MEMOIRS.

CONTRIBUTIONS *to the* ANATOMY *of the* SYMPATHETIC GANGLIA *of the* BLADDER *in their* RELATION *to the* VASCULAR SYSTEM. By FRANCIS DARWIN. (With Plates V and VI.)

THE work which forms the basis of this paper was undertaken at the laboratory of the Brown Institution, at the suggestion and under the supervision of Dr. Klein; and it is a pleasure to me to express my great obligation to him for the kind manner in which he has in every way aided me.

In Cohnheim's latest work on Inflammation ('New Researches on Inflammation,' by Dr. Julius Cohnheim, Berlin, 1873) he describes the dilatation which may be produced in the vessels of the frog's tongue by the direct irritation of that organ. And in his discussion as to the manner in which the phenomena are produced, he states his opinion that there is no reflex mechanism effected by peripheral ganglion cells, "for, in the first place, such ganglia are not demonstrated as yet, and, in the second place, no case is known in which reflex action takes place independently of the central nervous system." It is with the first of these reasons only that we are at present concerned. It is undoubtedly true that no such ganglia have been as yet pointed out in the frog's tongue, but in other organs they have been demonstrated. Dr. Lionel Beale, in the 'Philosophical Transactions' for 1863, has described and figured cells of this nature; fig. 46, plate xl, represents "a portion of the coat of a branch of the iliac artery of the frog; upon the surface external to the muscular fibres are seen some ganglion cells in process of development with their fibres, which ramify upon the muscular coat." Dr. Beale also says, in the 'Monthly Microscopical Journal' for August, 1872, p. 57, "In the bladder of the frog I have been able to follow fine nerve-fibres from the ganglia both to arteries and capillary vessels." In another place Dr. Beale says that similar fibres may be traced in small mammals, from the ganglia situated between the mucous and muscular coats of the intestine to capillary vessels. Dr. Klein suggested that the relations of ganglia to blood-vessels might be conveniently studied in the rabbit's bladder, where he has already pointed out the existence of numerous sympathetic ganglia ('Handbook for the Physiological Laboratory,' p. 73). The ganglia are found in considerable numbers in the bladder of this animal, but are more especially numerous in that of the dog. In the rabbit's bladder they are found most abundantly on the thickened lateral edges of the organ, along which the main blood-vessels also take their course; in the dog they are more numerous on the posterior than on the anterior surface of the bladder.

The method employed was that recommended by Dr. Klein (loc. cit.), viz. "bits of the fresh bladder are coloured with chloride of gold, and then steeped in acidulated water until they swell out into a gelatinous translucent mass, then membranous fragments stripped off with the forceps, or snipped off with the scissors, are spread out and covered in glycerin." I found it best to keep the bladder intact until after it had been treated with the acidulated water; if it is cut in half, the two pieces turn inside out as they swell up, and it is then very much more difficult to snip off thin strips from the external surface. The fragments should be placed on the glass slide with their external surface downwards.

The ganglia are situated in the external coat of the bladder, and are of such a size that many of them, in the dog's bladder at least, can be seen with the naked eye. Fig. 1 represents the posterior surface of the bladder of a young puppy, as seen with a very low power. It shows the general arrangement of the ganglia and the manner in which they are connected with each other by nerve-trunks; it will be noticed that they form chain-like plexuses running with the principal blood-vessels of the bladder; a chain of minute ganglia may also be remarked running partly round the base of the bladder.

