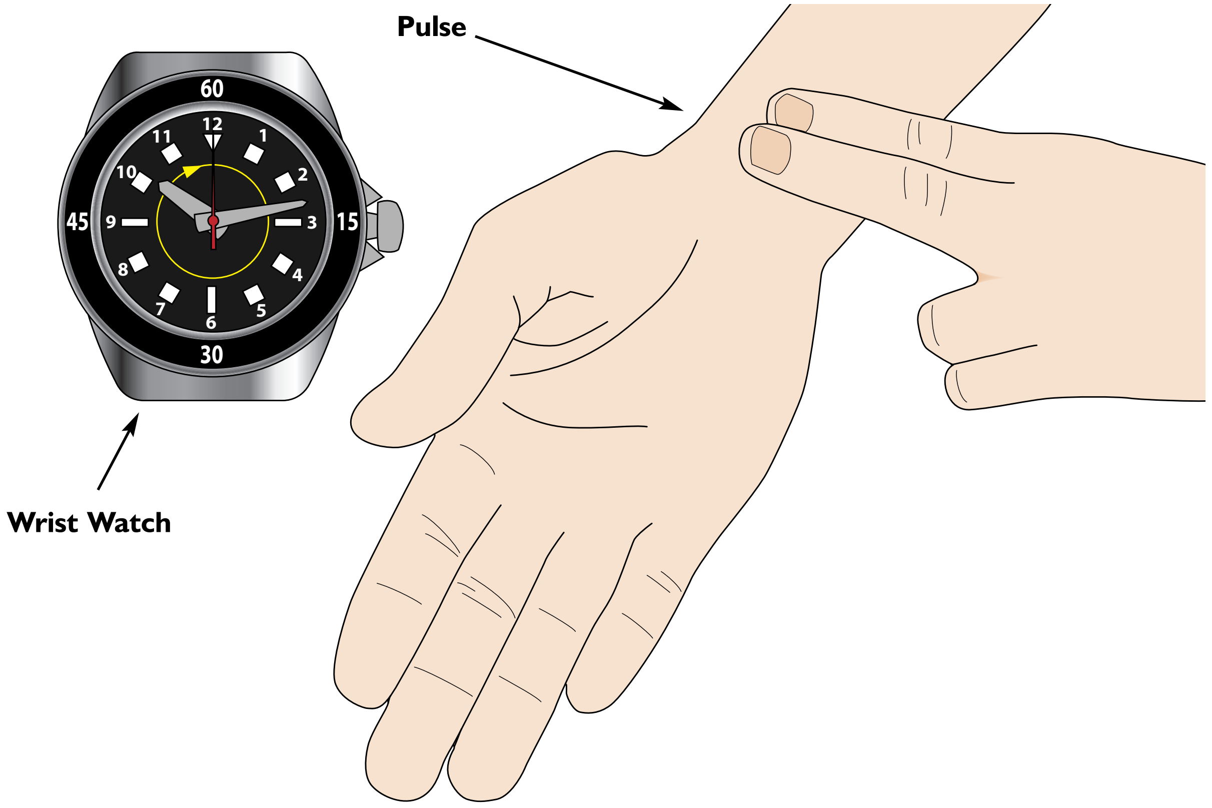
PROJECTS volume 10 1.1

See Volume 1 Page 10

**Question:** What is my pulse rate?

**Things you need:**

- Watch or clock with a second hand
- Paper and pencil




**Directions:**

1. Use your fingers to find your pulse on your wrist or neck. Do not press on the pulse point on your neck – you might faint.
2. Look at the second hand on your watch.
3. Begin to count your heartbeats when the second hand is at 12 o'clock.
4. Count your pulse for 60 seconds, or count for 30 seconds and multiply your results by 2.
5. Record your pulse. Repeat several times.
6. Repeat again during and after exercise.

**Scientific Process Elements:** collecting data, changing a variable, analyzing data, drawing conclusions

## Saliva and Digestion Project

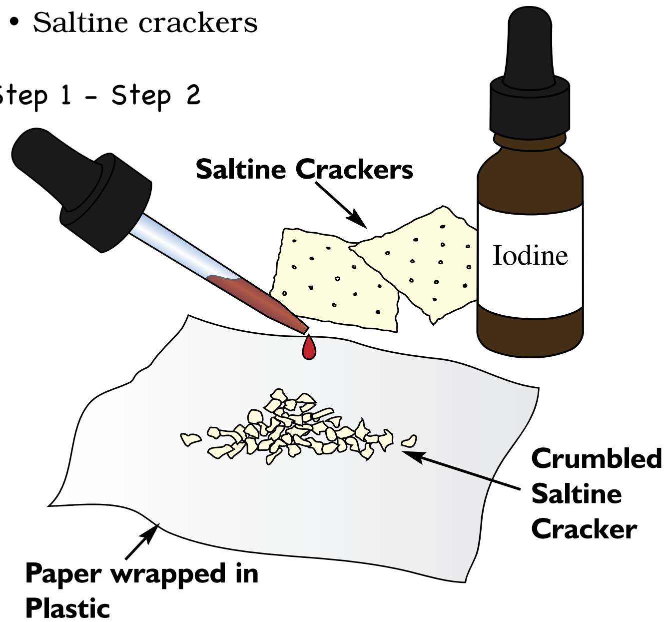
PROJECTS volume 10 1.2

See Volume I Page 13

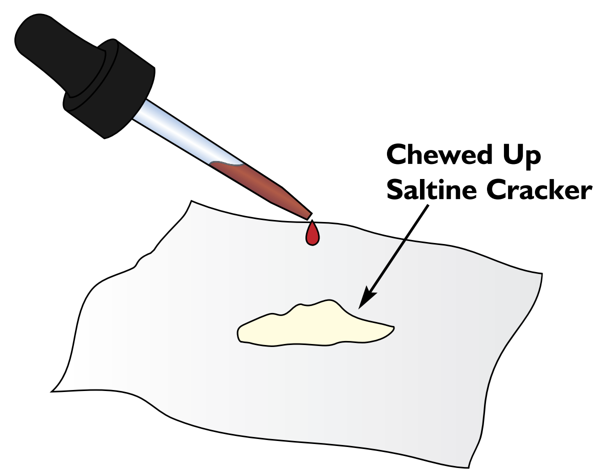
**Question:** What does saliva do to start the digestive process?

**Things you need:**
- Tincture of iodine (school nurse or drugstore)
- Eyedropper or cotton swab
- Saltine crackers
- White sheet of paper covered in plastic food-wrap

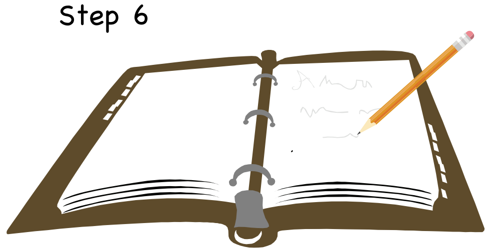
Step 1 - Step 2




Step 3 - Step 5




Step 6



**Directions:**
1. Place a saltine cracker on a piece of paper covered with plastic food wrap. Crumble it thoroughly, and spread it out evenly.
2. Put a drop of iodine on the cracker in several places. Note any color change.
3. Chew up a second saltine cracker. Chew it well and get it very wet with your saliva.
4. Spit the saltine mush out on the plastic wrap-covered paper and spread it out evenly.
5. Put a drop of iodine on the saltine mush in several places. What happens?
6. Record your observations.
7. You can use the iodine test to identify other foods that contain starch.

**Scientific Process Elements:** observation and description, demonstrating or verifying a scientific fact, experimenting or testing, recording data and observation, changing a variable in an experiment, drawing conclusions



## Muscle Movement Project

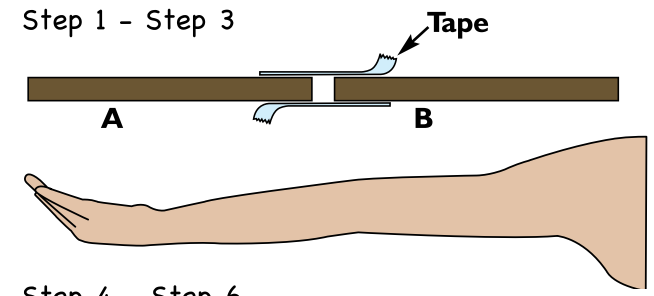
PROJECTS volume 10 1.3

See Volume I Page 16

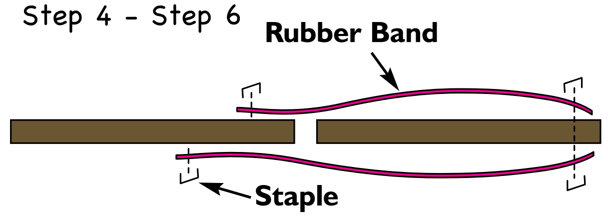
**Question:** How do muscles move our bones?

**Things you need:**
- Scissors
- Heavy cardboard or wood strips, the size of a ruler
- Tape
- Rubber band at least 1/8 inch (1/3 cm) wide
- Stapler

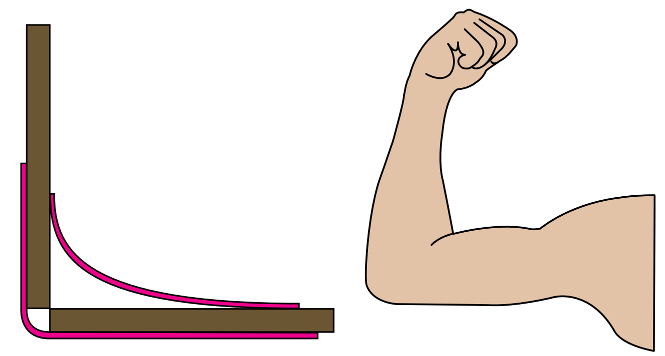
Step 1 - Step 3




Step 4 - Step 6




Step 7



**Directions:**
1. Mark the wooden or cardboard strips A and B. These represent the arm bones.
2. Lay the strips end-to-end, with the top of strip B to the bottom of strip A.
3. Pull the strips apart slightly (about 1/2 cm) and tape them together on both sides. This represents the elbow joint in your arm.
4. Cut the rubber band into two pieces, one slightly longer than the other. The rubber bands represent the bicep and tricep muscles.
5. Staple one end of the shorter rubber band to the top of strip A. Gently stretch the rubber and staple the other end about 1 inch (2 1/2 cm) below the top (taped) edge of strip B.
6. Turn the strips over. Staple one end of the longer rubber band to the top of strip A. Gently stretch the rubber band and staple the other end 1 1/2 inches (3 3/4 cm) from the top (taped) edge of strip B.
7. Turn the strips over again. Hold strip A in place and pull up on the bottom end of strip B.

Bend the model open and closed as shown in the drawing. Watch the top rubber band get shorter and the bottom rubber band get longer. This is what happens when you flex your arm muscles.

**Scientific Process Elements:** building a model to understand how something works, observation and description, drawing conclusions

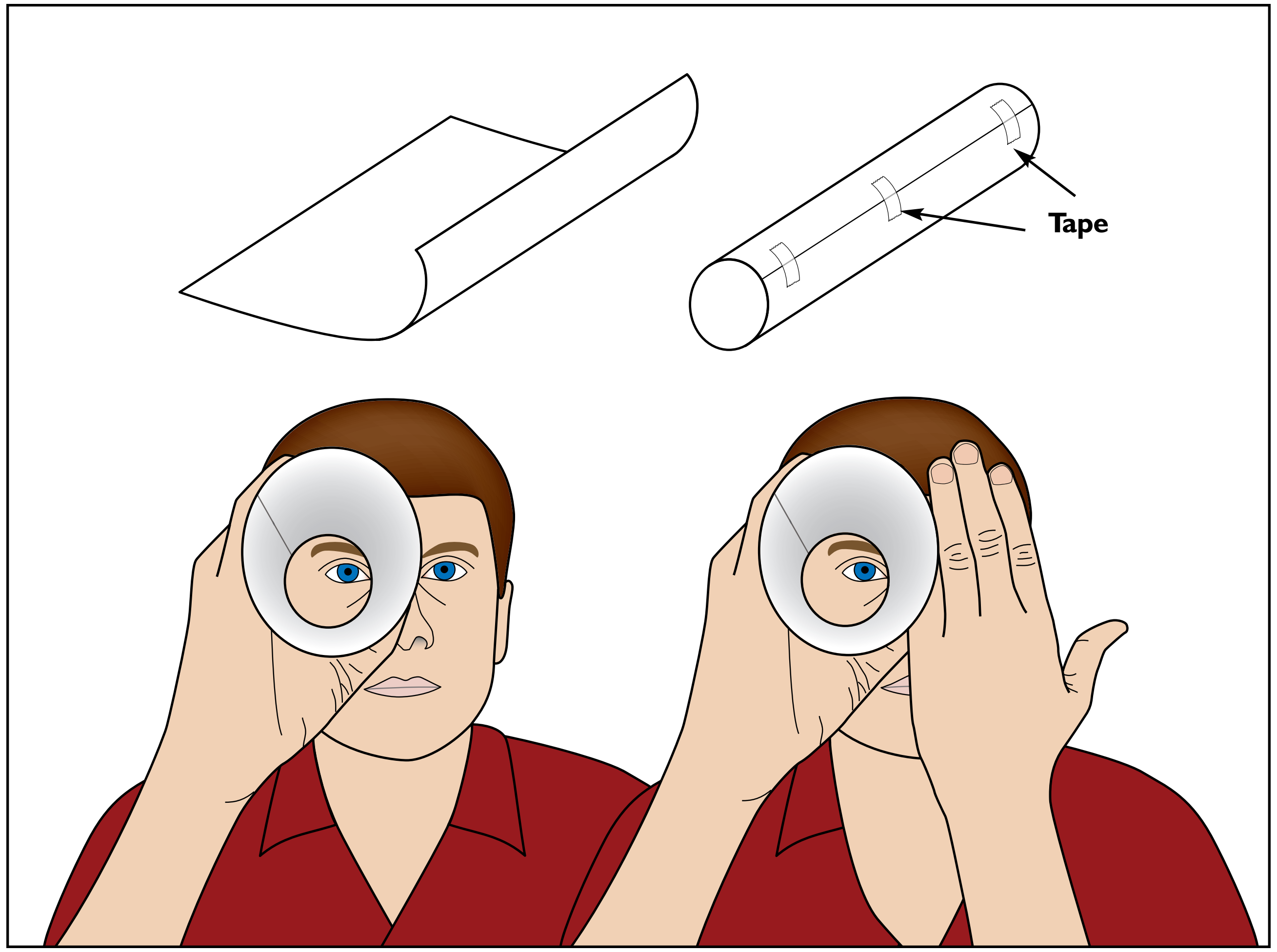
## Optical Illusion Project

PROJECTS volume 10 1.4
See Volume 1 Page 21

**Question:** How can I create an example of an optical illusion?

**Things you need:**

- Paper
- Tape




**Directions:**

1. Roll a piece of paper into a one-inch tube and tape around it to hold it together.
2. Hold the tube in your right hand and look through the tube with your right eye. (Keep both eyes open, looking straight ahead.)
3. Now bring your left hand up beside the tube (palm facing toward you), until it touches the tube.
4. Describe what you see as you look straight ahead.

**Scientific Process Elements:** observation and description, demonstrating or verifying a scientific fact, recording data and observations



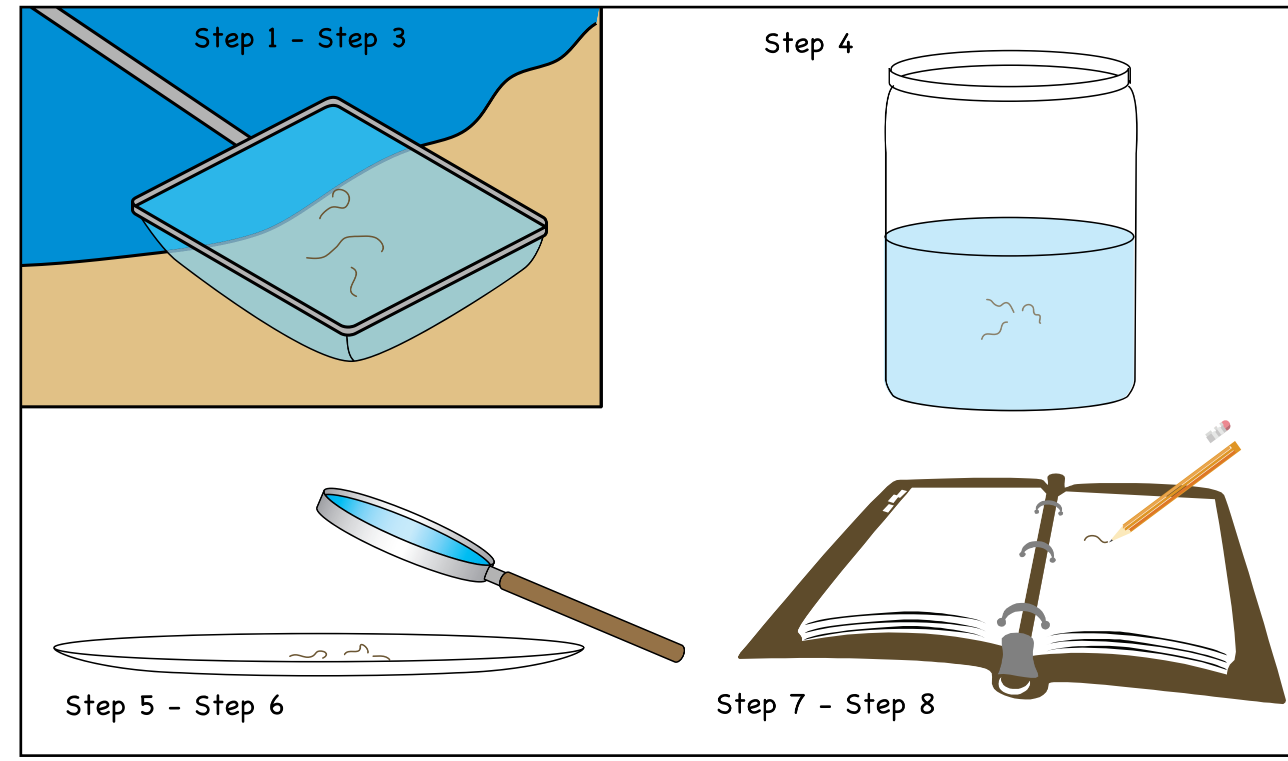
## Pond Water Project

PROJECTS volume 10 2.1
See Volume 2 Page 6

**Question:** What kind of animal life can I find in pond water?

**Things you need:**

- Aquarium net or kitchen strainer
- Large plastic container, pail, or jar with clean water in it
- Small dish or paper plate
- Magnifying glass
- Field guides from the library




**Directions:**

1. Find a small pond in a park or on school property. (If you do not have a pond near your house, you can use water from a lake, a stream, or a big puddle.)
2. Dip your net or sieve into the muck at the bottom of the pond.
3. Let it drain. Pour more pond water over it until it is free from mud.
4. Study the inside of the net for things that move. Swish the sieve or net in the container of water to transfer the living things.
5. Place specimens on the white paper plate or dish.
6. Use a magnifying glass and the field guides to identify what you have found.
7. Draw some of the specimens you found.
8. Return the specimens to the pond unharmed if possible.

