TABLE 3
A CORRELATION TABLE SHOWING RELATION BETWEEN IRON COLOR (A MEASURE OF IRON CONTENT) AND % GRANITIC TEXTURE ON 248 MAINE SANDS

Thus the amount of granitic material found in Maine sand has a relation to mortar strength such that the increase of granitic material results in a lowering of the mortar strength. The amount of granitic material is related to the amount of iron found in Maine sand, a large amount of granitic material indicating a low amount of iron. Part of the effects of the granitic material on mortar strength is accounted for by the lack of iron in the sand. There is, however, an independent relation as well, the iron content materially influencing strength even in sands constant in the amount of granitic materials.

¹ These PROCEEDINGS, 13, 264 (1927).

² U. S. Geological Survey, 34 (1899).

³ The writers are indebted to Dr. E. C. E. Lord, Petrographer of Bureau of Public Roads for this classification.

ON THE MECHANICS OF BLOOD FLOW, WITH SPECIAL REFERENCE TO THE INFLUENCE OF CHANGE OF POSTURE

BY DICKINSON W. RICHARDS, JR.

DEPARTMENT OF MEDICINE, COLLEGE OF PHYSICIANS AND SURGEONS, COLUMBIA UNIVERSITY AND THE PRESBYTERIAN HOSPITAL, NEW YORK

Communicated May 10, 1927

The recent development of reliable methods for determining total volume of blood flow in man, by Field, Bock, Gildea and Lathrop,¹ and by Henderson and Haggard,¹ adds a new and important measurement to the study of the mechanics of the circulation, comparable perhaps in significance to the discovery a generation ago of adequate clinical methods for blood-pressure determination.

With definite knowledge of these two factors, blood pressure and blood

flow, together with certain other data which are available, it should now be possible to examine problems of the circulation of the blood in man from a more strictly mechanical point of view than has heretofore been done.

We shall endeavor in the present paper to apply this point of view in a study of the effect of change of posture on blood flow.

It has long been known that in animals (except monkeys) the change from the horizontal to the vertical position is associated with a marked drop in blood pressure as well as a decrease in volume of flow. There is, for instance, the familiar experiment of holding a rabbit up by its ears, until the blood flow and arterial pressure reach the vanishing point, and the animal "bleeds to death into its splanchnic veins." The same phenomenon, to a less striking degree, occurs in dogs (Zybulski,² Friedmann³ and Hill⁴).

Lindhard,⁵ in 1913, was the first to measure in man the effect of change of posture on blood flow. Using Krogh and Lindhard's⁶ nitrous oxide method, Lindhard found that of seven subjects, four (all men) showed practically the same flow and three (all women) a definitely smaller flow in the upright than in the recumbent posture. With the improved method (based on Fick's principle) developed by Field, Bock, Gildea and Lathrop, Field and Bock,⁷ in determinations on thirteen subjects, found in every case a decreased flow in upright postures. There was an average decrease of 24 per cent in the sitting posture and of 50 per cent in the standing posture, as compared with the recumbent. These investigators also quote a series of determinations by Miss Turner, in which of 32 subjects in the sitting position, 17 had a smaller flow, 7 no change and 8 a rise, and of 19 subjects standing, 14 showed a smaller flow, 4 no change and one a larger flow. We have made several determinations in this laboratory on a small group of three subjects, using a method slightly modified from that of Field, Bock, Gildea and Lathrop, and have found the same changes as reported by Field and Bock, consistently lower blood flows in the sitting than in the recumbent position.

There thus appears to be in man a definite tendency for the volume of blood flow to be considerably decreased in upright postures—the same change that has been found to occur in animals.

Blood pressure changes in man in upright positions, as compared with recumbent, are, however, quite different from those found in animals. The literature on this point is somewhat confusing at first sight, because (1) some investigators have used supported vertical positions, and others these postures as maintained by the subjects themselves; and (2) some investigators have measured the systolic arterial pressures only, and others both systolic and diastolic pressures. With subjects supporting themselves in the standing position (which was the posture employed in the blood flow experiments of Field and Bock), and under normal external conditions,

the evidence is fairly conclusive that although the systolic blood pressure falls (Renquist⁸) the diastolic usually rises. The mean blood pressure, which is considerably nearer the diastolic than the systolic level, thus usually rises also, an average increase of 7 to 10 mm. Hg (Erlanger and Hooker,⁹ Barach and Marks,¹⁰ Hill,¹¹ Hill, Barnard and Soltau¹²). One must make exception, of course, of the situation in long continued experiments, where blood pressure falls considerably and symptoms of syncope supervene. There are also some individuals whose blood pressure will tend to fall even during brief periods in the standing posture. All studies agree in report-

FIGURE 1

Changes in circulation with change of posture (Lawrence, Hurxthal and Bock). These figures, it will be noted, give somewhat lower percentage changes in blood flow following change of posture than those found by Field and Bock.

