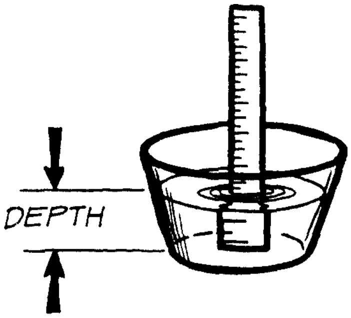
HEAT, TEMPERATURE, AND HEAT FLOW

The concepts of heat and temperature must be understood before a solar energy system can be understood. Often these two terms are misunderstood and, even worse, used interchangeably. However, these words have quite precise meanings.

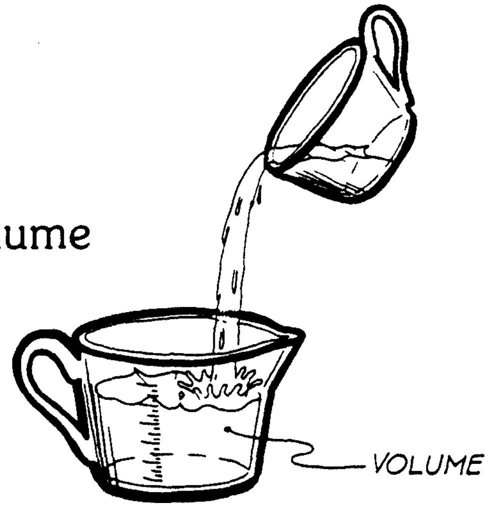
Heat and temperature differ in important ways. First, temperature can be measured directly with a thermometer, but heat must usually be measured indirectly. How hot something is, is a measure of its temperature, but how much heat it contains is not so easily determined. In fact, the heat contained in an object usually depends not only on what it's temperature is but also on other factors, such as what it is made of and how much of it there is.

Heat and temperature differ in another important way: heat costs money. When you heat your house for the winter, you buy heat from the local heat dealer--from the oil man or the gas or electric company, depending on how your house is heated. Whatever form your heat comes in, what is sent to your house costs money. The more heat that is sent, the higher the heating bills are. But you don't buy temperature. Temperature indicates how hot your house is, not how big your heating bills are. When considering solar energy systems in the pages that follow, always remember that what is wanted is heat, not temperature. The only way to save money by using a solar energy system is to have the sun pay for part of your heating bill-to provide you with heat.

A simple analogy to the heat and temperature of an object is the volume and depth of water in a cup. How deep the water is does not measure the cup's volume. Although the volume and the depth are related-generally, the deeper the water in the cup is, the more volume of water there is in it-depth is a different measure from volume. Also, the depth of the water can be mea-



Depth
and Volume

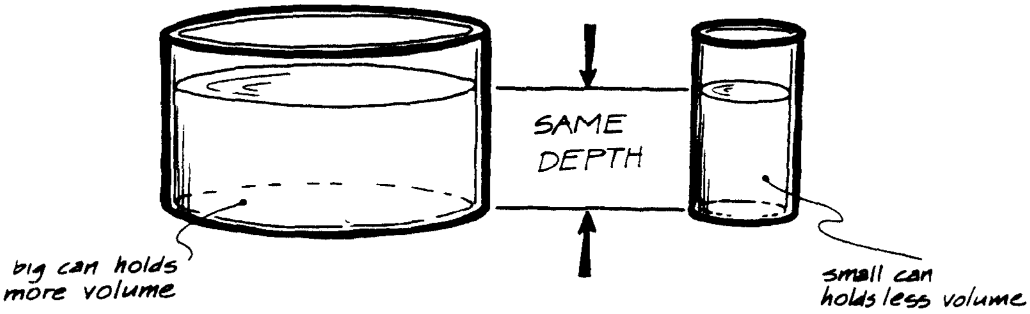


sured with a ruler, but a measuring cup must be used to ascertain the volume. According to our analogy, depth and temperature are easily measured, so they are like each other; volume and heat are measured only indirectly, so they are like each other too.

