

STUDIES ON THE VASCULAR SYSTEM OF THE THYROID GLAND.

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WITH 10 FIGURES.

It has long been known that the thyroid gland is a very vascular organ. This we would expect both from anatomical and physiological reasons, having such a rich gross blood-supply and exerting such a profound influence through its secretion upon the physical and nervous development of the body. Tschuewsky (1), by a series of carefully performed experiments, has supplied us with data upon the subject. He found that the amount of blood flowing through the thyroid per 100 gram weight of the organ to be 560 ccm. a minute. This same observer, using a like standard of calculation, found the amount of blood flowing through the head to be 20 ccm. per minute, and through the kidney 100 ccm. per minute. Thus the thyroid, according to him and using the blood-flow per gram weight as the standard of comparison, is twenty-eight times as vascular as the head and five and one-half times as vascular as the kidney. Tschuewsky also estimates by a series of calculations that in the dog the entire amount of blood in the body flows through these small glands sixteen times in one day. This enormous blood-supply has led to a great deal of physiological speculation and it has even been suggested that the main function of the thyroid gland consists in acting as a vascular shunt to protect the circulation in the brain (2).

In these studies, begun at the suggestion of Dr. Mall and finished through his constant advice and encouragement, an attempt is made to study a few of the main points of the microscopic blood-supply of this gland. The thyroid glands of the cat, dog and man have been studied principally and the glands were those of the adult ani-

mal. I wish here also to express my thanks to Dr. H. M. Evans for the use of several injected specimens of human thyroids which he had injected in connection with his work upon the parathyroids (3).

The histological structure of the thyroid has been the subject of considerable literature in the past. Baber's (4) classical studies of the minute anatomy of the structure of the thyroid gland was one of the most important of the early contributions to this subject. He described particularly the histology of the follicles and the lymphatics. Langendorff (6), Wölfler (7), Lustig (8), Biondi (9), Hürtle (10), Andersson (11), Kohn (12), Streif (13), Flint (14), Coco (15), and others have given us important contributions upon the subject. These studies show that considerable differences of opinion have existed as regards its histological structure. Wölfler found that the thyroid of the child as well as of the adult contains solid rows of cells at the periphery while the center of the gland is composed mostly of vesicles filled with colloid material. He does not seem, however, to have attempted to divide it definitely into a cortical and medullary portion. Flint does not believe that thyroid gland, of the dog and man at least, can be divided into either lobes or lobules, but that the septa from the capsule penetrate the parenchyma of the gland in an irregular fashion. He has, however, observed pictures that suggest definite lobulation, but thinks that if the original lobulation is present in the embryo it is later lost. Regaut and Pettijean (16) studying the dog, cat, pig and other animals also do not believe that the thyroid gland can be divided into lobules. They maintain that there is no such architecture present, that there is no distribution of blood vessels or lymphatics to warrant the conception of a lobule. Coco (15) gives a description of the structure of the dog's thyroid that summarizes and agrees in general with the conclusions of most observers, and with the descriptions in most text-books. According to him, the thyroid gland is surrounded completely by a thick capsule which gives off numerous prolongations of connective tissue. These septa penetrate the parenchyma of the gland, dividing and sub-dividing it into lobes and lobules. The septa which also support blood-vessels and nerves, become thinner and thinner and finally end by surrounding each follicle in the

form of a delicate membrane which supports the epithelial cells. The sections examined in the course of my own studies indicate a division of the gland by septa into lobes and lobules, and as will be shown in this paper, definite vascular units can be dissected out, which correspond to these structural units. Streif (13), by use of the Born wax model method, has shown that the glandular structure of the thyroid consists of closed follicles which are separated from each other by fine connective tissue. He also showed that a system of canals is not present and that the follicles do not communicate with each other.

There seems to be no extensive literature upon the microscopic blood-supply of the thyroid. Kohlrausch (17) in 1853 drew attention to the fact that the follicles are surrounded by a rich capillary network. This fact, as well as the presence of many lymphatic spaces surrounding the follicles, is mentioned in the textbooks of anatomy and histology. Wölfler devotes some space to the consideration of the blood-vessels. He studied them principally from the embryological standpoint, in their relation to the developing gland. He observed a network of capillaries surrounding each follicle and twigs from the blood-vessels to the follicles, but does not seem to have studied them further and no drawings illustrating these points are found in his monograph. Streckeisen (18) has made a very careful study of the gross distribution of the arteries supplying the thyroid gland. Landström (19) studied the gross distribution of the arteries and paid especial attention to the subject of the arterial anastomoses. His article gives a résumé of the work done upon this subject with a complete bibliography.

