SCIENCE BACKGROUND—*Properties of Matter*

Matter is anything that has **mass** and takes up space. **Atoms** are the fundamental building blocks of all matter. An atom is the smallest particle of an **element** that can exist and still have the properties of that element.

An element is a substance than cannot be broken down any further into other substances. There are more than 100 known elements ranging from hydrogen (the most abundant element in the universe) to oxygen (the most abundant element on Earth) to rare elements that have been made only in the laboratory.

Elements combine to form **compounds.** For example, water, the most abundant compound on Earth, is a compound of hydrogen and oxygen. The smallest possible amount of a compound is called a **molecule.** One molecule of water is made of two atoms of hydrogen and one atom of oxygen (H_2O).

Although an atom is the smallest possible amount of an element, atoms themselves can be broken down into subatomic particles, known as electrons, protons, and neutrons.

Protons and neutrons make up the **nucleus,** or center, of an atom. Each atom also has a certain number of **electrons**—negatively charged particles that move around the outside of the nucleus. Electrons are arranged in successive energy levels. **Protons** are positively charged. The number of protons in an atom is equal to the number of electrons, making the atom neutral. **Neutrons** have no charge. Usually, atoms of a given element have the same number of neutrons, but some do not. Those that do not are called **isotopes** of that element.

Matter has basic physical and chemical properties. **Physical properties** are those that can be measured without changing the basic identity of the substance. Some physical properties are malleability, ductility, mass, volume, buoyancy, and density.

The first property of matter that students explore is density. Density is the mass per unit volume of a substance. As long as the volume and mass of an object can be measured, either directly or indirectly, the density of the object can also be determined. Density is a characteristic physical property of a substance.

Chemical properties are those that describe how a substance may change or **react** to form new substances. Some chemical properties are combustibility, reactivity, and stability.

Matter exists in one of three phases or states: solid, liquid, or gas. A **solid** has a definite volume and a definite shape. A **liquid** has a definite volume, but not a definite shape. A **gas** has neither a definite volume nor a definite shape. A gas will fill whatever size and shape container it is put into.

Gas molecules bounce off the walls, creating pressure inside the container. Gas molecules can spread out or be pushed close together. The closer the molecules, the greater the number that hit the walls of the container—and the greater the pressure. This inverse relationship between volume and pressure of a gas at a given temperature is known as Boyle's law.

For a given substance, molecular activity increases as the phase changes from solid to liquid to gas. Energy related to movement is called kinetic energy. **Temperature** is a measure of the average kinetic energy of a substance. The more active the molecules, the higher the temperature. Absolute zero is the temperature at which all molecular motion ceases. **Heat** is the amount of energy transferred from one system to another due to differences in temperature.

Sometimes different kinds of matter can be mixed together without being changed. A **mixture** consists of two or more substances that are physically—but not chemically—combined. Each substance retains its own properties.

Mixtures may be **homogeneous,** that is, all of the dissolved particles are evenly distributed, so that the mixture looks the same throughout. Homogeneous mixtures are also called **solutions.** In a solution, the substance that is dissolved is called the **solute.** The substance in which the solute is dissolved is called the **solvent.** Mixtures can be separated by taking advantage of the different physical properties of the components. For example, a salt solution can be separated by evaporating the water, which leaves behind the salt.

Mixtures may also be **heterogeneous.** For example, orange juice contains larger particles that settle out, so that the mixture does not look the same throughout. The substances in a heterogeneous mixture can be separated by filtration.

These are both examples of **physical changes,** processes in which a substance changes its appearance but not its basic identity. **Phase changes**—that is, changes of state—are always physical changes.

A **chemical change** occurs when atoms are rearranged and a new product (or products) is formed. The resulting compound is held together by **chemical bonds.** The chemical bonds between atoms may be ionic or covalent.

Ionic compounds are compounds that form when electrons are transferred from one atom to another. Ionic compounds, therefore, are usually made up of an element that loses electrons easily (like metals) and an element that gains electrons easily (like nonmetals). Ionic compounds are good conductors of electricity because they form charged particles, or ions, when dissolved in water.

In **covalent compounds,** atoms share their electrons with other atoms in the compound. A molecule is made up of two or more atoms held together by covalent bonds. Covalent compounds do not conduct electricity because they do not form ions in water.

