THE DESCENT OF THE TESTES IN THE PIG; INTRA-ABDOMINAL PRESSURE SUGGESTED AS A CAUSE

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INTRODUCTION

Cryptorchism in man may be defined as that condition in which the testes, normally scrotal, are for some reason or other retained within the abdominal cavity proper. The condition may involve one or both testes, most generally the left, and the position in and at which they are retained may also vary. Ordinarily they are to be found at some place along the route normally traversed in complete descensus. Cryptorchism in man appears perhaps more often than is commonly thought. Statistics of the U. S. War Department show that its incidence of occurrence in enlisted men is somewhat more than three per thousand. Eisenstaedt (1927) states that about 3% of the children in the Hospital for Ruptured and Crippled Children (Chicago) exhibit this condition.

All animals below the Mammalia in the phylogenetic scale are normally cryptorchic. The Mammalia themselves present variety of testicular positions ranging from abdominal to permanently scrotal (Fig. 1). The testes are situated in the body in various positions according to the species and the age of the animal. In embryonic life the testes of all groups are to be found in the abdominal cavity, starting their development rather high up in the neighborhood of the kidneys. In the Monotremata, Cetacea and Proboscidea they retain their abdominal position throughout the life of the individual, becoming greatly enlarged at breeding times and dwindling afterwards. In the Edentata the testes may be primarily or secondarily abdominal or subintegumental. In the Rodentia, Insectivora, and Chiroptera the testes periodically change from an abdominal to a scrotal or subintegumental position. The testes of the Pinnipedia have a permanent extra-abdominal, subintegumental position in the inguinal canal, while those of the Carnivora, Artiodactyla, Perissodactyla and Lemuroidea are permanently scrotal in the adult. In the Primates the conditions vary, almost all the positions in which the testes are found in the animals above the Monotremata, Edentata and Cetacea being normally represented in different Primates (Frankl, 1895, page 186). The abdominal position is the primitive situation of the testes; the permanently scrotal is the latest and the highest in point of development. All gradations between the two are present but do not necessarily correspond to the phylogenetic position of the animal, (if complexity of the process in changing position is the criterion of degree of development). Thus in figure 1 the curve showing the degree of the

change is not a continuous curve but undulates, with peaks of development over low points in the phylogenetic curve.

The question arises whether cryptorchism be a case of reversion. Cryptorchism is obviously the result of a failure in some normal process. All structures which are generally present in the normal condition are present to some degree to crytorchism. Biologically the

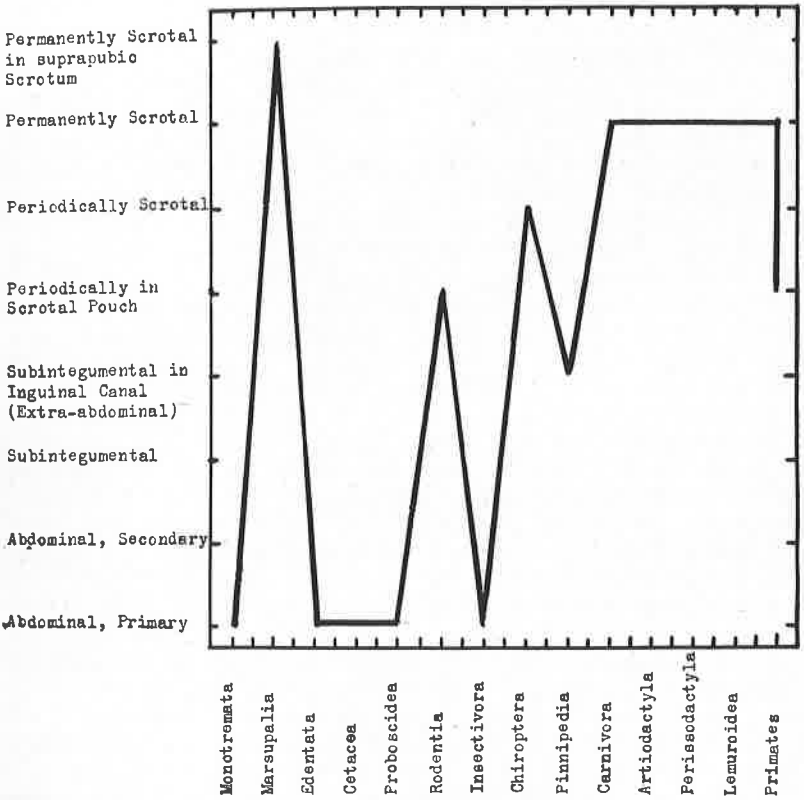

Fig. 1. Positions Occupied by the Testes in Mammals at Various Levels in the Phylogenetic Scale.

condition must then be considered as of a secondary nature. It may be the result of a reversion in some organ, an organ upon whose functioning the descensus is dependent for its stimulus, or as a result of whose functioning anatomical structures, which are concerned in the descensus, are influenced. Therefore, cryptorchism should be regarded simply as an arrested development process. (A bit of evidence supporting this view is the observation stated by Mason (1922) that the cryptorchic condition is often accompanied by a lack of development of the lateral incisors).

Genetically, cryptorchism is not of great importance since it is

one of those conditions which because of its very nature would tend to eliminate itself. However, anything which tends to incapacitate man or make him less efficient, or which lessens his chances of a happy and useful life, or which in any way prevents his functioning as a normal individual, is of economic importance and worthy of attention and investigation.

The effect of cryptorchism on man may be said to be of two sorts, physical and psychological. Mono-cryptorchids are potent and develop the usual secondary sexual characteristics. Probably the chief effect of this condition is of a psychological nature; the individual mistakenly feeling himself essentially different from others. Individuals with bilateral cryptorchism are always sterile and may be sterile and eunuchoid as well (Eisenstaedt, 1927). In the former condition histological examination of the testes reveals a more or less complete atrophy of the seminiferous tubules; in the latter both seminiferous tubules and interstitial gland cells are absent. In the former instance of bilateral cryptorchism there are exhibited the usual psychological conditions attendant upon sterility and the consciousness of physical difference. In this condition the secondary sexual characters are normal and the individuals manifest all evidence of virility except fecundity. However, when there is an atrophy of both tubules and interstitial gland there is an entirely different sort of individual. He is eunuchoid.

Eunuchism is physically characterized by an abnormal growth (Hikmet and Regnault, 1901) (Duckworth, 1906-1907). Eunuchs have a height (prepubital) above normal. This tallness is due to an elongation of the bones of the lower limbs, the result of the persistence of the diaphyseal cartilages. In some cases these cartilages persist throughout life without calcification. The axial skeleton does not elongate proportionately. Geddes (1910-11) in his studies of negro eunuchs found the axial skeleton relatively small; the long bones slender, feminine, with no projecting crests for muscular attachment; the femur weak and without normal curve. He also found the pelvis of eunuchs to be larger than normal in all directions but with the increase in breadth greatest. From this description of the skeleton it is obvious that the general contour of such individuals would be feminine. Other feminine physical characters are hirsutelessness, soprano voice, narrow and non-protruding larynx, soft white skin, hypertrophied mammae and a large amount of suprapubital fat. In these individuals also the penis and scrotum remain infantile.

The psychological effect of prepubital castration may be best pictured by the description of the eunuchs of Constantinople given by Hikmet and Regnault (1901) who say that these individuals have the following mental characteristics: "They are avaricious and miserly. They are greatly susceptible to suggestion and accept the slightest affirmation without proof. Not only are they devoid of judgment but accept the supernatural in preference to logical facts. Once having come to believe a thing it is impossible for them to change their minds. They are mentally inactive and extremely fanatical. They are neither

mean or cruel and remain faithful to their friendships and to their masters but are entirely lacking in courage. Like children they are gay, laugh at nothing and are astonished at everything; they are proud, sensitive and easily angered and are extremely fanatical." Of course, it should be remembered that some of these traits are probably merely manifestations peculiar to a certain type of environment. However, they serve to furnish an idea of what profound mental effects the absence of functioning testes may produce. Mentally and physically these individuals are incapacitated to a marked degree for many forms of labor, since they lack both strength and energy, and are usually indolent.

Cryptorchid children, then, are a matter of concern to their parents and society alike. It is a matter of general knowledge that cryptorchid testes, brought down from the abdominal cavity and placed in the normal scrotal position by operative procedure before puberty, may function normally; but if they remain abdominal until after puberty, they never produce sperm and the interstitial gland may also atrophy.[1]

Many orchidopectic operations have been performed and, from reports, with varied success. Eisenstaedt (1927), using a technic of his own, succeeded in placing all operated testes in scrotal positions in such a manner that no adhesions were formed, or torsions or obstructions occurred. According to this surgeon, the Germans report no less than fifty per cent of failures. However, fifty per cent of successful operations would warrant the use of operative procedure in the absence of less heroic methods. Probably the greatest objection to the operative method is the reluctance with which parents submit cryptorchic children to operation. To laymen there is more or less mystery enshrouding the functions of the sex gland and they, considering also the suffering, discomfort, and expense incidental to such treatment, naturally prefer to "let well enough alone." Before the individual himself arrives at a full realization of his condition, and its significance, it is generally too late for anything to be done.

