

TRANSACTIONS
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MICROSCOPICAL SOCIETY OF LONDON.

VOLUME III.

I.—*Observations on the Nature of Capillaries, and on the mode of arrangement of those in the Gills of Fishes.* By JOHN QUEKETT, Esq., Assistant Conservator of the Museum, and Demonstrator of Histology at the Royal College of Surgeons of England.

(Read May 19th, 1847.)

FROM the time of De Graaf, Ruysch, Lieberkuhn and other celebrated anatomists, the art of injecting the minute blood-vessels of animals and of the human subject with mercury, and with coloured fluids by means of a syringe, has been much practised both in this country and abroad, and the science of Anatomy has been wonderfully advanced by its use.

The first anatomist who appears to have applied the syringe to the filling of the blood-vessels was Regnerus de Graaf, a Doctor of Medicine, who lived about the middle of the seventeenth century; an engraving and full description of the syringe used by him was published in the year 1667, in a small treatise, entitled ‘*Traetatus de usu Syphonis in Anatomia.*’ Some authors claim the credit of the invention for Swammerdam, who is said to have first employed it in 1667. The fluids used by De Graaf were by him termed tinctures, and were coloured with copper, or with the juices of the leaves of violets or roses, or a solution of gamboge and indigo. He does not state whether the vessels so filled were dried and preserved, the chief object he desired being to trace more readily the different ramifica-

tions of the vessels. Since the time of De Graaf, however, various other substances have been used, and amongst the chief of these may be mentioned, injections of wax, tallow, varnish and size, with some colouring agent diffused through them; these are injected whilst hot, and when allowed to cool become so firm, that, with the exception of those of size, the individual vessels may be dissected away from the various tissues and organs to which they are distributed, and when perfectly dried and well varnished such preparations will keep for many years. From the circumstance of wax, tallow, and varnish requiring a high temperature to keep them fluid, unless the temperature of the part injected be also very high, at least above the melting point of the materials used, the fluid injected will not run into the most minute vessels, hence none but those easily discernible by the naked eye will be filled; this has been found inconvenient, and other fluids, such as size and isinglass, which melt at a very low temperature, and get solid on cooling, have been substituted; these will fill other vessels so minute that the microscope is required to discover their wonderful ramifications; and of all the important discoveries made by means of the microscope, perhaps the nature of the capillaries, and the capillary circulation, are the most highly to be esteemed, for it is to this instrument that we owe the proof of the correctness of the doctrine taught by the immortal Harvey, that the blood really circulates in the arteries and veins; though Harvey himself never witnessed the circulation, he argued, from the structure and arrangement of the valves in the heart and in the veins, that the blood must flow from the heart through the arteries to the veins, and from the veins back to the heart again, yet he knew nothing of the connecting vessels or capillaries. We are indebted for all that is now known of them to the microscope, and to the art of injection. It was left for Malpighi to make the discovery of the capillary circulation, and he, we are told, first noticed it in 1661, by the microscopic examination of the distended urinary, or allantoid bladder of a frog. Since then, the discovery of Malpighi has been confirmed by numerous other observers. Anatomists have been led to divide injections into the coarse and the fine, the coarse being used when the mode of distribution of the large arteries and veins is required for examination, the fine when an intermediate system of vessels between or connecting the arteries and veins, termed capillaries, is to be investigated; the coarse injections are sufficient for the unassisted sight, the fine for microscopic investigation. Lieberkuhn appears to have been the first to apply the microscope to injections. Many of

the injections of this celebrated man are still extant, and a few microscopists in this country are fortunate possessors of some of his beautiful preparations.

The older anatomists, we are told,* with Haller at their head, adopted a notion that arteries terminated in one of five ways: 1st, by openings on the surface of membranes; 2nd, in lymphatics; 3rd, in secreting canals; 4th, in fat; 5th, in veins. In those times the secretion of mucus and fat could not be understood, without presupposing the existence of open extremities. This view of the subject was strongly opposed by Mascagni, Prochaska, Sæmmering, Hunter and others, but there still remained a doubt whether there were not some communication between the blood-vessels and the secreting canals of the glands. In more modern times, the structure of the secreting glands has been studied by Müller and other physiologists in process of development in the embryo, and the secreting canals of the glands have also been injected, and no such communications have been found to exist, the radicles of the secreting canals being always closed at their radicle extremity.

