On the lymphatics of the pancreas / by George Hoggan and Frances Elizabeth Hoggan.

ON THE LYMPHATICS OF THE PANCREAS.

By GEORGE HOGGAN, M.B. (Edin.), and FRANCES ELIZABETH HOGGAN, M.D. (Zurich), M.K.Q.C.P. (Ireland). (PLATE XXIV.)

ALTHOUGH the pancreas is an organ which, from its position, is in a manner practically removed from all surgical interference, and in which it is almost hopeless to expect that a knowledge of the course of its lymphatics will enable us to detect clinically in the living subject the course of any disease specially involving the lymphatic system, nevertheless the lymphatic system in the pancreas possesses special interest for two reasons. In the first place, except that efferent lymphatics have been seen to emerge from the organ, nothing whatever seems to be known of its intrinsic lymphatics at the present day, and it appears to have enjoyed almost unique immunity from the rash and vague guesses which compiling anatomists have so liberally made regarding other more accessible organs like the bladder and uterus. In the second place, the pancreas may be taken as the type of the racemose glands throughout the body, such as the salivary and lachrymal glands, in none of which, to our knowledge, has any attempt ever been made to discover the existence or arrangement of the lymphatic system. The result of any satisfactory investigation into the lymphatics of the pancreas may therefore be held, from the similarity of the general anatomical structure of these glands, to be equally applicable to them all. Our ignorance in this respect is probably due partly to the comparative massiveness of these glands, and partly to the fact that they are so embedded in or surrounded by other tissue, that it would be difficult, in the event of any lymphatics being found in their immediate neighbourhood, to decide whether they belonged to the gland itself or to the contiguous tissues. At first sight, it would appear that their massiveness would render the glands unsuitable for imbibition by silver solution, which we hold to be the only trustworthy method at the present day; but there appears to be no reason why investigators should not have attempted investigations by the injection method, as

has been done in the case of the liver, kidney, ovary, and even the spleen; for anyone who did not hesitate to investigate the latter organ by means of the injection method, and to publish the results thereof, ought not to have hesitated afterwards to undertake a similar investigation on any other organ in the body. As, however, the investigation by means of coloured injections of the organs referred to has, even when undertaken by illustrious investigators, only saddled anatomical science with a burden of error which we shall afterwards illustrate in this paper, it may be considered fortunate that no similar attempts have been made or succeeded on the pancreas and other racemose glands. Thus, our task will be narrowed to giving the facts as we find them, and there will be no alleged facts, already enjoying the advantage of possession of anatomical minds, to disprove.

The pancreas is an organ to the study of which the advantages of comparative anatomy are peculiarly applicable. Although in man and the larger mammals it is a massive, solid organ, yet in some of the smaller mammals, the rodents for example, it is, we believe, the unique example of a naturally dissociated large racemose gland, which can be investigated not merely by silver and staining fluids for its lymphatics, but also for the rest of its component tissues, all of which can be suitably prepared without injury to the gland as a whole, and made perfectly transparent under the microscope. In the rodents, more especially and conveniently in rats, mice, and rabbits, the pancreas is spread out upon the mesentery like a fruit tree on a wall, the branches being represented by the various ducts, of which the terminal twigs continually anastomose, and the leaves being represented by lobules of acini of the gland, thin enough, after staining, to be rendered perfectly transparent for microscopical investigation. In fact, here we have an almost perfect natural dissociation of the gland substance, so that the development, as well as the relation of all the component tissues in the adult, can be perfectly studied, not only in the gland itself, but in their approaches to it, in the clear, transparent, gelatinous matrix of the mesentery, which intervenes between the lobes of the gland.

The manipulation necessary for investigating these structures is extremely simple. Only one apparatus, the histological rings

invented by us, is absolutely necessary. In the case of the rabbit, which we have found to be the most advantageous, the rings ought to be about $1\frac{1}{2}$ inch in diameter; this will generally be found large enough to include the whole of the pancreas. Immediately after the animal has been killed, the abdomen is opened widely in the mesial line. The omentum and the greater part of the small and large intestine are laid over to the right, so as to expose the duodenum and its mesenteric attachment. On the anterior surface of the mesentery, with the arborescent pancreas spread like an espalier upon it, there will be observed another portion of the intestine, with its mesentery lying like a loop adherent to the duodenal mesentery, midway between the root and the attachment of the mesentery to the duodenum. Holding the duodenal portion of the intestine firm with one pair of forceps, the other portion may be gently torn or separated from it, so as to leave the pancreas supporting mesentery intact; but at the same time the act of separating the two mesenteries will have left what may be called the anterior surface (in the natural position) of the pancreas denuded of endothelium, and specially suitable for imbibition of silver solution. The attached intestine may now be lifted up and its mesentery kept distended, while the lower ring is placed upon its anterior or denuded surface, and the upper ring jammed upon it from the opposite uninjured surface. The tambourine thus formed may then be excised with scissors from its connection to the spine and the intestine, and one or both surfaces of the membrane as it is now stretched upon the rings may have a 1 per cent. solution of silver poured quickly on and off, when after a short exposure it may be well washed with ordinary water. This preparation must afterwards undergo excessive exposure as compared with other tissues, in order to bring its lymphatics into view. Moreover, as it is generally advisable to stain the whole membrane with hæmatoxylin, so as to show the nuclei of the cells, it is well to expose it even to what may appear an injurious extent, as the process of staining seems subsequently to remove the brown tint to a large extent. The logwood-staining fluid is to be filtered upon it in the usual way, and when found sufficiently stained the membrane is well washed and clarified with alcohol and oil of cloves.

All this time it must be understood that the mesentery forming the membrane stretched between the rings has been touched by nothing except the different fluids. Shortly after clarification the membrane may be excised as a disc, and although thin as gossamer, it will retain its evenly spread out condition, so that if it be found suitable it may be at once mounted as a permanent preparation in varnish, without a wrinkle in its whole extent and without any injury to its surface. Between, however, its being subjected to the silver solution and its permanent preservation as a preparation, two or three days may require to elapse, during which it may be examined, when convenient, for the development of the image of the lymphatics. It will generally be found that the lymphatics are best seen, or only seen, on the inner (the originally denuded) surface of the tambourine membrane, as on the outer surface the serous endothelium of the peritoneum remains uninjured and well shown by its silver markings, while at the same time the endothelial cells interfere with our success, by preventing the silver solution from penetrating to a sufficient depth to demonstrate the lymphatics on that surface of the gland.