In my own studies the injection method was used practically altogether. Specimens were injected with various injection masses—India ink and carmine, ultramarine blue, vermillion (mercuric sulphide) granules in various per cent. gelatine solutions. In some cases single injections were made either into the arteries or veins, in other cases double injections were made, filling both arteries and veins. India ink and carmine both give very good injections of the follicular blood-supply, as the masses on account of the small size of their granules easily penetrate the capillary bed. Some very good

double injections were made by using carmine and ultramarine blue injection masses. The carmine was first injected into the arteries and continued until the capillary bed was filled; then ultramarine blue was injected into the arteries, forcing the carmine out through the capillary bed and over into the veins. The ultramarine blue granules fill the arteries, but fail on account of their large size to pass over into the capillaries, and if we stop at the proper moment we have a double injection, in which the arteries are injected blue, the capillaries and veins red. Partial injections also gave some very instructive specimens. After injection the specimens were hardened in alcohol or formalin, imbedded in paraffine or celloidin, cut and cleared in creosote. It was also possible, by taking a small piece of an injected gland, to dissect out under the binocular microscope, lobules and even single follicles. This, in the case of the human thyroid, gives perhaps the most instructive specimens, as a mounted specimen thick enough to contain a whole lobule, is usually too thick to be studied successfully under the microscope. Also a lobule or follicle when dissected out, can be turned about and studied from various sides.

The general form and shape of the human thyroid as well as its gross blood-supply is described in almost any text-book of anatomy. Also the variations in shape and position of the thyroid gland in various animals is described in the text-books of comparative anatomy. It will be remembered that the thyroid of the cat and the dog differs from that of the human in consisting of two bean-shaped lobes, one on either side of the trachea, which are connected in the cat by a very thin strip of an isthmus and more completely separated in the dog. In these animals, too, the inferior thyroid artery is of very small size and by far the greater part of the blood reaches the gland through the superior thyroid artery.

There seems to be considerable discussion as to the existence of anastomoses in the human thyroid, between the superior and the inferior thyroid arteries. Landström (19) and also Streckeisen (18) show clearly by their injections that such anastomoses are present upon the surface of the gland, not only between the arteries of the same side, but also between the two sides. In my own injections such sur-

face anastomoses were easily demonstrated. Landström also expresses the conviction that anastomoses also occur within the gland, but did not succeed in demonstrating them. The method that Landström employed was that of injecting the arteries with Woods' metal, and then taking a Roentgen-ray picture of the gland. In my own studies several glands were injected with celloidin, and then by digesting with artificial gastric juice, corrosion specimens were obtained in which the arterial tree could be followed from its trunk to its termination in the individual follicles. In no case was it possible to find definite arterial anastomoses beneath the surface of the gland. The arterial tree is so exceedingly complex that it is difficult to decide this point absolutely. It is also easy to imagine what a complex picture would be obtained by Landström's method. In many cases when from study under the microscope a definite anastomosis appeared to exist, yet after carefully moving the blood-vessels with a pair of fine needles it was seen that the two arteries did not really anastomose, but ran out each to its termination, entirely independent of the other. In many cases, large branches of the thyroid arteries would turn and twist about in great confusion, without, however, anastomosing. In the cat's thyroid, anastomoses occur as are seen in Fig. 1. Gelatin injections of the dog's thyroid, show a few anastomoses, but they occur between branches of the same artery, and not between branches of the superior and inferior thyroid arteries. At any rate, if anastomoses are present in my specimens of human thyroids they are of small size.