The author first became interested in cryptorchism several years ago and set out at that time to discover the reason for the retention of the right testis; for in the cases of mono-cryptorchism it is generally the right one that fails to make the descent. In this work the author used human fetus exclusively and succeeded in developing a technic which made possible the study of some delicate structures that by the ordinary methods of dissection from the ventral side are

[1]Moore (1926) concludes from some experiments on guinea pigs that there is a possibility that cryptorchic testes in man may become functional although not brought down to the normal position until long after puberty. It should be remembered, however, that Moore's experiments were on guinea pigs—rodents exhibiting a periodicity, *i. e.*, testes of rodents at intervals of varying duration normally are located in the abdominal cavity. It is to be expected that the testes of such animals would tolerate the abdominal position, when placed there artificially, for extremely long periods without suffering permanent injury. A similar tolerance is not to be expected in those mammals where the testes are never normally abdominal after birth.

almost sure to be torn, distorted, or entirely destroyed. The technic was very simple, involving removal of the skin and soft fetal body wall down to the peritoneum. By clearing in glycerine, and sometimes even without, it was possible to observe the mesenteries or peritoneal folds with their attachments to the right testis. The mesenteries once located could then be safely exposed. By this method it was found that the testis was attached to the caecum by no less than three distinct peritoneal folds, one of these being, in fetus of certain ages, partially wrapped around the caecum; this at a stage in the development of the fetus when the testis in its abdominal descent is just below the level of the caecum. The rotation of the colon and the approach of the testis to the internal ring being both consummated at about the seventh or eighth month, this suggested a possible relation between the two; the mesentery previously wrapped around the colon is unwound by its rotation, thus permitting, or at least not hindering, the descent of the testis. Failure of the colon to arrive at its normal position in which the ileum enters it from the left, results in the mesentery remaining furled about the caecum and thus prevents the descent of the testis. Proof of this theory would be found in a case of retained right testis exhibiting, as in the embryo, the peritoneal relationship to a colon which had failed to undergo the usual rotation. Of course, if the right testis is retained, with the colon at the same time in its normal position, it would at once indicate that retention was not in all cases due to a furled mesentery. As the left testis, which has no connection with the colon, may also be retained, although not so frequently as is the right one, it would seem that retention may be due to the lack of a force, whatever its nature, that causes the testes to migrate from their original position to the ring and thence to the scrotum and that an explanation of some cryptorchic conditions must be found in the solution of the descensus itself. Owing to the lack of clinical facilities it has been impossible to make the observations necessary to confirm the author's findings; so the work has not been completed and is only cited here as it suggested a broader problem, that of the descensus itself.

The object of the investigations reported in this paper was to get, (1) a correct knowledge of those anatomical structures most likely in one way or another to influence the descent of the testes and, (2) to determine if possible whether or not their development simply parallels the descensus process or is actually a factor in causing the testes to descend, and thus to clear the way for an investigation of the initiatory causes of the descensus. In practically all the literature on the subject, the gubernaculum, ligamentum testis and saccus vaginalis have been accorded a share in the responsibility for the descent. As it is apparent that these structures are at least concerned in the descensus, though perhaps in a passive way only, it will be largely with them that this paper deals. During the course of the investigation certain observations which seemed to have a bearing on abdominal pressure were also noted and as they, too, were of a morphological nature they are included and considered.

Historical

An examination of the literature reveals that the descent of the testes has been attributed to about five or six different causes. These are: (1) the shortening of the gubernaculum; (2) the shortening of the ligamentum testis; (3) the elongation of the saccus vaginalis; (4) the contraction of the external oblique and the transversalis fibers in the conus inguinalis in those animals having a conus; (5) intra-abdominal pressure due to respiratory movements at birth or, according to Klaatsch (1890), to the increase in the size of the testis at rutting time in Rodentia and Insectivora; and (6) by unequal growth or growth and degeneration.

As to unequal growth, or growth and degeneration, some investigators (Lockwood and others) claim that the abdominal descent is apparent only and is brought about by an increase in the inclination of the pelvis; or that the testes come to lie in the internal inguinal ring by a progressive degeneration cephalad and a growth caudad (Keibal and Mall, 1912). This, however, is plainly not the case as the testes are fully formed, vascularized, supplied with their ducts, and the developmental processes have for the time ceased before they begin to change their position from near the posterior one-third of the kidney to that close to the internal inguinal ring (Hill, 1906). Such growth explains the site of the newly formed sex gland but has no bearing upon the subsequent changes in position of that gland.

Klaatsch (1890) explains the descent of the testes in rodents as partly due to an intra-abdominal pressure generated by an increase in the size of the testes which takes place at rutting time. The testes of such animals become enormously enlarged. This enlargement of the testes at rutting time is exhibited by all animals having a periodic descent of the testes and also by those in which the testes are normally retained throughout life in the abdominal cavity. It would seem that, since the enlargement is due to the proliferation of the germinal elements of the testes, no sterile testis would enlarge, and so would not descend, and that failure to descend would then be due to sterility. In several cases in man observed by Griffiths (1894) in which either one or both of the testes were retained or halted at some place along the line of their descent the testes which had failed to reach their normal position in the scrotum were all undersized as was also the vas deferens. This evidence is weakened by the lack of corroborative observations; it but leads to the old question, "Is the testis retained because of lack of development, or does it fail to develop because of retention?" That the latter is the case is supported to a degree by experiments of investigaters who replanted in the abdominal cavity functional testes which had already made their descent. Testes thus transplanted degenerated rapidly. This, of course, might be due to faulty technic but an observed fact of somewhat common knowledge among surgeons supports this evidence. Thus it has long been known to surgeons that if a retained testis is brought down into the scrotum by operative procedure before puberty, the testis will function normally being in no wise harmed by its prolonged stay in the abdom-

nal cavity. There is a period roughly extending from birth to puberty in which the testis is dormant and the developmental processes have for the time ceased. It does not seem to matter just where the testis is located during the dormant period; it remains unimpaired. However, *if retained beyond puberty,* or the "awakening period," in some other place than the scrotal sac, the testis fails to resume normal development and in a short time it atrophies. It was the view of Owen (1840) that the testes became functional regardless of their position. He cites in support of this view a hearsay case of a man with both testes retained who apparently functioned sexually in a normal fashion. No statement of sterility or potency in this case is given as would be necessary to prove the functional activity of a testis, hence this case cannot be considered as contradictory to the foregoing statements. What, then, is the stimulus which initiates this renewed development and activity? Is its origin in the testis or has it an extra-testicular origin, say in the scrotum or some more remote part of the body? Is it a nervous stimulus reaching the testicular cells over the spermatic nerve and awakening them to renewed development? Could failure of the retained testis to resume normal development be entirely due to a nervous condition? Is the application of such stimulus dependent upon the location of the testis in the scrotal sac? It would seem that whatever the cause of the descent, it would hardly be due in man and in other animals, in which the testes have a permanent scrotal position, to the enlargement of the testis since there is no enlargement until puberty and long after the testes have found lodgment in the scrotum.

It was thought by some of the early investigators that the testes are brought down by the contraction of the cremasteric muscle incident to the contraction of the abdominal muscles in the first act of respiration. As the testes are already in the scrotum at birth in many animals, Hunter points out that this could hardly be the case. He states in connection with this that he does not believe the cremaster functions in pulling the testes down for this same cremaster appears in those animals exhibiting a complete and permanent testicond or cryptorchid condition. In this he is mistaken for some animals such as the hedgehog are without a cremaster.

That intra-abdominal pressure created by the abdominal muscles cannot be the cause of the descent seems also obvious since all mammals are at birth equipped with similar muscles regardless of the seat of the testes at any period in life, fetal or otherwise. Yet this conclusion may well be questioned in view of our present knowledge of the effects of some of the endocrine secretions on muscular activity, blood pressure, etc., and the observations recorded below, the significance of which will be clear in a later part of this paper.

Most investigators of the descensus testiculorum or allied problems (Lockwood, 1888; Klaatsch, 1890; Frankl, 1895, 1900) have credited the gubernaculum with exerting a traction on the testis, pulling it down into the inguinal canal, or into the scrotum, by the contraction of its smooth muscle elements, or by the involution of the cord itself.

