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THE HEMOLYMPH NODES OF THE SHEEP

STUDIES ON HEMOLYMPH NODES I.

A. W. MEYER

FROM THE
DIVISION OF ANATOMY
DEPARTMENT OF MEDICINE
STANFORD UNIVERSITY

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CONTENTS.

INTRODUCTION

Although a number of species were investigated, this paper has purposely been limited to the sheep (*Ovis aries*), in order that a more comprehensive review of large numbers of hemolymph nodes could first be made. For even a slight familiarity with the subject makes it evident that it is not only necessary to examine many nodes in the different regions of the same animal, but also to examine large numbers in different animals, and perhaps of animals of varying ages as well. Moreover, a very comprehensive comparative study, although probably indispensable for the elucidation of some of the intricate problems of structure, function and development, usually introduces many additional and related problems which tend to obscure the issue regarding a single species. By first subjecting one species to a thorough examination the problem can also be better defined, many conflicting statements can be ignored, and much confusion avoided. It also seemed probable that an initial and careful comprehensive examination of one species would make it possible to decide with some degree of certainty whether, as recently and so often before reiterated, these organs in a given species are true hemolymph nodes or not, and whether a transformation of hemolypmh nodes into hemal or lymphatic nodes takes place. To this, and to some other questions, an unusually large collection of material and a series of observations of some magnitude seem to justify a definite, even if not a final or necessarily a conclusive answer.

Although there are many considerations which would seem to suggest that the term *hemolymph* is a misnomer when applied to these nodes, this designation, which was suggested by Russel and first used by Robertson [24], is retained throughout a part of this article in order not to introduce a discussion of terms at the very beginning. It is necessary to state, however, that the terms peripheral and central sinuses have been rejected altogether, because no one has shown that they are comparable to the corresponding structures of lymph nodes. The only true sinuses of hemolymph nodes are the radicles of the venous system; the venous lacunae of Weidenreich; which structurally are tremendously dilated capillaries, and which form an integral part of the vascular system of the hemolymph node. The so-called peripheral and central sinuses of the hemolymph nodes can much more properly be designated as subcapsular or marginal and central—in the sense of internal only—blood spaces or areas, than as sinuses, since they are neither in direct communication with either the lymphatic or vascular circulations, as a rule.

The sheep was also chosen as the first subject of experiment and inquiry, because almost all investigators of hemolymph nodes had studied them in this animal to a greater or less extent; because the nodes are much more numerous than in any of the other domestic animals studied; and since a convenient, inexpensive, and also an abundant supply of material was afforded by the abattoirs, where an unlimited number of embryos and foetuses of all ages could easily be obtained. In addition, however, the carcasses of several dozen new-born lambs, two lambs of about five weeks old, and two young sheep six to eight months old, received special scrutiny. Besides, several thousand carcasses were examined and many thousands inspected in the abattoirs in various parts of the country. This varied material naturally afforded an excellent opportunity for observations regarding the relation of sex, age, breed, pregnancy, states of health and nutrition, castration, locality, seasonal changes, and hygienic conditions in general, to the occurrence, size, number and position of these "enigmatical structures." Living sheep could also be subjected to close scrutiny, the carcasses inspected later, and a thorough examination made of the viscera, with a view to detecting any possible compensatory relationship between hemolymph nodes and other organs, in varying conditions of nutrition and of health.

Distribution, Occurrence and Appearance

Even a cursory inspection of hundreds of carcasses in the large abattoirs confirmed the statement that the lumbar subvertebral region is the place in which the hemolymph nodes of the sheep are by far the most numerous, and that their occurrence near the renal arteries has been over-emphasized. Since the lumbar region is especially accessible, these nodes were chosen as the object of special study. In all except very fat sheep they lie exposed to view, and can always be recognized as a whole, even if not individually, as hemolymph nodes by the unaided eye. Hardening the tissue containing them in formaline, as stated by Warthin [31], did not, in my experience, make them any more conspicuous. Moreover, since their conspicuousness in the fresh state is due to the contained blood, any fixing or hardening agent which does not increase the color contrast between fresh blood and the fat in which they lie can, in the nature of things, not make them more conspicuous except in so far as shrinkage of the surrounding tissues makes them more prominent. Neither did formaline help materially in distinguishing very small nodes from punctiform hemorrhages, since it affected both alike, even if not to a like degree.

Even if they be small, a reasonably accurate count of the hemolymph nodes can, however, be made without difficulty in most cases *in the fresh state*. From careful counts in several dozen carcasses, supplemented by inspection of several thousand more, it was found that in sheep of mixed breeds the number of nodes in the lumbar sub-vertebral region varied from a few to at most fifty or sixty nodes. Although, to be sure, averages can mean little because of the great fluctuations which exist, a fair average number in this region in young sheep, according to my observations, would be twenty to thirty nodes. The total number in the whole animal varied, however, from half a dozen to a hundred and fifty nodes in exceptional cases. Three or four hundred nodes of *macroscopic* size, as estimated by Robertson [24] and confirmed later by Warthin [34] as an average number, were never found, in the entire body, including the viscera, even in the most exceptional cases. It is possible, to be sure, that there are breeds or conditions which justify the above estimates; but all evidence obtained in mixed breeds of Merino, Shropshire and Southdown—and just sheep—in the East, in the Middle States, and in the West, makes this supposition very improbable.

In foetuses near term, in several dozen new-born and in four lambs four weeks to six months old, for example, in which a careful examination of the fat in all regions was made with the aid of a hand lens, a dozen to a few dozen nodes at most were found. In the new-born only from four to six may be present. From the examination of a large number of foetuses the statement that the younger the foetus the fewer the nodes that can be recognized as hemolymph nodes, seems justified; for it is difficult indeed, as a rule, to successfully identify macroscopically any nodes as hemolymph nodes in any region, in foetuses less than three to four months old. Nevertheless, a striking fact is the occurrence of a greater number of hemolymph nodes in lambs and young sheep. In abattoirs, in which occasionally almost a thousand sheep are slaughtered daily, it is quite possible, in spite of customary mechanical osteological conversions of mutton into lamb, to determine—not in individual cases, of course—whether lambs or sheep are being slaughtered, by a cursory inspection of a number of nodes present in the lumbar region alone. Moreover, such a differentiation is especially easy when lambs and sheep have been put into separate pens before slaughtering, thus avoiding a mixing of the individual carcasses. In fact, these differences are sufficiently marked, so that even the butchers are aware of it and not infrequently comment upon the fact. In one instance, for example, in which a lot of six thousand wethers were slaughtered on successive days, two of the butchers spoke of the smaller number of nodes found in "Western" sheep, adding that in the home or "Eastern" sheep more were to be found. Their observations were entirely correct, but their conclusions were faulty, for it was incorrect to infer that locality or castration were the causative factors in this difference. v Schumacher [27] also mentions the fact that they are more common in young sheep. As reported by Weidenreich [37] and Warthin [31], the belief of butchers that sheep fresh from pasture have more hemolymph nodes, also found confirmation; but this is likely explained by the fact that such animals are usually lambs, or largely lambs or young sheep, rather than by the state of nutrition of the animals; for such an influence of diet would be as remarkable as surprising and unlikely.