There is about the lymphatics in this tissue the peculiarity that they require a comparatively high power in order to be recognised. A power of from 250 to 400 diameters should be used, and the crenated edges of the lymphatic endothelium must be the only permissible mark of recognition. The crenated edge of the endothelium of the lymphatics in this region, for some reason as yet inexplicable to us, appears to be specially well marked, as seen in figs. 4 and 8. In figs. 4 and 8, every one of the cells was outlined by the camera lucida, and the crenation there renders their recognition absolutely certain. When the lobules of the gland have been deeply stained, the lymphatics lying upon them will be recognised easily, even under a low power, by being of a much lighter blue or purple tint upon the dark purple background, in consequence, apparently, of the endothelium of the double lymphatic wall having protected the gland cells beneath them from the imbibition of the logwood staining fluid, the crenated lines being, however, previously sought for as a test of identification. Before we proceed to the description of these lymphatics, let us first give a *resumé* of the

opinions hitherto held, and held at the present day, with reference to the lymphatics of the pancreas.

Many of our best known workers who have made personal investigation into the general lymphatic system, do not even refer to the pancreas. Of these Teichmann is a notable example. Of those observers who do mention it, Cruikshanks appears to have been the earliest, and of its lymphatics, he says, at page 166 of his work on the lymphatics: "That the pancreas has lymphatics, I am well assured. I have seen them on a great many occasions rising out of the pancreas and joining the splenic plexus." Haller did not believe that the pancreas had any lymphatics, and he pointed out that the pancreas, in which other authors had previously asserted they were to be seen, was not the true pancreas but the mesenteric glands. Mascagni, at page 50 of his great work, says: "The lymphatics which come out of the pancreas follow the course of its blood-vessels, and enter the glands to which the splenic lymphatics pass, but have no connection with those of the liver or intestine." Cruveilhier, at page 491 of the 3d edition of his *Anatomie Descriptive*, says: "The lymphatics of the pancreas are not well known; it is probable that they enter the glands nearest to them." In *Quain's Anatomy*, 8th ed. vol. ii. p. 397, we are merely told that "its lymphatics terminate in the lumbar vessels and glands," and, in vol. i. p. 511, that "lymphatics emerge from the pancreas at different points, and join those derived from the spleen." Frey, at p. 491 of his *Histology*, 3d ed., says that "the lymphatics of the pancreas are numerous, but they require more minute investigation." Finally, we come to Sappey, who appears to be the latest investigator and author who has referred to these lymphatics. In his *Anatomie Descriptive*, published in 1870, p. 831, he states: "Their investigation is very difficult; nevertheless I have twice succeeded in injecting them. They come out of the pancreas at different parts of the superior border of the organ, and join the glands near the cœliac artery." In short, it will be seen by our extracts that, although several investigators have seen lymphatics extrinsic to the pancreas, not one has seen them within the organ, or pretends to describe, or even hint at, their probable relationship to the component tissues of the gland.

When we have placed before us what appears to be a thoroughly successful specimen of a pancreas of one of the rodents, prepared according to the method we have described, in order to demonstrate its lymphatics, we must carefully bear in mind that there is one source of error to be eliminated from our search. As the pancreas is spread out upon the mesentery, we naturally have near it, and sometimes upon or within it, the main efferent lymphatics, or lacteals, passing from the intestine to the receptaculum chyli. These, at first sight, might be taken to represent the lymphatics of the pancreas, and we, ourselves, were, at the beginning of this research, partly led astray by the presence of these lymphatics, which often lie in the line of the main chains of pancreatic lobules. Having, however, been made aware of this source of error, it is easy practically to eliminate it from interfering with the special lymphatics of this research. The efferent lymphatics or lacteals in question can always be recognised by means of their straight and regular course. Although formed by the junction of smaller branches on the side of the intestine, and even by the extrinsic efferent lymphatics of the pancreas, they remain of regular calibre, with valves at regular intervals, and as they grow larger by the junction of other channels, strengthening elements in the shape of smooth muscle-cells get applied to them externally, isolated and scanty at first, but forming a very respectable coat sometimes before they reach the receptaculum chyli. In most cases, the greater part of their course lies within the transparent gelatinous matrix of the mesentery, where they may be seen to receive efferent lymphatic branches from the pancreatic lobules. In the smaller rodents, like mice and rats, this elimination is much more difficult to make, but in the rabbit, from which we chiefly took the special material for this research, there is no difficulty whatever in making it. In figs. 2 and 5, for example, it scarcely requires the foregoing caution to enable us to state that the irregular and erratic lymphatics seen passing up through the axis of the chain of lobules are certainly not the efferent lacteals, but the efferent lymphatics of the pancreas itself, receiving tributaries from various parts of the surfaces of the individual lobules.

Although, physiologically, we have here, as elsewhere, only

two divisions, namely, the collecting and the efferent lymphatics, yet for the sake of anatomical description we must divide the latter category into two subdivisions, and this too independently of the efferent lymphatics, or lacteals proper, of the intestinal canal, which we have just eliminated from consideration. No one can find much difficulty in differentiating the broad network of vessels almost destitute of valves which form the collecting lymphatics proper of the organ, as shown in figs. 1 and 3, from the irregular lines or loops of valved lymphatics which lie in the axis of the lines of pancreatic lobes, and intertwine with the blood-vessels and pancreatic ducts in that locality, as seen in figs. 2 and 5, giving off branches, at nearly right angles to the efferent stream, which pass round or between the lobules to join the groups of collecting lymphatics on the opposite side of the lobes, as seen in figs. 2 and 6. These lymphatics we speak of as intrinsic efferent lymphatics, and they, with their collecting lymphatics, form the special lymphatics of the pancreas, of whose existence, condition, or relationships nothing has hitherto been known, or even suspected. While, however, the main efferent lymphatic stream seems to pass down in the axis of the chain of pancreatic lobes, we observe, as we follow it under the microscope, that comparatively large lymphatics pass off at frequent intervals from the chain of lobes and its intrinsic efferent lymphatics, and turning backwards wend their way through the mesentery, either to join the receptaculum chyli, or, as is most frequently the case, they join after a longer or shorter course one of the great efferent lacteals from the intestine, passing through the mesentery on its way to the receptaculum chyli. The lymphatics alluded to correspond to the vessels referred to by the writers we have quoted, and, although lying within the same field of the microscope with the other vessels, and, so to speak, within the area of the pancreas, we speak of them as the extrinsic lymphatics of the pancreas. The relation of such a lymphatic to the intrinsic efferent lymphatics is seen at *c*, fig. 5. After leaving the lymphatics seen in the axis of the lobes in that drawing, the extrinsic efferent trunk remains of regular size, and no longer forms loops or anastomosing branches. We have not drawn the straight efferent lacteals we referred to as sources of error, as to do so

