Heating the Atmosphere

You may have had an experience like this one. The campfire has burned down to a bed of hot coals, perfect for toasting some marshmallows. The only stick available is about a meter long, but you go for it. You can hardly stand the heat from the coals because the stick is short, but after a minute the marshmallow is brown and gooey. You pop it into your mouth. Yikes! Didn't wait long enough for it to cool.

This story includes a couple of intense heat experiences. But have you ever stopped to think about what heat really is? What is the heat that you felt coming off the coals and the heat in the marshmallow that burned your tongue?

Heat = Movement

Objects in motion have energy. The faster they move, the more energy they have. Energy of motion is called **kinetic energy.**

Matter, like nails, soda bottles, water, and air, is made of atoms and molecules. Atoms and molecules, even in steel nails and glass bottles, are in motion. In solids, the molecules vibrate back and forth. In liquids and gases, the molecules move all over the place. The faster molecules vibrate or move, the more energy they have.

Molecular motion is molecular kinetic energy, and that is heat. The amount of kinetic energy in the molecules of a material determines how much heat it has. The molecules in hot materials are moving fast. The molecules in cold material are moving slowly.

Heat Transfer

Heat can move, or transfer, from one place to another. Scientists sometimes describe heat transfer as heat flow, as though it were a liquid. Heat is not a liquid, but flow is a pretty good way to imagine its movement.

Heat flows from a hotter location (more energy) to a cooler one (less energy). For example, if you add cold milk to your hot chocolate, heat flows from the hot chocolate to the cold milk. The hot chocolate cools because heat flows away; the cold milk warms because heat flows in. Soon the chocolate and the milk arrive at the same temperature, and you gulp them down.

Heat Transfer by Radiation

There are many different forms of energy, including heat and light. If you heat an object, like the burner on a stove, to a high enough temperature, it will get red hot. When this happens, the burner is giving off two forms of energy, heat and light. If you put your hands near a lightbulb, you can see light and feel heat, even though you are not touching the bulb. This kind of energy that travels right through air is **radiant energy.**

Radiant energy travels in the form of **rays.** Heat and light rays radiate from sources like the intensely hot campfire coals, lightbulbs, and the Sun.

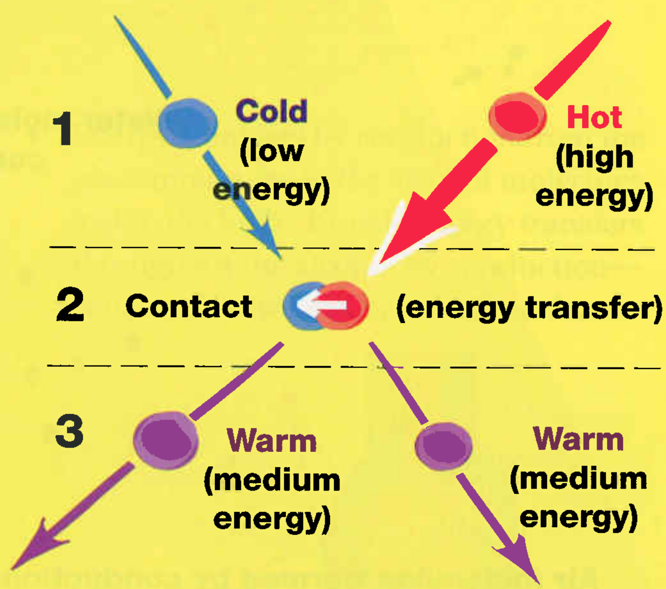
Energy rays from the Sun pass through Earth's atmosphere. We call this **solar energy.** When solar energy hits a molecule, such as a gas molecule in the air, a water molecule in the ocean, or a molecule in the soil, the energy can be **absorbed.** Absorbed energy increases the kinetic energy (movement) of the molecules in the air, water, or soil. Increased kinetic energy equals increased heat.

Radiation is one way energy moves from one place to another. Materials don't have to touch for energy to transfer from one to the other.