No definite grouping of the hemolymph nodes of the sheep was found to exist, although they occur more abundantly in fairly well-defined regions. Besides, in the lumbar sub- and para-vertebral regions they commonly occur in numbers in the para-rectal fat; more rarely near the renal vessels; and sometimes in a more or less complete series extrapleurally in the intercostal spaces immediately lateral to the vertebral column and near the origins of the great vessels, in close proximity to the lymph nodes between the cervical and thoracic portions of the thymus, and in the region of the head thymus adjacent to the para-thymus glands.

From the latter glands they are indistinguishable in the fresh state, as pointed out by Drummond [5] and as previously reported by the writer. They never were found on the diaphragm as reported by Warthin [34], on the parietes, or in the sub-scapular, axillary or inguinal regions as reported by Meek [17] in pathological conditions in man, and but seldom and only in very small numbers in the omentum and in the mesentery. The latter fact is in marked contrast to the occurrence of supernumerary spleens in the cat (*Felis domestica*) and dog (*Canis familiaris*) as reported elsewhere.* Those found in the thoracic cavity, in the cervical region, and especially in the intercostal spaces, were smaller, more spherical, and less prominent than those in the lumbar region. Moreover, large specimens were seldom found in any of these regions, the grouping was less distinct, and their presence less constant. The occasional intercostal hemolymph nodes not infrequently simulated small subpleural hemorrhages so closely that they could not be distinguished from them in the fresh state, by inspection alone, and they were too small and too flat for puncture injections.

In the cervical region their occurrence is far less constant than in the abdominal and thoracic regions; but they may lie anywhere between the thorax and the base of the skull. Usually one or even several nodes can be found, however, near the bifurcation of the carotid arteries; and it is not improbable that they have been mistaken for and described as para-thyroid glands. In this and in other regions they often lie so close to the blood vessels that Weidenreich's [37] conclusion that they never lie in direct contact with, even if in close proximity to them, is not confirmed; nor can I confirm v Schumacher's observations that they usually lie near large lymph vessels, except in so far as large lymph vessels are present in the lumbar region. It should be added, however, that identification of these small cervical nodes was not always made by means of injections, but by microscopic examination and from gross appearances. Since, contrary to the statement of White [39], the latter means of identification is not wholly reliable, the above conclusions are open to question as far as the occurrence of nodes in the cervical region is concerned.

No correlation between the size and the number of hemolymph nodes in one region with those in another region, or with the size, number and condition of the lymphatic nodes, or with any other condition, could be established. Neither were they found enlarged in cases of pneumonia, deep jaundice, tuberculosis, or severe infections with *Oesophag-*

*See appendix, V.

ostoma columbanum or streptococci. Pregnancy or castration in themselves seemed to have no effect upon them. The same is true of differences in sex, breed, variations in fatness or poor nutrition, the locality from which the sheep were obtained, or recent hygienic conditions under which they were kept. These conclusions confirm Weidenreich's [37] observations in these respects. To be sure, the implication is not that they are never or can never be affected by all or any of these things. In case of the human hemolymph nodes, for example, it will be recalled that Warthin [33] reported a definite relationship between the occurrence of hemolymph nodes and certain blood diseases, and that Meek [17] also found them present in various pathological conditions in man.

While the above statement gives the usual distribution, individual nodes may, however, occur *anywhere in the fat near the viscera, from the base of the skull to the coccyx.* Although no thorough examination was made, none were ever seen between the muscles of the extremities, as stated by Crescenzi,* for bovines. *No node was found to be constant in position, in size, or in occurrence.* The only constant characteristic, aside from questions of structure and function, is their remarkable variability, and their constant occurrence in fat. It is more than likely, however, that the latter fact is without special significance; and, as in the case of the lymphatic nodes, it is probable that this association between hemolymph nodes and fat has been entirely overemphasized, or misinterpreted even, for the regions in which hemolymph nodes occur are those in which fat is normally present in all animals. Besides, a similar association exists between the main vascular, lymphatic and nerve trunks, sympathetic ganglia, and lymphatic nodes, the kidneys, accessory spleens, etc. Besides, many of the pevertebral nodes are not imbedded in fat but can be moved with the overlying peritoneum.

The variations in the size of hemolymph nodes were as great as those in number, the extremes lying between those invisible to the unaided eye and rarely large oval nodes one or two centimeters long. Both the largest and the smallest nodes were found more frequently in the lumbar region, but it must be remembered that this region was examined much more carefully and extensively than any other. In the cervical and thoracic regions they were often quite spherical, and only from two to four millimeters in diameter. The smallest nodes were always more globular, and, as already stated, often simulated punctiform hemorrhages very closely. The larger ones, on the other hand, were generally

*Crescenzi, L.: Contributo allo studio dei gangli ematici nei ruminanti. *La Clinica Veterinaria.* Anno 29, 1906.

flattened on the sides sustaining the greatest pressure, and resembled lymph nodes somewhat more closely in shape. Occasionally a group of nodes, or a single node, was found, which looked like a mass of beaded blood vessels, the contiguous walls of which had fused. In other cases isolated nodes were found from which a beaded vessel or vessels (figs. 1 and 2) closely simulating a lymphatic vessel in form, but dilated with blood, could be seen plainly for some distance from the node, as noted by Weidenreich. In still other instances the appearance was that of a blood vessel of somewhat varying calibre, which formed a loop with local thickenings. Pressure upon these nodular areas of the vessels would easily bring about complete collapse in the area of pressure, followed by subsequent refilling with blood. This effect is in marked contrast to the results of pressure upon hemolymph nodes of any size and location, for these could never be reduced appreciably in size even if subjected to strong pressure. Instead of collapsing they would invariably burst. In some cases these nodular complexes were formed by a number of small nodes which lay in close proximity to each other, or had become more or less completely fused. (Figs. 3 and 4.) Further reference will be made to these later.