**Scientific Process Elements:** observation and description, recording data and observations, drawing conclusions, presenting data graphically

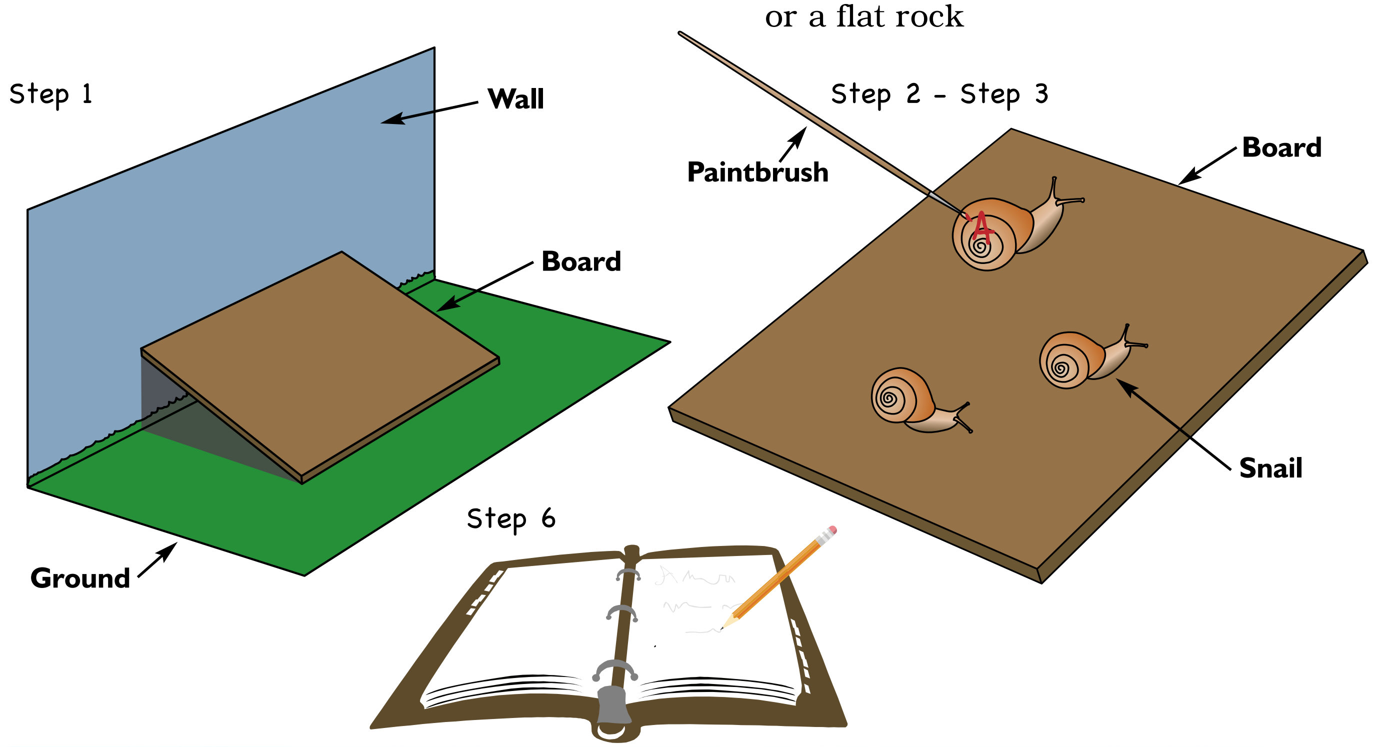
## Observing Snails Project

See Volume 2 Page 12

**Question:** Are snails active in the daytime or nighttime?

**Things you need:**

- Enamel paint or nail polish
- Small paintbrush
- Plywood board (about the size of a magazine cover) or a flat rock




**Directions:**

1. Lean the board or a flat rock up against a fence or wall, so that there is a 3-4 inch (8-10 cm) space between it and the ground surface. (It has to be dark under the board.) Or, lay it in grass or vegetation with one edge up on a rock, where you have noticed snails or found snail shells.
2. Early the next morning, turn the board over to look for snails.
3. Gently remove each snail and carefully paint its shell with a letter; A, B, C, etc. (Do not paint the backs of shelless slugs!) Replace the snails.
4. Check the board each morning and evening to see if any snails are missing. If new, unmarked ones show up, label them as well.
5. Look for your missing snails in other dark, damp places in the vicinity, or on the plants in the surrounding environment. You might find their silvery, dried slime trails. The trails may lead you to the snails.
6. Make notes about the snail's activities and about individual snails over the course of several weeks. You might do this all summer.

**Scientific Process Elements:** observation and description, collecting data, recording data and observations, drawing conclusions



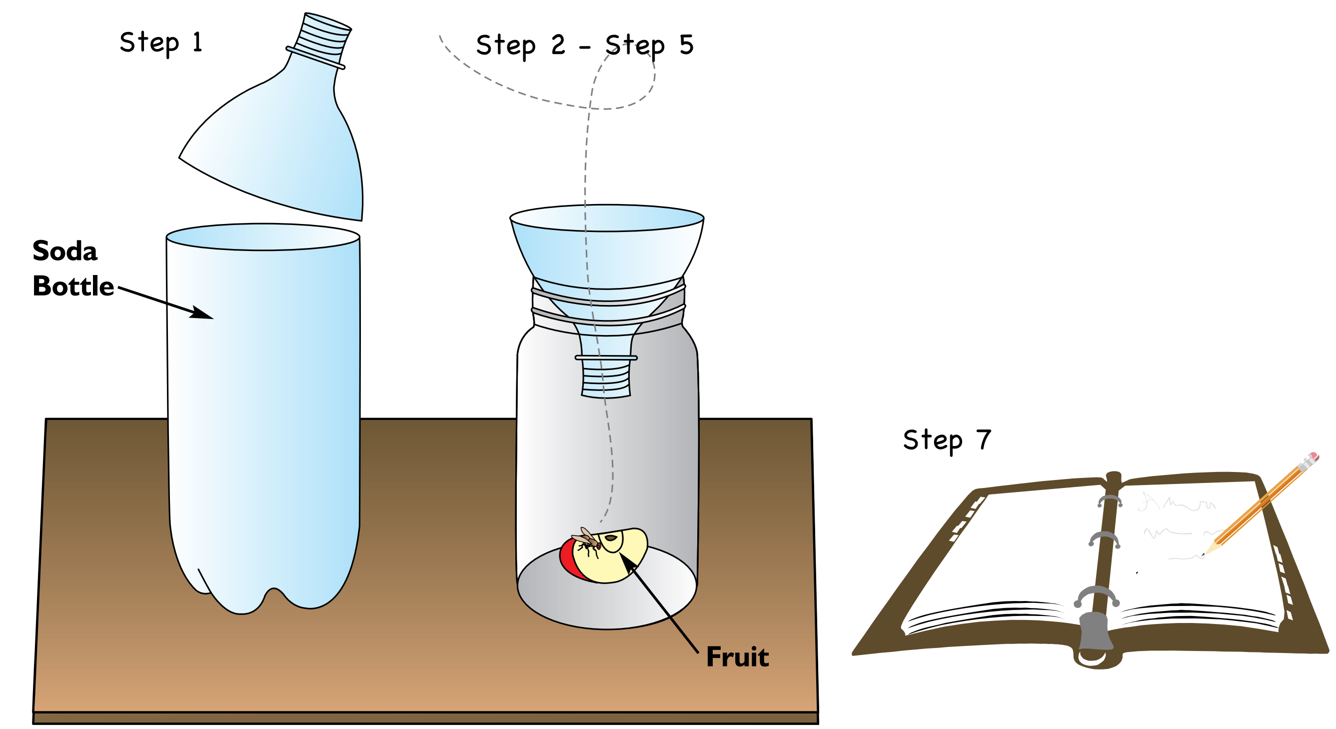
## Building a Fruit Fly Trap Project

See Volume 2 Page 14

**Question:** How and where can you find fruit flies?

**Things you need:**

- Plastic drink bottle or a small funnel
- Scissors
- Masking or duct tape
- 1/2 banana or bruised and spoiled apple, pear, peach, grapes, or old fruit juice
- Glass jar
- Baker's yeast - optional

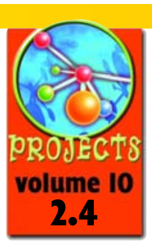



**Directions:**

1. If you don't have a funnel, cut 1/3 off the top of a plastic bottle to use for your funnel.
2. Put the fruit in the bottom of the glass jar. (Optional: Sprinkle some baker's yeast on the fruit. It works even better!)
3. Place the funnel, tube end down, into the glass jar. Tape the funnel to seal the joint between it and the jar.
4. Leave the jar out in your classroom or in your kitchen.
5. Look for fruit flies in the trap over the next few days.
6. Using a magnifying glass, notice the color of the fruit flies' eyes.
7. Record observations about the flies and their behavior.

**Scientific Process Elements:** building a model to study a subject, observation and description, recording data and observations

## Animal Hair Project

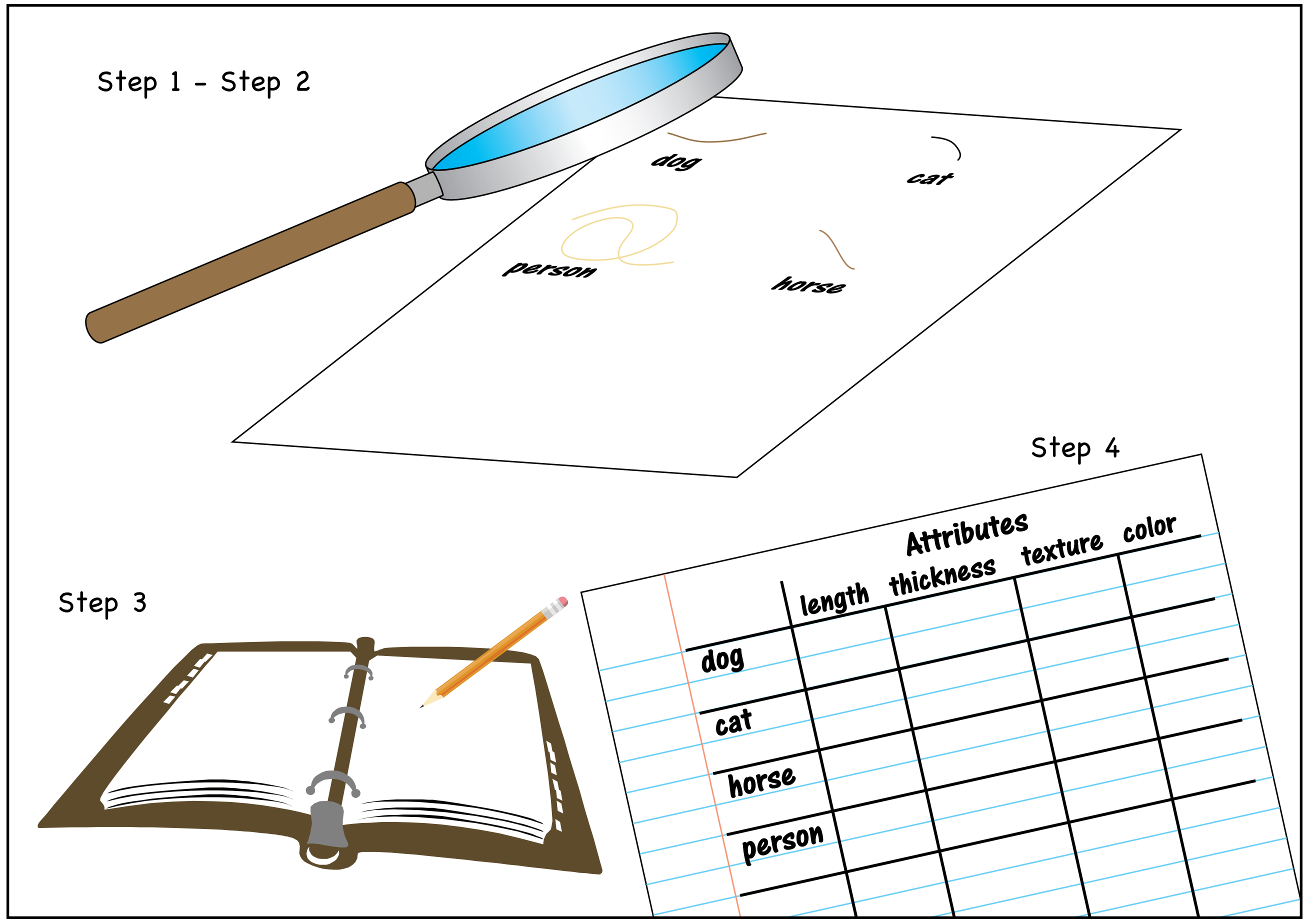



See Volume 2
Page 28

**Question:** Does animal hair vary with the species?

**Things you need:**

- Microscope or magnifying glass
- Hair samples from: people, dogs, cats, hamsters, rabbits, horses, sheep, etc.




**Directions:**

1. Never pluck hair samples from an animal. The best ways to collect samples are by brushing or combing the animal's hair or using tape to pick-up hairs an animal has shed onto furniture or floors. Label each sample.
2. Examine the hair specimens with the magnifying glass or microscope. Compare them for attributes such as: length, thickness, color, and texture.
3. Describe, or draw, your observations and comparisons.
4. Create a chart or table to present the data you collected (rows for the animals studied, and the columns for the attributes of their hair/fur.)

**Scientific Process Elements:** observation and description, collecting data, recording data and observations, analyzing data, drawing conclusions, presenting data graphically



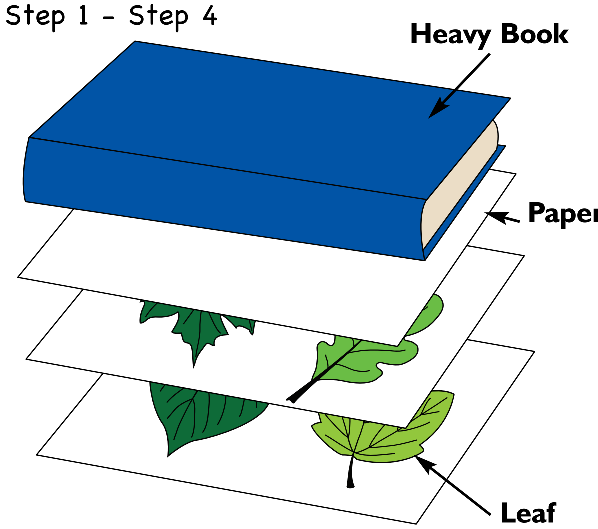
## Making a Leaf Display Project

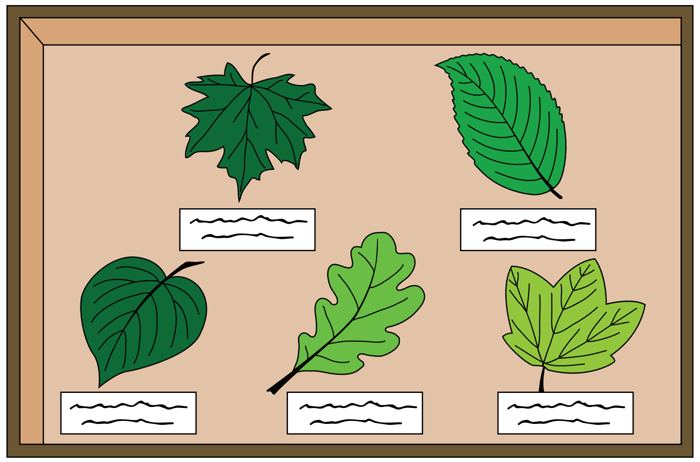

See Volume 3
Page 14

**Question:** How can I preserve plant leaves to study and identify?

**Things you need:**

- Leaves
- Glue
- Tape
- Old newspaper or paper towels
- Permanent marker
- White unlined paper
- A heavy book, or other flat weight
- Field guides to trees and plants




**Directions:**

1. Collect some interesting leaves from live plants, trees and shrubs.
2. Lay the leaves out, a few at a time, on a paper towel or sheets of old newspapers. If you know the name of the plant, write it down.
3. Add another piece of newspaper and more leaves, and repeat until you have all your leaves between layers of paper.
4. Place a heavy book on top of the pile and wait a few days until the leaves are dry and flat. (Some thick leaves may take longer.)
5. When the leaves are dry, sort them according to vein patterns, colors, leaf edge types, leaf surface texture, and other attributes.
6. Arrange and glue the dried leaves to sheets of white, unlined paper. Tape the leaf stalks to the paper, as glue usually won't hold them.
7. In the lower, right-hand corner of the paper, write the name of the plant, the date, the place that you collected it, and your name.

**Scientific Process Elements:** observation and description, collecting and recording data, analyzing data, presenting data graphically

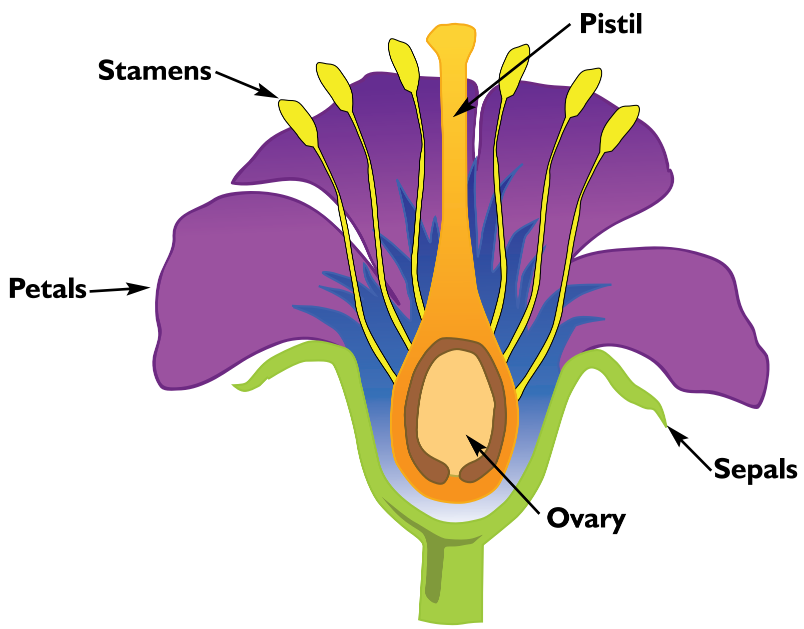
# Parts of a Flower Project


See Volume 3
Page 17

**Question:** Can I locate and identify the parts of a flower?

**Things you need:**

- Flower blossoms (several kinds)
- Small knife or scalpel (CAUTION: Ask permission from an adult to use a knife or scalpel)
- Tweezers
- Magnifier
- Large sheet of white paper
- Notebook or journal




**Directions:**

1. Count and record the number of the greenish sepals at the base of a flower. Remove them and lay them on your work surface.
2. Next, count and record the colorful petals. Remove them and place them on your work surface. Compare the number of petals to the number of sepals.
3. You should now be able to see the thin-stemmed male stamens with little knob-like tops. Count and record the number of stamens. Remove these with tweezers and put them with the sepals and petals.
4. The last remaining structure at the center of the flower is the female pistil(s). Does it appear to be segmented? How many segments does it have?
5. Carefully, across the bottom part, find the ovary. Do you see tiny, whitish egg cells, or ovules? (Use your magnifier.) How many pistils did your flower have? Count and record.
6. Repeat the dissection of flower blossoms from other plants. Compare them to each other.

