THE RANGE AND VARIABILITY OF THE BLOOD FLOW IN THE HUMAN FINGERS AND THE VASOMOTOR REGULATION OF BODY TEMPERATURE

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The physical regulation of body temperature depends mainly upon the physiological control of the peripheral circulation, when the environmental temperature is below that where sweating plays a major rôle. By adjustment of the peripheral blood flow the effective thermal conductivity of the tissues may be altered over a five or six-fold range of values, as shown by Burton and Bazett (1936) in water baths and by Winslow, Herrington and Gagge (1937) in atmospheric environments.

The regulation of the average flow to the requirements of heat elimination is, of course, brought about by the nervous control of the tone of the peripheral blood vessels. This control is mediated chiefly by the sympathetic system, though a measure of "metabolic" regulation of flow may exist in a denervated limb (Freeman, 1935). An inhibitory action mediated by fibres from the dorsal roots has been demonstrated in the frog by Bozler (1936) but it is not yet clear how much this must be considered in the mammal.

A series of researches in this laboratory on the activity of the sympathetic system has shown that under the influence of afferent stimuli it is in a state of continual fluctuation of tone. The activity of the sympathetic centres may be of a rhythmic and intermittent character which bears no obvious relation to any corresponding intermittence of afferent influences (Bronk, 1936). The activity of the cardiac sympathetic nerves (Bronk et al., 1936) shows the interaction of several rhythms of various origins. The setting of the average peripheral blood flow to the level required by the demands of temperature regulation must then be made by the modification of an underlying sympathetic tone which itself has a complicated pattern of activity.

Another complicating factor is that the regulation of peripheral flow to serve the function of elimination of body heat must proceed simultaneously with other types of regulation of blood flow. Among these are the supply of oxygen in accordance with the needs of local metabolic activity, and the
counteracting of changes in blood pressure and flow which might otherwise occur in tissues where constancy is of more vital importance.

It is of interest, therefore, to study in detail the range and fluctuation of blood flow in peripheral vessels, in order to obtain a clear picture of the operation of these factors in the control of body temperature. For this study the fingers were chosen for two reasons. They are richly provided with arterial-venous anastomoses (Clark, 1938), the function of which presumably is to effect large changes in the amount and distribution of the blood flow. The fingers also are practically free from muscular tissue. Since Friedlander et al. (1938) find that the physiological changes in blood flow in the muscles may be of opposite sign to those simultaneously occurring in the skin, this is an advantage in simplifying the interpretation of the changes of blood flow of the finger.

APPARATUS AND METHOD. The method of Hewlett and Van Zwaluwenburg (1909), which has been used by many investigators on the foot, the leg, the hand and the arm (see Freeman, 1935) has been adapted for the measurement of flow in the finger. This adaptation has been briefly reported (Burton, 1938) and a paper has recently appeared by Wilkins, Doupe and Newman (1938) in which a very similar technique was used.

The principle of the method of flow measurement is that, if the outflow of blood from a finger is suddenly arrested by occlusion of the digital veins, without interference with the inflow, the initial rate of increase of the finger volume measures the rate of inflow of blood at the moment of occlusion.

The finger plethysmograph (A, fig. 1) is a light metal cylinder covering the last two phalanges of the finger, to which it is sealed by a binding of gauze over zinc oxide paste. It is a great advantage to have a light plethysmograph carried freely by the finger, rather than one rigidly clamped to the bench. With the latter, every movement of the hand results in an artefact on the record, while the former is practically free from this even when no restraint is applied to the hand. Air transmission may be used instead of the customary water system, for temperature changes in a system of so small a volume cannot possibly take place rapidly enough to vitiate the flow determinations which occupy a few seconds only. The recording system consists of a capsule (C, fig. 1), about one inch in diameter, covered with a membrane of the thinnest rubber tied on under so slight a tension that a considerable increase in volume may take place with a negligible rise in pressure. A mirror chip (M) cemented at the periphery gives optical recording on the bromide paper of a recording camera. Plethysmograph and capsule are connected by pressure tubing. Where long distances of transmission are required, metal or glass tubing is used to avoid distortion of the wave-form of the pulsations. Calibration of volume change is easily made by substitution of a 1 cc. syringe for
TEMPERATURE REGULATION AND BLOOD-FLOW IN FINGER

439

the plethysmograph. Figure 2 A is the record of a sudden driving in of the plunger of the syringe and shows that the system is rapid in response and gives no sign of overshoot due to inertia.