The above relations between blood flow, pulse pressure and pulse rate have been fully confirmed in a very recent paper by Lawrence, Hurxthal and Bock.¹³ The average figures obtained by these investigators on a series of ten normal individuals are presented diagrammatically in figure 1. The actual blood pressure figures, though not listed in this paper, have been made available for our use through the courtesy of Dr. Bock. The changes with change of posture are irregular, but show, on the average, fairly close agreement with the findings of earlier investigators with a tendency toward slightly lower pressure values in the sitting and standing postures. The average diastolic pressures show a fall of 3.5 per cent in the sitting posture, and a rise of 2 per cent in the standing, as compared with the recumbent. The systolic pressures fall 7 per cent in the sitting

ing decreased pulse pressure in the standing position. The pulse rate increases 10 to 50 per cent.

In the sitting position, the mean blood pressure shows little change from that in the recumbent. There is a tendency toward a slight fall in systolic and rise in diastolic pressures (Erlanger and Hooker). Pulse rate increases slightly.

Thus we have these conditions on changing from recumbency: (1) in the sitting posture, practically no change in mean blood pressure, and a decrease of 24 per cent in blood flow; (2) standing, an increase in mean blood pressure of 7 to 10 mm. Hg, a sharp decrease in pulse pressure, an increase of 10 to 50 per cent in pulse rate, and a decrease of 50 per cent in volume of blood flow.

and 12 per cent in the standing. Thus the mean blood pressure falls slightly in the sitting posture and remains practically constant in the standing; these data are also included in figure 1.

The explanation that has been offered for this marked decrease in flow in upright positions is that it is due to stasis or stagnation of blood in the veins of the viscera and lower extremities. The fact of accumulation of blood in these channels is, of course, apparent from ordinary observation. The effect of venous distension itself, upon volume flow of blood, has not, however, been inquired into in any detail; not even so far as to determine whether such distension would actually tend to decrease or increase the flow. In fact, no precise definition of "stasis," so far as we are aware, has been given. That is to say, it is not clear whether it means simply accumulation of blood in veins, without reference to the flow of blood, whether it means that the volume of flow is decreased, or the linear velocity of flow decreased, or whether there is assumed to be complete stagnation and immobility of blood in certain regions of the venous system.

Granting the accumulation of blood in the visceral and lower extremity veins in the upright position, one must inquire, inasmuch as practically the whole body is involved, into the source of this increased venous blood. Some undoubtedly comes from the partially collapsed veins of the head region, and some in all probability from the pulmonary circulation, the congestion of which in the recumbent posture is relieved in the upright on account of diminished flow of blood into the right heart. This proposition is suggested by Field and Bock in their discussion of the phenomenon of orthopnea. Mere venous distension, however, will not diminish blood flow. If the pressure gradients remain the same in a given system of tubes, the distension or enlargement of the tubes in one part of the system will cause increased flow due to diminished resistance.

For the brief period over which the blood flow is studied during posture changes, the total blood volume and blood composition are here taken as constant. Under these conditions, and with the mean blood pressure either the same or increased, a significantly decreased volume of blood flow can occur only by decreasing the cross sectional area of the channels of flow over one or more regions of the circulation, and this in turn only through (a) withdrawing or side-tracking blood from the active circulation, or (b) through a redistribution of blood between arteries and veins. We are here obviously disregarding the hydrostatic effects produced by gravity as the vertical posture is assumed. This is probably justifiable, however, because if (a) and (b) were both constant, the circulation would become a system of rigid tubes, and in such a system any effect produced by increase of hydrostatic pressure on the arterial side would be counterbalanced by an equal change on the venous side. Hürthle,¹⁴ furthermore, in a paper to which we shall refer again presently, has shown that the

flow of viscous fluids in branching tubes is not appreciably affected by a varying arrangement and direction of the tubes with respect to the horizontal plane, such as occurs in the system of arteries, capillaries and veins.

