SCIENTIFIC AND HISTORICAL BACKGROUND

This investigation is about heat. When you lie on the beach on a summer afternoon, inch a little closer to a campfire, or give the hot-water handle a little turn to make the shower warmer, you are having a pleasant heat experience. Just like Goldilocks, we know when the heat is too low (this porridge is too cold), when it is too high (this porridge is too hot), and when it is just right. But what is heat?

Heat is not a substance that you can hold in your hands or store in a bottle. Heat is a condition of matter. Heat is energy, specifically, kinetic energy. Matter in motion has kinetic energy, and the kinetic energy of heat is associated with the atoms (or molecules) that make up the matter. The higher the state of excitation in the atoms, the more kinetic energy the atoms possess, and the hotter the matter is. In short, heat is movement of atoms.

The motion of atoms can assume two forms. The motion can be vibrational or linear. In solids, atoms do not move over and around each other; they stay locked in position with respect to one another. Increased kinetic energy produces greater vibrational movement. The increased vibration usually pushes the atoms farther apart because of the increased violence of the interaction between neighboring atoms. The result is that a mass of matter, such as a chunk of steel or a section of concrete sidewalk, will expand as it gets hot.

Atoms and molecules of fluids, including liquids and gases, also increase their motion as they get energized. Because atoms in fluids are not locked in position with respect to their neighbors, they have more freedom to move over, around, and past one another. The more energy they have, the faster they move. Molecules in a fluid move in straight lines until they collide with another molecule. The frequency and violence of collisions increase with the energy of the molecules. Forceful, frequent collisions push molecules farther apart, causing the fluid to expand.

Molecules in solids move by wobbling and jittering in place; molecules in fluids move from place to place.

Back to Goldilocks...Hot porridge, cold porridge, just right porridge—how did the different portions of porridge acquire different temperatures? Heat transfer. Heat (kinetic energy) can move from one place to another, but the net movement is always in one direction: from higher energy (hotter) to lower energy (colder). Heat transfer takes place in two fundamental ways: radiation and conduction.

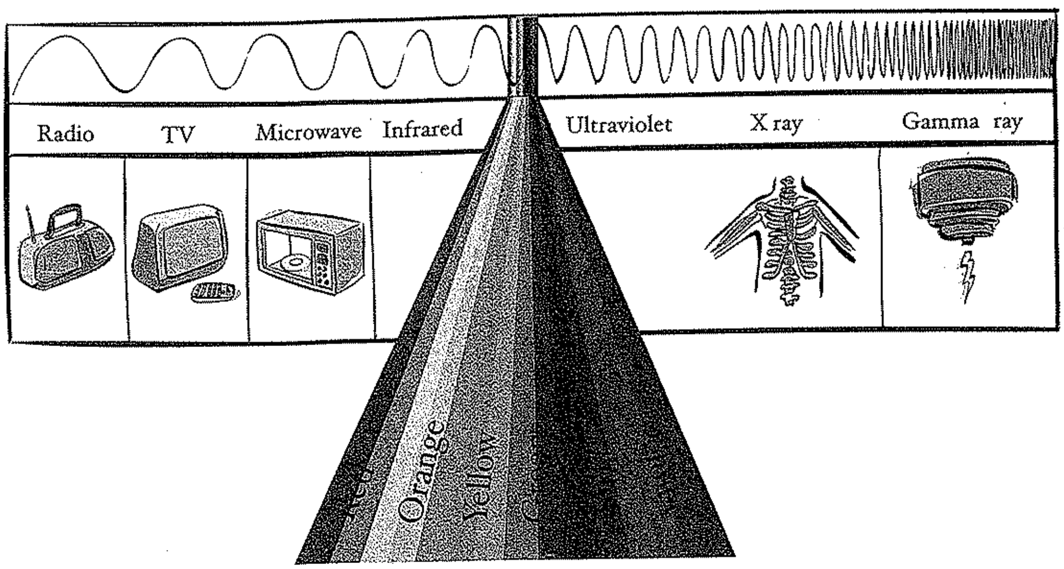
RADIATION

The most familiar source of radiant energy is our star, the Sun. The thermonuclear reactions going on inside the Sun produce unimaginable atomic activity. The output of these reactions is energy, and lots of it. Energy streams out in all directions in the form of electromagnetic **radiation,** which we can conceive of as rays. Some of the rays are visible, and we call them light. Others are not visible to humans, and we know them as X rays, microwaves, infrared, ultraviolet, radio, and so on.

Considered all together, they constitute the electromagnetic spectrum, a tiny portion of which we recognize as the rainbow. Even though the visible spectrum represents a narrow band of wavelengths in the overall electromagnetic spectrum, most of the energy radiated by the Sun falls in the visible spectrum and its invisible neighbors, the ultraviolet and infrared regions.

molecules in the porridge, and it got hotter and hotter as more and more radiant energy was absorbed. The porridge was so heated by absorption of radiant energy that it was too hot to eat.

Mama Bear made her porridge 20 minutes earlier. She went to attend to Baby Bear's needs while her porridge sat there on the table. The kinetic energy in the porridge transferred away in several ways. Most



Radiant energy travels through space. It needs no medium to carry it along. A ray of radiant energy will keep traveling until it smacks into an atom, at which time it may be reflected in a different direction, or absorbed by the atom. If it is absorbed, the kinetic energy of the atom increases, and that is heat. Heat can transfer from point A to point B over tremendous distances by radiation.

When Papa Bear put his porridge into the microwave, the rays of microwave radiation were absorbed by the water

important, the mush reradiated energy in the form of infrared rays. Kinetic motion of the molecules in the porridge declined as energy radiated into space. The porridge got cold.

The energy raining on Earth has several fates. About 30% of the energy reflects off clouds, air molecules, and Earth's surface back into space. About 20% is absorbed by clouds and atmospheric gases directly. The remaining 50% is absorbed by Earth's surface. The land and water heat up as a result.

energy. If it has a higher level of kinetic energy than the thermometer bulb you stuck in it, energy will conduct to the glass bulb. In turn, the energy will be conducted from the glass to the alcohol. The alcohol will heat up, expand, and push up the stem. The distance it pushes up the stem is an indirect measure of the kinetic energy of the source (porridge), and we call that temperature.

When you try the thermometer in Papa Bear's mush, energy is transferred to the alcohol and it expands until the top of the column indicates 90°C. A spoonful of that would conduct a painful dose of energy to your tongue. On to Mama Bear. The thermometer now has more kinetic energy than Mama's porridge, which has been sitting out for 20 minutes. Energy transfers from the thermometer to the mush, causing the alcohol to contract and retreat down the stem. The thermometer reads 20°C—room temperature—not a palatable breakfast prospect. On to Baby Bear's porridge, which still has more kinetic energy than the thermometer. The thermometer goes up, indicating 50°C. Perfect! A little milk and honey...

So the thermometer measures the amount of heat in a substance? No, not really. The thermometer measures the level of kinetic energy, which is related to heat but is different. The distinction between heat and temperature is difficult to master, and we do not expect students to acquire a fully formed understanding. The big idea in this investigation is that heat is energy, that it is manifest in the form of molecular motion, and that it can move from one place to another in several ways. Thermometers will be our ally as we experiment with heat-transfer phenomena, and we will use temperature to compare the kinetic energy of different materials as heat moves around.