SCIENCE BACKGROUND—*Erosion*

Earth's surface is constantly changing: Erupting volcanoes, colliding continental plates, and evaporating bodies of water expose new surfaces, while wind, rain, vegetation, and temperature changes slowly break down these surfaces in a process called **weathering.**

Weathering takes place in one of two ways: physically or chemically. **Physical weathering** is the mechanical breaking down of rocks and minerals. Hot days and cold nights cause rocks to crack. Water seeps into these cracks and freezes; plants take root in these cracks and grow. In both instances, the cracks are enlarged, causing the rocks to break into smaller pieces.

Chemical weathering is the breaking down of the earth's surface caused by changes in the chemical composition of rocks and minerals. **Acid rain**—rain that reacts with sulfur dioxide and nitrogen oxides in the air to form a weak acid solution—dissolves some minerals, causing them and the rocks they are in to wear away. **Oxidation**—the chemical reaction of rusting that occurs when certain substances (like iron) are exposed to oxygen in the air—can also cause rocks containing these substances to slowly wear away.

Erosion is the carrying away of weathered material by water, wind, or glaciers. Water from rain or melting snow **permeates** (is absorbed into) the ground until the ground becomes **saturated** (can absorb no more). Any additional water then becomes **runoff,** which combines with runoff from other areas to form creeks, streams, and rivers.

The amount of erosion that occurs because of flowing water depends on several factors. One is the speed of the flowing water: the faster the water flows, the more force it has to erode surrounding rocks and soil. Another factor is the rate of flow, or volume per unit time, of the flowing water: larger volumes of water carry more force and affect a larger area than do smaller volumes.

Another important factor to consider is the **composition** of the **soil** or other earth material being eroded. The weight and size of the **particles** play a significant role in determining how much material will be eroded and how far **sediment** will be carried before it is deposited. As sediment-rich, fast-moving water enters areas where the speed of the water is reduced, larger particles settle to the bottom. As the water's speed continues to diminish, even the smallest particles settle to the bottom. **Deposition** can occur wherever the water slows down, as happens when a river encounters flat land or a large body of water. These patterns of erosion and deposition are what create many of Earth's geographic landforms, including **meanders, levees, floodplains, alluvial fans,** and **deltas.**

Wind is another agent of erosion. Wind is generated when air moves from areas of high pressure to areas of low pressure. Warm air is less dense and so it rises, allowing the cooler, denser air to rush into the area of low pressure formed below it. The result is wind! Small particles of sand, silt, and clay are easily picked up and carried by wind.

One natural barrier to erosion caused by wind is **vegetation.** The roots of trees and plants anchor the soil in place. At the same time, foliage blocks, deflects, and otherwise decreases the force of the wind, preventing the wind from picking up most particles and causing it to deposit those that it is carrying. Erosion can be slowed down by artificial means as well. **Windbreaks** and **breakwaters** along shorelines help to decrease the strength of erosive wind and water.

SCIENCE BACKGROUND—*Solar System*

A **solar system** includes a **star** and all the objects that travel around it. Our Solar System includes our Sun (a star) and all its **satellites—planets, moons, asteroids, meteoroids,** and **comets.**

Like other stars, our **Sun** is a huge ball of glowing gases that are heated by nuclear fusion in the center of the star and produce tremendous amounts of heat and light. The Sun's radiation affects surface conditions on all its satellites. Surfaces on Solar System objects closest to the Sun are hot, while the surface of Pluto is very cold.

The planets, in order beginning with the one closest to the Sun, are **Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus,** and **Neptune.** Some planets, but not all, have their own satellites, or moons.

Scientists now consider there to be only eight planets (not nine) in our Solar System. Please review the information provided in *Pluto and the New Definition of a Planet* on page 136.

The motion of a satellite around another object is called an **orbit,** and its path is elliptical in shape. A satellite is held in its orbit by **gravity,** an attractive force between it and the object it is moving around.