**Scientific Process Elements:** observation and description, demonstrating or verifying a scientific fact, collecting and recording data



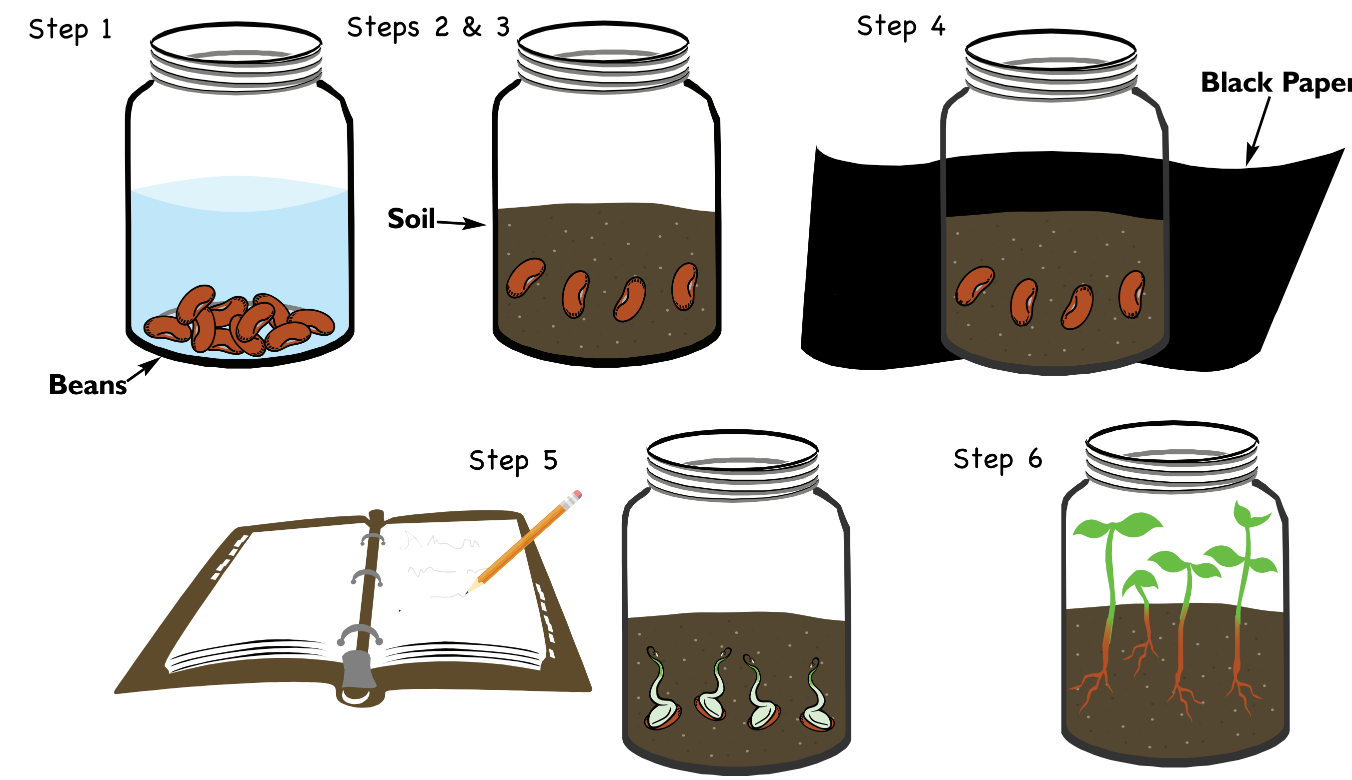
# Seed Germination Project


See Volume 3
Page 20

**Question:** What happens when a seed sprouts or germinates?

**Things you need:**

- Dry (uncooked) beans, corn, peas, or lentils
- Drinking glass or a wide-mouth jar
- Paper towels, soil or peat moss
- Black paper or cloth
- Rubber band




**Directions:**

1. Soak ten seeds of the same kind in water overnight and record any change that you notice.
2. Fill a glass or jar with damp soil, peat moss, or paper towels (sawdust or vermiculite works, too).
3. Place your seeds up against the inside of the glass or jar and push them down one inch (2.5 cm) into the soil or other material so that you can see them through the glass.
4. Wrap the jar with the black paper or cloth and hold it in place with a rubber band. Keep the jar in a warm (not hot), dark place.
5. Examine the seeds every day until they have grown roots, stems, and leaves. In a journal, record the date and then describe and draw the changes you see.
6. When the seeds have grown their leaves, you should place the container on a windowsill where they will have light and let them keep growing.

**Scientific Process Elements:** observation and description, experimenting, changing a variable in an experiment, collecting and recording data, analyzing data, drawing conclusions

## Mushroom Spore Prints Project

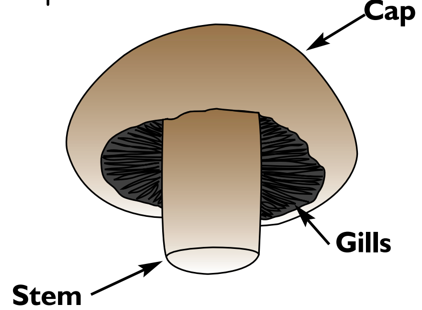
See Volume 3 Page 30

**Question:** Do mushrooms spores all look the same?

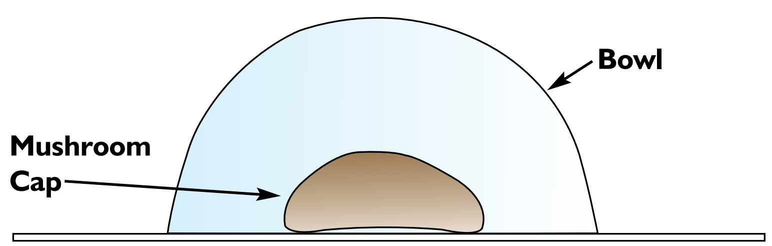
**Things you need:**

- Different kinds of mushrooms from the grocery store
- Paper: white, black (aluminum foil works, too)
- Bowl or jar that fits over a mushroom cap

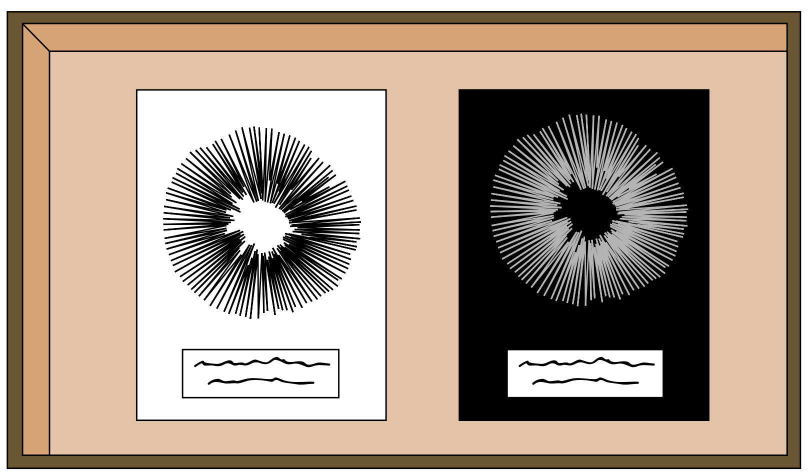
Step 1




Step 2 – Step 3




Step 4 – Step 5



**Directions:**

1. Select a mushroom with a fully formed cap, and detach its stem.
2. Place the cap, gills down, on a piece of paper. Use the white paper if the gills are dark, and the black paper if the gills are light.
3. Cover the mushroom cap with a bowl, and leave it undisturbed overnight.
4. Next day, carefully remove the cover, pick up the mushroom cap gently, and you should see a pattern on the paper. This is the spore print! Don't smudge it.
5. Compare the prints then cover the spore print with clear plastic wrap to preserve it. It will last for many years.

**Scientific Process Elements:** observation and description, demonstrating or verifying a scientific fact, presenting data graphically



## Soil Composition Project

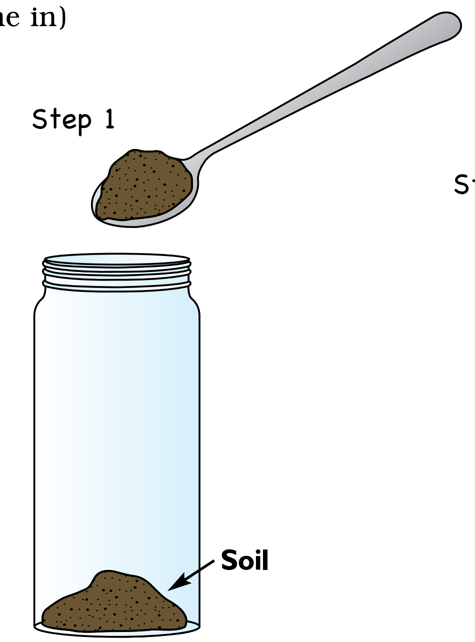
See Volume 4 Page 16

**Question:** How can I find out what soil is made of?

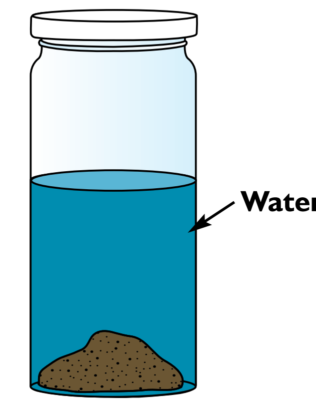
**Things you need:**

- Spoon, or garden trowel
- Container of soil
- Tall and narrow jar (like the ones that olives come in)
- Hand lens magnifier
- Water
- Permanent black marker

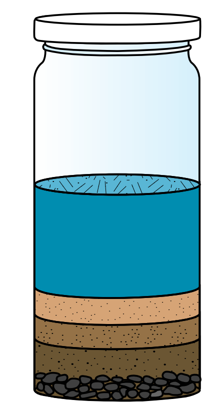
Step 1



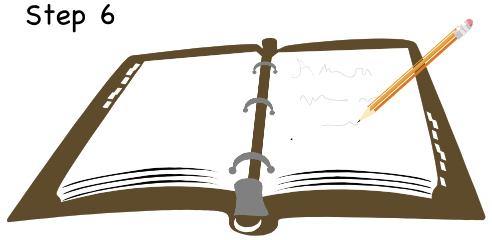

Step 2




Step 3 – Step 5



Step 6



**Directions:**

1. Place a few spoonfuls of soil in the jar.
2. Fill up the jar with water, and put the cover on tightly.
3. Shake the mixture of soil and water and allow it to settle for 20 or 30 minutes.
4. Watch as the rocks, sand, silt, and clay settle in layers, and the organic materials rise in a layer on top.
5. Mark the side of the jar showing the thickness of each layer of materials.
6. Examine each of the layers of soil materials with your magnifier and record your observations.

**Scientific Process Elements:** building a model to understand how something works, observation and description, demonstrating or verifying a scientific fact, recording data and observations, drawing conclusions

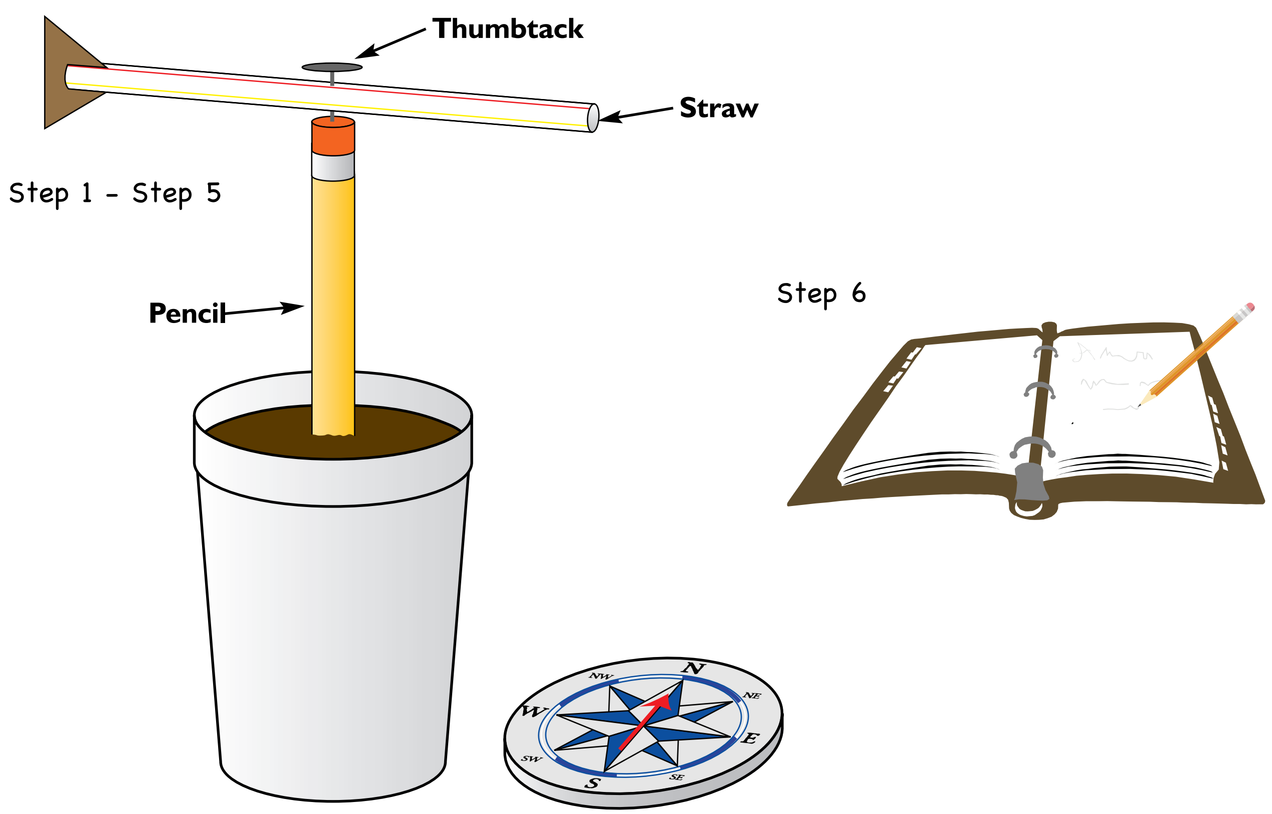
# Wind Direction Project

PROJECTS volume 10 4.2
See Volume 4 Page 37

**Question:** How can I find out wind direction?

**Things you need:**

- Compass
- Pencil with an eraser
- Thumbtack
- Drinking straw
- Small piece of heavy paper
- Glass or plastic cup filled with soil or sand




**Directions:**

1. Cut a small slit in one end of a drinking straw.
2. Cut a small triangle from a piece of heavy paper. Slide the pointed end of the triangle into the slit.
3. Push a thumbtack through the middle of the straw.
4. Stick the tack into the eraser on a pencil. Twist the straw so it moves easily.
5. Stick the sharp end of the pencil in the cup of sand so that the pencil stands up. The straw will point to the direction the wind is blowing.
6. Use a compass to determine the wind direction. Take readings at the same time of day, in various locations, over several days. Record your observations.

**Scientific Process Elements:** building a model to understand how something works, collecting data, recording data and observations, drawing conclusions, presenting data



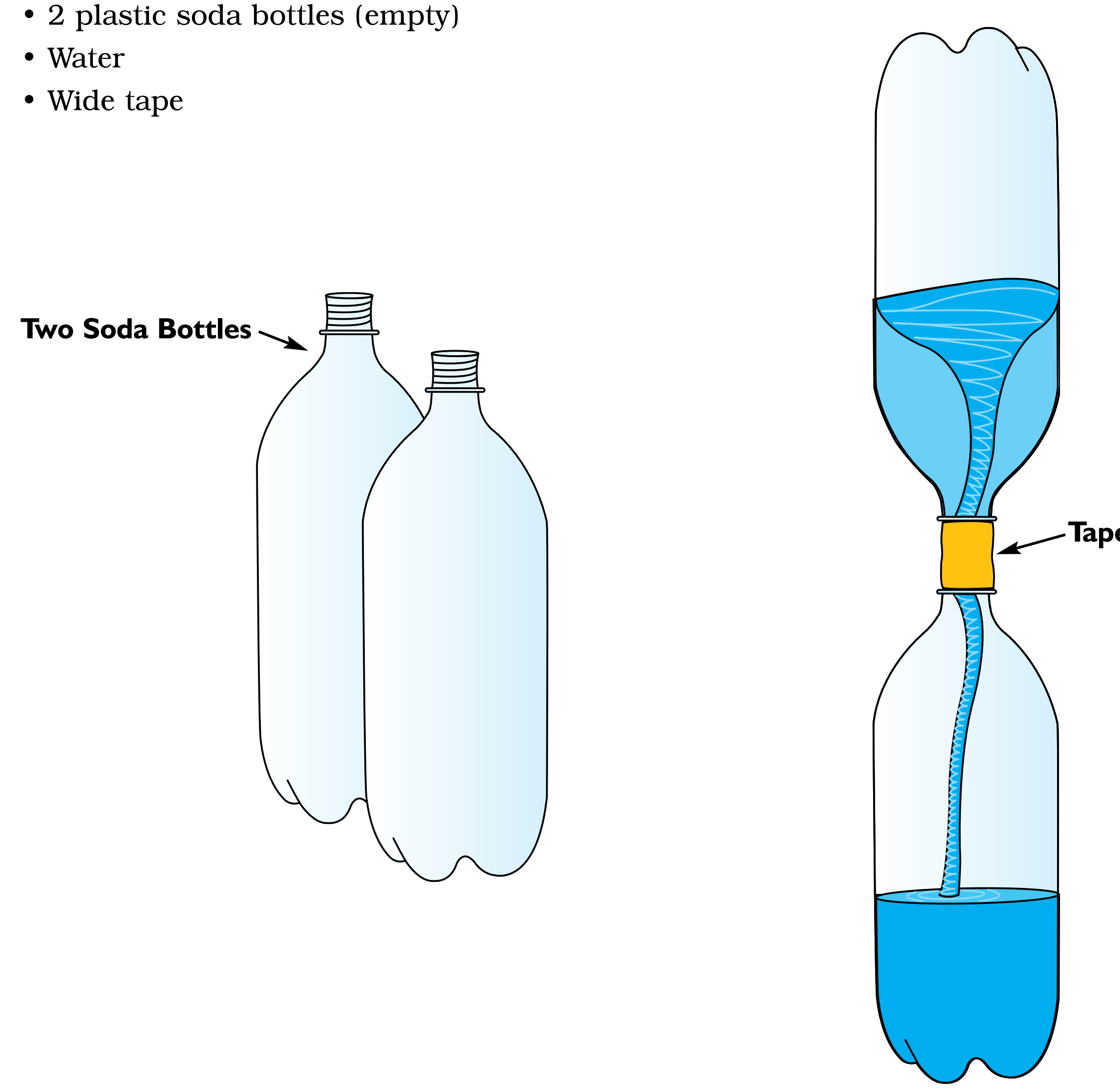
# A Tornado in a Bottle Project

PROJECTS volume 10 4.3
See Volume 4 Page 43

**Question:** Does water act the same way that air does, forming a funnel, or vortex, as it spins?

**Things you need:**

- 2 plastic soda bottles (empty)
- Water
- Wide tape




**Directions:**

1. Fill one bottle with water.
2. Place the empty bottle upside down over the full bottle.
3. Tape the openings of the two bottles together. Wrap the tape around several times so water won't leak out.
4. Turn the bottles over.
5. Rock the bottles in a circle as the water drains from one bottle into the other.
6. Watch the tornado-like water funnel that forms.

