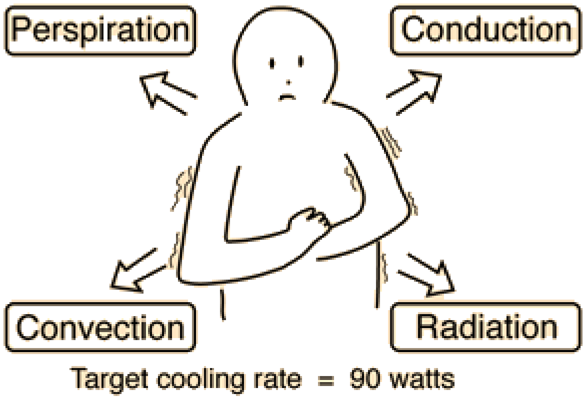
Perspiration Cooling of Body



For 600 gm/day perspiration, cooling rate Q/t = 17 watts.

Why is the heat of vaporization greater at body temperature?

When the ambient temperature is above body temperature, then radiation, conduction and convection all transfer heat into the body rather than out. Since there must be a net outward heat transfer, the only mechanisms left under those conditions are the evaporation of perspiration from the skin and the evaporative cooling from exhaled moisture. Even when one is unaware of perspiration, physiology texts quote an amount of about 600 grams per day of "insensate loss" of moisture from the skin.

The cooling effect of perspiration evaporation makes use of the very large heat of vaporization of water. This heat of vaporization is 540 calories/gm at the boiling point, but is even larger, 580 cal/gm, at the normal skin temperature.

$$\frac{Q}{t} = \left(600\frac{gm}{day}\right)\left(580\frac{cal}{gm}\right)\left(4.186\frac{J}{cal}\right)\left(\frac{1\ day}{24hr}\right)\left(\frac{1\ hr}{3600s}\right) = 17 watts$$

If the rate of evaporation of perspiration is [ ] gm/day = [ ] gm/hr

then the cooling rate is

Q/t = [ ] watts.

As part of the physiological regulation of body temperature, the skin will begin to sweat almost precisely at 37°C and the perspiration will increase rapidly with increasing skin temperature. Guyton reports that a normal maximum perspiration rate is about 1.5 liters/hour, but that after 4 to 6 weeks of acclimatization in a tropical climate, it can reach 3.5 liters/hr! You would have to just sit around drinking constantly, just to keep from getting dehydrated! That maximum rate corresponds to a maximum cooling power of almost 2.4 kilowatts!

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Heat Transfer by Vaporization

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If part of a liquid evaporates, it cools the liquid remaining behind because it must extract the necessary heat of vaporization from that liquid in order to make the phase change to the gaseous state. It is therefore an important means of heat transfer in certain circumstances, such as the cooling of the human body when it is subjected to ambient temperatures above the normal body temperature.

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Cooling by Evaporation

Because of the large heat of vaporization of water, the evaporation from a liquid surface is a very effective cooling mechanism. The human body makes use of evaporative cooling by perspiration to give off energy even when surrounded by a temperature higher than body temperature. The cooling process is an example of the approach to thermal equilibrium. The evaporative cooling rate is given by

$$\frac{Q}{t} = \frac{mL_v}{t} \quad where\ L_v = 539 cal/gm\ at\ 100°C$$

If **m** = ____ gm of water at 100 °C is evaporated in **t** = ____ sec, the cooling rate at 100 °C is

Q/t= ____ cal/s = ____ watts = ____ BTU/hr.

The cooling rate for a liquid (below boiling) is more complicated since the heat of vaporization changes with temperature, and the rate of evaporation depends upon ambient temperature and relative humidity.

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