If there is to be complete stagnation of blood anywhere in the venous side it will require either the draining of large amounts of blood into sinuses such as those of the spleen or the liver, with constriction of all other venous channels; or else, the actual stagnation of the blood in most of the branching venous vessels. The former possibility seems most unlikely; with increased hydrostatic pressure the venous vessels could hardly do anything but dilate; certainly all visible venous vessels are dilated in dependent positions; and the latter possibility can occur only if exactly equal pressures exist along all parts of the given stagnant sections of the venous system or if such sections are actually closed off by constriction at their proximal ends. The first of these hypotheses is impossible in a regularly branching system, and the second impossible in the existing venous system; that is, no vein of any size would close off against a positive pressure. The capillaries, moreover, contain only a small fraction of the total blood volume, and even they would not be likely to harbor appreciable amounts of stagnant blood; inactive capillaries, according to Krogh,¹⁵ are empty. From computations that will be made presently, it will appear that in order to provide for a decrease of 25 per cent in volume of blood flow, about 62 per cent of the total blood in the venous vessels would have to be thus sidetracked—an absurd figure. Thus the "side-tracking" hypothesis is inadequate. The above argument is of course indirect, but necessarily so as we have not been able to find in the literature any measurements of active blood volume in varying postures.

There remains the second (*b*) of the alternatives, namely a redistribution of the blood in the lower part of the body, specifically a contraction of the arteries, and a corresponding dilatation of the veins. We believe that this is an important factor in the production of a decreased flow in the upright posture in man.

There is, of course, nothing original in the notion of such arterial contraction; one would naturally assume that contraction occurs, inasmuch as the mean blood pressure in the upright posture in man is either maintained or else actually increased over that in the recumbent posture. More specifically, the decreased pulse pressure, which is a constant finding in such a posture change, is what would be expected on the basis of lowered blood flow, increased pulse rate and contracted arteries: that is, the greatly diminished stroke volume will cause less distension of the aortic and larger artery walls, thus diminishing the systolic pressure, whereas the greater arterial resistance will increase the diastolic pressure. The increased pulse rate would itself tend to have the same effect of lowering the pulse pressure in the standing position. With such a pulse increase,

if the mean blood pressure is constant, one would expect a constant blood flow, supposing the peripheral blood vessels to remain unchanged; a large *decrease* of blood flow, however, could be associated with a constant mean blood pressure, irrespective of pulse rate, only if the arterial (or venous) resistance were increased.

This raises the question of the heart itself as a factor in the circulatory adjustment now under discussion. Cardiac output has been shown by Krogh¹⁶ to depend largely upon venous inflow in such a manner that (a) when the inflow is "inadequate" and the auricular contraction is expended in filling an unfilled ventricle, the cardiac output is practically independent of rate of contraction; while (b) when the inflow is "adequate," and the auricular contraction is expended against a filled ventricle, causing a backward pulsation in the great veins, then the output is proportional to heart rate. Whether (a) or (b) obtains ordinarily in recumbent or upright postures in man is not known, but in either case the cardiac factor is not the dominant one; for if (a) obtains the heart rate makes little difference in the flow: while if (b) obtains there may be in upright postures some tendency toward a compensating increase of output from increased heart rate, but obviously insufficient, since the flow actually diminishes.

Direct experimental evidence of visceral arterial constriction in the upright posture was obtained as long ago as 1895 by Leonard Hill,⁴ working with dogs and monkeys. Hill found that in dogs, although a shift from the horizontal to the feet-down position resulted in a certain fall in pressure in the carotid artery, this fall was less than would be expected from the change in hydrostatic conditions, a partial compensation being brought about through vaso-constriction in the splanchnic arteries (the condition of these vessels being determined by measurement of pressures in the splenic artery). In the experiments with monkeys, he found this compensation to be practically perfect; that is, the splanchnic vaso-constriction was so extensive as to maintain the carotid pressure practically unchanged in the feet-down position. In fact, in some monkeys the analogy to the condition in man was complete, there being a slight rise in carotid blood pressure in the upright position. In the splanchnic veins, as was to be expected, the change in pressure followed closely the changes in hydrostatic conditions. From Hill's work on these animals it appeared that most of the compensatory arterial constriction occurred in the splanchnic vessels, and relatively little in those of the lower extremities.