The ganglia are of various sizes: the largest one observed has a long diameter of 0·9 mm., and a transverse one of 0·72; one of the small ganglia is 0·09 mm. in length by 0·045 mm. in breadth. They present considerable variety in their shapes and have irregular outlines, which may be roughly circular, oval, or polygonal. The nerve-trunks with which they are connected are made up of non-medullated nerve-fibres, with a *few* medullated fibres appearing occasionally. The ganglia are either situated at the points of intersection of several nerve-trunks or they are found seated on single trunks. In the former case the groundwork of the ganglion is made up of fibres passing in different directions, which form the means of communication between the different nerve-trunks; around this fibrillar core the ganglion cells are arranged, and with it their processes are incorporated. Contiguous nerve-trunks often communicate with each other by fibres which do not pass through the ganglion, but which form a peripheral meshwork, as at the smaller end of ganglion I in fig. 3. When the ganglia are not thus situated at points of intersection and interchange, they are found to be connected, as before stated, with single nerve-trunks. The simplest form of ganglion is that figured by Dr. Klein in the Handbook, where the nerve-trunk is enlarged at one place by a group of ganglion cells lying among its fibres. In other cases the number of cells is greater, and the ganglion presents the appearance of a cluster of cells traversed by a nerve-trunk; there is a variety of this arrangement in which part of a nerve-trunk forms the axis of a ganglion, while the remainder of the fibres pass close underneath the ganglion without being connected with it. Lastly, a ganglion may be situated on a nerve-trunk at its point of departure from a larger one, and in that case usually receives recurrent fibres coming from the parent trunk beyond the point of division.

The ganglion *cells* are of irregular spherical and ovoid shapes, and are about 0·02 mm. in length; they are made up a finely granular substance, and contain a single vesicular nucleus (or two nuclei), which is usually eccentric, and always contains a large shining nucleolus. All the cells whose processes can be distinguished are unipolar; fig. 6 shows a number of such pear-shaped cells forming a small ganglion; also the nucleated capsule in which each cell is contained.

In many of my preparations these ganglia possess a special system of blood-vessels, small arteries, and capillaries. In one of them there is a small artery running along one border of a very large ganglion; it gives off branches, which accompany the principal nerve-trunks arising from the ganglion, and also two branches for the blood supply of the ganglion; one of these passes up on the right, the other on the left, of the ganglion; they curve round to the upper border of the ganglion, so that it is nearly surrounded in an arterial circle. Of the branches given off from this circle, some anastomose with capillaries running with the nerve-trunks of the ganglion, and others pass into the ganglion and supply it. In many cases the ganglia are surrounded by networks of capillaries; an example of this arrangement may be seen in fig. 3. It will be noticed that the nerve-trunks belonging to the ganglion are accompanied by capillaries (D), which run either singly, or in pairs, one on each side of the trunk. As they approach the ganglion they give off branches, which anastomose with similar branches of other capillaries, and thus form a network, from which branches pass into the ganglion. In other cases there is no such entwining plexus, and capillaries may be seen simply running up to the ganglion, and entering it in the intervals between the ganglion cells.

Having thus briefly described the ganglia and the nerve-trunks, I shall proceed at once to consider their relations to the blood-vessels. Fig. 1 shows, as already stated, that the course of the nerves corresponds in a general way with that of the principal blood-vessels. Fig. 2 is a portion of a nerve-plexus seen with Hartnack No. 4, and shows in a more minute way the character of this relation. A description of this preparation will serve, perhaps, better than remarks of a more general nature, to make the reader acquainted with the usual relations existing between arteries, veins, and nerve-trunks in the bladder of the dog.

The vessels represented are an artery (A) and a vein (A_2), with a large branch given off by each of them. A large nerve-trunk (B), on which are situated a number of ganglia (C), runs parallel with the artery, and at some distance from it; a somewhat similar trunk runs with the vein. We may call these two, for the sake of convenience in description, the "arterial" and the "venous" nerve-trunks. The venous nerve-trunk is not in reality connected more with the vein than with the artery, and might more fairly be called a second arterial nerve-trunk. Indeed, it does not occur at all in most of my preparations; what we usually find is an artery accompanied by its vein on one side, and by a ganglionated nerve-trunk running on its other side.

The figure shows in what sort of way these two large nerve-trunks, the arterial and the venous, are connected by smaller trunks. The already mentioned branches of the artery and vein are accompanied by a ganglionated nerve-trunk, coming from a large ganglion on the arterial nerve-trunk.

