Safety in Numbers: Basics of Warmth

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If you've lived long enough to be able to read this sentence, then you've experienced the basics of warmth. When you get too cold, you put on a jacket or snug up the blankets. If you later start to get too warm, you unzip the jacket or kick off some blankets. Temperature regulation is a simple idea: keep your body within a certain temperature range.

If you're going to spend time outside, especially in the winter, it pays to know a bit more than the basics about warmth. One of my favorite books on the topic is *Secrets of Warmth*, written by Hal Weiss; the second edition was published by The Mountaineers Books in 1998. This essay will skim in a few pages what Weiss covers in detail in the first dozen pages of his Chapter 2. I hope that many of you will go on to read Weiss's entire book: it has taught me many techniques to keep safe and comfortable in the outdoors.

We'll use these insights in later essays to learn about warmth in various forms. Effective methods for cooking food and for keeping yourself warm as you walk or sleep all build on these basic principles.

Regulating Body Temperature

Most cars work pretty well across a wide range of temperatures. I've driven at substantially above 100 degrees in southwestern deserts and at substantially below 0 degrees in northeastern mountains. But if you try to drive at 200 degrees or at 100 below zero, your car will face all sorts of problems. Human bodies have a much narrower operating range. They work best when their internal temperature is near 98.6 degrees. If you get more than a few degrees from that number, bodies don't work well, and about ten degrees away from that, they stop working at all.

Balancing heat in a human body is like balancing money in a checking account: you have to make sure that you put in enough money to make up for what you've taken out. But there's an additional constraint: while they say that there is no such thing as being too rich, a human can in fact get too hot. So we have to ensure that our heat gain and our heat loss are almost perfectly balanced.

We'll therefore start by considering three ways that all objects gain and lose heat, and then turn to two ways that animals transfer heat.

How Any Object Transfers Heat

There are three primary ways that any physical object can lose heat.

Conduction. Transfer of heat from the object to an adjacent object.

Convection. Transfer of heat from the object to its liquid or gaseous environment.

Radiation. Transfer of heat by emitting electromagnetic radiation.

If you sit your hind end down on a big, cold rock, you'll lose heat as it is conducted into the rock. If you stick your warm hand into a sink of 50-degree water, you won't gradually heat up a little glove of water around your hand – that warmer water will move up, cooler water will move down to replace it, and your hand will quickly get cold. These convection currents play a crucial role in that process. You have probably seen people displayed in infrared or “night vision” images on television – the special cameras are sensitive to the energy that is radiating from their bodies.

Although we thought of them originally as cooling mechanisms, those same three mechanisms can also warm an object, including a person. Lean against the western side of a brick building right after a bright sunset, and you’ll feel the warmth flowing into your back by conduction. Move a foot away from the building, and you’ll feel the warmth that convection brings to you through the air. The sun’s rays that warmed the brick by radiation also warm you when you bask on a sunny day. Many kitchens have a convection oven, a microwave oven (which uses microwave radiation), and perhaps an electric hot plate, which heats a cast iron skillet on it by conduction.

We can usually speed up convection by increasing the speed of the flow of the environment around the object. If you hold your cold hands in warm air, they’ll eventually warm up as the air heats them. If you wave them back and forth, they’ll avoid cooling the air that surrounds them, and warm up a bit more quickly. And if you hold them under a hair dryer that is rapidly blowing hot air past them, they’ll warm up even more quickly yet. And the same goes for cooling your hands off in still cool air, with a breeze, and next to a fan.

How an Animal Transfers Heat

Because they are objects, all animals (including hikers) are subject to the three methods that we have considered so far. They also have two additional ways of losing heat.

> *Evaporation*. Heat is lost from a surface as liquid water turns to water vapor.
> *Respiration*. Heat is lost when an animal inhales cold, dry air and exhales warm, moist air.

Your body knows evaporation well: when you get too hot, you sweat, and the resulting evaporation cools you. Even if you look very carefully on a hot day, you won’t see a dog sweat: he has sweat glands only on his foot pads (where they enhance grip) and nose. So old Rover instead cools himself by panting, which increases evaporation in the lungs and the mouth. His rapid breathing results in substantial heat loss even on a warm day; our slower breathing isn’t effective at dumping heat in warm weather, but it can be crucial on a cold night.