would be unnecessary for this research, they being too well-known to histologists to require special delineation for comparison. In fact, purely efferent lymphatics, anywhere throughout the body, although they may form anastomoses and networks, as, for example, on the upper surface of the diaphragm, seldom break up into irregular-sized loops and meandering channels intertwining with the blood-vessels, such as are seen in fig. 5.

The course of the intrinsic efferent lymphatics, as seen in figs. 2 and 5, follows pretty closely the course of development of the organ. Beginning as a bud from the duodenal orifice, this gland in the rodents divides primarily into two divisions, and these subsequently into many other divisions, which diverge from the orifice like the ribs of an unfolded fan. As they elongate, these ribs not only give out branch ribs, in the same general direction of divergence, but they also give off branches which pass from one chain to another at every variety of angle to the general plane of divergence. In all this development, it must be understood that the formation of the chains of lobules is preceded by the formation of the duct beyond the ultimate point of lobule formation. This is very well shown in the cross chains, where the whole duct, formed of lozenge-shaped cells, is often formed before a single lobule is developed upon it, and the first evidence of lobules as buds composed of five or six cells, forming an embryo acinus, can be observed, and the whole subsequent course of development exactly studied.

In some such cases the development of collecting lymphatics for the future chain of lobules can also be watched, and this gives us a satisfactory conception of the progress of the lymphatic arrangement for this special organ. Tracing the lymphatics back from the head of the pancreas, we find them passing, as we have stated, in the general axis of the head or primary chain of lobules, either as one or more channels forming irregular dilatations or loops, intertwining with the blood-vessels and duct, sometimes passing on one side, sometimes on the other, of the root or attachment of the lobules to the duct, as seen in the figures. From what we have already stated, it will not be supposed that, because the whole lymphatic arrangement of the pancreas developes backwards from the head of the

pancreas, like the ducts of the gland, as if parallel and *pari passu* with these ducts, the lymph stream passes wholly down those lymphatics, as the pancreatic juice itself passes wholly along the gland ducts towards the main opening into the duodenum. At various intervals in the course of the development peripherally of the axial intrinsic lymphatics, the extrinsic branches pass off often at right angles to the chain of lobules, as at *c*, fig. 5, and these, turning backwards, take a course as already stated, towards the receptaculum chyli, or join some of the efferent lacteals passing thereto from the intestine. These branches drain off the greater part of the lymph before it has run far along the axial chain. In figs. 7 and 8, from the developing pancreas of a young rat, we have an example of the development peripherally of an axial chain of lymphatics. At *i*, fig. 7, is seen a cul-de-sac offshoot that probably will finally become one of the extrinsic efferents we have alluded to, which will drain off part of the lymph from the axial lymphatic lying upon the chain of lobules, and which is developing peripherally at the cul-de-sac *h*, fig. 7, shown under a higher power in fig. 8.

As the main duct of the chain divides dichotomously, or gives off connecting branches to other tracts, the lymphatic vessel or vessels, as in fig. 5, likewise send an offshoot in the same direction, until the whole pancreatic espalier is provided with a chain of lymphatics along each branch.

In the smaller rodents, like mice, the lymphatic system is seldom seen to get beyond this stage, but in the rabbit we have a further development of special collecting lymphatics connected with the intrinsic efferents by branches passing off at nearly a right angle to the main chain of axial lymphatics. Several of those special collecting branches are seen in fig. 2; and fig. 6 shows one of them under a moderately high power. At *a* we see the branch ending as a cul-de-sac applied flatly to the mass of the lobule *en face*, this being the manner in which many of the branches end as collecting lymphatics; while *b'* and *b'* in the same figure represent branches which pass between the lobules to join more complicated plexuses on the opposite surface, similar to those seen in fig. 1, and which latter embrace the lobule in the same manner as the paper nautilus grasps its shell.

From the position of the intrinsic efferent lymphatics, and the manner in which they intertwine with the vessels and ducts of the organ in the axis of the chain of lobes, they may be described in relation to the individual lobes as lying in the hilus of each, or upon the hilus surface of the lobe; but in that position there is the clearest evidence that they never pass into the substance proper of the lobe. On the contrary, when we trace the branches given off from them, as seen in figs. 2, 3, and 6, we find them either terminating as a flat cul-de-sac on the same hilus surface, or passing between the primary lobules (not acini) which constitute a lobe, and emerging on the opposite surface from similar clefts or interstices between lobules, and joining or forming a collecting plexus of lymphatics on that surface. In this respect the lymphatic arrangements upon an individual lobe, such as is seen in figs. 1 and 3, even although that lobe be almost microscopical in size, are identical with the lymphatic arrangements which obtain on such massive organs as the kidney and spleen in the larger mammals, the efferent lymphatics being found at or passing to the hilus, and the collecting lymphatics at the opposite point in the periphery of the lobe, the whole lymphatic arrangement being, as we have so often insisted, merely a peripheral drainage system of vessels, and that drainage system of such comparatively little importance that it is often altogether unrepresented or absent, and is therefore evidently not of primary necessity.

