SKIN TEMPERATURE AND HEAT LOSS

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The body temperature is usually taken either in the mouth or rectum or, in the case of infants, in the axilla or groin. The normal body temperature is generally considered to be 98.6°F., but there are fluctuations from this average which, with the ordinary individual, may amount to 2°F. in 24 hours, the minimum temperature occurring at about 4 A.M. and the maximum about 5 P.M. under conditions of repose, with higher temperatures during severe muscular work. As an indication of the presence or absence of fever, the temperature taken in any of the localities cited is perfectly satisfactory, but as a means of studying the total heat stored in the body such temperature records are very deceptive. The temperature in the mouth, axilla or groin, for instance, is almost invariably somewhat lower than that in the rectum. Thus, a gradient exists between the temperature deep in the trunk and the temperature near the surface of the body. This gradient has been studied and it has been found that between the temperature deep in the trunk and that 1 cm. from the orifice of the rectum or vagina there is a difference of from 2° to 3°C.[1]

The regulation of the body temperature through the circulation of the blood and through loss of heat is usually so perfect that a lowered temperature in one part of the body due to the diurnal change, for example, is paralleled in the other parts of the body. The temperature of the exterior of the body, the skin, is so influenced by the environmental temperature that it is subject to much greater fluctuations. With humans, parts of the skin are exposed continuously, such as on the forehead, face and hands, and in the case of women the neck and not infrequently the arms and shoulders are exposed. Parts of the body are well covered, especially the abdomen and the small of the back, while other parts are but scantily covered, such as the arms and legs. With men the protective clothing is more evenly distributed. Save in summer weather the skin is always warmer than the air, and consequently heat is lost to the environment. Is this exactly and fully compensated? Does the skin temperature stay at or near the body temperature? Does it remain constant? Is the source of the heat supply so rapid and continuous as to compensate exactly for rapid and continuous changes in environmental temperature?

Measurements of the skin temperature are now necessary in estimating and particularly in interpreting the loss of heat to the air. Unfortunately this temperature is measured only with difficulty, and mercury thermometers are of little use. The only satisfactory method is that of the thermo-junction. The idea of this apparatus is very old, but with its modern application it is possible to make a rapid survey of the skin temperature with an accuracy of 0.1°C. Indeed, by photographing the movements of a string galvanometer extraordinarily sensitive records may be obtained.[2] By means of this apparatus many surveys of the skin temperature have been made at the Nutrition Laboratory, to study the effect of varying amounts of protective clothing and changes in environmental temperature. In most of these surveys the rectal temperature was not recorded, but there are a sufficient number of records to justify the statement that the rectal temperature was not far from 37°C., plus or minus 0.5°C.

Numerous conditions were included in this study of the skin temperature. Thus, a survey of the skin temperature was made (*a*) after a night's rest in bed, when the subjects were well covered with bed clothing; (*b*) under the clothing, after the subjects had been lying for 2 or 3 hours in a known environmental temperature; (*c*) under the clothing with the subjects standing, after 4 to 6 hours in the temperature of the laboratory; and (*d*) under the clothing after prior exposure to external weather conditions. This latter survey led to a study of the immediate effect upon skin temperature of exposure to cold. Finally, the relation of skin temperature to heat loss has been considered from the standpoint of the direct radiation of heat, as measured with a pyranometer, and an analysis of the total loss of heat in a calorimeter chamber, as divided between loss due to the vaporization of water and loss due to the direct radiation of heat.

A survey of the skin temperature of 12 girls, 14 years of age, was taken under the bed clothing, after a night's sojourn in bed with the body well covered. The measurements were made at approximately 25 points on the body, of which 3 were on the head and face, 8 on the ventral side of the trunk, 6 on the arms and hands, and 8 on the thighs, calves and feet. The average skin temperature of the 12 girls was 33.2°C., ranging from 32.9°C. to 34.1°C. There was in general a fairly equable temperature about the abdomen and trunk, with a tendency for the extremities to be somewhat cooler as the distance from the trunk increased.

Under the protective covering of the usual clothing and after 2 or 3 hours in the same environmental temperature each individual has provided for himself under the clothing a layer of warm air, which Dorno[3] has designated as his "private climate."