Since the descriptions of the external appearance of hemolymph nodes found in the literature on the subject are quite adequate, this matter will be discussed here only in a purely incidental way. Intra vitam and not long post-mortem hemolymph nodes usually have the dark color of moderately venous blood. Rarely, however, light cherry red and scarlet nodes are seen. These are generally small, and lie immediately beneath the peritoneum. The prevailing color in fresh carcasses, however, varied from a bright red to dark chocolate, or even dull black. As pointed out by Robertson [24], this variation is probably chiefly due to differences in the degree of post-mortem oxygenation of the blood within the node. That this assumption is correct was shown by the fact that dark-colored nodes quickly turned to a bright red color when exposed to the air, provided of course that access to them was not made too difficult by the presence of a thick overlying layer of fat, or by the drying of the overlying peritoneum and capsule. This change to a bright color upon exposure is greatly accelerated by stripping the peritoneum overlying the node, or, still better, by exposing the node to pure oxygen. That this color change progresses gradually from the exterior to the interior can also be shown by sectioning nodes which have been exposed to the air or oxygen for varying intervals of time. Such sections show that the outer bright-red layer varies in thickness within limits, with the length of exposure to oxygen, for example. It was also noticed that in winter the color of nodes *in situ* on the carcasses was darker than in summer, which difference was evidently due to the fact that the severe cold of an open abattoir in a northern climate retarded the process of spontaneous post-mortem oxygenation, by making the overlying layers more impervious to the oxygen of the air, or by affecting the rate of chemical interchange. Ordinarily the change in color begins immediately after evisceration, and is noticeable at first in the smallest and most exposed node. However, the rate of the change of color is also dependent upon the presence and the thickness of the surrounding layer of blood in the peripheral blood space. That not all nodes change from a venous color when the abdomen is opened to a bright red upon exposure to the air later may, of course, be due to these and to other facts, as well as to variations in thickness of the capsule and the overlying fat. An examination of several hundred carcasses immediately after the abdomen was opened showed that the variations in color are very slight at this time. Very occasionally, however, a small scarlet node is seen among a group of venous-colored ones, which fact can probably be explained by differences in the circulatory conditions within the node. The peculiarly mottled appearance of nodes which often does not become very evident until fixation and hardening, can likewise be explained satisfactorily by peculiarities of structure. In these latter nodes, for example, the peripheral blood space is encroached upon here and there *intra vitam,* and often so as a result of shrinkage during fixation and hardening, by the lymphatic tissue—usually by follicles—and may hence be completely obliterated at some places. Wherever this occurs a gray patch or streak bordered by a deeper-colored area will be found on the surface. For like reasons the entire absence of the peripheral blood space before or after fixation might give a whole node a grayish color, or if absent over but a part of the node it might result in an appearance which might suggest that one portion has the character of a hemolymph and the other that of a lymph node, or that there are mixed or composite nodes. Besides these factors, still others, to be discussed later, have an important bearing upon the question of external appearance.

Exposure of hemolymph nodes to carbon dioxide, on the contrary, never produced the slightest visible changes in color. Such as were chocolate-colored when exposed to this gas remained so. The same was true if they were of any other shade. But if nodes thus exposed for a short time were still sufficiently fresh, subsequent exposure to oxygen would result in a change to the usual bright-red color of freshly coagulated blood. Exposure of fresh hemolymph nodes to gaseous hydrogen sulphide in pure or mixed form, or to weak or concentrated solutions of the same in water, in alcohol, and to an ammonia-alcohol mixture containing hydrogen sulphide would, on the contrary, invariably result in a rapid change to an intensely black color. It was also noticed that exposure of cut nodes in water saturated with hydrogen sulphide caused a more rapid change to a deeper black than exposure in a solution of 80 per cent alcohol similarly saturated. Since the latter solution contains much more hydrogen sulphide than the former, it is apparent that the slower and less pronounced color change in nodes immersed in it is probably due to the effect of shrinkage and hardening, and perhaps also to the dehydrating effect of the alcohol. If they were exposed to the action of diluted instead of concentrated gaseous hydrogen sulphide, a very gradual change to green followed that to black, thus giving the nodes a grayish color, as described by Warthin [36]. Furthermore, if the freshly cut surface of a node was thus exposed, these changes were much more rapid, and the green was frequently so deep that it simulated black. Solutions in water of hydrogen sulphide and of the yellow ammonium sulphide, in various concentrations had a similar action. However, if immersion of the nodes in a solution of sulphide, free from oxygen, was complete, no change from black to green took place at all. The black color remained permanent, and was retained in the alcoholic hardening solutions, as well as in all later processes. These facts suggest, of course, that the change from black to green is indeed an oxidation change of some sort; which conclusion is further confirmed by exposure of nodes to pure hydrogen sulphide, with subsequent exposure to pure carbon dioxide or to oxygen. Nodes kept in pure hydrogen sulphide, or subsequently exposed to carbon dioxide, remained black for days.

As in the case of the color changes due to oxygen, the color change due to these pure gases or mixtures of them was a very superficial one, even after prolonged exposure—for six to eighteen hours—to either gaseous hydrogen sulphide or to a solution of the same. Such exposure never resulted in a color change beyond the depth of one or two millimeters, even on the surface of a freshly-cut node. At greater depths into the node the original color was retained, even for twenty-four hours or more, until maceration and putrefactive changes produced the usual results. The same was true regarding the apparently permanent green color which followed the change to black. If fresh nodes or pieces of the same were immersed in 95 per cent alcohol saturated with hydrogen sulphide, they would undergo the usual color changes; but after weeks or months of immersion it was found that both the black and the succeeding gray color had completely disappeared, so that the tissue had the customary gray color characteristic of lymph nodes or of lymphatic tissue fixed in pure alcohol. This change in color occurred even if the alcohol, at the time when the tissue had lost the black color which was acquired through exposure to hydrogen sulphide, *still contained hydrogen sulphide in considerable quantity.* Sometimes the alcoholic solution contained a small quantity of a dull black deposit after the nodes had lost the black color. This deposit or precipitate, which appeared only after weeks of immersion, was finely granular, and quickly sank to the bottom after shaking.

The action of hydrogen sulphide was comparable to that of oxygen, then, in that its penetration was merely a superficial one, though the color change was apparently more rapid in the case of exposure to hydrogen sulphide than to pure oxygen. This was true, both when a change from dark venous to red, or from a sulphide-produced black to a green color, was concerned; and it may be *possible,* as has been suggested, that the jet-black color of nodes, occasionally found *post-mortem* in sheep, may be due to the action of hydrogen sulphide formed in decomposition (?) or from other tissue changes.

In writing of the color changes following exposure to hydrogen sulphide, Warthin [36] stated that "The important point is the fact that in the hemolymph nodes there may be such a quantity of iron-containing pigment that these nodes may take up hydrogen sulphide and become grayish or black in color, *while the spleen remains unchanged."* (The italics are the writer's.) Warthin further stated that the combination of hydrogen sulphide and iron is probably the cause of pseudo-melanosis, and added in a footnote that "The exposure of hemolymph nodes obtained from cattle and sheep produced results exactly like the autopsy findings in the above cases. The nodes quickly became discolored, some becoming uniformly grayish-black or brownish-black, others becoming spotted or streaked. The discoloration thus produced lasted for a longer time than that seen in human autopsy cases." The color changes reported by Warthin have been confirmed only as far as gross appearances are concerned, for frequent microscopical examination of nodes which had turned black spontaneously or upon exposure, never revealed a picture of pseudo-melanosis, nor was a single test for iron in either the ferrous or ferric forms ever positive. But I am well aware that these tests may not be relied upon with certainty, and, moreover, that the iron may be in the organic form and hence nevertheless present. Consequently, it might still be true that the change from red to black which is produced by exposure of nodes to hydrogen sulphide, although not directly attributable to, might yet be accompanied by the presence of an excess of iron in hemolymph nodes. Although Warthin's conclusion regarding the excess of iron in hemal nodes relies partly upon these color changes, it is interesting to report that the fresh blood of any animal turns black almost instantly on exposure to hydrogen sulphide. Evidently, then according to Warthin's reasoning the blood of a number of domestic animals must contain more iron even than the hemolymph nodes of these same animals: a conclusion in direct contradiction to that of Warthin. Moreover, it was found that not only the blood, but also the *spleen*, muscle, liver, blood vessels—in fact any fresh vascular tissue—would undergo identically the same color changes, and do so even more rapidly in some cases than the hemolymph nodes themselves. From these observations it is clear then that the hemolymph nodes very likely undergo these color changes when exposed to hydrogen sulphide, simply because they are very vascular; and not necessarily, as assumed by Warthin, because they contain an excess of inorganic iron. To be sure, Warthin may be correct in assuming that it is an iron compound which produces these changes. That is not denied here. What concerns us is whether or not these color changes necessarily indicate a greater content of iron on the part of the hemolymph nodes. That this is not the case the facts cited seem to establish beyond all question. To be sure, if, as has been claimed, hemolymph nodes are the seat of blood destruction, with resulting decomposition of blood pigment, it is possible, of course, that they do contain a large or even a larger amount of iron; but the above action of hydrogen sulphides is manifestly not a satisfactory criterion. Moreover, in another article Warthin [32] contradictorily enough reported that he found but a slight or no reaction for hemosiderin in hemolymph nodes. The latter observation, which is contradicted by some investigators, agrees entirely with the findings of the writer; and it seems possible, although perhaps not entirely probable, that differences in the freshness of the material may at least in some measure account for these discrepancies. v Schumacher [27] also emphasized the rare and sparse occurrence of pigment in the hemolymph nodes of sheep.

