COLD HANDS, WARM HEART

The physics and physiology of why you get cold and what to do about it

Regardless of your personal taste in clothing, the primary concern of most people outdoors is to keep comfortable. Going beyond this point to worry about survival is rarely considered. You can easily assume you will never be at risk and thus never adequately prepare. However, everyone who uses the outdoors should know how the body reacts to cold and what to do to achieve heat balance in a cold environment.

Although there is considerable difference in how individuals react, survival in the cold depends primarily on physiological well-being and use of protective clothing.

There are two kinds of anatomical responses for maintaining body temperature in a cold environment: those that decrease heat loss and those that increase heat production. The first is a complex physiological sequence which decreases the volume of blood circulating near the surface of the body. Neural feedback from skin temperature receptors triggers constriction of blood vessels near the skin. This in turn decreases heat transfer from the inner core of the body to the surface and ultimately decreases heat loss to the air. In the second, voluntary muscle action or the involuntary act of shivering accelerates metabolism and produces greater heat. Together, these responses seek to prevent a decrease in body temperature and maintain it within the narrow limits required for normal functioning.

One uncontrollable variable affects the body, the cold itself. A person may be subjected to cold in still air, wind, dry air or wet and all combinations of these. The particular nature of each combination affects the heat transfer and, hence, the method of control. For example, a moderate wind during the warm months is often quite refreshing but in the cold season can range from uncomfortable to disastrous. Wind rapidly removes heat from parts of the body with insufficient protective covering.

Thermal conductivity of water is about 24 times as great as that of dry air. This means humid air is a much greater conductor of heat than dry air at the same temperature. If clothing becomes wet, either from the outside air, rain, melted snow or perspiration, heat is transferred from the body as much as 24 times faster than with dry clothing. Whether moisture given off by the body is evaporated depends on the amount of moisture in the outside air, i.e. the relative humidity. If the relative humidity is 100%, the air cannot receive transpired body moisture and it condenses in the outer layers of the clothing. Moisture condensation within the clothing may also occur because of cooling in the insulating layers. The colder the air, the less evaporated moisture it can contain.

The two primary environmental factors that determine the degree of heat transfer from the body are wind and moisture. Their effects are felt regardless of the amount or the type of insulation used to cover the body.

Neither temperature nor wind alone are a good index of how cold it feels. The wind-chill index used by many government agencies represents the relative comfort of an inactive individual in dry air conditions. It combines actual ambient temperature and wind velocity into an equivalent still air temperature. However, the wind-chill index is only an approximation. The actual level of comfort or discomfort will depend on other variables such as relative humidity, degree of sun exposure, type

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and amount of clothing and physical condition of the person involved.

Heat is a form of energy produced by the body as a result of food consumption. First, foods are digested, then absorbed, and finally metabolized. Metabolism is the chemical change absorbed foods undergo within the cells which allows the body to sustain itself. The rate of total energy production, and also consumption, depends on many things, including the size of the individual and the degree of activity. The normal physical and chemical processes which sustain life in an inactive person consume energy at the rate of about 80 calories per hour or 2,000 calories per day. The total energy consumption would be this amount plus the additional energy used in muscular work. Depending on the degree of activity, total energy requirements may vary from 2,000 calories to over 5,000 calories per day. Only 18% to 22% of ingested food is converted into mechanical energy. The rest is liberated as heat. This heat is produced in all tissues of the body but primarily in the skeletal muscles. Even during rest, these muscles have a large energy requirement, which during work is increased enormously.

For about four hours following a meal, food is digested and absorbed into the system. During this period, carbohydrates are the major source of energy. Only a very small amount of the absorbed protein and fat is similarily utilized. The fraction of protein and fat not used to rebuild tissue structure and the amount of carbohydrates not used for energy are transformed into fat and stored in the body tissue. After absorption, energy requirements must be met from internal stores by transforming body fat.

Since we normally eat three meals a day, energy is derived directly from the food taken in. Of course, it is obvious where the energy must come from when there is no food to be absorbed — dieters are most familiar with this process.

Foods ordinarily are divided into three categories with the following caloric or heat equivalents: carbohydrates, four calories per gram; fats, nine calories per gram; and proteins, four calories per gram.