DEPTH <–=> *TEI'IPERATURE*

VOL UME *f·1ffAT*

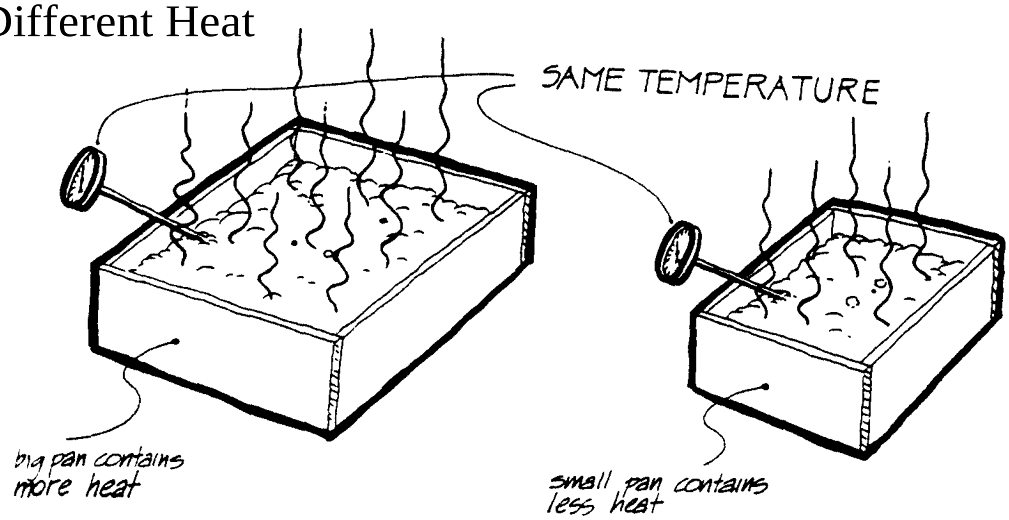
To see in more detail how depth is related to temperature, and volume to heat, let's consider a few simple cases. First, think of two different-sized cans that have the same depth of water in them. Though the depth of water in both cans is the same, the bigger can holds more volume. Similarly, if two pans



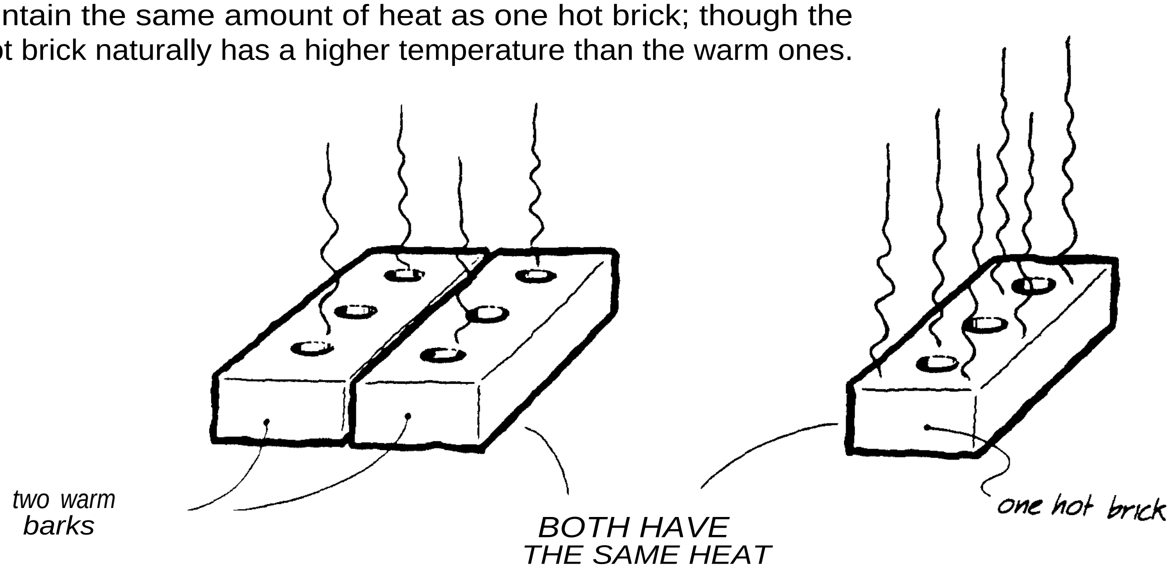
Same Depth but Different Volume

of dirt are heated in an oven for several hours, both will have the same temperature. But even though the temperature of both pans is the same, the bigger pan holds more heat. Just as the depth can be the same while the volume is different, so can the temperature be the same while the heat is different.

