46A Energy Transfer: Conduction, Convection, and Radiation

Tectonic plates move because of **convection currents** in the Earth's **mantle**. Convection occurs in the mantle because the lower regions of the mantle have a higher temperature than the upper regions. Although convection can result in moving matter, such as tectonic plates, the reason it occurs is because natural forces exist that attempt to make everything the same temperature. "Cold" doesn't actually exist, it is simply a term used to describe something or some place that has a lower temperature than another thing or place. Thermal energy, or heat, is responsible for temperature. In nature, thermal energy will always travel from a place with a higher temperature to places with a lower temperature. There are several different natural processes that help transfer thermal energy from warmer places to cooler places.

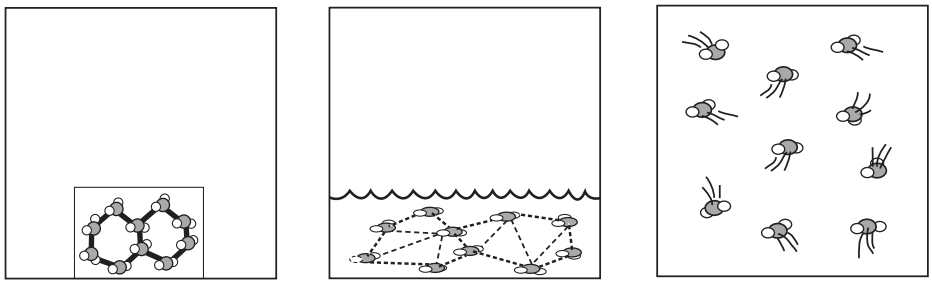
CHALLENGE

How does heat move from one place to another?

READING

Three phases of matter: Solids, Liquids, and Gases

Thermal energy, or heat, is related to how fast the **particles** that make up a material are moving. Faster moving particles contain more energy and produce higher **temperatures**.



Because of the direct relationship between temperature, particle motion, and energy, as the temperature of an object increases, the amount of thermal energy the object contains also increases. The movement of thermal energy is nature's way of trying to make everything have the same temperature. Thermal energy can move in three distinct ways, through conduction, convection, and radiation.

Conduction

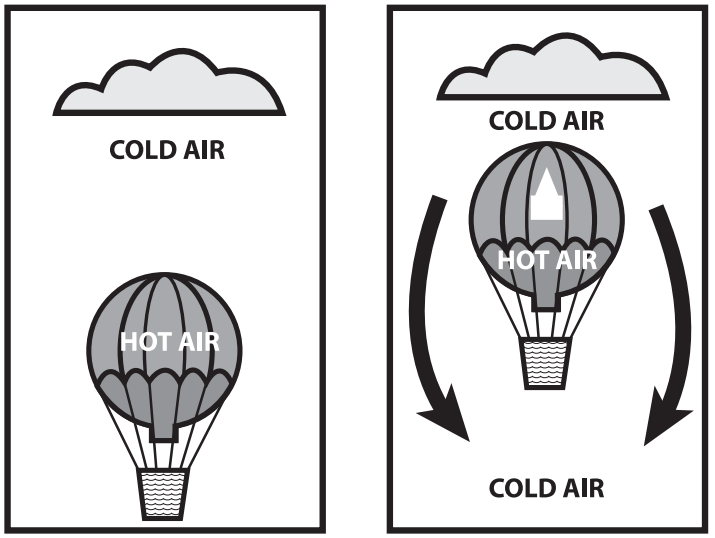
Conduction occurs when objects with different temperatures are in direct contact with each other. Imagine that you are holding one end of a long metal pole and that you move the pole so that the other end is in a fire. What happens next is that the end of the pole in the fire heats up. Then the thermal energy begins moving through the pole toward your hand. Thermal energy continues to travel up the pole so that the entire pole becomes warmer. Eventually your hand will begin to get warm. Depending on the length of the pole, the type of metal the pole is made of, and the temperature of the fire, the pole could become so hot that you would have to let go of it.

Conduction occurs because an increase in thermal energy causes an increase in the speed of molecules. So, when the end of the pole is placed in the fire, the tiny particles in the metal at the end of the pole start moving faster. These particles bump into the particles next to them and make those particles move faster. This process of fast-moving particles colliding with other particles and making them move faster is conduction. During conduction, although the particles can move much faster and energy can move a long distance, the particles themselves remain in the same basic position. Conduction can occur in solids, liquids and gases.