However, this view for the most part has long since been discarded, for a study of sections as well as certain gross dissections show that the gubernaculum is slack at one time in the descent of the testis and at another time even pushes the testis away from the internal ring by its rapid growth (Keibel and Mall, 1912). This does not exclude the possibility of the weight of the gubernaculum exerting some traction, though any traction due to the weight alone must be very small and can operate in either direction according to the position of the testis. When the human fetus is in the uterus, it generally hangs head downward. In this position the gubernaculum would tend, if it exerted any influence due to gravity, to push the testis away from, instead of pulling it towards, the internal inguinal ring. Hart (1910) suggests that the unstriped muscle fibers of the gubernaculum digest by an enzyme, or in some other way destroy, the areolar tissue in front of it as it grows towards the integument or the connective tissue just within the integument of the scrotum. He credits the gubernaculum with, in this way, tunneling out the inguinal canal for the evaginating saccus vaginalis into which the testis later on will descend.

The Present Investigation

Technic

The pig embryos and fetus used in this work were collected at a slaughter-house and preserved in a two per cent solution of formalin. A weak solution of formalin was used in order that the tissues, especially the peritoneal folds, might retain some of the flexibility of the fresh state. One difficulty encountered in the dissection of the peritoneal folds is the extreme ease with which they break, due to their brittleness caused by the preservative. A considerable amount of material was obtained in order that conditions found in one specimen might be verified by the dissection of numerous others in a similar stage. In order to facilitate such comparisons the pigs were classified as to size, placed in separate jars when brought to the laboratory, and the formalin replaced by fifty per cent alcohol. Dissections from the ventral and lateral surfaces were made on pigs in all stages of development, and the conditions tabulated. Serial sections were made of pigs of six, ten, fifteen, twenty and thirty millimeters, and the conditions as revealed recorded. Sagittal sections of these stages were also made. In both cases the material was stained *in toto* with borax-carmine and sectioned in celloidin. These sections were used to determine the development of the structures found in these particular sized pigs. Other sections were made through the testis and mesorchium at different levels of the testis in its descent into the scrotum. These last sections were cut in celloidin and counter stained with hematoxylin and eosin. Another set of serial sections starting at the top, or entrance of the saccus vaginalis and passing back or down to the integument of the scrotum were made, in order to discover, if possible, the relation of the gubernacum to the testis after the testis is once in the scrotum. The gross dissections of the embryos

were carried out with the usual technic; in older pigs all that portion anterior to the diaphragm was cut off before the dissection. Dissections of the spinal nerves supplying the anterior abdominal muscles, that is, the internal oblique, external oblique, rectus abdominis, and transversalis, were made on full term fetus. The ventral abdominal wall was also studied very carefully by means of microscopic sections, doubly stained in order to determine the time of completion of its musculature. The conditions of the various structures of interest in each pig above the 25 mm. stage are recorded in the following pages. All conditions both here and in the rest of the paper are mean conditions and are based on the study of a great many embryoes of each stage. Certain measurements of various structures and distances, thought to be significant, are to be found in table 1.

It is very unfortunate that the terminology used in the literature is varied and confused, many authors using entirely different terms for the same structures. A term is often used in such a way as to leave the reader in doubt as to the limitation of its meaning, or as to the structures, parts, or organs included under the term. This is particularly true of the term "gubernaculum." To avoid confusion, in this paper gubernaculum is used in the same sense as it is used by Hart (1910), *i. e.*, as that part of the connection between testicle and integument of the scrotum including in its structure smooth muscle fibers. The use of scrotal sac is limited to the integument of the sac containing the testicle and does not include the saccus vaginalis or any of its parts.

RECORD OF OBSERVATIONS MADE ON PIG EMBRYOS AND FETUS OF VARIOUS AGES

Before giving the detailed findings in the various stages of pig embryos and fetus studied, it seems advisable, for the convenience of the reader, to review, in as brief a way as possible, the development of the urogenital system up to the time of the disappearance of the mesonephros. In human embryos of 2.6 mm. (greatest length) there may be found a gland-like body situated retroperitoneally in the dorsal body wall on either side of the median line. This is the urogenital fold. It begins at about the level of the 4th cervical segment and extends caudad. As the progressive caudad growth takes place, the cephalic end degenerates so that when the growth is complete at the level of the 4th lumber segment, the urogenital fold does not extend the full length of the path it has traversed in its development. In human embryos of 26 mm. (greatest length) the urogenital fold is fully developed and extends from the first to the fourth lumbar segments. In the course of its development the urogenital fold divides longitudinally throughout its whole length except at the end, forming a median genital fold and a lateral mesonephric fold. The genital portion of the urogenital fold really develops before any division takes place (*fide* Keibel and Mall, 1912) and is imbedded in the mesonephric portion, the tubules of which degenerate in the region

TABLE 1

Length of important structures in various sized pigs

Length of Pig	Length of Gubernacularum		Length of Processus (Saccus Vacinalis)		Length of Ligamentum Testis		Length of Processus and Gubernaculum Together		Distance of Testis from Rings		Length of Testis (Long Axis)		Length of Progonal Mesorchium	
	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left
mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
37	Plica .5	.5	----	----	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
51	Plica .9	.9	Suggestion of one		1.9	1.9	-------	-------	4.5	6	-------	-------	-------	-------
70	1.5	1.5	1	1	2.4	2.4	2.5	2.5	5	5.5	-------	-------	-------	-------
95	2	2	2.5	2.5	3	3	4.5	4.5	5.5	6	5	5	-------	-------
105	3.5	3.5	4	4	3	3	7.5	7.5	6.5	7	5.5	5.5	-------	-------
135	1.5	3.5	7.5	7.5	1.5	1.4	9	9	3	3	6	6	-------	-------
140	15 [3] 13 [3]	14 [4] 3 10 [4]	17	13	.5	.5	19	17	2	3	6	7	7	4.5
160	15 [3] 13 [4]	14 [4] 3 10 [4]	17	13	0	0	19	17	2	3	6	6	7	4.5
220	6	6	46	46	.5	.5	0	0	¾ down in Scrotum		7	7	40	40

[3]Abdominal length.
[4]Scrotal length.

occupied by the future genital gland. A constriction takes place on the dorsal side of the mesonephric portion, which is now called the mesonephros, and its attachment is now by means of a stalk. The same sort of constriction takes place along the sides of the genital fold so that it becomes attached by a stalk to the mesonephros instead of being imbedded in it. The substance of the stalk disappears for the most part leaving the genital fold attached by a mesentery, the mesorchium. Thus the mesorchium is connected to the body wall only indirectly by the peritoneal covering of the mesonephros. During this time a fold of peritoneum, called the inguinal fold, develops from the posterior and lateral portion on the mesonephros, gradually growing out and into the anterior abdominal wall which at this time is at right angles to the dorsal wall. At the point in the anterior abdominal wall where the inguinal fold becomes attached, there is a ridge called the inguinal crest, or the crista inguinalis. From the mesonephros develop two tubes which grow in an antero-posterior direction. The more medial of these tubes is the Wolffian duct which lies lateral to the genital gland itself. In its backward growth it becomes connected to the bladder, or urethra, passing in its course over the umbilical artery and ureter but beneath the Müllerian duct. Its upper end is connected to the testis; thus is formed the vas deferens. The other duct, the Müllerian, grows backward into the urogenital sinus. In the male it normally disappears but in the female it forms the uterus by fusing proximally with its fellow of the opposite side. The distal portions form the Fallopian tubes. As the mesonephros disappears the mesorchium of the testis becomes continuous with the inguinal fold, the junction being at their point of contact with the Wolffian duct or vas deferens. Prior to the disappearance of the Wolffian body, the developing testes are attached to the body wall by what is no more than an extension of the peritoneum covering the mesonephros. This extension forms a mesentery or mesorchium which for convenience has been divided into three parts: (1) a progonal portion extending from the anterior end of the testis cephalad, and attached to the anterior end or portion of the Wolffian body; (2) a middle portion extending from the testis transversely to the Wolffian body; and (3) an epigonal portion extending from the caudal portion of the testis to the portion of the Wolffian duct at the posterior end of the mesonephros. It should be noticed that the testis has no direct connection with the anterior body wall; its connection being only through the epigonal portion of the mesorchium which, at the disappearance of the mesonephros, becomes continuous caudad with the inguinal fold through the vas deferens, and cephalad with the middle and progonal portions.

With this general account of the changes taking place previous to the time of the disappearance of the mesonephros, an examination of the detailed results secured in this study may be made.

The Six Millimeter Pig (Plate 1, Fig. 1).—In the six millimeter pig, the mesonephroi extend from the anterior border of the anlagen of the forelegs to the pelvis, and are larger than any of the other viscera

of the body. In human embryos of twenty-three millimeters the mesonephroi extend along the body for about one-third of the entire length of the body and occupy at least one sixth of the entire volume of the animal (Lockwood, 1888, p. 365). The mesonephros is retroperitoneal in position, being covered only on its ventral and lateral surfaces by peritoneum. The muscular portion of the abdominal wall, which is formed by the thoracic myotomes as they grow downward with the ribs, is not yet complete; in fact no muscle tissue is present in the ventral part of the abdominal wall at this time. The mesonephric ducts have begun their development.