Although there are great variations in the quantity of blood contained in hemolymph nodes, their vascularity, as judged by external appearances, did not seem to be affected by the rate or thoroughness of bleeding during slaughtering. In sheep which were bled slowly from one carotid or jugular only, or in others which were bled rapidly from both carotids and jugulars by severing all the ventral soft parts of the neck, the nodes were always found turgescent. If death occurred without bleeding, there was no marked difference save that the veins draining the nodes seemed a trifle fuller, and the color of the nodes a little darker; which latter fact may perhaps be accounted for by defective aeration of the blood during death. This failure of hemolymph nodes to become paler during death by bleeding stands in striking contrast to what is noticed in many lymph nodes. v Schumacher [27] also emphasized the effect of bleeding upon the color of lymph nodes and pointed out that lymph nodes in foetuses in which free bleeding is secured by severing the cord, are always much paler than those in foetuses which are killed without such bleeding. The significance of these differences in behavior between hemolymph and lymph nodes will be discussed in connection with the circulatory condition in the nodes.

Since the vein draining a node is usually dilated with blood, it can frequently be seen without difficulty on inspection. In almost any carcass one or two nodes can be found the veins of which are plainly visible from five to ten centimeters or more from the node, even if the latter is only a few millimeters in size. Anastomoses with the veins from adjacent nodes are quite common. The artery, on the contrary, is not seen on inspection alone, no matter how turgescent or large the node, or how prominent the vein. Pressure upon the nodes generally results in rupture, without visibly dilating the vein or the artery or decreasing the vascularity of the node. This inability to force out the blood by means of external pressure on the nodes was quite puzzling, until the peculiarities of their structure supplied an explanation.

Lymphatic and Vascular Relations

Lymphatic vessels were never detected or dissected out in the hilus of a hemolymph node however large, although it was often an easy matter to see and find them near a lymphatic node of much smaller size. Frequently lymphatic vessels of varying calibre and conspicuousness could be seen near hemolymph nodes, or even in contact with them; but even in the case of very large nodes no communication was ever noticed between them and the nodes, upon the most careful examination. Hence these observations confirm the conclusion of Weidenreich [37] in this regard and contradict Helly's [11] statement to the effect that lymphatic channels can be seen to enter the hilus of the hemolymph nodes, although not found within the node, and that nodes which lie near large lymphatics contain such vessels. Aside from the difficulty, or impossibility even, of seeing a hilus macroscopically in most of these nodes, it is well to remember in this connection that Helly did not state how the lymphatics were identified positively as such. Moreover, small lymphatic channels might be confined wholly to the capsule of the node or its large trabeculae without necessarily establishing any charasteristic connection with the parenchyma of the node itself. Helly's conclusions and observations are largely confirmed, however, by Forgeot [6 and 7] and v Schumacher [27]. The former described nodes in the lumbar region of goats and sheep, and under the pleura and pericardium of cattle, from which blindly-ending lymphatic vessels of varying form extended. In some cases these vessels returned to the neighborhood of the node and were markedly distended with red lymph. The several vessels were found to end blindly independently, or to be joined into a network which surrounded a node the main branches from which formed a common trunk, which also ended blindly. An examination of Forgeot's articles show very clearly, however, that he has included "red" or hermorrhagic lymph nodes, *i. e.*, lymph nodes with erythrocytes in the sinuses, among hemolymph nodes, an error against which v Schumacher rightly warns, and which has undoubtedly been responsible for much of the confusion. Nevertheless v Schumacher, who largely accepted and confirmed the conclusions and observations of Helly and Forgeot, basing his conclusions on an examination of adult and embryological material from the sheep, emphasized the fact that hemolymph nodes usually lie in the neighborhood of large lymph vessels, and that branches of the latter frequently extend considerable distances into the capsule without piercing the latter or coming into relation with the marginal sinus. Sometimes such lymphatic vessels were, however, seen to join the sinus, and these nodes v Schumacher excludes from hemolymph nodes, on the opinion of others. Nevertheless v Schumacher proceeds to state that all manner of transition forms between lymph and hemolymph nodes exist as far as the relation of the lymphatics to the nodes are concerned, and describes nodes with lymphatic vessels in process of obliteration in different places within and without the nodes, much as Helly has done. v Schumacher also came to the conclusion that hemolymph nodes are only rudimentary or undeveloped lymph nodes which have lost their connection with the lymphatic system as a result of the obliteration of the lymphatics at various points. Consequently, according to v Schumacher, a lymph node may become a hemolymph node by losing its lymphatics, and can again become a lymph node by regaining them. Since these conceptions and conclusions are based partly upon developmental considerations, they will be discussed especially in a separate article on this subject; but it may here be noted that the conclusion that a true hemolymph node is merely a lymph node devoid of lymphatic vessels and sinuses, is only possible upon a fundamental misconception of the real character of the vascular circulation of true hemal nodes.

These considerations at once raise the question of the relation between hemolymph nodes and the lymphatic system. In order to determine whether a direct connection exists between them, injection methods seemed to offer the best and perhaps the only positive proof. Since an abundant supply of material could be found in the carcasses of sheep, the abattoir again suggested itself as an especially good field for this work. Hence many hundreds—thousands—of injections were made directly into the nodes upon the fresh carcasses. Occasionally this was within ten minutes or a quarter of an hour after death. The results obtained by means of puncture injections with a hypodermic syringe into the nodes practically undisturbed *in situ* in the lumbar region, were surprisingly uniform. As node after node on the hanging carcasses was punctured and injected, the invariable result of the injection of a few drops of methylene blue, Prussian blue, India ink, etc., was the almost immediate appearance of the fluid in the *vena cava,* or occasionally in the common iliac veins. Since the appearance of even a fraction of a drop of the colored solutions or suspensions quickly became evident in the collapsed veins, it was, to be sure, an easy matter to decide between success and failure. To avoid error many hundreds of injections were made into nodes of various sizes, shapes, colors, and positions in the abdominal and thoracic cavities of sheep from a few weeks to four or five years old. By far the greatest number of these injections were made on the lumbar group, however.

v Schumacher, who agreed with Weidenreich and the writer as to the injections of the vein by means of puncture of the node, however, emphasized the fact that he obtained such a result by no means in every case, but only when one of the intra-nodal veins was pierced. In numerous instances v Schumacher found that only the sinuses in the interior of the gland were filled, and whenever the vein leaving the node was injected v Schumacher says he could always tell by serial sections that a *vein* in the interior of the gland had been punctured by the needle, so that the injection mass could pass directly into the large collecting veins at the hilus.

