vated reactions. The extent to which the effects of beryllium on phosphatases are involved in acute and chronic beryllium poisoning must be determined by further experimentation on beryllium-poisoned animals. The ability of manganese to counteract the inhibitory effects of beryllium on phosphatases *in vitro* is encouraging because it provides evidence of the possibility of reversing the combination of beryllium with tissue constituents and thereby suggests a possible approach to the development of therapy for beryllium poisoning. In this connection, experiments are in progress at the present time in which the effects of several metals on acute and chronic beryllium poisoning are being tested. The results of these experiments will be reported in detail elsewhere.

References

1. Bodansky, A. *J. biol. Chem.*, 1937, **120**, 167.
2. DuBois, K. P. and Potter, V. R. *J. biol. Chem.*, 1943, **150**, 185.
3. Grier, R. S., Hood, M. B., and Hoagland, M. B. *J. biol. Chem.*, 1949, **180**, 289.
4. Klemperer, F. W., Miller, J. M., and Hill, C. J. *J. biol. Chem.*, 1949, **180**, 281.
5. Sestini, F. *Chem. Centr.*, 1888, **59**, 1622.

The Skin Temperature of an Extremity as a Measure of Its Blood Flow

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Skin temperature often is used as an index of blood flow in the extremities, even though the relation may be merely implicit. The purpose of this communication is to emphasize the fact, mentioned by Lewis (*3*) and others, that skin temperature is valid as a measure of extremity blood flow under certain conditions only.

Skin temperature depends upon both the rate of heat supply to the skin and the rate of heat removal—that is, upon the temperature and flow rate of the blood, and the insulation and temperature difference between skin and environment. If the temperature difference is small, heat will be removed so slowly that even large changes of blood flow will have little effect on the skin temperature. This is illustrated in the figures, in which are plotted finger blood flow and finger temperature against time. (Finger blood flow was measured with the plethysmographic method of Goetz (*2*) using air transmission. The values given are the averages of the flow at systole and at the end of diastole. Finger temperatures were measured with small thermocouples attached with adhesive tape, and connected to an instrument sensitive to 0.15° C and recording at 80-sec intervals. The hand was bare.) At a room temperature of approximately 32° C it is obvious from Fig. 1 that the finger surface temperature bears no relation to changes of blood flow. The correspondence is scarcely improved at an ambient temperature of about 21° C (Fig. 2). The air movement in both these experiments was the same.

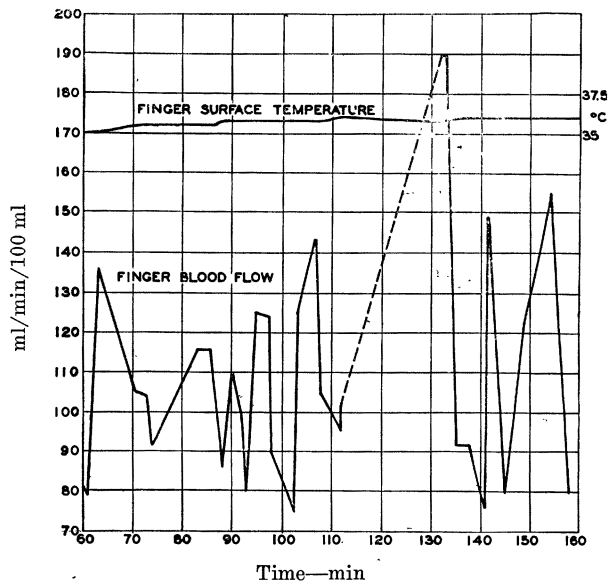

Fig. 1. Blood flow and skin temperature at 32° C ambient. Hand air insulation = 0.54 equivalent clo.

At about 7° C room temperature, with greater air movement, skin temperature follows the blood flow pattern fairly well, as can be seen in the example given in Fig. 3. At −34° C, with a gradient of 55–66° C between the bare hand and the ambient air, the lag between blood flow change and skin temperature change is probably negligible; for example, a very minor emotional disturbance may cause a fall of finger temperature of 8° C within 2 min; or a few deep breaths, of 3° C.

Our experience, exemplified by the figures, is that the heat loss rate calculated for the hand should be 12 kg-cal/hr (240 kg-cal/hr/m²) or more, if the skin tempera-

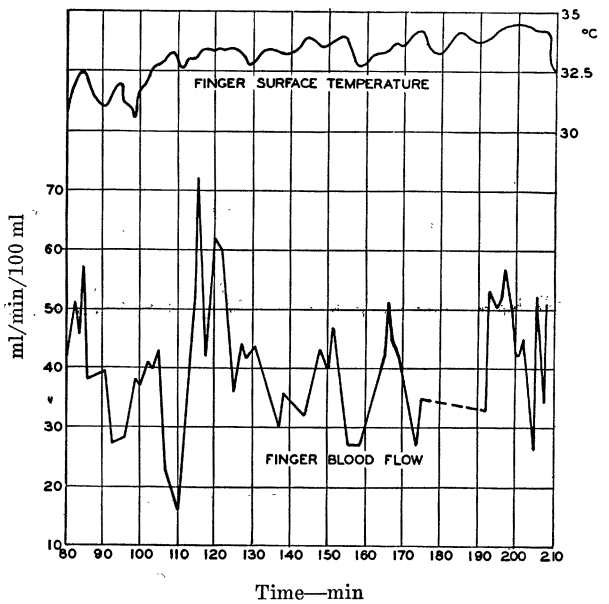

Fig. 2. Blood flow and skin temperature at 21° C ambient. Hand air insulation = 0.54 equivalent clo.