The capsule of the thyroid gland, like similar tissues, has a very scant blood supply. The arteries upon entering the gland give off small branches at various places which join each other to form a network throughout the substance of the capsule dividing it into large diamond-shaped areas. Each artery is accompanied, as a rule, by two veins, which are connected at various places by bar-like veins which run across the artery. The veins anastomose in the same manner as the arteries, and empty at various places into the large veins that are emerging from the interior of the gland. Occasionally a capsule vein empties into a vein within the gland, but such anastomoses are infrequent. The same general scheme of this circulation is ob-

served in the cat, dog and in man. The capsule of the thyroid gland has been divided by some into an internal capsule which can be stripped off only with some difficulty, and an external capsule which strips off readily. The above description refers to the blood-supply of this outer capsule.



FIG. 1.—Corrosion specimen of arterial injection of cat's thyroid, showing numerous anastomoses. $\times 5$.

The manner in which the arteries approach the thyroid gland show some variations in the cat, dog and man. In the dog the superior thyroid artery gives off two main branches, one anterior branch and a posterior branch. Each of these in turn give off four or five smaller

branches which penetrate the gland. In a certain specimen the total number of these branches from both anterior and posterior branches was nine. These branches plunge into the gland and immediately give off branches which run in various directions, some attempting to gain the periphery of the organ, others running still deeper towards

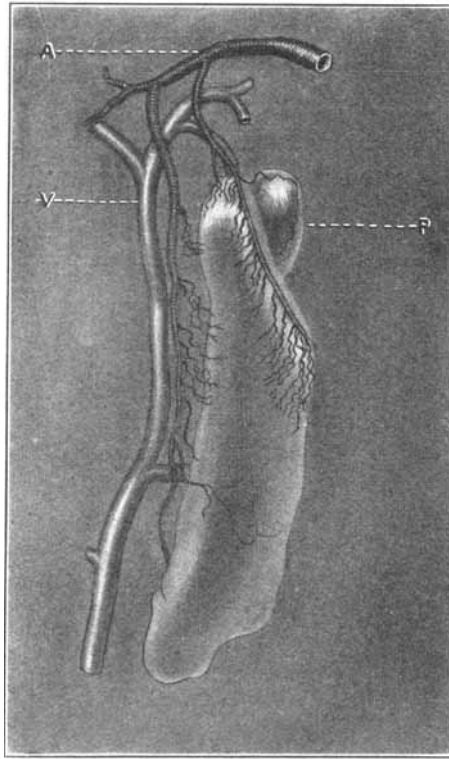


FIG. 2.—Gross blood supply of cat's thyroid. $\times 5$.

A.—Artery. V.—Vein. P.—Parathyroid gland.

the center. These arteries of the second order surround definite divisions of the gland and give off no branches, as a rule, to the follicles. The veins follow more or less the same course, but show frequent anastomoses.

The course of the arteries to the cat's thyroid is somewhat similar to that of the dog. The superior thyroid artery, however, gives off a

much larger number of branches before penetrating the gland. This is illustrated in Fig. 2. The superior thyroid divides into two main branches which course down the sides of the gland, each giving off a large number of branches, some of which are branches of the second order, others of which give off branches of the second order. The total number of the branches given off by the two main divisions of the superior thyroid artery in the specimen drawn is forty-one. The arteries of the second order are distributed as in the dog and pass between lobes of the gland.

The course of the arteries in the human thyroid resembles somewhat that of the dog, but presents differences which are apparent at

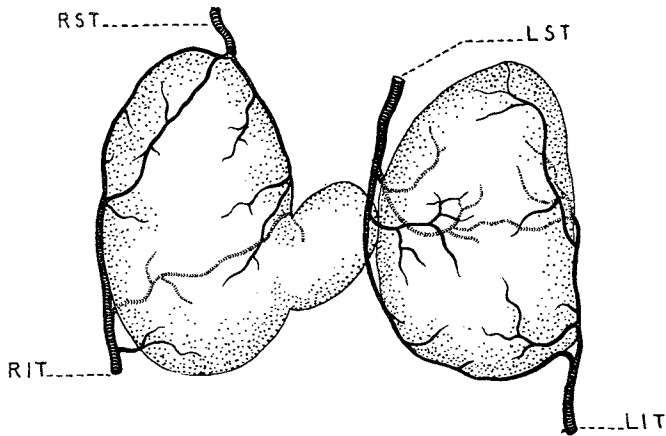


FIG. 3.—Gross arterial blood supply of human thyroid.

