

ON THE GROSS DEVELOPMENT AND VASCULARIZATION OF THE TESTIS.

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WITH 14 TEXT FIGURES.

While studying the development of the blood supply to the Wolffian bodies, my attention was called to the interesting manner in which the testis becomes vascularized. Accordingly, following a suggestion from Professor Mall, I injected a series of embryo pigs and later the testes of adult pigs, hoping that a thorough knowledge of the blood supply of this gland in the pig would facilitate the study of the vascularization of the human testis. In this I was mistaken, for the information gained from corrosions, injections, and cleared preparations of the testis of the pig was of comparatively little value in unravelling the interesting though complex blood supply of the sex gland in man. Hence, in this paper I shall confine myself to the gross development and blood supply of the pig testis, and will later publish the results of studies of the human gland.

The blood supply to the human male sex gland, to use a rather unique term for anatomical literature, is rational. It is much as one might expect, knowing the lobular arrangement. The vascularity of the pig testis, on the other hand, is quite unusual and it is difficult to imagine what causes could have produced such an unique arrangement.

Literature.—The literature on the vascularization of the testis is surprisingly meagre, considering the enormous bibliography which has accumulated on spermatogenesis and the descent of the testis. Kölliker, Mihalkovics, Bardeleben, Pflüger, Waldeyer, and many others have added much to our knowledge of these two subjects, but as yet comparatively little has been accomplished toward unravelling the blood supply. Kölliker traced the spermatic artery as it branched to supply the cord, epididymis and testis. He states that the blood vessels follow the trabeculæ of the sex gland after penetrating the albuginea near the

epididymis. He also describes a capillary network around the tubules. Astley Cooper has investigated a capillary plexus covering the internal surface of the tunica albuginea which he has termed the tunica vasculosa. But beyond this there is little to be found in the literature of the subject.

The vascular units which Professor Mall and his students have shown to be present in several organs and which they assume are to be found in all organs, have not as yet been demonstrated in the testis, and, indeed, aside from what has been cited above, nothing is known of the arterial or venous supply of the male sex gland. Dr. Mall has frequently demonstrated the presence of certain units of the blood system which may or may not be peculiar to the organ in which they are found and which correspond to the histological or structural unit of the organ. These units are composed of small branching blood vessels which pass into capillaries and the blood from which is collected into small veins. This theory of vascular units may be briefly summed up in the statement "similar blood supply to similar histological units." These vascular units have been proved to be present in the liver,¹ spleen,² and adrenal,³ but in the testis of the pig I can make out no definite units. In man, however, the lobular arrangement is less complex, and results have been so encouraging that probably these units will be shortly discovered.

Methods and Material.—The necessity of clearly understanding the development of the circulatory system in the earliest embryonic stages in order to properly interpret the course of the blood stream in the adult organs has been frequently emphasized. Accordingly, in attempting this research frequent use has been made of embryonic material. Embryo pigs, many of which were alive when delivered at the laboratory, were injected and cleared, and, after tracing the development of the circulation in these stages, the investigations were completed with adult material. For adult human testes I am indebted to Professor MacCallum of the pathological laboratory. To Professor Brödel I also wish to express my appreciation for several valuable specimens of human embryonic testes as well as for his helpful suggestions in making the illustrations. For the courtesies of their laboratory I wish to thank Professors Wiedersheim and Keibel of Freiburg.

All injections of embryonic material were made with India ink. In

¹ Mall, F. P.: A Study of the Structural Unit of the Liver. *Am. Jour. Anat.*, Vol. V, No. 3.

² Mall, F. P.: The Structure of the Spleen. *Johns Hop. Hosp. Rep.*

³ Flint, J. M.: The Blood Vessels, Angiogenesis, Organogenesis, Reticulum and Histology of the Adrenal. *Johns Hop. Hosp. Rept.*, Vol. IX.

the youngest stages, measuring from eighteen mm. to seventy-five mm., a hypodermic syringe with a fine needle forced the injection fluid into one of the umbilical arteries, and by watching the hind legs and head excellent results devoid of extravasation could be obtained. This mode of injection is particularly desirable in these early stages for it is not necessary to rupture the surrounding membranes and thus the embryo is protected against injury in handling. In larger embryos injections were made directly into the aorta by puncturing the left ventricle. Considerable pressure was necessary to overcome in the earlier stages the resistance resulting from the small lumen of the spermatic artery, and in larger embryos because of its remarkable tortuosity. On account of this pressure the Wolffian bodies were frequently doubly injected, the injection mass passing through the sinusoids and capillaries described by Minot into the veins. In nearly all such specimens the testes showed only an arterial and capillary injection. In this connection it may not be amiss to emphasize the advantages of India ink in all cases where a fluid is desired which will flow wherever the blood stream goes, and yet is resistant to the ordinary laboratory acids and to concentrated solutions of potassium or sodium hydroxide.

After the injection of each embryo, the right testis together with the Wolffian body, kidney, and aorta were removed and placed in ninety-five per cent alcohol for clearing, while the left sex gland with its appendages was prepared for sectioning. Of the various clearing procedures, the modified Schultze method⁴ was found to give the most satisfactory results. This method is as follows:

After the injections have been completed all unnecessary tissues surrounding the parts under investigation are removed and the specimens are placed in ninety-five per cent alcohol. The removal of adventitial tissue is most important, though entire embryos may be successfully cleared if openings are made into the abdomen, thorax and cranium. In embryos ranging above one hundred and fifty mm. in size, it is still better to make sagittal sections of the hardened specimens and to clear in halves. The alcohol should be frequently changed and large quantities should be used. In order to obtain transparent specimens the tissues must be completely shrivelled before removal from the alcohol, and the length of time necessary to accomplish this result depends, of course, upon the size of the objects. For very small specimens at least

⁴ Hill, E. C.: On the Schultze Clearing Method as Used in the Anatomical Laboratory of the Johns Hopkins University. Johns Hop. Hosp. Bull., Vol. XVII.

three days should be allowed, while for large objects the time should not be less than a week. Experiments with absolute alcohol in place of ninety-five per cent alcohol gave no better results, and its use is an unnecessary expense. The coagulation of the proteid occurs almost as quickly in one percentage as in the other.

