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Thermoregulation: Hot

Enough For You?

ANIMALS OF ALL KINDS live in hot, dry Southwestern deserts.

These creatures have adapted to survive sizzling summer days and frosty winter nights. To stay cool, a desert animal must avoid and shed heat. To stay warm, the creature must gather and store heat in some way.

THE MANAGEMENT OF BODY HEAT IS CALLED THERMOREGULATION.

Without proper thermoregulation, animals cannot survive. To understand thermoregulation, it is important to know a little bit more about heat.

In the 1700s, scientists thought of heat as a mysterious fluid, which they called "caloric." They thought that heat flowed from a hot into a cold substance in the same way water flows from a full into an empty cup. For more than 100 years, the caloric idea helped to explain observations about heat.

Ideas changed in the mid-1800s. New observations about heat could not be explained in terms of the caloric idea. Today, heat is just one part of the modern theory of thermodynamics. The theory says that heat is a form of energy, not a mysterious fluid. But we still say that heat "flows."

Scientists know that heat influences temperature. When a substance contains lots of heat, it is hot. When it contains little heat, it is cold.

The amount of heat in a substance is called its *heat content*. When a hot substance is put in contact with a cold substance, both substances eventually become warm. They reach a state called "thermal equilibrium." Heat from the hot substance flows into the cold substance until it is balanced between the two. As a result, both substances reach the same temperature. That temperature stays the same over time.

If left alone, heat always flows from hot to cold. This is the direction of spontaneous flow. "Spontaneous" means that the flow happens all by itself. No usable energy is consumed.

Substances or materials often come in contact with one another. During that contact, heat can flow from one substance to the other. This process is called *conduction*.

Any substance, including the skin, feathers, or fur of desert animals, is always in contact with its surroundings. That substance is always exchanging heat with those surroundings. If heat is added faster than it is lost, the heat content and temperature of that substance will increase. If heat is lost faster



The
Wright
Stuff
BY DAVID WRIGHT

The *caloric* idea lasted as an explanation for heat because it described many commonly observed effects of heat. **We now know that heat is the energy of moving molecules.** This explains the most careful observations we can make of heat effects. The molecules in liquids and gases bounce off each other like bumper cars. The molecules can't move around in solids. They vibrate in place, as if held together by tiny springs.

Examples of average body temperatures

BIRDS: 100-112° F
RABBITS, SHEEP AND CATS: 102.2° F
HORSES: 100.4° F
WHALES: 95.9° F
HUMANS: 98-99° F

(IN AMERICA AND FRANCE, "NORMAL" IS SET AT 98.6°. IN GREAT BRITAIN, 98.4° IS CONSIDERED THE NORMAL POINT).

SOME MAMMALS HIBERNATE IN THE WINTER AND DROP THEIR BODY TEMPERATURES DURING THIS TIME. THE MOST EXTREME EXAMPLE IS THE **ARCTIC GROUND SQUIRREL**, WHICH CAN DROP ITS BODY TEMPERATURE TO **28.4° F** WHILE IT HIBERNATES.

PERSPIRATION is efficient for cooling, but only if the air is dry. If the air is humid, the evaporation process is slow. Heat is not removed quickly. Unfortunately, perspiration requires a large amount of water, which usually is scarce in the desert.

Many desert animals do not have sweat glands. Birds and rodents, like dogs, must pant to cool themselves. When they inhale dry air, water found on the linings of the lungs evaporates. The evaporating water absorbs heat from the lungs. Heat is exhaled along with the water vapor. But if these creatures become dehydrated, they will overheat.



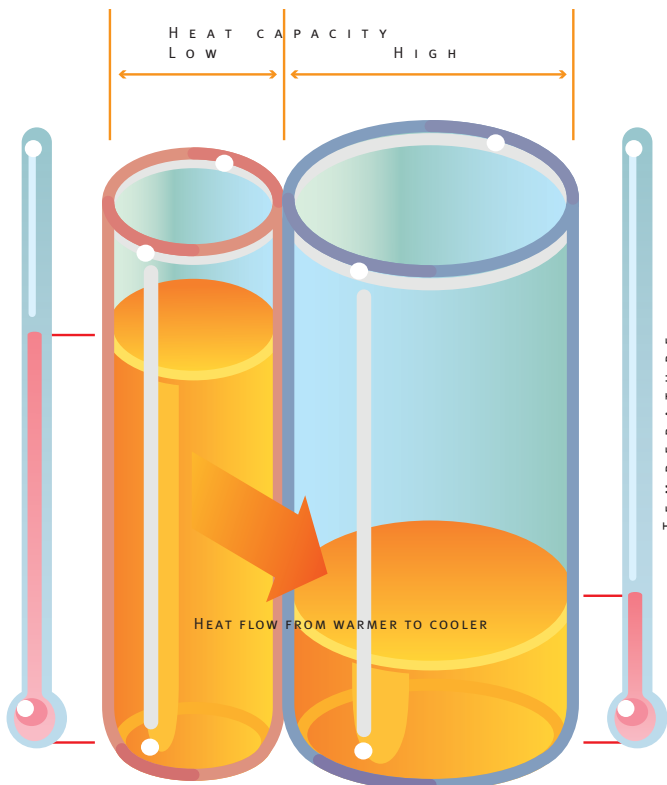
than it is added, heat content and temperature will decrease. If heat is added and lost at equal rates, the heat content and temperature will not change.

Every substance has a different ability to hold heat. This ability is called the *heat capacity* of the substance. Different substances have different heat capacities. As a result, they can have different heat contents, even though they may exist at the same temperature.