Assuming, then, that there is in the arteries of the viscera a contraction (whether in arteries or arterioles, or both, makes essentially little difference) resulting in a maintenance of mean blood pressure, and a redistribution of a corresponding amount of blood from arteries to veins, one must inquire what will be the effect on volume of blood flow. I think one can readily appreciate, qualitatively, that the blood flow will be diminished,

the increased pressure gradient in the arteries leaving a much lower gradient and, therefore, slower flow in the veins. The proposition can perhaps be more clearly stated as follows: in a system of circulating fluid flowing through first a narrower (arterial) set of tubes and then through a wider (venous) set of tubes, a contraction of the narrower set and corresponding dilatation of the wider, will result in a slower volume flow of fluid per unit of time, the pressure difference between the two ends of the system and the total volume of fluid remaining constant. This is obviously only a simple problem in maxima and minima, and its general truth can be apprehended at once. An approximate estimate of the relative quantitative changes in such a process as applied to blood flow, may, however, be obtained by a brief consideration of the conditions of flow of fluids in tubes.

The familiar law of Poisseuille, defining the flow of viscous fluids in cylindrical tubes, may be formulated as follows:

$$p = \frac{vl8\eta}{t\pi r^4}$$

where p = pressure, l = length of tubing, r = radius of tubing, t = time of flow, η = viscosity of fluid, v = volume of tubing = $\pi r^2 l$, v/t = volume of flow in unit time.

The law is derived on the basis of analogy between a viscous fluid and an elastic solid. That is to say, the fluid is considered as a material which is practically motionless at its outer surface, adjacent to the wall of the tube, and is elsewhere being "bent" in the direction of the fluid pressure, with the difference that adjacent particles are continually giving way and moving past one another in the direction of flow, instead of remaining fixed, as in the case of an elastic solid. Viscosity thus becomes analogous to elasticity in the mechanical sense.

The law depends, therefore, on homogeneity of fluid and smooth, stream-line motion of all parts of the fluid in the direction of flow, as two of the conditions of its applicability. There has been considerable doubt, for this reason, as to whether the law could be applied to the flow of blood in the blood vessels, the heterogeneity of the blood interfering in the smaller vessels, and eddy or vortex motions interfering in the larger ones. It was also doubtful whether the law could be applied to systems of branching tubes in both horizontal and vertical positions, or to a pulsating as well as to a continuous flow.

A critical study of this problem, both theoretical and experimental, was undertaken a few years ago by Hürthle.¹⁴ He found the law to be closely applicable, at ordinarily existing pressures, to the conditions of flow in all blood vessels down as far as the capillaries, with the important exception of one condition, namely, that the variation in diameter of the vessels, occurring as a result of their elasticity and the pulsatile flow of blood,

disturbed the proportionality between pressure and flow. With increasing pressure, there is a more than proportional increase of flow, the discrepancy at normal blood pressures amounting to from 15 to 30 per cent. This discrepancy depends on a number of variable factors, and in further studies Hürthle¹⁷ has not as yet been able to give an exact theoretical description of the relation in the vascular system between pressure and volume of flow.

In the present discussion, however, the pressure *changes* with change of posture are found to be slight, at least in the larger blood vessels where pulsatile variation in diameter is greatest, so that one may assume without gross error the applicability of Poisseuille's law to the flow in arteries and veins.

As far as the volume of blood and pressure changes are concerned, the capillaries are a relatively minor element, because in spite of their large total cross sectional area, and tremendous surface area, their average length is so slight—0.2 to 0.4 mm. (Krogh)—as to make the total volume of blood in them small, and the pressure loss negligible.

Since the available data, as given above, regarding changes of pressure and flow with change of posture represent only average and approximate measurements, it will not be profitable to attempt to use them for exact calculations of the effect of change of posture on the vascular system. We may, however, determine roughly the order of magnitude of such changes in the arterial and venous vessels. Assume as a first approximation that the mean arterial pressure remains constant. The capacity of the total systemic venous system is given by Hürthle¹⁸ as about 80 per cent of the total blood in the systemic circulation or roughly four times that in the arterial system. Let us consider, for purposes of simplification, that the venous and arterial systems consist of single tubes, each of length l ; the radius of the arterial tube will then be half that of the venous.

FIGURE 2

Schematic diagram of arterio-venous system.