Occlusion of the venous outflow is made by a small cuff (D, fig. 1) placed round the remaining phalanx of the finger. This is made of "drainage tubing" backed by adhesive tape. A bypass tape (E, fig. 1) is conveniently included in the system so that the volume may be returned to the baseline value after any considerable change, such as produced when the finger is being inserted in the plethysmograph or immediately before a flow determination.

Figure 2 shows typical records of flow determinations made at three different levels of blood flow. No signal is necessary to mark the point at which the occlusion became effective, as inspection of the shape of successive pulsations shows this point more accurately than any signalling device that could be devised. When the flow is in the low range (D, fig. 2) the diastolic volume rises linearly for many beats and there is no difficulty in estimating the initial slope. With higher flows (C, fig. 2) the increase of volume soon becomes less rapid and after ten or twelve beats the pressure in the finger vessels has risen sufficiently to make the outflow past the inflated cuff once more equal to the inflow, so that no further volume in-
crease occurs. With still higher flows (B, fig. 2) more care must be
exercised in drawing the initial tangent to the curve of diastolic volumes.
For the highest flow a special construction must be used to find the virtual
diastolic volume at the moment of occlusion (fig. 3). The point A is
obviously that at which occlusion became effective. The sudden rise AB
is a "cuff artefact" which is often present due to the pushing of tissue into
the plethysmograph by the inflation of the cuff. The height AC indicates

![Fig. 2](image_url)

![Fig. 3](image_url)

![Fig. 4](image_url)

**Fig. 2.** A, rapidity of response of the recording system. B, C and D, flow de-
terminations in the ranges of high medium and low flow respectively. E, case of
very high flow where the determination is not possible. Time in sec.

**Fig. 3.** Geometrical construction used when the flow is very great.

**Fig. 4.** Effect of different occlusion pressures. Numbers on the figures indicate,
from left to right, the occlusion pressure in millimeters of mercury, the flow in cc./
min./100 cc. indicated by the initial slope, and the total increase in finger volume in
cc./100 cc. Time in sec.

the level of the volume above the diastolic volume at the moment of
occlusion. A vertical is dropped from B to D, so that BD is equal to AC.
D is the starting point of the curve to be drawn through successive diastolic
volumes. The estimate of the initial slope in such cases is admittedly
subject to error, but repeated constructions on the same record gave corre-
spondence of the estimated flows within 10 per cent even in such an extreme
case as that of figure 3. In certain cases, notably in the sclerodermic
subject and in the normal at the upper limit of possible flow, the method is
not applicable. Here the distensibility of the vessels has become very slight, and the vessels are full to their limit, so that upon occlusion the total increase of volume is very small (fig. 2, E). All that is recorded here is a notable decrease in the size of the pulsation. In such cases the size of the pulsation before the occlusion is the indication that the flow is very great.

Figure 4 shows that over a wide range the occlusion pressure used in the cuff has little effect on the initial slope of the curves, i.e., on the measured value of the flow. Cuff pressures below 15 mm. Hg are likely to give estimates of flow that are erroneously low, due both to difficulty in drawing the initial tangent and to incomplete occlusion of the veins. Higher pressures than 55 mm. Hg again tend to give values that are too low, here because of interference with the inflow of blood. Between these limits repeated determinations give values which scatter considerably, due to physiological variation, but which show no systematic relation to the occlusion pressure. The total volume increase of the finger before constancy is reached, however, increases with the pressure, since more blood has to flow into the vessels before the pressure has risen sufficiently at the cuff for outflow to equal inflow.