We have already stated that in the pancreas of such a small animal as the mouse, the collecting lymphatics proper are generally absent, the intrinsic efferent lymphatics fulfilling the necessary function, but in these animals, and in innumerable instances in our preparations even of the rabbit's pancreas, large lobes, and even groups of lobes, are seen to be unprovided with any lymphatic vessels whatsoever. In the cases referred to the lobe or group may have developed upon or from one of the cross branches of the pancreatic duct at nearly the middle of the length of the duct, being separated from the rest of the secreting structure of the organ. It is easy there to examine the duct and accompanying blood-vessels on either side of the group of lobes, and to ascertain that no lymphatic accompanies them, and that therefore that isolated lobe or

group of lobes is unprovided with any lymphatics, which consequently cannot be an indispensable adjunct to these tissues. This, indeed, is only a narrow demonstration of a much wider principle, which becomes very evident when a comparative study of the lymphatics is made in many classes and sizes of animals, where in one class we find an organ destitute of lymphatics, which in another class (generally a larger one) is plentifully provided with them.

The collecting plexus of lymphatics, even where best developed upon the pancreas, as in fig. 3, presents features common to the same structures in many other organs in the body. The plexus found there might have been equally found upon or drawn from the sub-epithelial plexus of the intestinal canal (minus the culs-de-sac of the villous portion), from the greater curvature of the kidney and spleen (in the horse), from the lower surface of the diaphragmatic musculature, from the peritoneal surface of the transversalis abdominis, from the perichondrium or from the supra-pubic plexus in the mouse, and from numerous other localities in the body. In fact, there is a remarkable simplicity and similarity in the lymphatics throughout the body; differences can scarcely be said to exist, but only modifications in a general plan, of which the connecting links are always evident and easy of understanding. The innumerable specially descriptive names applied to various portions of vessels of the system—the Lymph-röhrchen, spalten, räume, the sinus, canaliculi, lymphatic sheaths, vasa serosa, &c.—are in most cases the outcome of fertile brains and clumsy injections, which have made artificially the cavities described as parts of a natural system, as we shall show in the course of this paper.

The relation of the collecting lymphatics to the other elements in the pancreatic lobes is extremely simple, and is shown in fig. 4. Huge drains, whose walls are formed by dovetailing tiles, lie upon the cellular structure of the lobe, and receive any excess of fluid that may ooze into them. No branched cells are to be detected in connection with them. This might be said to be due to the difficulty of detecting them upon the rather opaque cellular mass on which the lymphatics lie. But in fig. 8 there is no such inconvenience; the cul-de-sac there is evidently a purely collecting lymphatic. In the clear gelatinous matrix

the finest granule could be detected. The pyrogallate staining has also been applied so intensely that every nuclear or protoplasmic element in the vicinity of the lymphatic is made clearly and abundantly evident, but there is no trace of any minute channel beyond the walls of the cul-de-sac; in short, there is distinct evidence that the mythical vasa serosa or lymph-canalicular system of branched cells cannot have any existence there.

It often happens that branches of the lymphatics are observed leaving the close proximity of the lobule, and passing off for a a short distance and again returning to it, lying in the interval within the clear gelatinous matrix of the mesentery; and, as in such conditions a deep staining can be applied to its nuclei, we can form a satisfactory opinion as to the mode of development. This explains the projection of the cul-de-sac of the developing lymphatic in fig. 8. In such cases we generally find blood capillaries accompanying the growing lymphatic, as shown in figs. 7 and 8, as if these capillaries were the pioneers of the lymphatics. There is, of course, no relation between the development of the lymphatics and the development of the blood capillaries, the latter being formed of the terminal attachment and hollowing out of terminal cells, while the former has several endothelial cells in its periphery at its termination while undergoing development or extension, so that extension takes place by the interposition of new or wandering cells between the crenated margin of the lymphatic endothelium. These cells, by their growth and broadening out into lymphatic endothelium, serve to prolong the cavity of the developing lymphatic peripherally. This process can be followed by examining a series of terminal projecting culs-de-sac in developing lymphatics, similar to those in fig. 7. In fact, the development of the lymphatics resembles the growth of a capillary into a larger blood-vessel by the interposition of cells between the existing cells of its previously formed walls.

When we trace a lymphatic, or chain of lymphatics, along the axis of a chain of lobules until we reach what may be called its extreme peripheral termination, upon the last lobule of the chain, we generally find it terminate in a cul-de-sac, as in fig. 6, *a*, like a club-shaped finger-tip upon the thickest part of the

lobule, the axis of both being parallel to each other. Although, however, the tip or point of the cul-de-sac is actually broader than the channel behind it, there is never any attempt to send off small channels such as one might conceive the ultimate lymphatic radicle to resemble.

We have already stated that, owing to the protection given by the double endothelial wall of the lymphatic to the mass of the glandular tissue beneath it, the silver solution has not been permitted to permeate the mass at such points, and the excessive exposure to light which we previously urged as a necessity, while it renders the less protected surface of the glandular tissue of a dark brown colour, leaves the places covered by the lymphatics of a light blue tint, due purely to the staining of the logwood fluid. This is so well marked that there is no difficulty in recognising the course and shape of such lymphatics with powers much too low to recognise the crenated endothelium, which is alone the guarantee of a lymphatic.

In addition to the light blue images which mark the lymphatics, many other small light blue spaces may be observed upon the mass of the lobule that might be taken to be points of culs-de-sac of lymphatics penetrating the organ, and as evidence of complete permeation of the lobule by branches of the lymphatic system, such as exist almost unanimously in theory, but never in fact. When such isolated light blue patches are examined by a high power, more than sufficient to show with beautiful clearness the crenated edges of the contiguous lymphatics, it will be observed, in the first place, that such spaces possess no crenated lines which would argue the presence of a lining of lymphatic endothelium. Further examination will show that those spaces represent the crevices between the contiguous ultimate lobules, or even acini, of the gland. When in the living condition the silver solution was momentarily applied to the tissues, these lobules or acini being close together prevented the silver solution from penetrating between them and staining them. The subsequent extended exposure to hæmatoxylin allowed, however, that staining fluid to colour all the elements of a light purple tint. When, subsequently, the tissues were dishydrated by alcohol and essential oil a certain amount of contraction took place, more or less, but unequally, in the

different elementary tissues, so that the acinus, or lobule, shrinking from the contiguous acini, or lobules, left often a distinct interval or crevice, easily recognisable under the microscope.

