secretion (in a hot environment). Under cold conditions, the need for more heat and shivering or other muscular movements increase metabolism, which is, again, a reaction favorable to temperature regulation; but under very hot conditions metabolism also rises and this reaction is obviously harmful and indicates a balance of purely chemical over physiological control[14] resulting from increased chemical reactions with rise in temperature. In other words, it represents a breakdown or failure of the entire regulative processes. These reactions are governed by nervous or chemical stimuli from both skin and internal tissues. Nerves from the skin, for example, carry the sense impressions to the brain and the response comes back over another set of nerves, the motor nerves, to the musculature and to all the active tissues in the body, including the endocrine glands. In this way, a two-sided mechanism controls the body temperature by (1) regulation of internal heat production (chemical regulation), and (2) regulation of heat loss by means of automatic variation in the rate of cutaneous circulation and the operation of the sweat glands (physical regulation). The reactions involved in cold and in hot environments are on the whole radically different in nature. The mechanisms of adjustment involved are extremely complex and while they are receiving considerable study a complete understanding of their operation is still lacking.

In a certain middle range, normal and easy physiological regulation occurs by slight changes in the distribution of blood carrying heat between the skin and the inner organs, resulting in slight changes in the body surface temperature, and hence, in the rate of heat dissipation to the atmosphere. This easy balance gives a sensation of comfort. Above this range, the blood capillaries near the surface become dilated, allowing more blood and heat to flow into the skin, and thus increase its temperature and consequently its heat loss. If this method of cooling is not in itself sufficient, the stimulus is extended to the sweat glands which allow water to pass through the surface of the skin. This method of cooling is the most effective of all, as long as the vapor pressure and dew-point temperature of the air are sufficiently low to allow for evaporation. In high humidities, where the difference between the dew-point temperature of the air and body temperature is not sufficient to allow rapid evaporation, increase in heat loss may be had by increasing air movement. The body, under hot conditions, is in the *zone of evaporative regulation*, and for moderately extreme conditions perfect balance between heat production and heat loss may be attained, although at the cost of considerable discomfort.

In a cold environment, where environmental conditions are such as to remove heat too rapidly, the organism adapts in some degree by constricting the blood vessels leading to the surface, thereby reducing the blood flow and heat available for dissipation to the environmental surroundings. This adaptation is, however, partial and incomplete, and in an environment too cold for the clothing worn the temperature of the body tissues may fall, with accompanying discomfort and ultimate danger of serious chill. The process may go on for hours. The individual may move about and increase metabolism through muscular activity and thus balance the excessive heat demand of the environment, or he may reduce the loss by greater insulation of his body in the form of clothing.

Some of these phenomena which are important are shown graphically in Fig. 1. The dotted curves, from a study at the *John B. Pierce Laboratory of Hygiene*[15], are for subjects lightly clothed in a semi-reclining position and give the relation between the dry-bulb temperature of the environment (with about 45 per cent relative humidity) and the metabolic rate, the rate of heat dissipation by radiation and convection combined, and the latent heat loss due to evaporation of, perspiration and moisture from the respiratory tract. The smooth line curves, from the work of the A.S.H.V.E. Research Laboratory[16], give the same relationships for healthy, male subjects (18 to 24 years of age), seated at rest and normally clothed for winter-heated and air conditioned occupancy. The data for the semi-reclining subject also include the rate of heat storage (either positive or negative) due to a rise or fall in body temperature. For the normally clothed subjects a curve gives the total heat loss (that is, the

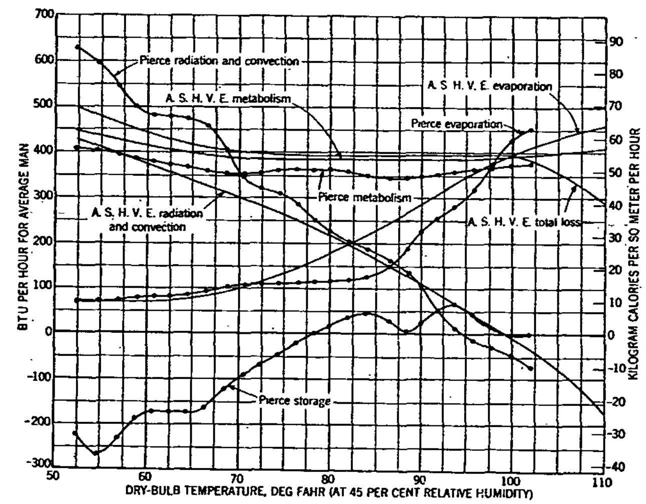

FIG. 1. RELATION BETWEEN METABOLISM, STORAGE, EVAPORATION, RADIATION PLUS CONVECTION, AND OPERATIVE TEMPERATURE FOR THE CLOTHED SUBJECT

sum of the radiation, convection and evaporative losses). Here, storage is given by the difference between the metabolism and total heat loss.

The small difference between the metabolic or heat production rates for the two types of subjects may be accounted for by the difference in activity. Heat exchange between the body and the environment by radiation and convection is greater for the lightly clothed subject, both for cool conditions where there is considerable heat loss, and for very warm conditions where there is a sensible transfer from the atmosphere to the body. The two curves for evaporative loss serve to show how physiological control uses evaporation of perspiration to maintain equilibrium, particularly at high temperatures. Below about 75 F for the normally clothed subject, and below about 85 F for the lightly clothed subject, evaporation loss is minimal and probably due to uncontrolled evaporation from the relatively dry skin and from the respiratory tract. Above these temperatures control is had by availability of perspiration for evaporation. The difference in the curves above 75 F is probably largely determined by the difference

[14]Loc. Cit. Note 13.

[15]A.S.H.V.E. RESEARCH REPORT No. 1107—Recent Advances in Physiological Knowledge and Their Bearing on Ventilation Practice, by C.-E. A. Winslow, T. Bedford, E. F. DuBois, R. W. Keeton, A. Missenard, R. R. Sayers and C. Tasker. (A.S.H.V.E. TRANSACTIONS, Vol. 45, 1939, p. 111).

[16]Loc. Cit. Note 13.