OBSERVATIONS ON THE STATE OF
THE BLOOD AND THE BLOOD-VESSELS
IN
INFLAMMATION.

BY

T. WHARTON JONES, F.R.S.,

FELLOW OF THE ROYAL MEDICAL AND CHIRURGICAL SOCIETY;
PROFESSOR OF OPHTHALMIC MEDICINE AND SURGERY IN THE UNIVERSITY
COLLEGE;
OPHTHALMIC SURGEON TO THE HOSPITAL, ETC.

Received May 9th.—Read June 14th, 1853.

It has not unfrequently been objected to the results obtained from microscopical observations on the web of the frog in the inflamed state, that we cannot safely argue from them as to the nature of the inflammatory process in man.

This, however, like many other general objections, is well or ill founded according to the sense in which the terms are employed. If in the objector's mind, the word "inflammation" conjures up the idea of a pleurisy or pneumonia, of a meningitis or encephalitis; nay, even of a conjunctivitis or iritis, with all the attendant symptoms, subjective as well as objective, functional disturbance and terminations, I admit that the objection is well founded. But if, on the contrary, all that we venture to deduce from our microscopical observations on the web of the frog in the inflamed state, be merely something concerning the general nature of the inflammatory process, something of the state of the blood and the blood-vessels in the inflamed part; something, in

short, in elucidation of the question as to the *proximate cause* of inflammation, so much agitated by the pathologists of the last century, then I apprehend that the objection is ill founded.

Still, there can be no doubt, that even as regards the simple elucidation of the state of the blood and the blood-vessels in an inflamed part of the human body, microscopical observations made on a transparent part of the warm-blooded mammal would be more satisfactory than similar observations on the cold-blooded reptile, especially when we take into consideration the marked peculiarity of character which the red blood-corpuscles of the mammifera present.

Accordingly, in pursuing my researches into the nature of the inflammatory process, I have not failed to direct attention to the microscopical study of the effects of wounds on the state of the blood and the blood-vessels in the web of the bat's wing, the bat being the only mammiferous animal which presents an external part of the body thin and transparent enough for microscopical examination.

Some results of this study, and also some results of an experimental inquiry into the influence of the nervous system on the state of the blood-vessels in inflammation, I beg leave to lay before the Royal Medical and Chirurgical Society, confident that any observations, however imperfect, relating to so important a subject in medical and surgical science, as inflammation, can never be without interest to them.

PART I.

The interdigital webs of the bat's wing are composed of duplicatures of skin with cellular substance, blood-vessels, nerves, and bands of elastic tissue interposed.

On either side of the elongated metacarpal bones and digital phalanges, there run an artery and corresponding vein, the trunks respectively of the arteries and veins of the webs.¹

¹ For a detailed account of the distribution and arrangement of the blood-vessels in the webs of the bat's wing, see a paper in the 'Philo-

The arteries and veins closely accompany each other, a nerve only intervening between them.

In regard to the connection between the ultimate arterial ramifications and the capillary network on the one hand, and between the capillary network and venous radicles on the other; in the frog, I have elsewhere¹ observed, that, although the capillaries all communicate together, a given part of the capillary network receives its blood more especially and directly from the branches of a particular artery, and pours its blood more especially and directly into particular venous radicles. This arrangement exists also in the bat's wing, though not so unconditionally; for in consequence of the more free anastomosis of the arteries with each other, and of the veins with each other, the part of the capillary network which receives blood from the branches of a particular artery, and transmits it to particular venous radicles, is more circumscribed.

The veins of the bat's wing, which are furnished with valves, are remarkable for their rythmical or heart-like contractions. The contractions of the arteries are tonic. At the same time that the arteries and veins thus differ in respect to their mode of contracting, their muscular coat, which is the seat of the contractility, differs in respect to the microscopical characters of its component fibres.²

As to the capillaries, I have not observed any change take place in the width of their bore attributable to contractility of their wall, which, as in the frog, appears to possess but a single coat.

The blood-corpuscles of the bat, both red and colourless, *Philosophical Transactions* for 1852, entitled:—"Discovery that the veins of the bat's wing (which are furnished with valves) are endowed with rythmical contractility, and that the onward flow of blood is accelerated by each contraction."—A copy of which I beg herewith to present to the Society.

¹ On the State of the Blood and Blood-vessels in Inflammation, ascertained by experiments, injections, and observations by the Microscope, in 'Guy's Hospital Reports,' second series, vol. vii, part 1, p. 6.