The Ten Millimeter Pig (Plate 1, Fig. 2).—The genital ridge, or part destined to become the reproductive gland, is differentiated from the mesonephros in the ten millimeter pig. The attachment of the mesonephros to the dorsal body wall is by a stalk. A stalk also serves as the attachment of the gonad to the mesonephros. The Wolffian duct is well developed.

The Twenty-five Millimeter Pig (Plate 1, Fig. 3).—In the twenty-five millimeter pig the substance of the stalks of the gonad and of the mesonephros has diminished considerably so that these attachments are nearly mesenteric in form. In case of the reproductive gland the mesentery thus formed is the mesorchium and at first is only as wide as the testis is long.

The Thirty-seven Millimeter Pig (Plate 1, Fig. 4).—The ventral abdominal wall of the thirty-seven millimeter pig, upon superficial examination, appears to be formed of embryonic connective tissue of a rather diffuse nature. No signs of musculature are discernible. Microscopic examination reveals no muscle fibers in the wall. The wall is of three layers which, passing from within to the outside, are as follows: (1) the peritoneum, (2) a thick zone of diffuse mesoblastic tissue, (3) a stratified integument. Both kidneys are well along in development and measure five millimeters in length. They lie dorsal to the Wolffian bodies, entirely hidden except at their extreme anterior ends. These ends are visible between the anterior ends of the Wolffian bodies and the median line. The testes measure three millimeters in length and lie about three millimeters from the brim of the pelvis. The depressions in which they lie are such that the lateral edges of the testes are hidden from view by the lateral and ventral portions of the Wolffian bodies. The Wolffian bodies measure eight millimeters in length, and extend cephalad to the anterior margin of the kidneys and caudad to the brim of the pelvis. Both usually appear at the same level, though in a few cases the right may be slightly posterior to the left in position.

The peritoneum covering the Wolffian body is attached dorsally to the body wall. Anteriorly and dorsally it extends beyond the kidney. In the region of the testis is formed a thin, two-layered mesentery which passes to the testis, including it between its folds. The mesentery thus formed is the only mesentery of the testis in pigs of this stage, and it passes directly from the testis to the Wolffian

PLATE 1

THE RELATIVE POSITION AND ATTACHMENTS OF THE GENITO-URINARY BODIES IN THE PIG

Fig. 1. The Six Millimeter Pig.

Fig. 2. The Relation of the Mesonephros to the Body Wall and to the Reproductive Portion of the Mesonephros. Note the Differentiation of the Reproductive Portion from the Mesonephros. Ten Millimeter Pig.

Fig. 3. Complete Differentiation of the Reproductive Portion of the Mesonephros. Twenty-five Millimeter Pig.

Fig. 4. Thirty-seven Millimeter Pig.

Fig. 5. Fifty-one Millimeter Pig.

Fig. 6. The External Appearance of the Ventral Abdominal Wall and Scrotum.

Fig. 7. Seven Centimeter (Seventy Millimeter) Pig.

Fig. 8. Nine and Five-tenths Centimeter Pig.

Fig. 9. Ten and Five-tenths Centimeter Pig. Note the Rotation of the Left Testis Slightly on Its Long Axis Towards the Median Line So As to Show the Middle Mesorchium.

Fig. 10. The Position of the Testes After the Shortening of the Ligamentum Testis in Thirteen and Five-tenths Centimeter Pig (Pig "A"). The Shortened Ligamentum Testis Is Hidden Beneath the Posterior Tip of the Testis and the Left Testis Is Rotated on Its Long Axis Medially to Show the Corpus Epididymus and Remains of the Wolffian Body.

Fig. 11. Fourteen Centimeter Pig. Note the Developing External Cremasteric Sac and the Widened and Shortened Gubernacula.

Fig. 12. The Opened Left Saccus Vaginalis of the Nineteen Centimeter Pig Showing Attachments and Relative Positions of the Testis, Epididymis, Gubernaculum, and Wolffian Duct.

ABBREVIATIONS

a.ab.w.—Anterior abdominal wall, reflexed posteriorly.
ad.—Adrenal.
al.—Allantois.
b.—Body wall.
cap.—Caput epididymis.
caud.—Caudate epididymis.
c.i.—Crista inguinalis.
cr.s.—Cremasteric sac.
c.—Colon.
ep.m.—Epigonal mesorchium.
f.l.—Fore leg anlage.
g.—Gubernaculum.
h.l.—Hind limb anlage.
in.r.—Internal abdominal ring.
k.—Kidney.
l.—Lung buds.
l.d.—Ligamentum diaphragmaticum.
l.i.—Ligamentum inguinalis.
l.t.—Ligamentum testis.
m.—Stalk which will become mesorchium.
mes.—Mesonephros.
m.mes.—Middle mesorchium.
m.r.—Milk ridge.
mu.—Mullerian ducts.
p.—Penis.
pl.d.—Plica diaphragmatica.
pl.i.—Plica inguinalis.
pr.mes.—Progonaal mesorchium.
p.v.—Processus vaginalis.
r.—Inguinal ring.
sc.—Scrotum.
s.—Stalk of dense tissue (mesentery) to mesonephros.
s.v.—Saccus vaginalis.
t.—Testis.
um.a.—Umbilical artery.
w.d.—Wolffian duct.

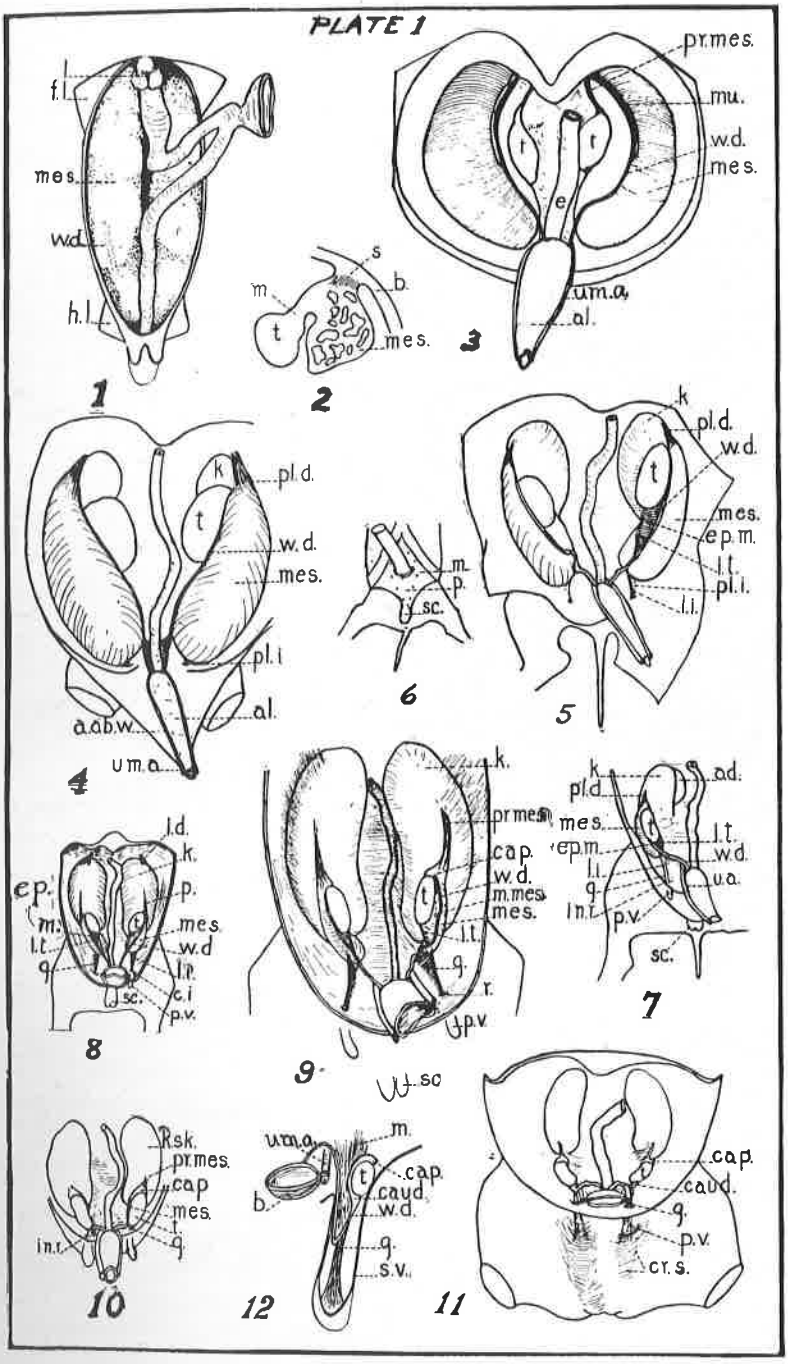
PLATE 1
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body, its width being the same (three millimeters) as the length of the testis. No ligamentum testis or crista inguinalis is discernible. A small triangular fold, the plica inguinalis, passes from the posterior part of the Wolffian body, a distance of about five-tenths of a millimeter, to the posterior and ventral abdominal wall where it is attached. It is at this point that the crista inguinalis will later develop.

