On the comparative anatomy of the lymphatics of the mammalian urinary bladder / by George Hoggan and Frances Elizabeth Hoggan.

ON THE COMPARATIVE ANATOMY OF THE LYMPHATICS OF THE MAMMALIAN URINARY BLADDER.

By George Hoggan, M.B. (Edin.), and Frances Elizabeth Hoggan, M.D. (Zurich), M.K.Q.C.P. (Ireland.) (Plate XXI.)

In the bodies of the higher animals, the urinary bladder presents the unique example of an organ of the nature of a reservoir, whose special function seems to be that of retaining, for a considerable time within the body, a substance of a purely excretory nature, noxious and poisonous in its action, whether that be regarded in its local effects following extravasation into the tissues, and causing gangrene or death of these tissues, or in its general effects by non-elimination from or re-absorption into the system, leading to coma and death of the individual.

That such an organ should stand in a special relation to the whole function of absorption, whether that be performed by the bloodvessels or the lymphatics, must be evident to every one, and we might expect that in it, absorption would be either non-existent, or at least at its minimum force. Naturally enough, the very name of absorbents, so unfortunately applied to the lymphatics, would equally lead one to infer that that system of vessels was either unrepresented there, or found only to an extremely limited extent. These two inferences regarding structure and function do indeed represent, as far as we can discover, almost all the opinions which have been held, in the absence of exact facts connected with the bladder, ever since the discovery of the lymphatics, or the miscalled absorbent vessels.

Even at the present day it may justly be affirmed that nothing definite is known of the lymphatics of the bladder. If we consult our English anatomical text-books, we find the whole question dismissed in a few words. The editors of Quain's *Anatomy*, 8th edition, tell us, page 512: "The *lymphatics of the bladder*, taking rise from the entire surface of that organ, enter the glands placed near the internal iliac artery." Brief and vague though may be the information thus given, it

is entirely erroneous, more so perhaps than the opinion recorded by Cruveilhier in 1852, at page 586 of his *Anatomie Descriptive*, where it is stated that "the lymphatics come from two sources: (1) from the mucous membrane, whose lymphatic plexus may be injected with the greatest facility (*sic*); (2) from the peritoneum." According to Sappey in his *Anatomie Descriptive*, vol. ii. 1876, page 856.

"The lymphatics of the bladder were first referred to by Zeller, first described by Cruickshanks, and represented by Mascagni; according to the latter two authors, they were even very numerous."

But, as Sappey very justly remarks,

"They were much more fortunate than all subsequent observers, for, since the publication of Mascagni's great work, no author has ever succeeded in finding these lymphatics. Surprised at this negative result, I have explored in my turn the two surfaces of the bladder, particularly the internal surface, at every point, and always without success. It would therefore appear to be destitute of this system of vessels; no facts at least demonstrate their existence."

He also states positively that

"The lymphatic vessels of the mucous membranes of the bladder and uterus have never been injected;"

and this statement, in opposition to that of Cruveilhier, is rendered very probable by the condition of the lymphatics in that locality. Further on he says:

"We may, however, observe on the external surface of the bladder, two or three absorbents on each side. These are the trunks which were seen by Cruickshanks and by Mascagni, but they do not come from the wall of the bladder, but from the prostate, and I believe that I have been the first to inject them."

It is interesting to note that this opinion of Sappey's, although we cannot confirm it, agrees perfectly with the results obtained from the very latest physiological experiments undertaken for the purpose of testing the comparative absorbent power of the different parts of the urinary tract.

As Professor Sappey is one of the most accomplished living anatomists, and has obtained great repute for his personal investigations into the lymphatic system, and written its most recent history, it may be well to conclude our review of the results obtained hitherto, by quoting from his recent work,

Les Vaisseaux Lymphatiques, published in 1874. At page 9, speaking of the lymphatics of smooth mucous surfaces, he says:

"Amongst the mucous membranes belonging to this group, there are several which are absolutely and constantly destitute of lymphatic vessels; such as the mucous membranes of the bladder, and ureters of man, and the mammalia in general. In vain have I explored the mucous membrane of the whole urinary tract in men and women, in infants, adults and old people, varying in a thousand ways the reagents proper for this investigation; the result of all my observations has been completely negative, and as there does not exist in the annals of science any fact attesting that other observers have been more fortunate than I have been, we must admit that nothing demonstrates the presence of these vessels in the mucous membrane of the urinary tract, and that very probably they do not exist."

The opinions we have quoted may possibly be held to warrant us in publishing our own investigations, which have been more fortunate in their results than those of our eminent predecessors, and put the existence of the lymphatics of the bladder beyond all doubt. If, however, we have been more fortunate than our more eminent fellow-workers, our success is not to be ascribed to greater skill, patience, or perseverance, but principally to the fact that we have hit upon better methods of investigation, supplemented by appliances introduced by ourselves, and under conditions that experience has enabled us to recognise. When we consider the character of the technical methods employed in the past for investigating the lymphatic system before the introduction of the use of solutions of silver, we can scarcely feel surprised at the small measure of success which has rewarded the labours of others in investigating the lymphatics of the bladder; for in that organ they are so very few in comparison with some other tissues, and so irregular, and even abnormal as compared with the distribution in other organs, that only by a rare accident could they ever have been demonstrated. As far as the present study of the comparative anatomy of these lymphatics in different animals is concerned, and the almost absolute necessity of examining them in their simplest form as found in the bladders of the smallest mammals, it would have been a physical impossibility to have done so by any of the methods of injection hitherto in use, as for example, in the bladder of a mouse, whose wall when distended

appears to be of the thickness of tissue paper, the whole organ when contracted forming a little pellet no larger than a mustard seed. Indeed, the present paper might very appropriately have been made the place for a review of the comparative merits of the various technical methods hitherto employed for the investigation of the lymphatic system, as there can be no doubt that the supposed absence of lymphatics in certain tissues and organs is an opinion due to the unsuitable character of such tissues and organs for the various methods of injection of the lymphatics within them, and of these the organ in question might be shown to be the most typical example. On the other hand, we must credit the injection methods with far greater errors in the opposite direction, through demonstrating vast lymphatic arrangements where they probably do not exist, as shown in certain well-known researches into the lymphatics of the liver, spleen, kidney, and similar organs. Such a review would, however, unduly lengthen the present paper; we shall therefore reserve it for another research to be published shortly, and at once proceed to the method with its special modifications and precautions, by means of which we have been enabled to demonstrate the course and relations of the lymphatics of the bladder, and which must be closely adhered to by others wishing to verify our results. Even supposing the lymphatics of the bladder to have been completely demonstrated by the injection method, it would still be a great gain to have demonstrated them by the silver method also, owing to the gross errors due to injection methods now existing in the anatomy of the lymphatic system, and leading to equally unfortunate conceptions as to its physiology and pathology.