Same Temperature but Different Heat



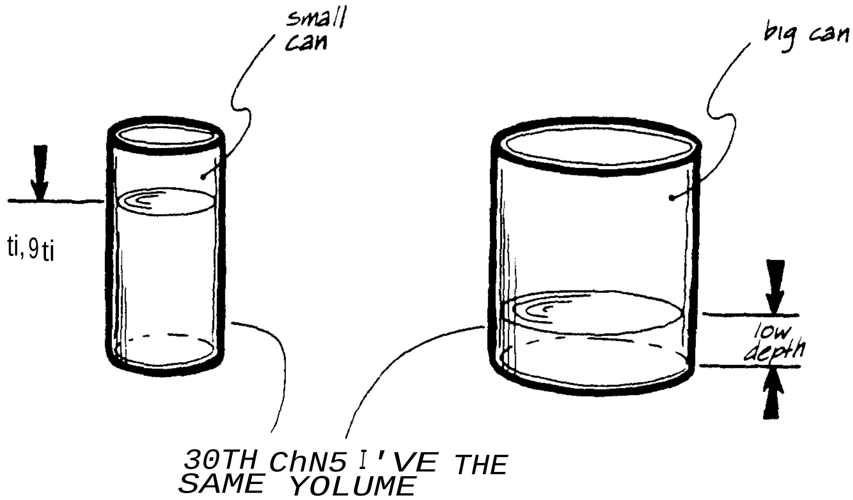
Second, let's consider two objects in which the heat is the same yet the temperatures differ. Two warm bricks could contain the same amount of heat as one hot brick; though the hot brick naturally has a higher temperature than the warm ones.



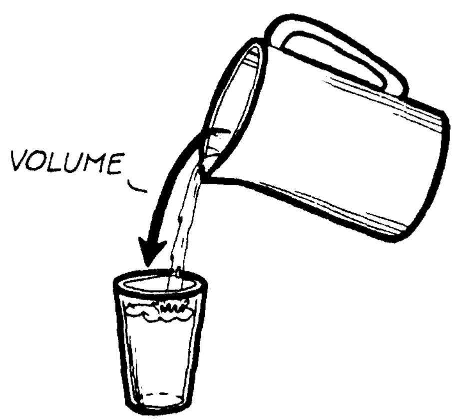
Same Heat but Different Temperatures

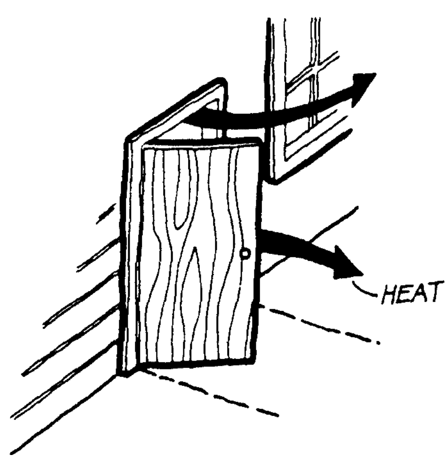
In the same way, two cans can hold the same volume but have different depths.

Same Volume
but
Diff erent Depths



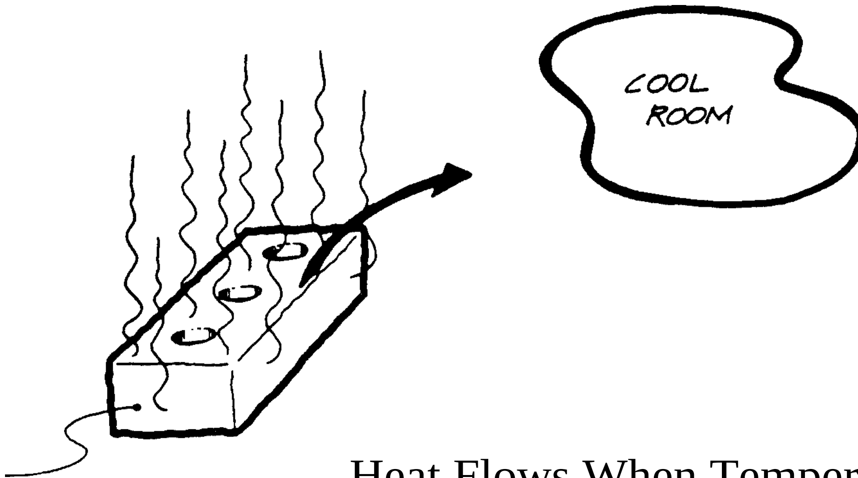
The analogy is helpful in another way. Both volume and heat flow--both can move from place to place. When you pour water out of a pitcher into a glass, volume flows from the pitcher to the glass; when you open a door on a cold day, heat flows from inside the house to the outdoors.





