in the normal situations of comfort there is no change in body temperature, S is zero. It has a positive value when the body heats up and is negative with body cooling. R and C may be positive or negative, depending upon the direction of the skin-environment temperature difference. Evaporative exchange is always positive since a negative value (condensation) could only occur with a dew-point temperature higher than the surface temperature and this would be incompatible with life.

Heat exchange by radiation is proportional to the difference in the fourth powers of absolute radiant temperature of the body surface and of surrounding surfaces. As a first approximation, however, R may be expressed in terms of the simple temperature difference:

$$R = K_r A_r (t_s - t_w)$$

where $K_r = K(T_s^3 + T_s^2 T_w + T_s T_w^2 + T_w^3)$ = approximate constant over modest ranges in T_s and T_w (K being the universal radiation constant, and T_s and T_w absolute radiant temperatures of body surface and surrounding surfaces, respectively); A_r = effective radiation surface area of body (about 0.8 × actual surface area for sitting subject); and t_s and t_w = radiant temperatures of body surface[2] and surrounding surfaces, respectively.

Heat exchange by convection depends upon the temperature difference between the body surface and surrounding air and upon the air velocity. Since "still" room air always has significant motion, the theoretical minimum exchange with free convection can be neglected and, practically, the convective exchange may be expressed as follows:

$$C = A\, K_c \sqrt{V} (t_s - t_a)$$

where A = surface area of body in square feet; K_c = coefficient of heat exchange by convection at unit velocity; V = effective air velocity in feet per minute; and t_s and t_a = temperatures of the body surface and air, respectively.

Evaporative heat loss is directly proportional to the amount of water evaporated from the body surface and respiratory tract. For a completely wetted surface, the evaporative rate depends upon the vapor pressure difference (VP_s − VP_a), where VP_s is the vapor pressure of water at skin temperature and VP_a is the partial pressure of water vapor in the air. At any given vapor pressure difference, evaporative rate increases with air velocity. For conditions of maximum evaporative cooling with the body surface completely wetted, the following expression has been derived:[3]

$$E_{max.} = AK_e V^{0.4} (VP_s - VP_a)$$

[2] Human skin and ordinary clothing radiate like black bodies; the radiant temperature is, therefore, the actual surface temperature.

[3] M. Nelson, L. W. Eichna, S. M. Horvath, and T. F. Hatch, Thermal exchanges of man at high environmental temperatures, *Am. J. Physiol.*, **151**, 626 (1947).

where A = surface area of body in square feet; K_e = coefficient of heat exchange by evaporation at unit velocity; V = effective air velocity in feet per minute; and VP_s and VP_a = as given above.

According to these several equations, it is seen that thermal exchange between the human body and the environment depends upon four external *physical* factors: air temperature, radiant temperature, air velocity, and moisture content of the air. The several rates of exchange are modified, of course, by the kind and amount of clothing worn.

Heat exchange is also subject to delicate *physiological* control. The metabolic rate may be increased spontaneously by shivering to counteract body cooling, and with continued cooling, the individual may engage in deliberate activity to increase heat production. In the heat, on the other hand, the experienced individual reduces his activity to keep M within acceptable limits. In cool environments, R and C are automatically reduced by a decrease in the rate of blood flow through the surface tissues, which thereby limits the amount of heat brought to the surface. The skin temperature is thus lowered but internal body heat is conserved. Conversely, in warm environments, blood flow to the surface is increased; this raises the skin temperature and R and C go up if positive or decrease if negative. The greatest degree of physiological adjustment is provided through the mechanism of sweating and evaporation. With minimum activity in cool environments and under normal conditions of comfort, there is no need for active sweating and the only evaporative heat loss is the amount fixed by evaporation in the respiratory tract (proportional to volume rate of breathing and difference between the constant water vapor pressure in expired air and the partial vapor pressure in inhaled air) and by the rate of water transfer to the skin (insensible perspiration). Since insensible perspiration is limited in amount, heat loss by this avenue is ordinarily independent of the moisture content in the air. Evaporative heat loss under comfortable conditions amounts to 20 to 25 per cent of total output. With increasing heat load, metabolic or external, however, active sweating is initiated by the need for greater evaporative cooling to maintain thermal balance. Up to a certain point the desired balance is obtained and the sweating and evaporative rates will thus be automatically limited without regard to the moisture content of the air. A *maximum* evaporative cooling rate is reached with higher heat loads when sweat is produced in excess of the evaporative rate. At this point, the body becomes completely wetted and there can be no further increase in the cooling capacity, which is now limited by the air velocity and the vapor pressure difference, as outlined above.

Changes in human response at rest to different environmental temperatures are portrayed in Figure 1. Shown separately are: metabolic rate, the sum of heat exchanges by radiation and convection, heat loss by evaporation, and changes in body heat content (storage). Over a considerable range in environmental temperature no change occurs in metabolic rate. In environments up to 85° F., evaporative heat loss remains at a low level since M is adequately offset by R