After the specimens have been sufficiently shriveled they should be placed in one per cent potassium hydroxide. When a higher percentage is resorted to, so rapid is the action that the safety of the specimen is endangered, and it was the use of the strong solutions recommended by Schultze which caused the loss of much valuable material. In this weaker solution the tissues become transparent in from four to forty-eight hours, depending upon the size of the specimens. After sufficient clearing in this medium they should be transferred to twenty per cent glycerine, in which clearing continues and a certain amount of hardening occurs, rendering the tissues firm enough to permit of dissection. Should the specimens be as transparent as is desired, they may be removed from time to time to higher percentages of glycerine till at last they are permanently stored in pure glycerine. A certain amount of shrinkage is noted in some organs after an immersion in this fluid for a year or more, but when the specimens are studied immediately after being cleared the measurements are practically the same as in the fresh tissue. The shrinkage which some observers have noticed is probably due to transferring the specimens too rapidly to higher percentages of glycerine. After some experimenting we have found that embryos hardened in formalin can be cleared also, though in this case 10 per cent potassium hydroxide is essential and the specimens must remain in this solution for several weeks or months.

Blood pigment in some instances will not be entirely removed by this process alone and in organs, such as the kidney, transparency can sometimes only be obtained by a secondary treatment. After passing through the one per cent potassium hydroxide as outlined above and being placed in twenty per cent glycerine, the specimens containing the objectionable pigment are treated with equal parts of fifty per cent ammonium hydroxide and one per cent potassium hydroxide. In this solution there is comparatively little danger to the specimen on account of the hardening produced by the twenty per cent glycerine. Indeed, in cases where it is deemed advisable for any reason to stop the clearing action, or it is found to be more convenient to continue the process at some future time, the objects may be removed to this twenty per cent glycerine and retained in this medium until a more fitting time when much higher

percentages of the caustic solution may be resorted to without danger to the specimens. The specimens may be studied in glycerine or by a method devised by Bardeen may be mounted upon glass slides and placed in any desired position in jars of glycerine. The objects are removed from pure glycerine, wiped and quickly washed. They are then placed in a little thick gelatin solution and are laid upon a warm glass slide. As soon as the gelatin is hardened the specimens are returned to the pure glycerine without any danger of becoming loosened from the slide. The purity of the glycerine should be assured, as the presence of foreign substances such as water may tend to soften the gelatin.

The clearing reagents advocated by Van Wijhe^{*} and Lundvall^{*} did not give the same degree of transparency as was gained by following the above method, though in clearing the capsule of the adult testis beautiful specimens were obtained by using absolute alcohol and xylol as outlined by Van Wijhe. In following the distribution of the blood vessels in the capsule, quite satisfactory results were obtained by the very practical and simple method devised by Flint in his work on the adrenal.⁸ "After carefully dissecting away all of the paricapsular connective tissue from the injected and hardened gland, it is cut in half, longitudinally, with a sharp razor and the parenchyma is scraped out with a scalpel. The remaining fibrous capsule is then treated exactly like a section and, after dehydration, is cleared and mounted in a cell."

Although the modified Schultze method is particularly applicable to embryonic tissues, yet sections of the adult testis 3-4 mm. thick, the arteries and veins of which had been injected with India ink were speedily rendered transparent by a clearing treatment similar to that for the less resistant embryonic tissue.

In preparing injections for corrosion specimens of larger embryonic and adult testes, great difficulty was experienced until it was discovered that seven per cent celloidin would flow quite readily through a medium-sized hypodermic needle. Thus in injecting the adult sex gland it was only necessary to find the point at which the spermatic artery reached the gland in order to avoid the difficulty met with in forcing the injection mass through the many coils of artery which lie in the cord of the pig near its attachment to the epididymis. The corrosion was accomplished with hydrochloric acid and pepsin, after which the specimens

^{*} Van Wijhe, J. W.: A New Method for Demonstrating Cartilaginous Mikroskeletons. Koninklijke Akademie van Wetenschappen Te Amsterdam, 1902.

^{*} Lundvall, H.: Ueber Demonstration Embryonaler Knorpelskelette. Anat. Anz., pp. 219-223, Band XXV.

were washed and placed permanently in glycerine. Because of the thick and very resistant albuginea a rapid corrosion was more easily obtained when the fresh gland was placed for an hour in concentrated hydrochloric acid, after which it was treated in the usual way with a ten per cent aqueous solution of this acid for twenty-four hours, followed by the ordinary peptic digestion in the thermostat.

Gross Development of the Testis.—Keibel in his Normentafel for the pig gives the anlagen and traces histologically the development of the organs, but gives no measurements of these organs.

TABLE SHOWING IN MILLIMETERS THE LENGTH OF THE BODY AS COMPARED TO THAT OF THE KIDNEY, WOLFFIAN BODY, AND SEX GLAND OF PIG EMBRYOS.

The measurements were made from vertex to breech, and include all of the embryos in each uterus. In case of asymmetric development of these glands in any embryo averages were made of the lengths of both organs.