The body normally consumes available carbohydrates in preference to fats or proteins to fulfill energy demands. It uses fats or proteins only as secondary fuels when the carbohydrates supply becomes inadequate.

Heat production increases as a direct result of eating, but contrary to reason more heat is produced than the caloric value of the food intake. It comes from food reserves and is partly dependent upon the type of food ingested. Consumption of carbohydrates and fats result in an "extra" energy level of about 5%, while proteins produce an increase of up to 30%.

The point is that body heat is made possible by only one means — metabolism of ingested food. You must eat to live. You cannot cram down a doughnut and cup of coffee in the morning and expect to put in a 20-mile day on skis without feeling the effects of an inadequate fuel supply.

Our body surface exchanges heat with the outside by radiation, conduction, convection and water evaporation. To maintain a constant body temperature, total heat production must equal total heat loss.

Radiation is the direct exchange of heat energy between surfaces not in contact. There is radiant transfer from the body to clothing, to a tent or other shelter, to the cloud cover or to outer space. The rate of heat transfer depends on the temperatures of the surfaces and increases drastically as their difference increases. Radiation is a leading cause of heat loss under many conditions. The head and neck are most vulnerable.

Conduction is the direct transfer of heat from molecule to molecule. The body surface loses heat by conduction through direct contact with cooler objects, such as water, snow, metal and of course, air.

Convection is the process whereby air next to the body is heated, moves away and is replaced by cooler air in an endless cycle of circulation. It is greatly facilitated by the wind which continuously maintains a supply of cool air.

Heat is also lost by evaporation of water from the skin and respiratory tract. As moisture vaporizes from the body's surface, the heat required to drive the process is extracted from the body, cooling its surface. Even in the absence of sweating, there is a loss of water by diffusion through the skin. This transpired moisture amounts to approximately 20 fluid ounces per day in the average person and accounts for a significant fraction of total heat loss.

Although evaporation accounts for a substantial loss of body heat, little can be done to prevent it. Because of this, it is better to aid rather than hinder the process by wearing fabrics that breathe. If water vapor cannot pass through insulating fabrics, it condenses, wets the clothing and may even freeze, forming a complete barrior to moisture.

Physiologists view the body as a central, heat producing core, surrounded by a layer whose insulating capacity can be varied to maintain the core temperature at approximately 99 degrees fahrenheit. If the skin were a perfect insulator, its outer surface would equal the environmental temperature and there would be not heat loss from the core. The net heat transfer, due to conduction, convection or radiation would then be zero. The skin, of course, is not a perfect insulator and the temperature of its outer surface generally lies somewhere between that of the surrounding external environment and the inner core.

The skin's effectiveness as an insulator varies with the amount of blood flow which diminishes the insulating capacity of the skin by carrying core heat to the surface. The more blood that reaches the skin from the body's core, the more closely the skin's temperature approaches that of the core and the more heat lost.

With exposure to cold, just the opposite happens. Skin blood vessels constrict, reducing blood flow toward the surface and making the skin a more effective insulator. This vasoconstriction reduces skin temperature and the rate of heat transfer. The lower limit is the point at which maximum skin vasoconstriction has occurred. Any further drop in the environmental temperature causes excessive heat loss. At this point the body must increase heat production to maintain its temperature balance. Vasoconstriction may make the skin on the fingers undergo as much as a 99% reduction in blood flow during exposure to cold. While protecting the body's core, this phenomenon is sacrificial in nature. The extremities become extremely susceptible to frostbite.

Vasoconstriction, however, is physiologically impossible in the head and neck region. Because this area contains many blood vessels near the surface yet close to the heart, it is a tremendous heat exchanger. Special attention to control heat transfer here is vital. An unprotected head may lose up to one-half of the body's total heat production at an environmental temperature of 40 degrees fahrenheit and up to three-quarters of total body heat production at five degrees fahrenheit.

While considering vasoconstriction and vasodilation, something should be mentioned about tobacco and alcohol.

Nicotine produces vasoconstriction in the extremities. This can cause a skin temperature drop of as much as 10 degrees for the fingers and toes. The effect is temporary and depends on the individual involved.