No evidence could be found that repeated venous occlusion and release at intervals of 10 seconds or less gave any systematic change in the blood flow of the finger, though with the hand or the arm where longer times of occlusion are necessary this may be a source of error.

RESULTS. Range of the blood flow. In some 50 determinations of the flow in the fingers of seven normal subjects a range of from 1 cc./min./100 cc. of tissue up to a maximum of about 90 cc./min./100 cc. tissue was encountered. These experiments included the administration of constrictor and dilator drugs and the use of extremes of temperature, both local and general. Even in cases of Reynaud's disease with maximum constriction of the blood vessels, flows less than 0.5 cc./min./100 cc. tissue were not found. Average values over a five minute period lying anywhere between 15 and 40 may be taken as normal for the subject who is comfortable as regards the temperature of the surroundings. Dilatation produced locally by immersion in water at 44°C. or reflexly by heating for 30 minutes with hot pads on the legs gave a maximum flow usually between 80 and 90 cc./min./100 cc. In certain cases, however, even this enormous flow of blood may be exceeded. In a subject living for several days in a hot and humid room (dry bulb temperature 32.4°C., wet bulb, 26.3°C.) the maximum flow was found to increase during five days of acclimatization from 96 to 122 cc./min./100 cc. In the following period in a cold room (dry bulb temperature 21.1°C., wet bulb, 16.0°C.) the minimum flow measured decreased in three days from 16 to 1.8 cc./min./100 cc. The limits of

1 Details of these results will be given in a paper with H. C. Bazett and J. C. Scott, in collaboration with whom the experiments on acclimatization were made.
the range of flow in the fingers therefore are variable according to the degree of acclimatization to the environment, and summer and winter values would be expected to differ.

Determinations on different fingers of the same subject, and on the fingers of different subjects where the volume of the finger differed greatly gave similar values for the range of blood flow when expressed per 100 cc. of tissue.

Fluctuation of the blood flow. Successive determinations of flow made only a few seconds apart seldom give values which approach equality (fig. 5 A). They may indeed differ by as much as 50 per cent of their average value (fig. 5 B). Accompanying such changes in the indicated flow there is a corresponding change in the size of the volume pulsation, and also in the finger volume (the "baseline" of the pulsations). There is a very close correlation between the computed values of the flow and the size of the volume pulsation at the moment when the determination was made. Figure 6 shows the extent of this correlation for measurements on a single subject. Here the correlation coefficient is 0.88 ± 0.015. In view of this it does not seem possible that the apparent fluctuations of flow are the result of large errors of measurement. They must indicate, rather, a very great physiological variability in the blood flow of the finger.

The flow may change so rapidly that in a determination the curve of rise of volume during venous occlusion has an unusual shape as in figure 5 C, which shows a record made on a subject having a very marked cardiac arrhythmia in the respiratory cycle. Figure 7 shows the result of a series of flow determinations every 10 seconds on the same subject, lying quietly and comfortably. Three series of determinations are plotted in
which the average flow was in the low, medium and high ranges. It will be noted that there are "waves" of change, the amplitude of which is greatest in the middle range of flow. In the low range, i.e., in constriction, the flow remains relatively constant. In dilatation the tendency is to remain high with occasional brief decreases in flow. The figure suggests that the fluctuation is not entirely random in its nature, but may be a complex result of several rhythmic components. Flow determinations cannot well be made at intervals more frequent than every six seconds, and are inadequate to determine whether this is so. For the detailed analysis of the fluctuations another method, however, is available, for making use of the close correlation of figure 6, the size of successive pulsations may be used as an index of the fluctuations of vasomotor activity.

