

MORPHOLOGY OF THE TUBULES OF THE HUMAN TESTIS AND EPIDIDYMIS

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TWELVE FIGURES

The intention of this paper is to show accurately the form of the seminiferous tubules of the testis and of the tubules of the epididymis, and to trace their development in man, especially in the late embryonic and fetal stages. With this study the blood vessels are so intimately associated that a description of them is added.

TESTIS

Many attempts have been made heretofore to decide whether the tubules are single with blind ends, or anastomosing, or merely branching, but the methods used gave contradictory results, and were unsatisfactory. Teasing methods are not convincing, because, in spite of the particularly tough reticular tissue described by Hill as encircling them, the tubules are easily broken; and injections are never complete, as the injection mass is forced through the walls of the tubules before the resistance of the many convolutions is overcome. The method employed as a basis of this paper is the study of serial sections, from which usually wax reconstructions have been made. The material is human, though frequently the many embryos of pig, sheep, cat, rabbit, etc., in the Harvard Embryological Collection have given valuable assistance in interpreting the human material.

Allen has given us an account of the origin of the seminiferous tubules, of the rete testis, and of the connections of this latter with the tubules of the Wolffian body on the one hand and the

testis tubules on the other. His results, obtained by studying pig and rabbit, I have confirmed, with slight variations in man. Briefly stated, Allen's facts are these; the testis tubules originate as cords of epithelial cells containing germ cells, which grow inward from the peritoneal epithelium covering the middle third of the genital ridge; the rete is formed of similar cords growing inward from the anterior third of the same ridge. Both sets soon lose their attachments to the peritoneum, so as to lie free within the ridge. The rete cords, forming a network, grow into the mediastinum, extending caudally to reach the inner or central ends of the testis cords, with which they become joined. On their way, the rete cords unite with the glomeruli of the Wolffian body, thus completing the passages by which the products of the seminiferous tubules are later carried away from the gland. The testis cords Allen described as anastomosing and branching, and occasionally growing parallel to the surface.

Further detailed study of these testis cords gives rather surprising results. Instead of branching and anastomosing irregularly, as suggested by Allen's description, the cords form a complete network, every cord anastomosing with others, leaving no free ends except those at the periphery and those near the mediastinum. The bases of the cords, at the periphery of the gland, form free ends when they have lost their connection with the peritoneal epithelium from which they grew; and the distal ends of the cords, which, since growth is centripetal, are found near the mediastinum, are also usually free ends, though occasionally two may join at their tips. Otherwise all the cords are joined by anastomosing branches. As a whole this network is crescentic in cross section, occupying a peripheral zone of the genital ridge, of which the mediastinum is the eccentric core; this brings the central ends of the cords nearer together, and accounts for the occasional anastomosis of their tips.

Although this network (fig. 5) seems at first sight to be quite irregular, a more critical study shows that each of the cords has three (occasionally four) sets of branches, so that there are three sets of cross connections joining the radially disposed cords. One set of branches is given off a little distance from the peritoneal

epithelium, and the branches run more or less parallel to the surface, as described by Allen; the second and third sets are given off respectively nearer the mediastinum. Beyond the third set of branches the cords grow centripetally without further branching. The figure or pattern thus produced, which is given in a very much simplified and idealized form in figure 1, results apparently from the fact that the testis cords possess a normal rate of branching, and are moreover limited in length by the thickness of the genital ridge. Three, or possibly four, sets of branches, a certain distance apart, are all that each cord produces.

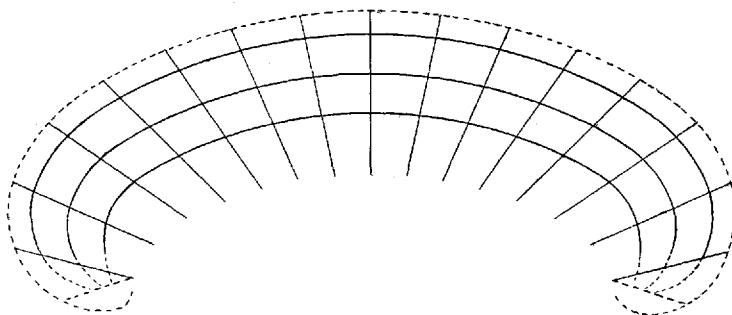


Fig. 1 Diagram of testis network of human embryo of 20 mm. Outer dotted line represents germinal epithelium, solid lines represent testis cords.

The cords forming this network vary in diameter, and, though usually approximately round, in certain places they are flattened, forming plate-like structures, often where three or four cords join. Sometimes these plates are pierced, making larger or smaller rings.

This network is completed shortly after the cords have become detached from the peritoneal epithelium, and before the central tips have joined the rete cords; in the human embryo this corresponds to a length of about 20 mm. to 22 mm. Further growth takes place in two ways; by the increase in diameter of the cords, and by the increase in thickness of the genital ridge, caused by the lengthening of the radially disposed cords, not at their ends, but throughout their whole extent, so that the cross connections are

more widely separated. No more branches are produced. With this there occurs, apparently, an absorption of the peripheral free ends into the network, leaving the outer set of cross connections as a series of arches, joining the ends of the radial cords (fig. 6). Also, since the cross connections do not lengthen so much as the radial cords, the network assumes a distinctly radial appearance.

There now occurs a partial destruction of the network. Although there is a general increase in the diameter of the cords, certain ones, usually, but not exclusively, those forming cross connections, remain of their original size or even become smaller. Many of these attenuated connections soon become severed, strand after strand, and the loose ends are absorbed into the network. This partial destruction of the network goes on for a long time, in the human embryo certainly from 22.8 mm. to 9.1 cm., perhaps longer; in the later stages, when the cords have become more established, the loose ends are not usually retracted or absorbed, but remain as short knobs or as long branches with blind ends.