I am at a loss to account for v Schumacher's failure to inject the veins of hemal nodes in practically all cases by means of puncture of the node. To be sure, the choice of nodes is of primary importance, and no one can be positive that he has selected a hemal node if he fails to inject the vein or lymphatics. Besides, no one will doubt that a *venous radicle* must have been penetrated by the needle or its wall penetrated by the injection mass, if the vein leaving the node is filled; but after examining numerous nodes which had been injected by puncture, I must entertain the gravest doubts as to the possibility of determining the exact point of puncture of a venous lacunae. For even the smallest needle or capillary glass tube bears a marked disproportion to the size of the numerous venous radicles in a node. Besides, it would be likely to pierce so many —or none—for most of the hemal nodes are small, as v Schumacher rightly emphasizes. Hence locating the exact point of puncture of the wall of a particular venous lacuna through which the injection mass is supposed to have entered, must be open to serious error, even if possible. Moreover, veins are not always present within a node; venous lacunae or sinuses take their place frequently.

It was generally very easy to see the injected fluid pass from the hemolymph node to the *vena cava,* pushing the blood in the vein leaving the node before it. As more fluid was injected, a steady stream, sometimes inter-mixed with blood and bubbles, could be seen passing to the *vena cava* or the iliac veins. Frequently the injected fluid would pass in a somewhat roundabout way to reach its destination in the large veins; and occasionally it would leave the node in two directions from the same or from different points. Clamping of the vein on its way to the *vena cava* led to rupture of the node upon further injection, but not to the injection of lymphatics. Anastomosing veins would occasionally become filled with fluid; but several times only did an adjacent or distant node seem to change its color very slightly. For a time this inability to inject one node from another in the fresh hanging carcasses was very puzzling, for it was evident that the veins from several nodes not infrequently joined on their way to the *vena cava.* Besides, it will be recalled that Weidenreich [37] reported that it was easy to inject a node from a neighboring one. This apparent contradiction of Weidenreich's results was emphasized further by the fact that it was never possible to inject secondarily smaller hemolymph nodes which lay in actual contact with the larger ones, from which the injection was made. This was true, even when it was afterwards found by injection of differently colored fluids from the individual nodes concerned that they were drained by branches of the same vein. Naturally the fact that small veins draining hemolymph nodes are usually full of blood, suggested that the failure to inject one node from another probably was mainly due to the presence of blood, and to some condition within the nodes which prevented a re-flow of this blood to the arterial side. Such conditions alone, it seemed, could explain the above facts, for a system of filled tubes could naturally not receive more fluid without further distention of the vessels of the node, or of leakage or rupture. Consequently, the fat in the lumbar region, including the great vessels, containing especially numerous nodes, was excised *en masse,* as Weidenreich had done. By means of puncture injections of the nodes it was now found a very easy matter to force the injected fluids into adjacent or occasionally distant nodes, even if the flow toward the excised *vena cava* was unobstructed. Hence Weidenreich's observations were easily confirmed by using similar methods. But these results now required an explanation; for why should there be such difficulty in injecting one node from another with the nodes undisturbed *in situ* in the carcasses? Although I have no wholly satisfactory explanation, it is probable, it seems to me, that the manipulation incident to excision of the tissue emptied the veins which drained the nodes, sufficiently to permit the injected fluid to enter. Besides, as shown by the many points of leakage when injections were made into nodes contained in excised tissue, the numerous anastomosing veins which are severed during removal of the tissue also gave opportunity for relief of pressure in several directions. Hence the condition of a system of closed tubes partially or totally filled with fluid no longer existed. It is evident, of course, that it is not essential that the vein which drains a node be completely full of blood to prevent the injected fluid from entering the node, or, on the contrary, that it and the node must be completely empty before any injection mass can enter. All that is manifestly necessary is that a sufficient quantity of blood be contained in the main or in the anastomosing veins to completely fill, or perhaps to sufficiently distend, the venous spaces within the node to make further injection impossible. For in case of a small node even a fraction of a drop of blood in advance of the injected fluid might effectually prevent a successful injection, unless the veins and venous spaces within the node are partially or totally empty. Since these conditions probably obtain more or less in excised tissue, it was possible to inject a series of three or four nodes lying in a row from one of their number, with a few drops of fluid. It was also occasionally possible to inject incidentally a network of minute retro-peritoneal veins—not lymphatics—from nodes in the excised tissue; although such a result was never obtained in the many injections made directly into nodes *in situ* on carcasses. These veins, which after being injected formed a network of the greatest delicacy, were so fine that they were barely visible to the unaided eye.

In a large series of puncture injections, it was never possible to inject a lymphatic vessel or a lymph node from a hemolymph node unless the point of the needle pierced the hemolymph node, thus allowing the injected fluid to enter the retro-peritoneal tissues. A series of puncture injections made into the surrounding tissues and body wall proved equally ineffectual for injecting the hemolymph nodes or blindly ending lymphatics. Both lymphatic vessels and lymph nodes, on the contrary, were injected comparatively easily by either of these methods, and injections into lymph nodes always led to the well-known results. The usually characteristically beaded lymphatic channels were instantly apparent, other lymph nodes were injected, and the injected fluid soon ran out of the cut end of the *thoracic duct* in the cervical region, just as it had previously run out of the *vena cava* in the thoracic region. Nor did the injection of some unusually large—3-4 mm.—lymphatic channels occasionally seen in the lumbar region, result in the injection of anything but lymph channels and lymph nodes. In three carcasses, for example, especially large lymph channels three to four millimeters in diameter lay superficially among a group of hemolymph nodes in the lumbar region. The injection by puncture of methylene blue into these large lymph vessels, even when the thoracic duct had been clamped and lymph nodes on all sides were injected both peripherally and centrally, resulted negatively, as before, as far as injection of hemolymph nodes is concerned, even when high pressure was used. Hemolymph nodes, on the other hand, were never injected, even if they lay side by side with or directly upon or beneath injected lymph nodes; and not a trace of the injection was ever found in them upon microscopical examination.

The facts just cited, together with others to be considered, prove conclusively, it seems to me, that, as maintained by Weidenreich [38], the circulation of true hemolymph nodes, exclusive of the capsule at least, has no connection whatever with the lymphatic system. They prove further that there probably are no nodes of a mixed type having sinuses common to the vascular and lymphatic systems, and that consequently the word hemolymph is a misnomer when applied to these nodes of the sheep. Since, then, all these so-called hemolymph nodes are solely in direct connection with the vascular system alone, and contain no lymph spaces, the designation of hemal node first used by Clarkson [2] is preferable, and will hence be used in this discussion.

