FILTRATION AS A POSSIBLE MECHANISM IN THE LIVING ORGANISM

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Since the teaching of Ludwig, filtration has generally been regarded as a mechanism by which might be explained the passage of lymph through the capillary wall, and of dilute urine through the glomerulus. Now it appears to me that no difference of pressure on either side of a membrane, such as might produce filtration, can exist in the body, owing to the structure of the tissues and the physical conditions under which the circulation proceeds. The contents of the living cells are a colloidal solution, about 80 per cent. of which consists of water, and this solution must practically, like water, transmit pressure equally in all directions. The only exception to this will be in the case of structures in which the colloidal matter is in an anisotropic condition, a condition of structure produced by strain in definite directions. The connective tissues are of such a nature, and confine the cells of the body into different organs or parts, *e.g.*, the capsules of glands, and aponeuroses of muscles. In each organ or part we have the cells (muscle fibres, gland cells, 80 per cent. of which is water) surrounded by capillary networks and tissue lymph. An examination of an injected microscopic specimen of kidney, pancreas or muscle at once suggests that pressure transmitted through the wall of the capillaries is transmitted to the immediately surrounding structures equally in all directions.

Let us first consider the glomerulus of the kidney in which filtration is supposed to take place. The pressure in the glomerular capillaries, which is supposed to filter fluid through the capsule, must

be transmitted equally through the practically fluid cellular structures surrounding the glomerulus, and, as shown by Fig. 1, must compress equally the capsules, the exit-tubule A, and the neighbouring convoluted tubule B. It seems most improbable that the capsule should be held open by its own elasticity and act as a filter funnel, for are not the cells of which it is composed formed of a colloidal solution of which about 80 per cent. is probably water? Even if the capsule could act in the way supposed, it seems clear that the exit tube leaving the capsule is exposed to as great a pressure as exists within the capsule, for, firstly, the pressure transmitted through the wall of the glomerular capillaries must reach the exit tubules and, secondly, the

FIG. 1

arterioles which feed the glomeruli run among the convoluted tubules, and the pulsatile force transmitted through the wall of these arterioles cannot be less than that transmitted through the wall of the glomerular capillaries. Further, the loops of Henle and the collecting tubules are surrounded not only by capillaries, wherein we have no reason to suppose the pressure is less than in the glomerular capillaries, but also by the larger branches of the renal artery, through the walls of which the pulsatile force of the heart is transmitted, and this force cannot be less than the pulsatile force which is transmitted through the wall of the capillaries.

The conditions then are shown in Figure 2.

FIG. 2

The collecting tubes are exposed to no less a blood pressure than the capsules or secreting tubes.

Looking at the microscopic structure of the tubules in an unhardened section of kidney, it seems to me impossible that the tubules can stand open by their own elasticity. Their walls are formed of a watery colloidal solution, and practically must transmit the capillary pressure equally in all directions. I think, therefore, no filtration pressure can exist. I believe that the glomerular venule is smaller than the arteriole, not so as to increase the blood pressure in the glomerulus, but because the capsule secretes water, and a smaller volume of more concentrated blood passes away from than enters the

glomerular vessels. The difference between the diameters of the afferent and efferent vessels probably can be taken as a measure of the amount of concentration the blood undergoes.

Holding to the above view of the conditions in the kidney, I do not conceive as possible the distribution of pressure shown by Fig. 3, which is given in Starling's text book (after Morat).

FIG. 3

The curves, 1, 2, and 3, are supposed to show the pressure in the glomerular capillaries, (1) in the normal condition, (2) in the condition of vaso-constriction, (3) of dilatation of the venule B. It seems impossible that there should be the wide difference of pressure between A and C shown in curves 1 and 2, for if such a pressure existed C would be obliterated by the pressure transmitted through the walls of A; also, C would be obliterated by the pressure of the urine supposed to be filtered through the walls of A into the capsule. The obliteration of C would at once lead to the pressure in C approximating to that in A. There is, moreover, no evidence that the venule B is a contractile tube.

I hold the view that the whole kidney is expanded at each stroke of the heart by a force which equals the systolic pressure minus that

part of the pressure which is spent in expanding the walls of the renal vessels. In other words, the whole kidney substance is expanded at uniform pressure which is equal to the pressure in the renal vein. The blood flow is maintained by the fall of pressure gradient between arteries, capillaries, and veins, the pressure which is transmitted through the walls of the arteries and capillaries being less than that transmitted directly through them.

The kidney expands with blood, as a whole, during systole, and shrinks during diastole, and there is nothing in favour of the supposition that the pressure on one part of the renal tubule can be greater than on another. The pressure of the secretion cannot be normally greater than the pressure *in* the veins, for otherwise the secretory pressure would compress the veins. If the secretion be obstructed the pressure of both it and of the blood in the veins must rise together. The secretion moves onward, I take it, by phenomena of adsorption.