**Scientific Process Elements:** building a model to understand how something works, changing a variable, observation and description, drawing conclusions

## Water Power and Pressure Project

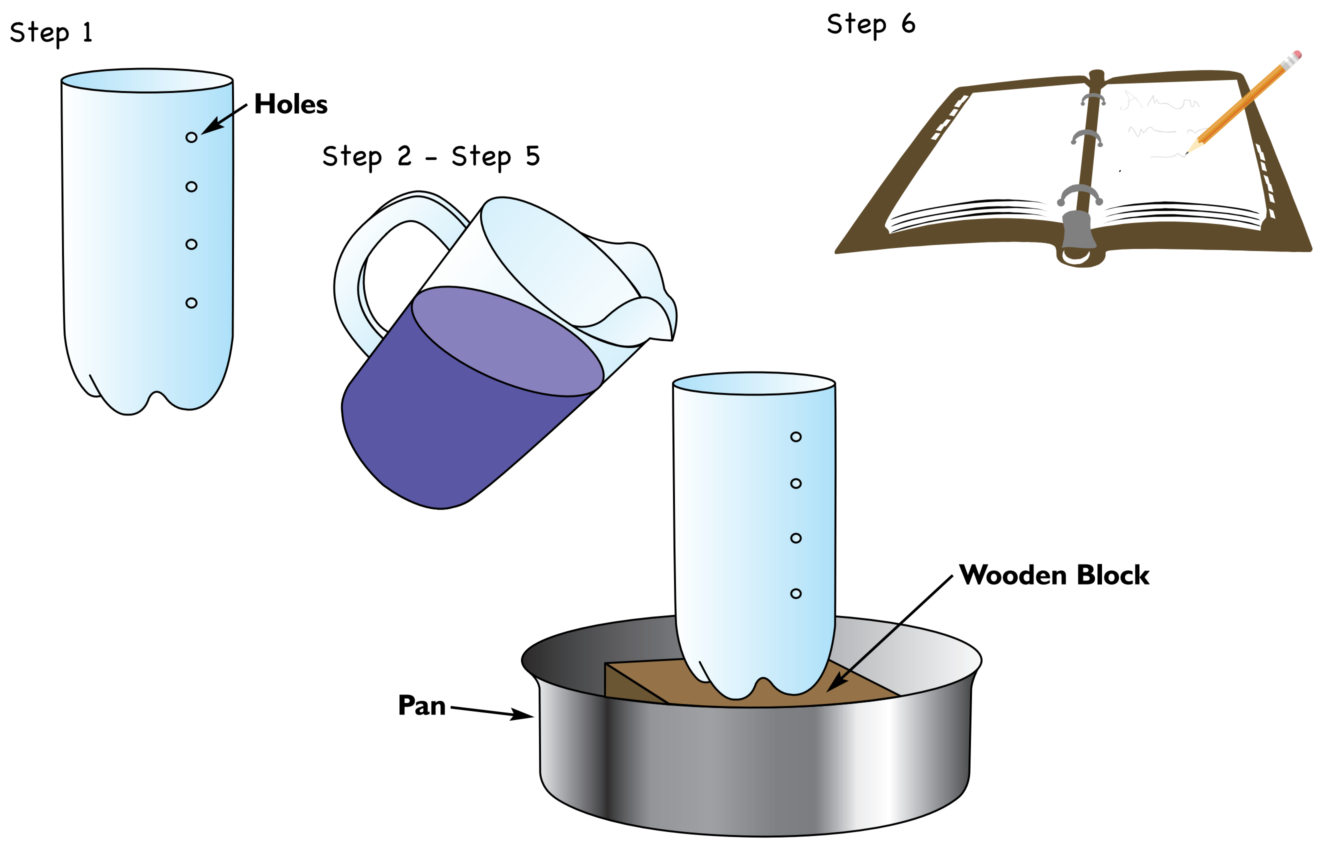
PROJECTS volume 10 4.4

See Volume 4 Page 48

**Question:** What relationship is there between the depth of water and the force it exerts?

**Things you need:**

- One-liter soda bottle with its tapered top part cut off
- Colored Water
- A nail
- A pan large enough to hold a liter of water
- A block of wood large enough to set the bottle on




**Directions:**

1. With the nail, carefully puncture one side of the bottle at four different levels.
2. Place the bottle in the pan on the wooden block.
3. Cover (seal) the punctures with your fingers while a helper fills the soda bottle with colored water.
4. Release all your fingers at the same time.
5. Watch the water spurting out of each of the holes. Notice the distance each arc of water reaches.
6. Record your observations.

**Scientific Process Elements:** building a model to understand how something works, observation and description, recording data, demonstrating or verifying a scientific fact, drawing conclusions



## Surface Tension Project

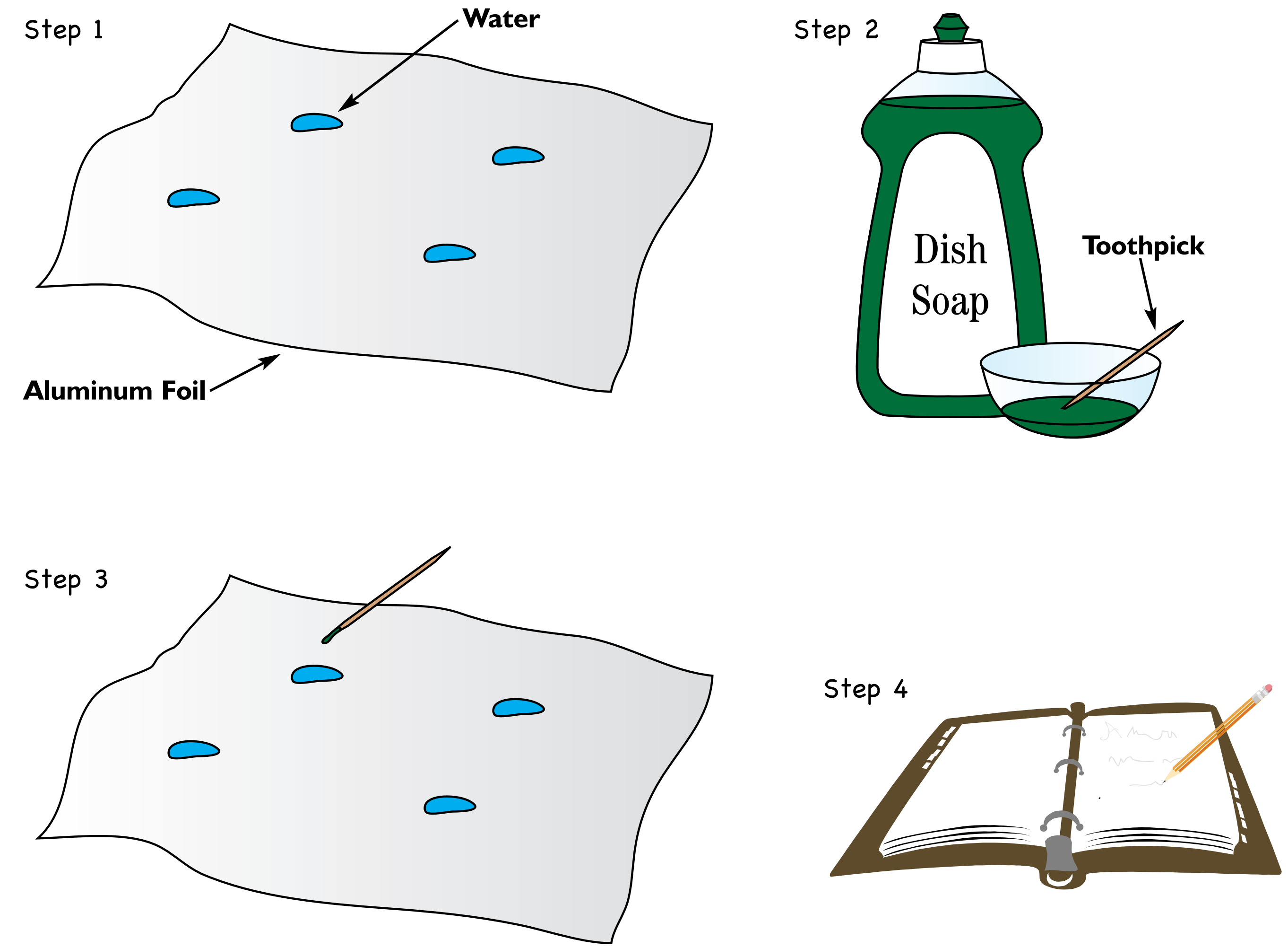
PROJECTS volume 10 5.1

See Volume 5 Page 30

**Question:** Why do we use soap with water to wash dishes?

**Things you need:**

- 8-inch square of aluminum foil
- Water
- Teaspoon of liquid soap in a bottle top or small dish
- Toothpick or cotton swab




**Directions:**

1. Place several drops of water on the square of foil. Move them around by tipping the foil sheet. Notice how they appear and behave as they move.
2. Dip the toothpick in the liquid soap.
3. Touch the end of the toothpick to one of the drops of water.
4. Record your observation and your conclusion.

**Scientific Process Elements:** observation and description, experimenting, recording observations, drawing conclusions

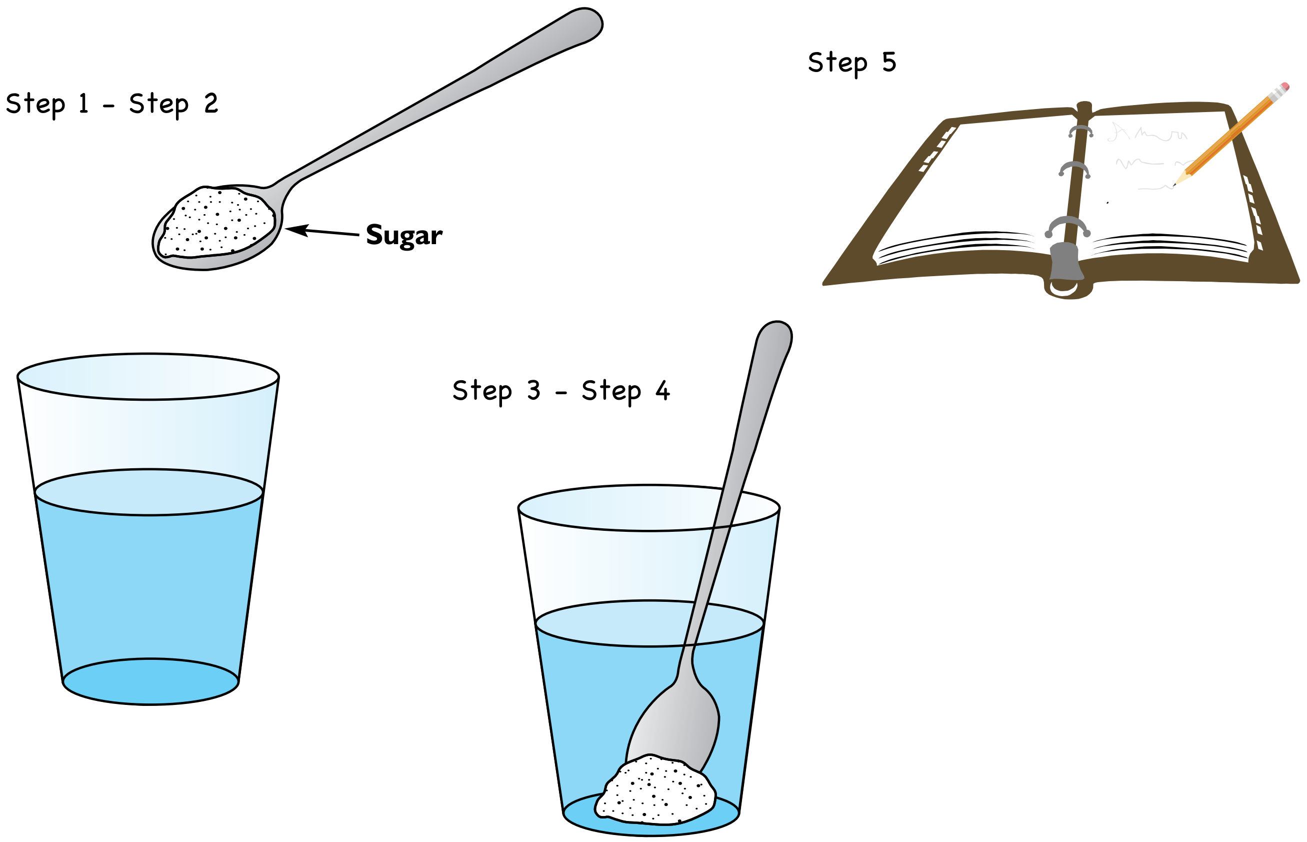
# Making a Solution Project

**Question:** What kinds of things dissolve in water?

PROJECTS volume 10 5.2
See Volume 5 Page 37

**Things you need:**

- Glass or plastic cup
- Water at room temperature
- Sugar, table salt, flour, baking soda, and rice grains
- Small spoon or a half spoon measure




**Directions:**

1. Fill half of the cup with cold water.
2. Add sugar a half a spoonful at a time. Stir each time until the sugar dissolves completely. Record how many half spoonfuls dissolved.
3. Repeat with a new cup of water and salt. Record how many half spoonfuls dissolved.
4. Repeat with the other substances you collected.
5. Record your findings.
6. Repeat each trial with hot water.

**Scientific Process Elements:** observation and description, demonstrating or verifying a scientific fact, collecting data, recording data and observations, changing a variable, drawing conclusions



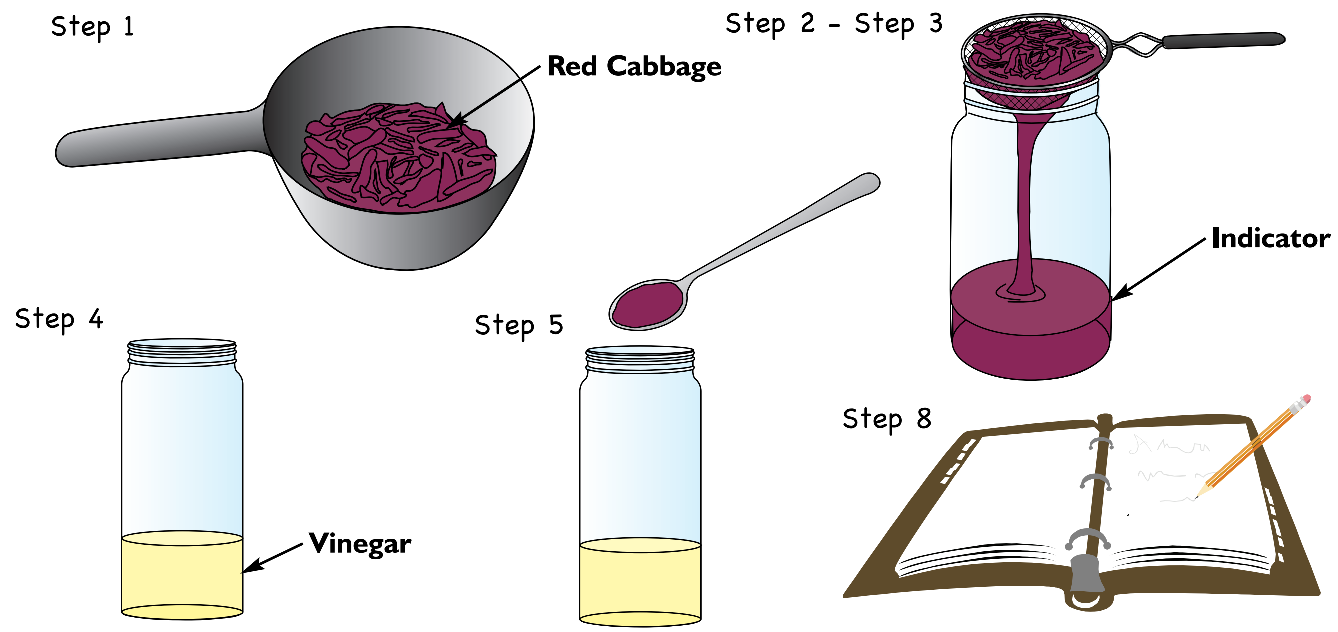
# Acid or Base Project

**Question:** What common liquids and powders are acidic and which ones are basic?

PROJECTS volume 10 5.3
See Volume 5 Page 42

**Things you need:**

- Chunk of red cabbage, chopped into pieces, or 10 blackberries, crushed
- Bottled water
- Knife and chopping board
- Small cooking pot and stove
- Strainer
- 3–5 jars
- Collection of substances to test: (examples: vinegar, tap water, baking soda, table salt, sugar, dishwashing soap, ginger ale or any colorless soda, lemon, apple, or orange juice)




**Directions:**

1. Bring the chopped cabbage or crushed blackberries to a boil in 2 cups (1/2 liter) of water.
2. Let the water and food cool. Then strain the liquid into the largest jar. Toss out the remaining food in the strainer.
3. The liquid indicator should be dark red or purple.
4. Put a small amount of a substance you want to test into a clean jar. (If it is a powder, place some on a piece of aluminum foil or a dish.)
5. Carefully add a teaspoon of the indicator you made.
6. Note the color change. The indicator will turn red in the presence of an acid, and green in the presence of a base.
7. Repeat for all the substances you gathered.
8. Make a list of the substances that were acidic and the ones that were basic, and the neutral ones in between.

**Scientific Process Elements:** experimenting or testing, demonstrating or verifying a scientific fact, changing a variable, collecting data, recording data and observations

## Oil and Water Project

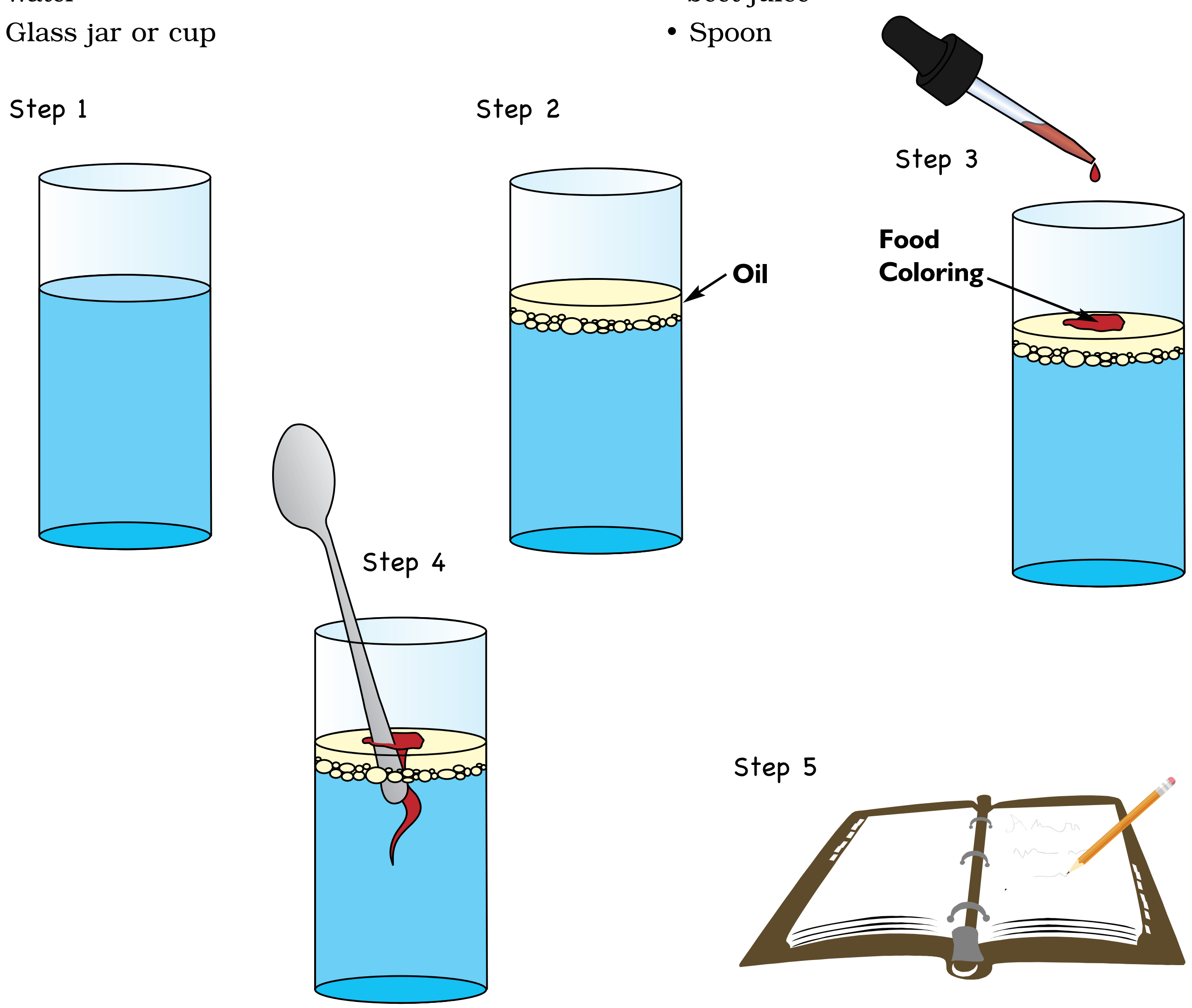
PROJECTS volume 10 5.4

See Volume 5 Page 45

**Question:** What happens when you mix oil and water?

**Things you need:**

- 1/2 cup of cooking oil (examples: olive, canola, vegetable)
- Water
- Glass jar or cup
- Eyedropper
- Food coloring, poster paint, or beet juice
- Spoon




**Directions:**

1. Fill 2/3 of the glass with water.
2. Slowly add half the oil. Let the mixture stand for 10 minutes.
3. Carefully put a few drops of the color liquid into the oil layer, using the eyedropper. Notice what happens when the color meets the liquid.
4. Now using the end of a spoon, push the beads of color liquid into the water layer.
5. Record your observations.