A survey taken when the subject had been lying, well covered for 3 hours, showed usually somewhat lower skin temperatures over the whole body than the temperatures noted after a night's repose in bed. The temperature of the extremities is greatly affected by the environmental temperature in the bedroom or that existing prior to the observation, the placing of a hot-water bottle at the foot of the bed resulting in a very rapid and marked equalization of temperature over the entire surface of the body. Laboratory assistants, clothed and standing after 4 to 8 hours in the laboratory, showed much the same picture, with, however, a noticeable reaction to the environmental temperature, for on days in midsummer, with temperatures of about 30°C., the entire skin was at a much more even temperature than under any other conditions.

A temperature survey taken under the clothing, immediately after the subject entered the laboratory in the morning, showed invariably a distinct correlation between the skin temperature and the temperature of the exterior, this correlation being noted even in the well-protected parts of the trunk. Thus, on a very cold February day the entire trunk may have a skin temperature as low as 31°C., with the temperature of the legs and feet falling off to not far from 24° to 25°C.

With one subject rapid exposure to a cold environment was made by suddenly removing the clothing. The equable skin temperature existing in the "private climate" is almost instantly destroyed by exposure for but one or two minutes to a temperature of about 15°C.

The effect of muscular work upon skin temperature was pronounced in the case of a nude male subject. In this case the temperature of the right side of the body was measured at 13 points after one hour's exposure to a room temperature of 20°C. The average skin temperature of these points, which prior to exposure must have been not far from 33°C., fell with this subject to 30°C. The subject then began riding a stationary bicycle, and at the end of 13 minutes the average skin temperature had further fallen to 28.2°C., but as the work continued throughout the morning for over $2^1/_2$ hours, the average temperature did not go below 27.5°C., since the muscular work maintained the temperature at this level. Furthermore, the skin temperature of the legs, where most of the physical exercise was being carried out, in a number of instances actually rose as a result of the muscular work.

The significance of skin temperature in the loss of heat by radiation has been too long neglected. Thanks to the kind coöperation of Dr. Charles G. Abbot of the Smithsonian Institution, a series of observations was made by him at the Nutrition Laboratory upon one of our subjects, using his pyranometer, and it was found possible from his observations to predict closely the skin temperature. Thus, Dr. Abbot's observations point clearly to the fact that the human skin acts as a true "black body," and hence the temperature of the skin may be taken in conjunction with the temperature of the environment as an excellent indication of the loss of heat by radiation. Such a computation is complicated, however, in the case of the clothed individual, owing to the stagnant air of the "private climate" and owing to the fact that normally an appreciable proportion of the heat is lost by the vaporization of water through the lungs and skin. Indeed, approximately one-third to one-quarter of the water lost from the lungs and skin (more in extremely warm weather), is that vaporized from the skin.

From calorimetric observations it has been found that the maximum amount of heat thus far measured as given off by direct radiation was in the case of a subject who rode nearly 20 hours on a bicycle ergometer, producing the total amount of 7137 calories per 24 hours, of which essentially one-half was lost by the vaporization of water vapor while 3656 calories were lost by direct radiation.

The significance of heat loss to the environment, its relation to environmental temperature, air movement, humidity and protective clothing, is only equalled in importance by a careful study of the heat production. Our observations lead us to the conviction that, save under extreme conditions, heat production and heat loss are two essentially independent processes. Very considerable fluctuations in the heat stored in or lost from the body are possible, resulting in rather profound changes in the temperature of the peripheral tissues without appreciable alteration in heat production.

The details of the temperature measurements are about to be given in a forthcoming number of Asher-Spiro's Ergebnisse der Physiologie.

[1] Benedict, F. G., and E. P. Slack, *Carnegie Inst. Wash. Pub.*, No. **155**, 1911.

[2] Benedict, F. G., W. R. Miles, and A. Johnson, *Proc. Nat. Acad. Sci.*, **5**, 1919 (218–222).

[3] Dorno, C., *Medical Climatology and High Altitude Climate*, Vieweg and Son, Brunswick, 1924 (58).

THE PASSAGE OF SLOW CANAL RAYS THROUGH HYDROGEN

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One of the well known properties of canal rays is that of changing their charge while passing through a gas. The charged atoms alter from positive to neutral or back again to positive at almost every collision with a gas molecule. Rückhardt[1] has investigated canal rays of positive hydrogen atoms having a velocity between 1.6×10^8 and 2.3×10^8 centimeters per second (13,000 to 26,000 volts), and found that the radius of the hydrogen molecule deduced from the number of collisions at which charge alterations occur varies from 1.13×10^{-8} cms. for the fastest rays to 2.0×10^{-8} cms. for the slowest.