	Vertex- Breech.	Kidney.	Wolffian Body.	Testis or Ovary.
Uterus 1	20	1.2	7.3	1.5
	21	1.2	7.3	1.5
	20	1.1	7.4	1.4
	23	1.2	7.2	1.5
	22	1.3	7.1	1.4
	21	1.0	7.3	1.5
	20	1.2	7.2	1.5
Uterus 2	28	2.5	9.0	1.7
	28	2.6	8.0	1.6
	29	2.5	8.5	1.7
	27	2.4	9.2	1.7
	28	3.0	7.0	1.7
	29	2.7	8.7	1.4
Uterus 3	31	3.9	9.2	2
	33	4.0	9.1	2
	33	3.8	9.0	2
	35	3.7	9.1	1.9
	33	4.1	8.9	2
Uterus 4	40	5.8	10.0	3.2
	41	5.9	10.0	3.2
	40	5.9	11.0	3.1
	42	5.9	11.0	3.1
	41	5.8	10.0	3.1
	43	6.0	11.2	3.2
	41	5.8	10.5	3.2
	42	5.9	11.3	3.2
	39	5.6	11.5	3.1
	41	5.9	10.0	3.0

	Vertex- Breech.	Kidney.	Wolffian Body.	Testis or Ovary.
Uterus 5	49	7.3	11.0	3.5
	49	7.8	10.5	3.2
	49	6.8	12.0	3.2
	48	8.0	10.0	3.5
	50	7.8	10.5	3.5
Uterus 6	68	11.7	11.8	4.0
	67	11.5	12.0	4.0
	68	11.5	11.4	4.0
	69	11.4	11.5	3.7
	67	11.2	11.2	3.8
	68	11.5	11.7	4.0
Uterus 7	85.0	14.5	10.2	4.6
	84.6	14.7	10.0	4.4
	84.4	14.3	10.5	4.6
Uterus 8	94.3	15.7	9.2	4.8
	94.5	15.9	9.0	5.0
	94.3	15.6	9.0	5.1
	94.0	15.5	9.8	5.0
	94.4	15.7	8.7	5.0
	94.3	15.6	8.9	4.7
Uterus 9	120.0	18.0	7.0	5.0
	121.0	19.0	7.2	5.3
	120.0	19.0	7.5	5.0
	120.5	18.5	7.0	5.5
	120.8	18.2	7.0	5.2
Uterus 10	15.5	23.5	Epididymis	Testis
	15.0	22.8	7.0	5.8
	15.8	23.0	7.0	5.6
	15.0	24.0	7.3	5.5
Uterus 11	210.0	31.0	8.2	6.0
	211.0	30.0	8.0	6.3
	210.5	35.0		6.5

A study of the foregoing table shows little variation in the body lengths of the embryos in each uterus. In the cases of abnormal development of the kidney, it is interesting to note the corresponding size of the Wolffian body. That a balancing of function exists between these two glands is suggested by the fact that an embryo having an unusually large kidney development has correspondingly small Wolffian bodies.

The measurements were made regardless of whether the sex gland was male or female, although in embryos beyond thirty-three mm. in length this sex distinction is observable.

In the adult pig testis the measurements vary considerably. The average might be placed at sixty-five mm. long, forty-two mm. deep and thirty-seven mm. wide with an average weight of sixty-eight grammes. These results are of interest when compared with those obtained by Krause⁷ for the human adult sex gland. His averages were thirty-seven mm. long, twenty-eight mm. deep and twenty-four mm. wide, with the weight falling fifteen and twenty-four and a half grammes.

Development of the Blood Supply.—Concerning the embryonic development of the testis much has been written and it seems useless to enter into a discussion of the histogenesis and descent of the gland. Among the more recent studies of these subjects the article by Allen⁸ on the ovary and testis of mammals will be found to contain a comprehensive survey of the literature and in this monograph the author outlines minutely the growth of the testis of the pig. He, however, makes no mention of the blood supply.

The first macroscopic indication of the vascularization of the testis is found when the embryo pig is thirty-three mm. in length. At this time the sex gland is situated relatively lower on the mesial surface of the Wolffian body, which may to some extent account for the low level at which the spermatic artery arises from the aorta. Concerning the origin of this artery there has been some discussion as to whether at times it may arise from one of the lower Wolffian arteries. Of the seventy-five or more specimens ranging in length from twenty-five mm. to two hundred and twenty mm., only one was found in which the artery arose otherwise than from the aorta. In this exception the spermatic artery came from the most caudal Wolffian artery close to its origin from the aorta.

In the thirty-three mm. stage seen in Fig. 1 no convolution is apparent in the spermatic artery which courses ventral to the Wolffian arteries. In this figure, as well as in the two following ones, it was found advisable to lay back the Wolffian body from its normal position in order to more clearly demonstrate the vascular supply to these glands. The renal artery which penetrates the kidney when the embryo is twenty-eight mm. in length is quite prominent and a few glomeruli are seen

⁷ Krause, W.: *Zum Spiralsaum der Samenfad.* Biol. Cent., 1881.

⁸ Allen, B. M.: *Embryonic Development of Ovary and Testis of Mammals.* Am. Jour. Anat., Vol. III, No. 2.

in the cleared specimen. As in the human embryo, rotation of the kidney occurs before the entrance of the blood supply, as has been shown by Pohlman.⁹ My study of sections of pig embryos places the rotation of the kidneys in this genus between twelve and fifteen mm.¹⁰ In the human embryo Pohlman has shown that the vascularization occurs between twenty-five and thirty mm., while in the pig I find this vascularization of the kidney at twenty-eight mm. The adrenal, which is depicted

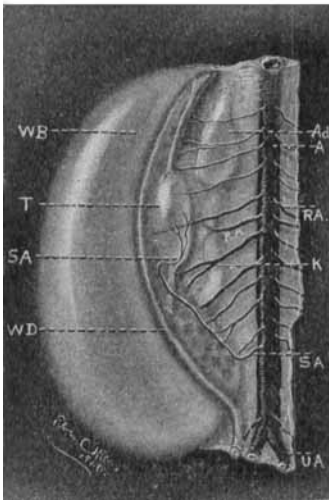


FIG. 1.

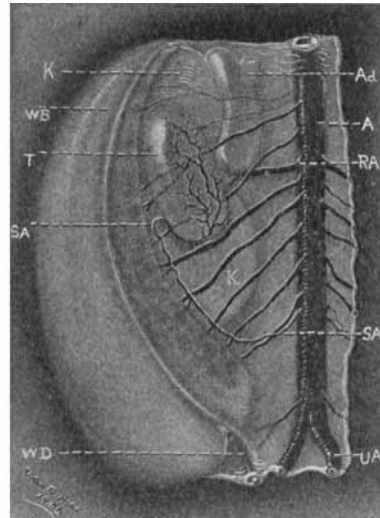


FIG. 2.