**Scientific Process Elements:** observation and description, demonstrating or verifying a scientific fact, recording data, drawing conclusions



## Experimenting with a Pendulum Project

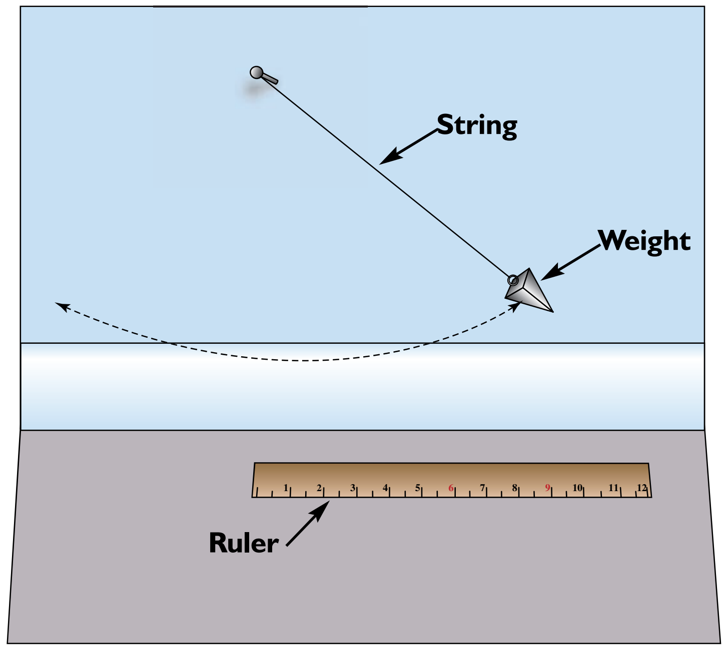
PROJECTS volume 10 6.1

See Volume 6 Page 10

**Question:** How can I make a pendulum and experiment with it?

**Things you need:**

- Piece of string
- Ruler
- Tack
- Small heavy weight (fishing sinker, small metal bolt or nut, small stone etc.)
- Timer or clock




**Directions:**

1. Tie a weight on the end of a 12-inch (31 cm) piece of string.
2. Tack or tie the end of the string to an object, such as a bulletin board or a handle so that the weight can swing back and forth. Observe and record how your pendulum moves.
3. Lay the ruler beneath the pendulum so that the end of the ruler is directly under the weight when it is at rest, or motionless.

**Investigations with your pendulum:**

1. Measure and record the length of your pendulum string.
2. Pull the weight to the side until it is directly over the 3 inch (8 cm) mark on the ruler. Let it go and record how many swings (over and back = one swing) the pendulum makes in one minute.
3. Now try it from the 6-inch mark (15 cm). Any difference?
4. How many swings does the pendulum make in one minute if you shorten the string by one half?
5. How many swings in a minute if you double its length?

**Scientific Process Elements:** building a model to understand how something works, observation and description, experimenting, changing a variable in an experiment, collecting and recording data, analyzing data, drawing conclusions

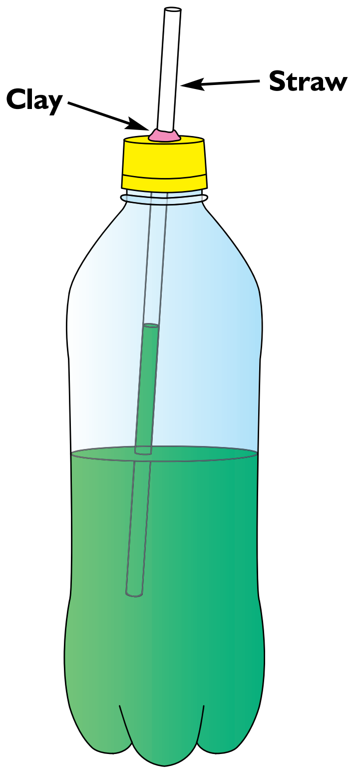
# Thermometer Project

PROJECTS volume 10 6.2
See Volume 6 Page 36

**Question:** How does a thermometer work?

**Things you need:**

- Clear plastic bottle with a cap
- Drinking straw
- Scissors
- Water
- Food coloring
- Clay
- Pan filled with hot water
- Pan filled with cold water




**Directions:**

1. Fill a clear plastic bottle halfway with water.
2. Add food coloring and put on the cap. Shake the bottle until the water turns a color.
3. Use scissors to punch a hole in the cap big enough to hold a straw tightly. Put clay around the hole to seal it.
4. Put the straw in the hole. Blow gently into the bottle. The air you add will push on the surface of the water in the bottle and cause water to rise in the straw. Stop when the water is about halfway up the straw.
5. Put the bottle in a pan of hot water. What happens to the colored water level in the straw?
6. Put the bottle in a pan of ice water. What happens to the water level in the straw?

**Scientific Process Elements:** building a model to understand how something works, observation and description, experimenting or testing, changing a variable in an experiment, demonstrating or verifying a scientific fact, recording data and observations, drawing conclusions



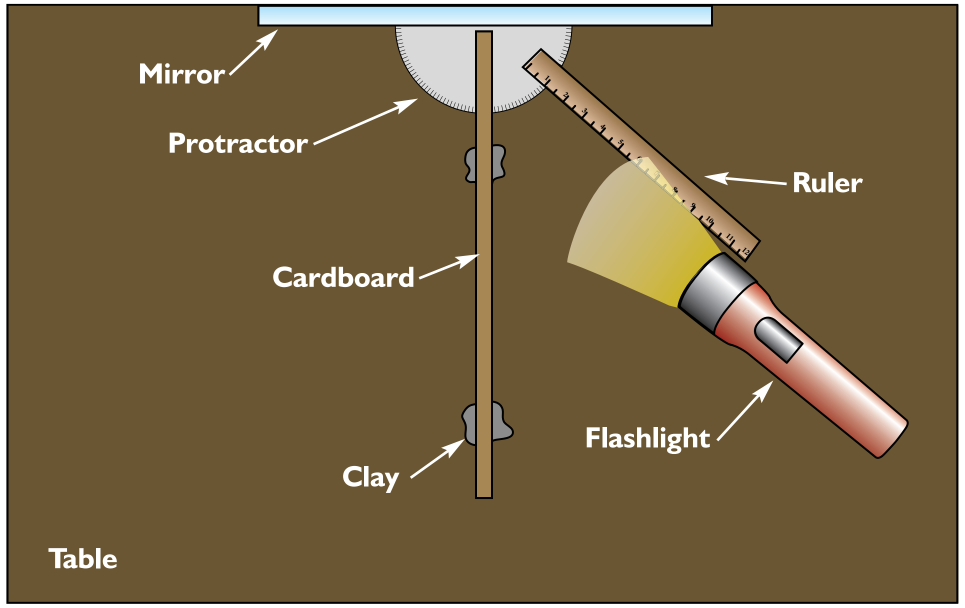
# Reflection Project

PROJECTS volume 10 6.3
See Volume 6 Page 48

**Question:** When you shine a flashlight on a mirror, does the light reflect off the mirror at the same angle as the light coming from the flashlight?

**Things you need:**

- Mirror with a straight edge
- Sticking tape
- Flashlight
- Ruler
- Piece of 8 1/2" X 11" (21,6 cm x 28cm) cardboard
- Clump of clay
- Protractor
- Desk or small table




**Directions:**

1. Place a desk or table against a wall.
2. Place the mirror on the edge of the desk and tape it to the wall behind the desk or table.
3. Place the protractor with its flat edge against the mirror's bottom edge.
4. Prop the cardboard up in the clump of clay. Place it on the desk, perpendicular to the surface of the mirror and lined up with the center of the protractor. Leave about a half an inch (1 cm) between it and the mirror surface.
5. Darken the room.
6. Shine the flashlight at the mirror at a point above the center of the protractor.
7. Look from the other side of the cardboard until you can see the light from the flashlight bulb.
8. Use the ruler to draw sight lines to and from the mirror. Use the protractor to check the angles that the flashlight beam goes to and from the mirror.

**Scientific Process Elements:** observation and description, demonstrating or verifying a scientific fact, drawing conclusions

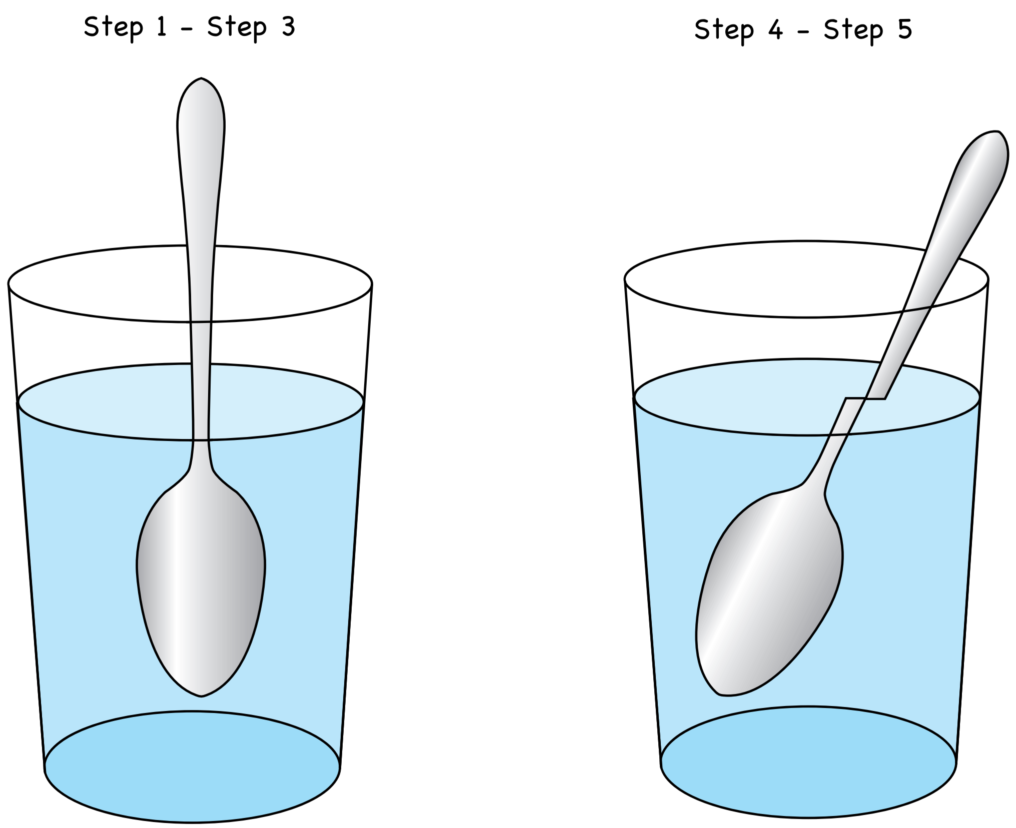
## Refraction Project

PROJECTS volume 10 6.4

See Volume 6 Page 50

**Question:** How can I see an example of light bending?

**Things you need:**
- Clear glass or plastic cup
- Water
- Spoon




**Directions:**
1. Fill a cup 2/3 full of water.
2. Put a spoon into the cup and hold it up straight.
3. Hold the cup at eye level and look at it.
4. Move the spoon so it is at an angle.
5. Observe the change. The two halves of the spoon do not line up.

**Scientific Process Elements:** observation and description, demonstrating or verifying a scientific fact, recording data and observations



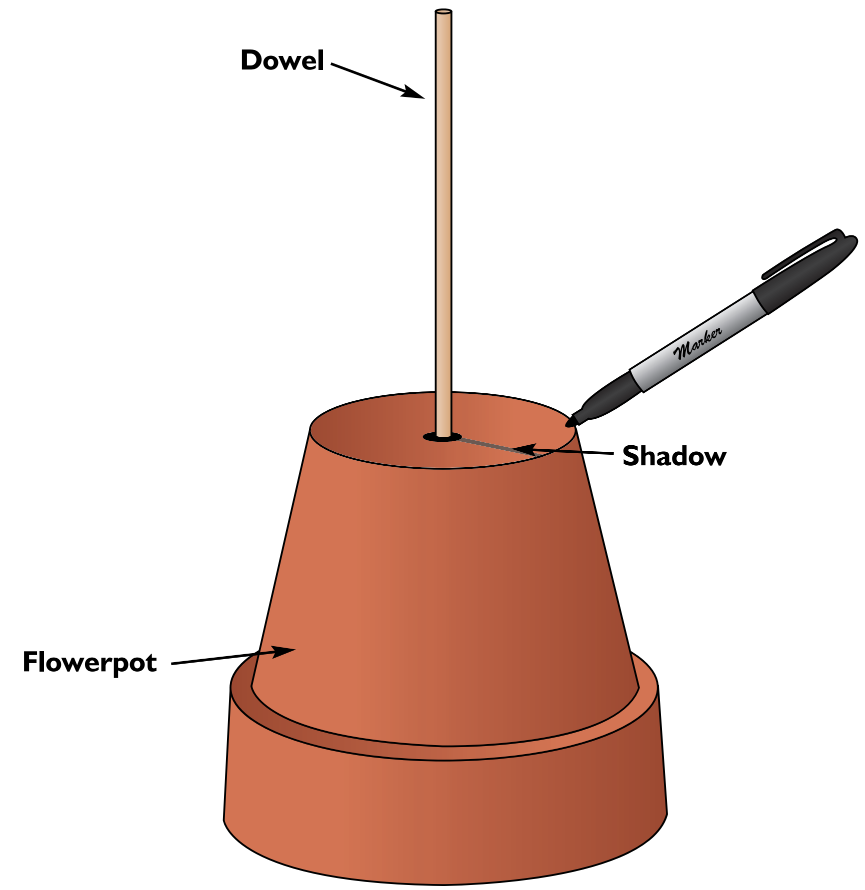
## Making a Sundial Project

PROJECTS volume 10 7.1

See Volume 7 Page 11

**Question:** How can you tell time with a sundial?

**Things you need:**
- Dowel or any slim, round stick
- An 8-inch flowerpot
- Clock or watch
- Permanent black marker




**Directions:**
1. Select a site that is sunny all day long.
2. Turn the flowerpot upside down.
3. Place the stick inside the hole and into the ground beneath.
4. In a period of time, from dawn to dusk, and at the top of each hour, mark where the shadow hits the edge of the pot bottom with a black mark. Write the hour at each mark.
5. On sunny days, use the sundial to tell the time. Make sure you don't move the flowerpot, or the times won't be correct anymore.

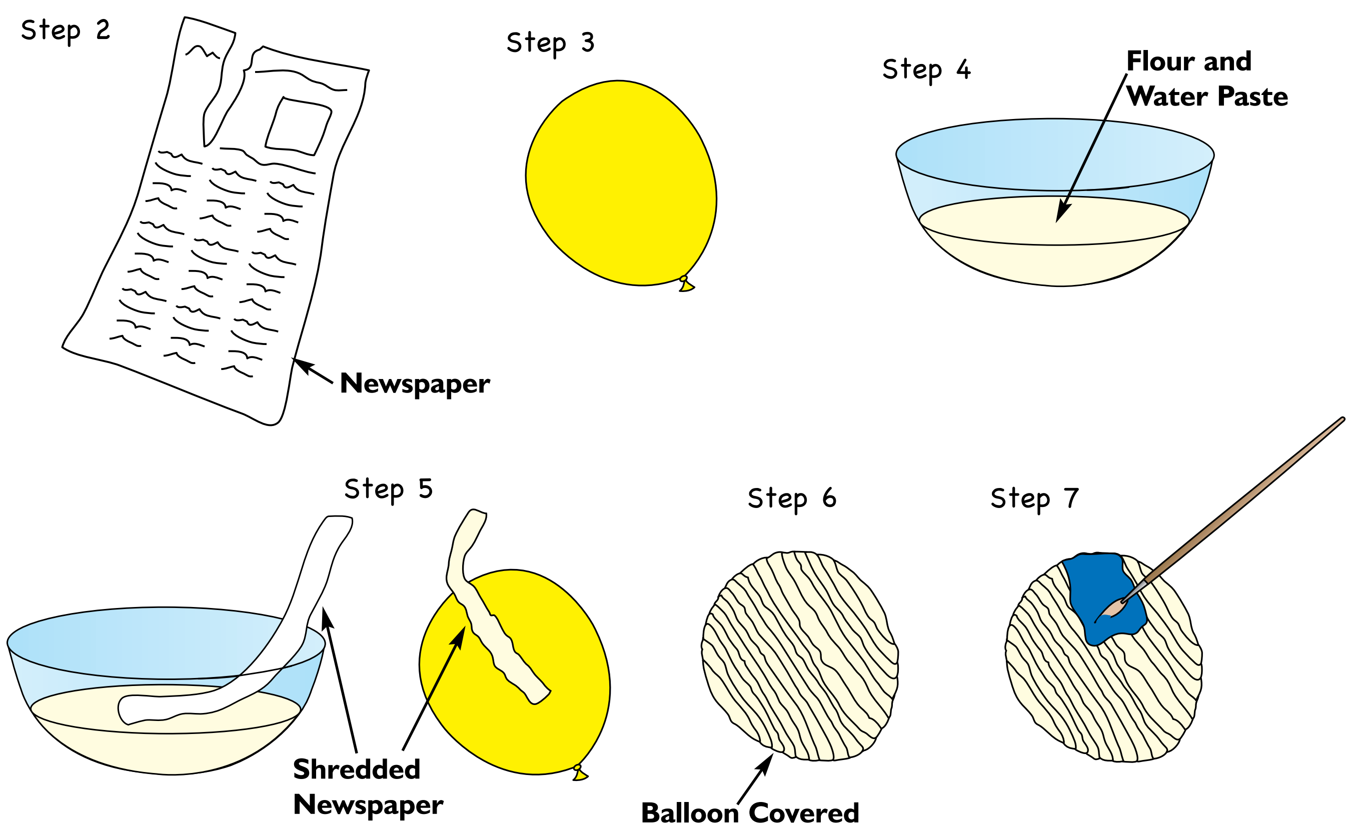
**Scientific Process Elements:** building a model to understand how something works, observation and description, demonstrating or verifying a scientific fact, collecting and recording data, drawing conclusions

## Papier-mâché Planetary Models Project

PROJECTS volume 10 7.2
See Volume 7 Page 14

**Question:** How can I make models of the planets, using papier-mâché?

**Things you need:**
- Old newspapers
- Large, flat pan
- Flour
- Water
- Paints of various colors
- Small round balloons
- String




**Directions:**
1. Locate photos of the planets, showing comparative size, colors and other features. Use these to guide you in making your models.
2. Shred newspaper into long narrow strips.
3. Blow up a small balloon and tie the end shut.
4. Mix the flour and water into a thin paste.
5. Wet strips of newspaper with the flour/water mixture and apply them to the balloon until the whole balloon is covered in several layers.
6. Set the covered balloon aside to dry and repeat steps 1-5, until you have one for each planet. (Blow up the balloons according to the relative size of each planet.)
7. When all the covered balloons have dried, paint them according to your photos of the planets and display them in your classroom or school library.