The clearly demonstrated existence of such spaces leads us to one of the gravest considerations in connection with the whole anatomy and physiology of the lymphatic system, as built upon the results of comparatively late researches made by the most distinguished histologists of Germany in particular, and the arguments which we are about to bring forward ought to have the effect of destroying all confidence in the correctness of the results arrived at by those observers, pending further investigation. That spaces, crevices, or cavities, such as we have described, actually exist within our preparations, admits of no manner of doubt, by simple microscopic observation; and it is equally evident that, were the canula of an injecting syringe plunged at random into the solid mass of the gland, such cavities would certainly be the first to be filled by the injected fluid, and the cavities thus injected would be described as being parts of the lymphatic arrangement of the organ; for the injection method shows only the casts of cavities, whether natural or artificial, and offers no guarantee like the crenated endothelium to stamp the characters of the lymphatic system. Probably, in such an injection, some lymphatic channel would also be opened into and injected, and this would lead to the filling and distention of the efferent valved lymphatics extrinsic to the organ, which would seem to confirm the relation of such cavities to the lymphatic system, but in reality would only confirm a gross but almost universal error. We have long been aware of this error in a large number of researches into the lymphatic system by means of coloured injections, we having, by long study of the system by means of the silver method, acquired an almost indefinable consciousness of what is and what is not a lymphatic in such injections; but it is only lately that we have been able to explain the cause of it, and ultimately to reproduce at will a demonstration of the process in operation under the microscope, a process which we propose to describe.

What we have said of the production of the blue spaces or cavities in the pancreas is equally an explanation of the cause of error, or rather of the existence of the spaces in other tissue

and organs, which probably do not exist during life. The application of what are known as hardening or fixing fluids, produces a certain almost imperceptible change in the volumes of the different elemental tissues of the body. The amount of this change, however, varies considerably in different elements, as, for example, between the protoplasmic element, or cells, and the gelatinous matrix which binds the cells together in groups. In consequence of this, when a tissue formed of these different elements is exposed to the same hardening fluid, whether alcohol, chromates, or Müller's fluid, the differential contraction in the volume of each respectively, causes, so to speak, a shrinking of the one element away from the other. In the pancreatic tissue under consideration, we saw that either the cell-formed acini or lobules shrink away from the gelatinous matrix, or from each other, so that spaces are left where formerly the tissues were in apposition. Such spaces are not, however, found only between the acini or between the acini and the gelatinous matrix of the mesentery, in which the gland-tissue lies more or less embedded, but also around the blood-vessels, ducts, and even the lymphatic vessels themselves. When a tissue has been prepared by fixing or hardening fluids (and we generally find the observers we shall afterwards allude to recommending this preliminary hardening as indispensable for a successful injection of the lymphatics), the consequence is that the cavities thus artificially formed are the first injected, and they are afterwards described as the lymphatics of the part. Now for the demonstration of the fact.

If we take the pancreatic tissue under consideration, stretch it firmly upon our histological rings, and apply the silver solution so as to demonstrate the locality and cells of the lymphatic vessels and gland acini, stain it slightly with hæmatoxylin so as to show the exact character of all the tissues, wash it and dis-hydrate with alcohol in the usual way, and clarify with oil of cloves, naturally enough the thin gelatinous membrane of the mesentery will be more quickly clarified than the smaller and outlying lobules of the gland which follow next in order. (We shall suppose that clarification is effected by pouring a few drops of oil of cloves on a sheet of glass upon which the reversed tambourine is placed, and gently heated from time to time).

The large lobules forming thick masses of acini, are the last to yield, and require slight heating from time to time, to complete the process; but when that process is all but complete, it is stopped while only a shade of haziness remains in the centre of the larger lobules, which are generally those nearest the head of the gland. The all but completely clarified disc must now be excised, and a bed of very thick varnish (or balsam) having been prepared for it on a slide, it is deposited thereon, a sufficient quantity of the same thick varnish placed upon the tissue, and the cover-glass applied and pressed down. If, now, the preparation be gently heated, a minute quantity of vapour will become developed from the centre of the incompletely clarified lobules, and from the centre of the axial group of blood-vessels, ducts, and lymphatics. The slide may now be placed under the microscope, and the whole process observed step by step. The vapour is noticed extending by little jumps, passing upwards along the outsides of the vessels as an immense beautifully branched air-bubble, whose ramifications appear black by the transmitted light of the microscope mirror. From the group of axial vessels it passes on to the periphery of the lobule, sending on its black slender processes, as at fig. 9, so as to form a network between the acini in the mass of the lobule and upon its surface, filling, especially, the very light blue spaces we have been considering some pages back. It does not travel within the lymphatic trunks and blood-vessels, but so completely surrounds or ensheaths them externally as to demonstrate satisfactorily, even to the most sceptical observer, the mistake of the whole hypothesis of lymphatic sheaths of blood-vessels, nerves, &c., upon which so many fabulous theories stand at the present day, in medical science. Here we have an exact reproduction of the errors existing in numerous researches on the lymphatics of organs, which can be watched, step by step, under the microscope.

These appearances are, however, not permanent, but may disappear in from a few hours to a few days, according to the amount of moisture left in the preparation after clarification and embedding in thick varnish. The more complete the vapour injection the more confused the image of the whole gland becomes, in consequence of the closeness of the vapour

injected network, and the irregular refraction of light, which adds to the confused appearances. On this account it is difficult to draw, even by the camera lucida, and as, moreover, the most correct drawing given by us would still be liable to suspicion of unconscious deception, we were fortunate in getting our friend Mr Fowke, of the British Medical Association, to photograph directly under the microscope, a preparation of pseudo-lymphatics such as we have described, and we think it well worthy of being represented in fig. 9, copied direct from the microscopic photograph by the lithographer. The photograph was taken a few hours after the preparation had been made, and the latter now shows no trace of the former vapour injection, which has become absorbed by the varnish. It will be understood that a satisfactory demonstration can only be obtained from an uninjured tissue; an ordinary cut section would not reproduce it, and one may vary infinitely the kinds of tissue experimented upon. The muscular abdominal wall of a mouse shows this process in action very well. In it the vapour passes around and between the muscular fibres of each layer, and thus, with the three layers of the transversalis, external and internal oblique, we have the lines of vapour lying across each other according to the direction of the fibres in each layer. In the walls of the urinary and gall bladders, the vapour injection follows the direction of the felted bundles of smooth-muscle fibres, so as to give an exact reproduction of certain drawings of the lymphatics in similar tissues.