² See the paper above referred to, in the 'Philosophical Transactions' for 1852.

resemble those of the blood of man in shape and structure. The red corpuscles are about $\frac{1}{4200}$ th of an inch in diameter. They are seen under the microscope to agglomerate into rolls, like those of human blood, not only in blood out of the body, but also in blood within the vessels, under the conditions to be mentioned below. The colourless corpuscles occur in the forms of both granule and nucleated cells. Measured while stagnant within the vessels of the living animal, the colourless corpuscles were full $\frac{1}{3600}$ th of an inch in diameter. In blood out of the body, the granule cells when distended with water, measured about $\frac{1}{3000}$ th of an inch; the nucleated cells about $\frac{1}{3200}$ th of an inch, their nuclei being about $\frac{1}{4800}$ th of an inch.

In the perfectly undisturbed state, the flow of blood in the arteries of the bat's web is uniform and rapid; so rapid that individual corpuscles cannot be recognised. In consequence of the free anastomosis of the arteries with each other, we may see the blood, in a given artery, flowing sometimes in one direction, sometimes in another. Often, we see the blood flowing backwards for a considerable distance in one artery, and then, at last, turning into an anastomosing artery, proceed in a direct course.

The arteries being capable, by virtue of the tonic contractility of their walls, of varying in width, the rapidity of the flow of blood in them is subject to variation, independently of any variation in the force of the heart's action. When the constriction of an artery is excited by slight pressure over it, if the vessel has not closed in, the flow of blood, though retarded, may continue direct; but it is sometimes seen to become retrograde, and, after continuing so for a more or less considerable distance, then joins the direct stream in an anastomosing artery.

If the constriction be so great that the artery becomes nearly or wholly closed in, the flow of blood ceases altogether at the place; but into the artery below the constriction, a stream enters in a retrograde direction by one branch and escapes in a direct course by another. From the artery above the constriction, the stream passes off by the first con-

siderable branch. The disturbance of the flow of blood now described as a consequence of constriction of an artery to closure, is similar to that which we shall find occasioned by section of an artery. In both cases, also, the resulting impediment to the flow of blood in the capillaries is similar.

When an artery is much dilated, a condition which may be induced by the application to the surface of the web of some irritant, such as a solution of sulphate of copper with *vinum opii*, the stream of blood is seen to be more or less accelerated. This important fact was discovered independently by Mr. Paget in the bat,¹ and by myself in the frog.²

In consequence of the rythmical contractions of the veins, and the pressure of valves, the flow of blood in these vessels is remittent, an acceleration taking place at each contraction. When the force of the heart's action does not bear very energetically on the veins, in consequence of the circulation in the arteries and capillaries not being quite free, the flow of blood in the first-named vessels becomes intermittent, being now chiefly maintained by their own rythmical contractions.³

The capillary circulation is seen to be accelerated or retarded, according to the degree of freedom with which the blood flows in the arteries and veins. The capillaries themselves are mere passive tubes.

As to the manner in which the blood-corpuscles comport themselves within the vessels:

Within arteries and veins, the red corpuscles keep together in the axis of the stream, and do not manifest any tendency to adhere to the walls of the vessels like the colourless corpuscles. When there is an impediment to the

¹ Lectures on Inflammation, at the Royal College of Surgeons, in 1850.

² The Essay in 'Guy's Hospital Reports,' *ut supra*. This essay, it may be mentioned, left my hands before Christmas, 1849.

³ For a detailed account of the flow of blood in the veins of the bat's wing, see the paper in the 'Philosophical Transactions,' already referred to.

onward flow of blood, the red corpuscles agglömerate together in rolls similar to what we see in blood removed from the body; but when the blood is again permitted to flow freely, the rolls are broken up and the corpuscles are carried along confusedly mixed together. In the stream within the capillaries, the red corpuscles may often be seen arranged in a linear series, overlapping each other's edges; but on the occurrence of any impediment to the flow of blood, the red corpuscles become aggregated, so that we may sometimes see a single long roll occupying the axis of a capillary.

Colourless corpuscles may be seen adhering to, or rolling or sliding sluggishly along the walls of the vessels. I have observed this both in arteries and in veins. Towards the end of a protracted sitting, after the web had been much irritated, I have seen, in the venous radicles especially, colourless corpuscles accumulated in great numbers, as we so often see them in the frog. This, however, I have not found to occur so frequently in the bat.

PART II.

Having premised these observations on the distribution, structure, and endowments of the blood-vessels of the bat's web, and on the phenomena of the circulation of the blood in them, we are prepared to enter on the consideration of the effects of wounds of the web on the state of the blood and the blood-vessels implicated.

An artery, on being cut across, becomes constricted upwards in the direction of its trunk, and downwards in the direction of its ultimate ramifications; and so far as this constriction extends, the flow of blood in the vessel is arrested. In a minute or two, however, relaxation of the wall of the artery, and dilatation of its bore, are observed to take place, and then we find that in the upper part of the artery, the flow of blood becomes re-established as far down as the first considerable branch proceeding from it above the place of section: by this branch the stream passes off.