Analysis of the fluctuations. Figures 8 A and 8 B show that the changes in finger volume and in size of pulsation respectively are indeed of a rhythmic character. Figure 8 C is the result of detailed measurement and plotting of the size of pulsation in records such as figure 8 B. The complexity of the changes is due to the presence of at least two types of rhythmic fluctuation. The first of these is the well known fluctuation of flow in the respiratory cycle, studied by Bolton, Carmichael and Sturup (1936) and by Shulman, Mulinos and Lieb (1938). Simultaneous records of the respiration proved the respiratory origin of the waves of small amplitude and period seen at R in figure 8 C. In most subjects the amplitude is such that a variation of some 20 per cent in flow is indicated in each respiratory cycle. In a subject, otherwise normal but having a very marked cardiac arrhythmia of respiratory nature, whose cardiac rate swung between 45 and 85 per minute in each respiratory cycle, the fluctuation in flow amounted to 60 per cent. Even in the normal, the inflation of the lungs by a deep breath causes a momentary almost complete cessation of flow in the fingers.
The second component consists of much slower waves of large amplitude, marked X in figure 8 C. Their period varies from as little as 15 seconds to as much as 120 seconds, the longer periods being associated with a high average flow. Characteristically in this case the shape of the fluctuation (fig. 8) indicates a rapid constriction followed by a slower recovery of dilatation. Since there is such a marked vasoconstriction from a deep breath, a simultaneous respiratory record was examined in one case to make sure that the large rhythmic constrictions were not related to periodic "sighing" of the subject. No such relation was seen.

Though these slow waves were found in all records examined, their amplitude and frequency varied greatly in different individuals under the same conditions of temperature. Figure 9 shows records taken with a slower camera speed on four different normal subjects. Repeated measurements on different days indicated the same differences in relative amplitude of the waves, which must, therefore, reflect a difference in the stability of the sympathetic system in these individuals.

A third component of the fluctuation that may be present is the con-
striction in response to the stimulation of pain, startle or emotion. For instance, at the points marked by arrows in figure 9, an unexpected noise was made behind the subject. The resulting constriction is plainly seen. Even the mere asking of a question of the subject sometimes resulted in such a response. This type of response was strikingly seen also in a series of experiments with Dr. Hugh Montgomery on the effect of drugs upon blood flow in the fingers in which a subcutaneous injection of saline or of distilled water was routinely used as a control during the course of the experiment. This invariably produced a constriction (fig. 10). It will be noted that constriction preceded by some seconds the actual insertion of the needle of the syringe, which produced a slight further effect. The mere anticipation of an injection was sufficient to produce a constriction. The peripheral blood flow is a much more sensitive index of "psychic" constrictions than the blood pressure or cardiac rate, which may simultaneously show little significant change.

Fluctuation in different parts of the body. Simultaneous records have been made of the volume pulsation in two fingers of the same hand, in a finger and in one of the opposite hand, and of a finger and a toe volume pulse. The fluctuations are closely correlated in parts of the body as widely separated as a finger of the right hand and the left big toe. The extent of the correlation is shown by figure 11. The demonstration of a
Fig. 10. Changes in pulsation and in flow in a finger induced by the anticipation and the administration of a subcutaneous injection.

Fig. 11. Correlations between simultaneous values of the pulsation in different digits.
bilateral symmetry of the changes is practically as perfect as the errors of measurement would allow. Between the changes in finger and toe there is more scatter in the correlation diagram, but this occurs mostly in the middle range, and is due to the fact, as inspection of figure 8 shows, that when the flow is changing rapidly a slight time difference in the changes will have a major effect. There is no doubt that the rhythmic changes in blood flow are simultaneous over a large part of the peripheral vascular bed.

