How does humidity affect cooling?

A laboratory experiment from the Little Shop of Physics at Colorado State University

Overview

When travelers discuss the different climates they have experienced, many will agree that the summers in Texas are much less comfortable than Colorado despite the fact that the summer highs for these regions are very similar - generally within a few degrees of each other. So why the difference? We've all heard that "it's a dry heat" in Colorado but what does that mean? How does the lack of humidity in Colorado make a 32˚C day seem more bearable than a 32˚C day in Texas?

Necessary materials:

- An indoor/outdoor thermometer
- Small stuffed animal
- Rubber bands
- Water
- Small fan
- Spreadsheet calculator for relative humidity and dew points based on wet bulb/dry bulb temperature differences

Included as a part of the experiment is an spreadsheet to calculate the relative humidity and dew point temperature from the dry bulb/wet bulb temperatures.

Theory

The terms dew point and relative humidity seem like they are interchangeable. They are related, but have different meanings. Dew point is the temperature at which the air becomes saturated and water vapor condenses into liquid forming dew, like dew in the early morning. Relative humidity is the percentage of water that is actually in the air compared to how much water the air could possibly hold at a certain temperature.

$$\text{RH} = \frac{\text{Water the air } \textit{does} \text{ hold}}{\text{Water the air } \textit{could} \text{ hold}} \times 100$$

The indoor/outdoor thermometer takes two readings: one of the "wet" temperature and one of the "dry."

In the vapor pressure dice game we learned hot air can contained more water vapor then cold air. A good analogy for understanding dew point and relative humidity is to think of nesting dolls where each doll is associated with a range of temperatures. The largest doll would be associated with hotter temperatures and be able to contain more water vapor, whereas the smallest doll would associated with colder temperatures and contained the least amount of water vapor. If you are in the smallest doll you are at a cold temperature, the dew point would be low, and you could have any range of relative humidities. A 50% relative humidity in a larger doll would mean more water va-

por than a smaller doll with 50% relative humidity. In the Molecules in a Box experiment we learned the more molecules in a box the more pressure it would exert. In the case of a larger nesting doll with 99% relative humidity, the water vapor would exert more pressure than a smaller nesting doll with 99% humidity. Scientist refer to this as partial pressure because there are other molecules in the air, nitrogen and oxygen for example, also exerting different pressures.

In this activity, your students will be measuring relative humidity by constructing a whimsical psychrometer or wet bulb/dry bulb thermometer. The psychrometer was invented by Dr. Adolf Aßmann in the late 19th century and enables atmospheric scientists to measure how much moisture is in the air. In this experiment, one probe of the thermometer will be shielded from radiation and moisture inside the apparatus while the other will be in a humid environment exposed to moving air. This will cause the latter probe to record a lower temperature than the former. When the water in the stuffed animal (or Humidibeast) evaporates, it absorbs energy, lowering the temperature. The amount of water evaporated from the Humidibeast depends on the moisture content of the ambient air. By measuring the two temperatures, we can determine the relative humidity of the air.

Doing the Experiment

Soak the Humidibeast thoroughly with water and use the rubber bands to secure one probe of the indoor/outdoor thermometer to it so the animal's hide covers the sensor*. It is better to use room temperature water to ensure the wet bulb temperature stabilizes quickly. Set up the fan so that it blows across the animal, encouraging evaporation. Have students observe the difference in temperature readings between the wet and dry. Once the two temperatures have reached a stable point, have students record the values and disassemble their equipment. If the two values are very different then the relative humidity is low meaning that more of the water in the Humidibeast could (and did) evaporate. If, however, the values are closer together then we know that the relative humidity was rather high and the air could not hold much more moisture. When students have resumed their seats, have them use the provided chart to determine the relative humidity and dew point temperature. Discuss how this might vary in different parts of the world or other times of the year.

Summing Up

If you are taking a walk in the park on a warm summer day, your body will attempt to thermally regulate itself by sweating. When the sweat evaporates it leaves your skin cooler - you are in essence a Humidibeast yourself in this situation. If, however, the relative humidity is already very high then less of the sweat will be able to evaporate since the air can not hold much more moisture. In this case, your body will not be able to cool itself and you will feel much warmer. This is why the a hot summer day in Colorado doesn't seem as severe as the same temperature day in Texas.

For More Information

CMMAP, the Center for Multiscale Modeling of Atmospheric Processes: http://cmmap.colostate.edu

The spreadsheet calculations were taken from the NOAA website:
http://www.srh.noaa.gov/images/epz/wxcalc/rhTdFromWetBulb.pdf

Little Shop of Physics: http://littleshop.physics.colostate.edu

*No Humidibeasts were harmed in the development or execution of this experiment.