Below the wound, a retrograde stream of blood is kept up in the cut artery through the medium of an anastomosing vessel; but this retrograde stream passes off in a direct course by branches leading from the artery. The branches of the artery by which the blood enters in a retrograde direction, and those by which it passes out in a direct course, vary according to the mode in which the particular vessel happens to ramify at the place of section.

The retrograde stream flows more or less sluggishly, and the blood is loaded with red corpuscles.

I have not found veins become constricted after section like arteries.

In the upper segment of a divided vein, there is no further flow of blood up to the first considerable branch which joins the vessel above the wound. From the vein below the place of section, the blood which enters in a natural direction by one set of radicles flows out in a retrograde course by another set.

The re-establishment of the flow of blood in the upper segment of the artery, it has been said, extends only as far down as the first considerable branch immediately above the wound, although the artery may have become dilated down to that place. If there has been no bleeding from the cut vessel, the part of it between the wound and the branch above by which the stream passes off, is frequently seen to contain, at first, few or no corpuscles; but eventually, a greater or less number of corpuscles accumulate within the vessel, principally on one side, where they may be observed oscillating up and down.

In the artery below the section, the retrograde stream may not reach up as far as the wound, though up to that place the artery may have become dilated. An accumulation of blood-corpuscles, however, takes place similar to that just described in the vessel immediately above the wound.

These accumulations of blood within the cut ends of the artery form internal clots.

From the stream of blood which enters the upper segment of a divided vein, as above described, corpuscles enter the

part of the 'vessel next the wound, where they may be observed oscillating.

The lower part of the divided vein may not be at first filled with blood-corpuscles as far up as the wound, but in general, an accumulation eventually takes place, as in the artery below the wound.

The effect on the circulation in the part to which the divided vessels lead, is :

The blood in the last arterial ramifications, in the capillaries, and in the venous radicles flows tardily, and becomes loaded with red corpuscles which aggregate together. In some of the vessels, there takes place actual stagnation of the aggregated corpuscles.

This effect is explained by the circuitous route the blood has to follow through anastomosing branches to arrive at the last arterial ramifications, and to escape from the venous radicles. The blood moving slowly in consequence of diminished *vis a tergo*, the red corpuscles are allowed to aggregate, and being so aggregated, they move on less readily than the fluid plasma. The result is that more and more red corpuscles accumulate, until, in the vessels least under the influence of *vis a tergo*, the accumulation is so great that stagnation takes place.

In consequence of the free anastomosis of the vessels, the adjacent parts participate more or less in the obstruction of the circulation, more so perhaps than is the case in the frog, though, on the other hand, the obstruction in the part implicated, is, for the same reason, less in the bat than in the frog.

The effects of wounds of the web of the bat's wing on the state of the blood and the blood-vessels implicated, which I have now traced, are, in all essential respects, similar to those which I described in 1850, as occurring in the web of the frog's foot.¹

The effect of constriction of the small arteries in inducing congestion of blood-corpuscles in the capillaries and venous

¹ Guy's Hospital Reports, ut supra.

radicles, is the same also in the bat as in the frog. I may add, I have observed a similar effect in the mesentery of the mouse.

The application therefore to the human body, which I formerly ventured to make of my observations on the frog, finds support in every respect, from the observations on the bat now recorded.

PART III.

Though I think there can be no doubt that the inflammatory redness of, let us say, the human conjunctiva, excited by a wound, by cold, or by the irritation of a foreign particle in the eye, is owing to congestion of red corpuscles in the vessels, and that the blood, thus loaded with red corpuscles, flows sluggishly in some of the vessels, and is in others altogether stagnant; and though I think there can be no doubt that this state of matters is induced in the same manner as that in which I have described it to be brought about in the frog and bat, still, it may be a question whether a sluggish flow or stagnation of blood in the small vessels be really the condition on which the redness, reputed inflammatory, always depends in the human body, or whether there are not cases in which the redness essentially depends on a dilated state of the arteries, and a more copious and freer flow of blood in the part?

In reference to this question, I offer the following observations:

In my Essay in 'Guy's Hospital Reports,' already referred to, an effect of section of the ischiatic nerve in the frog is stated to be dilatation of the arteries and a fuller and more rapid circulation of the blood in the web. To give an example:—The ischiatic nerve of the left leg of a frog being divided, the arteries of the web were found, on examination, dilated, and the stream of blood in them fuller and more rapid. The blood in the capillaries and veins especially appeared to be unusually loaded with red corpuscles. The relaxed arteries yielding more readily to the blood injected into them at each stroke of the heart, their pulsations were

more evident. The general effect to the naked eye, was increased redness of the web. Four days after the arteries were found still dilated, and the circulation in the web very free; epidermis exfoliated.