*Fluctuations of cardiac rate and blood pressure.* With each of the large periodic constrictions of figure 8 there is a simultaneous increase of cardiac rate (which could be measured for each beat from the records). An example is shown on figure 8 C (H.R.) and one in figure 12. The cardiac change is complicated, however, by a subsequent slowing due no doubt to the operation of the carotid sinus and aortic arch reflexes, so that the records of heart rate show diphasic changes where the volume pulse records are monophasic. There is then a discharge of impulses in the cardiac sympathetic nerves, or an inhibition of vagal impulses, simultaneous with the peripheral constrictions. It is interesting to note that though the heart is markedly slowed the progress of the constriction is not halted.

It is obvious that widespread simultaneous changes of the peripheral vessels over the body must produce changes in blood pressure. The latter is not readily measured with sufficient rapidity in the human for the purpose of finding the amount of these. It may be shown, however, that the changes in pressure occur, and are of the opposite sign to the blood flow changes (fig. 12). If the pulsation of the brachial artery is recorded from a small bag under a Riva Rocci cuff held constant at a pressure just below the systolic pressure, “spikes” appear whenever the blood
pressure rises above that of the cuff. It is obvious from figure 12 that there is a rise of systolic pressure simultaneous with a decrease in the pulse volume recorded from a finger on the opposite side of the body. (The time lag in the volume change over that of pulse-volume may be noted.) By holding the cuff at about the diastolic pressure, changes in the latter may be followed by the appearance and disappearance of the flattening of the waves at the end of diastole or by other diastolic criteria. In the large waves of constriction, diastolic pressure as well as systolic rises, but in the fluctuations of smaller amplitude, such as the respiratory waves, the relation is very complicated. Diastolic pressure may here be rising as systolic falls, probably because of the complicating factor of change of cardiac rate.

Fluctuations in a sympathectomised limb. Simultaneous records were made of the volume pulsations in a finger on the unoperated and on the operated side of a patient in whom a unilateral cervical ganglionectomy had been done some months before the experiment. The resulting correlation diagram is shown in figure 11. While the size of pulsation on the unoperated side varied between the usual limits, the pulsation of the sympathectomised side had a much smaller range of variation and remained close to the value found in a normal dilated limb. Correlation between the pulsation on the two sides is small, but it is clear that any that exists is of the opposite sign to that found between normal digits. The pulsation of the sympathectomised digit tends to increase when that of the normal digit is small. Thus its fluctuations are in phase with those of the blood pressure changes which accompany the widespread vasoconstrictions of the normal vessels and may be attributed to a passive dependence upon the mean blood pressure. The experiments with the sympathectomised subject show that the occurrence of normal rhythmic changes of flow in a limb is dependent upon an intact peripheral sympathetic system.

Modification of the rhythms by temperature regulation. The modification of the amplitude of the fluctuations by the temperature conditions has already been mentioned. When the subject is cold and the average blood flow is low the fluctuations are small in amplitude. In conditions of full dilatation when the subject is uncomfortably warm and sweating, it is again less (fig. 7). Here the constrictions, which still occur at intervals, are often slight so that the size of pulsation does not fall far below the maximum dilatation value.

Temperature regulation also modifies the frequency of the periodic constrictions. Statistical studies of the intervals between successive constrictions that occur in the course of a long experimental period (80 min.) have been made, in collaboration with Dr. R. M. Taylor, at different environmental temperatures. In the same subject the average period
increased from 50 seconds at 24°C. to 80 seconds at 30°C., while the period of commonest occurrence increased from 30 seconds to 50 seconds. Within an experimental period of constant temperature the rhythm is often seen to pass from a slow to a faster tempo for a short period. In such periods of faster rhythm the pulsation never reaches the full dilatation value between constrictions, so that the average pulsation, and therefore the average flow, decreases.

Both the frequency of the waves of constriction and the magnitude of the contractions of the blood vessels are therefore modified by the integrated sum of afferent stimuli from temperature receptors.