FIG. 1. Cleared specimen of the testis, kidney, and Wolffian body of an embryo pig 33 mm. in length, showing the first appearance of vascular supply to the testis. $\times 6$. W. B., right Wolffian body, 8.6 mm. in length; Ad., adrenal; A., aorta; T., testis measuring 2 mm. in length; S. A., spermatic artery; K., kidney, 3.8 mm. in length; W. D., Wolffian and Müllerian ducts; U. A., umbilical artery.

FIG. 2. Cleared specimen of the right testis, kidney, and Wolffian body of an embryo pig 48 mm. in length, showing the commencement of convolutions in the spermatic artery and the increased blood supply. $\times 6$. K., right kidney, 6.5 mm. in length; Ad., adrenal; W. B., Wolffian body, 10 mm. in length; A., dorsal aorta; R. A., renal artery; T., testis, 3.5 mm. in length; S. A., spermatic artery; W. D., Wolffian and Müllerian ducts; U. A., umbilical artery.

⁹ Pohlman, A. G.: Concerning the Embryology of Kidney Anomalies. *Am. Medicine*, Vol. VII, No. 25.

¹⁰ Hill, E. C.: On the First Appearance of the Renal Artery and the Relative Development of the Kidneys and Wolffian Bodies in Pig Embryos. *Johns Hop. Hosp. Bull.*, Vol. XVI.

in the illustration merely as a land mark, is densely injected but no attempt has been made to show its blood supply and in this and the following series it appears as if uninjected.

The Wolffian body at this time receives from ten to twelve arteries which richly supply the gland. In many cases a pressure sufficient to insure a perfect injection of the sex gland resulted in a double injection of the Wolffian bodies and kidneys. In the Wolffian bodies the sinusoids described by Minot are beautifully demonstrated in sections of five to twenty μ in thickness.

Allen⁸ has noted a great activity in the formation of the primitive sex cells of the seminiferous tubules and of the cords of Pflüger and rete cords about this time, and it is possible that this increased activity is due to the presence of the blood stream. Allen has also shown a sex differentiation in the embryo of twenty-five mm. which he bases upon histological observations. Through a study of the vascularization, this sex distinction is clearly marked at 33 mm., for as Clark¹¹ has shown "upon the peculiarities of each circulation the differential signs of sex are based, a visible dorsal vessel always indicating a male; an alabaster-like non-vascular white cortex a female embryo." This distinction, however, is true more particularly of the pig and is of doubtful value in differentiating the human sex glands.

In the embryo of forty-eight mm. (Fig. 2) the spermatic artery is found to have encircled a greater portion of the capsule of the sex gland and a certain amount of convolution is evident in the artery just before it reaches the testis. These convolutions are more marked as descent of the gland occurs, and this may be due in part to an attempt to shorten the artery. Thoma, however, in his studies of the development of the vascular system gives no such method of shortening. Nor, indeed, could this explanation account for the subsequent convolutions which occur after the testis has begun its descent from below the lower pole of the kidney. In this latter case there is a most decided lengthening accompanied by more marked convolutions. A similar condition is not found in the human embryo, nor to such marked extent in the mouse of this stage.

Microscopic sections demonstrate the capsular artery branching with a certain definite regularity on the surface of the gland, and sending minute arteries into the substance of the testis. A thick section shows these vessels entering perpendicularly and giving off branches which form capillary anastomoses around the medullary cords.

¹¹ Clark, J. G.: *The Origin, Development, and Degeneration of the Blood Vessels of the Human Ovary*. Johns Hop. Hosp. Rept., Vol. IX.

When the embryo has attained a length of eighty-seven mm. (Fig. 3) several of the anterior Wolffian arteries have disappeared and there is a decided atrophy of the organ itself. The capsular artery, a name which may be applied to that portion of the spermatic artery which supplies the albuginea and glandular substance proper, is seen to give off many

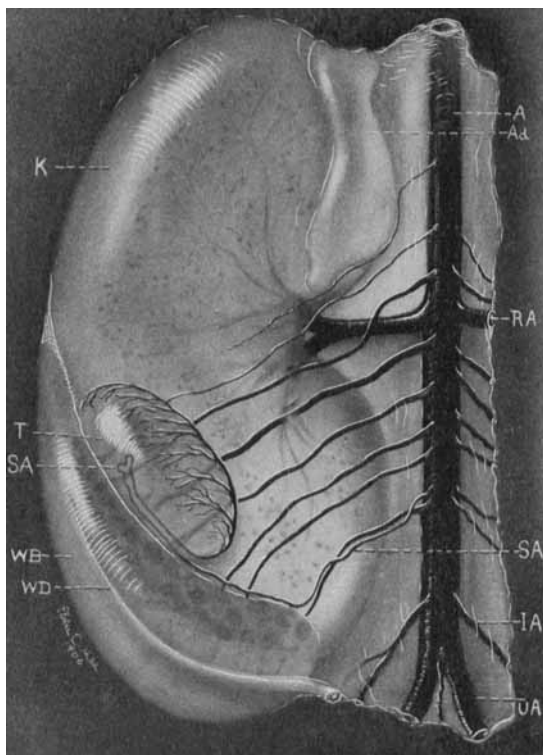


FIG. 3. Cleared specimen of the right testis, Wolffian body and kidney of an embryo pig 87 mm. long, showing descent of testis and atrophy of the anterior Wolffian arteries. $\times 6$. A., dorsal aorta; K., right kidney, 14.7 mm. in length; S. A., spermatic artery; W. B., Wolffian body, 9.5 mm. in length; W. D., Wolffian and Müllerian ducts; I. A., iliac artery; U. A., umbilical artery.

small branches, some of which are growing over the surface of the organ while others are penetrating deeply into the substance of the gland. In several specimens of this and later stages the capsular artery is found to divide into two main branches immediately after reaching the gland. The attachment of the sex gland to the Wolffian body is quite firm at this time.