RST—Right superior thyroid artery. RIT—Right inferior thyroid artery.
LST—Left superior thyroid artery. LIT—Left inferior thyroid artery.

first sight. The human thyroid gland differs from that of the dog in shape, in the presence of a well-defined isthmus and in the fact that in man the inferior thyroid artery is as large or larger than the superior thyroid. Variations in the gross blood-supply of the human thyroid are common, but a general scheme seems to be present, with differences in method of anastomoses. Such a general scheme is shown in Fig. 3. Here we see the superior thyroid artery approach-

ing the upper poles of the gland, and the inferior thyroid arteries approaching from beneath. Each artery gives off four or five branches, some of which supply the anterior, some the posterior surface of the gland. The main continuations of these arteries are prone to run along and upon the margins of the gland, and the superior and in-

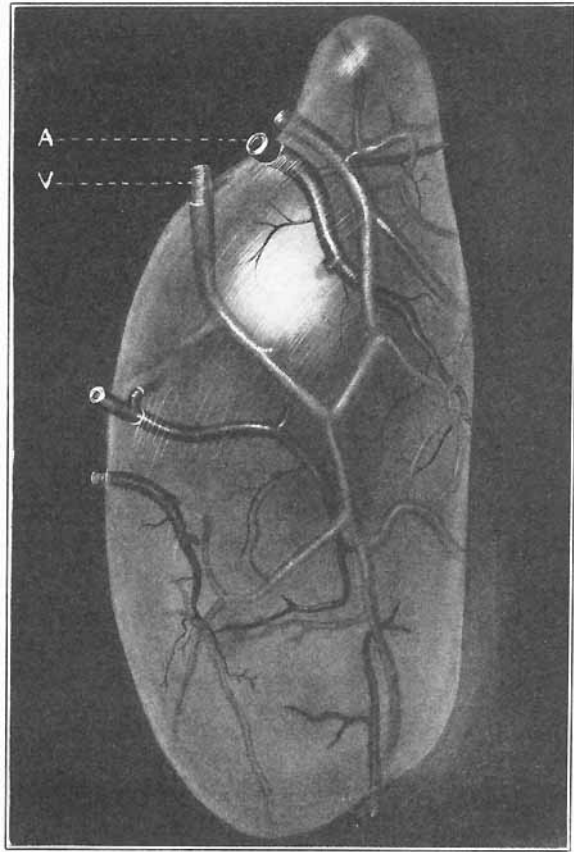


FIG. 4. —Drawing illustrating the venous network upon the surface of human thyroid with accompanying arteries.

A.—Arteries. V.—Veins.

ferior thyroid arteries upon the same sides anastomose, two anastomoses occurring between each artery in the specimen from which

Fig. 3 was drawn. The general scheme of these anatomoses varies considerably in the different human thyroids. Landström, in his article to which reference has previously been made, gives excellent drawings of some of these variations.

In the human thyroid, few large arteries are present in the depths of the gland, and in this respect it differs from the dog. In other words, in the human the branching of the large arteries takes place mostly upon the surface of the gland, and having by their branching obtained their approximate distribution, the smaller branches are sent in.



FIG. 5.—Drawing illustrating arteries of third order passing between lobules and arteries of fourth order supplying the lobules in the human thyroid (partly diagrammatic).

The further distribution of the arteries is essentially the same in both the dog and man. The arteries of the third order, as is shown in Fig. 5, pass between the lobules and give off arteries of the fourth order which supply the lobule. Each lobule is composed of a number of follicles and is supplied usually by from two to five arteries, the number of arteries depending upon the size of the lobule. Fig. 6 and Fig. 7 show two lobules which have been dissected out

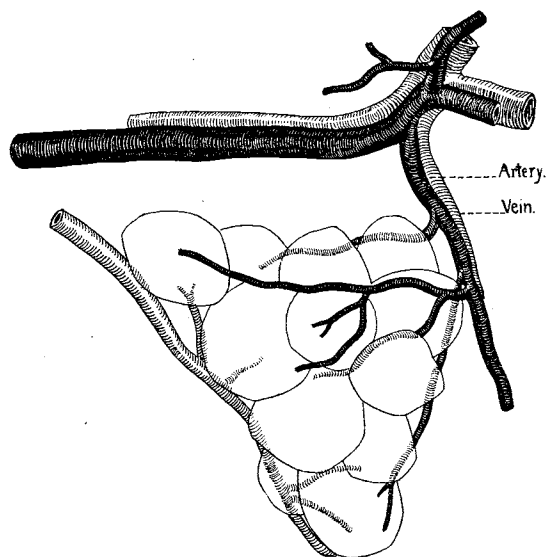


FIG. 6.—Lobule of human thyroid dissected out.