Discussion. The extraordinary range of blood flow in the fingers, permitting a hundred-fold change between minimum and maximum values, must be related to their functions as radiators of body heat (Grant and Pearson, 1938) since such a range cannot represent a provision for metabolic needs. The range found in the hand is less (Freeman, 1935) from a slightly higher minimum (1 cc./min./100 cc.) to about 20 cc./min./100 cc. The similarity of the minimum values suggests that these represent the basic requirement of blood flow for the maintenance of the metabolism of the skin. Field, Belding and Martin (1938) give values for the oxygen consumption of the various tissues of the rat (0.3 cc./hr./gm. wet weight for skin). If it may be assumed that the relative metabolic activity of different tissues is the same in man as in the rat, a value for human skin may be deduced by multiplying the value for the skin of the rat by the ratio of the total metabolism per gram in the two cases (0.2 for man, 1.1 for the rat). Taking the values for available oxygen in the blood in severe ischemia given by Freeman, Shaw and Snyder (1936), a simple calculation yields as the minimum requirement of blood flow the value 0.8 cc./min./100 cc. tissue, agreeing closely with that found in full constriction. For the hand, because of the presence of muscle, the minimum requirement would be greater.

Analysis of the fluctuations of flow reveals that the heat regulation is not achieved by the setting of the peripheral flow to an appropriate steady level except at the ends of the range of adjustment. In the middle range of flow it is achieved rather by the modification of an underlying intermittence of flow between high and low values; an intermittence which reflects the rhythmically fluctuating character of the tone of the sympathetic system. A crude analogy might be drawn with the operation of a temperature regulated water-bath, where the constancy of the average temperature is accomplished by the adjustment of the relative durations of the “on” and “off” periods of the heater.

The increase in the frequency of the discharge of sympathetic bursts as the temperature of the environment is lowered should probably be regarded as the primary mechanism of control of the average blood flow,
though modification of the number of impulses in each burst undoubtedly also plays a part in the grading of the contractions of the smooth muscle. Bozler (1936) shows that following a brief stimulus of the sympathetic nerves the relaxation of the blood vessels of the frog's limb may not be complete for two minutes. The sluggishness of the response of the effectors supplied by the sympathetic system in the mammal has been discussed by Adrian, Bronk and Phillips (1932). It is to be expected then that with rapidly occurring bursts, as in cold conditions, the result would be a maintained state of contraction of the vessels, with only partial relaxation between the bursts. The diminished amplitude of the fluctuation of flow in the cold conditions may thus be a consequence of the slowness of response of the effectors.

The existence of rhythmic fluctuations is of great interest on its own account. The simultaneous widespread nature of the constrictions and the accompanying cardiac acceleration shows that the sympathetic system is discharging as a whole, driven by a physiological centre, a conclusion reached also by the study of the electrical activity of the sympathetic nerves (Bronk, 1934). The faster rhythms have previously been known and studied. Bronk et al. (1936) studied both the cardiac and respiratory rhythms as well as others of different frequency. The respiratory constriction has been studied recently by Bolton et al. (1936) and by Shulman et al. (1938). The much slower rhythms here discussed are linked by the existence of accompanying blood pressure changes to the Traube-Hering or Mayer waves (Traube, 1865; Hering, 1869; Mayer, 1876; Irving, 1938). Some have regarded these as representing the activity of a failing vasomotor centre, as gasping respiration does that of a failing respiratory centre, for in anesthetised animals they are not constant in occurrence (Alkjaer, 1934; Speigel and Taga, 1930). Alkjaer (1937), however, finds slow waves always present in the blood pressure of unanesthetised humans, though suppressed in psychic constriction. Wilson (1936a) studying the visible changes in blood vessels of the ear of rabbits and dogs showed that they were synchronous with blood pressure changes, and, moreover, that the waves were suppressed by the common anesthetics (Wilson, 1936b). In the unanesthetised rabbit they were always present as long as the animal was awake. In humans, unless in a state of constriction, the waves have invariably been seen in the experiments. Rhythmic fluctuations in vasomotor tone are then rather to be regarded as normal in the unanesthetised animal. The phenomenon is then not of casual interest but of fundamental physiological importance.