**Scientific Process Elements:** building a model to understand how something works, demonstrating or verifying a scientific fact, presenting data graphically

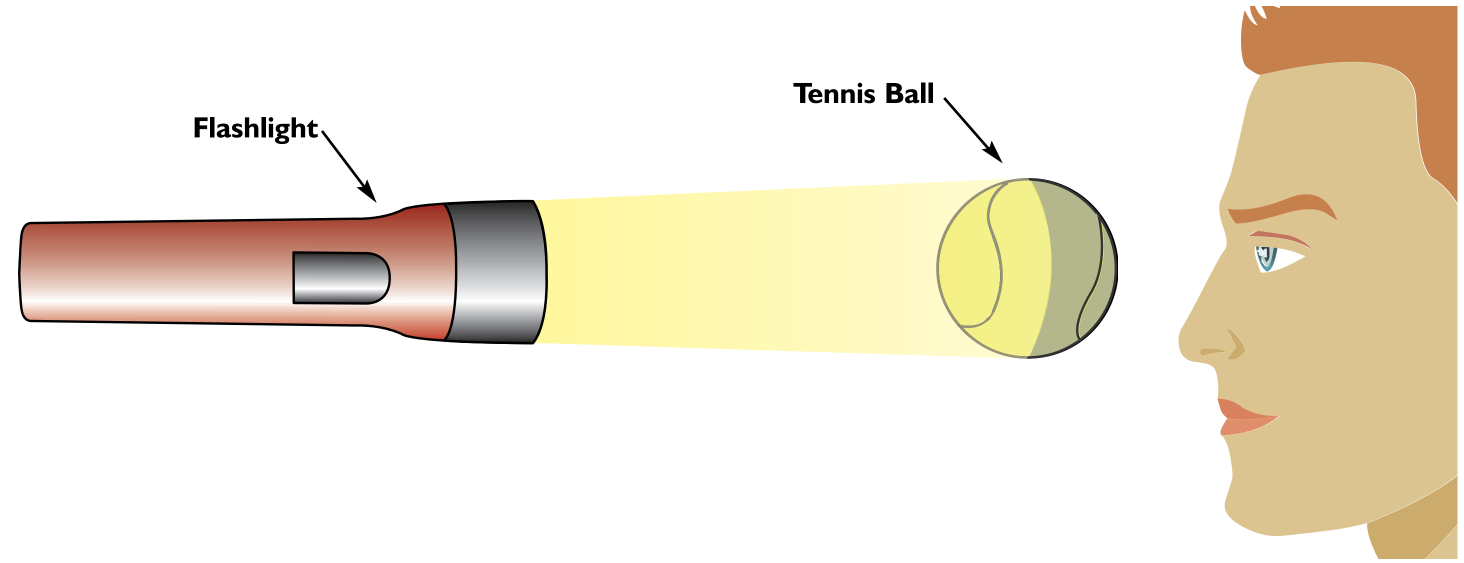


## Solar Eclipse Project

PROJECTS volume 10 7.3
See Volume 7 Page 18

**Question:** What happens during a solar eclipse?

**Things you need:**
- Flashlight
- Tennis ball
- Darkened room
- A helper




**Directions:**
1. Place a flashlight on a table.
2. Direct the light at you. You represent a viewer on Earth.
3. Place the tennis ball between the flashlight and your line of sight.
4. Have your helper move the tennis ball toward you or away from you until it blocks the flashlight beam from your vision.
5. Now move the tennis ball slowly sideways to mimic the movement of the Moon and the end of the eclipse.

**Scientific Process Elements:** demonstrating or verifying a scientific fact, observation and description, drawing conclusions

## Finding the North Star Project

PROJECTS volume 10 7.4

See Volume 7 Page 42

**Question:** How do I find and identify the North Star?

**Things you need:**

- Clear night, away from street and city lights
- Constellation guide (school library or Internet)
- Compass

**Directions:**

1. Find a spot without too many electric lights, on a moonless night.
2. Look up into the northern sky. (Use the compass to locate the northern direction.)
3. See if you can identify a group of stars that is shaped like a big dipper.
4. Follow an imaginary line up from the two stars at the end of the Big Dipper's cup.
5. The first brightest star that you find is Polaris.

**Scientific Process Elements:** observation and description, demonstrating or verifying a scientific fact, recording data and observations



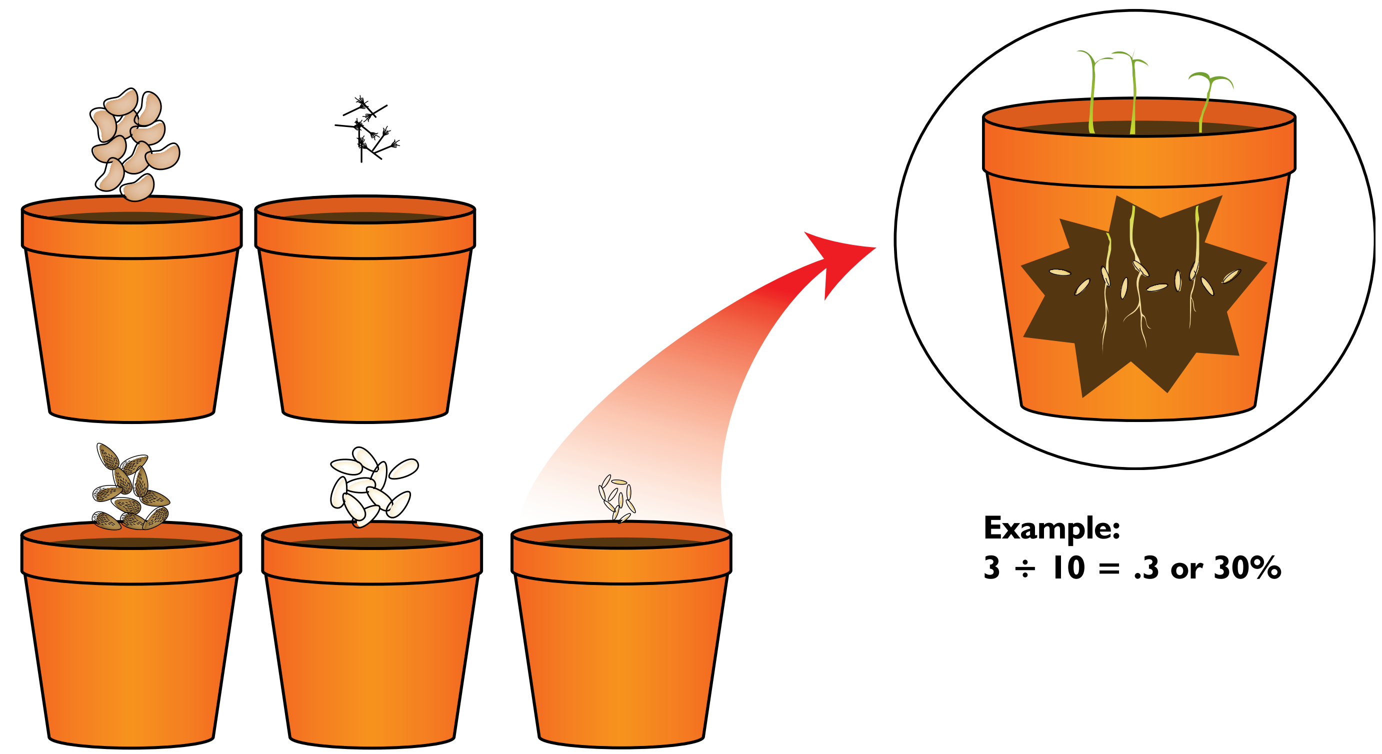
## Analyzing Data: Seed Germinating Project

PROJECTS volume 10 8.1

See Volume 8 Page 19

**Question:** What percent of the seeds germinated in the investigation?

**Seed Germination:**
Repeat the seed germination investigation (page 15) with 5 different kinds of seeds. Record the number of seeds (in each set of 10) that fully germinate (develop roots, stems, and small leaves).



**Example:**
$3 \div 10 = .3$ or 30%

**Directions:**

For each kind of seed:

1. Count the number of seeds out of 10 that fully sprouted after 6 days.
2. Divide the number of seeds that sprouted by the number of seeds you planted. If 5 seeds sprouted, divide 5 by 10. The answer (.50) can be expressed as 50 percent.
3. Use a calculator to find the percent of germination for each batch of seeds.

**Scientific Process Elements:** collecting data, analyzing data

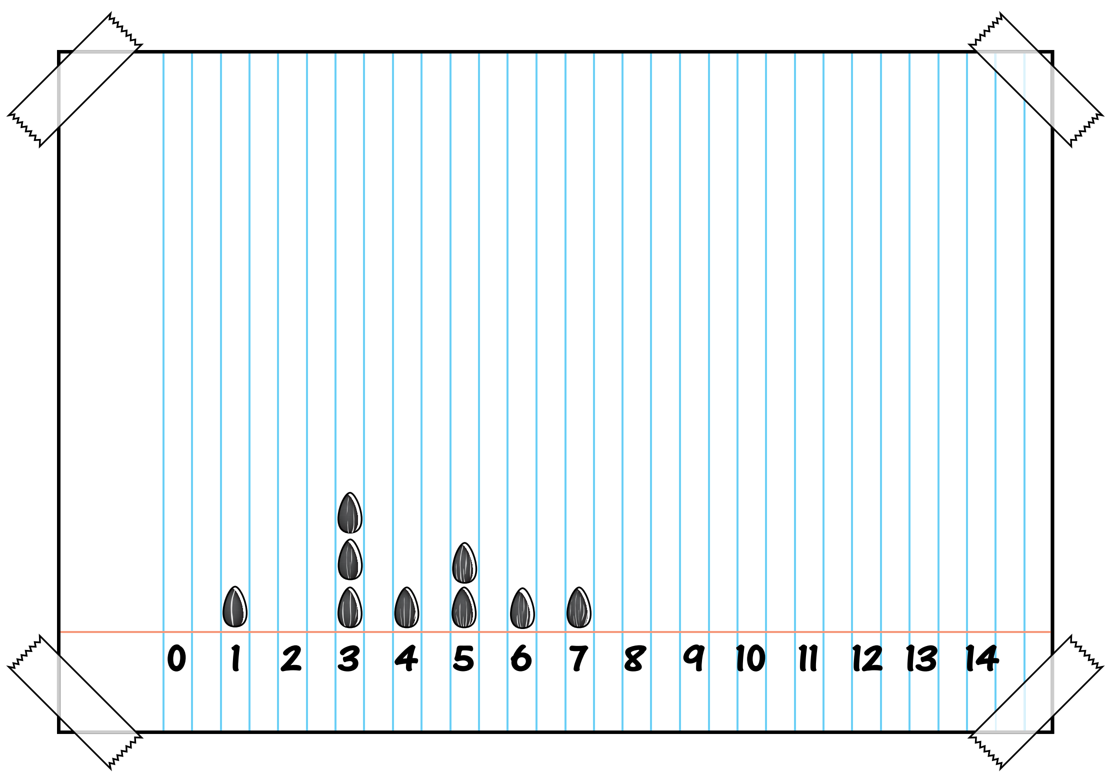
# Presenting Data: Graphing the Distribution of Variations in Sunflower Seeds Stripes Project

See Volume 8 Page 34

**Question:** How do sunflower seeds stripe vary?

**Things you need:**

- 100 striped sunflower seeds
- Lined composition paper (Graph paper columns are a bit too small for the seeds you will paste on the paper)
- Cellophane tape
- Glue




**Directions:**

1. Tape the lined paper to your work surface, in front of you, with the lines running vertically (up and down) rather than horizontally (from side to side). Number the bottom of every other column from left to right, starting from zero.
2. Count the total number of white stripes on a sunflower seed and place the seed in the column with the matching number. For example, if the seed has three white stripes, glue the seed in the column above the number 3. (Start the seed gluing at the bottom of each column and add further ones above.)
3. Repeat step #3 until your have counted the stripes on, and glued, all 100 seeds in the columns. Your resulting histogram will look like a bar graph. It displays the distribution of stripe counts of sunflower seeds in your sample of 100 seeds.

**Scientific Process Elements:** collecting and recording data, analyzing data, presenting data graphically



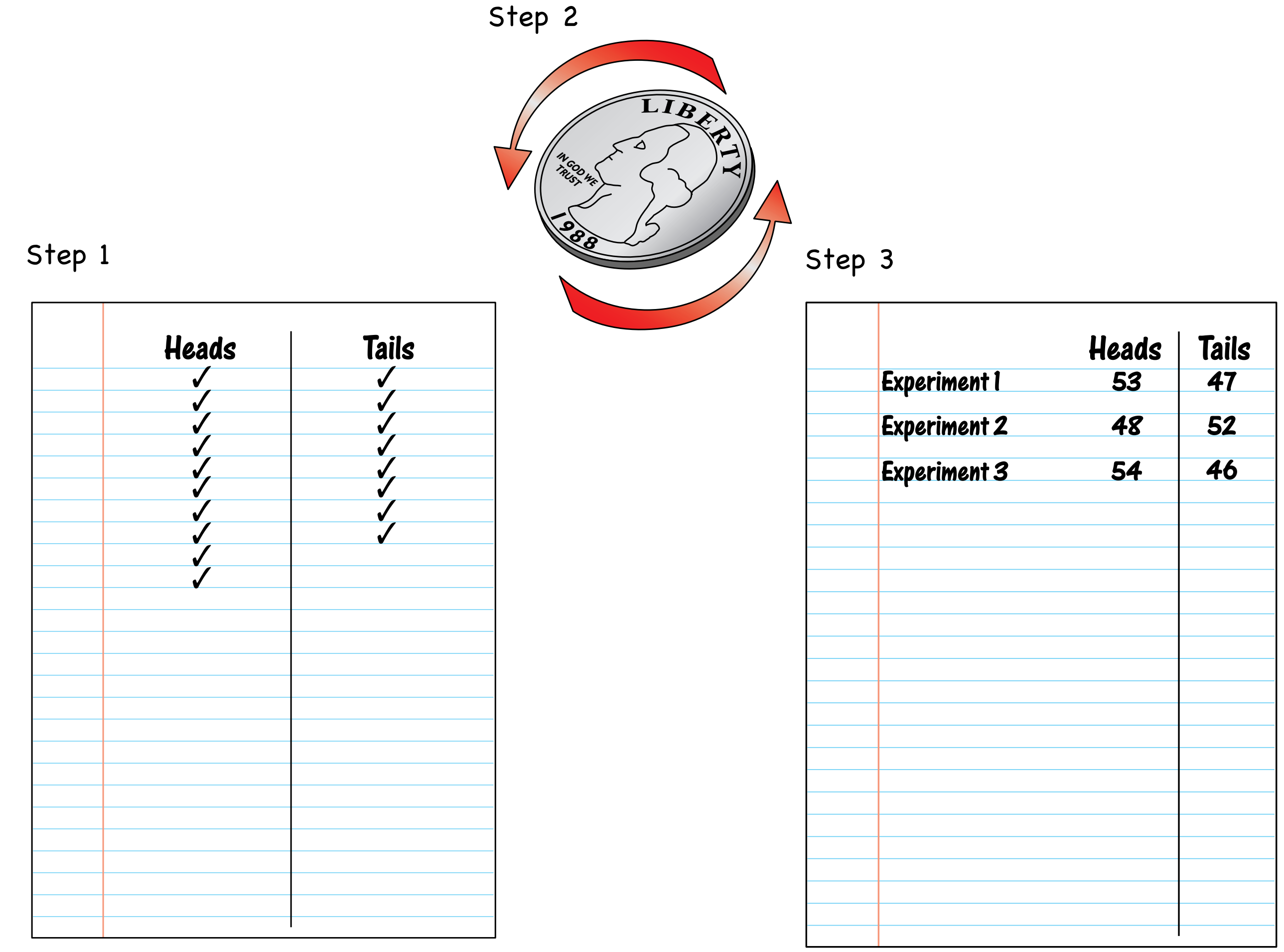
# Probability Project

See Volume 8 Page 36

**Question:** When there are only two choices in an even, such as heads or tails in a coin toss, what are the chances of either side being selected?

**Things you need:**

- Coin
- Paper
- Pencil




**Directions:**

1. Draw two columns on a piece of paper. Write "Heads" over one column and "Tails" over the other.
2. Flip a coin in the air 100 times. Each time it lands, make a mark in the proper column.
3. After 100 flips, count the marks in each column. Compare your totals with a 50-50 probability.
4. Repeat this experiment 10 times (100 flips in each trial).
5. Add the 10 totals for heads. Add the 10 totals for tails. Are they equal?

**Scientific Process Elements:** experimenting or testing, collecting, recording, and analyzing data

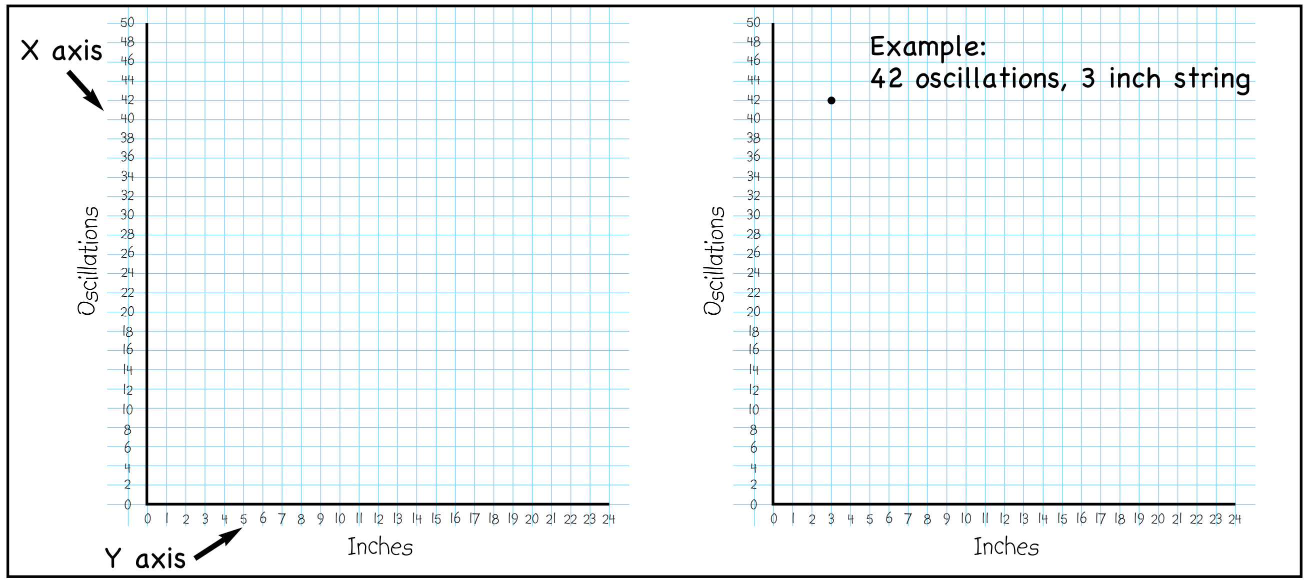
# Presenting Data: Graphing the Pendulum Project

See Volume 8 Page 42

**Question:** How can I show the data from the Pendulum Investigation (page 25) in a graph?

**Things you need:**

- Graph paper and pencil
- Data collected from the following pendulum investigations:
  - Number of swings (over and back = one swing) the 12-inch (30 cm) string pendulum makes in one minute from a 3-inch (8 cm) starting point
  - Same data using a 6-inch (15 cm) string pendulum from the 3-inch (8 cm) starting point
  - Same data using an 18-inch (46 cm) string
  - Same data using a 24-inch (61 cm) string




**Directions:**

1. Draw a vertical line up the left hand side of the graph paper for the X axis and a horizontal line across the bottom for the Y axis.
2. Number the X axis of the graph paper in even digits from 1–50. These numbers represent the number of swings, or oscillations, of the pendulums.
3. Label the Y axis with units of length. These numbers represent the differing lengths of the pendulum string. Label the lines from 1 to 24 inches (1 to 61 cm).
4. On each of the lines for a given length pendulum, place a dot on the horizontal line to indicate the number of oscillations you counted for that length. When you have entered all the data, connect the dots in a line from left to right.
5. Label or name your graph: The label tells what the graph shows.
6. Write your conclusion by answering this question: How does the length of a pendulum string affect the number of swings per minute?