Organic compounds are complex compounds that contain carbon and are found in, or originate from, living things. One of the simplest types of organic compounds, hydrocarbons, contains only carbon and hydrogen atoms. **Hydrocarbons,** as well as other kinds of molecules, may have the same chemical formula but different molecular shapes. These are known as **isomers.** The chemical properties of isomers differ because the shape of a molecule affects its properties.

Another group of chemicals is acids and bases. **Acids** are compounds that produce hydrogen ions (H+) in water. **Bases** are compounds that produce hydroxide ions (OH-) in water. Acids and bases are measured on a **pH scale,** which ranges from 0 to 14. The higher the concentration of hydrogen ions, the lower the pH and the stronger the acid. The greater the concentration of hydroxide ions, the higher the pH and the stronger the base. When a solution has equal numbers of hydrogen and hydroxide ions, the solution is neutral and has a pH of 7. When acids and bases are mixed together in the proper amounts, they neutralize each other to produce water and a salt.

Oxidation is a chemical reaction that occurs when a substance is exposed to oxygen. An oxidation reaction occurs when iron is exposed to oxygen, producing iron oxide, better known as rust.

SCIENCE BACKGROUND—*Plants*

Green plants, photosynthetic protists, and blue-green algae directly or indirectly feed most living things on Earth. They do this through **photosynthesis**—the making of **glucose**, a simple sugar, from water, carbon dioxide, and light energy. In addition, these organisms take in the carbon dioxide that most animal cells give off during **cellular respiration**, and provide the oxygen needed by animal cells for this same process.

The overall chemical reaction of photosynthesis can be expressed by the following equation:

$$\text{Carbon dioxide} + \text{Water} \xrightarrow{\text{light, chlorophyll}} \text{Glucose} + \text{Oxygen}$$

This equation states, "Carbon dioxide plus water combine to form glucose and oxygen in the presence of light and chlorophyll." The **chlorophyll**, or green pigment, in plants absorbs light energy. The energy is needed to split the water molecules and begin the construction of the glucose molecules.

This process appears relatively straightforward. However, photosynthesis is not just one reaction. It is a series of reactions, each of which is controlled by a different enzyme.

Cellular respiration is characterized as the reverse of photosynthesis. It can be expressed by the following equation:

$$\text{Glucose} + \text{Oxygen} \rightarrow \text{Carbon dioxide} + \text{Water}$$

This process releases the energy in glucose and makes it available to the cells. Plant, as well as animal, cells must undergo respiration in order to function. Photosynthesis, however, is the process we are most familiar with in plants. In addition, it provided the oxygen that animals need to survive.

SCIENCE BACKGROUND—*Magnetism and Electricity*

A **magnet** is an object that attracts other magnetic materials, such as iron, or materials that contain them, such as steel. This attractive force is called **magnetism.** Magnetism is a natural physical property that was first discovered by the ancient Greeks. In 600 B.C.E. Thales of Miletus wrote of rocks that attracted bits of iron and that were both **attracted** and **repelled** by other similar rocks. The rocks were located near the town of Magnesia. Today we know that the rocks contained the mineral magnetite (Fe_3O_4), an iron oxide also known as lodestone. The most common magnetic materials are iron, cobalt, and nickel.

Magnets share certain characteristics: (1) a magnet can attract magnetic materials; (2) every magnet has two **poles** that are equal in strength; (3) a magnet's force is strongest at its poles; (4) like poles repel and unlike poles attract (The Law of Magnetic Attraction); and (5) each magnet is surrounded by an invisible force, called its **magnetic field,** which can act on a magnetic object from a distance. The invisible magnetic field of a magnet can be observed by sprinkling iron filings on a sheet of paper covering the magnet. The filings line up along the **field lines,** which show the direction and strength of the **magnetic force.**

When a magnetic material, such as a nail that contains iron, is exposed to a bar magnet, the nail becomes a **temporary magnet** and is attracted to the bar magnet. A temporary magnet loses its magnetization when removed from a magnetic field. When the nail is removed from the bar magnet's magnetic field, it loses its magnetization.

A **permanent magnet,** however, will retain its magnetization after removal from the magnetic field. Permanent magnets can occur naturally, for example, lodestone. They can also be created by exposing a magnetic material to a very strong magnetic field. If you have a horseshoe-shaped magnet in your classroom, it was probably made in this way. Even a "permanent" magnet may not last forever. Hitting it, dropping it, or heating it above a certain temperature, called the **Curie temperature,** can cause a magnet to lose all or part of its magnetism.