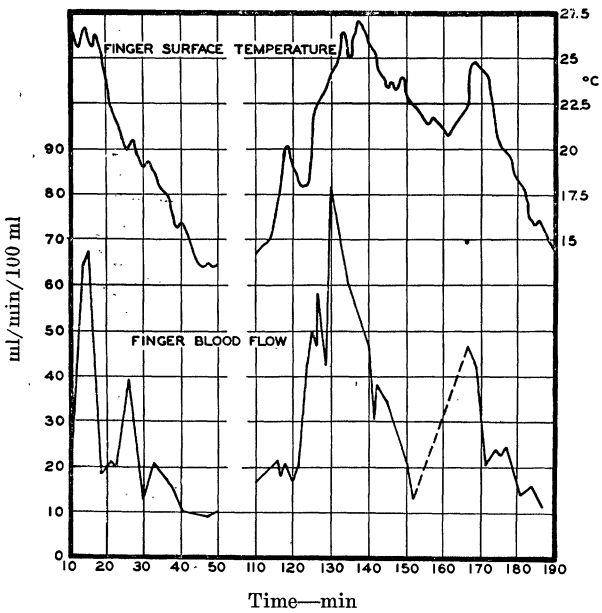

FIG. 3. Blood flow and skin temperature at 7° C ambient. Hand air insulation = 0.30 equivalent clo.

ture is to follow closely the blood flow changes. It is likely that this approximate minimum applies to other areas of the body. This heat loss rate corresponds, for example, to an air insulation over the bare hand of 0.54 equivalent clo[1] (insulation unit) and a temperature difference of 24° C between hand and air; or to a temperature difference of 13° C if the air insulation is 0.30 equivalent clo.[2] Thus, if the temperature of the hand is expected to fall to 21° C the ambient temperature should be −3° C; or 8° C for the higher air movement. If only gross, slow changes of blood flow are to be measured, correspondingly lower heat loss rates may be adequate.

Good blood flow rates may be achieved in normal persons even with high gradients, provided that only the part under investigation is exposed to the cold, and the rest of the body is warm. This can be done by insertion of, say, the extremity of a nude subject into a cold box in a warm room; or by exposure to a cold room of the extremity of a warmly dressed subject. It is true that minute variations of temperature can be measured with high sensitivity apparatus, and that these, with some lag, might represent blood flow more exactly than do the examples given. Such a technique has serious drawbacks, and it would appear advantageous to apply the laws of heat transmission in order to amplify and accelerate temperature changes.

In summary, if direct measurement of blood flow is not feasible, and skin temperature is used instead, the part of the body under investigation must lose heat at a rate of more than about 240 kg-cal/hr/m² for good correspondence between blood flow and skin temperature changes. If local cold stimulus must be avoided, a flow method must be employed.

[1] The clo equation is not strictly applicable to a portion of the body, having been derived for the body as a whole (*1*).

[2] Recent determinations with an electrically heated manikin give an insulation of the air around the hand of 0.54 equivalent clo when that of the whole body is 0.82 clo; and of 0.30 equivalent clo when the average for the body is 0.43 clo.

References

1. GAGGE, A. P., BURTON, A. C., and BAZETT, H. C. *Science*, 1941, **94**, 428.
2. GOEZ, R. H. *Brit. J. Surg.*, 1939, **27**, 506.
3. LEWIS, THOMAS, *Vascular disorders of the limbs*. New York: Macmillan, 1936.

The Action of Penicillin on *Bacillus subtilis* Growing in the Absence of Amino Acids[1]

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Gale and his co-workers (*2*) have reported that Gram-positive bacteria are able to assimilate glutamic acid from the medium in which they are grown and to concentrate the free amino acid within the bacterial cell. Gram-negative organisms, on the other hand, appear to be unable to do so. They further observed that when certain strains of *Streptococcus faecalis* and *Staphylococcus aureus* were exposed to penicillin during the logarithmic phase of growth, the ability to concentrate free glutamic acid in the resting cell was lost. Subsequently Bellamy and Klimek (*1*) noted that a strain of *Staphylococcus aureus* which had been trained to grow in extremely high concentrations of penicillin changed from its usual morphology to that of a Gram-negative coccobacillus and acquired the ability to grow in a medium containing no amino acids. Gale (*2, 3*) also found that a strain of *Staphylococcus aureus* trained to grow in a medium deficient in amino acids, acquired *pari passu* a considerable degree of penicillin resistance. He therefore suggested that "penicillin interferes with the mechanism whereby certain amino acids are taken into the cell, and that the sensitivity of the cell to penicillin is then determined by the degree to which its growth processes are dependent upon assimilation of preformed amino acids rather than upon their synthesis."

At least two objections may be raised to this hypothesis. In the first place, some of the Gram-negative coliform organisms are inhibited by high concentrations of penicillin, and yet most of them require no amino acids for growth (*7*). Secondly, *B. subtilis*, a Gram-positive organism with many strains sensitive to penicillin, has been reported in some instances to grow in media containing only ammonia as a source of nitrogen (*5*).

A search was therefore made for strains of *B. subtilis* which would grow in a synthetic medium devoid of amino acids in order to determine whether such strains would be inhibited by penicillin.

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