The fact that obliteration of the renal vein stops secretion altogether completely agrees with the views put forward by the writer.

I base my opinions on the experimental observations which I have made upon the brain. I found that it takes the same pressure to reduce the expansion of the brain into a trephine hole, as to reduce the amount of blood in the pial capillaries. This pressure is the same as the pressure in the venous sinuses, and the pressure of the cerebro-spinal fluid. The whole brain substance and the cerebro-spinal fluid are at the same pressure, that is the pressure which is transmitted through the walls of the blood vessels—the force of the heart minus that part of the force spent in overcoming the viscosity of the blood and of the vascular wall.

The pressure *within* the capillaries is, of course, higher than in the venous sinuses, and this pressure gradient maintains the flow, but the pressure transmitted through the wall of the capillary is equal to—not greater than—that in the veins. Thus the venous outflow cannot be impeded by the pressure transmitted through the wall of the capillaries. The pressure thus transmitted being equal to the cerebro-spinal fluid pressure, there exists, in my opinion, no force for producing filtration of this fluid.

Let us suppose that the above conclusion is wrong, and that the pressure in the capillaries of the choroidal fringes is greater than in other cerebral capillaries, and that cerebro-spinal fluid is filtered through by this excess of pressure, then this fluid being at a higher pressure would compress the veins and capillaries in the surrounding parts of the brain wherein the pressure is lower, and the flow being obstructed therein, the pressure in these parts would quickly rise to that of the cerebro-spinal fluid. In other words, the filtration would come to an end.

The only condition under which filtration seems possible is when the skull is freely opened so that the cerebro-spinal fluid can escape. In such case we have a capillary pressure (in the horizontal posture) about 110 mm. of water higher than that of the atmosphere. In the vertical head down posture it might be over 100 mm. of mercury.

In a limb enclosed by the skin the conditions are the same as in the brain or kidney. The bony nature of the cranial wall limits the expansion of the brain with blood beyond a certain part, and the connective tissue of the skin and aponeuroses, and of the renal capsule limits expansion in the same way.

In the limb, just as in the brain, the pressure of the blood on the living cells (muscle-fibres) and on the lymphatics is the same, and the conditions do not allow of a filtration pressure which can explain the flow of lymph. Only when the skin is wounded can a filtration pressure come into play.

The flow of lymph is maintained, not by a *vis a tergo*, but by the pulsatile expansion and shrinking of the organs, by the respiratory pump, by the expressive action of the muscles, and by gravity acting in changes of posture.

A simple illustration may make clear my point of view.

FIG. 4

In the simple type of animal represented in Fig. 4, let A represent a pulsatile heart, which by its contraction stirs up the fluid which fills the coelom. An excreting gland B, is obviously exposed to the same fluid pressure, both in its secreting and conducting part, and filtration can take no share in the process. In the mammal, similarly, the secreting part and the conducting part of a gland or lymphatic are alike surrounded by capillaries, and are equally exposed to the pressure of the blood transmitted through the walls of these vessels.

It is the chemical activity of the living cells, phenomena of adsorption, osmosis, etc., which produce the turgescence of the cells, the secretion of lymph, of urine, and of secretions, and alterations in the circulatory system do not act by mechanically modifying a filtration pressure, but by modifying the activities of the living cells.

Since writing the above, I have read a paper of W. Filehne and Biberfeld, just published in Pflüger's *Archives*. Filehne and Biberfeld express the same view as to the kidney as is set forth in this paper, a view which I have taught for a long time.* The following passage gives Filehne and Biberfeld's conclusions :—

‘Ja selbst wenn ein Filtrationsdruck Wirklich die Bowmanschen Kapseln mit Flüssigkeit füllen könnte, so würde bei der alsdann erfolgenden Fortpflanzung der Drucksteigerung über das Parenchym der ganzen Niere hin, eine Kompression der so sehr langen und so vielfachgewundenen Harn-kanälchen stadthaben. Das abgeschiedene Harnwasser würde sich also durch eben den Druck, der seine Filtrirung Veranlasst hat, selber den Ausweg Verlegen. Ein Abfließen, ein Fortschieben des Harn-wassers is eben nur möglich, wenn ein “Druck” die Flüssigkeit von hintenher treibt, der den allgemeinen Parenchyndruck nicht steigert. Dies könnten z. B. osmotischen Druckdifferenzen leisten nicht aber ein hydrostatischer Filtrationsdruck.’ — *Arch. f. d. ges. Physiol.*, January 4, 1906.

* See note in *Recent Advances of Physiology*, p. 618, the preface of which is dated November 26, 1905.