**Scientific Process Elements:** collecting and recording data, analyzing data, presenting data graphically, drawing conclusions



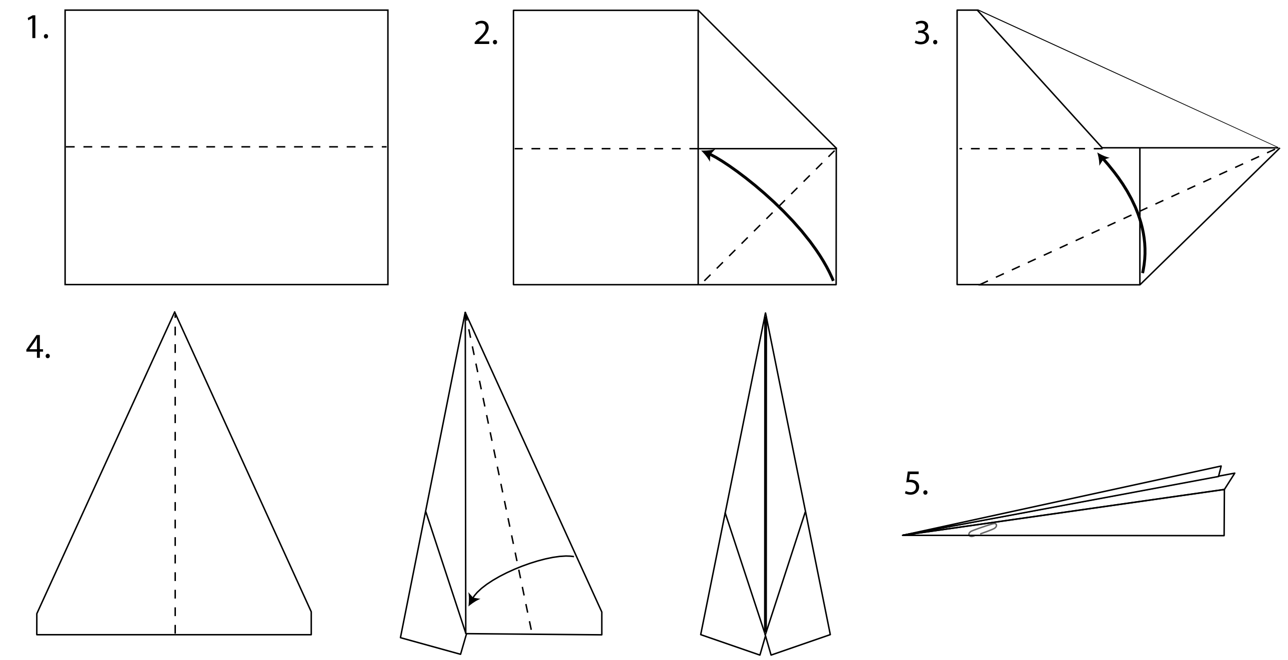
# Making a Glider Project

See Volume 9 Page 23

**Question:** What is a good wing shape for a glider?

**Things you need:**

- Rectangular pieces of paper
- Paper clips




**Directions:**

1. Fold a piece of paper in half lengthwise. Open it again.
2. Fold the two corners of the paper at the top down to the center crease.
3. Fold the two corners at the top down to the center crease again.
4. Turn the paper over. Fold back wings on both sides.
5. Place a paper clip at the nose of your paper glider to hold the folds together.
6. Throw your glider forward into the air. Measure how far it travels. Repeat 5 times.
7. For each set of 5 trials or test flights, change one variable: change the position or number of paper clips, change the folding patterns to get a different wing shape, change where you fly the planes – indoors or out of doors.
8. Record your observations.

**Scientific Process Elements:** building a model to understand how something works, observation and description, collecting and recording data, changing a variable in an experiment, analyzing

## Making a Rheostat Project

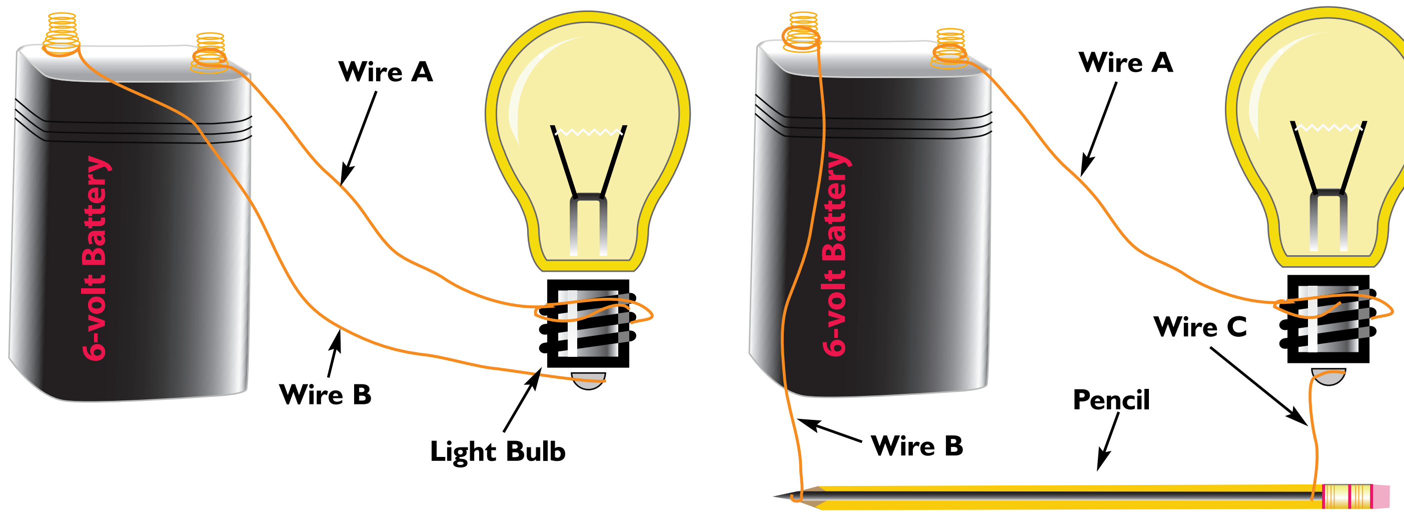
PROJECTS volume 10 9.2

See Volume 9 Page 26

**Question:** How does a rheostat work?

**Things you need:**

- 6-volt battery
- 3 light copper wires or leads, each about 4 inches long
- Flashlight bulb in a base or holder
- Wooden pencil




**Directions:**

1. Split a pencil in half, lengthwise, revealing the length of the pencil lead. The pencil lead is made of graphite, a form of carbon.
2. Create an open circuit as shown in the diagram:
   - Attach one copper wire, A, to the positive terminal of the battery.
   - Attach another copper wire, B, to the negative terminal of the battery.
   - Fix the end of wire A to one of the flashlight bulb fixture's screws.
   - Attach wire B to the contact point at the bottom of the light bulb screw.
3. Check if electricity flows in the circuit by connecting the ends of wires A and C. If the circuit is complete, the bulb will glow.
4. Now move wire B from the flashlight bulb contact point to the tip of the pencil lead. Attach one end of a third wire, wire C, to the flashlight bulb contact point. Attach the other end of wire C to the pencil lead near the eraser. Slide one wire at the tip and slide the other along the lead from the eraser end toward the tip.
5. Notice what happens to the light bulb's glow.
6. Try other pieces of materials in the circuit in place of the pencil lead. Try both metallic and non-metallic materials.

**Scientific Process Elements:** building a model to understand how something works, demonstrating or verifying a scientific fact, experimenting or testing, observation and description, changing a variable in an experiment, drawing conclusions



## Making a Microscope Project

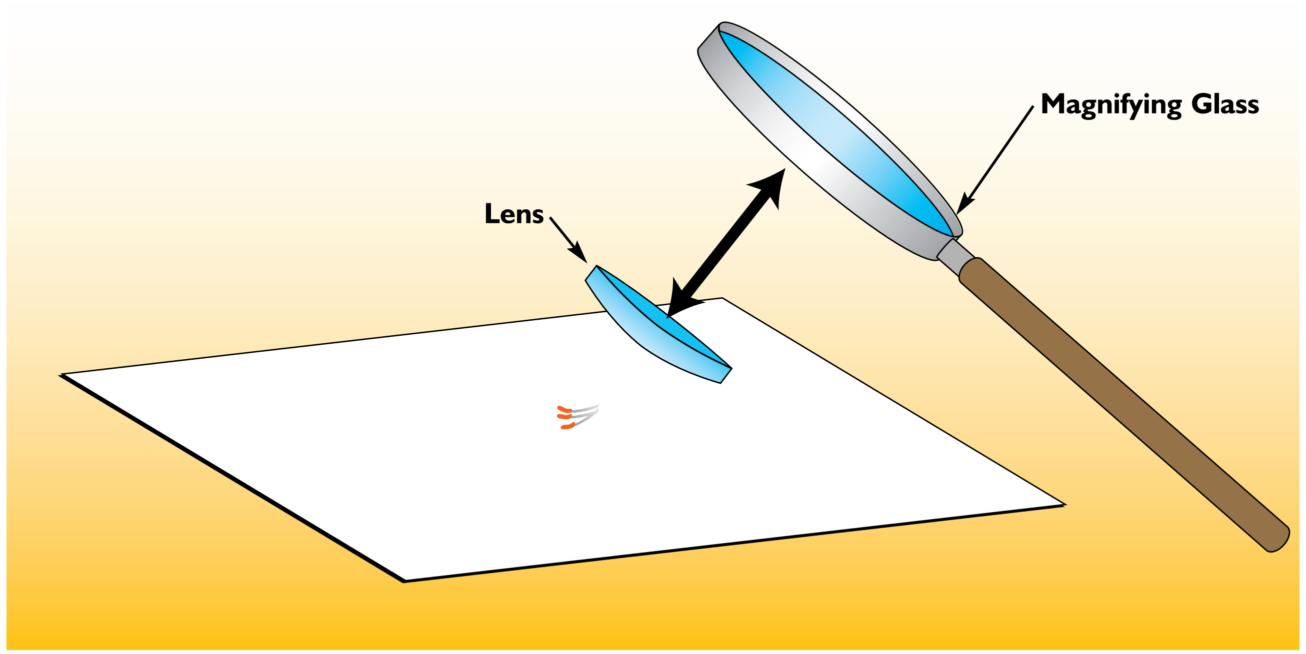
PROJECTS volume 10 9.3

See Volume 9 Page 31

**Question:** Will a very simple model of a microscope work?

**Things you need:**

- Magnifying glass
- Convex lens from a discarded disposable camera or a field biology lens
- Small object, such as a plant stamen or a hair, to examine
- Sheet of white paper




**Directions:**

1. Place the object on a sheet of white paper.
2. Hold the magnifying lens close to your eye.
3. Hold the other lens over the object.
4. Adjust the distance between the two lenses until you find the distance that enlarges the object and presents the clearest view of it or brings it into focus.

**Scientific Process Elements:** building a model to understand how something works, experimenting or testing, observation and description

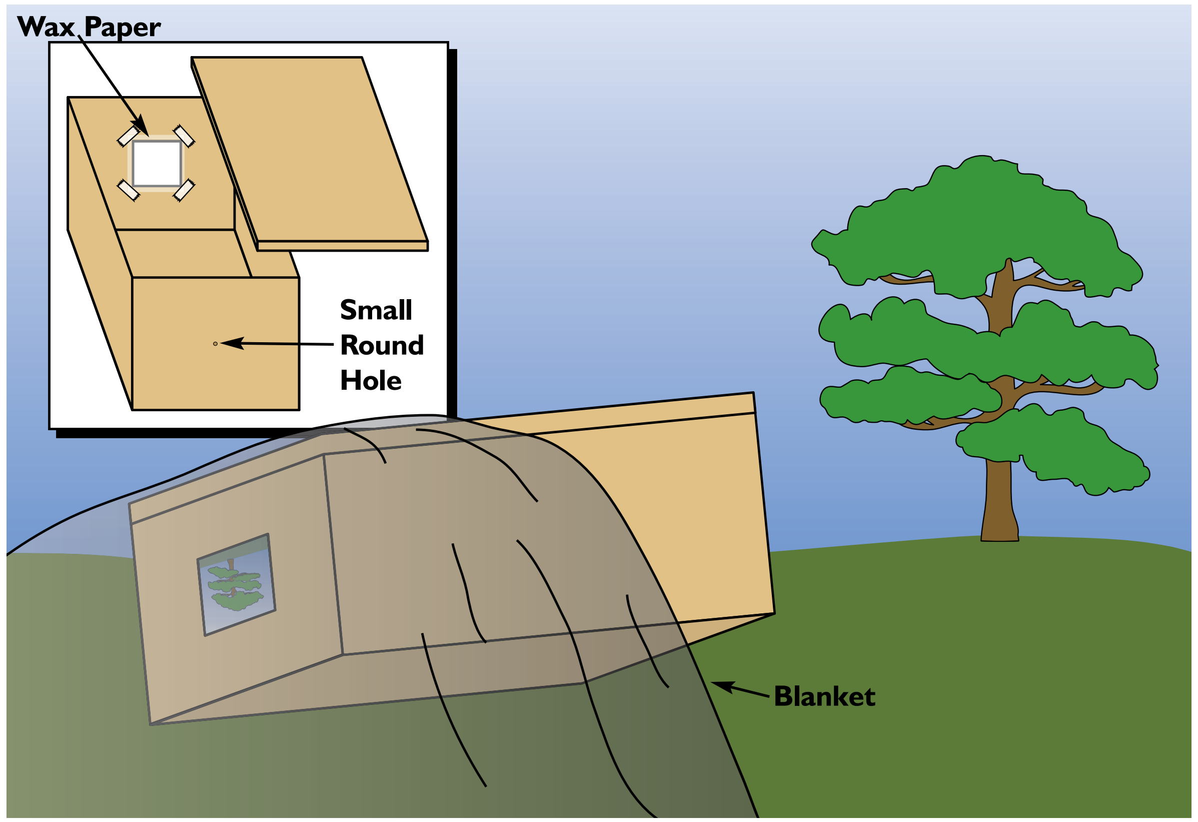
# Making a Camera Project

PROJECTS volume 10 9.4
See Volume 9 Page 50

**Question:** How can I show how an image forms in a pinhole camera?

**Things you need:**

- Shoebox or columnar oatmeal box
- Round toothpick or knitting needle
- Scissors
- Wax paper
- Tape
- Blanket




**Directions:**

1. Poke a small, round hole in one end of the box. Cut a larger square in the other end (about 3 inches or 8 cm square).
2. Inside the box, tape a piece of wax paper over the square hole. Put the lid back on the box.
3. Cover your head and the box with a blanket. Allow only the pinhole in the box to stick out from underneath.
4. Point the 'camera' at something bright and colorful. Look at the square for the upside-down image.
5. Try using your camera outside in the sunlight. Record your observations. Remember, never look directly at the Sun.

**Scientific Process Elements:** building a model to understand how something works, observation and description, experimenting or testing, collecting and recording data



**abdomen** (AB-duh-men): the part of the body containing the stomach and intestines
**absorb** (ab-SORB): to soak up liquid
**action force** (AKT-shuhn, forss): the force that is acting on something, for example someone pulling on a rope
**activist** (AC-tiv-ist): a person who speaks or shows support for a cause
**acute** (uh-kyoot): able to detect things easily
**adaptation** (ad-ap-TAY-shuhn): a change that a living thing goes through, so that it fits better into its environment
**agar** (AH-ger): a jelly-like substance produced by some algae
**agriculture** (AG-ruh-kul-chur): farming
**amino acids** (uh-meen-o ASS-ids): chemical compounds with which the body builds protein
**amplitude** (AM-pluh-tood): how tall waves are
**ancient** (AYN-shunt): very old
**antennae** (an-TEN-uh): a feeler on the head of an insect
**anther** (ANN-thur): the male flower structure that produces pollen cells
**antibiotic** (an-ti-bye-OT-ik): a drug that kills bacteria
**asexual** (ay-SEX-you-uhl): reproduction without eggs and sperm
**atmosphere** (AT-muhss-fihr): the mixture of gasses that surround a planet
**atom** (AT-uhm): very small part of an element
**auxin** (AUX-in): plant substance that may speed up or slow down growth
**axis** (AK-siss): the imaginary line going through the middle of a planet or other object that it rotates around; a line at the side or bottom of a graph
**axon** (AK-sohn): the usually long part of a nerve fiber that carries signals away from the nerve cell body
**bacteria** (bak-TIHR-ee-uh): microscopic living things that exist all around you and inside you
**band** (band): a narrow ring of material that goes around something
**batch** (bach): a group of things that arrive together or are made together
**bay** (bay): a portion of the ocean that is partly enclosed by land
**botanist** (BOT-uhn-ist): one who studies plants
**by-product** (bye-PROD-uhkt): something left over when another thing is produced
**canyon** (KAN-yuhn): a narrow, deep river valley with steep sides
**capillary** (KAP-uh-ler-ee): the smallest blood vessels in your body
**carbohydrate** (kar-boh-HYE-drait): a food substance produced by the plant process called photosynthesis
**carbon dioxide** (KAR-buhn dye-OK-side): a gaseous chemical compound of oxygen and carbon
**carnivorous** (kar-NIV-uhr-uhss): meat eating
**cartilage** (KAR-tuh-lij): a strong, elastic, fibrous tissue
**cavity** (KAV-uh-tee): a hole or hollow space in something solid
**cell** (sel): a basic, microscopic part of an animal or a plant
**cellular** (SEL-yuh-lur): made of or to do with cells
**centrifugal force** (sen-TRIF-yuh-guhl, forss): a force that pushes you away from the center
**centripetal force** (sen-TRIP-uh-tuhl, forss): a force that pulls you toward the center
**chain reaction** (chayn, ree-AK-shuhn): when a change keeps happening over and

over again until it is controlled
**chemistry** (KEM-is-tree): the scientific study of substances
**chlorophyll** (KLOR-uh-fill): a green pigment used by plants to absorb sunlight energy during photosynthesis
**chloroplast** (KLOR-uh-plast): a plant cell structure that contains the green pigment, chlorophyll
**chromosome** (KROH-muh-sohm): the part of the cell that contains the genes that gives living things their characteristics
**chrysalis** (KRISS-uh-liss): a butterfly at the stage of development between a caterpillar and an adult
**circuit** (SUR-kit): a group of electronic parts that are connected and make a circle
**circulation** (sur-kyuh-LAY-shun): the movement of blood in blood vessels through the body
**climate** (KLYE-mit): the usual weather in a place
**clot** (klot): a solidified clump of blood cells and plasma
**colon** (KOH-luhn): the last half of the large intestine
**combine** (kuhm-BINE): to join or mix two things together
**commercial** (kuh-MUR-shuhl): transporting passengers or cargo for profit
**complete** (kom-PLEET): all the parts needed or wanted
**complex** (KOM-pleks): having a large number of parts
**component** (kuhm-POH-nuhnt): a part of a system
**composite** (kom-POZ-it): made up of many parts from different sources
**composition** (kom-puh-ZISH-uhn): combining of parts to form a whole
**compress** (kuhm-PRESS): to press or squeeze something until it is smaller
**conduction** (kuhn-DUHKT-shuhn): how heat moves through solids
**conductor** (kuhn-DUK-tur): matter that allows heat to pass through it
**conservation of energy** (kon-sur-VAY-shuhn, EN-ur-jee): energy can be changed into another form, but cannot be created or destroyed
**continent** (KON-tuh-nuhnt): one of the seven large land masses of the Earth
**contract** (kuhn-TRAKT): to get smaller
**control** (kuhn-TROHL): to make something or someone do what you want
**convection** (kuhn-VEK-shuhn): how heat moves through liquids and gases
**cramp** (kramp): pain caused by a muscle tightening suddenly
**culinary** (KUH-lin-airy): having to do with cooking foods
**culture** (KUHL-chur): a growing population of an organism in a lab dish
**deciduous** (di-SIJ-you-uhss): trees that shed their leaves every year
**decomposer** (dee-cahm-POZ-er): an organism, such as a fungus, that digests dead material and absorbs nutrients to live
**deficient** (di-FISH-uhnt): lacking something necessary
**dense** (DENSS): crowded, or thick
**desert** (DES-urt): a dry, often sandy area where hardly any plants grow because there is so little rain
**diagnose** (dye-ugh-NOHSS): to determine what disease a patient has or what physical or mental problem
**diameter** (dye-AM-uh-tur): a line going straight through the center of a circle, from one side to the other