On the right or uninjured side, the arteries and circulation in the web remained unaffected, and the epidermis did not exfoliate.

Besides exfoliation of the epidermis, cedema of the leg and foot not unusually takes place after division of the ischiatic nerve; a tendency to ulceration is also manifested. But, on the other hand, I have observed that the granulations of a wound of the web are more luxuriant.

Here, it is to be observed, that the relaxation of the muscular coat of the arteries, on which their dilatation depends, appears to be the effect of section of the sympathetic fibrils bound up in the ischiatic nerve, and not of section of the proper spinal fibrils of that nerve. Thus, I find that if we lay open the lower part of the vertebral canal of a frog, and remove the roots of the nerves supplying the posterior extremities, together with the corresponding portion of the spinal marrow, so that all sensation, motion, and reflex action in the posterior extremities are abolished; the arteries are nevertheless seen, on examination of the webs under the microscope, to retain their contractility, nay, they appear even more disposed to become constricted. If now the ischiatic nerve (which comprises not only the spinal fibrils,—sensitive and motor,—the roots of which were with the corresponding portion of the spinal marrow destroyed, but also the fibrils from the sympathetic as yet uninjured), be divided on one side as high up in the thigh as possible, the result is that the skin of the extremity subjected to the experiment becomes, even to the naked eye, redder from vascular injection than that of the opposite extremity, and on examination of the web under the microscope, the arteries are found considerably dilated. In the web of the opposite extremity, on the contrary, the arteries are seen still much constricted—some even to closure.

Though after section of the ischiatic nerve, the arteries,

in these experiments, were not wholly deprived of their contractility, their tendency to become constricted was very small in comparison with that manifested by the arteries of the opposite extremity in which the ischiatic nerve was not cut.

The increased redness and heat of the ear and side of the head which supervene in Bernard's experiment of cutting the sympathetic in the neck—of a cat for example—can only be explained, I think, by supposing a fuller flow of blood in the parts in consequence of the arteries having become dilated from impaired contractility of their walls.

From the preceding facts and considerations, we are led to the conclusion, that the state described as inflammation of the eye supervening on section of the fifth pair, and of the lungs and stomach supervening on section of the par vagum, may possibly be owing to dilatation of the arteries (from paralysis of their muscular coat induced by section of the sympathetic fibrils contained in the nerves above named), and consequent fuller flow of blood.¹

If this be so, we should have two different forms of disease reputed inflammation—the one primarily depending on a state of the blood-vessels and circulation of the affected part, and directly the converse of that on which the other depends.

However this may be, there is, I think, little doubt that the ordinary form of inflammation is that which depends, for its commencement, at least, on constriction of the small arteries, congestion of blood-corpuscles in the capillaries, and impeded circulation in the part.² In such a case, I have shown by experiment on the frog, that resolution is effected by the application to the web of a drop of *vinum opii*, or of any of the other agents which possess the property of causing dilatation of the arteries and acceleration of the

¹ In cases of disease implicating the fifth pair, for example, the sympathetic fibrils contained in it might not be destroyed, but merely irritated. In such case, constriction of the arteries of the eye, &c., it is to be inferred would be induced.

² See Guy's Hospital Reports, *ut supra*, p. 55.

flow of blood, an experiment which I adduced¹ as an interesting illustration of the *modus operandi* of stimulating collyria, applied to the eye for the cure of catarrhal ophthalmia.²

Considering that section of the ischiatic nerve has, for its effect, dilatation of the arteries and acceleration of the flow of blood, I subjected to this operation a frog in which I had previously excited inflammation of the web by the application of a solution of salt, in order to observe whether re-establishment of the circulation would be thereby promoted. The result was, that the circulation speedily became re established. In another frog in which the second web of one of the feet presented considerable congestion and stagnation of blood-corpuscles, independently of any application of solution of salt, and in which a drop of vinum opii failed to produce resolution, the ischiatic nerve was cut as high up in the thigh as possible, whereupon the stagnation began to be dispersed.³

¹ Guy's Hospital Reports, pp. 49-50, 60.

² See also a paper, on the Nature and Treatment of Pustular Ophthalmia, as an illustration of Inflammation and the Healing process in their simplest manifestations, in the 'Medical Times and Gazette' for January, 1852.

³ The activity of the flow of blood in the web after section of the ischiatic nerve, was not so great in the cases in which the roots of the spinal nerves with the corresponding portion of the spinal marrow were previously cut out, as in the cases here spoken of. The cause of this I have not yet investigated.