The results of this process may be seen by comparing the models of tubules from embryos of 37.0 mm. and 9.1 cm. (figs. 6, 7, 8 and 9), a full description of which will be given later. At a glance, the destruction of the network and the consequent isolation of certain cords can be easily traced, as the figures are still uncomplicated by convolutions.

During this time the inner or central ends of the radial cords have come into contact with the rete cords, which also have formed a network. The rete network, the 'Keimdrüsennetz' of Mihal-kowicz and other older writers, is quite irregular, of small mesh, and persists throughout life. It occupies the mediastinum testis, and in the lower two-thirds of this spreads out in a fanshape, filling the space enclosed by the mass of the testis cords, which is itself crescentic in section. A single testis cord may come directly in contact and join with the rete network, or peripheral rete cords may extend far into the area of the testis network, so that the boundary line between rete network and testis network is irregular and wavy (fig. 6). These extensions probably indicate the position of the septa of the adult testis, along which the tubuli

recti often run for some distance before joining the seminiferous tubules. Frequently two testis cords anastomose just before joining a rete cord; on the other hand, one testis cord may be connected with several rete cords.

In regard to the age at which the testis and rete cords join, I find such differences between my findings in man and Allen's in pig and rabbit that they seem worthy of note. Allen gives the time of junction as about 13.0 cm. in the pig, and 21 days in the rabbit; in both cases the rete cords were already hollow before joining. In man the development of this connection is much more rapid, though there seem to be quite wide individual variations. At 16.0 mm. there is no extension of the rete cords downward, while at 23.0 mm. the cords have already grown past the upper glomeruli into the mediastinum, and in embryos of 32.0 mm. have already united with the testis cords. (In one embryo, H. E. C., no. 819, of 19.0 mm., this union has taken place.) For some time after joining, the rete cords in man remain solid, without lumen. This precocious development of the rete cords in man may be correlated with the small size and rapid degeneration of the mesonephros, as compared with that of pig and rabbit. In the sheep, another embryo with large mesonephros, the rete again develops late; whereas in the cat, whose mesonephros is small, the rete cords and testis cords have nearly joined at 24.0 mm. (H. E. C., no. 467).

By the end of the third month or the middle of the fourth the rapid destruction of the testis network probably ceases, though many connections may be severed much later; my preparations give no information on this point. The cords become so long that they are forced into convolutions, which increase progressively till puberty; on the other hand the cords decrease in diameter, becoming more and more slender until at seven months they are of about one-half as great diameter as at three months. From seven months on there is a gradual increase in calibre. This reduction in size may be due to a rearrangement of the cells to allow for the rapid increase in length. The convolutions are in short, stiff curves, which remain within a small area, condensing the connective tissue around them. It thus happens that different parts of

the same tubule are isolated from each other, and lie in compartments, which can be easily recognized in the adult testis, marking subdivisions of the parenchyma between the septa.

The greatest complexity of convolutions is in the peripheral part of the gland, and apparently in the cross connections, not in the radial cords, which latter may frequently be seen in the adult running from the rete with only a slightly wavy course to a con-

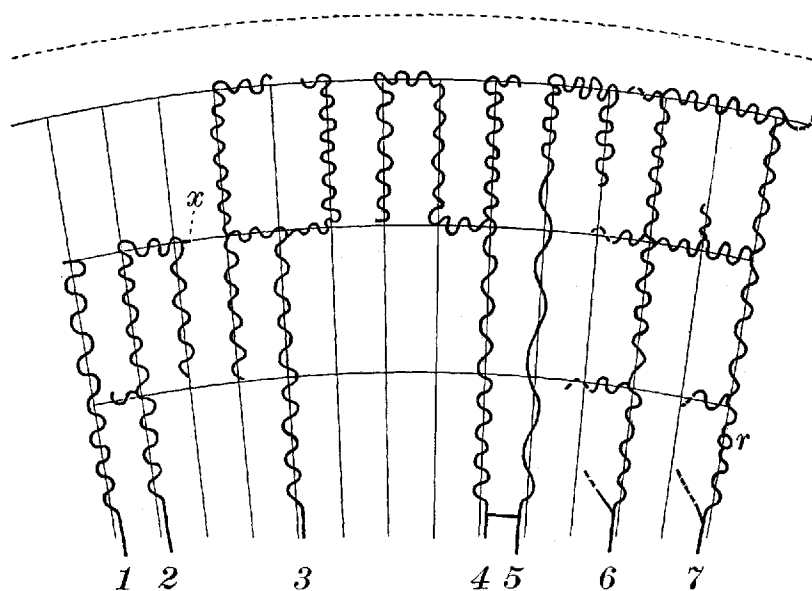


Fig. 2 Diagram of the course of several tubules in testis of seven months fetus, made by noting their connections and the positions of the various branches in the gland. The original network is represented by fine lines, the permanent portions of the tubules by heavy lines; rete connections at bottom of figure.

volute portion situated near the outer surface of the gland. The diagram (fig. 2) gives the approximate course of several tubules in a fetus of seven months and suggests from what part of the original network they have been derived, while the model (fig. 11) shows the actual form of some of the tubules at the same age. In the adult I have been unable to follow completely any single tubule but from the portions studied I feel convinced that, except for

the greater number of convolutions, the conditions are similar to those found at seven months.

From the diagram we see that there are to be found tubules with no connections whatever, except that with the rete, ending blindly; others with several branches which end blindly; others anastomosing with their neighbors. In one a short blunt knob, *x*, was seen (found also in the adult testis) such as has been described as commonly present by some authors. But to me the most interesting part of the diagram is the preservation, at seven months and probably in the adult, of the course, connections, and position of each tubule as determined for it by the original network of the testis cords.