In addition to the mere technical knowledge of the employment of silver solutions, the present investigation requires special manipulation and precautions to be taken according to the size of the animal. Under all circumstances, the animals selected should be as lean as possible, as fat, even if completely confined to the fat cells, gets shed in the necessary manipulations, and the tissues, thus rendered greasy and in a manner waterproof, do not allow of satisfactory imbibition and consequent differentiation by the silver solutions. The next condition to be obtained is one of primary necessity in the case of every

animal, both great and small; the wall of the bladder must be distended to its utmost capacity, for no method hitherto proposed is capable of demonstrating the lymphatics in question if the wall of the bladder be either flaccid or contracted. This distension has to be attained in various ways according to the size of the animal, and the surface of the bladder to be treated. In the case of the horse, as an example of a large bladder, we need not attempt to demonstrate upon it the great efferent lymphatics on its outer or peritoneal surface, as these are too large and extended for microscopical examination. Moreover, the bladder wall is too thick to be rendered transparent when the internal surface is to be treated with silver and examined by transmitted light, and the following steps are therefore necessary.

As soon as the animal is dead, the bladder is extracted with a portion of the urethra and ureters attached. The latter having been ligatured, a cannula with stopcock is inserted and tied into the former, and the bladder, having been emptied of urine, is well washed out with distilled water. Air is then pumped in with the ordinary injection syringe until the bladder is distended to its utmost capacity. It will now be found easy to dissect the whole of the musculature off the mucous portion of the bladder, and this portion is thin enough to be rendered transparent, and does not contract injuriously when the bladder is opened into and the distending air allowed to escape. Different parts of this inner portion of the bladder wall may now be excised and mounted on the histological rings invented by us,[1] the epithelial side lying upon the outer surface of the tambourine thus formed, whence the epithelium may be more or less completely removed by scraping it off with a scalpel. A 1 or 2 per cent. solution of nitrate of silver in distilled water is then quickly poured on and off one or both surfaces, and after exposure to a dull light for a few minutes, the whole is washed well with distilled water, and a 1 per cent. solution of chloride of gold in distilled water is applied for a minute to either or both of the surfaces which have been silvered. It is then well washed and carefully exposed, turning, if possible, the untouched surface to the light (when either surface exists

[1] See *Jour. de l'Anat.* for Jan. 1879, or *Journal of the Royal Miscroscopical Society* for June 1879, page 357.

as such), so that the metallic salt may be first reduced at its deepest zone of penetration into the tissues. In this condition it may be examined from time to time under the microscope, and if it prove to be a successful preparation, it may be clarified in the usual way with glycerine or oil of cloves, and the disc *afterwards* excised and mounted as a permanent preparation.

Under almost all circumstances it is inadvisable to inject the bloodvessels previously with transparent coloured injection. Apart from the fact that such coloured injection generally gets bleached by the action of the silver solution where it touches it, and that the injection tends to render the tissue less transparent, the injection is unnecessary; for the silver shows the bloodvessels distinctly wherever these exist in the neighbourhood of any lymphatics made apparent, the character of all the vessels being made evident by the cell-markings of their walls, and the relationship with the rest of the tissues being satisfactorily demonstrated.

As for the size of the histological rings employed, it will be found that those of an inch inside diameter[1] are most convenient, but those of two or even three inches diameter may sometimes be found advisable where it is desired to investigate the relation of lymphatics upon a large portion of surface, such for example, as the trigone, and it is always advisable to have a sufficient number of pairs of rings at hand to be able to utilise the whole of the bladder wall, as only a small percentage of preparations may prove successful. It is also to be borne in mind that when a portion of tissue has once been mounted on the rings, it must not again be removed from them until it is either to be definitely rejected as worthless, or has been finally clarified for permanent preservation as a preparation.

The same steps that we have enumerated in the case of the horse are applicable to the bladders of sheep, goats and swine, only in these cases great care must be taken not to distend the bladder unduly, as the lining epithelium becomes readily fissured, and the surface partially destroyed for examination. Where it is inadvisable or difficult to dissect off the musculature, the bladders after distension may be hung up for a few hours, so as to render the muscular wall less ready to contract when opened

[1] Rings of this size are supplied by Messrs Burge & Warren, 42 Kirby Street, Hatton Garden, London, E.C., at ten shillings per dozen pairs, prepaid.

into. The sensitiveness of the living tissues to the silver reagent does not seem to be appreciably affected by that lapse of time, according to our experience.

It will, of course, be understood that the preparations obtained by the foregoing method in large animals merely give the minute anatomy and relationships of small portions of the lymphatic supply, like the portions shown in figs. 2 and 3, from the sheep, as only such can be placed under the microscope. To get a view of the general plan of the lymphatic system as it is applied to the bladder as a whole, one must have recourse to the bladders of the very smallest mammals, where, as in fig. 1, the greater part of the lymphatic system may be seen almost within the same field of the microscope. Indeed, as the portion of bladder wall from which fig. 2 was drawn, was only $\frac{1}{3}$ of an inch square, and the lowest power of the microscope under which the lymphatics could be recognised and differentiated from the other vessels, gave a camera lucida drawing 8 inches square, from which fig. 2 was afterwards reduced by photography, the impossible size of a drawing of the lymphatics of the whole vesical wall in which these vessels were large enough to be recognised, may easily be imagined. It is for this reason that the comparative anatomy of the lymphatics of the organ in different sized animals becomes of special utility.