Anatomists now, with one consent, agree that in all organic textures, the transmission of the blood from the minute branches of the arteries to the minute veins, is generally effected by the capillary network, between the meshes of which the proper substance of the organ lies; this structure is commonly termed parenchyma, and speaking of it as a tissue, it is termed parenchymatous tissue; thus, for instance, in a specimen of injected lung or kidney, or in a villus from the intestine, the parts not occupied by blood-vessels constitute the true parenchymatous tissue of the organ. All microscopists are familiar with the circulation in the foot of the frog, and the tail of the newt; this is, for the most part, the capillary circulation. The ramifications of the minute arteries form repeated anastomoses with each other, and these anastomoses terminate at last in a continuous net-work, from which the small branches of the veins take their rise. The point at which the arteries terminate and the minute veins commence, cannot be exactly defined; the transition is gradual, but the intermediate net-work is so far peculiar, that the small vessels which compose it maintain nearly the same size throughout; they do not diminish in diameter in one direction, like arteries and veins, hence the term capillary, from *capillus*, a hair.

The size of the capillaries is proportioned in all animals to that

* Müller's Physiology, translated by Baly, vol. i. p. 227.

of the blood corpuscles ; thus amongst the *Reptilia*, where the blood-corpuscles are the largest, the capillaries are also the largest, but it does not follow that they should be always of the same size in all the tissues of one and the same animal, for if we examine and carefully measure in the human subject their sizes in different tissues, we shall find that they vary greatly even in individual tissues, and at a rough estimate, examples may occur as large as a thousandth, whilst others are as small as the four-thousandth or five-thousandth of an inch. They should be measured if possible in their natural state ; when injected, their size is slightly increased, but when dried they diminish so considerably, that in some specimens vessels imperfectly filled with injection have been known to shrink from the three-thousandth to the twenty-thousandth of an inch.

In foetal animals, having the blood corpuscles larger than those in the adult state, the capillaries also are larger.

Capillaries are, with very few exceptions, always supported by an areolar net-work, which serves not only as an investment to them, but connects them intimately with the tissues they are destined to supply.

Having said thus much of the nature of the capillaries, we will now proceed to consider those points which are the more immediate objects of this paper ; *viz.*, the distribution of the capillary system in the respiratory organs of Fishes.

In the majority of osseous fishes there are four gills on each side, supported by long curved branchial arches. Each gill consists either of a single or a double series of lancet-shaped laminae attached to the branchial arch, something like the teeth to the back of a comb. When there is only one series of laminae, the gill is termed *uniserial*, but when two, *biserial*. The branchial arches in osseous fishes are more or less bony, and from the lower convex surface are given off in uniserial gills one, in biserial two, elastic, more or less round filaments, which form the outer support or framework of the laminae ; and if the mucous membrane and all the soft parts be removed, it will be found that in many fishes a series of more minute filaments are given off at right-angles from the inner side of the larger one, each of these smaller filaments serving not only to support the laminae, but each one performing the same office to the outer margin of the folds of mucous membrane on the laminae, as the larger filament does to the lamina itself ; this skeleton of the lamina resembles in every respect a small comb. Upon this framework we have a fibrous or areolar tissue, which not only invests the little teeth, but

fills up all the interspaces between them, and over this are situated the plicæ or transverse folds of the respiratory mucous membrane, which, in some of the large fishes are upwards of a thousand in number, the outer margin of each fold, as before stated, being supported by a process of the outer filament of the lamina. In Plate I. fig. 1, is shown one of the laminae from the eel, and in fig. 1 *a*, are seen both the outer filament, and the plicæ of the mucous membrane, each supported by a process from the large filament. The filaments have by some authors been described as bony, but even in the salmon and eel they contain no ossific matter, being composed of a cellular structure, somewhat of the nature of cartilage or newly-developed horn; the outer margin is made up of small circular cells arranged in rows at right angles to the length of the filaments, whilst on the inner surface the cells are of an elongated oval figure, and arranged in lines parallel to the length of the filament.

The arteries termed branchial, which bring the impure blood to the gills, run along the convex border of the branchial arch, and opposite each pair of laminae, divide into two or more branches, which run along the outer thick margin of the lamina to its extremity, and in their course give off two transverse branches, one for every fold of mucous membrane of the two flat or opposed surfaces of the laminae; in these folds the artery breaks up into a net-work of most wonderfully minute capillaries; the branchial vein begins in these capillaries, and the entire series unite into transverse branches, from which large venous trunks are formed: these run along the inner or attached edges of the laminae, as shown in Plate I. figs. 3 and 3 *a*, there being branchial arteries on one margin and branchial veins on the other, and between the two the net-work of capillaries shown in figs. 1 *a*, 2 *a*, &c.