The Fifty-one Millimeter Pig (Plate 1, Figs. 5-6).—Superficial examination reveals no signs of an abdominal musculature on the ventral surface. Microscopic examination of the abdominal wall shows it to be in all respects like the abdominal wall of the thirty-seven millimeter pig. Upon dissection, the kidneys are found to measure seven millimeters in length and to appear at the same level. In some few pigs the right kidney may be slightly posterior in position to the left. The testes rest in cup-shaped depressions on the mesial surfaces of the Wolffian bodies near their anterior ends. The right testis is slightly nearer the site of the internal inguinal ring than is the left; the distance of the ring from the posterior margins of the right and left testis being four and a half and six millimeters, respectively. The Wolffian bodies measure about eight millimeters in length and are located at the same level.

The Wolffian bodies are attached to the dorsal abdominal wall, and the ligamentum diaphragmaticum to the ventral surface of the kidneys. This fold or ligament is continuous from the kidney over the anterior portion of the Wolffian body to the lateral and dorsal surface of the testis. Posteriorly the Wolffian body exhibits an inguinal fold (plica inguinalis) which extends from an eminence on the posterior and ventral abdominal wall to the posterior portion of the Wolffian duct. The plica inguinalis measures nine-tenths millimeters in length and in its free margin the inguinal ligament is developing. The eminence to which it is attached, the crista inguinalis, is formed by the crescentric invagination of the peritoneum of this region.

The mesorchium proper, which, in the thirty-seven millimeter pig, is only as wide as the testis is long, is, in the fifty-one millimeter pig beginning to spread out fan-like by the extension of its posterior margin. It extends through a distance of one and nine-tenths millimeters to the point of departure of the Wolffian duct from the Wolffian body. No ligamentum testis is yet formed, but there are signs of the connective tissue fibers growing from the dorsal body wall over the Wolffian body and into the mesorchium along the posterior portion of its free margin. Signs of an invagination at the junction of the plica inguinalis and the crista inguinalis may be seen. This is the beginning of the saccus vaginalis.

The Seven Centimeter Pig (Plate 1, Fig. 7).—In the seven centimeter pig the teats of the milk ridges are easily observed, forming a row on either side of the umbilicus. Small scrotal eminences are present but poorly defined. The abdominal wall comprises a diamond-shaped area which appears thin but on dissection is found to contain a

complete muscle layer. Microscopic examination of the wall shows diffuse plain muscle fibers. The *right and left kidneys* appear at the same level and measure nine and ten millimeters respectively. The *testes* both measure three millimeters in length and are located on the brim of the pelvis with the left slightly posterior in position to the right. Both testes overlap the anterior ends of the Wolffian body and the posterior region of the kidneys. The *Wolffian bodies* appear at the same level and measure about seven millimeters in length; the left being slightly smaller than the right.

Passing from the anterior end of the Wolffian body toward, but not to, the anterior end of the kidney is a free triangular fold of the peritoneum, the *ligamentum diaphragmaticum,* which, owing to the development of the kidney cephalad, appears to be receding posteriorly. Another fan-shaped fold, the *middle* mesorchium, measuring two and four-tenths millimeters along its wide margin, connects the testis to the Wolffian body. A triangular fold passes from the posterior end of the Wolffian body caudad to the umbilical artery. Its apex is at the site of the crista inguinalis. This peritoneal fold is the plica inguinalis enlarged and containing in its free margin the rudimentary gubernaculum. Microscopic examination of the fold and gubernaculum reveals the presence of connective tissue and unstriped muscle fibers.

An invagination about one millimeter in length represents the further development of the processus vaginalis, the first signs of which were found in the pig of fifty-one millimeters. The processus is solid, its lumen being still occluded by the plica inguinalis and the gubernaculum. Microscopic examination reveals the presence of transversalis and internal oblique muscle fibers in the walls of the processus. The inguinal canal is potentially present though with no lumen, as this is occupied by the solid vaginal process.

The posterior portion of the Wolffian body is attached along its dorsal surface to the dorsal body wall by a triangular fold which passes along the dorsal body wall to the edge of the bladder, and mesially to the umbilical artery where it ends in a point. The ventral margin of this fold passes anteriorly to the point of departure of the Wolffian duct from the Wolffian body, forming the mesentery of the duct. Dorsally the anterior two-thirds of the Wolffian body is connected by a mesentery to the posterior one-fourth of the kidney on its ventral surface. This portion of the Wolffian body is therefore no longer connected directly to the dorsal body wall but indirectly through the kidney.

The Eight and One-half Centimeter Pig (Plate 1, Fig. 8).—In the eight and one-half centimeter pig the milk ridges, which in the seven centimeter pig flare out laterad in the region of the umbilicus, are seen to be nearly parallel to each other, due to the drawing in of their middle portions mesially. On dissection, sparse fibers and strands of the abdominal muscles are discernible even by the unaided eye, and are thickest along the region of Poupart's ligament. The scrotum is slightly

more pronounced than in the earlier stages. Except that the left testis is much nearer the median line than the right this stage differs in no essential respect from the seven centimeter stage. All parts have grown, of course, except the Wolffian body which has dwindled somewhat in size.

The Pig of Nine and Five-tenths Centimeters.—The nine and five-tenths centimeter pig presents the same external features as the pig of eight and five-tenths centimeters. The kidneys of this stage appear at the same level and have enlarged enormously, measuring seventeen millimeters in length. Both testes are enlarged, measuring five millimeters in length. They are still located in the depressions on the medial surfaces of the Wolffian bodies, their anterior margins being just one centimeter from the anterior ends of the kidneys. The posterior margins of both of the testes are five and five-tenths millimeters from the internal inguinal rings. Both testes are at about the same level on the brim of the pelvis. The Wolffian bodies have decreased a little though not nearly in proportion to the increase in size exhibited by the kidneys. The right Wolffian body measures one centimeter in length; the left, one millimeter less. The bladder has enlarged and flattened dorsoventrally. Both umbilical arteries have enlarged considerably. The Wolffin duct has become readily evident to the unaided eye and passes from the anterior end of the testis and Wolffian body to a point on the dorsum of the bladder.

The progonal portion of the mesorchium leads from the anterior tip of the Wolffian body, which is at the level, and touches the anterior tip, of the testis, to the ventral surface of the kidney, about one centimeter from its anterior end. The middle mesorchium is enlarged and fan-shaped. Its anterior border passes transversely to the Wolffian body. The posterior and ventral borders pass posteriorly to the caudal end of the Wolffian duct. The entire primary mesentery of the Wolffian body has disappeared, the folds of the peritoneum passing directly from the sides of the body to the ventral surface of the kidney which they cover. The inguinal fold is, of course, present but considerably thickened. It passes from the crista inguinalis to the Wolffian body near its duct; dorsally it passes to the dorsal body wall. The processus vaginalis is about four millimeters long, slightly enlarged in comparison with the previous stage. It still is without a lumen, being made up solidly of tissue. This is due, as in previous stages, to the continuation of the fold. With its included smooth muscles and connective tissue, it is the rudimentary gubernaculum. Nothing, in addition to that already mentioned, is revealed by microscopic examination of this structure.

The Pig of Ten and One-half Centimeters (Plate 1, Fig. 9).—In the pig of ten and one-half centimeters the milk ridges are parallel, since they are in their permanent position. The abdominal wall is no longer semi-transparent, being well reinforced with muscle. These muscles constitute the permanent musculature and are striped. The scrotum is divided by a prominent longitudinal ridge. The kidneys have in-

creased greatly in size and measure about eighteen millimeters in length. They appear to be at the same level. The testes have also increased somewhat in size. They measure six millimeters in length and appear at the same level on the brim of the pelvis and in the middle of the Wolffian body. The posterior margin of the right testis is six and five-tenths millimeters and the left seven millimeters from the internal inguinal ring. The Wolffian bodies have decreased in transverse diameter but have, at the same time, elongated from eight and nine to ten millimeters. They therefore present a very slender appearance. The epididymis is well formed, especially the caput which occupies its permanent position on what is now the anterior end of the testis. The Wolffian duct has enlarged and passes from the caput along the median and ventral surface of the Wolffian body to a point on the dorsum of the bladder.

