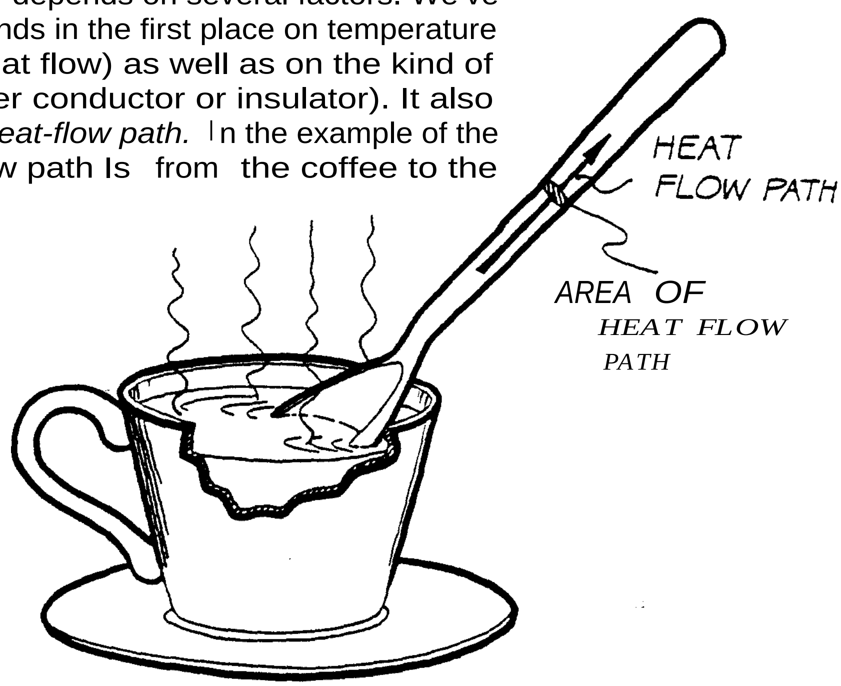
CONDUCTION AND CONVECTION

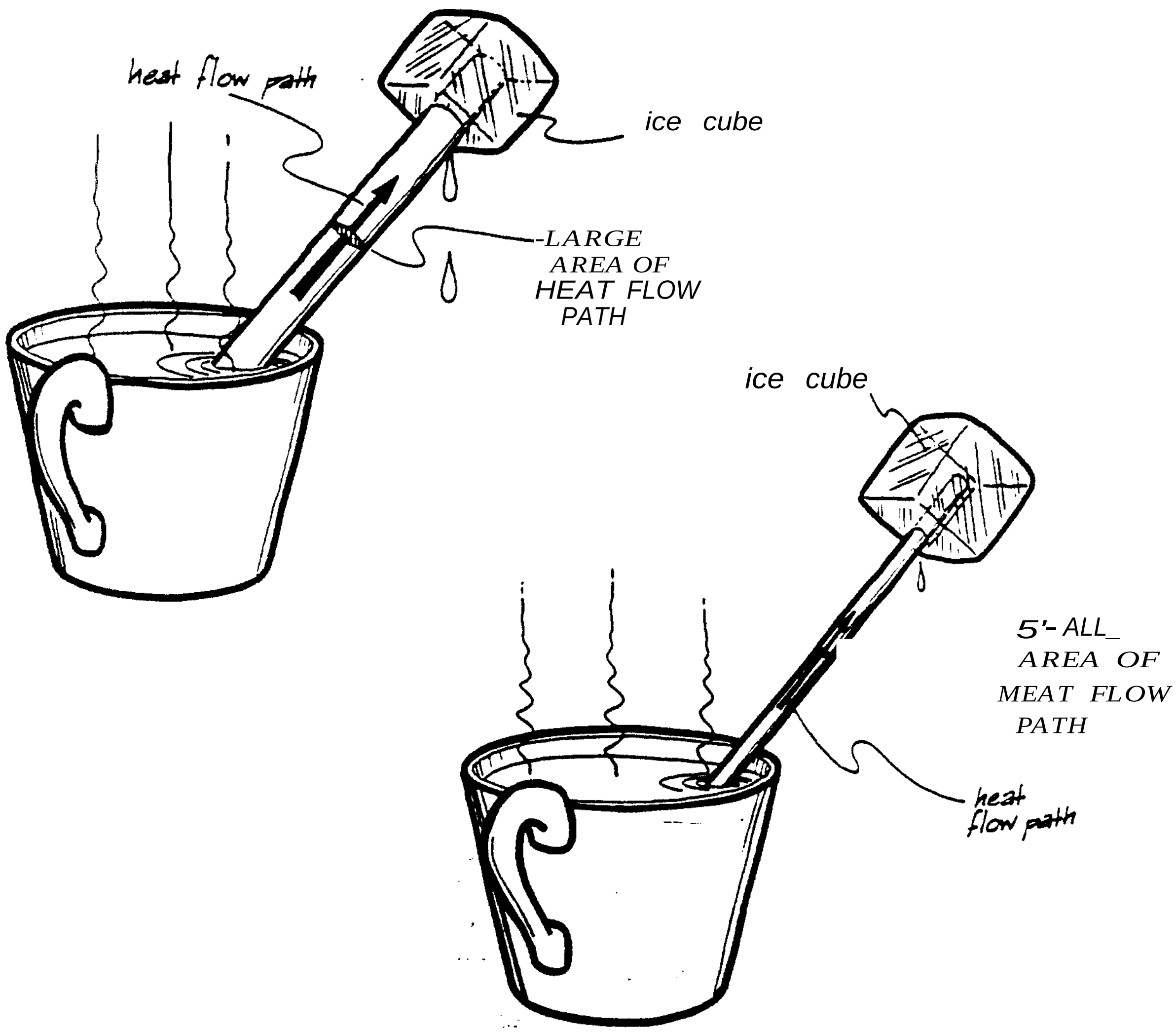
First, let's look at *conduction. Two* kinds of materials are involved in conduction heat flow: *conductors* and *insulators.* Conductors let heat flow through them easily, but insulators prevent heat from flowing. Most metals, such as silver, copper, aluminum, and steel, are good conductors of heat. Insulators, on the other hand, are usually lightweight materials, such as straw, fiberglass batting, or plastic foam. Other materials, such as glass, concrete, rubber, wood, and dirt, are neither good conductors nor good insulators; heat passes through them more easily than through an insulator but not as easily as through a conductor.

