In this episode, I'll be covering a series of misconceptions related to heat and temperature. They are:

1) Heat rises
2) Hot air rises
3) Atoms get bigger when you heat them up
4) Temperature and heat are the same thing
5) Sweat cools you off in the same way as pouring cold water on you
6) An object at 0 degrees has no heat
7) When you touch a cold object, it transfers some of its coldness to you
8) All ice is 0 degrees Celsius

1) Heat does not rise. Heat cannot rise. Heat is not even a thing that could be seen even if it could rise. Heat is a form of energy.

When some students finally come to realize that heat is not a thing that can rise, they modify the statement to say "Hot objects rise." This is not necessarily true either. A hot rock will sink in a cool lake. A hot space capsule sinks through the air. An ice cube floats in warm water. So this explanation is not sufficient either.

To be correct, the statement should read, "Less dense materials float in fluids that are denser than they are." Then, the explanation for a hot air balloon is that the balloon is less dense than the surrounding air, so it floats. What's even more beautiful about this is that the same explanation can be used for a helium balloon, a fishing bobber, an iceberg, or the Titanic . . . ok, maybe not the Titanic, but some other large ship.

To understand the distinction, it will be necessary for students to have been taught previously how temperature affects density. But when these two concepts are taught separately, a clear understanding is possible. When they are combined together, they become confused.

To crush this misconception, have students put hot rocks in cold water and put an ice cube in warm water to see a hot object sinking and a cold object floating. It will not be enough to ask them, "What would happen if you put a hot rock in cold water?"; have them actually do it. Put a helium balloon in the freezer and show them that a cold helium balloon will still float. Put it in liquid nitrogen and it will not float anymore until it warms back up again. Spend time explaining temperature and phases of matter on an atomic level. If students do not understand what temperature is, they cannot understand this concept.

To test if students actually understand, give them some practical problems to tackle and explain. Build a hot air balloon and have them explain in detail how it floats. Put a baby food jar of colored hot water in an aquarium and remove the lid and ask students to explain why the colored water moves up.

2) The misconception about hot air rising is almost a semantic issue. Some students see hot air rising as an almost anti-gravity issue. The hot air does not rise, the less dense hot air is pushed up or "buoyed up" by the denser cool air. And students should know that "hot" and "cool" are being used as relative terms here. There are storms on Neptune caused by air that is -200 degrees Celsius rising in air that is -220 degrees Celsius. The terms hot and cool are relative. This whole issue is avoided if one says less dense and

more dense (my spell check says to use “denser,” but I prefer “more dense”). So, the misconception here is that hot air does not magically rise; it is pushed up by the cooler, more dense air around it.

To crush this misconception, have two aquaria; one with hot water and one with cold water. Put a baby food jar of colored hot water in each one and remove the lid. Students will see that the hot water rises in the cold aquarium and does not rise in the hot aquarium. This will show that hot things do not magically rise if there is no difference in density. It is the difference in temperatures, and therefore densities, that allows the fluid to push the hot material up.

3) A common misconception amongst students is that atoms get larger when they are heated. I recorded a separate podcast on this topic. Please download that episode and listen to it individually.

4) Students very commonly believe that temperature and heat are exactly the same thing. When they call an object “hot” or “cold” and you ask them if they are referring to heat or temperature, they will likely respond “Huh? Same thing.”

Temperature and heat are not the same thing. An object can have high temperature and very little heat. An object can also have very low temperature and a lot of heat. Temperature is simply how fast molecules are moving in an object like billiard balls on a pool table. Heat is a form of energy that depends on the temperature as well as the type of molecule, and how many molecules in the object. Temperature is measured with a thermometer. Heat cannot be measured directly.

The best analogy I have seen for temperature versus heat was on a science cartoon series called Eureka. They asked “Which would you rather have, a cup full of 100-dollar bills or a swimming pool filled with 1-dollar bills?” The value of an individual bill represents temperature and the total dollar value represents heat. Although the temperature in the cup is higher, the heat in the swimming pool is greater. By looking at the swimming pool, you could tell the metaphorical temperature, but you cannot tell how much heat there is. This helps show why temperature is directly measurable and heat is not. You can tell how fast molecules are moving, but there is no device that can simultaneously measure the temperature of the molecules, the type of molecule and how many molecules there are. Have students consider being in a cold swimming pool and thinking how little help it would be to pour one cup of hot water into the pool. Have them try it. Pour a small cup of hot water into a large aquarium and see how little the temperature changes because the cup of water has so little heat.