The foregoing method, applicable to the bladders of large animals, it is impossible to use in the case of the smallest mammals, for which, therefore, special manipulations are necessary. If not altogether impossible, one could rarely succeed in distending with air the delicate bladder of a mouse, which when distended is only of the size of a large pea, with walls of exceeding tenuity. Even if this could be done, and the muscular tissue would not subsequently contract, there would scarcely be sufficient extent of tissue to be distended, even upon a very small ring; and, moreover, owing to the amount of tissue wasted by this process, only a portion of the surface of the organ could thus be prepared at one time.

Under normal conditions, the bladder of a mouse is generally found more or less contracted or empty of urine; and if violence were used or fear occasioned in destroying the animal, the little urine contained within the bladder would certainly be shed, and

the organ contracted. Special precautions are, therefore, necessary, first, to obtain a bladder fully and naturally distended by urine, and secondly, to prevent the urine from being shed. If rats and mice in confinement are liberally supplied with water, they keep on drinking it and playing with it. Their bladders are then continually found distended with urine, and such examples, if carefully treated, serve well for demonstrating the lymphatics near the outer surface. The plan we follow is to kill the animal almost unconsciously with chloroform, then to throw a ligature round the neck of the bladder, so as to enable us to take the organ out of the body. The outer surface having been treated by the silver and gold solutions in the manner already described, and sodden in glycerine, which soon destroys all contractile power in the muscular wall, the small organ is placed on a glass slide and snipped in the necessary directions to convert the spherical wall into a plane surface, and it may afterwards be sealed up as a permanent preparation. In this way fig. 1 was prepared from the outer surface of the bladder of a mouse, distended with urine, and it shows perfectly the general plan of the main efferent lymphatic channels of the mammalian bladder.

Although, however, the extreme thinness of the musculature of the bladder in these little animals enables us to recognise the branches or affluents ramifying amongst the muscle fibres, it gives us none of that certain evidence of their relation to the mucous surface which only preparation of the tissue from that surface could afford, and we have not yet been able to devise a method by which a sufficient amount of tissue of the bladder of the mouse could be prepared to demonstrate the lymphatics upon the mucous surface. We have, however, succeeded in rats, and preparations thus obtained show that in these little creatures the lymphatics are arranged on the same principle as in the bladders of the larger mammals.

Finally, in treating of the bladders of animals of the size of the rabbit or Guinea pig, we have introduced modifications which may even be necessary in the case of contracted portions of the same organ from the larger animals. When in these animals we wish to demonstrate the lymphatics on the outer or peritoneal surface of the organ, it is advisable to distend them with air as previously recommended, and to treat that surface as recom-

mended in the case of the mouse. When, however, the inner surface has to be treated it is useless distending the organ, which may be at once divided into any two halves. We then take a slab of cork, such as is used for cork soles, into which a number of circular holes of different sizes have been cut, capable of letting the different sized rings pass tightly through them. Choosing a circular hole of apparently appropriate size for the tissue to be prepared, the portion of bladder is stretched evenly across it and fastened by small pins in the cork at the edge of the hole, the epithelial surface being left uppermost. It is now easy to apply the lower ring of the pair through the hole and jam the upper ring upon it, with the tissue stretched as a membrane between the two, which may then be prepared according to previous instructions.

When we study and compare the lymphatics of the bladder of the smaller with those of the larger mammals, we find that, notwithstanding the difference in size, there is a wonderful identity between them, both as regards their size, distribution, and relationships, an identity that is by no means common in other organs, and which is due probably to the similarity in shape which prevails in this organ in the different classes of the mammalia; whereas the great modification in the shape of such organs as the uterus, pancreas, intestinal canal, &c., causes considerable difference in the arrangement of their lymphatic system. The general plan of the lymphatics of the bladder taken as a whole throughout the mammalia, presents considerable divergence from the general plan of the distribution in other organs, a divergence which is due probably to difference both of structure and function; and in order to appreciate it thoroughly we must carefully keep in mind the structure of the bladder itself, and the manner in which that differs from organs formed of similar tissue.

Although, like the intestinal canal, the bladder is described as possessing or being formed of four coats, the mucous, submucous or areolar, the muscular and serous coats, coming in similar order in both, yet the plan of the lymphatics in both is essentially dissimilar. In the first place, probably in consequence of a difference of function, the great layer of submucous collecting lymphatics of the intestinal canal may be said (with one excep-

tion, to be afterwards noted) to be almost unrepresented in the bladder. Again, in the intestinal canal the lymphatics (or lacteals) may very distinctly be divided into two categories,—1st, the collecting or submucous, and 2d, the efferent, including under that head the so-called intermuscular and subserous lymphatics. In the bladder no such clear distinction exists, for the collecting and efferent lymphatics seem blended together at what may be considered their ultimate source, as if the function of collecting had, with certain exceptions near the orifice, by means of some slight modifications, been grafted upon the terminal valved lymphatics, as shown in figs. 2, 3, 4 and 7. In the greater part of the bladder, moreover, there is no abrupt termination of a lymphatic corresponding to the lymphatics of the villi, and the ultimate lymphatic vessels remain in the condition of endless loops or chains, for the most part accompanying the bloodvessels, an abnormal condition for ultimate or collecting lymphatics.

Again, in the intestinal canal we have the two distinct layers in the muscular coat, in each of which respectively the fibres lie in one definite direction, but at right angles the one to the other, and acting in correspondingly different directions at different times. These separate the submucous and subserous lymphatics into two very distinct layers (without taking into account a third, the intermuscular, which Auerbach has almost unnecessarily described as a special layer, for it is merely a portion of the plexus of efferent lymphatics), but no such arrangement exists in the bladder, no portion of whose lymphatics can well be described as a special layer. These comparative differences in the plan of the lymphatics in two organs formed of the same elements and arranged in the same order, are evidently due to modifications in the arrangements of each of these layers, and it is in the specific structure of each of them as they exist in the bladder, that we may expect to find the reason why they differ not only from the arrangements in the intestinal canal, but from the general plan of the lymphatics throughout the body.