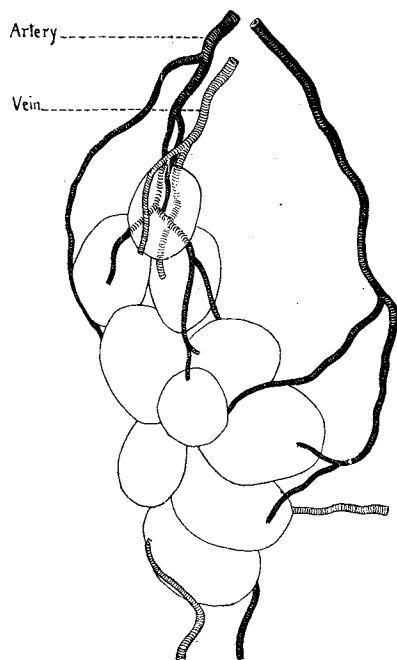


FIG. 7.—Lobule of human thyroid dissected out.

with their blood-supply intact. They resemble, to use the classical Malpighian expression, a cluster of grapes, over which arteries and veins can be seen twining about. These arteries of the fourth order run over the surface of the lobules and give off fol-

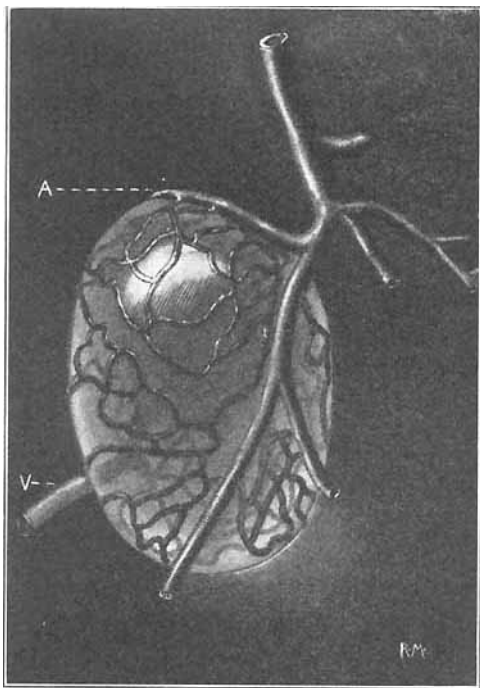


FIG. 8.

FIG. 8.—Single follicle of human thyroid dissected out, showing its follicular artery A, and follicular vein V. $\times 85$.

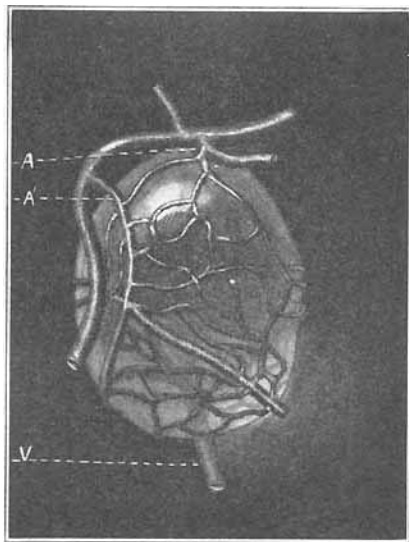


FIG. 9.

FIG. 9.—Single follicle of human thyroid dissected out, showing a follicle receiving its blood-supply from its own follicular artery A, and also from the follicular artery supplying an adjacent follicle A'.

V.—Follicular vein. $\times 85$.

licular arteries to each follicle. The follicular arteries end in a rich capillary network which surrounds each follicle. The vein which arises from this capillary network upon the far side to the artery, follows fairly closely the course of the artery. Figs. 8 and 9 show

the termination of the follicular artery at the follicle, the capillary network and the vein arising from the far side of the follicle.