5) Many students believe that sweat cools you down because water is cool. But sweat comes out at exactly the same temperature as your skin, maybe even a little hotter. It is not cool. So, how does it cool you then? It cools through evaporation.

You’ve probably heard that steam burns worse than hot water. This is not a misconception, it is true. It takes heat to boil water and it gives that energy back when it condenses. It also takes heat to evaporate water. In the case of sweat, the heat to evaporate the sweat comes from you. Your skin gives it the energy that it needs to evaporate and then it takes that energy with it.

This also helps to explain why it feels so much hotter on a humid day. When there is a lot of water in the air, sweat does not evaporate well. It stays on your skin and does nothing. The water that some students think is so cool does not cool you at all when it cannot evaporate. On humid days, students are covered by sweat and it does not cool them.

You can crush this misconception by having students put a thermometer into a bottle of rubbing alcohol and note the temperature. Then have them take the thermometer out and allow the alcohol to evaporate. The temperature will immediately drop. It is not the alcohol itself that is cool. It is the evaporation that causes the cooling. The rate of cooling can be increased by blowing on it and this is one of the reasons why a breeze feels so good on a hot day. If students are too young to do this demonstration with alcohol, use water. The effect is not as great, but it will work. In fact, this is how humidity can be determined. Scientists compare the temperature of a dry thermometer to a wet thermometer that has been spun in the air. The more humid it is, the less difference there will be in the temperature readings because the water cannot evaporate as easily. A big difference in temperatures between the wet bulb and dry bulb thermometers indicates low humidity.

6) Many students think that an object with a temperature of zero has no heat. This is true . . . but only if you are measuring the temperature in Kelvin. 0 Kelvin is the point where an object would have a temperature of zero. 0 Celsius is actually 273 Kelvin and 0 Fahrenheit is 255 Kelvin. An object at 0 Celsius or 0 Fahrenheit does have heat. An object at 0 Kelvin would not. There is one caveat, though . . . Although scientists have been very close to absolute zero, they have never reached it. It is not possible to have a temperature below 0 Kelvin so having negative heat is not possible. So it is accurate to say that everything on Earth and likely everything in the universe contains heat because everything has a temperature greater than 0 Kelvin.

7) Many students also believe that when they touch something cold, coldness is transferred from the cold object to their body. There is no such thing as cold. An object feels cold because it has less heat than you. The sensation of cold is the feeling that we get when heat leaves our body to enter an object with lower temperature. It is not coldness leaving the object and entering you, it is heat leaving you and entering the object.

Temperature is the vibration of molecules or atoms. All molecules and atoms are vibrating. Therefore, all objects have temperature. The faster the molecules are vibrating, the more temperature they have. Heat energy always flows from an object with higher temperature to an object with lower temperature.

Related to the misconception above, many students believe that an object with a negative temperature has negative heat and negative heat is called coldness. The only absolute temperature scale is the Kelvin scale and there are no negative temperatures on the Kelvin scale and 0 Kelvin has never been reached.

8) Many students believe that because the freezing point of water is 0^oC that all ice is at that temperature. But 0^oC is simply the maximum possible temperature for ice under

normal conditions. If your freezer is set to -4^{o}C, then the ice cubes will be -4^{o}C. If it is -24^{o}C in Siberia, then the snow and ice there are at -24^{o}C.

It is true that a glass of ice water is usually at 0^{o}C. When you put ice cubes into a drink, the cubes cool down the drink by absorbing heat energy from the drink. As the ice cubes warm up, the drink cools down. Normally, there is more drink than there is ice. So the cubes go up to 0^{o}C and then begin to melt. So once the cubes have been sitting in the drink for a couple of minutes, the entire drink will very likely be at 0^{o}C. The same is true for ice that has been sitting out of the freezer for a few minutes. It will absorb heat energy from the air until it reaches 0^{o}C and then begin to melt.

To break this misconception, turn the freezer in the chemical store room down as low as possible for one day. Take ice cubes out and immediately measure their temperature. This can be difficult with a thermometer, but the infrared thermometers that you just point at an object would work great.

In summary, heat does not rise, but less dense objects are pushed up by more dense fluids. Atoms do not get bigger when you heat them up, they simply get farther apart.   Temperature and heat are two different things. Sweat cools you down through evaporation. An object at 0 degrees Celsius or Fahrenheit still has heat. Ice does not have to be at 0^{o}C. And there is no such thing as cold, only lower temperature.