Conduction heat flow depends on several factors. We've already learned that it depends in the first place on temperature difference (as does all heat flow) as well as on the kind of material involved (whether conductor or insulator). It also depends on the *area* of the *heat-flow path.* In the example of the silver spoon, the heat-flow path Is from the coffee to the spoon's end.



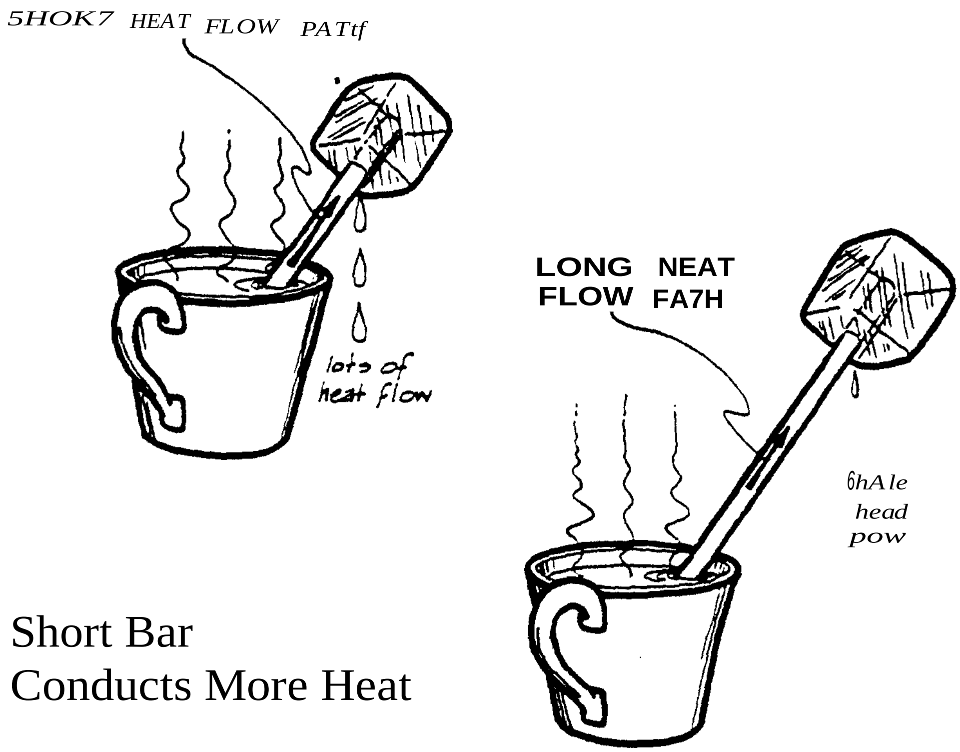
Conduction
Heat Flow Path

To understand how the heat-flow path changes the conduction heat flow through an object, suppose we try to melt an ice cube using a cup of hot coffee. If we put one end of a silver bar into a coffee cup and hold an ice cube against the other end, the ice will hold one end of the bar at a fixed temperature (since ice melts at 32' F); how quickly the ice melts will measure how much heat is flowing through the bar from the coffee. A thick bar will melt the ice more quickly than a thin one because a thick bar lets more heat from the coffee through-the heat-flow path of the thicker bar has a bigger area.