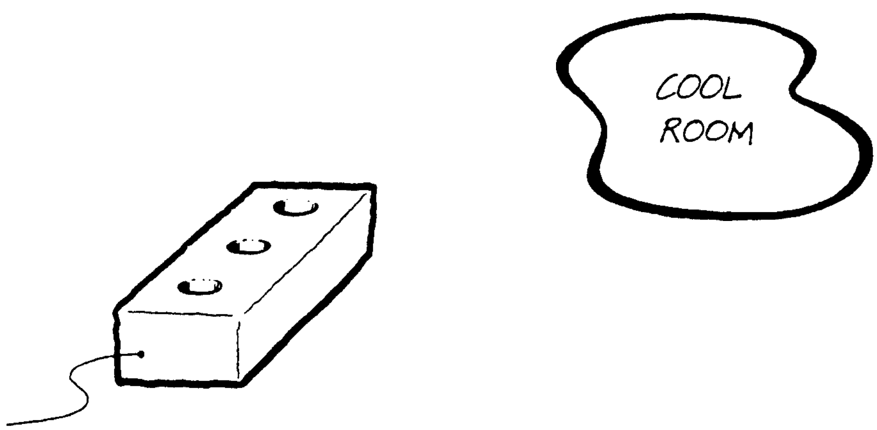
Heat and Volume Can Flow

Why does heat flow? Heat flows from one place to another because the temperature of the two places is different. A hot brick loses heat to a cool room. The *temperature differ ence*-the brick's temperature minus the room's temperature-drives the heat from the brick. Heat leaks from the brick until the temperature difference is gone. No more heat flows from the brick when it becomes as cool as the room it is in.



MGK

Heat Flows When Temperatures Differ

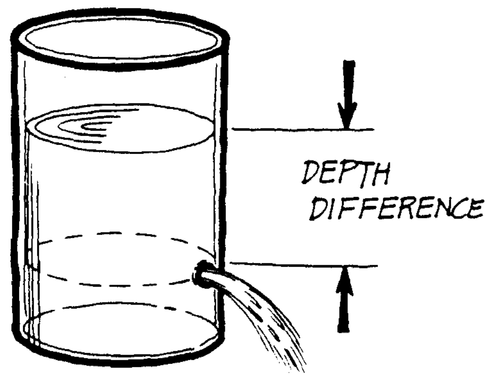


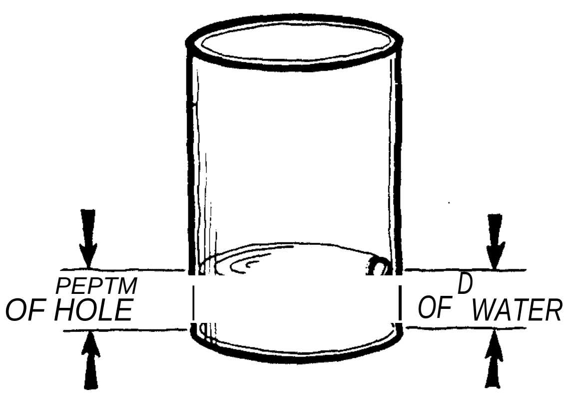
COOL BRICK

No Heat Flows When Temperatures Are Equal

Similarly, a full can of water will leak volume from a hole in the side of the can. The depth of the water is higher than the depth of the hole, so the *depth difference* drives volume out through the hole. Eventually, all the volume that can leak out does so. When this happens, the water depth has fallen so that it is the same as that of the hole. There is no more depth difference, so no more volume flows out through the hole. Just as a difference in temperature causes heat to flow, so a difference in depth causes volume to flow. When there is no temperature difference, heat flow ceases; when there is no depth difference, volume flow ceases.