It is as yet uncertain whether it is wholly justifiable to speak of the rhythmic vasomotor changes as truly "spontaneous." Doupe et al. (1937) found that "spontaneous" changes of toe volume did not occur in patients with lesions of the cauda equina, and concluded that the vaso-
constrictions normally seen resulted from afferent impulses from the legs, possibly consequent to periodic venous engorgement. It has been noted in these experiments that the volume changes of the digits are to some extent independent of the flow changes, as though the venous system, which greatly affects the volume in distinction to the volume pulsation, acted independently of the arteriol-artery system controlled by the sympathetic (Turner et al., 1937). Possibly the periodic constrictions of the venous system are due to afferent stimulation and reflex action while the arteriolar constrictions are truly spontaneous. It may be noted also that in the experiments of Doupe and his co-workers the subjects were held as far as possible in a state of maximum dilatation in which spontaneous constrictions would be expected to be absent or very infrequent. The widespread distribution of simultaneous waves of constriction certainly are difficult to explain on the grounds of afferent impulses from local venous engorgement. Also if this were the explanation, a greater frequency of the constrictions would be expected with a greater average blood flow, which would more rapidly fill the veins. The relation between frequency of constrictions and the average blood flow, however, is the reverse, the rhythmic constrictions being less frequent in dilatation than with lower flow.

A second possibility must be examined. Temperature regulation might not merely modify the rhythm but be the cause of the rhythmicity. After a period of high blood flow, the skin temperature might fall due to increased loss of heat until afferent impulses from cold receptors reached a threshold, below that of sensation, yet sufficient to stimulate the centre to initiate a constriction. This possibility cannot be dismissed until a careful study has been made of the relation between the rhythmic fluctuation of flow and skin temperatures.

The accurate adjustment of the average value of so fluctuating a flow in the peripheral vessels, to a level which ensures the measure of constancy of body temperature achieved by the homeotherm, is one of the most highly developed integrative mechanisms of the nervous system.

SUMMARY

A simple plethysmographic method of recording the volume pulsations of the finger has been adapted to the measurement of instantaneous values of the blood flow of the finger in cc./min./100 cc. of tissue. The measurement may be repeated at intervals as short as six seconds.

The range of blood flow in the fingers is from 0.5 to 1.0 cc. as a minimum up to 80 to 90 cc./min./100 cc. tissue for full dilatation. The maximum and minimum values are subject to change upon slow adaptation to high or low temperatures. The minimum value found is shown to correspond with that calculated from the basal oxygen consumption of skin. The
tremendous range of flow, made possible by the arterial-venous anastomoses, represents not a metabolic need of the tissues but the mechanism for temperature regulation by elimination of body heat.

A close correlation is found between the size of the finger volume pulse in cc./100 cc. and the blood flow in cc./min./100 cc. of tissue. This has been used in a study of the nature of the marked fluctuations in the flow which occur from moment to moment.

These are rhythmic in character, the rhythm having two main components, a respiratory fluctuation of small amplitude and a slower rhythm of periodic constrictions of large amplitude. These are simultaneous in the digits of all the extremities of the body and are accompanied by cardiac acceleration and rise of blood pressure. A rhythmic fluctuation of the activity of the entire peripheral sympathetic system acting as a whole is therefore indicated. The connection with Traube-Hering or Mayer waves of blood pressure is pointed out. A third component of constrictions due to pain, startle or emotional stimuli may also be present.

The rhythm is markedly modified by the conditions of temperature regulation. The amplitude of the waves is greatest in the middle range of blood flow and of temperature, is less in dilatation, and least in constriction. The frequency of the rhythm is also modified, the faster rhythms being associated with cooler conditions and with lower average values of the flow.

Physical regulation of body temperature is accomplished, not by the setting of the peripheral blood flow to an appropriate steady level, but by the adjustment of the average of a flow which is fluctuating rhythmically between high and low values.

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