Although today it is well known that magnetism and electricity are linked, this fact was not established until the nineteenth century. In 1820 Hans Christian Oersted discovered that an electric current naturally produces a magnetic field. Ten years later Michael Faraday discovered that the opposite was true as well. An electric current can be induced in a wire by passing it through a magnetic field. These fundamental principles are called **electromagnetism.**

At its most basic level, magnetism is the result of electrons moving about the nucleus of an atom. The moving electric charges approximate a small electric current, which generates a tiny magnetic field. The magnetic field of the electrons in a region can merge to form a larger magnetic field called a **domain.** When the domains are aligned, the material exhibits magnetic properties and is considered magnetic. When the domains are not aligned, the material does not exhibit magnetic properties and is not considered magnetic.

Earth acts like a giant magnet. The swirling molten iron in the outer core acts like an electric dynamo, generating Earth's magnetic field. A **compass** is a magnetized needle mounted on a pivot so that it can swing freely to align itself with Earth's magnetic field. The magnetized needle in the compass responds to Earth's magnetic field in the same way that iron filings respond to a smaller magnet. Just like any magnet, Earth also has north and south magnetic poles, which are different from its geographic poles, the northern and southern tips of the axis around which Earth rotates.

Electromagnetism makes possible the use of powerful electromagnets. An **electromagnet** is made by coiling a wire around an iron core. When an electric current is run through the wire, the magnetic field it produces magnetizes the iron core. More coils around the iron core produce a stronger magnetic field and, therefore, a stronger electromagnet. The major difference between magnets and electromagnets is that the magnetism produced by the electromagnet can be turned on and off. When the current is switched off, the magnetic field also is turned off and the magnetization disappears. An electromagnet is a temporary magnet.

The relationship between electricity and magnetism forms the basis of the **electric motor** and the **generator.** An electric motor converts electricity to mechanical energy. A generator converts mechanical energy to electricity.

Electric motors accomplish this energy conversion through the interaction of an electromagnetic field and a magnetic field. In their simplest form, motors are a single coil of wire that, when connected to an electrical energy source, creates an electromagnetic field. This field interacts with the magnetic field of a stationary permanent magnet. The attraction and repulsion between the two fields creates a torque on the coil of wire causing it to rotate. Thus the electrical energy is converted to mechanical energy. In a more complex motor, the coil of wire is attached to a drum that rotates within the field of the permanent magnets. The interaction of the two magnetic fields causes the drum to rotate. The advantage of this motor is that a pulley can be attached and used to lift or pull an object.

A generator operates on the opposite principle. It uses mechanical energy to spin a coil of wire within a magnetic field. This induces an electric current in the wire. Similarly, a magnetic field can be spun around a wire to induce a current in the wire. Hydroelectric generators and dams, which generate much of this country's electricity, use the latter method. At these facilities, the release of water, previously dammed in a reservoir, provides the source of mechanical energy used to spin giant magnet-containing turbines past copper coils. This induces an electric current in the copper wires.

In this Broward County Hands-On Science program, students will learn that magnets are much more than just objects that hold notes against refrigerator doors. Electromagnetism, made possible by magnets, has many important applications in our technological society including motors, solenoids, and generators.

SCIENCE BACKGROUND—*Solar Energy*

Solar energy is the energy generated by the star in our solar system known as the Sun. The Sun is an immense sphere of hot, glowing gas more than 100 times the diameter of Earth. The temperature at the core of the Sun is estimated to be about 15 million degrees Celsius (27 million degrees Fahrenheit), while the temperature at the surface of the Sun is estimated to be about 6,000°C (11,000°F). The distance between Earth and the Sun is about 93 million miles.

The Sun gives off energy in the form of electromagnetic radiation. This energy emanates from the Sun in all directions. Only one two-millionth of the total solar electromagnetic radiation is received by Earth, but without this solar energy, Earth would be a cold, lifeless planet.

Once the solar energy reaches Earth, about one-third of it is reflected by clouds, deserts, and snow fields. The other two-thirds is absorbed by water in the atmosphere, by land and water masses on Earth's surface, and by plants.