In order to understand the plan of these lymphatics, we must form our conceptions of the structure of the organ especially in relation to that plan, and consequently differing from those generally taught. We may put aside entirely the layers of cells

which form respectively its serous or peritoneal and its mucous or vesical coats or layers as having practically little connection with its lymphatic system, and concentrate our attention upon the muscular coat, with its matrix of gelatinous or so called white fibrous tissue, which also forms a lining or layer on either of its surfaces, and contains, besides the muscular elements, the whole of the bloodvessels, lymphatics and nerves of the organ. For our present purpose, moreover, the musculature of the bladder cannot be conceived or described as formed into distinct layers, dissections notwithstanding. The bundles of smooth muscle fibres or cells, which form it lie upon and across each other at every variety of angle, and pass continually from one surface to the other, like the lymphatics amongst them, the only group of fibres worthy of special notice being the broad thin layer or band of parellel fibres lying upon the peritoneal surface of the musculature in the antero-posterior line of the body, extending for a certain distance on either side of the mesial line, and shown at *lm.*, fig. 1. It is evident that there is a special relationship between that band of fibres and the main chain of efferent lymphatics on either side of the mesial line before they leave the organ, the course of the lymphatics being parallel to the direction of the fibres, whose general formation has probably led to the band being adopted near its outer borders as the track most suitable for the main lymphatic vessels.

In our use and conception of the term gelatinous tissue or matrix, we wish it to be understood that, as far as the natural condition exists, or the action of the silver and gold reagents used by us is concerned, no such term as fibrous or areolar can be applied to it. It is a structureless hyaline matrix, staining dark purple by the reagents employed, and showing all cell-formed tissues within it as bright white objects. This explanation may assist in making our preparations and drawings more intelligible.

Let us now follow the course of the lymphatics in their relation to the structure of the bladder as we have described it. Laying aside altogether the text-book dictum that "the lymphatics of the bladder enter the glands near the internal iliac artery," as insufficient and incorrect, let us trace the main lymphatic channels backwards from the points where they leave the bladder. These points are mainly two, one being the neck of

the bladder and the other the urachus, as shown in fig. 1, where the two great efferent lymphatic streams are seen in the relation they bear to each other, and to the great band of superficial muscle fibres upon or at the border of which they are placed. Each of the two groups was drawn separately by the camera lucida, and afterwards joined so as to lie in the straight line which they naturally form, but which had been made artificially into a curve by the conversion during the preparation of the spherical wall into a plane surface; and as they are there presented, they give a true picture of the plan of the lymphatics which encircle the bladder for a certain distance on either side of the mesial line of the organ. Beginning at the upper border of the drawing, we find the embouchure of the group of efferent lymphatics, which leave the bladder at the upper or anterior surface of the neck of the organ, and whose affluents are drawn from the whole of the anterior or inferior surface of the one side intervening between the neck and the urachus *u*, the most distant superficial affluents taking their drainage material from the tissues at the base of the urachus, forming an anastomosis there with the embouchure of the great efferent lymphatic or lymphatics which leave the bladder by way of the urachus. From that point the lymphatic stream first mentioned passes downwards and backwards on the anterior surface of the bladder, gathering in affluents as it goes, forming two great channels in the present case, but in other specimens it may have either one or more large trunks which pass towards the neck and leave the organ at that point. The other great group having its embouchure at the urachus, midway down the drawing, was probably the main one in fœtal life. Passing from its embouchure, we find the lymphatic stream flowing from the fundus and back of the bladder, gathering in its affluents from every side, and from the neighbourhood of the neck of the bladder posteriorly, and pouring the lymph thus collected through one or more main streams which leave the bladder at the urachus.

In addition to these two great streams on each side of the bladder, we have numerous smaller branches passing from the sides of the bladder towards the neck, but these are of little extent and importance as compared with the two great streams

figured in our drawing. It ought, however, to be stated that it is very seldom that so complete a demonstration can be obtained as that shown in fig. 1. This is probably due to the fact that the main efferent lymphatics do not always lie so superficially, and that only portions of the line of vessels are generally made evident.

Although near to their embouchure, those lymphatics lie almost entirely within the layer or coating of gelatinous tissue on the peritoneal surface of the musculature, they cannot be spoken of as a separate system of subserous lymphatics. Under all circumstances, there is a certain thickness of gelatinous tissue interposed between them and the serous cells of the peritoneum, and even close to their embouchure thin isolated bundles of muscular tissue may be seen at various places to intervene between the main lymphatic and the serous endothelium. Moreover, it is to be observed that all the affluents which form the main stream by their junction proceed from the substance of the musculature, and nowhere do they commence in the organ as the superficial subserous plexus seen elsewhere in the body. When we track these numerous affluents backwards from their junction with the main stream, we find them passing obliquely through the felting of muscular bundles until they reach the inner surface. This can be specially well seen in the bladder of the mouse, where the musculature is so extremely thin that, when treated from the peritoneal surface, the lymphatics may be traced to a great extent throughout their course. In many instances, after reaching the inner surface, they may be observed to turn again backwards, and become superficial for a short distance on the peritoneal surface of the musculature, showing thus the effect of the irregular or felted character of the musculature in destroying all resemblance to the sheets or layers of lymphatics seen in the intestinal canal, and which are evidently due to the regular arrangement of the muscular layers.

To observe the intimate relations of these lymphatic affluents with the inner or mucous surface of the musculature, it is generally advisable to use preparations treated from that surface, and for that purpose we must select the bladders of the larger mammals, which are large enough to be mounted and prepared on histological rings. While describing that surface, let it be

understood that the lymphatics have special relations to it at the trigone which they do not possess elsewhere upon the great extent of inner surface of bladder wall exclusive of the trigone. We will, therefore, for the moment, leave the surface of the trigone out of consideration, and speak only of the great mass of bladder wall as a whole. The general relationship of the lymphatics to the inner surface is shown in figs. 2, 3, and 7 from the bladders of the sheep and mare, which were drawn from preparations treated from the peritoneal surface, after the greater part of the musculature on that surface had been removed, for the purpose of allowing the reagents to penetrate as far as the vesical epithelium; and in fig. 6, from the monkey, which had been treated from the inner surface. It must, however, be understood that the lymphatics do not appear everywhere on the wall as plentifully as they are seen to do in those drawings, the spots from which they were drawn having been specially selected for that purpose, on account of the greater number of the lymphatics seen there, and the more intimate relations which they consequently showed with the bloodvessels and other tissues of the same locality.