Let r = radius of artery, $2r$ = radius of vein, l = length of venous and of arterial system, p = loss of pressure in arterial system, P = total loss of pressure = constant, $P - p$ = loss of pressure in venous system, V = volume of fluid = $\pi r^2 l + \pi (2r)^2 l$ = constant, f = volume of flow per minute through the system. Applying Poisseuille's law:

$$p = \frac{f l 8 \eta}{\pi r^4}, \quad P - p = \frac{f l 8 \eta}{\pi (2r)^4}.$$

Adding and solving for flow:

$$f = 0.94 \frac{\pi P r^4}{l 8 \eta}.$$

In order to diminish the flow to half this value, that is to $0.47\pi Pr^4/(l8\eta)$, keeping the total volume and total pressure loss constant, it can easily be computed that the arterial radius will have to be about 0.83 time its original value, and the venous radius 1.04 times its original value. Thus, applying this to the blood flow, one sees that the requisite decrease in volume of flow, in passing from recumbent to upright posture, is attained by an arterial constriction of only 17 per cent in radius, and a venous dilatation of 4 per cent. The important change here is, of course, the arterial contraction, the diminution in flow being almost the same without the venous dilatation.

It should be emphasized that the above figures are by no means intended as close approximations to the actual state of affairs in the normal circulation. They do indicate, however, that relatively slight changes in distribution of the blood between arteries and veins can cause considerable alteration in blood flow.

It can readily be seen from the preceding discussion that alteration in the caliber of the venous vessels will cause relatively little change in pressure or volume of flow. Thus supposing a venous distension such that the radius $2r$ in the diagram becomes $2.5r$, the total pressure loss remaining the same, but the total volume of fluid increasing, the resultant change is to increase the flow by about 3.5 per cent of its previous value. Similarly, if the venous channel is diminished, as by "side-tracking" of blood, this channel will have to be decreased to 38 per cent of its previous volume to cause a decrease in flow of 25 per cent, and to 24 per cent of its previous volume in order to cause a 50 per cent decrease in flow.

Our rough calculations, as stated, have assumed the mean arterial pressure to remain constant. In the standing position the pressure is often actually increased; there is also probably a tendency for blood flow to increase due to peripheral muscular contractions. These factors thus place an added burden, as it were, on the vasoconstricting mechanism, in its provision for a 50 per cent decrease in blood flow. Without accurate data, calculations are out of the question, but with the flow varying as the fourth power of the radius, one may presume that the method of arterial constriction will be sufficient to provide for the observed decrease in flow.

There is one other possible mechanism of adjustment of blood flow which should be mentioned. This was outlined by Krogh¹⁹ in the series of papers referred to above, regarding venous supply to the heart. He demonstrated that in the portal system there exists a special mechanism for throwing an additional volume of blood into the rest of the circulation, by reason of the double set of resistances in this system, (1) intestinal arterioles, capillaries and venules and (2) liver venules and capillaries. It is on account of the latter that the portal vein pressure is about 25 mm. Hg whereas in other large systemic veins the pressure is only 5 or 10 mm. Hg. By

strong contraction of intestinal arterioles, the pressure gradient there can be increased, thus decreasing the pressure in the portal vein system, which thereupon empties itself more or less completely into the vena cava. The effect of this upon blood flow, according to Krogh, is an increase, by increasing the venous supply to the heart. Thus one would expect by this mechanism, a simultaneous increase of blood flow and blood pressure upon contraction of intestinal arterioles. It is clear, however, that no such adjustment occurs with change of posture, for although intestinal arterioles undoubtedly do contract with the body in the upright position, and blood pressure is maintained, the large hydrostatic effect increasing portal vein pressure will outbalance the other tendency to decrease this pressure, and these veins will, therefore, further distend and blood flow will diminish.

The present paper has been restricted to a consideration of the application of Poisseuille's law to a single simple physiological phenomenon. Other applications will suggest themselves. The relation, for instance, between linear velocity of blood flow and volume of blood flow becomes apparent; and the limitations within which these two measurements are proportional, or nearly so, can be easily worked out (cf. the work of Blumgart and Weiss²⁰). This relation has been pointed out by Hürthle¹⁸ but no application of the relationship demonstrated. There has been, in fact, with a few exceptions (Hürthle, Schleier,²¹ Murray²²) little application of the principles of Poisseuille's law to problems of the circulation, and perhaps for this reason a persistence in physiological terminology of such vague terms as "peripheral resistance" and "venous stasis."

This law, of course, does not apply exactly to the flow of blood in the vascular system, but with the exceptions noted above, the applicability is close, and if further studies can determine, even approximately, the pressure-flow relationship, one may venture the hope that general problems of blood flow, both physiological and clinical, may be dealt with in concepts that are more precise, and better founded on mechanical principles, than has heretofore been possible.