Since these results seemed to indicate that hemal nodes are entirely independent of the lymphatic system, injections were also made from the abdominal *vena cava* and aorta, in order to determine whether the spaces found in hemal nodes are in direct connection with these vessels. Such injections were made on two lambs seven to eight months and four to six weeks old, and six foetuses from four to five months old. Three of these lambs were bled to death. In case of the other lamb and the foetuses, some relief from back pressure due to the contained blood was secured by incision of the *vena cava*. Injections of filtered carmine and Prussian blue gelatine were made directly into the abdominal portions of these vessels. The carcasses were kept immersed in warm water and a high uniform pressure (200-250 mm. Hg.) was maintained continuously for a period of one-half to three-fourths of an hour. Besides this, the injection was limited as far as possible to the lumbar region by clamping the main branches of the great vessels. Since the injection mass was thus limited to a small field, the behavior of the hemal and lymphatic nodes could be observed more carefully during the progress of the injection. Although at first it was attempted to mark the site of some of the typical hemal nodes, by transfixing the adjacent tissue with a small pin, the high pressure used on the filtered gelatine caused considerable leakage at the point of puncture, which threatened to obscure the field. Hence this method was abandoned.

Upon completion of the injections, the bodies of the foetuses were cooled, and fixed, *in toto*, in formaline. In case of the lambs, the whole lower half of the body was likewise preserved, in order to leave the area under observation undisturbed. All nodes were later dissected out by means of a lens when necessary, and cut serially in paraffine. It was found advisable to remove all nodes found in a given area, because of the difficulty, or impossibility even, of distinguishing injected hemal and lymphatic nodes *by external appearances*.

During the course of the injection it was disappointing to notice how quickly even the smallest lymph nodes, distant often from the place of injection, would quickly change their color due to entrance of the injection mass, while much larger near-by typical—as judged by external appearances—hemal nodes showed no color change whatever. That this apparent failure to inject the great majority of the hemal nodes was not due to a faulty technique, was shown by the fact that the whole carcasses were so well injected, in spite of ligation of the main branches of the great vessels, that even the small parathymus glands had changed their color and were found on microscopic examination to contain much injection mass.

Before giving a statement of the results obtained by these injections, a rough sketch of the microscopic structure of the more usual hemal nodes seems advisable. In the majority of these nodes, a view of a section made in any plane presents the following well-known appearances. Externally there is a fibrous capsule varying considerably in thickness in the same and in different species, beneath which there usually is found a continuous or, oftener, a discontinuous so-called peripheral sinus, of inconstant width, which generally contains more or less blood and lymphocytes. As a rule, by far the larger area of the node is composed of lymphatic tissue, containing the well-known blood sinuses, or better, blood islands or spaces.*

A definite cortical and medullary portion, or an arrangement of the lymphatic tissue into medullary cords, was never seen. The arteries are inconspicuous as a rule, and the veins frequently still more so. In addition to the inconstant, large central venous spaces in direct connection with veins more or less evident partially collapsed or open spaces, the so-called venous lacunae of Weidenreich may also be present throughout the parenchyma. When evident they are usually best seen near the periphery of the parenchyma, and frequently contain a small number of erythrocytes and lymphocytes, the former often being found in varying states of degeneration. The blood islands and spaces other than the peripheral or subcapsular blood space, and the main arteries, often have a more central position, however; but the veins generally branch soon after entering the node and traverse the peripheral sinus, or better the marginal or subcapsular blood space. Although rarely noticeable throughout the node, the trabeculae are few and small, as a rule. The coarser reticulum is plainly visible under low-power magnification, and is more evident in the partially filled blood spaces, especially in the marginal one. Since this sketch is to serve merely as a basis for a statement of results obtained by injection, a more detailed and accurate statement of structural variations and relations is deferred.

Injections made from the *vena cava,* and by puncture from a node, always gave a very characteristic and uniform result. No matter how little of the injected fluid gained access to the node, it almost always lay as an exceedingly irregular mass, often of minute breadth, which zig-

*Since the blood islands are usually masses of erythrocytes contained in the lymphatic tissue, rather than empty spaces temporarily devoid of blood, although such undoubtedly occur, the term blood space might preferably be restricted to the empty areas, which once contained blood islands; and since neither of these nor the peripheral sinus are really such, the term sinus had better be restricted to the dilated venous radicles in direct connection with the circulation.

zagged about, but small amounts of which were but seldom found in the peripheral or central—in the sense of internal—blood islands or blood spaces. (Fig. 2.) However, if the injection was a fairly complete one, the gelatine mass or the India ink was distributed quite uniformly throughout the node, and some of it was rarely found within the follicles; although instead of penetrating these, it usually surrounded them. In some places, the masses of injected material formed an incomplete and a very irregular circuit, parallel and internal to the peripheral blood space, which was, however, always separated from the former by a very thin barrier of lymphatic tissue. In case of injections of India ink by puncture, the resulting picture was always similar to that obtained by injections from the *vena cava*; but since the puncture injections were generally much completer, a greater amount of injection material was present. In these instances some of it was found in the peripheral blood space (sinus), in some of the blood islands, and not infrequently in some of the follicles as well. These puncture injections, whether made directly into a node or indirectly into an adjacent one, were, of course, also venous injections (figs. 5 and 6). Strangely enough, out of scores of nodes injected from the venous side, only a few showed the injection mass lying in large blood spaces in the center of the node. In two cases of injection by puncture, the India ink also found its way into an artery lying near a vein, wholly outside of a node. In the latter cases it seems likely that the ink entered the outlying artery through accidental puncture of one of its branches within the node, rather than by passing from the larger blood sinuses or lacunae into a capillary or an arteriole and then to the parent trunk. Unfortunately, however, the material at hand does not justify a definite conclusion regarding these rare accidental results.

Carmine gelatine injections from the aorta gave very similar results. (Fig. 7.) If the injection of the node was only a partial one, however—as was usually the case—the injected mass was found mainly in the venous lacunae at the periphery, and to a far less extent near the center of the node. Hence in the case of a complete injection it would be difficult indeed to distinguish an arterial from a venous injection, were it not for the fact that in the former the main arteries and their branches, and frequenly some arterioles and capillaries, are well injected, thus making differentiation comparatively easy. Arterial injections from the aorta also differed from most of the venous injections made by puncture, in the fact that the injection mass seemed to penetrate the filled blood spaces with more difficulty. This result may have been due, however, to the differences in pressure and to interference with the architecture of the node by the puncture in case of direct puncture injections, as well as to other things to be discussed presently. Unfortunately, none of the nodes injected from the aorta had a sufficiently definite peripheral (sinus) blood space to afford good evidence regarding its relation to the arteries. That the injection mass could have entered the peripheral (sinus) blood space follows, however, from the fact that the latter always contains more or less blood. Hence both it and the central blood spaces must, to be sure, communicate in some manner with the vascular system, even if not directly with it as a rule, or with the artery.