The progonal portion of the mesorchium passes from a point on the ventral surface of the kidney about six millimeters from its anterior end to the extreme anterior part of the caput epididymis. At its anterior end it spreads out and is lost in the general peritoneal covering of the kidney. The middle mesorchium presents the same appearance as in the pig of nine and five-tenths centimeters except that the ligamentum testis has thickened, is more rounded and contains more connective tissue. Microscopic examination shows no muscle fibers present in this ligament at this time. The gubernaculum is attached to the Wolffian duct at a point opposite and lateral to the attachment of the ligamentum testis. Besides being attached to the duct it spreads out somewhat over the surface of the kidney itself. From its anterior attachment it passes through a distance of three and five-tenths millimeters to the internal inguinal ring and into the processus vaginalis, where microscopic examination shows it to be lost in the wall of the processus. The processus itself is made up of the extended fibers of the transversalis and the internal oblique muscles, and measures in length four millimeters, which is a decided increase over the length observed in the pig of nine and five-tenths centimeters. It extends for its entire length into a lymph space which reaches from the internal inguinal ring to the neighborhood of the scrotal anlagen. At this stage a cremasteric sac has been formed by the extended fibers of the external oblique muscle. This sac is thin-walled and encloses the distal two-thirds of the processus vaginalis.

The Thirteen and Five-tenths Centimeter Pig (Plate 1, Fig. 10.)—This stage shows a continued development of the abdominal musculature beyond that of the preceding stage. The scrotal eminences are more prominent and are partially divided by a longitudinal groove. The kidneys likewise show a continued development; the left kidney measures two centimeters and the right, which in position is slightly posterior to the left, two millimeters less. The testes are both the same size, six millimeters in length. The right testis is about three millimeters from the inguinal ring and the left a fraction less than this distance.

The progonal portion of the mesorchium is attached about one centimeter from the posterior end of the kidney. The gonal portion of the middle mesorchium has continued to grow longitudinally. The ligamentum testis measures on the right side one and four-tenths millimeters. The gubernaculum on both sides measures one and five-tenths millimeters.

The saccus vaginalis has increased both in length and width and measures seven and five-tenths millimeters. The Wolffian bodies and the epididymis are gone except for a trace.

The Fourteen Centimeter Pig (Plate 1, Fig. 11).—The abdominal musculature of a pig of this size shows considerable development over the preceding stages. The scrotal anlagen are much more pronounced and show on dissection considerable embryonic connective tissue in their makeup. The kidneys measure twenty-one millimeters in length, an increase of one millimeter over that of the thirteen and five-tenths centimeter pig. They occupy the same relative position as before. The testes show no increase in size but have descended somewhat into the pelvis.

The progonal mesorchium is connected at its anterior end to the posterior and ventral surface of the kidney farther back than in the immediately preceding stage. The right one measures seven millimeters and the left four and five-tenths millimeters. They both spread out toward the median line and with the disappearance of the Wolffian body are now connected or continuous with the middle mesorchium, the ligamentum testis, and the fold described as passing from the post-Wolffian portion of the Wolffian duct to the posterior portion of the Wolffian body and the dorsal abdominal wall. The progonal and middle portions of the mesorchium, however, are not continuous with the gubernaculum, the Wolffian duct forming the connection between the two folds above and the gubernaculum below. The ligaments of the testes have decreased considerably in size and measure only one-half of a millimeter. The gubernaculum is attached to the Wolffian duct, not opposite the attachment of the ligamentum testis, but about one millimeter mesad. The attachment is such as to suggest that the caudal end of the testis should enter the ring first. The gubernacula are quite different in length, the right measuring two millimeters and the left just twice as much. The above lengths for the gubernacula are only their intra-abdominal measurements. They are really very much longer, being practically the sum of the lengths of the saccus vaginalis and their intra-abdominal portions. The saccus vaginales have both increased enormously in length. The right measures about seventeen millimeters and extends into the inguinal canal fully two-thirds of the length of the canal. The left saccus measures about thirteen millimeters and extends its full length into the canal. Both sacs are expanded at their distal ends and are filled with the muscular and connective tissue of the gubernacula. Considerable embryonic connective tissue is also present in the distal ends of the sacs. Large flattened bands of muscle fibers from the

external oblique surround each saccus vaginalis, forming the external cremasteric sac. There is no anatomical connection between the saccus vaginalis and the cremasteric sac or the scrotum.

There is no change of note or significance in pigs between fourteen and nineteen centimeters in length.

The Nineteen Centimeter Pig (Plate 1, Fig. 12).—In the nineteen centimeter pig the musculature of the abdominal wall is well developed but not complete, owing to the presence of the umbilical cord. However, at the base of the cord there is a ring of connective tissue into which the aponeuroses of the muscle fibers in that region insert. The kidneys appear to be at the same level and measure thirty millimeters in length. Their posterior margins are about four millimeters from the anterior margins of the testes. The testes are both of the same size and are located with the left testis just entering the internal inguinal ring. The testis could be drawn back out of the ring by the slightest pull on its mesorchium which remained when the testis was in the ring.

The progonal, middle and epigonal mesorchia have the same connections as in the fourteen centimeter pig. They have increased in size and the one mesentery formed by their fusion passes from its origin on the dorsal abdominal wall beneath and on the posterior tip of the kidney to the testis along its entire length. Therefore, in the case of the left testis, it extends down into the saccus vaginalis. The gubernaculum is much thickened and passes from the Wolffian duct the full length of the saccus vaginalis to be inserted in its distal end. The Wolffian duct is shaped like a hairpin, with the closed end of the pin down in the saccus vaginalis below the testis. The gubernaculum has extended its fibers along the duct with the result that that part of the duct itself appears in the saccus vaginalis at a lower level than the end of the gubernaculum proximad to the testis.

The Hairy Pig of Twenty-two Centimeters (Figs. 2, 3).—It is of interest to know whether or not there are any structures, muscular or otherwise, present in the ventral abdominal wall of the full term pig that may act to increase intra-abdominal pressure. As already noted in this stage the testes have not as yet obtained their permanent position in the scrotum. Cross sections through the anterior abdominal wall were made at the various levels. A section through the wall at about the level of the anterior margin of the kidneys reveals muscle fibers in rather compact and well defined bundles, the outlines of the ventral abdominal muscles being well differentiated (Fig. 3, *A*). The tendonal aponeuroses of these muscles have fused in the mid-line to form the linea alba. Although well outlined, the two recti muscles occupy positions somewhat farther from the mid-line than they do in their permanent positions. Passing beneath the recti muscles from side to side are the fibers of the transversalis muscles, more compact than any of the other muscles at this level. Figure 3 *B* represents a section made 5 mm. anterior to the umbilicus. All muscles are present but not as well formed, and, with the

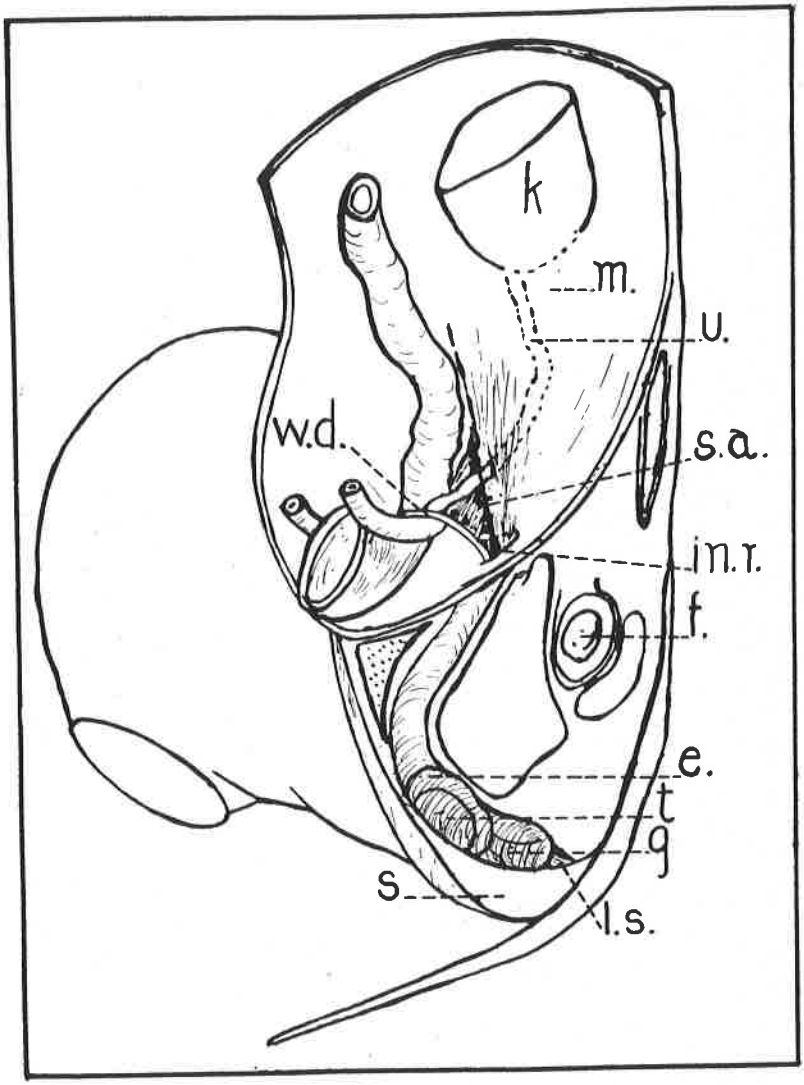

Fig. 2. The twenty-two Centimeter Pig (The Hairy Pig). A Sagittal Section Showing the Testis in Almost Its Permanent Position. e., Epididymis; f., Head of Femur; g., Gubernaculum; k., Kidney; l.s., Ligamentum scroti; m., Mesorchium; s., Scrotum; s.a., Spermatic Artery; s.v., Saccus vaginalis; t., Testis; u., Ureter; vas., Vas deferens.