THE BLOOD VESSELS

Hill has described the development of the blood vessels of the testis in the pig, and in a later work has apparently taken for granted that, although the adult arrangement in pig and man differ widely, the early development is similar in each case. In the pig the spermatic artery arises as a separate vessel from the dorsal aorta, caudal to the last mesonephric artery, or rarely as a branch of the latter. It makes its way horizontally to the mesial border of the Wolffian body, and then turns upward, toward the head, passing mesial to the mesonephric arteries, and crossing over the last five or six of them, to reach the genital gland; it thus approaches the testis from the caudal end. In man there is no such vessel formed. The arteries to the Wolffian glomeruli in the region of the future testis send branches to supply the gland directly, so that at first there are many spermatic arteries, which enter all along the attachment of the testis to the Wolffian body.

On examining embryos of other mammals in regard to the origin of their spermatic arteries, I find that in sheep, rabbit, cow, and deer (*cervus capreolus*) a separate vessel is formed to supply blood to the genital gland, whether it be testis or ovary; while in the cat the arteries to the glomeruli send branches directly to the gland. In sheep, the new artery is more apt to arise as a branch of the last mesonephric artery than as a direct outgrowth from the aorta, and in one deer embryo of 19.6 mm. (H. E. C., no 1230)

one ovarian artery is a branch of the mesenteric artery. I find here, then the same grouping of animals that occurred when the time of junction of rete cords and testis cords was under consideration; species with large Wolffian bodies (so far as my limited studies show) provide a new vessel for the genital glands, while those with small Wolffian bodies utilize branches from the nearest arteries.

In man and cat the mesonephric arteries anastomose freely with each other before entering the glomeruli, and with the early degeneration of the glomeruli the number of mesonephric arteries diminishes gradually, until one only is left; this one is, however, connected with all the arteries of the testis, and so becomes the single spermatic artery. The factors in this decrease in number of the Wolffian arteries seem to be the descent of the testis, which stretches them into long parallel vessels, and the ingrowth of the cords which are to form the cortex of the suprarenal body, which occurs directly in the course of these vessels, and presses upon them. Incidentally it may be mentioned that small pieces of this suprarenal tissue are often carried down with the lengthening arteries, and left as the small aberrant glands not infrequently found on the posterior wall of the abdominal cavity, along the course of the spermatic artery. In a human embryo of 37.0 mm. (H. E. C., no. 820) there are two complete spermatic arteries in each side, and four or five arterial stems parallel to the main arteries either joining them or ending blindly, evidently recently obliterated. In an embryo of 44.3 mm. (H. E. C., no. 293) one artery on each side remains, with two or three obliterated pieces beside it. In both embryos suprarenal tissue appears along the course of the arteries. This method of arriving at a single spermatic artery on each side in man accounts for the wide range in its point of origin in the adult, as described in the text-books of anatomy.

The veins of the testis in all the mammals examined arise as simple offshoots from the sinusoids of the Wolffian body in the neighborhood of the genital gland.

The blood vessels of the testis in man, then, arise as two capillary networks, one from the branches of the efferent arteries of the

glomeruli of the mesonephros, the other from the sinusoids. Both sets interdigitate with the network of cords, and extend beyond the the outer cross connections of the network so as to lie just underneath the peritoneal epithelium. The flow of blood is in two directions from the hilus or mediastinum testis toward the periphery, and from the periphery toward the center; the veins also return the blood in both directions. There are at first, then, no terminal arteries or veins. As certain cords become destroyed, the capillaries lying near them are allowed to assume a straighter course; they then become the more favored vessels, grow larger and are established as main arteries or veins. Since the cross connections of the network are those most frequently severed, the radial vessels are the most favored, and hence the main arteries and veins of the testis run radially. But not infrequently, as we have seen, the radial cords are severed, and this fact accounts for the few main vessels which, though not figured by Hill, are commonly present in the adult testis, running diagonally or even for some distance parallel to the surface of the gland, quite deep within the substance. Another curious arrangement of vessels not mentioned by Hill, is found in the testis; three or four arteries run parallel to one another for long distances to supply an area which would usually be served by a single artery with short branches. To explain this it is only necessary to imagine that certain cross connections of the cord network which may at first have separated the different vessels quite widely, were destroyed late, after each vessel was well established, and that subsequent radial growth drew the vessels together.

The terminal arteries are at their first appearance probably portions of the capillary network not favored by a direct course. In the fourth month three sets of terminal arteries can be made out, one set situated between the outer and second sets of cross connections of the testis cords, another between the second and inner sets of cross connections, and a third set nearer the rete. At seven months new arteries have grown from these, and also apparently from the main stems of the radial and peripheral arteries, so that the picture is much complicated; yet even in the adult, the embryonic arrangement of three main branches from each radial artery

can be traced in some places. (Hill, fig. 12.) In both the fourth and the seventh months a vascular unit can be made out, as the veins are arranged in a network around the terminal arteries in the usual manner. Hill mentions "vascular units which correspond to units of structure and which repeat themselves similarly throughout the organ," but does not state what these units of structure are; I have found in the testis of seven months and in the adult that the structural unit corresponding to the vascular unit consists of a number of coils of a single tubule enclosed in a compartment, as described earlier in this paper. The border veins of the unit lie in the connective tissue which surrounds the convolutions, the terminal artery pierces the compartment. It is probable that the terminal artery is the causative factor in this unit; the portion of a tubule situated nearest to the artery would be more favorably placed for growth and consequent convolution, than the portions of the tubule further from the blood supply; the convolutions would therefore form around the arteries, one set for each terminal artery. These units are quite large, readily visible to the naked eye; the capillaries surrounding the tubules are therefore of considerable length. As structural units they are not typical, like the unit of the lung or of the salivary glands, since they only very occasionally represent the terminal, blind ends of the secreting or active portion of the gland, and since there is no constant relation between the terminal artery and the channel through which the secretion leaves the unit. One tubule passes through several units, but all the convolutions within a unit belong to the same tubule.