A peculiar feature to be noticed here is that the lymphatics seem to be found as a rule only in the neighbourhood of the lines of the bloodvessels, around which they twine and alongside of which they lie in a close relationship that is seldom found in other organs or tissues. These parallel groups of bloodvessels and lymphatics are not found as a rule upon the outer surface, but only upon the vesical surface of the musculature or within its felted bundles, and do not lie, as elsewhere, wholly within the internal or mucous layer of gelatine. Indeed, bloodvessels, lymphatics, and muscle bundles seem to form a feltwork with each other specially characterised by its irregularity. It often happens, moreover, that a lymphatic is seen to emerge suddenly from the mucous surface of the musculature and to pass into the gelatinous layer, where it makes a short knee-like bend, and passes again as abruptly back into the musculature, these irregularities being similar to those we have described as taking place very frequently beneath the serous surface of the organ.

This peculiar relationship between the lines of bloodvessels and intertwining lymphatics, on the one hand, and the absence of

any special system of valveless collecting lymphatics, as seen in other tissues, on the other hand, suggest a limited function for the lymphatics of the bladder, a function confined to taking up at once the lymph or serum exuded from those great blood-vessels, and thus preventing it from passing into the bladder through the sodden epithelial cells which line it, while at the same time there are no collecting lymphatics close to that surface for the purpose of acting as the draining adjuncts to that area as in the case of the submucous lymphatics of the intestinal canal, lest from their position they might also drain off material from the cavity of the bladder injurious to the organism. Although immediately underneath the epithelial lining of the bladder there is a very thin layer or network of blood capillaries, yet that layer is almost too insignificant in normal conditions to cause an exudation of lymph or serum into the bladder, or to require an arrangement on its deep surface to carry away the minute quantity of lymph exuded from the plexus. This condition may explain, on the one hand, why there appears to be little or no perceptible absorption from the vesical cavity in normal conditions, but great absorption in inflamed conditions, where absorption would be probably due to and confined to the distended bloodvessels, and not to the lymphatics at all, and, on the other hand, why in cases of cystitis the amount of albumen to be found in the urine seems to be excessively great in proportion to the amount of pus contained in it.

It appears also probable to us that the lymphatics of the bladder represent a condition which, if it cannot exactly be called a rudimentary type, might at least be called an instance of arrested development. We have found that in embryonic life, as a rule, the lymphatics are represented to a great extent only by those vessels which afterwards become the special efferent lymphatics of tissues and organs, and that, as growth progresses, we have a continuous development from the peripheral extremities of these existing lymphatics of the special collecting and generally valveless lymphatics. This continuous development in the lymphatics does not even cease when the adult state has been attained, but becomes more plentiful as age advances, as may be well seen in studying the collecting reservoirs on the lower surface of the diaphragmatic musculature in

young and old adult animals of the same species. We are of opinion, therefore, that the lymphatics have developed in the bladder only to the stage of efferent vessels in the neighbourhood of the smaller arteries and veins. Having reached that point, instead of developing a system of collecting lymphatics without valves away from the neighbourhood of the bloodvessels, they have merely modified their condition by forming rudimentary meshes or loops intertwining with and around the bloodvessels, sufficient to carry away the lymph exuding from these vessels, but unfitted to act the part of a general drainage system for the whole surface.

Again, if the commonly used term of subserous lymphatics be ever applied to the efferent lymphatics seen in fig. 1, it must be understood as applied only relatively, and in no such sense as it is often applied elsewhere to collecting lymphatics,—like those, for example, found on the lower surface of the musculature of the diaphragm. The branches which form these efferent lymphatics are seen without exception to emerge from the musculature, and never to commence either as loops or as terminal branches within the substance of the subserous layer of gelatine. Indeed, they bear a similar relation to the serous surface that the roots of trees bear to the surface of the ground.

When we turn to the mucous surface, we find that here the lymphatics have just as little claim to be described as arising from or as forming a submucous category, for the collecting lymphatics we have described seldom appear so far from the substance or surface of the musculature as to be wholly embedded in the gelatinous layer of that surface. We may therefore reject as an entirely erroneous guess the dictum of Cruveilhier, that the lymphatics of the bladder arise from both surfaces; and similarly we may dismiss the even more indefinite guess of the former compilers of Quain's *Anatomy*, who describe the lymphatics as arising from the whole surface of the organ, without specifying which surface they refer to, or if both surfaces are included under the head of the whole.

With regard to other conditions, we may note that, notwithstanding the large size of the vessels, and the large number of crenated endothelial cells in the circumference of the walls of the larger lymphatics of the bladder in large mammals, as seen

in fig. 3, from the sheep, these walls receive no strengthening elements in the shape of muscle, or branched cells, or fibres while they remain within the substance of the organ, even in so large an animal as the horse.

This, however, is merely a feature they possess in common with the lymphatics of other organs in all the mammalia we have yet examined. In such cases, the strengthening muscular coat or coats of lymphatic vessels only appear in the great efferent trunks extrinsic to special organs. Notwithstanding that, in figs. 2, 3, and 6, the three companion structures—arteries, veins, and lymphatics—appear to be of somewhat similar dimensions, it must be borne in mind that, while arteries and veins diminish in size, and can be traced in the preparations to their ultimate capillary twigs, the lymphatics, on the other hand, seldom become much smaller than they appear in these figures, although they are to be found very much larger. As shown there, the lymphatics may be held as representing the ultimate radicles of the lymphatics in what is by far the greater portion of the wall of the bladder. Indeed, the general rule throughout the body is that, unlike the bloodvessels, the lymphatics constituting the ultimate radicles of the system are very much larger than the efferent lymphatics continuous with them, and to which they bear the same relation that a lake or reservoir bears to its efferent stream. This is very evident in the collecting lymphatics of the lower surface of the musculature of the diaphragm, in the lymphatics of the mucosa of the whole intestinal canal and many other localities, and this principle is even represented in the bladder in the case of the lymphatics of the mucosa of the trigone, which we previously pointedly excepted from the foregoing description of the lymphatics of the rest of the bladder-wall. To the lymphatics of that exceptional portion of the mucosa we now proceed.