exception of the internal oblique and transversalis, they are separated by an abundance of embryonic connective tissue. About 15 mm. posterior to the umbilicus, the fibers of the obliquus internus muscles have disappeared and in their place is a thick layer of embryonic connective tissue separating the obliquus externus from the recti muscles. The penis is present in the mid-line beneath the skin and is surrounded by the aponeuroses of the two external obliques. After covering the penis these aponeuroses dip down through the thick layer of connective tissue to fuse with the tendons of the recti and the transversalis muscles and form the linea alba. The muscles at this level are not so well defined as in the first two levels (Fig. 3 *C*). Just anterior to the symphysis pubis all muscles, except the external oblique and the recti muscles, have disappeared. The external obliques are not well formed. The penis is found in the same situation as before. A new structure, the abdominal tunic makes its appearance. This structure, which helps to support the abdominal viscera in the ungulates, is a dense bundle of yellow elastic connective tissue (Cunningham, Vol. I, page 360). It is not well formed as yet and is of short extent (Fig. 3 *D*).

It will be seen from examination of these figures that, (1) at full term the abdominal wall exhibits a complete musculature only in regions anterior to the umbilicus, (2) the region of incomplete musculature is somewhat egg-shaped with the small end of the egg immediately posterior to or extending slightly anterior to the umbilicus, (3) the muscle fibers are striated, and (4) the abdominal tunic is present in the immediate pre-pubic region only.

Dissection shows the mesorchium to measure forty millimeters from its origin to the internal ring; it extends into the saccus vaginalis for about twenty-five millimeters. The saccus vaginalis itself measures about forty-seven millimeters in length. It has widened considerably at the distal end which is hard and attached to the connective tissue of the scrotum. The scrotum is well formed and the testes can be felt in it about three-fourths of the way down. They are not yet in their permanent position. The gubernaculum is six millimeters long and about three millimeters in width. The ligamentum testes is about half a millimeter long. The scrotum is well formed, and is attached to the saccus vaginalis by the ligamentum scroti. It contains the cremasteric fascia.

Discussion

It was observed in the pig of nineteen centimeters, and stages above, that the mesorchium of the testis was taut. The testis could not have been pulled down into the scrotum any farther without tearing the mesorchium and overcoming the resistance offered by the Wolffian duct and other structures connected to the testis. However, a slight pull upon the mesorchium was sufficient to draw the testis back into the abdominal cavity. It will be seen, then, that should the gubernaculum shorten for any reason whatever, rather than pull

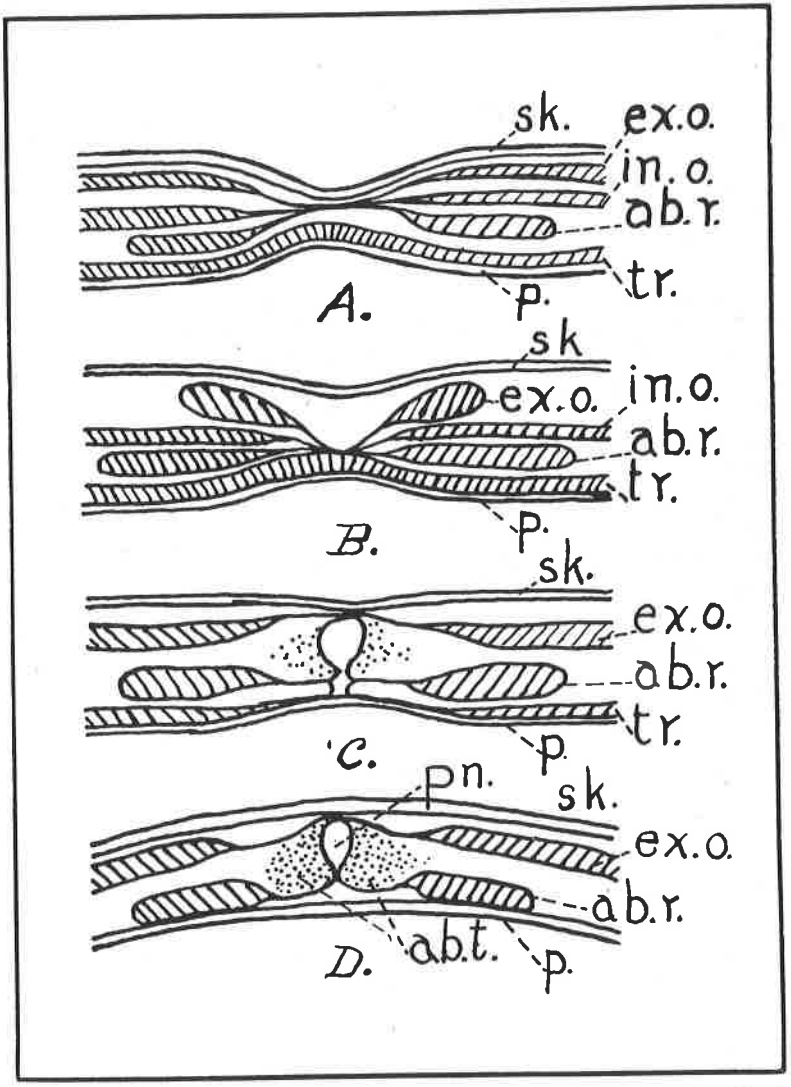

Fig. 3. Sections through the Abdomen of the Hairy Pig (Twenty-two Centimillimeters). *A.*, At the level of the anterior margin of the kidney. *B.*, Five millimeters anterior to the umbilicus. *C.*, Fifteen millimeters posterior to the umbilicus. *D.*, Just Anterior to the symphysis pubis. ab.r., Abdominal recuts; ab.t., Abdominal tunic; ex.c., External oblique; in.o., Internal oblique; p., Peritoneum; pn., Penis; sk. Skin; tr., Transversus.

the testis down into the scrotum, it would tend to pull the distal end of the saccus vaginalis to which it is attached back into the abdominal cavity. This would result in an inversion of the saccus vaginalis itself.

That the gubernaculum does shorten is easily observable and is shown by its condition in the various stages of the pig fetus (Table 1). From the time the gubernaculum is first apparent to the unaided eye in the thirty-seven millimeter pig until the testes are resting on the brim of the pelvis and the Wolffian body is almost gone in the pig of ten centimeters, there is continued growth of the gubernaculum. In the thirty-seven millimeter pig the gubernaculum measures but five-tenths of a millimeter while in the ten centimeter pig it has increased in length to three and five-tenths millimeters. However, in the stages following the gubernaculum apparently shortens to less than half of this length.[2] In the pig of thirteen and five-tenths centimeters the testis has dropped down from the brim of the pelvis and is now only three millimeters from the internal inguinal ring. It will be noticed that this is less than half the distance of the testis from the ring in the pig of ten centimeters. The apparent shortening of the gubernaculum is a little more in proportion to its length than the decrease in the distance of the testis from the ring. These observations would at first seem to indicate that the gubernaculum is exerting traction, since the testis approaches the ring as the gubernaculum shortens. This, however, cannot be the case, since, as has already been pointed out, the inertia of the testis and its attachments is greater than that of the saccus vaginalis. True with the fetus in the usual or upright position, the pull of gravity would be in line with the pull exerted by the shortening gubernaculum, and the testis with its attachments would move towards the ring. However, as the fetus is rarely in an upright position, more often the reverse, it is necessary to find some force which is strong enough and can act in such a way as to push or pull the testis towards the inguinal ring. It has been contended by many that the fact that the gubernaculum is equipped with smooth muscle fibers and shortens, is proof in itself that it has the function of traction. This is probably true to a certain and very limited extent. It can act only as a tractor on things offering less resistance than that provided by the inertia of the evaginated saccus vaginalis. *It seems quite possible that the saccus vaginalis would offer enough resistance to allow the gubernaculum in its shortening to exert a pull on the vas deferens and testis sufficient to keep them properly oriented, that is, to keep the caudate epididymis and the vas deferens ahead of the testis as it descends in the abdominal cavity and enters the ring.* Without some device

[2] "Apparently" is used here since it is possible that the gubernaculum's absolute length remains constant but that, due to the elongating saccus vaginalis in which it might have been partially included, its intra-abdominal portion became less. It has no effect upon our argument whether it is real or only an apparent shortening, but as it has been credited with shortening, it will be considered in this discussion as possibly being absolute.

for maintaining proper orientation the testis would be very apt to change the position of its axes in relation to the rest of the body. Should the testis present its side instead of an end to the entrance of the inguinal canal it could not enter, with the result that the testis would be retained. Again should the testis be allowed to rotate about its axes the vas deferens would become kinked and occluded.