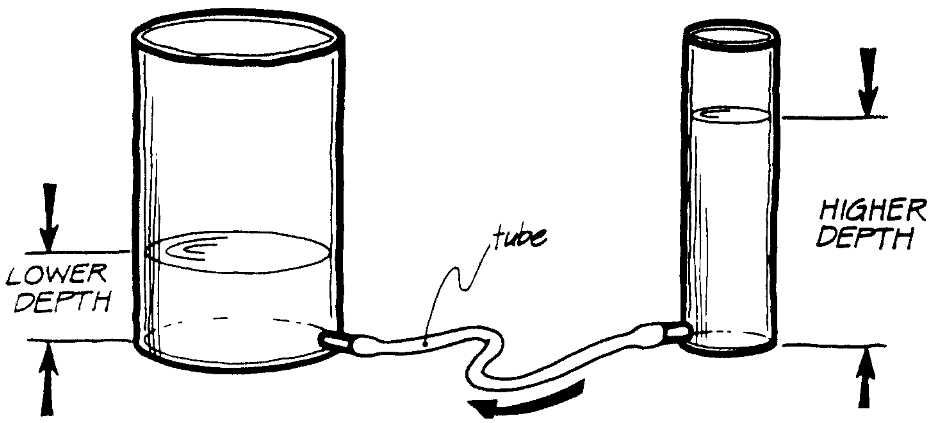
Volume Flows
When Depths Differ





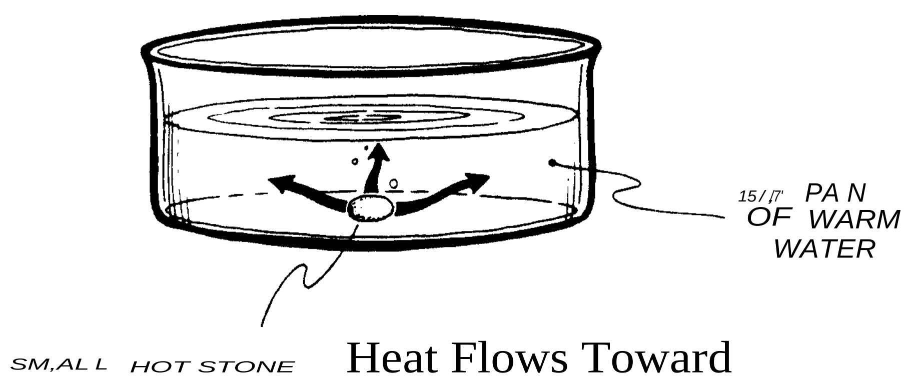
No Volume Flows
When Depths Are Equal

The *direction* of volume flow is always downhill--from a higher depth to a lower one. If two cans having different depths are connected by a tube, volume will always flow *toward* the depth that is lower. Note that the narrow can has much less volume than the wide one. Even so, volume flows toward the can with the lower depth. It's depth, not volume, that causes volume to flow.



Volume Flows Toward Lower Depth

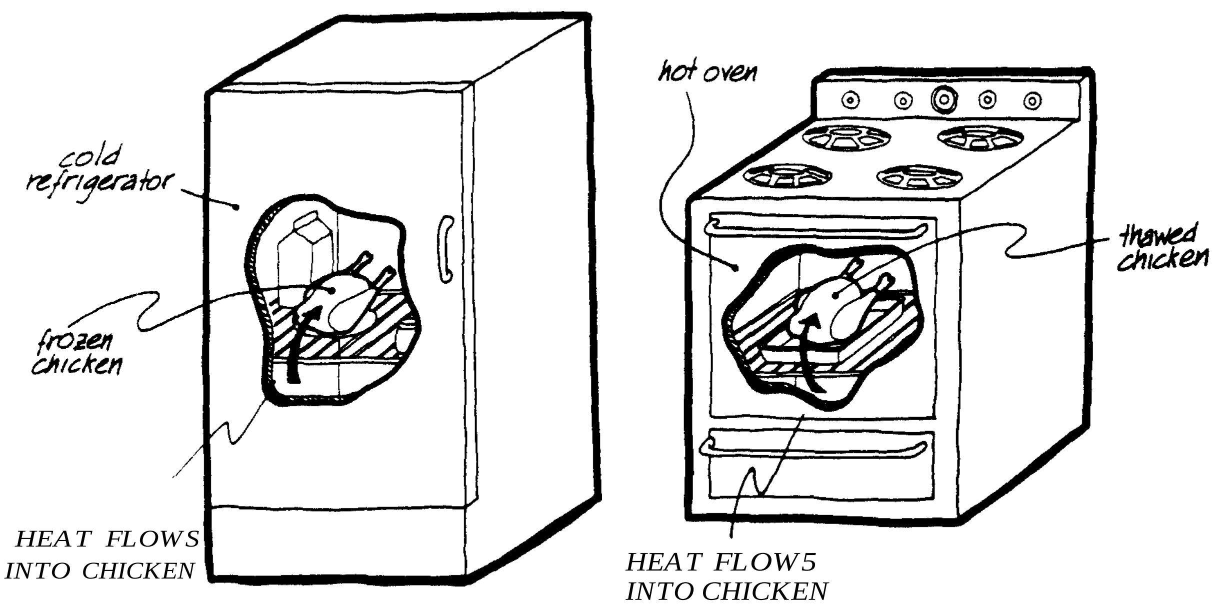
Similarly, heat flows downhill from a higher temperature to a lower one. If a small, hot stone is put into a big pan of warm water, heat will flow out of the stone and into the water, since the stone is hotter than the water. Heat flow is always toward the object with the lower temperature-in this case, the water. Even though the big pan of water has much more heat than the hot little stone, heat still flows from the stone into the water. It's the temperature that makes the heat flow, not the amount of heat each object has.