Convection

Like conduction, convection involves contact between materials with different temperatures. Unlike conduction, convection can cause significant changes in the location of a material's particles. Convection occurs when a body of material (group of particles) of a different temperature moves into an area and takes the place of the body of material that used to be there. Winds and changing weather conditions are a result of convection. A simpler example of convection is a hot air balloon. The air inside the hot air balloon is heated by a burner until it is much warmer than the air outside the balloon. This causes the balloon

(a body of higher temperature) to move upwards, pushing aside, and taking the place of the outside air (a body of lower temperature) that used to be above it. At the same time, the outside air moves into the place where the hot air balloon used to be. The common expression "hot air rises" is a description of convection. However, convection could also be described just as correctly as "cold air falls." Convection can only occur in fluids (liquids and gases) where the particles of the material can move around and are not fixed into a specific position like they are in a solid.



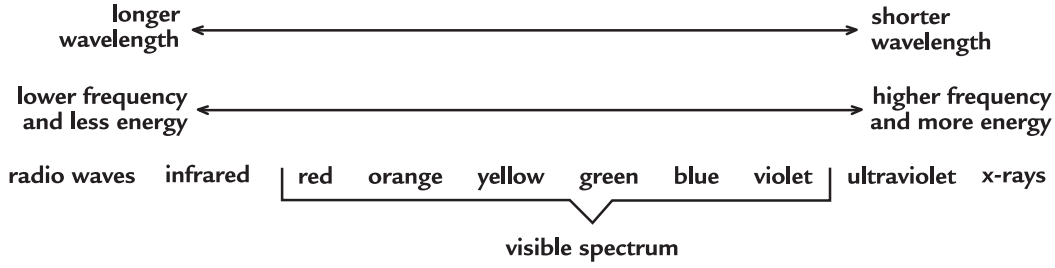
Convection occurs in nature all the time, with no balloons involved. As you learned in the previous activity, convection currents deep within the earth cause the movement of the tectonic plates that make up Earth's surface. In the atmosphere, convection is continually moving air masses of different temperatures upwards and downwards, causing warm and cold fronts, winds, and other weather phenomena. Convection currents in the oceans move vast quantities of water at one temperature into areas that have a very different temperature. This influences the climate of certain areas and the quantity and type of fish and other ocean resources found in certain areas of the oceans.

Convection occurs because of differences in **density**. As a body of liquid or gas changes temperature, the density of that body of material also changes. Density is a measure of how tightly packed together the particles of a material are. Higher density means that the particles are packed closer together. Material with a higher density will sink down through a **fluid** material which has a lower density. Vice versa, mate-

rial with a lower density will float upwards through a body of fluid material which has a higher density. As you learned before, as the temperature of a material increases the particles of the material move faster. In a fluid, the particles also move farther away from each other because when they collide, they bounce farther apart. Because the particles are bouncing farther apart, the hotter material made from these faster moving particles becomes less dense. If a body of material is heated to the point that it has less density than the fluid material surrounding it, it will begin to rise upwards. As the heated material rises, it carries its energy along with it, and convective heat transfer, or convection, occurs.

Radiation

Radiant energy, or radiation, does not occur because of faster moving particles. In fact, radiation can transfer energy through areas where there are no particles (a **vacuum**). If it weren't for radiation, energy from the Sun would not be able to travel through space and provide us with light and heat. Radiation is energy emitted from the atoms and travels away from the atom as a **wave**. All **atoms** have the same basic structure: a **nucleus** surrounded by a "cloud" of mobile **electrons** that travel in defined areas called energy levels. When an electron moves from a higher energy level to a lower energy level, radiation is released. Radio waves, microwaves, infrared, visible light, ultraviolet light and x-rays are all types of electromagnetic radiation. An important difference between each of these types of radiant energy is the length of the waves associated with each type.



All materials emit radiant energy. The type and amount of radiant energy emitted changes as the temperature of a material changes. Lower temperature materials emit lower energy electromagnetic waves having longer wavelengths than the waves emitted by higher temperature materials. The only wavelengths that humans have the ability to

detect directly are in the infrared and visible ranges. Our bodies sense infrared radiation as heat and our eyes sense visible radiation as light and color. While the wavelengths in the range called infrared radiation are most closely associated with heat, all wavelengths of light that are absorbed by a material can cause that material to become hotter.

ANALYSIS

1. Which form of energy transfer is most likely associated with:
   a) the movement of magma
   b) making pancakes
   c) getting a sunburn
   d) toasting a piece of bread
   e) using an ice pack
   f) ironing a shirt
   g) a large change in the high temperature from one day to the next
2. Describe some characteristics of radiation that make it different than either conduction or convection.
3. Briefly describe one example of how energy transfer influences conditions in your environment.