When water on Earth's surface is heated by solar energy, the water molecules near the surface of the water are released into the air as water vapor. This process is known as evaporation. As this water vapor rises through the atmosphere, it encounters cooler air, causing the water molecules to join with other water molecules and form water droplets. This process is known as condensation. These droplets join together with other droplets to form fog and clouds and, eventually, fall back to Earth as precipitation (rain, sleet, and snow).

In a process called photosynthesis, plants use solar energy to convert water obtained from the soil and carbon dioxide obtained from the air into food. This food is used to fuel plant growth and maintenance. Because all animals eat either plants or other animals that eat plants, solar energy can be considered the ultimate source of all life on Earth.

The absorption of solar energy is affected by many variables. The most important of these is the angle at which the rays of sunlight strike Earth's surface. The more direct the rays, the more likely the solar energy is to be absorbed by the surface it strikes, and the less likely it is to be reflected. It is wintertime in the northern hemisphere when the rays of sunlight striking Earth are least direct (at their most angled). As a result, temperatures are at their lowest point of the year.

People have become increasingly aware of the costs of fuels used in the production of heat and electricity. This awareness has led to the research and development of devices that can be used to collect, store, and convert solar energy into usable energy. For example, **solar collectors** are now commonly used to heat water in schools, offices, and homes. Large solar concentrators transfer heat energy collected during the day to underground basalt blocks where it is stored and then released for use at night. **Solar cells** also convert solar energy to the electrical energy needed to power household systems and appliances.

Solar cells are constructed from thin layers of semiconductor materials. (One of the properties of semiconductor materials is their ability to release electrons to an adjoining layer of metal when exposed to sunlight.) This produces a voltage, which causes a small electric current. Many solar cells are needed to produce a larger current. Improvements in solar cell design, as well as reductions in the cost of their production, are making it more cost-effective to directly convert solar energy to electricity.

SCIENCE BACKGROUND—*Work and Machines*

A **force** is a **push** or **pull** on an object. **Work** is performed when an object moves as a result of a force acting upon it. If a force is exerted on an object (such as a wall) and the object does not move, then no work is done. This principle is expressed in the following equation:

Work = Force × distance

Machines are devices that help people do work; they may be complicated, requiring electricity or fuel to operate, or they may be quite simple, requiring only the force provided by a human being or an animal. Regardless, machines make doing work easier because they change either the magnitude or the direction of the force that is applied. If a machine magnifies an input force, it is said to confer a mechanical advantage. All six types of **simple machines** that students will examine in this module enable a person to either transfer, modify, or change the direction of an applied force.

Levers are one type of simple machine. All levers consist of four components: an **arm,** a **fulcrum** (the pivot point), a **load** (the object to be moved), and an **effort** (the force needed to move the load). The positioning of these components can be manipulated to increase the mechanical advantage. A good example of a lever is the playground seesaw.

Friction is a force that opposes **motion** when two surfaces come in contact with each other. Regardless of how it may feel, no surface is perfectly smooth. When two surfaces rub against each other, the roughness—the tiny bumps, craters, and splinterlike projections—of one surface "catch" on the roughness of the other surface, resulting in friction. **Lubricants** are substances that reduce friction by allowing the contacting surfaces to slide on the lubricant rather than on each other.

One of the world's most important inventions was that of the **wheel.** The wheel reduces the amount of friction between the surfaces of two objects as one passes by the other.

An **axle** is a shaft inserted into the center of a wheel. An axle is fixed to the wheel, and is smaller in diameter than the wheel. Each time the axle makes a complete revolution, the wheel makes a complete revolution, and vice versa. The **wheel and axle** is a second type of simple machine.

Traction is a type of friction that is beneficial in accomplishing work. Traction, or moving friction, is the amount of contact between two surfaces necessary for one surface to travel across the other. Increased traction between the wheels of a vehicle and the surface over which they travel will reduce the amount of slippage of the wheels over the surface, thereby increasing the amount of work accomplished for the force applied.

A **gear** is a toothed wheel. When effort is applied to a gear (the **driving gear**), whose teeth mesh with another gear (the **driven gear**), the force is transferred to the driven gear, causing the driven gear to turn. A driven gear turns in the opposite direction of the driving gear. **Gear ratio** is the ratio of the number of rotations of the driving gear to driven gear. For example, a gear ratio of 1:5 indicates a driving gear that is five times the size of the driven gear, so that for every rotation of the driving gear, the driven gear rotates five times.