Before passing from this question, let us offer a few examples of the errors we have referred to, which may be examined in proof of what we have advanced. In Ludwig and Zwarykin's paper on the lymphatics of the dog's kidney, figs. 15 and 16 reproduce the errors we have described, fig. 15 by injection, and fig. 16 as the natural result of an amazing preliminary process of rendering the kidney artificially œdematous by ligature of the ureter during life, leading naturally to the grotesque and grossly erroneous appearances described as lymphatics. In Tomsa's paper on the lymphatics of the spleen, all the nine figures are drawings equally erroneous. In Macgillivray's paper on the lymphatics of the liver, figs. 7 and 10 reproduce the erroneous artificial injections seen round the vessels of our preparations of

the pancreas; figs. 1, 3, and 9 are also errors. Of Leopold's paper on the lymphatics of the uterus, fig. 8 is entirely wrong. It does not show a single lymphatic, and fig. 7, while it shows the lymphatics correctly in its lower half, shows a large number of what he calls lymphspalten, lymphrohren, &c., which have actually no existence. As that figure is probably a section from one of the uteri on plate i., we may take the whole of the figures in that plate to be equally erroneous.

In an article on the structure of the uterus, in the *Medicinskt Archiv* of Stockholm, for 1867, Lindgren gives in fig. 2, plate iv., what he considers to be a view under a high power of the main lymphatics of the mucosa of the neck of the uterus, with lymphatic radicles proceeding from them. The two lymphatics lie parallel to each other, and between them lie a large number of branched cells in a transparent matrix. The blue injection fills the two lymphatics, and branches off from them along the spaces in which lie the so-called branched cells of the connective tissue. The drawing bears the stamp of honesty, as a reproduction of the appearances seen, and, taking these appearances as they stand, they form a complete demonstration of the theory that the radicles of the lymphatics are the cavities surrounding, or in which lie, the cells of the connective tissue. But the whole thing is a deception. The great blue cavities, shown as lymphatics, are not lymphatics, which have everywhere complete walls formed of endothelium, unlike the spaces seen in Lindgren's drawing, and the cells separated from their matrix, by means of contraction of their substance, have allowed a certain amount of the blue fluid to penetrate between them from the large spaces. We have referred at some length to this example, on account of its value as an instance of the artificial cavities we have described. This list might be greatly extended, but the examples we have quoted may serve to show the serious character of the errors which at the present day are accepted as facts.[1] It will

[1] While the present paper was in the hands of the printer, an article remarkably illustrative of the mistakes we deprecate has appeared in English. It is a research by Dr E. Klein on the lymphatics of the skin, and appears in the report of the medical officer to the Local Government Board. This research is illustrated by twenty coloured plates, seventeen of these being of the lymphatics of the skin of the Mammalia. In our opinion not one of the latter represents the lymphatic system. Nothing could be more beautiful than the manner in which the coloured injection has followed the course or sheaths of the blood-vessels, breaking up into small branches as they break up, exactly as in the deceptive

be, however, understood that all researches into the lymphatic system by the injection method are not equally fallacious. The plates in Teichmann's splendid work on the lymphatics, and Ludwig and Schweigger Seidel's drawings of the lymphatics of tendon and aponeurosis may be instanced as examples of apparently absolutely correct injections.

The general lessons taught by the existence of the errors we have pointed out are:—(1) the lymphatic system of the solid organs, which have only, as yet, been investigated by the injection method, may be considered practically unknown, and the former opinions erroneous; (2) the results obtained by the injection method ought never to be depended upon, except where they have been confirmed by the silver method.

It has been a great misfortune that the method of silver imbibition or injection should have succeeded to the methods of injection by mercury and coloured masses, as, had the order been reversed, there cannot be much doubt that at the present day little would have remained unknown of the lymphatic system. Unfortunately, silver solution can only be applied to surfaces, but the injection method may still prove a valuable auxiliary in showing the connection between lymphatics on opposite surfaces, when once these have been previously demonstrated by silver, so as to avoid the risk of future mistakes, in injecting non-lymphatic cavities.

At the present day, there is no reliable method for investigating the lymphatics of the pancreas, where the organ forms a solid mass, any more than in the case of any other special solid organ. If the injection method were to be used, or had ever been used, in that organ, it would only reproduce the erroneous and misleading appearances seen in fig. 9, and we are glad to have had the opportunity of demonstrating what the cause and character of those appearances would be before they had obtained a footing as recognised facts in anatomy, as is already the case with

process described by us, but in a fashion never found in the lymphatic system. In this way Dr Klein not only demonstrates lymphatics within the papillæ, where normally they never exist, but, by forcing the injection between the epidermic cells, he demonstrates lymphatic radicles in the sweat glands and hair follicles. In the text Dr Klein criticises in a not unfriendly manner the methods employed by us in a similar research, but it appears that he wrote either before or in ignorance of the existence of our extended and illustrated article on the lymphatics of the skin published two years and a half ago in the *Journal de l'Anatomie*. We only regret, in the interest of scientific truth, that we find occasion to answer his criticisms by such a wholesale condemnation of the method which has led astray so distinguished an histologist as Dr Klein.

the lymphatics of the other organs we have specially referred to. Although it may have appeared wandering from the special subject of this paper to have referred to them, yet the causes and examples of these errors are so general, and easily explicable, that we thought we could do no better, when showing the source of the errors, than give crucial examples in point from accepted researches of the most capable and renowned investigators in this department of research.

The results that we have obtained from the pancreas of rodents, in regard to the lymphatic system, can be easily and correctly applied to the solid pancreas of the larger mammals, and also to the large racemose glands throughout the body, by supposing the dispersed lobules compressed together in a mass. The following conclusions may therefore be taken as generally applicable throughout the series :—

1. *Accompanying the axial arrangement of blood-vessels and pancreatic ducts, one or more irregular efferent lymphatics will be found intertwining with the other vessels, and forming at times a network around these.*

2. *These efferent lymphatics are largest where the other vessels and ducts are largest, and they divide dichotomously with these vessels, as they pass to subordinate lobules of the glands.*

3. *As the lymphatics approach the individual lobules, they lie on the hilus surface, and give off branches which spread over each lobule on its external or peripheral aspect, and terminate either as broadened out cul-de-sac terminations, or in the general form of loops or meshes.*

4. *When* (hypothetically) *a racemose gland is surrounded by other tissues, the main efferent lymphatics pass directly from the gland to the surrounding tissues, instead of passing to the termination of the main duct of the gland.*

5. *In the pancreas, although the great chains of axial intrinsic efferent lymphatics tend towards the opening of the main duct, little of the lymph within them reaches that point, being drawn off from the axial lymphatics by extrinsic efferent branches passing off at nearly right angles from them. These pass either backwards along the mesentery to join the receptaculum chyli, in rodents, or at the superior border, to join the lymphatics lying along the splenic artery in man and the larger mammals, as described by Sappey and others.*

Description of Plate XXIV.