Imagine that heat really is fluid and that a substance is a cup. The diameter of the cup represents its heat capacity. The amount of fluid in the cup is the heat content. The height of the fluid in the cup represents the temperature.

The desert is hot because the soil absorbs heat from intense sunlight. This is called radiant heating. Sunlight is a form of radiation that contains many different kinds of light, including infrared light. Infrared light carries heat and is not visible to the human eye.

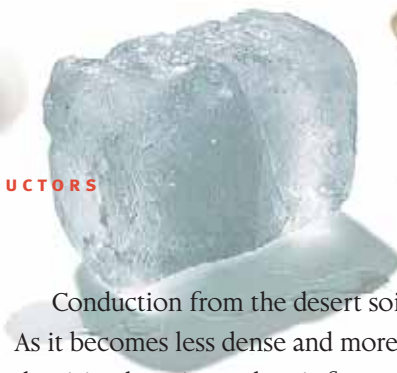
The same heat content can result in different temperatures, depending on the heat capacity of the substance.



This is what sweat looks like on the surface of your skin — enlarged thousands of times by electron microscope. The image was made from a latex rubber mold of a fingerprint. Living things cannot be viewed in an electron microscope because the energy of the electron beam used to illuminate the subject would fry it!



CONDUCTORS



INSULATORS

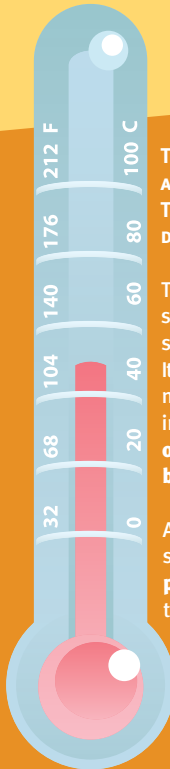
Heat flows quickly through some substances. These are called **thermal conductors**. Heat flows slowly through substances that are **thermal insulators**. The flow of heat into or out of a substance depends on conduction. The storage of heat depends on insulation. Thermoregulation depends on both conduction and insulation.

Substances that are good thermal conductors: metal or water.

Substances that are good thermal insulators: wood, bone or rock.

What characteristics of these materials affect heat flow?

Desert birds, like this turkey vulture, often soar effortlessly for hours by riding on thermals, the updrafts of rising air created by convection. By gliding on thermals, the birds conserve precious energy as they hunt for food.



TEMPERATURE IS A MEASURE OF HEAT. THERE ARE SEVERAL DIFFERENT TEMPERATURE SCALES.

The **Fahrenheit** scale is the oldest system for measuring temperature, still common in the United States. It was invented by German physicist named Daniel Gabriel Fahrenheit in 1724. He set the **freezing point of water at 32 degrees**, and the **boiling point at 212 degrees**.

Anders Celsius invented the Celsius scale in 1743. He set the **freezing point of water at 0 degrees** and the **boiling point at 100 degrees**. This system is now used in most countries and among scientists everywhere. It is also called the Centigrade scale.

The **Kelvin** scale measures the ultimate extremes of temperature. It was invented in 1848 by Lord William Thomson Kelvin. In the Kelvin system, zero degrees — or “**absolute zero**” — is the temperature at which there is no molecular motion and therefore, no heat at all. There is no temperature colder than absolute zero. Absolute zero is equal to -273 degrees Celsius or -460 degrees Fahrenheit.

Conduction from the desert soil causes the air to get hot. The air expands. As it becomes less dense and more buoyant, the hot air rises. To replace the rising hot air, cooler air from above sinks to the desert floor. That air then absorbs heat and the cycle continues. When heat moves because hot air rises and cool air sinks, the process is called *convection*.

Desert animals have adapted ways to stay cool during the hot desert day. They stay in shade or find a cool place underground to avoid radiant heating and conduction from the soil. Most desert animals are nocturnal, which means they are active only at night. This is thermoregulation through behavior.

Thermoregulation also depends on the way in which heat interacts with matter. Substances can exist in solid, liquid, or gas form.

The form, or *phase*, of a specific substance is determined by its heat content. Think about water. If ice absorbs heat, it will melt to form liquid. If the liquid absorbs heat, it will evaporate to form steam or vapor. However, if that water vapor loses heat, it will condense to form liquid. If the liquid loses heat, it will freeze into ice.

The change between phases is called a transition. For animals, evaporation is an important process for cooling—melting, freezing, and condensing are not practical methods for thermoregulation.

For example, if an animal has enough water in its body, it can use evaporation to stay cool by perspiration (sweating) and respiration (breathing). Animals with sweat glands perspire to cool large areas of skin. Water is secreted through pores in the skin. When it evaporates, the water vapor carries away heat from the skin.

Lizards, snakes, and other cold-blooded animals cannot generate body heat from the energy in their food. To stay warm, they absorb the heat they need from the surrounding environment. They absorb heat directly from sunlight. They also use conduction to absorb heat from the hot desert soil. They retain that heat by insulation.

Coyotes, javelinas, rodents, birds, and other warm-blooded desert animals also absorb external heat. But they also use chemical energy from food to generate large amounts of internal body heat.

As long as food is plentiful, warm-blooded animals have a distinct advantage for thermoregulation. Warm-blooded animals can stay warm even when it is cold outside for long periods of time. On the other hand, cold-blooded animals don't need as much food to survive extreme temperatures because these creatures don't use the energy from their food for thermoregulation.