Fig. 4 (128 mm.) shows a marked increase in the diameter of the spermatic artery, and also greater tortuosity of this vessel. The sex gland is seen to have assumed a different position in relation to the remains of the Wolffian body. This semi-rotation is, perhaps, caused by the convexity of the lower pole of the kidney as the testis in descending



FIG. 4. Abdominal cavity of an embryo pig 128 mm. in length, cleared specimen of a right testis taken from an embryo of the same size and substituted in order to show the relative positions of the organs. $\times 6$. This figure also shows the great tortuosity of the spermatic artery and by a comparison with Fig. 3, illustrates the occurrence of semi-rotation; *K.*, right kidney, 18.2 mm. in length; *S. A.*, spermatic artery; *A.*, dorsal aorta; *T.*, testis, 5.3 mm. in length; *U.*, ureter; *R.*, rectum; *W. M.*, Wolffian and Müllerian ducts; *U. A.*, umbilical artery; *B.*, bladder.

assumes a more dorsal position. Frequent anastomoses are noticed upon the capsule, and a small twig at the anterior end of the gland anastomoses with the branch from the spermatic artery which supplies the future globus major. Since the blood supply to the epididymis is not shown in any of the drawings, this branch has not been indicated.

The entrance of the testis into the internal ring occurs between the sizes of one hundred and ninety and two hundred and twenty mm. The left gland usually enters the internal ring first, and in Fig. 5 (210 mm.)

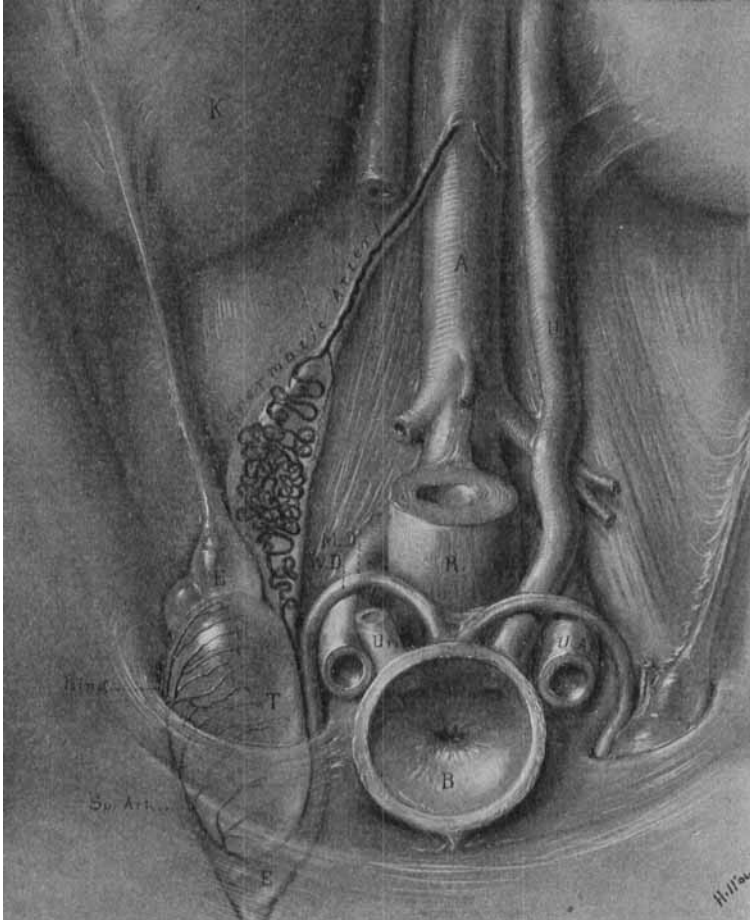


FIG. 5. A transparent specimen of the right testis of an embryo pig 210 mm. in length. The relation of this gland to the other organs was obtained from a fresh tissue specimen of an embryo of the same size. $\times 6$. In this figure the left testis is seen to have nearly passed the internal ring, while the right sex gland has just entered. *K.*, right kidney; *A.*, dorsal aorta; *E.*, epididymis; *U.*, ureter; *R.*, rectum; *M. D.*, *W. D.*, Müllerian and Wolffian ducts; *U. A.*, umbilical artery; *B.*, bladder; *T.*, testis, 6 mm. in length.

only the globus major of the epididymis is apparent. The capsular artery has sent out branches which nearly encircle the sex gland, and

these encircling arteries have almost completed their growth around the testis. A certain limited portion lying close to the epididymis is never encroached upon by these branching arteries. From the spermatic artery before it reaches the testis several branches arise, from five to seven in number, which supply the cord and globus major and minor. Frequent anastomoses are seen on the albuginea, and small branches which encircle the anterior portion of the gland form anastomoses with

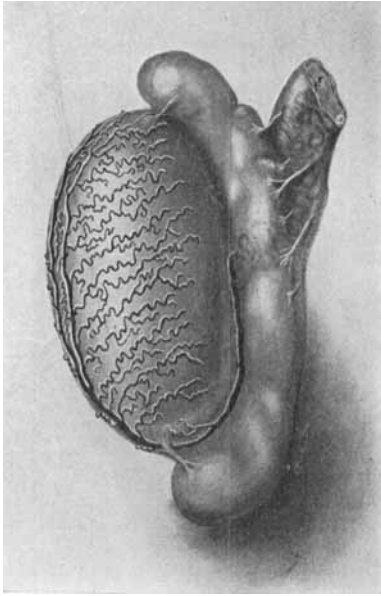


FIG. 6.

FIG. 6. The macroscopic appearance of an arterially injected adult pig testis, showing peculiar tortuous arrangement of the branches of the capsular artery in the tunica albuginea. $\times \frac{1}{2}$.