**diatom** (DYE-uh-tahm): one-celled algae that have shells of silica
**digit** (DIJ-it): any Arabic numerals from 1 to 9, and sometimes 0
**dimension** (duh-MEN-shuhn): the dimensions of an object are the measurements of its length, width, and height
**distance** (DISS-tuhnss): the amount of space from one place to another
**domesticate** (duh-MESS-tuh-kate): to tame something so it can live with or be used by humans
**donor** (DOH-nur): someone who gives something
**drag** (drag): slowing something down
**electromagnet** (i-lek-tro-MAG-nit): a magnet made by an electric current
**electromagnetic force** (i-lek-tro-mag-NET-ik, forss): a combination of electrical and magnetic forces that attract (push towards) or repel (push away)
**electromagnetic spectrum** (i-lek-tro-mag-NET-ik, SPEK-truhm): all the forms of energy that travel as a wave
**electron** ( i-LEK-tron): a particle that moves around the nucleus (center part) of an atom
**ellipse** (i-LIPS): an oval shape
**elliptical** (i-LIP-tik-uhl): having an oval shape
**emit** (i-MIT): to release or give off
**endangered** (en-DAYN-jurd): put in a dangerous situation; threatened
**energy** (EN-ur-jee): the ability to do work
**engineer** (en-juh-NIHR): someone who is trained to design and build structures
**environment** (en-VYE-ruhn-muhnt): the natural world of the land, sea, and air
**enzyme** (EN-zime): a chemical that causes chemical reactions to occur in living things
**equation** (i-KWAY-zhuhn): a mathematical statement that one set of numbers or values is equal to another set of values or numbers
**equator** (i-KWAY-tur): an imaginary line around the middle of the Earth
**erode** (i-RODE): to wear away by water and wind
**escape velocity** (ess-KAPE, vuh-LOSS-uh-tee): how fast something needs to travel to leave the Earth's gravity
**ethanol** (EH-than-all): an alcohol produced by yeasts from the fermentation of sugar
**evergreen** (EV-ur-green): a shrub or tree that has green leaves throughout the year
**evolution** (ev-uh-LOO-shuhn): the gradual change of living things over thousands of years
**evolve** (i-VOLV): to change slowly
**examine** (eg-zam-uhn): to look carefully at
**experiment** (ek-SPER-uh-ment): a scientific test to try out a theory or to see the effect of something
**expose** (ek-SPOZE): to come in contact with a disease organism
**extinct** (ex-STINGKT): when a type of plant or animal has died out
**fatal** (FAY-tuhl): causing death
**feces** (FE-seez): excrement from bowels
**fermentation** (fur-men-TAY-shun): a chemical process used by some bacteria and fungi to digest sugars
**fertilization** (fur-till-eye-ZAY-shun): the joining, or union of and egg and a sperm cell

**fertilize** (FUR-tuh-lize): to begin reproduction in an egg by causing sperm to join with the egg
**fertilizer** (FUR-tuh-lize-ur): a substance, such as animal manure, compost, or a chemical that promotes plant growth
**fetus** (FEE-tuhss): a baby or an animal before it is born, at the stage when it is developing in its mother's womb
**fission** (FISH-uhn): when an atom is split into two smaller atoms
**flood plain** (fluhd plane): an area of low land near a stream or river that easily floods
**foliage** (FOH-lee-ij): the leaves of a plant
**force** (forss): any action that changes the shape or movement of an object
**frequency** (FREE-kwuhn-see): the number of times something moves in a second
**friction** (FRIK-shuhn): when things rub against each other, it causes them to slow down
**frond** (frahnd): the green leaf-like part of a fern
**fuel** (FYOO-uhl): something that is used as a source of heat or energy, such as coal, wood, gasoline, or natural gas
**fuse** (fyooz): a device that stops electricity flowing when there is too much current
**fusion** (FYOO-zhuhn): when parts of two atoms join together to make a new atom
**gamete** (gam-EET): the male (sperm) or female (egg) reproductive cell of an organism
**gel** (gehl): a thick, jelly-like substance
**generation** (jun-uh-RAY-shuhn): the time between the birth of parents and the birth of their offspring
**genetic material** (juh-NET-ik muh-TIHR-ee-uhl): the cell parts that carry the biological instructions (chromosomes, genes, and DNA)
**genetics** (juh-NET-iks): the study of the ways that personal characteristics are passed along from one generation to another by genes
**geologic** (jee-o-LOJ-ik): having to do with the study of soil and rock
**geologist** (jee-OL-uh-jist): a scientist who studies rocks and the Earth's crust
**gill** (gil): the organ on a fish's side through which it breathes
**glacier** (GLAY-shur): a huge sheet of ice found in mountain areas and polar regions
**gravity** (GRAV-uh-tee): a force that pulls things toward Earth
**grid** (grid): a set of straight lines that cross each other to form a regular pattern of squares
**habitat** (HAB-uh-tat): a place or natural condition where a plant or animal lives
**haze** (hayz): smoke, dust, or moisture in the air that prevents you from seeing very far
**hearing aid** (HIHR-ing ayd): a device to help a person hear
**hemisphere** (HEM-uhss-fihr): one half of a sphere such as the Earth or a planet
**herbaceous** (hur-BAY-shus): non-woody plants
**herbivore** (HER-buh-vor): a plant-eating organism
**hormone** (HOR-mohn): a chemical substance produced in body glands that controls growth and development
**humanoid** (HYOO-min-oyd): having human-like characteristics
**hypothesize** (hye-POTH-uh-size): to make a temporary prediction or educated guess about the cause or outcome of an event



**ice cap** (eyess kap): a mound of ice that covers an area of land
**inactive** (in-AK-tiv): a volcano that is not currently active or erupting
**incision** (in-SIZH-uhn): the act of cutting into the body for surgical purposes
**incisor** (in-SIZH-ur): a front cutting tooth
**incomplete** (inn-cuhm-PLEET): not finished or missing parts
**inertia** (in-UR-shuh): an object at rest will stay at rest and an object in motion will stay in motion, unless acted on by an outside force
**infection** (in-FEK-shuhn): an illness caused by bacteria or viruses
**inflatable** (in-FLEY-tuh-buhl): an object that can be filled with air
**inherit** (in-HER-it): passed down through genes from parent to child
**insulation** (in-suh-LA-shuhn): material that keeps heat in or out
**insulator** (IN-suh-late-ur): a covering which prevents heat or electricity from escaping
**internal** (in-TUR-nuhl): inside the body
**International System of Units** (in-tur-NASH-uh-nuhl, SISS-tuhm, YOO-nitz): a standard way of measuring something
**involuntary** (in-VOL-uhn-ter-ee): done without a person's control
**irreparable** (ihr-REP-er-uh-buhl): not able to be repaired
**kinetic energy** (ki-NET-ik, EN-ur-jee): energy caused by movement
**landscape** (LAND-skape): a large area of land that you can view from one place
**larvae** (LAR-vee): insects at the stage of development between the egg and the pupa, when it looks like a worm
**larynx** (LA-ringks): the upper part of the trachea (windpipe) containing your vocal cords
**latex** (LAY-teks): the milky juice of the rubber tree
**Latin** (LAT-uhn): the language of the ancient Romans
**length** (lengkth): the distance from one end of something to the other
**lens** (lenz): a curved piece of glass or plastic
**lichen** (LYE-kuhn): plant composed of a fungus and an algae
**light** (lite): a form of energy
**lunar** (LOO-nur): to do with moons
**logic** (LOJ-ik): thoughtful and accurate reasoning or thinking
**lungs** (LUHNGSS): a pair of bag-like organs inside many animals' chests that they use to breathe
**lymph node** (limf noad): small organs that hold the colorless liquid lymph that bathe your cells and tissues
**machine** (muh-SHEEN): a device or tool that uses energy to make work easier
**magnet** (MAG-nit): a metal object that pulls iron or steel toward it
**mass** (mass): the amount of physical matter that an object contains
**mate** (mate): to join together for reproduction
**matter** (MAT-ur): anything that takes up space and has mass
**measure** (MEZH-ur): to find out the size, capacity, weight, etc. of something
**measurement** (MEZH-ur-ment): saying how big something is, how much it weighs, or how hot it is
**membrane** (MEM-brayn): a very thin layer of tissue that lines or covers organs

or cells
**merge** (murj): to join together to become one thing
**meristem** (MEH-reh-stem): plant cells at the tips of roots and stems, and under the bark, where growth can occur
**metabolism** (muh-TAB-uh-liz-uhm): the process of changing food, water, and oxygen into energy and body cells
**Metric System** (MET-rik, SISS-tuhm): a system of measurement based on tens that uses basic units such as the meter, liter, and gram
**microscopic** (mye-kruh-SKOP-ik): too small to be seen without a microscope
**microwaves** (MYE-kroh-waves): waves that can go through a solid object
**mineral** (MIN-ur-uhl): a natural substance, such as gold, quartz, or copper, that is not a plant or animal
**mitochondria** (mitt-oh-KAHN-dree-uh): a cell structure that takes energy from nutrients and makes it available for other cell processes
**mixture** (MIKS-chur): something consisting of different things mixed together
**moisture** (MOIST-chyer): the amount of water in the air
**molar** (MOH-lur): a broad, flat grinding tooth at the back of the mouth
**molecule** (MOL-uh-kyool): the smallest part of a substance that displays the characteristics of that substance
**momentum** (moh-MEN-tuhm): the force of something when it is moving
**motion** (MOH-shuhn): when something is moving
**mucus** (myoo-kuhss): a slimy fluid that coats and protects your mouth, nose, throat, and breathing passages
**native** (NAY-tiv): an animal or plant that originally lived or grew in a certain place
**navigate** (NAV-uh-gate): to travel using maps, compasses, or the stars as guides
**negative charge** (NEG-uh-tive, charj): one of the two kinds of charges, positive and negative, that go in opposite directions in an electrical current
**neutral** (NU-trel): neither positive or negative
**normal** (NOR-muhl): usual or regular
**nuclear** (NOO-klee-ur): to do with the energy created by splitting atoms
**nuclear energy** (NOO-klee-ur, EN-ur-jee): energy made when an atom breaks apart
**nuclear fusion** (NOO-klee-ur FYOO-zhuhn): the release of energy when atoms are combined, or fused, together
**nucleus** (NOO-klee-uhss): center section of either an atom or cell
**number** (NUHM-bur): a word or symbol used for counting and for adding and subtracting
**numeral** (NOO-mur-uhl): the symbol that represents a number, such as 4 or IV
**nurture** (NUR-chur): to take care of
**nutrient** (NOO-tree-ehnt): a necessary substance found in foods
**observation** (ob-zur-VAY-shuhn): when scientists watch what they are studying very carefully and write down what they see
**observatory** (uhb-ZUR-vuh-tor-ee): a building that has telescopes and other instruments astronomers use to study the sky
**organ** (OR-guhn): a part of the body that does a specific job
**organic** (or-GAN-ick): carbon-containing substance remaining after a living thing has died



**organism** (OR-guh-niz-uhm): a living plant
**ovary** (OH-vur-ee): the female structure that contains egg cells
**oxygen** (OK-suh-juhn): a colorless gas component of air
**paleontologist** (pay-lee-uhn-TOL-uh-jist): a scientist who studies fossils
**parasite** (PAIR-uh-site): an animal or plant that gets its food by living on or inside another animal or plant
**particle** (PAR-tuh-kuhl): an extremely small piece or amount of something
**passive** (PASS-iv): to let something happen without a fight or resistance
**pesticide** (PESS-tuh-side): a chemical used to kill pests, such as harmful insects
**phenomenon** (fe-NOM-uh-nom): an event or a fact that can be seen or felt
**phloem** (FLOW-uhm): tubular cells in plants that carry food from leaves to roots
**photons** (FOH-tons): particles or small pieces of light energy
**physics** (FIZ-iks): the study of matter and energy
**pistil** (PIS-tuhl): the female structure at the center of a flower
**plane** (plane): a flat surface
**planks** (plangks): a piece of lumber that is cut thicker than a board
**plankton** (PLANK-tuhn): microscopic algae and protozoa that live in the ocean
**poacher** (POHCH-ur): a person who hunts or fishes illegally
**pole** (pohl): one of the two points that are farthest away from the equator, the North Pole or the South Pole
**pollen** (PAH-lehn): the male cells of flowering plants
**pollinate** (POL-uh-nate): to carry or transfer pollen from the stamen to the pistil of the same flower or another flower
**pollination** (pah-luhn-AY-shun): the transfer of pollen from one flower to another
**pollution** (puh-LOO-shuhn): harmful materials that damage or contaminate the air, water, and soil
**population** (pop-yuh-LAY-shuhn): the total number of people who live in a place
**positive charge** (POZ-uh-tive, charj): one of the two kinds of charges, positive and negative, that go in opposite directions in an electrical current
**potential energy** (puh-TEN-shuhl, EN-ur-jee): stored energy
**preservation** (pres-ur-VA-shuhn): to protect something so that it stays in its original state
**pressure** (PRESH-ur): the force of one object pushing on another
**prism** (PRIZ-uhm): a plastic or glass shape that separates light into the colors of the spectrum
**probe** (prohb): a tool or robotic spacecraft used to explore something
**properties** (PROP-ur-tee): special qualities or characteristics of something
**pupa** (PYOO-puh): an insect at the stage of development between a larva and an adult
**quantity** (KWAHN-tuh-tee): an amount or number
**rabies** (RAY-beez): a viral disease that attacks the nervous system transmitted by the bite of an infected bat, dog, raccoon, or such
**radiation** (ray-dee-AY-shuhn): the sending out of rays of light, heat, or particles
**radioactive decay** (ray-dee-oh-AK-tiv, di-KAY): when the center of an atom breaks apart
**rain forest** (RAYN FOR-est): a lush, moist forest with many kinds of plants and animals

**reaction force** (ree-AK-shuhn, forss): a force that reacts against a force being put on it
**recessive** (ree-SESS-iv): tending to recede, to stay in the background
**reflect** (ri-FLEKT): when light bounces or bends off a surface
**reflex** (ree-FLEKS): an automatic action without a person's control
**refract** (ri-FRAKT): when light is bent as it passes through different materials
**regular** (REG-yuh-lur): happening or reoccurring at the same time
**resistant** (re-ZIS-tent): having the ability to withstand
**resource** (REE-sorss): something valuable to a place or a person
**respond** (ri-SPOND): to react to something
**revolve** (ri-VOLV): to orbit around an object
**rhizoid** (RYE-zoyd): tiny, hair-like structures that hold mosses, ferns, and liverworts to the rocks, logs, or soil that they grow on
**ridge** (rij): a narrow raised strip
**rotate** (ROH-tate): an object turning around and around its center point or axis; to turn around and around like a wheel
**salt** (sawlt): a chemical compound formed from an acid and a base
**satellite** (SAT-uh-lite): a moon or other heavenly body that revolves around, or orbits, a larger heavenly body
**science** (SYE-uhnss): studying nature and the physical world by testing, experimenting, and measuring
**segment** (SEG-muhnt): a part or section of something
**sexual** (SEX-you-uhl): reproduction with eggs and sperm, or pollen cells
**shed** (shed): to fall out, to give off
**solar** (SOH-lur): to do with the Sun
**specimen** (SPESS-uh-muhn): a sample or an example used to stand for the whole group
**sphere** (sfihr): a symmetrical geometric shape like a ball, all points on the shape are the same distance from the center
**stable** (STAY-buhl): firm and steady
**stamen** (STAY-mehn): the male flower structure that is composed of an anther at the tip of a long, thin filament
**static electricity** (STAT-ik, i-lek-TRISS-uh-tee): electricity that builds up on an object and does not flow
**strain** (strayn): a variety or kind
**strand** (strand): something that looks like a thread or string
**subatomic particles** (suhb-a-TOM-ik, PART-tuh-kuhls): the smaller parts of an atom including the protons, neutrons, and electrons
**successive** (suhk-SESS-iv): following in a logical or sequential order
**suffer** (SUHF-ur): to experience pain, discomfort, or sorrow
**supersonic** (soo-per-SON-ik): traveling through air faster than the speed of sound
**surface** (SUR-fiss): the outside or outermost layer of something
**surgical instruments** (SUR-ji-kuhl IN-stre-ment): tools used for scientific or medical purposes
**symbol** (SIM-buhl): a design or object that represents something else
**synapse** (SIN-apse): the junction across which a nerve impulse passes from one axon to another, or from an axon to a muscle cell



**synthetic** (sin-THET-ik): something that is man-made
**temperature** (TEM-pu-uh-chur): the degree of heat or cold in something
**terminal** (TUR-muh-nuhl): ending
**tetanus** (TET-nuhss): a bacterial disease that causes your muscles to become rigid. It can be fatal.
**theory** (THIHR-ee): an idea that explains how or why something happens
**thorax** (THOR-aks): the part of an insect's body between its head and its abdomen
**threatened** (THRET-uhnd): animals and plants likely to become endangered in the near future
**topiary** (TOH-pee-air-ee): a hedge that is trimmed in the shape of some object or animal
**topsoil** (TOP-soil): the top or surface layer of soil
**toxin** (TOK-sin): a poisonous substance
**trait (trate):** a quality or characteristic that makes one person or thing different from another
**transmitted** (trans-MIT-ted): to send forward, to pass on or communicate
**transplant** (TRANSS-plant): to surgically replace a diseased organ with a healthy one
**trench** (trench): a long, narrow ditch
**tropisms** (TROP-izmz): plant growth movements
**turbine** (TUR-bine): a machine that uses steam, water, or gas to create energy and is often used in jet engines
**undesirable** (uhn-di-ZYE-ruh-buhl): not wanted, not pleasant
**Universe** (YOO-nuh-vurss): everything that is in space including the Earth, stars, and planets
**vacuum** (VAK-yuhm): a sealed place from which air has been emptied
**valley** (VAL-ee): an area of low ground between two hills or mountains
**vapor** (VAY-pur): fine particles of mist or steam
**varied** (VAIR-eed): changed or altered
**vascular** (VASS-kyoo-lur): having a network of blood vessels
**venom** (VEN-uhm): a poison produced by some snakes and insects
**vertebrae** (VUR-tuh-bray): the individual bones of the spine
**vertebrate** (VUR-tuh-brate): any animal that has a backbone
**via** (vye-uh): by way of
**vinyl** (VAYHN-l): a type of plastic
**visible spectrum** (VIZ-uh-buhl, SPEK-truhm): the colors you can see; the colors of the rainbow (red, orange, yellow, green, blue, indigo, and violet)
**volt** (vohlt): a unit used to measure the electrical force in a battery
**wild** (WILDE): natural or not tamed by humans
**wind resistance** (wind ri-ZISS-tuhnss): a force that pushes against another object
**work** (wurk): a force acting on an object to move it across a distance
**xylem** (ZIE-luhm): tubular cells in plants that carry water and nutrients from roots to leaves