The osseous fishes in which the gills have been more particularly examined, are the salmon, wolf-fish (*Anarrhicus*) and eel, of the latter the river eel requires special mention. Three of the lancet-shaped lamellæ of this fish are represented in different positions in Plate I. figs 1, 2, 3, as seen under a magnifying power of twenty diameters; portions of the same magnified a hundred diameters, are represented at figs. 1 *a*, 2 *a*, 3 *a*; the first three figures serve to show the lateral lamellæ and plications of the mucous membrane, whilst the last three exhibit very plainly the beautiful net-work of the pulmonary capillaries, distributed upon it; these are of nearly uniform size ($\frac{1}{40000}$) in diameter, and the interspaces of the net-work much smaller than the diameter of the capillaries themselves, but still so cha-

racteristic of a respiratory mucous membrane, that a practised eye would immediately discern their true office.

In the cartilaginous fishes, the arrangement of the gills presents many varieties; those only to be described here occur in the rays and lampreys; in the former, the branchial arches are composed of soft cartilage, and do not hang loose in the branchial chamber as in most osseous fishes, but are attached by both extremities, so that the chamber is divided into five compartments distinct from each other, each having an orifice on the external surface of the body. The branchial lamellæ are given off from the arches in the form of folds, parallel to each other and continuous with the mucous membrane; in the first four cavities there are two gills, one on the anterior and the other on the posterior surface of the arch, but in the last cavity there is only one gill, and that on the anterior part of the arch.

In the lampreys there are no branchial arches, but seven branchial cavities or pouches, perfectly distinct from each other, each of which has two openings, one communicating with the pharynx, and the other situated on the external surface of the body; the interior of each chamber is lined with the branchial mucous membrane, which is plicated transversely, in the same way as it is on the laminae of the osseous fishes, and each fold has its characteristic net-work of capillaries. In the river lamprey (*Petromyzon fluviatilis*), the capillaries are quite as small, if not smaller, than in an eel of the same size, but it is in *P. marinus*, and more especially in the rays, that the most largely developed net-work is found; in these latter, the blood corpuscles are also of larger size than in other fishes. Portions of one of the laminae from *P. marinus* are represented as seen under a power of twenty diameters, at fig. 4, and under that of fifty at fig. 4 *a*, and similar specimens from the ray, in figs. 5 and 5 *a*; these, although only magnified to one-half of the extent of those of the eel, exhibit the capillaries, nevertheless, much more plainly.

Of all the fish in which I have been able to inject the capillary plexus satisfactorily, the eel exhibits the smallest vessels; in an eel about twelve inches in length, the laminae were on an average not much more than one-quarter of an inch long, and on each lamina I was able to count upwards of eighty plicæ, each having a plexus of capillaries so minute, that a good defining power of fifty diameters was required to make them out, and one of a hundred diameters to show them satisfactorily, the diameter of a single capillary being the four-thousandth of an inch, so that it becomes a question whether vessels so small as these were ever seen by the early microscopists.

In the rays and lampreys, the capillaries being so very much larger, $\frac{1}{3200}$ in diameter on an average, can of course be more readily distinguished, but even these require a good microscope for their due exhibition; which may account in a great measure for the silence, on this point of anatomy, of all the authors whom I have consulted on the subject of the circulation in the respiratory organs of fishes. To fill up a certain portion of this hiatus, and to show how wonderfully minute are these capillaries, and yet in their arrangement so characteristic of the vessels performing a similar office in the higher orders of animals, this paper has been brought before the Society on the present occasion.

EXPLANATION OF PLATE I.