The peripheral layers of the original capillary networks, both arterial and venous, interdigitate with the peripheral portions of the cords, while these portions are still attached to the peritoneal epithelium from which they grew. When this connection is lost and the peripheral ends of the cords have been absorbed into the network, the peripheral vascular networks remain, and become incorporated in the vascular layer of the tunica albuginea; the main vessels are given their prominence by their direct connections with the main radial vessels within the testis. In the ovary, this

same peripheral layer of the vascular network is buried within the organ, and becomes the system of arched vessels found between the medulla and cortex. For in the ovary, the original or medullary cords degenerate, and new cords (Pflüger's cords) grow from the surface, carrying before them the vessels which lay just beneath the surface. From these new vessels grow peripherally, while the network, which supplied the medullary cords for the most part is lost. The terminal arteries of the ovary, then, like the real sexual cords, are secondary affairs when compared with similar structures in the testis.

EPIDIDYMIS

The precursors of the epididymis are the anterior mesonephric tubules, which form the ductuli efferentes, and the anterior portion of the mesonephric duct, whose convolutions form a large part of the head and the tail of the epididymis, while the posterior part remains unconvoluted and forms the ductus deferens. As in the case of the testis tubules, this paper deals with the more detailed morphology of the epididymal tubules in man, especially in the late embryonic and fetal stages.

Perhaps the most accurate accounts of the Wolffian tubules are those of MacCallum, who studied pig, and, less thoroughly, man, and Grafe, who worked with chick material. According to MacCallum the tubule of a fully formed Wolffian body, in the pig, is a long affair, running from the glomerulus in sweeping curves, from mesial to lateral border of the organ (see his text-figure no. 8). Some of these tubules were seen to branch soon after leaving the Wolffian duct, others just before entering the glomeruli. "Evidences of anastomosis and the formation of networks of tubules were also made out," particularly in the region of the dorsal border. MacCallum made models from serial sections and also injected fresh material; the anastomoses and networks were found by the latter method. Grafe also found branches of the tubules, and affirms that they indicated new tubules which have grown by budding. He also made a point of the fact that some of the tu-

bules enter the duct on its dorsal aspect, some on its ventral. In the chick the tubules are not so long nor so convoluted as in the pig.

In man also the tubules seem to be of two more or less distinct groups, one entering the mesonephric duct on the ventral, one on the dorsal side, and these two groups run with few convolutions along the ventral and dorsal borders of the gland respectively to the glomeruli, which lie far dorsally. The tubules of the ventral set thus approach nearer to the genital anlage than their respective glomeruli, but this is not true of the dorsal set of tubules. None of the tubules in man ever attain the extreme length found in pig, sheep, rabbit, and other animals which retain functioning Wolffian bodies to an advanced embryonic age. MacCallum found the full formation of the Wolffian body in the pig at between 40 mm. and 95 mm., while in man he noted a reduction of the number of tubules after 12 mm. This latter statement, however, I cannot reconcile with what I have found in the embryos of man in the Harvard Embryological Collection, unless very wide individual differences occur. MacCallum counted 27 tubules in one Wolffian body in a human embryo of 12 mm., 20 in one of 14 mm., and 9 in one of 20 mm.; while, as the following table shows, I have found no constant reduction in the number of tubules up to 44 mm.

Number of tubules in one Wolffian body

LENGTH OF EMBRYO	H.E.C. NO.	TUBULES
4.0	714	23
7.5	256	34
8.0	817	28
9.1	734	35
9.4	529	37
10.0	1000	34
11.5	189	30
12.0	816	27
16.0	1322	30
19.0	819	25
22.8	871	31
37.0	820	33
44.3	293	32

These numbers are not affected to any appreciable extent by the formation of new branches, as in no case have I found more than five or six of these in one Wolffian body. That the tubules must remain as functioning and useful parts of the embryo longer than is suggested by MacCallum will be evident when we consider that the kidney in man is only beginning to be provided with glomeruli and convoluted tubules in an embryo of 20 mm.; but there seems to be no constant relation between the size of the Wolffian body and the growth of glomeruli in the kidney, since the kidney in pig is fully as far advanced at 20 mm. and in later stages as in man, in spite of the much larger and longer lasting Wolffian body. Hill agrees with Pohlman, that the vascularization of the human kidney takes place between 25 and 30 mm., a little later than the presence of glomeruli would indicate, and gives the size for pig embryos as 28 mm. The cause of the continued growth and activity of the mesonephros in the pig and several other animals, even after the kidney is apparently able to act as an excretory organ, is a subject which I shall have to leave for future investigation.

Of these mesonephric tubules the 6th to the 20th in pig, the 12th to the 20th in rabbit lie, according to Allen, opposite the rete region, and presumably (though it is not so stated by him) join with the rete cords. In man the rete region is more cephalad, opposite the first eight or nine glomeruli; but the rete cords anastomose not only with these but with many others in their course down the mediastinum. Occasionally the first one or two glomeruli do not join the rete, and remain as small cysts, losing their tubules (fig. 3). Such isolated glomeruli would give rise to the appendix epididymis, described by Toldt as being present in 27 per cent of cases examined. The disconnected tubules of such glomeruli would end blindly, as shown in fig. 3 and 4, and in fig. 12, and would ordinarily lie inconspicuously among the convolutions of the epididymal duct; if the upper glomerulus and its tubule were separated by a considerable distance from the others, as I have seen it in two of the embryos studied, this blind tubule might form the infrequent lower paradidymis of Toldt, a single tubule in a connective tissue sheath lying behind the head of the epididymis.