The most significant result obtained from these injections was that the so-called venous lacunae or radicles could generally be injected from both the *vena cava* and from the aorta. It is true that these injections were not of equal completeness, and also varied in certain other minor respects; yet the above fact seems to demonstrate conclusively that the venous lacunae, or true venous sinuses of the hemal nodes of the sheep, occupy a position intermediate between the veins and the arteries, and hence bridge a gap between them. However, as already stated, the fact that the blood spaces are more easily injected by puncture than from the aorta, can readily be explained by the fact that higher pressures were undoubtedly used, that a more direct and sudden entrance of the injection mass is effected, that the architecture of the node may be seriously disturbed, and that the needle may happen to stop in the parenchyma, in the case of direct puncture injections. Moreover, in case of injections from the aorta the injection mass, which enters slowly through the artery, can pass directly onward into the wide venous lacunae and large veins, without producing any appreciable back pressure in them, because of the difference in calibre between the arterial capillaries and venous sinuses. Hence the injection is likely to be incomplete. That the injection masses or the pigment, are generally found in the venous lacunae or true sinuses, and not in the blood islands and spaces, is explained by the fact that the former are usually empty spaces, with permanent walls which, although usually in a state of total or partial collapse, are directly connected with the arteries, and hence offer far less obstruction to the entrance of the injection mass than the blood spaces. The latter are traversed by reticulum and are filled with blood which has no easy and free means of escape. Furthermore, the communication between the venous lacunae and blood spaces is, as a rule, only an indirect one.

The great irregularity in shape of the injection masses and the pigments, in both arterial and venous injections, somewhat suggested extravasations. This was probably due to the necessarily incomplete nature of these injections; and that they were not extravasations is shown by the entire absence of points of rupture, and by the identical character of the injection masses in nodes injected indirectly from an adjacent one, under conditions of free outflow to the *vena cava* through the vein common to several nodes. For under such conditions serious structural derangement is avoided, or at least made improbable, because excessive pressures cannot be produced if the entrance of the injection mass is a very gradual and gentle one. The irregularity in form of the injection mass is further accounted for by the fact that the venous lacunae or true sinuses are encroached upon to a varying extent by the surrounding parenchyma, thus offering different amounts of obstruction to the onward flow of the injection masses or fluids; and by the fact that a partial injection of such wide, irregular channels must of necessity vary greatly in calibre.

The partial character of the injections in hemal nodes injected from the arterial side can be accounted for by the fact that the path of least resistance is undoubtedly in the direction of intra-vitam flow. Hence the injection mass can easily enter some empty venous lacuna or sinus, and pass directly into the vein or the larger venous radicles, rather than flow from one lacuna to another, until all or almost all are filled. Consequently it happens that only a sufficient number of venous lacunae may be injected to conduct the injection mass away as fast as it enters through the artery. Since both the arterioles and capillaries, and to a less extent also the venous lacunae, are usually in a state of partial or total collapse and more or less encroached upon by the parenchyma, they naturally offer varying resistances to the injection mass. Consequently limitation of it to certain lacunae is further promoted. The injection of the venous lacunae which lie at the periphery of the node in the lymphatic tissue, directly internal to the peripheral or subcapsular blood space, to the exclusion of those more centrally located, can be explained by the fact that the vein is often in more direct connection with them, as shown in fig. 8; and that as it leaves the node it rarely receives a number of tributaries which encircle the node, pierce the capsule, enter the lymphatic tissue, and open directly into these lacunae near the periphery. The presence of accessory or accessory tributary veins also can explain why only a very small portion of a section of a node may contain injection mass, and why the injected fluid, in case of puncture injections, can rarely be seen to leave the punctured node in several directions.

In those instances of venous injections in which some of the central or internal and the peripheral blood spaces contain injection mass, the path taken by the latter can usually be found easily in numerous places.

These paths apparently always lie through a narrow barrier of lymphatic tissue between venous lacunae and the blood spaces. It follows from this, and from other considerations, that the peripheral and central blood spaces or islands are not necessarily, or even usually, in direct open communication with the venous system in many nodes. Hence it is easy to understand why color changes are not more manifest in hemal nodes during the progress of injections from the *vena cava* or aorta or during bleeding, and why pressure exerted upon isolated excised nodes does not empty the filled blood spaces. Moreover, it also helps to explain why, in case of puncture injections, the injected fluid is usually seen in the *vena cava* before any recognizable change in appearance of the node takes place, if the injection is made slowly enough. The probable correctness of this explanation is further confirmed by the results obtained by injection in series of a number of nodes lying in a row in excised tissue, by puncture from the largest of them. When, for example, nodes 1, 2, 3 and 4, having a common effluent, were injected with India ink from node 1 under a free outflow, a sequence of events was observed as follows. The vein draining the adjoining nodes and tributary to the vein draining node 1, also became filled. Now if these nodes and their veins form a series of decreasing size, the resistances offered to the inflow of ink necessarily vary; and hence it may happen, as was actually the case, that node 2 becomes injected before, and more completely than nodes 3 and 4. Consequently, node 2 showed external color changes, while 3 and 4 did not do so, or did so but slightly. On cutting such an injected series, it was found that in node 2, which had turned black, the ink had penetrated into the peripheral and some of the central blood spaces, as shown in fig. 6. In node 3, on the contrary, which had undergone no color change, the ink was confined entirely to the venous lacunae or true venous sinuses; while practically no ink at all had entered node 4, which had likewise undergone no color changes. It is evident, however, that an outward change in color would occur in all nodes, whether they contained a peripheral blood space or not, if a sufficient quantity of the injection mass penetrated the node.

It follows, from these facts, that it is generally very easy to distinguish between an arterial and a venous injection from sections of injected nodes; and I fail to see why Drummond declared it to be impossible to do so. This would be true even in the case of a venous injection, in which the lacunae, the blood spaces, and the veins were entirely empty before injection; for in such a case the arteries would remain uninjected, which would not be the case if the injection had been made from the arterial side. It is usually just as easy to distinguish an injected hemal from a lymphatic node injected from the vascular system; unless, perhaps, some difficulty might be experienced in case of a lymph node in which extravasation of the injection mass into the parenchyma or lymphatics had occurred. For, aside from the fact that small lymph nodes readily manifest color changes, the injection mass as a rule entirely fills the arteries or veins, is not at all or but slightly mixed with blood, is confined in vessels of regular calibre with closed walls, and consequently has not those irregular outlines characteristic of injections in hemal nodes. Moreover, vascular injections of the lymphatic nodes always show a very characteristic arborization, (fig. 9), the distribution of the injection mass throughout the specimen is quite uniform, and the capsule is rarely also surrounded by a network of fine injected capillaries, a veritable *retia mirabilia.* It should be mentioned in this connection, however, that Weidenreich [37] stated that the vein, and especially the artery, frequently branches as it approaches the hilus of hemolymph nodes, sending branches to the capsule and thus giving the whole a very artistic appearance, which may cause confusion in embryonic nodes.

These differences in the behavior of hemal and lymphatic nodes upon injection can easily be accounted for, it seems to me: for in the lymph nodes the injection mass merely has to penetrate permanent channels of gradually changing calibre, lined throughout by endothelium and surrounded by tissue, which can easily yield, because the lymph sinuses, which form a comparatively large portion of the total volume of the node, are easily compressible. In hemal nodes, on the contrary, the injection mass, instead of traversing a closed permanent system, must apparently traverse very irregular, often collapsed, and no doubt to a certain extent discontinuous because evanescent, channels of greatly varying calibre, which often have but minute inter-communications, and which also communicate indirectly with the blood spaces of the node. It is obvious, to be sure, that improvements in technique may invalidate some of these statements, but they are in harmony with results obtained with all solutions, suspensions and masses used in the present series of experiments.