- Fig. 1. A branchial lamina of a common eel, showing the concave edge along which the branchial vein runs, and the small transverse plicæ or folds of the mucous membrane.
- Fig. 1 a. A portion of the same more highly magnified, to show the capillary plexus upon the fold of the mucous membrane.
- Fig. 2. One of the laminæ of the common eel, showing the folds of mucous membrane given off from both sides of the lamina.
- Fig. 2 a. A portion of the same magnified one hundred diameters.
- Fig. 3. One of the laminæ of a common eel, showing the convex border on which the branchial artery, and the concave one on which the branchial vein runs, and the folds of mucous membrane between them.
- Fig. 3 a. A portion of the same magnified one hundred diameters.
- Fig. 4. A portion of one of the laminæ of a lamprey (*Petromyzon marinus*), showing the broad transverse folds of the mucous membrane.
- Fig. 4 a. A portion of the same magnified fifty diameters, to show the capillary plexus on the folds.
- Fig. 5. A portion of one of the laminæ of a ray (*Raia batis*), showing the folds of the mucous membrane.
- Fig. 5 a. A portion of the same magnified fifty diameters; it shows the large size of the capillaries composing the plexus.

Fig. 1.

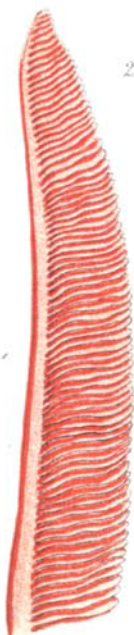


Fig. 2.

20 dia^s



Fig. 3.

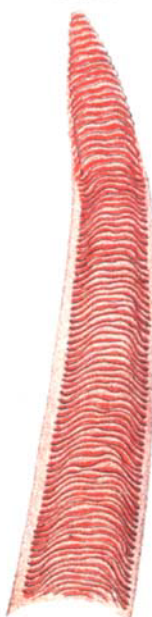


Fig. 1 a. 100 dia^s

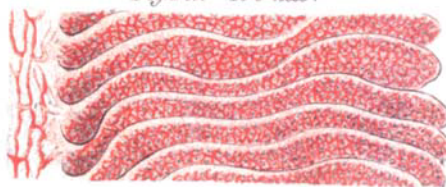


Fig. 2 a. 100 dia^s



Fig. 3 a. 100 dia^s

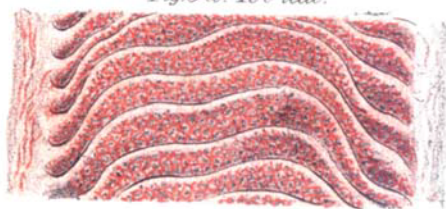


Fig. 4. 20 dia^s

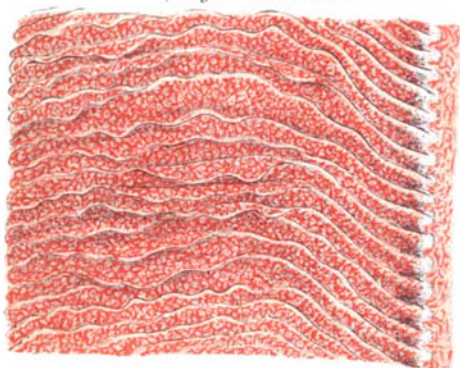


Fig. 5. 50 dia^s

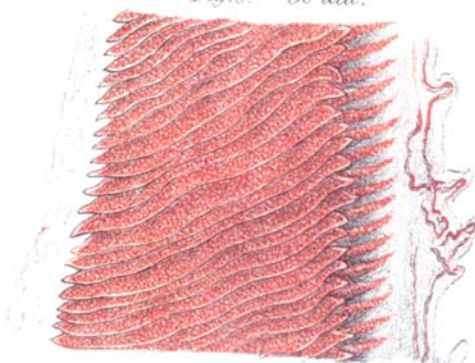


Fig. 4 a. 50 dia^s

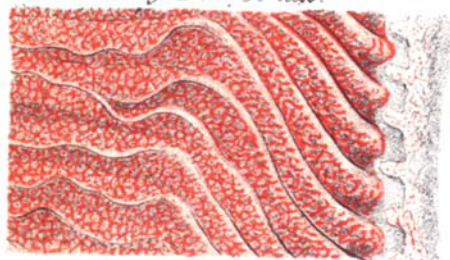
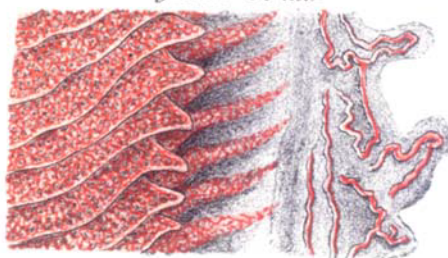


Fig. 5 a. 50 dia^s



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