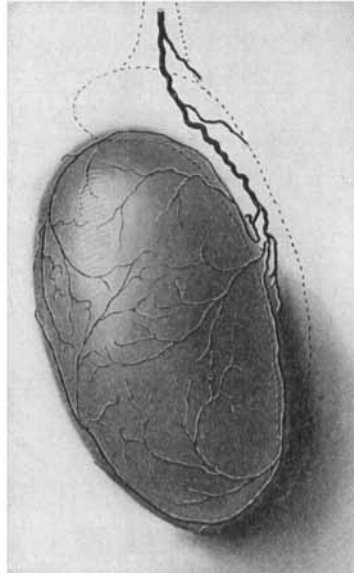


FIG. 7.

FIG. 7. A macroscopic drawing of the left injected testis of a human fetus of seven months. $\times 6\frac{1}{2}$. The dotted lines show the position of the cord and epididymis.

arteries supplying the globus major: thus allowing blood to penetrate the testis should the posterior portion of the capsular artery become occluded. The Müllerian ducts are atrophied and appear as ridges upon the Wolffian ducts which have increased in diameter of lumen and in thickness of wall.

The relations of the superficial blood supply in the testes of the adult pig and mouse and of the human fetus of seven months together with

the comparative positions of the spermatic cords is shown in figures 6, 7 and 8. In the illustration showing the testis of the human embryo, the arteries are found to encircle the gland, being distributed to the under surface of the albuginea. Frequent anastomoses are formed similar in many ways to the adult superficial supply in the mouse, but differing materially from the arterial distribution in the capsule of the pig testis. The relative position of the spermatic cord to the epididymis is quite noticeable and may be due to the differences in the manner of suspension of the gland with reference to the horizontal plane of the body. The comparative size of the globus major and minor is also markedly different. In the pig the globus minor is at times as large and not infrequently larger than the globus major. Few convolutions are apparent in the human embryonic gland, while in the testis of the embryo mouse as well as in the adult a certain amount of tortuosity is met with, not, however, anywhere near as marked as in the pig.

Arterial and Venous Supply of the Adult Testis of the Pig.—The capsular

artery gives off on the internal surface of the Tunica albuginea at rather regular intervals tortuous rib-like branches which nearly encircle the gland. These branches penetrate the substance of the gland following the septa and entering perpendicularly till they reach the mediastinum. Except in a very few instances no branches are given off from these perpendicular arteries until after the abrupt retro-flexion occurs

near the center of the gland. After this sudden backward bending, many branches are given off which, coursing toward the surface of the testis, send off smaller twigs which in turn divide into capillaries around the seminiferous tubules and supply the stroma of the gland. The veins collect from these capillaries and merging into larger vessels follow the septa directly toward the albuginea where passing under the arteries on the internal surface of the tunica albuginea, they encircle the gland and passing toward the epididymis form the pampiniform

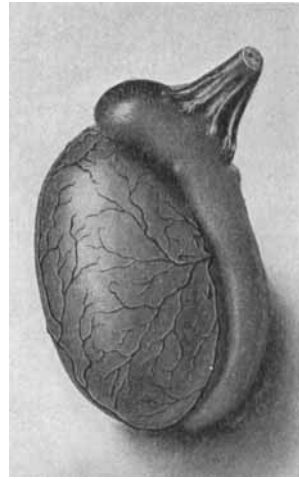


FIG. 8. The capsular distribution of the spermatic artery in the testis of the adult mouse. $\times 3\%$. This illustration, together with Figs. 6 and 7, show the relative positions of the cords and the albugineal blood supply.

plexus. These veins are about twice the size of the branches from the capsular artery and show an intricate anastomosis. Upon cross section of a doubly injected gland some seven or eight perpendicular descending arteries will appear and perhaps eight to twelve collecting veins.

The extreme vascularity of the gland is shown in Fig. 10, which is an arterial and capillary injection made with India ink and cleared by

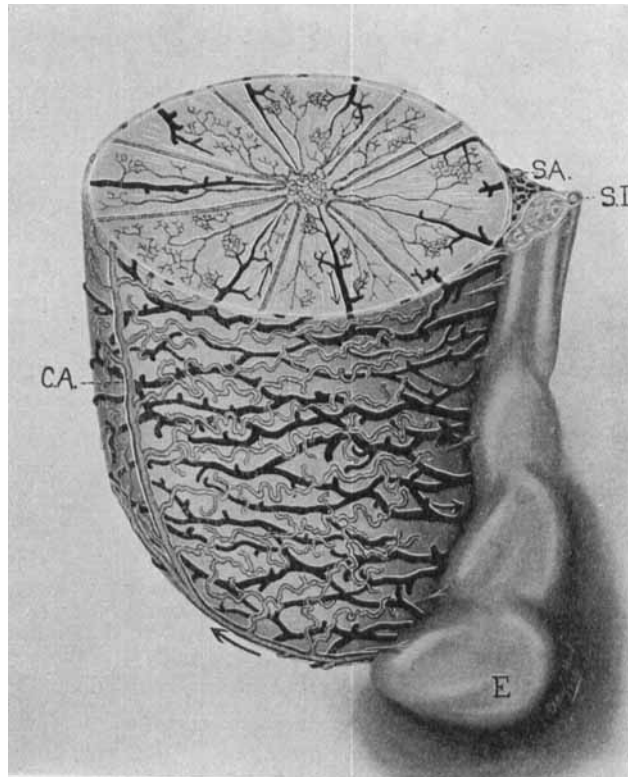


FIG. 9. A semi-diagrammatic representation of the circulation in the left testis of the adult pig. $\times 1\frac{1}{2}$. *E.*, globus minor of the epididymis. The arrows indicate the course of the blood stream. The arteries and capillaries are red; the veins, blue.

the modified Schultze method. The anastomoses around the tubules are so profuse that they give the section an appearance of ancient mail armor.