Heat Transfer by Conduction

Think about that hot toasted marshmallow or maybe a slice of pizza straight from the oven going into your mouth. This kind of memorable experience is another kind of energy transfer. When energy transfers from one place to another *by contact*, it is called **conduction.**

The fast-moving molecules of the hot pizza bang into the slower molecules of your mouth. The molecules in your tongue gain kinetic energy. At the same time, molecules of the hot pizza lose kinetic energy, so the pizza cools off. Some of the pizza kinetic energy is conducted to heat receptors on your tongue, causing them to send a message to your brain that says "Hot!"



A "hot" molecule with a lot of kinetic energy collides with a "cold" molecule with little kinetic energy. Energy transfers at the point of contact. The cold molecule then has more energy, and the hot molecule has less energy.

When you heat water in a pot, the water gets hot because it comes in contact with the hot metal of the pot. Kinetic energy transfers from the hot metal molecules to the cold water molecules by contact, which is conduction.

Heat Transfer to the Atmosphere

The atmosphere is heated by radiant energy from the Sun—solar energy. Lots of different kinds of rays are sent out by the Sun, but the most important ones are visible light and invisible light called infrared radiation. It seems pretty straightforward. The molecules in the air absorb the incoming radiation to increase their kinetic energy. But that's not what happens.

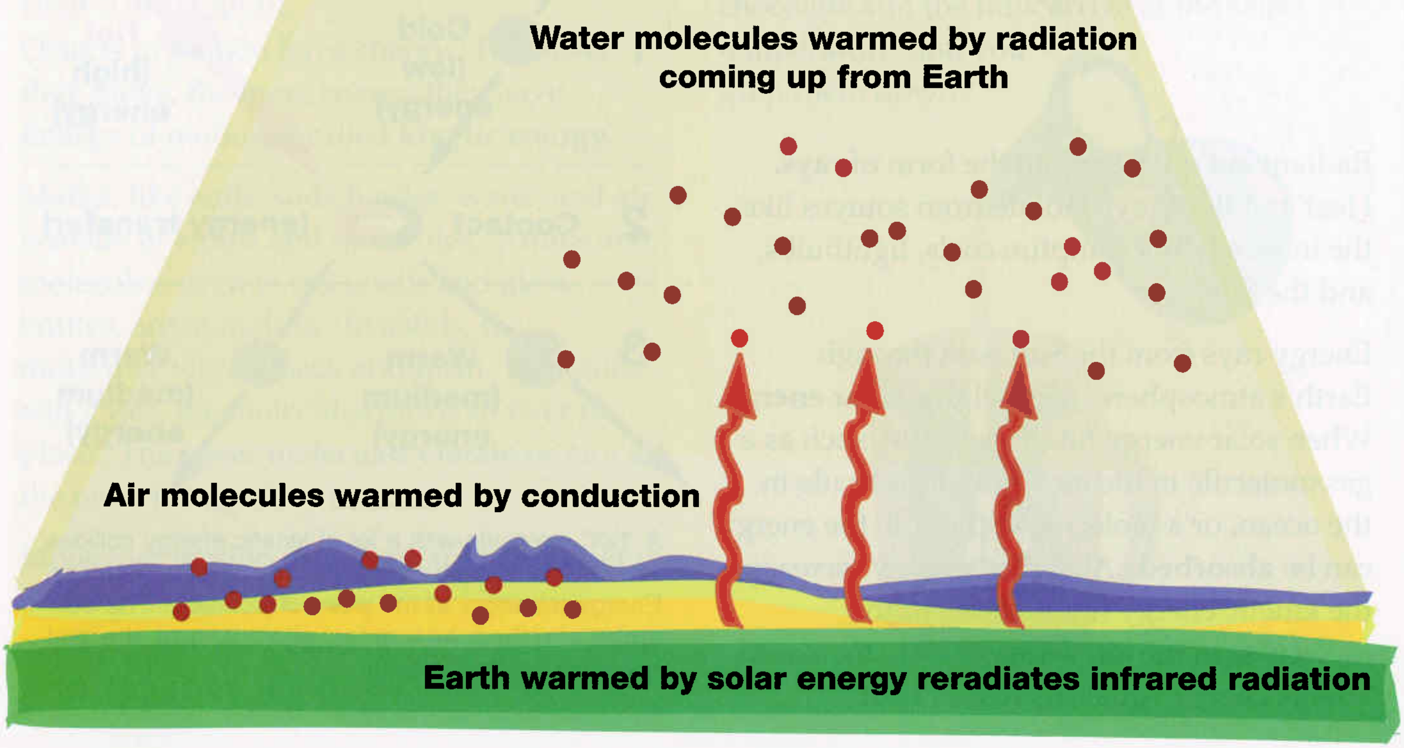
Air is 99% nitrogen and oxygen molecules. Neither of these molecules absorbs visible light or infrared radiation. It just doesn't happen. Only water vapor and carbon dioxide absorb significant amounts of radiant energy, and this is mostly infrared rays, not visible light.