A third type of simple machine is the **pulley.** The pulley is similar to the wheel and axle except that the pulley's wheel rotates around a stationary axle. The outer rim of the pulley is grooved to accommodate a rope or chain. Using a pulley, the direction of force can be changed, even reversed, so that pulling down on a rope around a pulley raises an object attached to the other end of the rope.

The fourth type of simple machine is the **inclined plane.** An inclined plane is a simple machine that does not move; it is a ramp connecting a lower elevation to a higher elevation. The same amount of work is performed when pulling an object up an inclined plane as when lifting an object straight up. The advantage of using an inclined plane is that less force is needed because the object is moved over a greater distance.

Close inspection of a **wedge**—a fifth type of simple machine—reveals two inclined planes placed back to back. Wedges are used to split solid objects or to separate two objects from each other. When force is applied to the wide end of the wedge, the narrow end of the wedge is driven into the object, widening the opening and allowing the wedge to penetrate deeper with each application of force.

The sixth type of simple machine, a **screw,** is actually an inclined plane wrapped around a cylinder. The protruding inclined plane on the shaft of the screw is known as the threads.

Simple machines not only help us do work, they can also be used as art. A **mobile** is an assembly of delicately balanced levers suspended from above by a thread or wire. The fulcrum of the bar holding the different objects is moved to one side or the other so that objects of different weights balance each other.

SCIENCE BACKGROUND—*Forces and Motion*

Long before being knighted for his remarkable advances in the fields of both physics and mathematics, Sir Isaac Newton (1642–1727) was a curious child who was mechanically inclined. When he grew up, these traits helped him revolutionize the way science is studied today. Newton was famous for building experimental equipment (and for often inventing the tools that were needed) in order to answer his many questions about the natural world. When Newton was in his early twenties, he discovered the law of universal gravitation and his laws of motion. He also developed an entirely new type of math called calculus. He studied optics and was the first to prove that colors combine to make white light. The physics of motion that Newton developed, called Newtonian mechanics, transformed the understanding of objects in motion from the smallest marbles on Earth to the largest planets in the solar system.

In the third century B.C.E., a Greek mathematician named Aristotle had tried to figure out the connection between **force** and **motion.** Aristotle believed that the natural state of an object was at rest and that a force was needed to keep an object in motion. Both of these assumptions are reasonable because they are supported by our everyday observations of the world around us. However, Aristotle was not considering all the forces acting on an object. He was not accounting for friction. When two bodies are in contact with each other, they exert forces on each other due to the interaction of the molecules in one body with those in the other. The contact force exerted by one object on another is called a **frictional force.**

In the early 1600s, Galileo Galilei (1564–1642) decided to reexamine Aristotle's view about objects at rest and in motion. After many experiments rolling objects down inclined planes, Galileo came to the conclusion that it was equally natural for an object to be in motion as to be at rest.

When a moving object slows down, it is because a force, such as friction, is acting on it. In order to keep an object moving while friction is at work, another, opposite force must be applied. This is why it seemed to Aristotle that a constant force was needed to keep an object in motion.

Galileo is thus credited with the development of the concept of **inertia**—the tendency of an object to remain at rest or continue in the same direction, at the same speed, until a force, such as friction, is applied to it.

Isaac Newton was born the year that Galileo died. Several years later, as a young man, he picked up where Galileo had left off. Newton gave much credit to Galileo's idea of inertia and the role it played in the formulation of his first law of motion.

Newton's First Law of Motion. An object continues in its initial state of rest or motion with uniform velocity unless acted on by an unbalanced external force. **Velocity** is the measure of an object's speed and direction. This is also called the **law of inertia.**

Newton's Second Law of Motion. The acceleration of an object is inversely proportional to its mass and directly proportional to the resultant external force acting on it (force = mass × acceleration).

Newton's Third Law of Motion. Forces always occur in pairs. If Object A exerts a force (called an **action force**) on Object B, an equal but opposite force (called a **reaction force**) is exerted by Object B on Object A.