A microscopic section of the injected testis, stained and cleared by the Van Wijhe method shows beautifully under low power the manner in

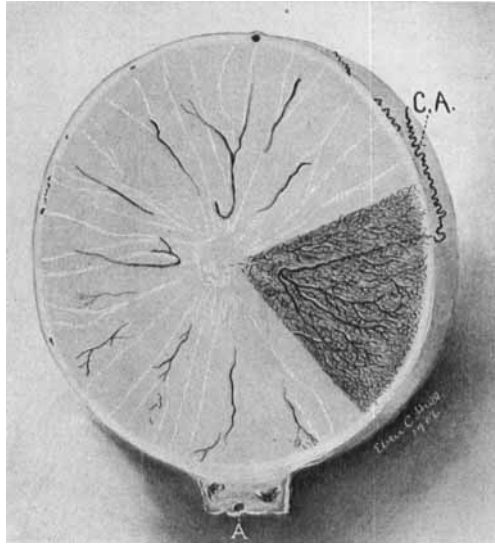


FIG. 10. A thick cleared cross section of the testis of an adult pig. $\times 1\%$. This shows the arteries and rich capillary network. C. A., tortuous branch of the capsular artery which can be seen penetrating to the mediastinum of the gland and there forming the typical loop before giving off any branches. A., spermatic artery in its course along the epididymis. The section was taken about midway between the globus major and minor, and as most of the epididymis was dissected away an atypically shaped piece of tissue remains.

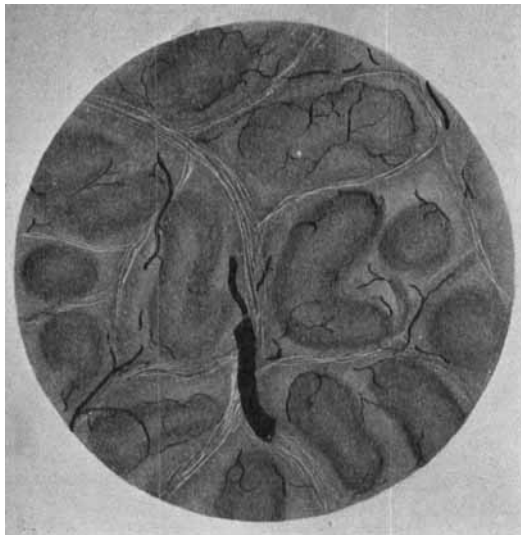


FIG. 11. A microscopic section of an injected testis of an adult pig cut 50μ , showing the capillary supply around the tubules. \times about 40.

which the capillaries encircle the tubules. In Fig. 11 are seen the capillaries, some larger arteries and a portion of one of the large ascending perpendicular branches given off shortly after the looping of the descending perpendicular branch near the center of the gland. The tubules of the pig testis show this capillary arrangement somewhat better than do those of the human adult male sex gland, for as was shown by Krause the tubules of the human testis measure two-tenths of a mm. in diameter, while I find that the tubules of the sex gland of the pig are between two-tenths and three-tenths mm. in diameter.

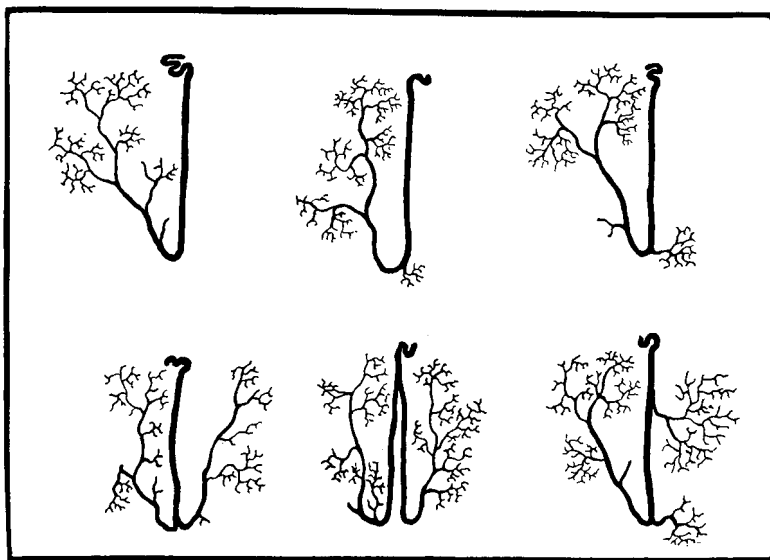


FIG. 12. Corrosion specimen of the testis of an adult pig, showing the typical arterial loops. $\times 2$.

The various types of arterial loops comprising the descending perpendicular artery and its ascending branches are shown in Fig. 12. These loops were taken from corrosion specimens of the adult testis of the pig. In the figure they are arranged in order of frequency, the last having a recurrent branch before the abrupt looping, being very rare. No similar arrangement was found from studies of corrosions of the human gland.

What the causes are which produce this peculiar arrangement it is difficult to say. In the first five figures representing early embryonic stages the arteries were found to penetrate the gland perpendicularly but to give off branches as they descended.

This is depicted in Fig. 13.

No typical looping occurs till after the gland is in the scrotum and the subsequent rapid development has begun. This leads one to surmise that the sudden growth, which changes the embryonic organ from one measuring, 6 mm. x 3 mm. x 2.8 mm. unto the adult gland measuring 65 mm. x 42 mm. x 37 mm., is accountable for this peculiarity of blood supply. This seems to be especially plausible when the relative positions of the mediastina of the human and pig testes are compared. Probably the development is so rapid that the arteries which enter perpendicularly

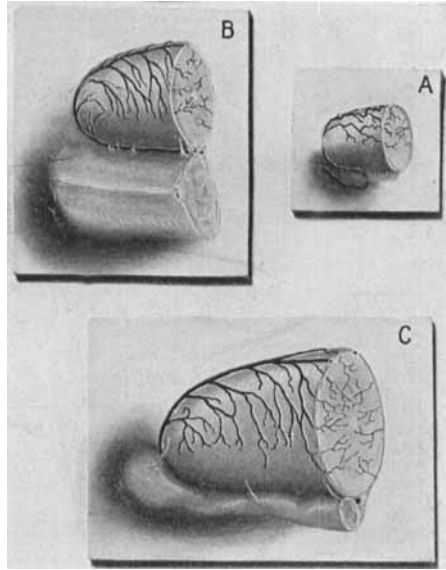


FIG. 13. *Fig. 13a* shows the left testis of an embryo pig 48 mm. in length. Then entrance of the perpendicular branches of the capsular artery is shown. $\times 9$.