Owing to the elliptical shape of orbits, a point exists along every orbit at which a satellite is closest to the object it is orbiting and another point at which it is farthest away. A planet at its closest point to the Sun is said to be at **perihelion;** at its farthest point it is at **aphelion.**

A scale model of the Solar System can help us visualize and better comprehend the relative sizes of, and distances between, objects in the system. To create scale models of objects, their actual dimensions must first be reduced, or scaled down. A numerical ratio is used to represent the scale of reduction. For example, the **ratio,** or scale, of 1 cm:9,000,000 km means that 1 centimeter in the model represents 9 million kilometers in the actual object.

The same scale must be applied to all objects in a system if their relative sizes and distances are to be accurately represented. However, because of the tremendous distances that separate planets from the Sun and from one another, two different scales must be used to model the Solar System in the classroom. One scale serves to model the planets' relative sizes; the other scale serves to model the relative distances of their orbits from the Sun.

Models can also help to demonstrate time periods, such as planetary **days** and **years.** A planet spins on an imaginary axle—its **axis**—that passes through its center. One complete spin, or **rotation,** is called a day on any planet, regardless of the Earth-time it takes to complete. All planets rotate at different speeds, so the lengths of their days vary considerably.

One complete orbit, or **revolution,** of a planet around the Sun constitutes a year on that planet, regardless of the Earth-time it takes to complete. Generally speaking, the farther a planet is from the Sun, the longer its year, although planets do travel at different speeds.

Our Solar System contains other satellites besides planets and their moons. **Asteroids** are tiny planets that orbit the Sun. **Meteoroids** are small bits of matter that also orbit the Sun. If a meteoroid's orbit brings it too close to a planet, gravity may pull the meteoroid toward the planet's surface. A meteoroid becomes a **meteor** when it rushes through the **atmosphere** of a planet and the friction between it and the molecules of the atmosphere cause it to burn white-hot. Any fragment of the meteor that goes on to impact the surface of the planet is then known as a **meteorite.**

Comets, still another type of satellite, are like huge dirty snowballs, a mile or more in diameter, consisting of ice-covered dust and rock particles. As a comet approaches perihelion in its orbit, the Sun's radiation vaporizes its icy surface, sending gases and dust particles streaming away from the comet's head in a shining "tail." Sunlight reflecting off particles in the comet's tail makes the comet visible to us on Earth.

Our Sun is but one of the estimated 100 billion stars in the Milky Way **galaxy,** which itself is but one of countless massive star clusters scattered through the universe. From Earth we can see other stars in our galaxy besides our Sun. Distances from Earth to these other stars, as well as their distances from one another, are so great that we measure them in light-years. One **light-year** is the distance light travels in one Earth-year, or about 9.46 trillion km.

The relative distances of stars from Earth cannot be determined by their apparent relative brightness. Lights farther away appear dimmer than nearby lights of equal intensity. However, stars glow at different intensities, so a bright, distant star appears closer to us than a dimmer, nearby star.

People who lived in ancient times often viewed patterns of stars in the night sky as shapes of actual or fictitious persons, animals, or events. Often the images were derived from myths—stories depicting gods and goddesses, heroes and heroines, or celestial battles. The areas of the sky containing these star-patterns are called **constellations.**

While the patterns of stars in the constellations do not change, Earth's revolution around the Sun causes our view of the constellations in the night sky to change from season to season. Then, after a full year has passed, we see them in their original positions once again.

Because of ongoing exploration and technological advances, we are constantly gathering new information about our Solar System and the galaxy. A good source of current information is the NASA website, www.nasa.gov.

SCIENCE BACKGROUND—*Human Body*

The **human body** consists of several **organ systems.** The **skeletal system** in an adult human consists of 206 **bones.** These bones provide support for the body, protection for internal organs, and places of attachment for **muscles.**

Movement of, and in, our bodies is the responsibility of the **muscular system.** There are three kinds of muscles in the human body: skeletal, cardiac, and smooth. **Skeletal muscle** is striated, or striped, in alternating bands of light and dark. We move skeletal muscles voluntarily. Skeletal muscles are attached to bones by **tendons** (the exceptions are the tongue and the pharynx). When skeletal muscles contract, they move bones, and therefore, parts of our bodies.