The number of mesonephric tubules which join with the rete, as described by Allen and others, varies in the specimens examined from eleven to nineteen or twenty. The rete cords do not always meet the glomeruli, but in man not infrequently connect with the proximal part of the mesonephric tubule. This is the result of the course taken by the ventral tubules in the human mesonephrost as described above, for the rete seems to join with the nearest, part of the tubule. Tubules thus tapped along their course are,

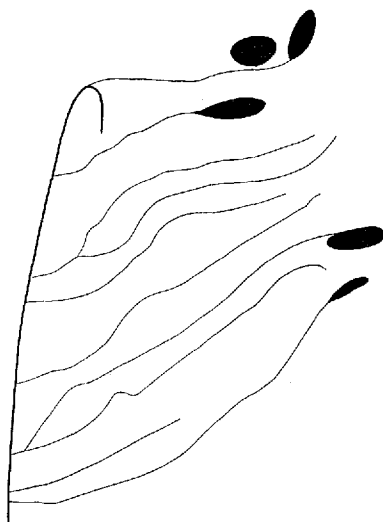


Fig. 3 Diagram of epididymal tubules of a fetus of 10 cm. To show slight branching and disconnected upper glomerulus. Many glomeruli have entirely disappeared; rete not indicated.

by a rearrangement of their parts, brought to seem like two tubules each arising from the rete, one running to the duct, the other ending blindly, usually with an expanded end. Such a blind tubule may be seen in fig. 4, 2, and in a fetus of seven months I have traced five or six similar tubules. It is probable that these are the tubules of the appendages of the rete testis, as described by Roth and Poirier, and also the upper, shorter ductulus aberrans,

described by other writers as opening into the rete and ending blindly. Roth and Poirier regarded them as tubules which, after acquiring a union with the rete, lost their connection with the Wolffian duct; but the presence of the blind tubules I have de-

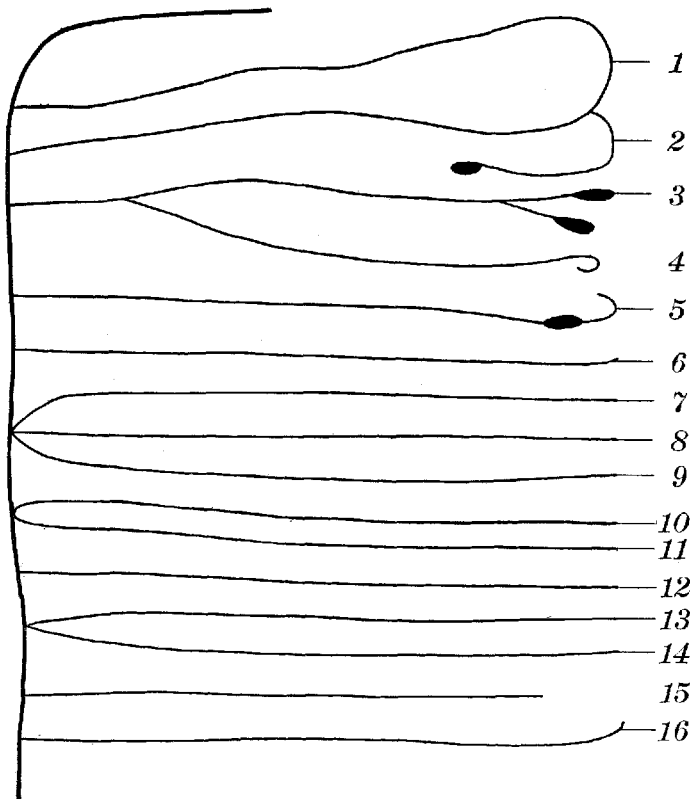


Fig. 4 Diagram of epididymal tubules of a seven months' fetus. Junctions with rete indicated by fine lines.

scribed renders unnecessary such an unlikely supposition as the separation of the tubule and the duct after a new channel has been formed. These tubules may lie inconspicuously among their neighbors or, as in the seven months fetus, be grouped together in a separate sheath of connective tissue.

In several embryos and in a fetus of three months and another of seven months I have found tubules lying in the rete region and yet unconnected with the rete cords (fig. 4, 4 and 15). In the older fetus such tubules are of smaller diameter than the ductus epididymis, but have a similar epithelium. If separated from their neighbors, these tubules would form the lower ductulus aberrans. The upper paradidymis of Toldt (organ of Giraldés) is probably correctly described by him as mesonephric tubules lying below the rete region but maintaining their connections with the duct.

While not dealing in this paper with the histological differentiation of the epithelium lining these tracts, I may mention that this differentiation seems to depend not on the portion of the mesonephric tubules or duct which gives rise to any tubule in the adult, but on the connections which are permanently established. At three months the epithelium of the tubules and duct is similar, all trace of former differentiation having disappeared; at about seven months a new differentiation takes place, but this time all the tubules connected with the rete show a similar epithelium, all tubules connected with the duct have duct epithelium. Thus tubules of like origin may at seven months and later be lined by different kinds of epithelium. The similarity of the epithelium in the duct and the blind tubules emptying into it seems to me to point distinctly toward a secretory function of this coiled tube.

As will be seen from the diagrams, (which have been compiled after carefully following each tubule in serial sections of the organs, and which have been offered instead of models or actual reconstructions, as showing more clearly the courses and connections of the different tubules), there are several cases of branching in each epididymis, as found by MacCallum and Grafe in the Wolffian body. In only one fetus was an anastomosis found (fig. 4, 1 and 2), and the formation of a more considerable network was nowhere seen. It is probable that tubule 5, in the same diagram, originally anastomosed with tubule 4 or some other, since in this way the position of the persistent glomerulus may be explained, by imagining two tubules running to the same glomerulus, only

one of which joined with the rete. But anastomoses among the vasa efferentia of man must be considered as of rare occurrence.