One property of a moving object is **momentum.** Momentum equals the mass of an object multiplied by its velocity. Momentum is not a force, but it is an indication of the force with which an object could act, for example, in a collision. For two objects that interact with only each other, the total momentum of the pair remains constant in time. This concept is called **conservation of momentum.**

Another law of conservation is that of energy. **Energy** is the ability to do work. **Work** is done when a force causes an object to move a distance. Energy has many forms, such as mechanical, thermal, nuclear, light, electrical, and chemical, and is constantly flowing and changing form. The **law of conservation of energy** states that energy can never be created or destroyed, only changed from one form to another. The amount of energy in a closed system remains constant over time.

A ball rolling down a track is an example of a closed system. At the top of the track, the ball has **potential energy.** This is energy possessed by an object because of its position or height. Because work was done to move the ball to a height, it now has an equivalent amount of energy. As the ball rolls downward, that energy is released and is capable of doing work. Its potential energy is converted to **kinetic energy**, or energy possessed by an object because of its motion. The ball also loses some energy to friction and heating of the track. However, this energy was not destroyed. It remains part of the system and is therefore conserved.

Many forces can be involved when an object falls. The predominant force is gravity. The famous story of how Isaac Newton discovered gravity—after being hit on the head by a falling apple—is most certainly just that, a story. However, a falling apple may have inspired him in his thinking about what forces act on a falling object, which led to his discovery of the **law of universal gravitation.**

The law states that every particle of matter attracts every other particle of matter. The greater the particles' masses and the closer they are, the stronger the attraction. This attraction, called **gravity**, affects everything from apples hanging in trees to the Moon orbiting Earth, and even astronauts in space.

Astronauts in the space shuttle are seen "floating" about with no floor to stand on. Why is this floating sensation experienced in orbit? Many people believe it is because the astronauts are so far from Earth's gravitational pull, but this is not the reason. The same gravity force that keeps you in your chair also keeps the astronauts, and the Moon, in orbit. If Earth's gravity were turned off, orbiting astronauts, and everything else held by Earth, would fly off into interplanetary space.

The shuttle is falling toward Earth just as you would be if your chair suddenly broke. But the shuttle is traveling so fast (8 km/sec) that Earth curves away from it as it falls. If the shuttle were not continually falling toward Earth, its horizontal velocity would send it flying away from our planet. The astronauts are just falling around Earth without ever reaching the ground (until they slow their speed and come in for a landing).

The best term to describe the astronaut's condition is **free fall** because that is what the astronaut is doing. **Microgravity** is the official NASA term for this free fall experience.

When a force is applied to an object and the object moves, **work** is accomplished (work = force × distance). Machines are devices that help us do work by moving things easier, faster, or farther. **Simple machines** are the basic components of which all other machines are made. They include the lever, wheel and axle, pulley, inclined plane, wedge, and screw. The **mechanical advantage** of a machine is the ratio of the output force to the input force. The **efficiency** of a machine is a measure of how much work input is changed to useful work output.

SCIENCE BACKGROUND—*Movement of Earth and the Moon*

Astronomy is the oldest of the sciences. Our earliest ancestors examined the skies and tried to understand the daily, monthly, and yearly cycles that they observed. This understanding was a matter of survival. They needed to predict dawn and dusk, seasonal changes, tides, and other phenomena in order to plan for planting, hunting, fishing, migration, and defense.

Thousands of years later, we still experience the celestial bodies in very much the same way our ancestors did, making the exploration of the sky a part of our common heritage as inhabitants of planet Earth.

The apparent size and distance of objects in our **solar system** can be misleading. The **Sun** is more than 100 times the diameter of Earth and makes up more than 99 percent of the solar system's matter. Yet if we modeled the Sun to be 1 cm in diameter, Pluto would be located more than 40 m away.

The Moon is also much farther from Earth than it appears. In fact, the distance is about thirty times the diameter of Earth. The Moon's diameter, however, is less than one-quarter that of Earth, and its volume only about one-fiftieth of Earth's.

Historically, humans have struggled to understand their place in the universe. In ancient times, Earth was thought to be the center of the universe. The first to suggest that Earth instead revolves around the Sun was Aristarchus of Samos, an early Greek astronomer who lived from about 310 to 230 B.C.E.

Aristarchus reasoned that because the Sun is so much larger than the Earth, it was more likely that Earth **revolved** around the Sun. Later Greek astronomers, including Aristotle and Ptolemy, rejected his ideas. It would be almost 1,800 years before they were revived, by Nicolaus Copernicus, a Polish scientist who lived from 1473 to 1543. Just two months before his death Copernicus published his life's work: *De Revolutionibus Orbium Coelestium (On the Revolutions of the Heavenly Spheres)*.