Drawings made by the aid of the Camera Lucida.

Fig. 1. View, under very low power, of several groups of collecting lymphatics, *a*, *a*, in the pancreas of the rabbit; *b*, small portion of intrinsic efferent lymphatics; *d*, *d*, lobes of pancreas; *e*, *e*, vessels and nerves passing through mesentery, $\frac{1}{6}$.

Fig. 2. View, under similar power, of the intrinsic efferent lymphatics in the pancreas of the rabbit, $\frac{1}{6}$.

Fig. 3. Enlarged view of a portion of the group of collecting lymphatics seen in the centre of fig. 1; *f*, *f*, points where the collecting plexus becomes continuous with the efferent lymphatics on the opposite side of the lobe. Only the lobules and acini are shown in this drawing, $\frac{1}{100}$.

Fig. 4. Greatly magnified view of a portion of fig. 3, showing the pancreatic cells, *g*, forming acini, the capillaries *e*, and their relation to the lymphatic *a*, $\frac{1}{300}$.

Fig. 5. Group of intrinsic efferent lymphatics from the pancreas of the rabbit, showing an extrinsic lymphatic *c*, passing off from the intrinsic efferent group to join the efferent lacteals lying within the mesentery, $\frac{1}{18}$.

Fig. 6. Enlarged view of a portion of intrinsic efferent lymphatics, breaking up into branches which pass between the pancreatic lobules to join the collecting lymphatics on opposite surface of lobe. At *c* is an efferent lacteal lying upon the lobe, into which the intrinsic efferent branch *b* subsequently opens, $\frac{1}{100}$.

Fig. 7. Lymphatic in course of development upon the pancreas of a young rat. The cul-de-sac termination *h* appears to be the peripheral extension of the lymphatic, while the cul-de-sac *i* appears to be the prolongation backwards of what will become an extrinsic efferent lymphatic, $\frac{1}{50}$.

Fig. 8. Greatly magnified view of the cul-de-sac *h* in fig. 7, showing its relation to the wandering cells *l*, *l*, blood capillaries *e*, *e*, and nuclei of peritoneal endothelium *m*, *m*. The cells *l*, *l*, are the so-called fixed branched cells of the connective tissue, which have no connection with the lymphatic, $\frac{1}{200}$.

Fig. 9. Pseudo-lymphatics, as they appear in the pancreas of a mouse, the dark-coloured ramifications being merely artificially and intentionally made channels, filled with air or vapour, which by refraction appears black. This view was photographed direct from the preparation under the microscope, by Mr Francis Fowke; *d*, pancreatic lobules; *j*, pseudo-lymphatic branches; *k*, main channel, $\frac{1}{100}$.

In the above figures the following letters apply equally throughout; *a*, collecting lymphatics; *b*, intrinsic efferent lymphatics; *c*, extrinsic efferent lymphatics; *d*, pancreatic lobes; *e*, vessels and nerves; *f*, junction of efferent with collecting lymphatics.

Figs. 7 and 8 are from preparations stained with silver and pyrogallate of iron; all the others are stained by silver, gold, and hæmatoxylin.

Fig. 1.

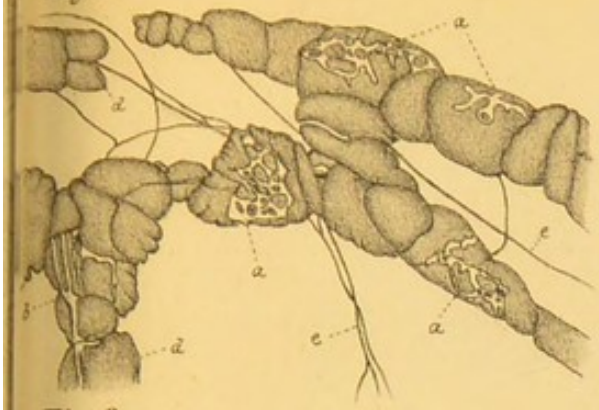


Fig. 2.

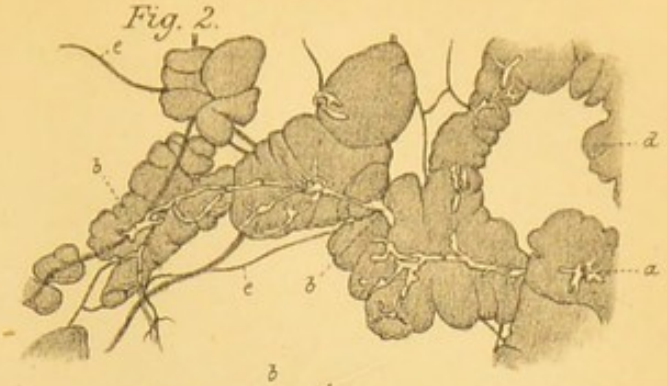


Fig. 3.