Examination of Table 1 shows that after the testis is in the canal and orientation is no longer necessary, the gubernaculum does not continue to shorten but rather elongates. This elongation is to keep pace with the rapid progression of the saccus vaginalis down the canal into the scrotum. The rate of growth of the saccus is at first much faster than the descent of the testis into the scrotum. This probably presents a reason for the rapid growth of the gubernaculum which takes place at this time. Should the gubernaculum not elongate with the saccus vaginalis it would result in an inversion of the saccus just as would happen if the gubernaculum should exert its pull against the testis and its attachments. The gubernaculum cannot shorten or recede toward the scrotum except as some force pushes or pulls the testis and its growing mesentery down into the canal. The saccus vaginalis having once attained its maximum length, the gubernaculum again shortens as the testes finish their descent (See Pig of Twenty-two Centimeters).

What has been said of the gubernaculum is, for the most part, true of the ligamentum testis. Our observations on the pig show that the ligamentum testis shortens before the gubernaculum does, and in so doing brings the posterior end of the testis close against the Wolffian duct. It is quite necessary that this be done, since, as was pointed out in the case of the ten centimeter pig, the positions of the testis, ligamentum testis, Wolffian duct and gubernaculum are not in a straight line; rather in their relations one to another they form what may be called a cord with a sharp but diagonal bend in its center. In order to exert any governing influence on the orientation of an attached object a free cord must act through a straight line. With the ligamentum testis shortened so that the posterior end of the testis lies snug against the vas deferens there is formed such a cord, exerting its force directly, and through a straight line upon the testis. Unlike the gubernaculum, the ligamentum testis does not elongate after the testis is in the canal. It continues to shorten until in the sixteen centimeter pig it is of no appreciable length and cannot be measured. The question may be asked, why does not the ligamentum testis elongate, as does the gubernaculum, to compensate for the rapid elongation of the saccus vaginalis? It does not do so for a very good reason. Should the testis be set adrift in the canal with a loose ligament there would be great possibility of its rotating on its long axis. This would kink, or perhaps cause a sharp bend in the vas deferens. Why does not the testis and its duct rotate together, twisting the elongated gubernaculum? They do this sometimes with detrimental effect to both. However, this is of rare occurrence as the connection of the gubernaculum is along a considerable length of the vas defer-

ens as was found in the pig of nineteen centimeters; a type of connection which tends to prevent rotation.

As was stated elsewhere in this paper, Hart thinks that the smooth muscle fibers of the gubernaculum may have a digestive effect upon the connective tissue through which the inguinal canal passes and that it tunnels through this tissue, thus forming the canal and making way for the saccus vaginalis in its descent into the scrotum. That this could not possibly be the case is apparent when we examine the structure of the saccus vaginalis and the connections and relations of the gubernaculum with it. The saccus vaginalis is made up of three main layers: An inner layer of peritoneum, a middle layer composed of fibers of the transversalis, and an outer layer made up of the extended fibers of the obliquus internus. The gubernaculum itself lies between the peritoneum and the middle layer and is therefore separated from the connective tissue in the course of the canal by the middle and outer layers of the sac. In this position it could not exert the influence suggested by Hart (1910).

As to the function of the saccus vaginalis, it is not possible that it has anything to do with the descent of the testes, unless it is to assist in orientation, as has already been suggested.

Returning for a time to a further consideration of intra-abdominal pressure as a probable solution of the problem of the descent of the testes, the question may be raised whether any of our observations on these pigs of various stages hint at intra-abdominal pressure as the cause of the descent. It was noted that striation of the abdominal muscles was first observed in the ten and five-tenths centimeter pig. In this stage the testes lie on the brim of the pelvis and (Table 1) six or seven millimeters from their respective rings. In the next stage studied, the thirteen and five-tenths centimeter pig, the testes made a sudden descent towards the rings through a distance of a little more than three millimeters. Again, the abdominal musculature is all present in the ten and five-tenths centimeter pig, although the aponeuroses are not complete. These tendonal aponeurosis become more complete as the pig fetus nears full term. The musculature and aponeuroses are entirely complete only after birth and with the disappearance of the umbilical cord, but they approach completion as the testes descend and are practically complete at the time the testes enter their respective rings (see the Nineteen Centimeter Pig, the Hairy Pig of Twenty-two Centimeters, and Plate 1, Fig. 2). When is voluntary muscle capable of exhibiting tonic contraction? Could this question be answered with assurance thus, "Only when it becomes striated," there would indeed be cause to believe that the appearance of striation and entire abdominal musculature simultaneously in one stage and the rapid partial descent of the testes in the following stage are significant. The completion of the abdominal musculature and aponeuroses, with their ability at this stage to withstand considerable strain, appearing at the time when the testes are beginning their descent into the scrotum, together with the appearance of the abdom-

inal tunic, also indicate a relationship between abdominal musculature and the descent of the testes.

Summary

(1) The gubernaculum exhibits a period of continuous growth from its first appearance in the thirty-seven millimeter pig up to the nineteen centimeter stage. In the latter stage the saccus vaginalis has attained considerable length and the testis is well through the inguinal ring. The gubernaculum has kept pace with the elongating saccus vaginalis, although its intra-abdominal length shows a decrease in and after the thirteen centimeter stage. After the testes are well within the ring and as the saccus vaginalis elongates, the gubernaculum also shows a decided elongation. However, after the saccus vaginalis has reached its permanent position in the scrotum and no longer elongates and when the testis is approximately three-fourths of the way down to its permanent position, the gubernaculum undergoes an involution, shortening to six millimeters in the twenty-two centimeter pig. The inertia of the testis, the mesorchium, and the Wolffian duct is greater than that of the gubernaculum and saccus vaginalis, and these structures cannot exert sufficient traction to cause the testis to change position. It is possible, however, that these structures may exert a pull sufficient to orient the testis and its duct for their entrance into the ring. The great lengthening of the gubernaculum after the testis is within the ring is to prevent inversion of the saccus vaginalis by its own rapid growth.

(2) The saccus vaginalis in the pig has almost attained its permanent position in the scrotum before the testis has descended more than, at most, a third of the way from the ring into the scrotum. Elongation of the saccus vaginalis, therefore, does not cause the testis to descend. Indirectly through the gubernaculum it assists in orientation of the testis.

(3) Striation and the appearance of all the elements of the abdominal musculature immediately precede the initial descent of the testes from the brim of the pelvis towards the ring. The appearance of a practically completed abdominal musculature and aponeuroses occurs just prior to the descent of the testis into the scrotum, although an entirely completed musculature and aponeuroses are present only after birth with disappearance of the umbilical cord and when the testes are in their scrotal position. The abdominal tunic, a structure which gives support to the abdominal wall, also makes its appearance at this time. All of these structures are elements either having to do with the contraction of the musculature of the abdominal wall or enabling the wall to withstand the stress and strain of its own contraction and consequent intra-abdominal pressure. These facts suggest a relationship between the abdominal musculature and the descent of the testes.

Conclusions

(1) The function of the gubernaculum, ligamentum testis, and saccus vaginalis, is that of orientation of the testis in its abdominal descent. In addition to this, the saccus vaginalis affords protective coverings for the testis in its scrotal position.

(2) Several of the conditions described above would lead to the conclusion that there exists a relationship between the abdominal wall and the descent of the testes. These are as follows: (a) The striation of the abdominal muscles just preceding the partial descent of the testes from the brim of the pelvis towards their respective rings, (b) the appearance of the abdominal muscles previous to this time, (c) the practical completion of the abdominal musculature, aponeuroses, and abdominal tunic by the time that the testes begin the scrotal portion of their descent, and (d) the entire completion of the abdominal musculature, aponeuroses and abdominal tunic immediately after birth, *pari passu,* with the disappearance of the umbilical cord and the attainment by the testes of their final and permanent position in the scrotum.

(3) The solution of the problem of the descensus of the testis will probably be found in a further study of intra-abdominal pressure.

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