If only a tiny part of the atmosphere gets hot from incoming solar energy, how does the rest of the atmosphere get hot?

Visible light *is* absorbed by Earth's surface. The land and seas warm up. The air molecules that come in contact with the warm land and water molecules gain energy by conduction. But there is more.

The warm land and seas also **reradiate** energy. This is a very important idea. Earth actually gives off infrared radiation that can be absorbed by water molecules (mostly) and carbon dioxide molecules in the atmosphere. The energy absorbed by the small number of water molecules is transferred throughout the atmosphere by conduction when hot water molecules bang into oxygen and nitrogen molecules.

The atmosphere is not heated from above; it is heated from below.



Temperature and Thermometers

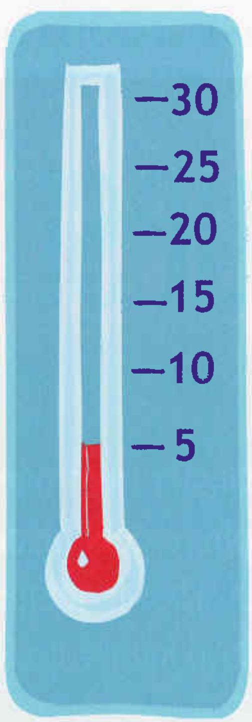
How can you find out just how much heat is in the part of the atmosphere where you are? With a thermometer.

A thermometer measures temperature. **Temperature** is a measure of the average kinetic energy of the molecules in a material. If a thermometer is surrounded by air, it measures the average kinetic energy of the air molecules. If it is surrounded by water, it measures the kinetic energy of the water molecules. If you hold the thermometer bulb between your fingers, the thermometer measures the average kinetic energy of the molecules on the surface of your fingers.

If you stick a thermometer in a cup of cocoa, under your tongue, or in a freezer, it will measure the average kinetic energy of the molecules touching it in those places.

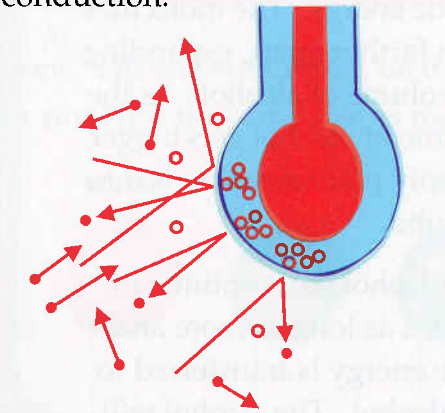
How Does a Thermometer Work?

Think about an alcohol thermometer on the wall in a cold cabin. The kinetic energy in the air molecules is low. The kinetic energy in the glass and alcohol molecules is low. The air molecules and the glass thermometer bulb have the *same* kinetic energy. The top of the column of alcohol is at 5°C. Brrrr, it's cold, so you turn on the heater.