Animals can gain heat in all of the ways that we’ve considered: they can conduct heat from a warm rock, use convection to extract heat from warm air, or absorb radiation while basking. But the majority of the heat that we humans generate comes from metabolizing the food that we eat: our bodies transform food into heat.

You’ll feel that heat most clearly when you walk briskly up a trail: if you were comfortable all layered up before your walk, then you’ll have to open up and shed layers shortly. But we generate heat throughout the day, even when we are sleeping. Our outside might appear stationary, but inside our heart is pumping blood, our chest is expanding and contracting to facilitate breathing, and our internal organs are working away. All of these activities produce heat as a side effect.

The human body attempts to avoid getting too warm or too cold. If you are well hydrated, your blood effectively transfers heat from a warm region to a cold region. That is the origin of the old saying:

> "If your feet are cold, put on a hat."

If your extremities are cold, then the blood vessels in them constrict to avoid dumping your heat to the environment. Conversely, if the extremities are too warm, the vessels will expand to dump the excess heat into the skin and then environment (that approach usually works, but can prove fatal in an environment like a hot tub). In dire circumstances, our body will start to shiver to exercise muscles to generate heat.

Putting the Pieces Together

It was August, 2001, and the second night of a six-day Expedition Seminar on Mount Rainier. The previous day a storm had set an August record of about three inches for single-day rainfall at Paradise Inn at 5400 feet. But we had walked from there to the Cowlitz Glacier near Camp Muir at 10,000 feet, and the three inches of rain down low turned into three feet of snow up high, whipped by 40mph winds with a temperature in the mid 20's. The three of us burrowed into our three-man tent, and buttoned up tight. Each of us squirmed his way into his sleeping bag, and we settled in for the night.

Our bodies were generating enough heat to warm the down in our bags, and the bags soon reduced the heat lost to convection. The self-inflating foam pads under us minimized the heat lost by conduction to the snow. Each climber was soon comfortably warm. And slowly the bitter cold in the tent turned to a slight nip: as we exhaled, our breath warmed the air in the closed tent. The biting, low-humidity cold air was replaced by gentle, moist, warmish air. And we slept.

I woke up shortly before dawn. My face appreciated the non-freezing air, but my body was chilly. I first groped around, and then studied the situation with my headlamp. When I had gone to sleep, I had 2.5 inches of down loft in my sleeping bag. I could now feel that the loft was just half that, and my bag's cover was soaked. I finally put the pieces together: the relatively warm air in our tent was at one-hundred percent humidity from our respiration. The down in my bag had "wet out": it soaked up the water vapor and collapsed. I therefore added on all my layers, crawled back in, and did isometric exercise to warm up.

When day finally broke, the storm had left, and the sun was stunningly bright. I opened all vents in the tent, and quickly felt the warm, wet air replaced by cooler, dry air. But my down bag was completely useless. I had seen down like this after I had washed it: cloudy fluffiness is replaced by wet clumps of useless feathers. So there I was at 10,000 feet on day three of a six-day trip, without a sleeping bag. Was the trip over? What could I do?

I thought about using my body heat to dry out the bag. I've done that with wet gloves or shirt: go to sleep with the cold object on your belly (ouch!), and through the night, your body heat evaporates the moisture. But I've seen a down bag still soaking wet after hours in a clothes drier, so I knew that approach couldn't work. Were there any other options that you can think of?

I was first out of the tent, so I flung my bag on top of it, with the black side of the bag out to absorb the blessed heat of the sun. I was hoping that this might cut my loss to just one day of waiting in camp before I moved up. But the black bag sucked up the sun's radiation, and the liquid water on the down evaporated quickly into the low-humidity air. There was absolutely no wind that day, which decreased the heat the bag lost by convection. I was amazed and delighted to find that after a couple hours of baking, my bag was completely dry, and the trip was back on. The knot in my stomach came quickly untangled.

I learned two important rules that day:

> In cold mountains, warm air is often wet air.
> Summer or winter, vent your tent.

This essay contains very few numbers. Weiss's wonderful book gives typical numbers for all of the processes that we've studied: the rate of the base metabolism for an average sleeping adult male is about 70 calories per hour, for example. But we now have names for effects that we've known our whole lives, and we'll be able to reduce those to numbers in later essays.