It is unnecessary for us to enter here upon a description of the difference between the general mucosa of the bladder and that firm, smooth portion overlying the trigone, which accounts for the peculiar character of the lymphatics found within it. Figs. 4 and 5 from the mucosa of the trigone of the bladder of a monkey, sufficiently explain the character of these lymphatics, fig. 5 being drawn to the same scale as figs. 2, 6, and

7 for comparison with them. It is easy at once to recognise that those large irregular lymphatics forming *culs de sac* are undoubtedly the collecting and commencing vessels of that system, and that they are in continuation with the deeper-lying ordinary lymphatics on the surface of the musculature, similar to those shown in fig. 6 from the side of the orifice of the bladder in the same animal. These lymphatics in figs. 4 and 5 bear no relation whatever to the bloodvessels of the locality, and lie, as a rule, immediately underneath the superficial network of blood capillaries which extends over the whole of the inner surface of the organ.

The mucosa here is much thicker than elsewhere in the bladder-wall, the gelatinous matrix being filled with branched cells which have no connection with the lymphatics, and with smooth muscle cells or fibres which lie either as irregular small bundles or as solitary cells unconnected with the general musculature of the wall, and at times lying even superficial to some of the lymphatics. In short, those irregular shaped dilated lymphatics being merely projections from the ordinary lymphatics of the wall formerly described which form numerous anastomoses with each other, may strictly be considered as the actual commencement of the lymphatics of the bladder. Indeed, apart from the isolated group shown in figs. 4 and 5, taken from the centre of the trigone, the ordinary lymphatics show a tendency to throw off dilated branches whenever they approach the neighbourhood of the trigone, as seen in *e*, fig. 6, which locality is on the left of the anterior angle T of the trigone. It ought scarcely to be necessary for us to repeat here what we have so often repeated elsewhere, that there is no evidence whatever that more minute lymphatic radicles exist in the shape of minute canals formed by the cells of the connective tissue or the cavities in which such cells lie. Although in certain structures, as, for example, the subserous layer of the parietal peritoneum, the branched cells are so numerous that they often appear to be in connection with the lymphatic channels found there, yet elsewhere, and the bladder is a tissue or organ in point, these branched cells are seldom seen near lymphatics, except when, as at *c*, fig. 3, they are due to the presence of blood capillaries, from which capillaries they have probably escaped as wandering cells,

the numerous branched cells within the mucosa covering the trigone being exceptional in character like those of the peritoneum, but even then they have no connection with the lymphatics. It may, however, be necessary for us to go on repeating such statements until certain German investigators cease drawing hypothetical branched cells in formal connection with lymphatic channels, and teaching that these cells, or the cavities in which they lie, are the radicles of the lymphatic system. It would be too much for us to deny that future investigators may yet demonstrate lymphatic radicles of which at present we can form no conception. What we affirm is, that as the silver and gold solutions show all cell-formed or protoplasma-lined canals in our preparations as bright white elements in the purple hyaline matrix of gelatine, no lymphatic radicles like those described could exist without being made evident. Hitherto they have certainly not been made evident; they have only existed as hypotheses, not as facts, at all events in the mammalia.

Another hypothesis, equally unfounded, and due to the same school of investigators, may demand a passing word in connection with that portion of the bladder which is covered by the peritoneum. Although we have already shown that the lymphatics of the bladder, even where they exist in the subperitoneal layer of gelatine, have their affluents all coming from the musculature, it might still be suggested that they had a connection with the peritoneal cavity by means of the stomata which certain German observers have described in serous cavities, and more especially upon the lower surface of the centrum tendineum of the diaphragm. If such orifices did exist, we might fairly expect to find them even more readily at the bottom than at the top of the cavity, as fluids are generally held to seek the lowest and not the highest level, and if they exist on the diaphragm they ought also to exist upon the bladder. We have examined, in numerous instances, the silver-marked peritoneal endothelium covering the bladder as well as several hundred specimens of the diaphragm, and have invariably failed to find any evidence of the existence of such structures as stomata. Laying aside, however, our own observations in the matter, although as the discoverers of the great collecting lymphatic

reservoirs on that same surface of the diaphragm, where our predecessors, quick to observe minute objects, failed to observe these large objects, we might fairly claim to have examined that surface even more carefully than they had done; laying aside also the complete reversal of the simplest principles of hydrostatics, which absorption of fluids through stomata on the roof of the peritoneal cavity entails, we can still offer one anatomical objection to the hypothesis that the peritoneum forms part of the lymphatic system which it will be difficult to overcome. That objection lies in the character of the crenated endothelium found throughout the lymphatic system, never wanting there, never found elsewhere, and never found lining the peritoneal cavity of the mammalia. The cells lining that cavity resemble much more the endothelium of veins than of lymphatics. No similarity, however, exists between the structure of the peritoneum and that of the lymphatics, so that even hypothetically there is no foundation for establishing an anatomical connection between the two by means of stomata or other imaginary communication. As for the physiological experiments of Professor von Recklinghausen, who first started the hypothesis, we have only to remark that, even if the almost unavoidable injury done to the delicate walls of the reservoirs we discovered on the same surface of the diaphragm did not fully account for absorption from that surface of milk and Berlin blue, so as to fill the whole lymphatic system of the structure, the fact that, to effect absorption, the natural position of the structure of the animal had to be reversed, must vitiate the deduction he derived from the experiment. Apart, however, from the hypotheses, if stomata existed at all in the peritoneum, they ought to have existed on the peritoneal surface or covering of the bladder in connection with its subserous efferent lymphatics. This they certainly do not, and, speaking plainly, we hold the existence of stomata in the mammalia to be either imaginary or the result of rough manipulation.