Summary.—The decrease in volume of blood flow in man on assuming the upright posture from the recumbent is shown to be associated with arterial constriction. The discussion is based on the application to the circulatory system of Poisseuille's law of flow.

¹ Field, H., Bock, A. V., Gildea, E. F., and Lathrop, F. L., *J. Clin. Inv.*, **1**, 1924 (65-85); Henderson, Y., and Haggard, H. W., *Am. J. Physiol.*, **73**, 1925 (193-253).

^{2,3,4} Zybalski and Friedman, quoted in Hill, L., *J. Physiol.*, **18**, 1895 (15-53).

⁵ Lindhard, J., *Skand. Arch. Physiol.*, **30**, 1913 (395-415).

⁶ Krogh, A., and Lindhard, J., *Ibid.*, **27**, 1912 (100-125).

⁷ Field, H., and Bock, A. V., *J. Clin. Inv.*, **2**, 1925 (67-76).

⁸ Renquist, Y., *Skand. Arch. Physiol.*, **43**, 1923 (128-137).

⁹ Erlanger, J., and Hooker, D. R., *Johns Hopkins Hosp. Rep.*, **12**, 1904 (145-378).

¹⁰ Barach, J. H., and Marks, W. L., *Arch. Int. Med.*, **11**, 1913 (485-494).

- ¹¹ Hill, L., *J. Physiol.*, **22**, 1897 (xxvi).
- ¹² Hill, L., Barnard, H., and Soltau, A. B., *Ibid.*, **22**, 1897 (xix).
- ¹³ Lawrence, J. S., Hurxthal, L. M., and Bock, A. V., *J. Clin. Inv.*, **3**, 1927 (613-629).
- ¹⁴ Hürthle, K., *Pflüger's Arch.*, **173**, 1918 (158-171).
- ¹⁵ Krogh, A., *The Anatomy and Physiology of Capillaries*, New Haven, 1922.
- ¹⁶ Krogh, A., *Skand. Arch. Physiol.*, **27**, 1912 (126-140).
- ¹⁷ Hürthle, K., *Pflüger's Arch.*, **200**, 1923 (66-81).
- ¹⁸ Hürthle, K., in Zuntz and Loewy, *Lehrbuch d. Physiol.*, Leipzig, 1920.
- ¹⁹ Krogh, A., *Skand. Arch. Physiol.*, **27**, 1912 (227-248).
- ²⁰ Blumgart, H. L. and Weiss, S., *Proc. Soc. Exper. Biol. Med.*, **23**, 1926 (694-696).
- ²¹ Schleier, J., *Pflüger's Arch.*, **173**, 1918 (172-204).
- ²² Murray, C. D., *Proc. Nat. Acad. Sci.*, **12**, 1926 (207-214).

THE NATURE OF THE INSENSIBLE PERSPIRATION

BY FRANCIS G. BENEDICT AND CORNELIA GOLAY BENEDICT

NUTRITION LABORATORY OF THE CARNEGIE INSTITUTION OF WASHINGTON, BOSTON,
MASS.

Read before the Academy April 25, 1927

The fact that all humans are continually losing weight, even when quiet or asleep, has been known since the days of Sanctorius in 1614. The quantitative relation between the size of the body and the loss in weight per hour has been determined, and the loss has been found to be larger with the larger person. Furthermore, physical activity, even if moderate, increases the loss.

The measurement of the insensible perspiration can be obtained with an inexpensive decimal balance, sensitive to 10 grams, by weighing the person just before going to bed at night and again in the morning upon rising. If due precautions are taken with regard to the inventory of clothing and accessories and the avoidance of any intake of food or drink, and if account is taken of any loss in urine or feces, the insensible loss is readily computed. This will amount to not far from 100 or 200 grams in an overnight rest. On a more delicate balance, sensitive to 0.1 gram, the periods of measurement may be as short as 15 minutes. Indeed, 4 or 5 consecutive 15-minute periods will almost invariably indicate a regular loss.

In the Nutrition Laboratory we have measured the insensible loss of a number of normal subjects, and in coöperation with Dr. Howard F. Root, of Dr. E. P. Joslin's clinic, measurements have also been made on diabetics and on toxic goitre patients from Dr. F. H. Lahey's clinic. Simultaneous metabolism studies gave the data for the comparison of the loss per hour and the metabolism. The relationship was found to be close, a low metabolism usually accompanying a low insensible perspiration. If the values