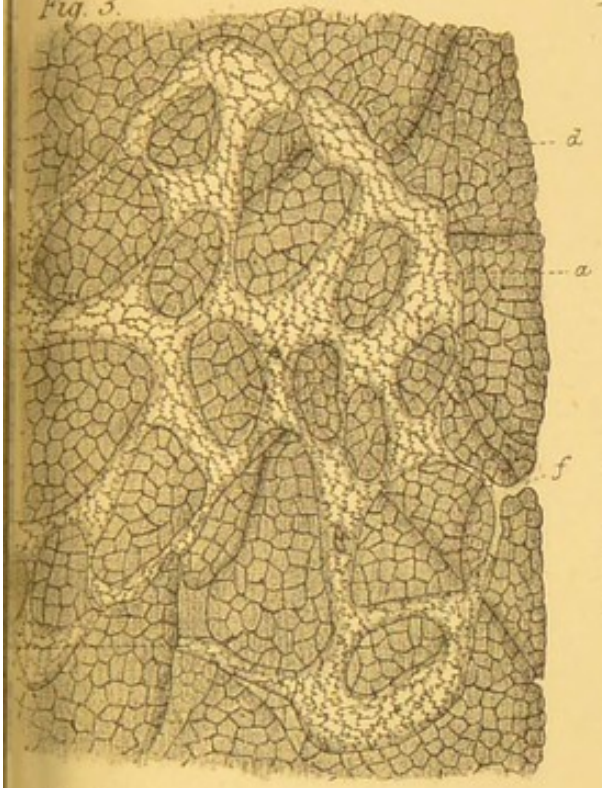


Fig. 5.

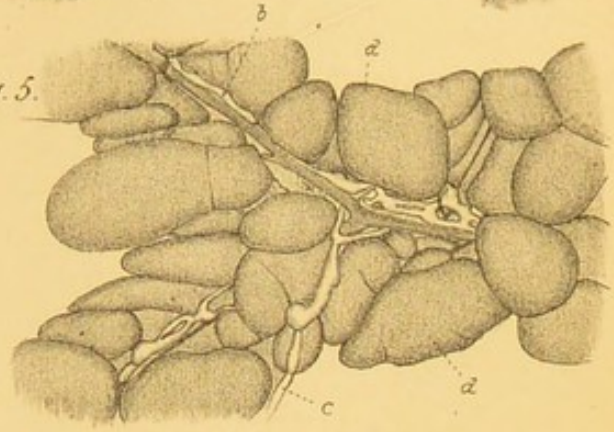


Fig. 6.

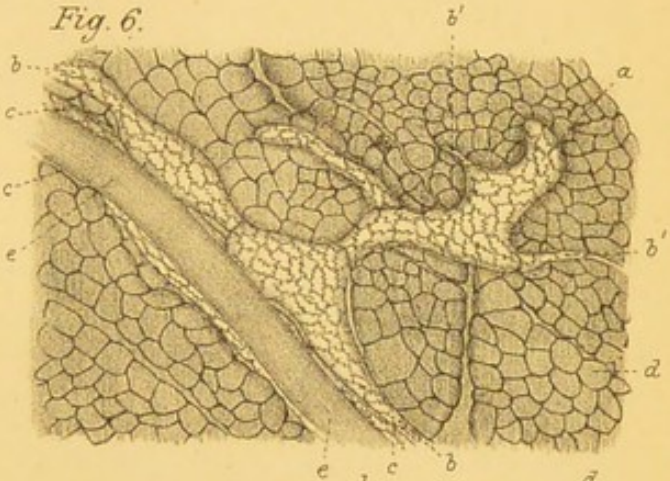


Fig. 4.

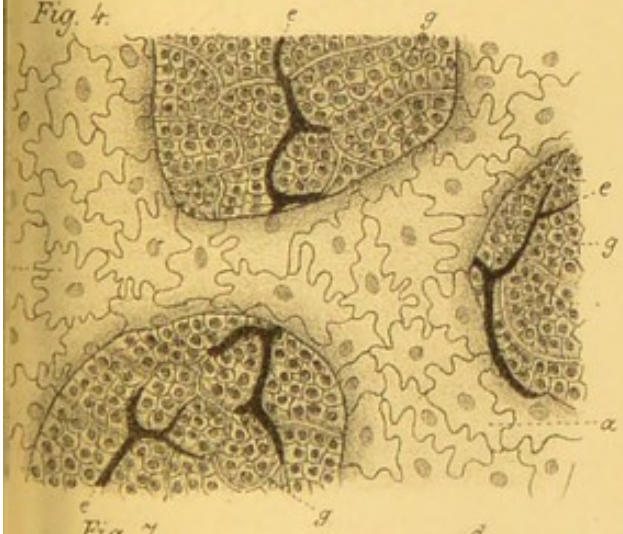


Fig. 8.

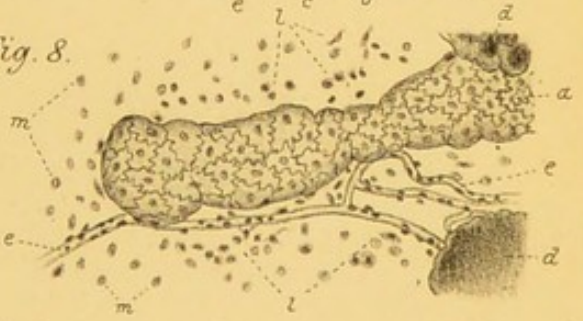


Fig. 7.

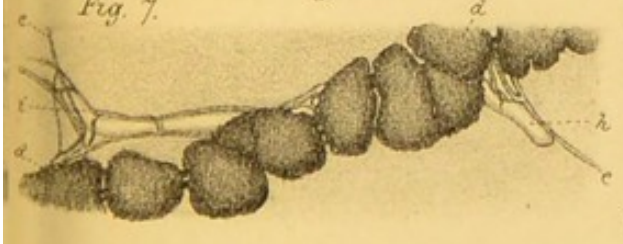
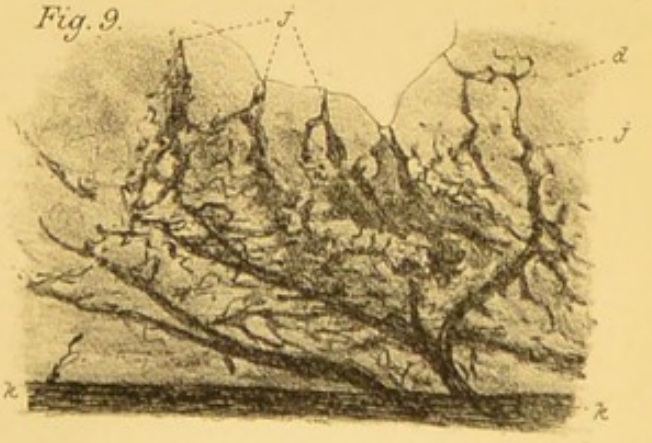


Fig. 9.



G. Huffam del.

F. Ruth, Lith. Edin.