Convolutions of the vasa efferentia and the ductus epididymis begin to appear at about the fourth month of fetal life, as was found to be the case with the testis tubules. Here also the convolutions are in short, stiff curves, and here also certain portions of the tubules form groups of coils, joined by unconvoluted portions, each group ultimately developing a vascular unit of its own. In the case of the *coni vasculosi*, single vasa efferentia are usually separated by connective tissue, though occasionally two or more may be intertwined; each *conus* contains several units. In position the *coni* are of two distinct groups, lying mesial and lateral respectively to the convolutions of the ductus epididymis. This arrangement, not described in the text-books, seems to be due to the two sets of mesonephric tubules which enter the duct on its ventral and dorsal aspect respectively, as described above; the ventral tubules form the lateral group of *coni vasculosi*. The head of the epididymis thus shows three main lobes, more or less distinct, the middle lobe containing the ductus epididymis.

CONCLUSIONS

1. The testis cords, growing from the germinal epithelium of the genital ridge, form a network with three sets of anastomosing branches. After completion, this network breaks down partially, leaving certain cords as persistent stems. The tubules of the adult show, in their course, connection, and position in the testis, traces of this network. Testis tubules may be single, ending blindly, may branch, or may anastomose.

2. The unit of the testis is a considerable number of coils of one tubule, enclosed within a sheath; there are many units for each tubule, connected by less convoluted portions.

3. The spermatic artery is not a special vessel, as in the pig, etc., but the survivor of the mesonephric arteries in the genital region. The others were obliterated by stretching and by the

growth of the cortex of the suprarenal gland. Pieces of this latter are common along the course of the spermatic artery.

4. The mesonephric tubules in man join the duct on either its dorsal or ventral side. The dorsal ones run dorsally, so that the rete tubules join their glomeruli; the ventral ones take a more ventral course, so that the tubules before reaching the glomeruli pass by the mediastinum testis, and are joined by the rete tubules. The glomerular ends of the ventral tubules form the appendages of the rete testis, (Roth and Poirier), and the upperductulus aberrans.

5. The rete tubules in man develop opposite the first eight or nine mesonephric glomeruli, but are connected with many more in their course downward in the mediastinum. The first one or two may remain unattached, forming the appendix epididymis, their tubules making the lower paradidymis (Toldt). Tubules below the junction of the rete form the lower ductulus aberrans and the organ of Giralaldés.

6. The small percentage of cases in which these appendages are found is due to the fact that the tubules involved frequently lie inconspicuously among the convolutions of the normal ducts.

7. The epithelium lining these appendages depends upon their final connections, not upon their origin.

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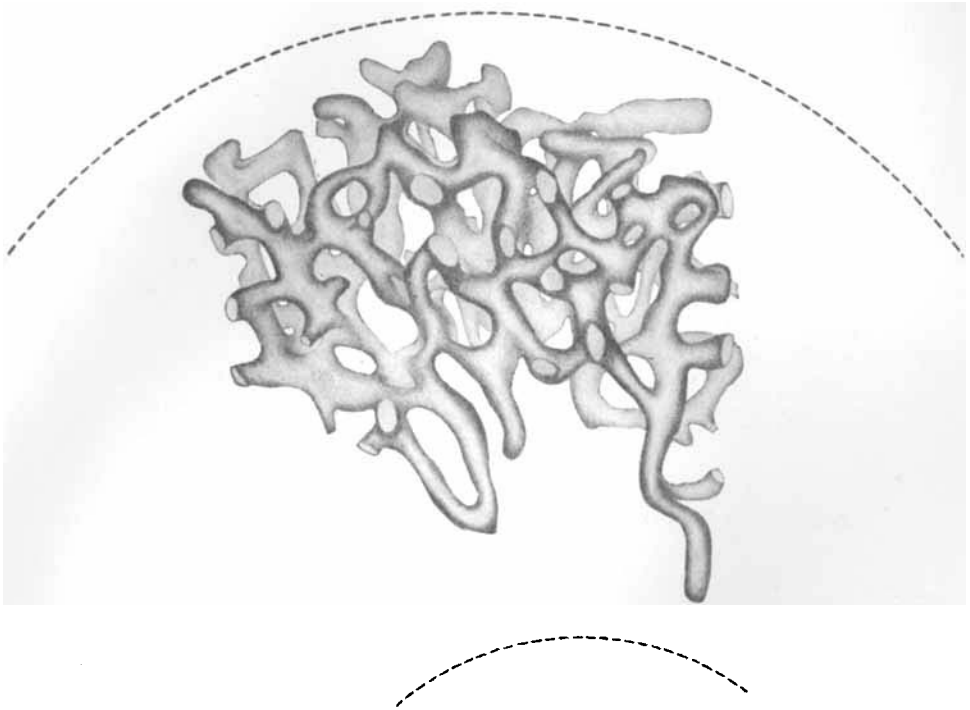


Fig. 5 Model; testis of human embryo of 22.8 mm. (H. E. C., no. 871). A segment of a transverse slice is shown; the limit of the genital ridge and the outer border of the mediastinum testis are indicated by dotted lines. The proximal or peripheral ends of the cords have already lost their attachment to the peritoneum; the distal or central ends are seen reaching toward the mediastinum, in one case uniting at their tips. Except for these two sets there are no free ends, each branch forming an anastomosis with others; the cut surfaces represent connections beyond the extent of the model. The arrangement of three cross connections shows best at the two cut edges of the model; plates and ring formation are also to be seen. $\times 180$ diam.