Cardiac muscle is found in the heart. Like skeletal muscle, cardiac muscle is striated in structure. Unlike skeletal muscle, cardiac muscle is not under our voluntary control. Individual cardiac muscle cells contract on their own, without stimulus. However, the synchronization of many cells is required to make a rhythmic heartbeat. The heart's rhythm is controlled by a node in the right atrium that generates electrical impulses that trigger the dilation and contraction of the heart's chambers.

The third type of muscle, **smooth muscle,** is not moved voluntarily—it is controlled by the part of our nervous system called the autonomic nervous system. Smooth muscle tissue lines most of the hollow organs in our bodies (intestines, **blood vessels,** urinary tract, and so on). The **cells** of smooth muscles are spindle shaped and are arranged in dense sheets.

The **central nervous system** includes nerves throughout the body that, once stimulated, produce **impulses.** These impulses travel to the brain, where they are evaluated. After evaluation, a response is then sent from the brain to the appropriate muscle for a reaction. The time between when the body is stimulated and when it responds is known as **reaction time.** Reaction times can vary from individual to individual.

Sensory organs are connected to the nervous system and relay messages throughout the body regarding a multitude of **stimuli.** Through a system of sensors, the tongue, ears, eyes, skin, and nose convert physical sensations about **taste, hearing, sight, touch,** and **smell** into electrical impulses that are then transmitted to the brain by the nervous system.

The **circulatory system** consists of the **heart, blood, arteries, veins,** and **capillaries.** They function together to distribute **oxygen** and **nutrients** to, and remove wastes from, the cells in the body. This is accomplished by the circulation of blood, which is achieved by the heart pumping blood through the veins and arteries of the body. The pumping action of the heart also forces blood to and from the lungs. In the lungs, the blood releases carbon dioxide and receives oxygen. The same pumping action that forces oxygen-depleted blood to the lungs forces oxygen-rich blood back to the heart and then to the body.

The **respiratory system** includes the lungs, **trachea,** bronchi, and the channels leading outside the body (the mouth and nose). We inhale when the **diaphragm** contracts, causing the chest cavity to expand. Our lungs then expand and pull in oxygen-rich air through the mouth or nose and through the trachea and bronchi. When the diaphragm relaxes, the chest cavity contracts, and carbon dioxide-laden air is forced out of the lungs through the bronchi, trachea, and the nose or mouth.

Each organ of the body serves a specific function: the heart circulates blood; the lungs replenish oxygen to, and remove carbon dioxide from, the blood; the brain processes information; and so on. The largest organ of the body is the **skin.** Skin is flexible and has two layers. The thin, outer layer is called the **epidermis** and the thick, inner layer is called the **dermis.** Skin functions as a physical barrier between our bodies and the outside environment, providing protection from microorganisms, ultraviolet rays, and other particles and substances. Skin also helps to regulate the internal temperature of the body. When body temperature increases, moisture is released to the surface of the skin through sweat **glands.** This perspiration evaporates, cooling the skin and the body.

The body gets its energy from food. The food must first be broken down into a form that the body can use. **Teeth** begin the **digestive process** by breaking chunks of ingested food into smaller pieces. Each type of tooth is specialized for a certain function, such as cutting, tearing, or grinding. Swallowing pushes the chewed food to the stomach where it is further processed and then passed to the intestines where nutrients can be absorbed. Once absorbed, the nutrients are distributed throughout the body by the blood.

Fats, proteins, carbohydrates, vitamins, and **minerals** are processed by the body. Fat in the food we eat provides a concentrated source of energy, but this fat is often stored in our bodies instead of being used immediately. Too much fat is not desirable in a healthy diet. Proteins are broken down into amino acids, which are used to build and repair muscles and other parts of the body. There are two types of carbohydrates: simple carbohydrates, which are **sugars;** and complex carbohydrates, which are **starches.** As digestion proceeds, the starches are broken down into sugars that are used by the body for energy. Different foods contain various minerals and vitamins. A diet with the proper balance of these nutrients should be consumed to maintain good health.

SCIENCE BACKGROUND—*Simple 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. **Simple machines** 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.

SCIENCE BACKGROUND—*Electromagnetism*

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.