Although the artery and vein generally enter the node together, in external form the hemal nodes of the sheep are usually oval or spheroidal, and, as previously stated, without a definite hilus. It is true that the larger nodes generally have a more definite hilus, but accessory veins usually do not have accessory hiluses. After piercing the capsule, the artery and vein generally part company at once, and only exceptionally traverse the substance of the node as contiguous structures. (Fig. 10.)

The artery branches frequently, as it penetrates deeper into the node, the smallest branches usually being found easiest near the periphery. Although the arteries can only rarely be seen opening directly into venous lacunae, they can frequently be seen in the lymphatic tissue near them. Since the smallest arteries, arterioles, and the capillaries are practically always empty and collapsed, identification of the capillaries is necessarily difficult. Rarely an artery can be seen to traverse a small node, branching as it does so, and leaving the node approximately opposite to the point at which it entered, with apparently the same calibre. (Fig. 11.) It is evident that such variations of the vascular system of the node as these can also easily account for a number of anomalous results obtained in the course of injections.

Immediately after piercing the capsule the veins, on the other hand, often communicate by means of very wide openings directly with the extensive venous lacunae which lie parallel to the peripheral (sinus) blood space, when present, near the outer border of the lymphatic tissue; but they can only rarely be seen to communicate with the subcapsular or central or internal blood spaces of the parenchyma. (Figs. 8 and 10.) Less frequently they can also be seen to communicate directly with the deeper-seated lacunae, and with large blood spaces in depleted nodes. Accessory veins, which were clearly tributary to the peripheral (sinus) or subcapsular blood space, and hence affluent veins, were occasionally found, however. (Fig. 12.) In some nodes, on the contrary, it was impossible to detect the presence of a single vein or venule within the node itself, although serial sections were made. This was found to be the case even when numerous sections of arteries and arterioles could be found. This fact, and the entire absence of injected veins within some nodes, can be accounted for by the fact that in some cases the veins apparently come into relation with the peripheral venous lacunae only. Consequently, in the absence of the peripheral (sinus) blood space they can be seen only where they pierce the capsule. Moreover, in some cases the trunk of the vein does not pierce the capsule at all, but merely comes into contact with it in such a way that communication with the intranodal circulation is effected by means of an opening in the adjacent wall of the vein, the node appearing to be sessile upon the vessel. Since no separate vascular trunk exists between the node and the tangent vein in these instances, the near wall of the latter might be thought of as being continued through the capsule, and forming its venous circulation. As in case of the artery, however, so the vein in rare instances may run nearly through the center of the node, communicating directly with the venous lacunae as it penetrates deeper and deeper into the lymphatic tissue, apparently without the intervention of venules or capillaries.

The above considerations and observations seem to indicate quite clearly that the blood which enters a hemal node, wholly devoid of blood islands and a peripheral (sinus) or subcapsular blood space, through the artery, passes through arterioles and capillaries directly into the venous lacunae or true sinuses. From here it may, in some cases at least, at once enter the larger central venous spaces, if present, and hence pass directly to the vein; or it may in the absence of a main intra-nodal vein enter the efferent vein directly from the lacunae. Since in the above case the absence of blood islands and blood spaces has been assumed, the relation of these structures to the circulatory conditions will be considered farther on. Consequently the only thing open to question in the above premises is the manner of termination of the arteries, their relation to the blood spaces or areas when present, and to venous lacunae, and the relation of the latter to the vein. That the arteries end in capillaries, is easy to demonstrate; but it is very difficult to demonstrate satisfactorily that these capillaries communicate directly with the venous lacunae, except experimentally. The presence in arterial injections of the injection mass in the lacunae is, of course, alone sufficient evidence to establish a direct connection between the latter and arteries; but it must be admitted that the actual demonstration of a direct continuation of an injected capillary into an injected lacuna is only very occasionally possible. This fact may, to be sure, be accounted for by the contractility of the small arterial endings, and especially by shrinkage of the node, as a result of which the injection material contained in the fine arteries is forced out into the relatively very much larger venous lacunae. The direct communication of the lacunae with the larger venous spaces, or with the veins, can, however, be seen easily, and can be demonstrated satisfactorily in both injected and non-injected specimens, even in the case of some very depleted nodes. Since the lacunae form a venous plexus of widely varying calibre, which must usually be many times the volume of the arterial tree, a decided disproportion between the size and volume of a capillary and the lacunae into which it empties naturally exists. Consequently it is evident that a decided slowing of the blood current must also take place here.

Although all attempts to demonstrate the existence of an endothelial lining in the lacunae by means of silver stains have so far been futile, it cannot be doubted from microscopical examination of the ordinary specimens alone that such an endothelium exists. For, except at points here and there where small gaps are found, the injection mass of India ink is always retained by a very definite wall. The existence of discontinuities in the walls of the lacunae can, however, also be demonstrated microscopically, and is further proven by the escape of some of the injected pigment or gelatine mass into the surrounding lymphatic tissue in specimens in which extravasations can be excluded because they were injected under conditions of a free outflow. This is true no matter how carefully the injection has been made. In many places a communication of the lacunae with the surrounding parenchyma is further suggested by the arrangement of the lymphocytes and erythrocytes in portions of empty or partially empty lacunae. In some instances a number of lymphocytes and blood corpuscles are so arranged as to suggest that they are entering the lacunae from the parenchyma. The peculiar disposition of these cells may be a purely accidental one, to be sure; but the comparative frequency of these very suggestive cellular arrangements would seem to imply that this is not the case. If these appearances were due to damage done to the specimens, it would be impossible to explain why the walls of the lacunae always curve gently outward and disappear among the surrounding lymphocytes, rather than ending abruptly and projecting into the interior of the lacunae and giving the appearance of torn ends. Moreover, there is nothing in the distribution of the pigment that suggests an explosive rupture, such as is frequently seen in case of extravasations.

It is to be remembered in this connection, to be sure, that since considerable quantities of erythrocytes are frequently found in the parenchyma and sinuses of lymph nodes, these must have penetrated not only the walls of the blood vessel but those of the lymph sinuses as well, in so far as they did not enter the latter through the afferent lymphatics. However, there is a marked difference in appearance of the parenchyma of hemorrhagic lymph nodes and typical hemal nodes; and no matter how the presence of erythrocytes in lymph nodes may be explained, it seems highly improbable to me that their presence in hemal nodes can be similarly explained. Helly concluded that hemorrhages are responsible for red lymph nodes, while v Schumacher reiterated with increasing emphasis that in both hemorrhagic lymph nodes and hemal nodes the erythrocytes likely enter the sinuses and the parenchyma through places in the walls of veins and capillaries which have been weakened by the passage of lymphocytes. Neuman thought the walls were weakened by disease. v Schumacher also explained the presence of extravasations of injection mass in the parenchyma of lymph and hemal nodes in this