The relations between the capillaries and the cells of the follicle are seen in Fig. 10. The capillaries lie just outside the cells in the connective tissue that forms a sort of capsule for each fol-

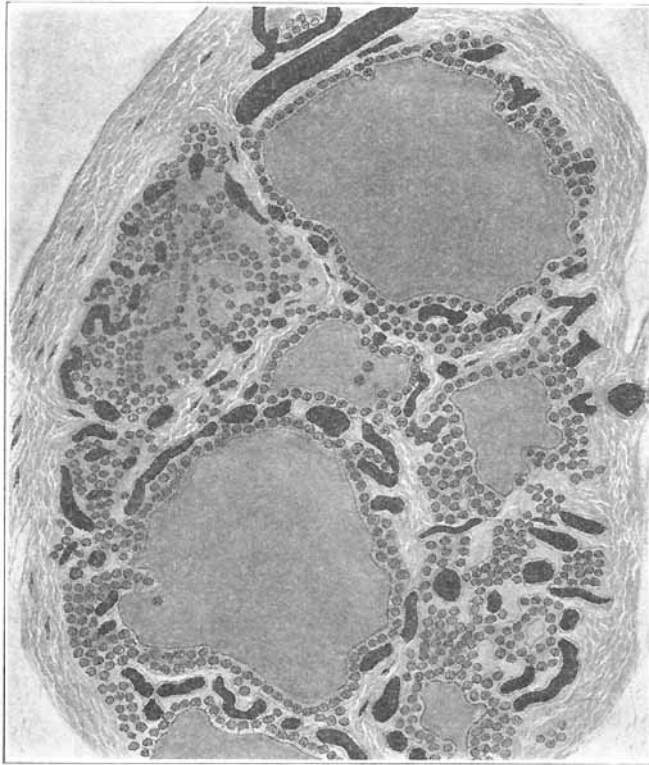


FIG. 10.—Drawing illustrating the relation between the follicular network of capillaries and the cells of the follicle in the human thyroid. Capillaries in solid black. $\times 200$.

licle. It is also noted that compared with the size of the individual cells, the capillaries are very gross structures. This is interesting from the standpoint of the secretory changes in the thyroid. According to Andersson, Hürtle, Biondi and others, the colloid mate-

rial passes from a follicle into the lymph spaces by a gradual obliteration, "melting" or bursting, of some portion of the wall of the follicle. As the meshes in the capillary net are large as compared with the size of the cells, it can be conceived that quite a number of cells can be destroyed without affecting the integrity of the capillary network. Thus an opening sufficient to permit the escape of the colloid material can take place without rupturing a capillary and causing hemorrhage, or at most only a few capillaries need be ruptured. That some capillaries are often ruptured, is shown by the frequent finding of red blood cells in the lymph spaces and in the cavity of the follicle.

The veins that return the blood from the follicles follow closely the path of the arteries, show frequent anastomoses and finally reach the surface of the gland where they anastomose freely.

The average size of the arteries of the first order is .15 mm.; those of the second order .1 mm.; those of the third order .03 mm.; and lastly the follicular arteries are .0125 mm. in size. The capillaries of the follicular network average .008 mm. in size. These measurements are those of the normal human thyroid.

The finer distribution of the blood vessels in the cat's thyroid differs somewhat from that of the dog and man. In the cat the arteries of the second order pass between lobes and the arteries of the third order pass between lobules just as in man. Arteries of the fourth order passing to the lobules are also present, but not so constant. In the cat, however, no follicular arteries are present. Each follicle is not surrounded by a rich capillary network and supplied by its own follicular artery, but the follicles are placed in a loose, wide network, each mesh of which in a cross section appears to surround a single follicle. This network has depth as well as length and breadth and surrounds the follicle in three dimensions. The arteries which supply the lobules, approach the lobules and immediately split up into capillaries without giving off any follicular arteries. The veins collect from the capillaries at a point somewhat removed from the arteries often directly opposite them, but soon approach them and follow the same general course.