Thick Bar Conducts More Heat

The length of the heat-flow path is also important. Less heat flows through a longer bar than through a shorter bar because the length of the heat-flow path impedes the flow of heat.

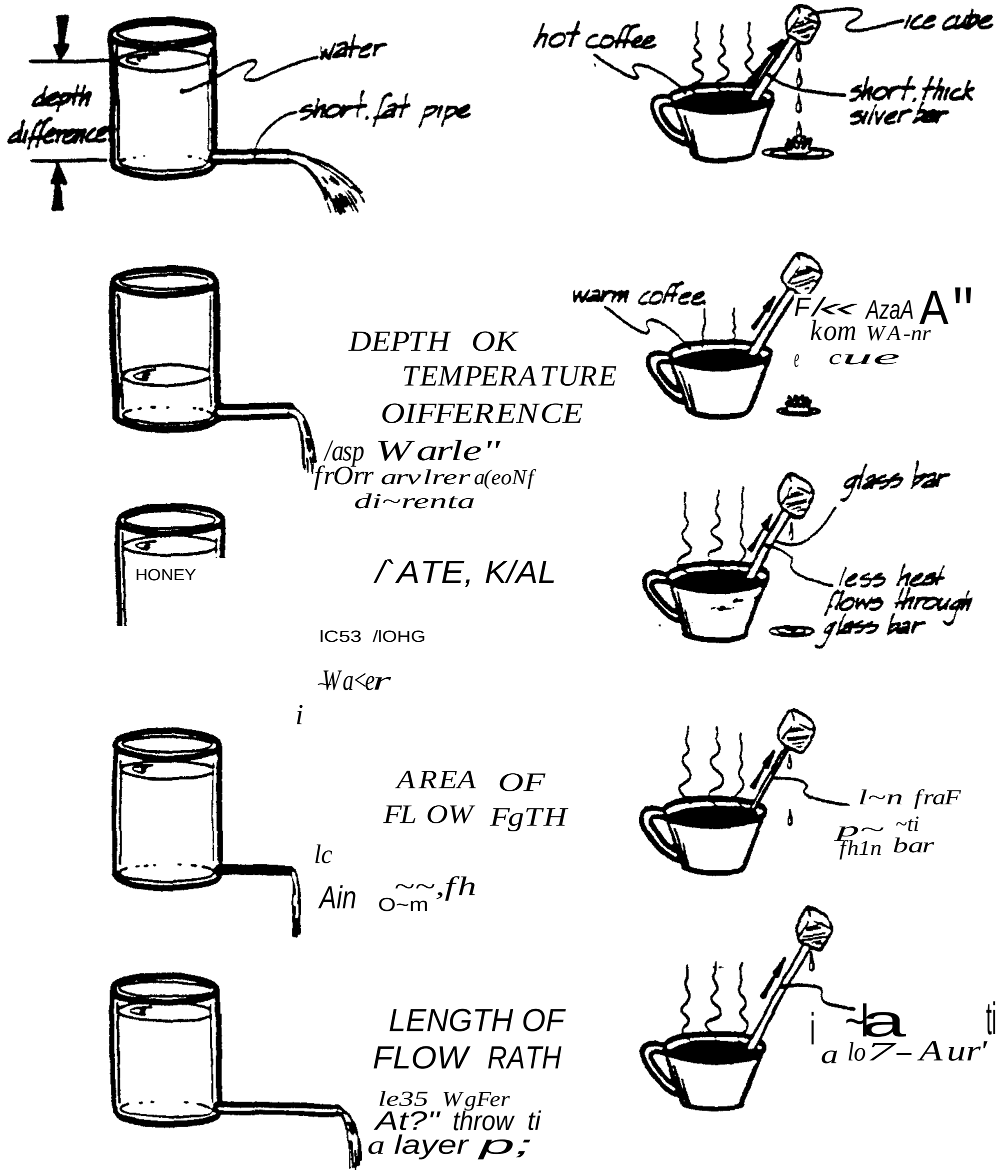


Short Bar
Conducts More Heat

Four factors affect how,much heat will flow through a material by conduction: temperature difference, material, area, and the length of the heat-flow path. By analogy to water flow, think of a pipe attached to the bottom of a big tank.