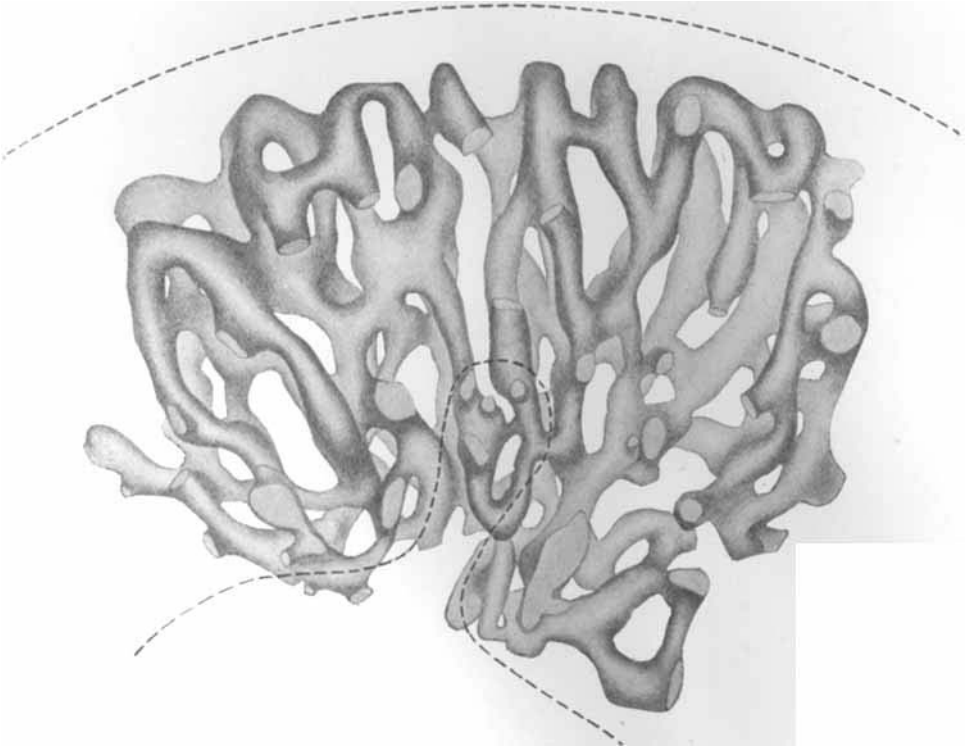
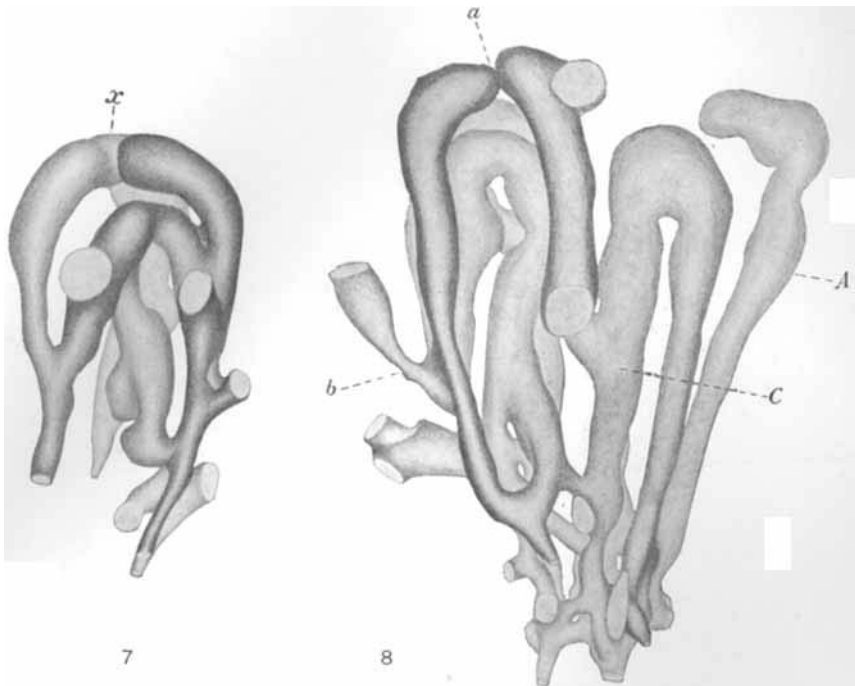


Fig. 6 Model; testis of human embryo of 37.0 mm. (H. E. C., no. 820). Orientation same as in fig. 4. Peripheral ends of cords have been absorbed, leaving a series of arches as the outer border of the figure. The rete network has already joined the cords, and rete cords can be recognized by their small diameter; the lower dotted line indicates their irregular extension. Other cut ends represent, as before, anastomoses beyond the limit of the model. Fewer cross connections, more radial disposition of cords. $\times 180$ diam.



Figs. 7, 8 and 9 Models; human fetus of 9.1 cm., age given as three months. Tubules from different parts of same testis; figs. 8 and 9 two views of same model. The rete cords are slender with cut ends. The large cut ends represent anastomoses with tubules not modeled. Loops formed by radial tubules and cross connections are seen, some including the peripheral set of cross connections, some the second set; while shorter connections of the central set can be made out nearer the mediastinum. In fig. 8, at *a*, a peripheral loop is just breaking apart; in fig. 7, at *x*, another has just been severed. At *b* and *c*, in figs. 8 and 9, the tubules are very small and will probably part in a short while. Tubule *A* is unconnected except near the rete, and consists of a radial cord with the greater part of a peripheral loop. Tubule *B* has a short anastomosing branch representing the inner set (at *e*) and a looped end consisting of the outer two sets of connections and the part of the radial tubule between them, the rest of which has been lost. Tubule *C* has all three sets of connections represented. Ring formation can be seen at *r*. $\times 90$ diam.

Fig. 10 Model; human fetus of about 10.0 cm., age given as 106 days. Convolutions have begun, chiefly in the cross connections; the tubules have become of nearly even diameter. The only blind ends are at *x* and *y*. Tubule *A* is connected with three rete tubules, and extends only to the inner cross connection, which can be traced through a few convolutions to another radial limb, also without branches till near the rete; a separate short loop is thus made. Cross connections belonging to the other two sets are recognizable, and can be traced easily in the actual model. $\times 90$ diam.