This description of the thyroid blood-supply must be taken only as indicating a general scheme. Certain variations will, of course, be noted. The size of the lobules, depending upon the number of follicles composing it, will, of course, vary and with it the number of arterial branches supplying it. Also the blood-supply of the individual follicles is subject to certain variations. In many cases a single follicle, as shown in Fig. 9, besides receiving its blood-supply from what might be termed its own follicular artery, receives small branches from an artery which supplies an adjacent follicle.

The veins while in general following the course of the arteries, also show many variations. Often the vein which springs from the follicular network, instead of passing back side by side with the artery, empties into a vein which follows the course of an artery supplying follicles on the far side of the lobule. Such a picture is seen in Fig. 6. The capillary network surrounding the follicle anastomoses very commonly with that of an adjacent follicle.

Thus it is seen, that in the thyroid, too, we have a definite system of blood-supply, a definite system of vascular units, which repeat themselves with a greater or less constancy throughout the entire organ. These vascular units correspond in most instances very closely with the structural units.

The smallest vascular unit present is the follicular unit, which consists of the follicular network, each in the case of the dog and man, with its own artery and vein. In the cat, as already stated, this network is not so rich and distinctive, and follicular arteries and veins are not present. Yet, the large mesh containing the follicle is the homologue of the network and may be regarded as the smallest unit present. This vascular unit corresponds to the histological unit of the individual follicle.

The next vascular unit in size is the lobular unit. This is composed of (1) the arteries of the fourth order which run over the clumps of follicles having as their direct branches the follicular arteries, and (2) the arteries of the third order which pass between the lobules. This vascular unit corresponds to the structural unit of the lobule.

The next vascular unit which comes into consideration is what might be termed the lobar unit, and is formed by the arteries of the second order, which surround collections of lobules or lobes and give off arteries of the third order. The corresponding structural unit is not so easily determined as are the lobules, but they may be considered as a collection of lobules, which is marked off from a similar collection of lobules by denser septa. The term lobe as used here is the microscopic lobe and does not refer to the lobe of gross anatomy, the term which is applied to a much larger anatomical division of the gland, for in the human the gland is considered as composed of a median and two lateral lobes, and in the dog the term lobe is applied to what is really gross-anatomically considered a right and a left thyroid gland.

As arteries of the first order, for the sake of simplicity, have been grouped together, the branches of the thyroid arteries which ramify over the surface of the gland, supply definite regions and penetrate it giving off branches of the second order.

Finally as the largest unit present, the prime unit, we have the thyroid gland itself, supplied by the thyroid arteries, superior and inferior, which differentiate it from the standpoint of vascularization from surrounding structures such as the thymus, submaxillary gland, etc.

An exhaustive study of the lymphatics of the thyroid does not lie in the scope of these notes. Many observers, among them Baber (5) and more recently Renaut and Petijean (16), have described them and most of the text-books refer to their presence, their extreme richness and their general distribution. Yet a short consideration of their relation to the blood vessels may be of interest. The lymph spaces surround each follicle just outside the capillary network, filling in as it does the interstices left between the follicles. The relation between the capillaries and the lymphatics also indicates how the individual follicles are surrounded by lymphatic spaces. These spaces connect with larger trunks which definitely run in between the different lobules. These trunks in turn run into larger ones between the lobes which follow fairly closely the course of the blood vessels and becoming larger finally unite to form a network of

lymphatics beneath the capsule. From there they empty into lymphatics draining the gland, which usually follow the blood vessels out, one trunk passing upwards towards the submaxillary gland and the other passing to the lower cervical region, as described by Baber and figured by Bartels. In one injection the lower trunk of the left gland was seen to pass directly into the left subclavian vein. These observations were made upon the dog alone.

In connection with the enormous blood supply of the thyroid gland, an anatomical study shows conditions favorable to a rapid and consequently a rich blood supply. The numerous arteries, the fact that each artery does not terminate until it reaches the follicle, the ultimate unit of the gland, would, theoretically considered, aid rather than retard a rapid circulation through the gland. It is rather interesting to note that the thyroid with its follicular artery and vein, resembles to a certain extent the kidney with its glomerulus and vasa afferentes and efferentes, and that the kidney, according to Tschuewsky, shows a blood supply exceeded among the organs he examined, only by the thyroid gland.

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