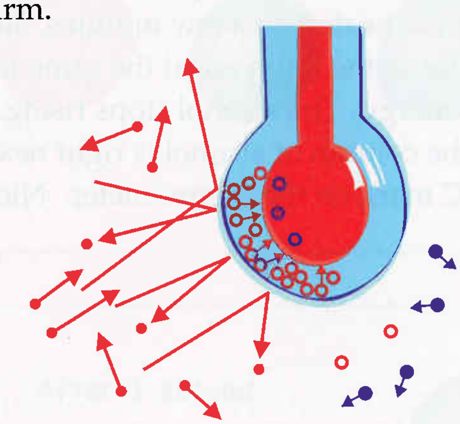


Pretty soon warm air is flowing into the room. Warm air has more kinetic energy than cooler air. The energy added to the room in the form of fast-moving air molecules starts a chain of events.

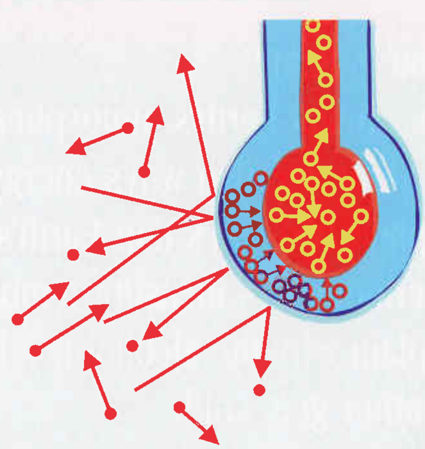
- Molecules in the warm air collide more often with the glass thermometer bulb. Energy transfers to the molecules of glass by conduction.



- Kinetic energy transfers by conduction from molecule to molecule in the glass bulb until all of the glass molecules are warm.

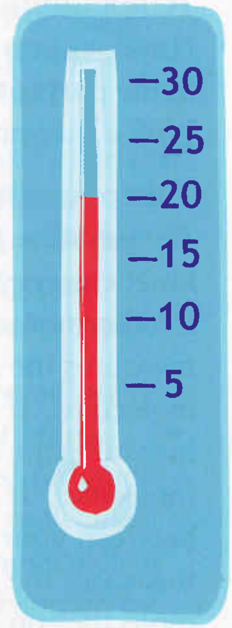


- Energy transfers by conduction from the glass molecules to the alcohol molecules inside the bulb. Kinetic energy transfers throughout the alcohol by conduction—collisions between alcohol molecules.



- The alcohol molecules push on one another more forcefully because of the increased kinetic energy. The molecules push farther apart, expanding the volume of alcohol. As the volume of alcohol gets bigger, the only place it can go is into the tube.
- The alcohol will continue to expand as long as more and more energy is transferred to the alcohol. The alcohol will continue to push up the tube.

When the room is warm, you turn off the heater. In a few minutes, all the molecules in the room are at the same level of kinetic energy. The alcohol stops rising. The top of the column of alcohol is right next to the 20°C mark on the thermometer. Nice and warm.



As long as the kinetic energy of the alcohol molecules stays the same, the level of the column of alcohol will stay the same, and we say the temperature is steady at 20°C.

What happens if you open the window? The whole process goes into reverse. Molecules in cool air have less kinetic energy. Heat energy transfers by conduction from the glass tube to the air. Heat then transfers from the alcohol to the now-cooler glass. The alcohol molecules lose kinetic energy and slow down, and the alcohol contracts. The liquid level gets lower in the tube. Kinetic energy will transfer from the molecules in the room to the molecules outside through the open window. The chill of low kinetic energy will set in once again. The thermometer will once again dip to 5°C. Brrrr.

Think Questions

1. What is heat?
2. What heats Earth's atmosphere?
3. What are the two ways energy can transfer from one material to another?
4. Explain two ways that Earth's atmosphere gets heated.
5. Thermometers measure temperature. What is temperature?
6. Explain why the alcohol level in a thermometer goes down when the weather gets cold.