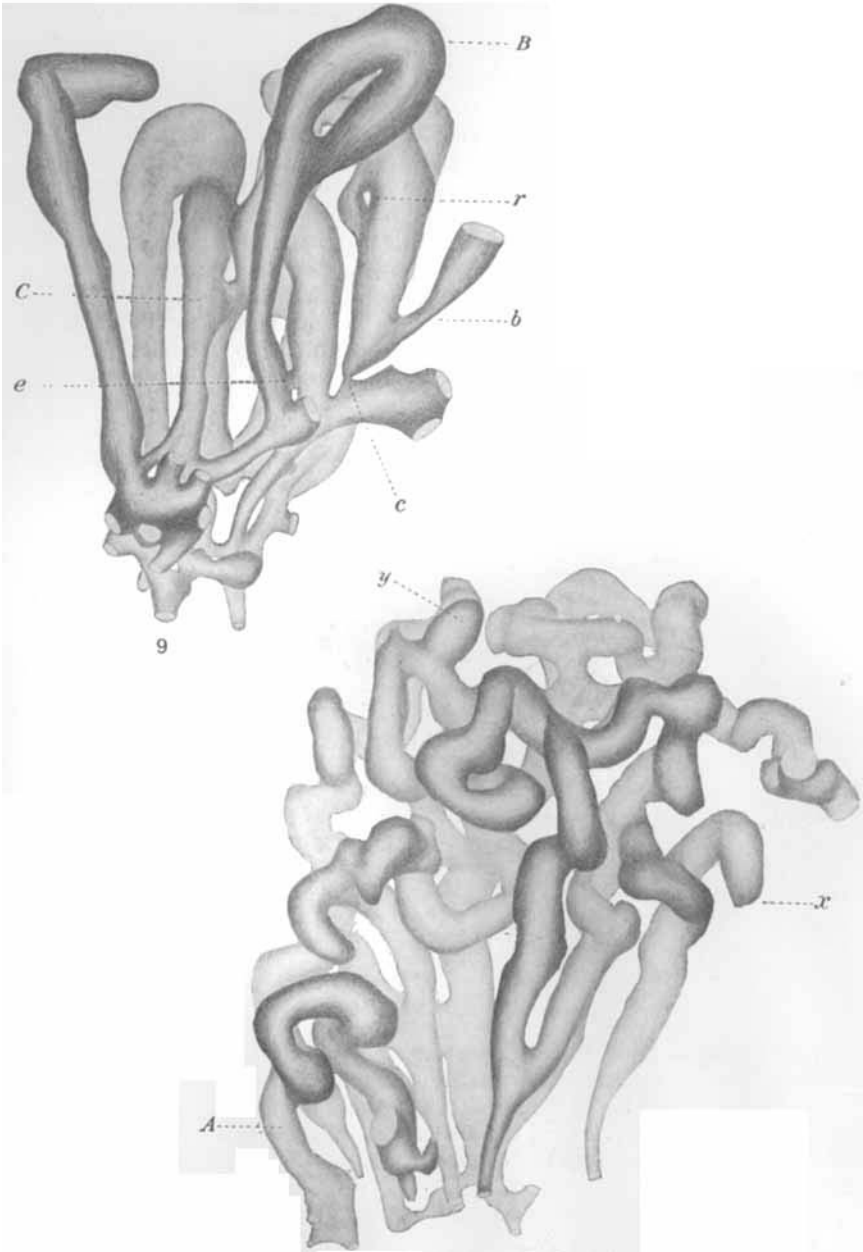
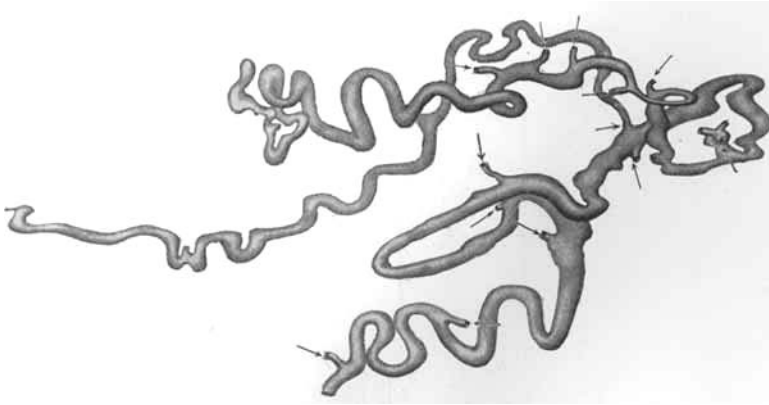


PLATE 1

Fig. 11 Model; human fetus of seven months. Two tubules of the testis with their connections. The tubules are colored red and yellow, (tubules *A* and *B*). Cross connections between them, of which there are two, are colored two shades of orange and represent the outer and middle sets. From the outer cross connection come two branches, one anastomosing with other tubules, not modeled, the other ending blindly at *x*. From the other cross connection there is also an anastomosing branch, *a*; while other branches from tubule *B*, which should be considered as belonging to the middle set, are seen at *b* and *c*. The inner set of cross connections is represented by branches *y* and *z*, of which *y* ends blindly. Tubule *B* joins another before meeting the rete tubule (fig. 5) while two rete tubules connect with tubule *A*. The group of tubules in yellow, between the middle set of cross connections and the periphery, form a unit; a single artery supplies them, and a network of veins surrounds them, lying partly between them and the tubules in orange. At *r* a ring is seen in the course of tubule *A*. $\times 90$ diam.



12

Fig. 12 Reconstruction; epididymis of human fetus of about 10 cm., age given at 106 days. The Wolffian duct is shown with fifteen Wolffian tubules opening into it one of which is traced to the rete (shown by the fine line), the others represented as cut short. The upper end of the duct is probably the first tubule which has failed to unite with the rete. The connections of all the tubules is shown in fig. 4. $\times 40$ diam.