Heat Flows Toward Lower Temperature

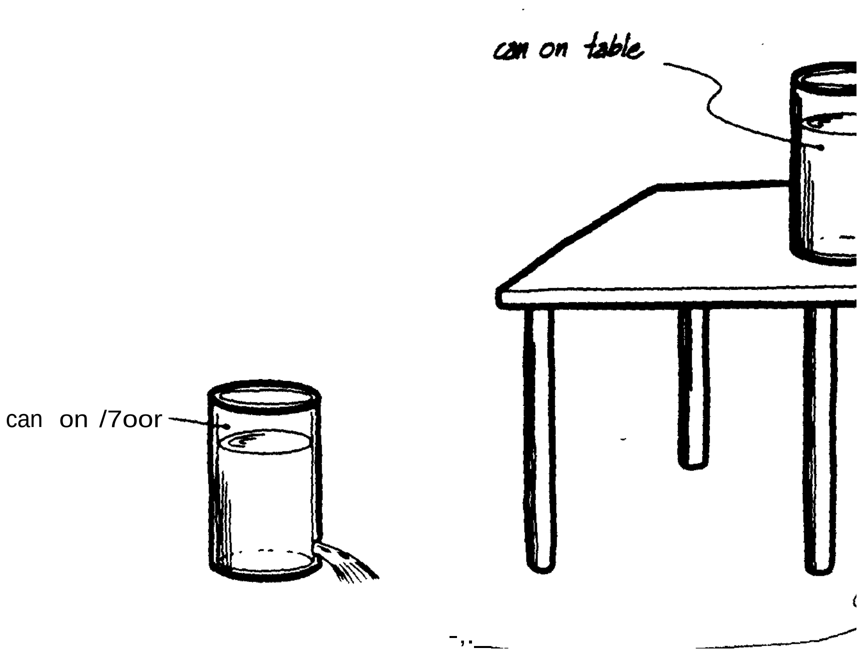
Just as volume flows downhill toward lower depths, so heat flows downhill toward lower temperatures. Only a depth difference (not volume) can cause volume to flow, just as only a temperature difference (not heat) can cause heat to flow.

You may think it strange that heat flow is the same at cold temperatures as at hot temperatures. But consider this example. Suppose we took a frozen chicken out of the freezing compartment of a refrigerator and put it into the main part of the refrigerator. The chicken would warm up-heat would flow into it-even though it was in a cold refrigerator. Since the chicken started out colder than the refrigerator, heat had to flow into it to get it to be as "warm" as the refrigerator. If we then put the chicken into a hot oven, more heat would flow into it until it became as hot as the oven. In this example, heat flow depends only on the temperature difference between the chicken and its surroundings, not on whether the surroundings are hot or cold.



Heat Flows Only Because Temperatures Differ

By analogy, the same volume flows from a hole in a can whether the can is on the floor or a table. Only the depth difference between the water level and the hole is important, not whether the can itself is raised or lowered.



Volume Flows Only Because Depths Differ