Before concluding this paper on the lymphatics of the bladder, it may be well to give a short résumé of the results obtained from the physiological and clinical experiments on the absorbing cavity of the urinary tract, in order that our readers may form their own conclusions as to the relationship between the

anatomical and physiological conditions. For most of the facts of this abstract, we are indebted to an exhaustive account published in 1871 by Dr Alling,[1] that being the latest work on the subject that we have been able to discover. Dr Alling begins his subject by stating that, at that date, even in spite of the numerous works that had been published during the past fifty years, the most contradictory opinions were still upheld by physiologists and medical men, who could not be brought to accept any one general conclusion on the subject. First, M. Sejalos (père) in 1824, admits the absorption of medicinal substances by the bladder. M. Sejalos (fils), in 1862, thinks he can agree in the foregoing opinion, and regards absorption there as being at least as active as in the stomach. Bérard also admits it, but to a less extent than by other mucous surfaces. Civiale considers absorption to be nearly absent. Professor Longet came to the conclusion that absorption took place, but he admitted that his observations might not always appear conclusive to every one. MM. Susini and Kuss, in 1867, absolutely deny that any absorption takes place; M. Dumarquay admits it to a certain extent. M. Bert, in 1869, at the Société de Biologie, announced that, as the result of experiments, he had proved absorption by the bladder to take place; and, at the same time, M. Brown-Séquard remarked that in Russia and Italy advantage was taken of that fact in the treatment of cholera. In 1867, Sir Henry Thompson denies absorption by the bladder; while Dr Braxton Hicks asserts the contrary.

Alling's own results were as follows:—

1*st*. The healthy bladder does not absorb appreciably either medicinal or poisonous substances.

2*nd*. The healthy urethra absorbs both.

3*rd*. Absorption very readily takes place in the inflamed bladder.

He also explains the contradictory views by stating that, with the exception of Susini, all those who had found absorption had tied the urethra at the meatus, and they had consequently mistaken absorption by the urethra for vesical absorption. He had opened the abdomen in dogs, tied the neck of the bladder,

[1] *De l'Absorption de la muqueuse vésico-uréthrale*, par le Dr Edouard Alling, Paris, 1871.

and tested with atropine and strychnine. He also tested with morphia upon his own bladder and found absorption *nil*, he being at all times very sensitive to the drug. Dr Braxton Hicks' observations were in agreement with his own experiments, that observer having injected morphia into the empty bladder in cystitis, where the concurrent inflammation accounted for the great absorption.

Finally, to sum up the results of our own observations upon the lymphatics of the bladder, we formulate the following conclusions:—

1. Strictly speaking, the only pure collecting lymphatics of the bladder are to be found (with slight and immaterial exceptions) in the mucosa covering the trigone. These may therefore technically be considered the origins of the lymphatics of the bladder.

2. Generally speaking, the lymphatics of the bladder do not arise from either surface, but exist in their ultimate form as a mixture of collecting and efferent lymphatics, forming irregular elongated loops or chains accompanying and intertwining with the lines of smaller arteries and veins, which form great meshes upon the inner surface of the musculature of the organ.

3. From these endless loops, larger branches, generally unaccompanied by bloodvessels, pass very obliquely through the substance of the musculature. These affluent branches anastomose frequently with each other, and upon the outer surface of the musculature form by their junction the larger or main efferent lymphatics.

4. These efferent lymphatic vessels are well provided with valves, and lie principally within the gelatinous layer or matrix intervening between the serous endothelium and the musculature, and thus pass on either side of the mesial line, some towards the urachus and others towards the neck of the bladder, at which points they leave the organ and have no further connection with it.

DESCRIPTION OF PLATE XXXI.

Drawings made by the aid of the Camera Lucida.

Fig. 1. View of the main efferent lymphatics in the bladder of a mouse. These lie for the most part at and parallel to the border of the superficial longitudinal band of muscle *lm* on either side of the mesial line of the organ. *u*, urachus, towards which a main efferent lymphatic *el*, passes round the fundus from the base near to the line of *ah*, the inferior hypogastric artery. On either side of the anterior border of the base of the urachus, another great lymphatic stream collects its affluents *al*, and passes downwards towards the neck of the bladder near *ag*. The affluent lymphatics *al*, are generally seen coursing within the muscular wall for some distance before joining the efferent streams *el*. $\frac{1}{15}$.

Fig. 2. View under a very low power of the collecting lymphatics on the mucous side of the muscular wall of the bladder of a sheep at the fundus, showing their peculiar general relationship to the bloodvessels of the part. *a*, arteries; *v*, veins; *l*, lymphatics; *m*, muscles; *n*, nerve bundle. $\frac{1}{4}$.

Fig. 3. Magnified view of a portion of the lymphatics seen in fig. 2, at its upper border, showing the intimate relation of the lymphatics *l*, with the bloodvessels and other tissues. This figure was drawn from the untouched mucous surface, while fig. 2 was drawn from the opposite surface of the preparation. *a*, artery; *v*, vein; *m*, muscles. A number of branched cells, probably wandering cells, are seen near the capillaries at *c*. $\frac{1}{50}$.

Fig. 4. Terminal collecting lymphatics or reservoirs lying within the mucosa of the trigone of the bladder of a monkey, immediately underneath the superficial capillary plexus of bloodvessels. *m*, smooth muscle fibres, solitary and in small bundles; *v*, veins; *b*, branched cells in matrix of gelatine surrounding the lymphatics. $\frac{1}{50}$.

Fig. 5. View under very low powers of the cluster of lymphatics from a portion of which fig. 4 was drawn. It is drawn under the same power as figs. 2, 6, and 7, for comparison with these as to size. $\frac{1}{4}$.

Fig. 6. General arrangement of lymphatics on the inner side of the musculature of the bladder of the monkey, on the left side of the orifice of the urethra. *O*, orifice; *T*, left anterior angle of the trigone; *l*, lymphatics; *v*, veins; *e*, dilated lymphatics corresponding to collecting vessels: Where the lymphatics seem abruptly to end, they are merely passing into the musculature. $\frac{1}{4}$.

Fig. 7. Peculiar sacculated condition of lymphatics of the inner side of the musculature of the bladder of a horse, near its orifice, for comparison as to size and distribution with those of the monkey and the sheep in figs. 2, 5, and 6, being drawn under the same power. *av*, arteries and veins; *l*, lymphatics. $\frac{1}{4}$.