Four factors *also affect how much* fluid will flow through the pipe. As shown in the following figure, lots of volume will flow out of a tank of water through a short, fat pipe. But depth difference affects the volume flow: if the tank isn't full, less will flow out. Second, the material also has an effect. Less volume flows if the tank is filled with honey than if it's filled with water. Third, flow-path area affects volume flow; there is less flow through a thin pipe than a fat one. Fourth, the length of the flow path is important, since less water flows through a long pipe than through a short one.

Volume Flow and Conduction Heat Flow



Now let's discuss *convection*. Heat flow by **convection** occurs when a gas such as air or a liquid such as water flows by a surface. In the example used earlier, the surface was your skin as air blew by it. As with conduction heat flow, convection heat flow depends on several factors. One factor, we've already learned, is temperature difference. In convection heat flow, it's the temperature difference between the surface and the convecting gas or liquid that's important. Other important factors are:

1. the area of the surface
2. the speed of the air or water over the surface
3. whether it's gas or liquid that flows by the surface.

More Convection from Large Surfaces

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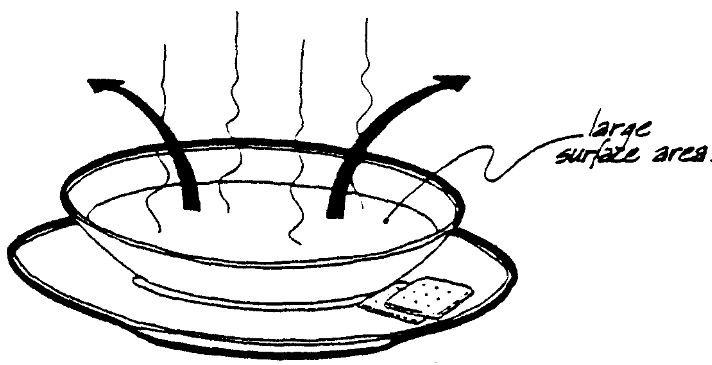
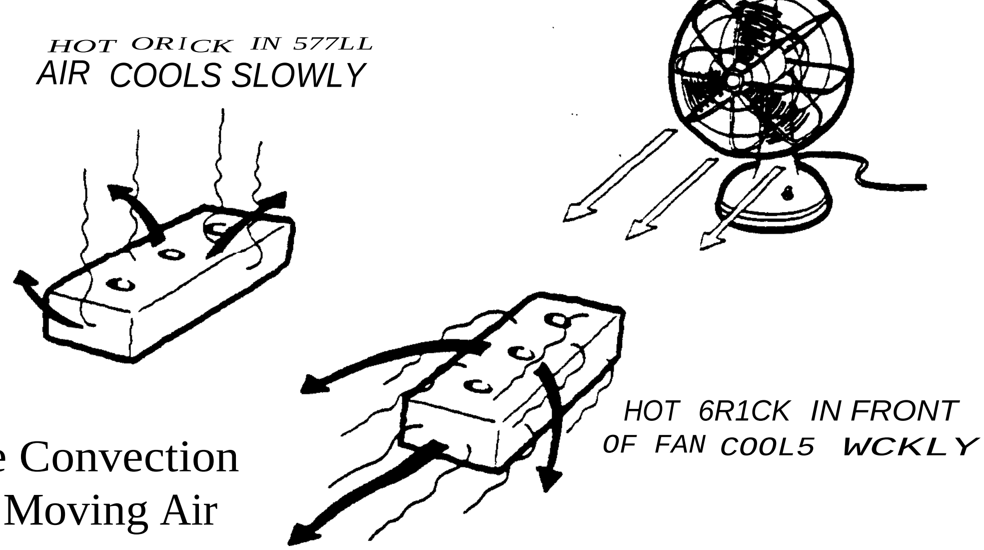