In addition to the two large nerve-trunks, it will be seen that the main artery is accompanied by smaller ones, which are connected with the ganglia of the plexus, especially with those on the arterial nerve-trunk; these trunks run close to the artery, and are connected with each other by transverse nerves, so as to enclose the artery in a kind of coarse mesh-work.

These smaller trunks are represented in fig. 2 as abruptly truncated in some places; in reality, it is at these points that the artery receives its nervous supply, the trunks being here seen to enter the adventitia, where they fade away, and gradually lose themselves. The veins are not accompanied by any such plexus of smaller nerves.

In some preparations, chiefly from the bladder of the rabbit, there is a somewhat simpler method of supply; here we cannot distinguish a large nerve-trunk, and an entwining plexus of small nerves, but the artery is accompanied by a ganglionated nerve-trunk, whence branches pass directly into its adventitia.

Figures 3 and 4 are drawn from a preparation of the rabbit's bladder, showing this kind of arrangement. The artery A in Fig. 3 is accompanied by a nerve-trunk, on which are situated the two ganglia I and II, which are in reality connected by the continuity of the trunks B_1 and B_1. A nerve-trunk (supposed to be interrupted at the line *ef*) comes off from ganglia I; it enters the adventitia of the artery, and disappears at *a*, where it almost meets a similar trunk coming from ganglion II. Ganglion I gives off another trunk, which supplies the artery in a different manner.

This is shown in fig. 4, B representing the nerve and A the artery. The diminution in size, which may be noticed in the nerve after it has crossed the artery, is due to the loss of several of its fibres, which enter the adventitia of the artery at *a*.

The fact that nerves are found arising from ganglia, and distinctly supplying arteries, is again illustrated in fig. 5. A ganglionated nerve-trunk, not shown in the figure, runs, roughly speaking, parallel with the artery (A); B_1 and A_1 the principal nerve-trunks of the artery, are connected with two ganglia situated close together on this trunk. Where B_1 reaches the artery it divides into two sets of fibres, one of which passes superficial to, the other in the depth beneath the vessel. The superficial division gives off a few fibres, which enter the adventitia (*a*), and then divides into two branches; one of these loses itself in the adventitia on the opposite border of the artery, the other ends by spreading out into an irregular fan of nucleated fibres on the superficial surface of the vessel. The nerve-trunk A_1 also divides into two branches, one of which terminates close to the last described branch of B_1, and in the same way, *i. e.* by spreading out on the artery, and the other comes to an end in the adventitia. The distribution of that part of B_1 which passes beneath the artery is unimportant; it is connected with a small nerve-trunk running with the main artery, and with another one accompanying a branch which the artery gives off.

Cohnheim appears to think that it is necessary for the supply of an artery that there should be ganglion cells situated in the coats of the vessel itself. From what has been said, it will be seen that this is not necessarily the case. The arteries are accompanied by ganglionated nerve-trunks, and the ganglia are sometimes situated on the adventitia, but in that case they do not appear to be more instrumental to the nervous supply of the artery than ganglia which are not so situated.

There is very little to be said concerning the smaller arteries. I have already mentioned that the branches of large arteries are accompanied by ganglionated nerve-trunks, which are connected with the nerve-plexus belonging to the main vessels. Arteries of smaller size are often entwined with delicate, nucleated, nerve-fibres, but I have not been able to trace these fibres to ganglia.

The veins appear to be very scantily supplied with nerves; I have only been able to make out, in one preparation, any connection between them and ganglionated nerve-trunks. In this preparation there are a small number of ganglia, and a few rather small nerve-trunks; these form a very irregular plexus, which appears to be connected with two large veins, but not with the artery which accompanies them. A ganglion is seated on one of the veins, and a trunk arising from it most probably supplies the vein, as it appears to lose itself in the adventitia.

With regard to capillaries my observations are more satisfactory; I have distinctly seen delicate nerve-fibres arising from the cells of a ganglion, and supplying the neighbouring capillaries, which in some cases form part of the vascular plexus which surrounds the ganglion.