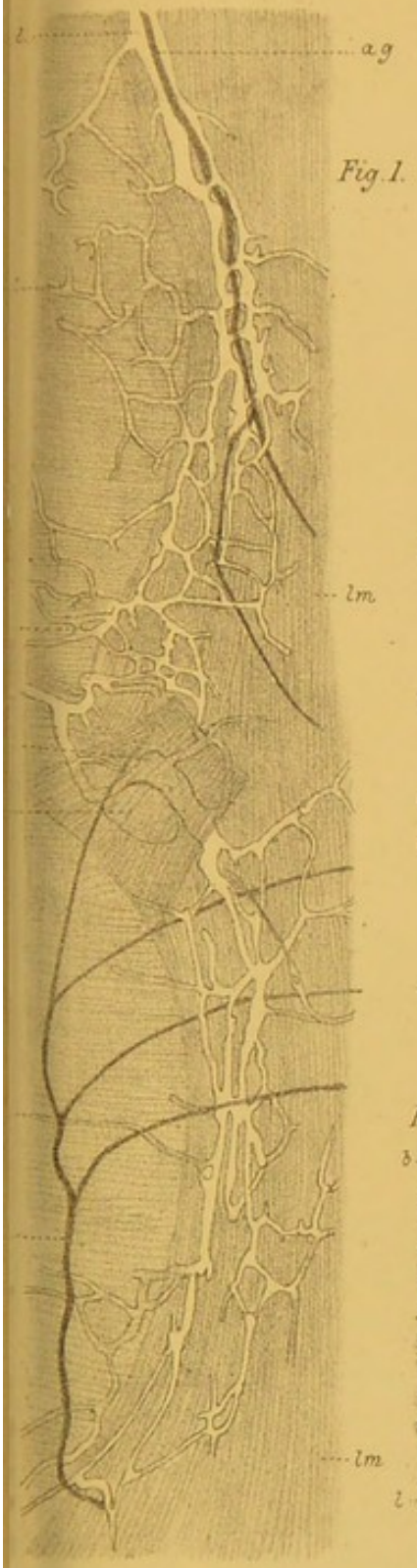


Fig. 1.

Fig. 2.

Fig. 3.

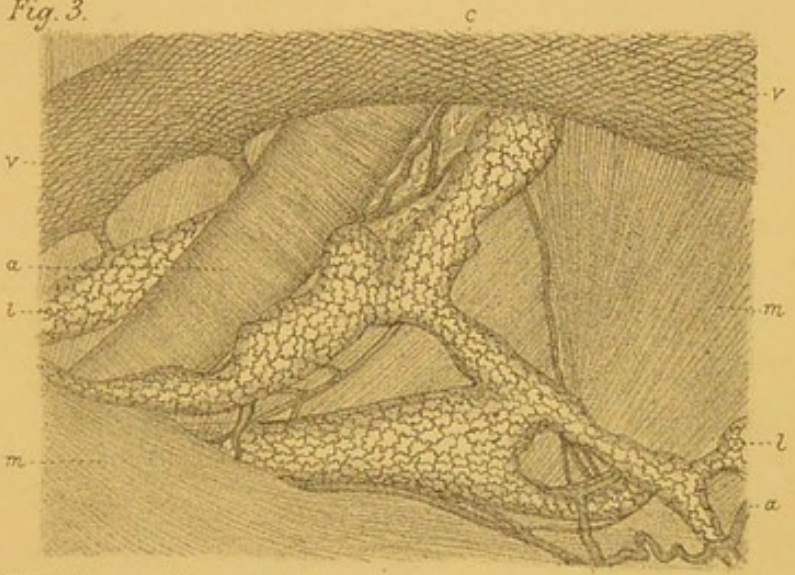
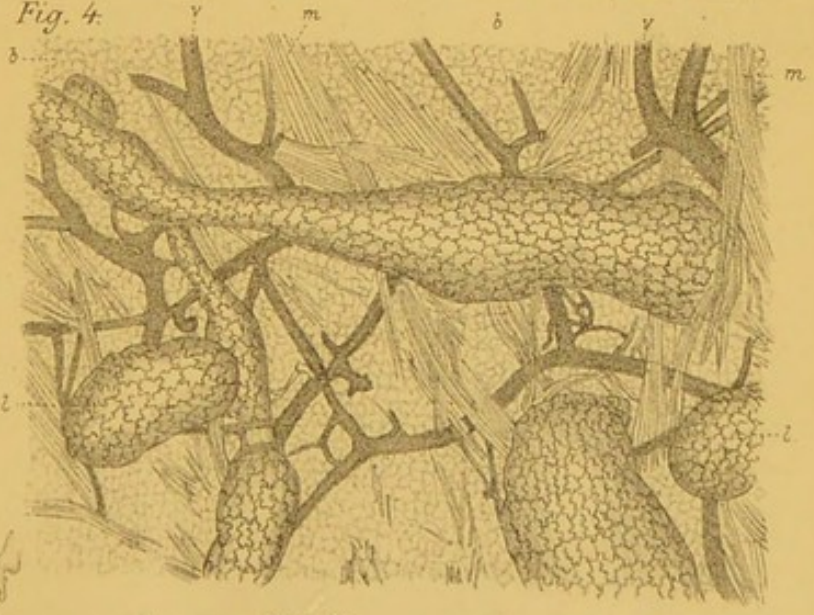


Fig. 4.



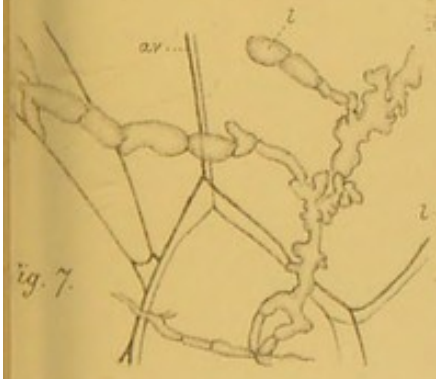


Fig. 7.

Fig. 6.

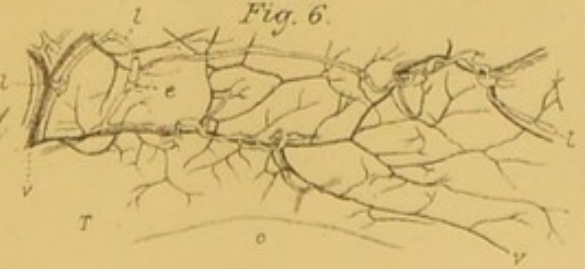


Fig. 5.

Hoffman, del.

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