Fig. 13b illustrates the depth of penetration of these same arteries in the testis of an embryo pig of 87 mm. $\times 9$.

Fig. 13c shows the entrance and distribution of these same arteries in the left testis of an embryo pig of 210 mm. $\times 9$.

in order to penetrate to the center are of necessity twisted back upon themselves in supplying the rapidly growing tubules whose development must be toward the circumference. The mediastinum is in the center of the gland and hence the tubules in developing radiate from this as a center.

The Blood Supply to the Albuginea—The vascular supply to the albuginea is shown in Fig. 14.

Above the large capsular arterial branches and veins which supply the

glandular tissue of the testis and which lie on the inner side of the tunica albuginea, is found a delicate plexus of small arteries, capillaries and veins grouped in irregular polyhedral forms, mostly of four or five sides, having an area of from nine to sixteen square millimeters. The arteries enclosing these polyhedrons spring from the encircling capsular branches and lie external to them. These small vessels are usually ac-

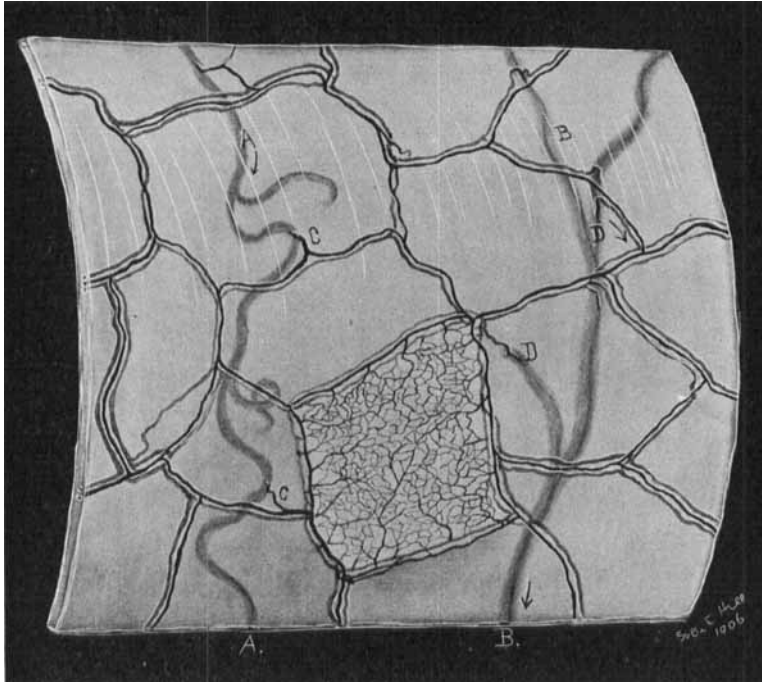


FIG. 14. A cleared specimen of the tunica albuginea of the testis of an adult pig, showing the arrangement of the vessels supplying this tunic. $\times 9$. This specimen was studied in glycerine with a magnification of 80 diameters (Leitz) for the capillaries of the individual lobules, and with a magnification of 8 diameters for the arrangement of the lobules. Drawn with camera lucida. A., one of the tortuous capsular arteries given off from the main capsular artery. These vessels lie below the small arteries supplying the albuginea. B, an encircling capsular vein which ultimately empties into the pampiniform plexus. These veins also lie beneath the arteries and veins supplying the albuginea and also pass under the large capsular arteries. C, a small artery arising from a capsular artery. D, a small vein emptying into a capsular vein. The arrows indicate the course of the blood stream.

companied by venæ comites which carry back the blood to the encircling veins. Each lobule is filled with a network of capillaries. In corrosion

specimens this superficial albugineal blood supply appears as a fine mesh over the larger encircling arteries and veins. A few of the veins collecting from these superficial vascular lobules empty directly into the pampiniform plexus, but as a rule the course is as described.

SUMMARY.

1. The measurements of the embryonic testis, Wolffian body and kidney from the time that the embryo is 20 mm. in length till the sex gland enters the internal ring are given.

2. A comparison of the size and weight of the human testis with that of the adult testis of the pig is made. The comparative sizes of the seminiferous tubules of the adult pig testis and human testis is noted.

3. The testis of the pig receives its first blood supply when the embryo is 33 mm. in length, the kidney having received its blood supply when the embryo has attained a length of 28 mm.

4. Out of seventy-five specimens only one exception was found to the usual source of the spermatic artery, and in this case the artery instead of coming directly from the aorta arose as a branch from the most caudal Wolffian artery.

5. Marked convolutions in the spermatic artery are first evident when the embryo is 48 mm. in length.

6. A change in the position of the testis relative to the remains of the Wolffian body is noted between 110 and 130 mm. This change is almost a semi-rotation; the testis assuming a more lateral position and having the future epididymis between it and the aorta.

7. The entrance of the testes into the internal rings occurs when the embryo has attained a size of 190-220 mm. Generally the left testis enters first.

8. The differences between the superficial blood supply in the human embryonic testis and the testes of the adult pig and mouse are indicated, and the relative positions of the spermatic cords to the epididymes are shown.

9. The vascularization of the testis of the adult pig is diagrammatically represented, and a theory to explain the peculiarities of the arrangement of the vessels is advanced. This hypothesis is based upon a suggestion from Dr. Mall that the sudden growth of the testis brings about a backward looping of the arteries in order to supply the rapidly developing semi-inferous tubules.

10. The vascularization of the tunica albuginea is illustrated by a drawing made with the aid of a camera lucida.