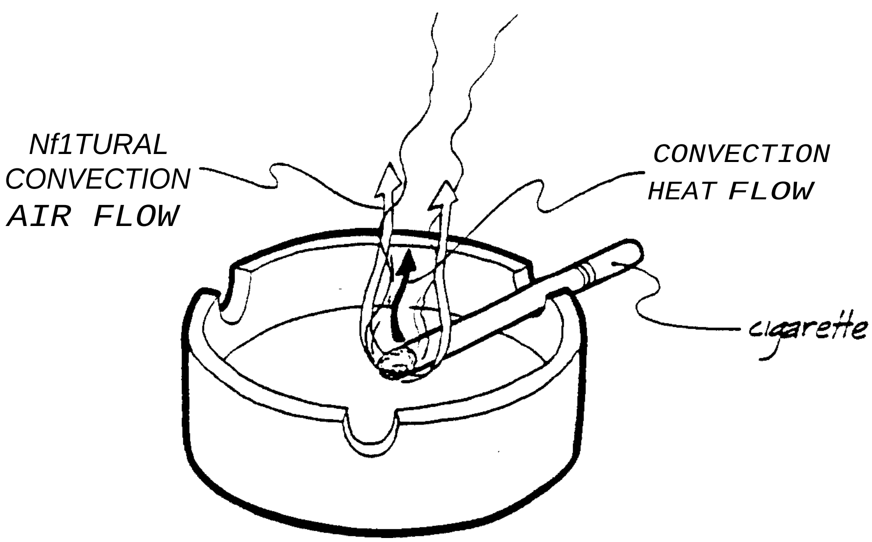
BOWL CCCL5 CUICKLY

The larger the surface area is, the more convection heat is lost from the surface. If you have the same amount of soup in a bowl as in a mug, the bowl will cool faster than the mug because its surface area is larger than the mug's. Second, the speed at which the convectiog gas or liquid flows by the surface influences how quickly the heat flows. Suppose two bricks are placed in an oven, heated to the same temperature, and then taken out. One is placed on a table in still air; the other is placed in front of a fan. The one sitting in still air would cool much more slowly than the one sitting In front of a fan. You might think that the brick in still air wouldn't have any air flowing by it at all. Actually, air is flowing by-but much more slowly than if the fan were blowing air by it. The brick heats the air near it, which gets lighter and rises and is replaced by cooler air, which in turn is warmed and rises. This phenomenon Is called natural *convection,* since no fan is needed to cause the air to move: the air rises past the surface simply because the surface is hot.



More Convection with Moving Air

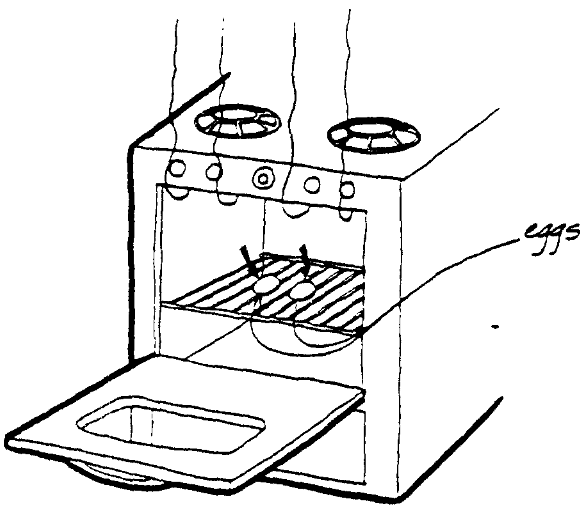
Smoke rising from a cigarette illustrates how natural convection removes heat from burning tobacco; the smoke moves with the air, showing how a hot object causes air to move by it. Conversely, cold surfaces also cause convection, but in the opposite direction. Convection currents fall from a cold object, as you may have noticed when opening the freezer door to the refrigerator.

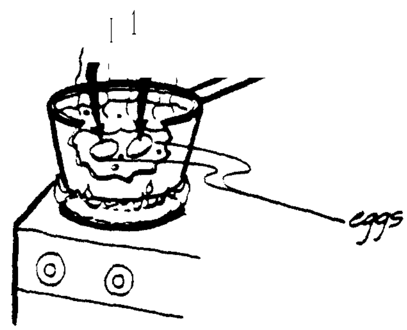


Natural Convection in a Cigarette

The last factor that is important in convection heat flow is whether a gas or a liquid is involved. Liquids are. much better than gases at causing heat to flow from a surface. Eggs cook in a few minutes in boiling water, but they would take many times longer to cook in an oven at the same temperature. The eggs gain heat slowly by air-a gas-convecting over them, but they heat up quickly when water-a liquid--is convecting over them.

Water Convects Better Than Air





E_*45 COCK .LOWLY
I/V AN OVEN
;~Z CONV5f70N)

ECGc5 COOK QUICKLY
IN A PAN
(W,4,TER CONVECTION)

In summary, convection heat flows fastest when there are big temperature differences of large surfaces with liquid flowing by them quickly. Little convection heat flows with small temperature differences of small surfaces In still air.