In the Copernican model of the universe, Earth and all the other **planets orbit** around the Sun. His theory was disputed, but Copernicus was later proved right by Galileo Galilei (1546–1642), an Italian physicist, or what was then called a natural philosopher. Galileo was arguably the first modern scientist because he used mathematics, astronomy, and physics together with observational and experimental evidence to elucidate the laws of nature.

Galileo was the first to observe the planets through a telescope, and what he saw persuaded him that Copernicus was right. Around 1610, while observing Jupiter with his telescope, Galileo discovered four of the planet's moons, which are now called the Galilean moons. The moons were orbiting the planet roughly in the same plane, as predicted by Copernican theory.

In 1632 Galileo published a book titled *Dialogue Concerning the Two Chief World Systems*. Galileo was arrested for supporting the Copernican view and the book was banned. Galileo died in 1642 while still imprisoned, but eventually other scientists corroborated his observations and he and the **heliocentric** ("sun-centered") worldview were vindicated.

The most obvious effects of the relationship between Earth and the Sun are day and night. A **day** is the time it takes Earth to make one complete **rotation** on its **axis.** As Earth rotates on its axis, the side of Earth facing the Sun experiences day. Twelve hours later, when Earth has completed half a rotation, that same side experiences night. When a globe is placed outside and aligned with Earth, or **rectified,** all places on the globe that are in sunlight also are experiencing daylight on Earth.

Sundials make use of Earth's rotation to tell time. Since the shadow cast by a marker, or **gnomon,** is always directly opposite the position of the Sun, the gnomon's shadow can be used to monitor the change in the Sun's position throughout the day. If the sundial is numbered appropriately, one can know the time of day by observing on which number the gnomon's shadow falls.

During the course of a **year,** the length of days and position of the Sun in the sky from any point on Earth vary considerably. Though the Sun seems to change position in the sky, it is actually Earth that moves around the Sun. A year is the time it takes Earth to make one complete revolution around the Sun. The plane in which the Earth orbits the Sun is called the **plane of the ecliptic.** Earth's axis is tilted at a 23.5° angle relative to this plane. Because of this, sunlight shines directly perpendicular to the equator only on the **equinoxes** in March and September. The Sun appears lower in the sky during winter and higher during summer at the same time of day, which changes both the length of day and the angle at which sunlight strikes Earth. The shorter days and less-direct angle of the Sun's rays mean that less heat reaches those areas experiencing winter. Opposite conditions produce the heat of summer. The shortest and longest days of the year are the **solstices,** when the direct rays of the Sun strike Earth farthest south and north of the equator.

While Earth's cycles produce our daily and yearly schedules, months are based upon the motion of the Moon. The **lunar phases** result from how much of the lighted part of the Moon we see during its monthly orbit around Earth. During full Moon the entire side of the Moon visible from Earth is sunlit. During new Moon, the side we see is dark and the sunlit side is not visible to us at all.

Eclipses occur when shadows cast by one celestial object fall on another. They happen when the Sun, Moon, and Earth are all aligned. If the orbit of the Moon were not slightly inclined to the orbit of Earth, we would experience eclipses every month! Partial or total **solar eclipses** occur when the Moon passes between Earth and the Sun. Partial or total **lunar eclipses** occur when Earth passes between the Sun and the Moon.

The Moon influences Earth in ways far more significant than eclipses, however. The Moon's gravity creates a bulge, or high tide, in the ocean on the side of Earth facing the Moon. Centrifugal force associated with Earth's revolution around the center of gravity of the Earth-Moon system creates another bulge in the ocean on the opposite side of Earth. These two bulges are Earth's **high tides.** The areas between the bulges are **low tides.** The bulges remain in the same position relative to the Moon because that's where the forces are acting. However, Earth continues to rotate beneath these points. From the perspective of an observer on Earth, the tides move in and out, changing from high to low twice a day—but it is really the observer who is moving from tide to tide as the Earth rotates through the bulges.