Alcohol in moderate amounts produces vasodilation in the extremities, just the opposite of smoking. It also affects the heat center in the brain, causing a small but significant core temperature drop. This decrease is rarely realized consciously, because a peripheral vasodilation produces a simultaneous feeling of warmth in the extremities. The result is a chilling of the peripheral blood and an ultimate decrease in body temperature.

Thus, both tobacco and alcohol are detrimental to proper control of body temperature. In view of their effects on circulation, not to mention the more obvious physiological reactions, abstinence, or at least moderation, while engaged in winter wilderness travel would be advisable.

The body can increase its heat production only through muscular action, either voluntary or involuntary. Either method assumes that there is sufficient fuel supply to support such action.

In adapting to extreme cold, the body produces heat by a gradual overall increase in skeletal muscle tension, culminating in shivering, which may continue for the entire duration of exposure or until the available energy is expended and exhaustion results. Since the muscle contractions produced by shivering produce no external work, the energy consumed appears as internal heat. Intense shivering produces heat approximately equivalent to walking at a fast pace. It is nevertheless to be avoided. Shivering is a way the body cries "Help!" in a last-ditch effort to maintain normal inner core temperature.

When skin temperature falls low enough to cause numbness, touch perception and pain sense is impaired. The agility of limb muscles is decreased, and it becomes difficult to perform coordinated movements. This phenomenon, technically known as hypothermia and commonly referred to as exposure occurs if heat loss is allowed to proceed unchecked.

As the body's inner core temperature begins to drop below 99 degrees the first indication of hypothermia appear. Shivering begins and there is difficulty in performing precise tasks. Loss of alertness and impaired speech follow with continued decrease in temperature. The victim ultimately becomes completely irrational and lapses into a state of unconsciousness. The chances of anyone helping himself out of such a perilous situation are obviously very small. Rescue and immediate attention are necessary for survival.

An important mechanism for altering heat loss is changing surface area. Everyone has watched a dog curl into a ball when resting in the cold. The same principle applies to a man, who can draw his knees to his chin, his shoulders or perform other maneuvers to reduce the surfaces exposed to the cold.

Clothing is the single most important component of heat regulation. The principle is simple. The outer surface of the clothing now becomes the true exterior of the body. Again, surface area is of prime importance. The value of increasing the thickness of insulation around an object is limited, since heat conduction is proportional to surface area. As the thickness of the insulation around a cylindrical or almost cylindrical object (arms, legs, torso) increases, the surface area through which heat can be lost also increases by the same amount. This results in an effective decrease in the heat retaining value. For example, to double the value of an insulating layer one inch thick, it is necessary to increase its thickness to almost three inches.

This relationship demonstrates the difficulty of insulating an inactive person in a cold environment. For example, no thickness of insulation, regardless of type, is sufficient to keep the hands warm indefinately under certain conditions even when the rest of the body is adequately warm. The only way to maintain warmth in this case is by placing the hands next to the torso or under the armpits. The insulating ability of clothing is determined by its type, thickness and the volume of air trapped within and between the clothing layers. The skin loses heat directly to the air trapped by the clothes. The clothes in turn transfer the heat from the inner air layer to the outer environment.

Sweating in a cold environment destroys the heat retaining value of insulation. Water is continuously secreted through the skin. Some of the water evaporates at the skin surface, which requires body heat. This water vapor migrates toward the outer surface of the clothing until it reaches a layer whose temperature causes it to condense, wetting the clothing and losing the heat that had kept it vaporized. The condensed water now migrates back toward the skin by a wicking action, only to be recycled by a similar process all over again. This is why insulation must be able to breathe. Body moisture must be disposed of, but without overloading the insulating layers of clothing with water.

Water accumulation in clothing is hard to control. The destructive effects are best avoided by providing adequate ventilation during exertion and by drying garments at every opportunity. Open all zippers during exercise and close them during cool-down. Another way is to wear several thin layers of clothing so that one or more can be removed as heat is produced during exertion. Regardless of the method, it is best to remain on the cool side of comfort to minimize the chances of sweating. The cardinal commandment of cold weather adaptability is, "Be warm but don't sweat."

Ignorance often makes people overreact in the face of danger. The usual tendency is to fight the natural elements rather than adjust to them. For precisely this reason, many people have lost their limbs and lives while engaged in potentially uneventful winter wilderness adventures. So make sure you know what to expect and how to cope with the unexpected.

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