Mariners learned the pattern of tides long ago. They also found that the motions of Earth are so regular that they could use the position of the stars in the sky to determine their ship's position on Earth. They set up a grid system using **longitude** and **latitude** lines. Latitude lines are parallel circles running east and west around the globe. Longitude lines are great circles that run north and south through both poles. By measuring the altitude of the North Star, mariners could calculate their latitude. By comparing local noon with a clock keeping Universal Time, they could calculate their longitude. This type of star-guided navigation is called **celestial navigation.**

SCIENCE BACKGROUND—*Resources and the Environment*

Pollution is the contamination of the **environment** by the introduction of substances—called **pollutants**—in quantities that are harmful to living things. Pollution takes many forms, from the yellow haze that hangs over a city on a hot, windless day, to the hundreds of miles of coastline smothered in crude oil after an oil spill, to the earth-shaking roar of a jet as it barrels down the runway. These are examples of **air pollution, water pollution,** and **noise pollution.**

Pollution can also be the result of natural Earth processes: the high concentration of pollen on a warm spring day; the smoke that envelops a town located downwind from a raging brush fire; the ash that blankets a village following the eruption of a nearby volcano.

Pollution is a cost associated with society's use of **energy.** Most of the energy we consume comes from **nonrenewable** energy sources. **Resources** are things taken from the living and nonliving environment to meet the needs and wants of a population. A nonrenewable resource is one that takes a very long time to replace. Coal is a nonrenewable resource. The coal burned today to make electricity began forming 300 million years ago — long before dinosaurs ever walked on Earth. Other **fossil fuels,** such as oil and gas, are also nonrenewable.

The limited supply of usable energy sources places great significance on the development of **renewable** energy sources. Renewable resources are those that are available in unlimited supply or that can be replaced in a shorter period of time. Wood is one renewable resource. It takes just dozens of years, not millions, to grow a tree. But that is still a long time. This is why **alternative energy sources,** such as wind and solar power, are being investigated.

The supply of resources can be extended through **recycling.** The familiar slogan "Reduce, Reuse, Recycle" reminds us of this important effort. Resources can also be extended through decreased use. This is called **energy conservation.** Every time we turn off a light that is not being used, we are practicing energy conservation. The less energy we use, the less we have to produce. And reduced energy production means reduced pollution.

Pollution can also result from ways in which humans alter the environment. These include **land use practices,** such as agriculture and mining, as well as the disposal of wastes, for example, in a **landfill.**

Pollution takes its toll in many ways. It causes people to curtail their outdoor activities by rendering certain areas—a pond, a field, or a beach—off-limits to the public due to contamination.

Pollution can also cause injury or illness, whether it's an allergic reaction to pollen, dust, and mold spores, gradual hearing loss due to exposure to loud noises, hepatitis contracted from drinking water **contaminated** by raw sewage, or labored breathing—even respiratory failure—caused by inhaling automobile exhaust, chemical vapors, and other noxious fumes. Infants, the elderly, and those suffering from chronic illness are especially vulnerable to the hazards of pollution.

Plants and animals suffer the effects of pollution just as much as, if not more than, people do. In fact, plants and animals are often the first to be adversely affected by pollution. Plants are especially susceptible to a type of pollution called **acid rain.** Acid rain forms when moisture in the air combines with nitrogen oxides or sulfur dioxides released when fossil fuels are burned. Scientists tell us that the disappearance of a species from an ecosystem is a good indicator that something is wrong in the environment, and that if the pollution continues unabated, the entire **ecosystem** could collapse. It might take years—and millions of dollars in cleanup efforts—before living things return to the area and begin to thrive again. Sometimes the damage is irreversible.

Not all pollution is harmful to all living things. In fact, some types of pollution are beneficial to some life forms. For example, the pollen that makes you sneeze in spring is necessary for the reproduction of plants. Ash from forest and brush fires and volcanoes fertilizes the soil.

In these activities, students learn how both natural and people-made pollution threaten the air we breathe, the water we drink, the soil in which our plants grow, and the plants and animals that share our environment. Students begin to realize that Earth's resources are interconnected in such a way that the contamination of one directly affects the purity of the others—and subsequently the health and well-being of all living things.

For years scientists have been warning of the dangerous—and irreversible—effects of pollution. Many think that the next generation will prove to be the turning point in the fight to clean up the planet—its land, water, and air. But in order for that to happen, people must recognize the ways in which they contribute to the problem. The Broward County Hands-On Science program shows students just that, and encourages them to start thinking more about, and acting differently toward, their Earth.