BLOOD SUPPLY TO THE GENITALIA AND ACCESSORY GENITAL ORGANS OF THE GOAT

by

James Henry Magilton

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INTRODUCTION

The anatomy of the goat has not been a matter of much concern in the past. The goat has not been an important part of the agricultural economy of those nations which have had funds available for research. Consequently, most of the research that has been done has been with cattle, swine, sheep, and poultry.

Recently, there has been an increasing interest in this species as a research animal. Barcroft and co-workers (1934) studied conditions of foetal respiration in the goat. Pohl *et al*. (1941) measured the transfer of radioactive sodium across the placenta of the goat. Various workers have pointed out several advantages of the goat as a research animal. They are not expensive to purchase and they tolerate wide variations of temperature. Therefore, their housing need not be elaborate, except where temperature control is critical in the project under study. They are content to live in almost any surroundings, are easily handled and relatively unexciteable. Their larger size makes it easier to perform intricate surgical operations than is possible in the guinea pig, mouse, and rat.

The anatomy of the bovine and the sheep has been used as a guide for that of the goat in years past. This has been adequate from a clinical standpoint, in treating diseases of the goat. If the species is to be used in medical research, however, accurate studies must be made of its anatomy. It was with this point of view that the author was encouraged to study the anatomy of the blood supply to the genitalia of the male and female goat.

REVIEW OF LITERATURE

The anatomy of the blood supply to the reproductive tract of most domestic animals, excluding the goat, has been well described. Nomenclature in general has been a problem in all species through the years. This is particularly true in the area of the reproductive system.

The pudendo-epigastric trunk in the bovine arises from the deep femoral artery and divides into the caudal deep epigastric artery and the external pudendal artery (Habel, 1960). Emmerson (1940) states that in the bovine the prepubic artery arises from the femoral artery and divides into the posterior abdominal and external pudic arteries. This is in agreement with Sisson and Grossman. Sisson and Grossman (1953) refer to this vessel as the "prepubic artery (Truncus pudenda-abdominalis)" in the bovine and horse. They state that the artery arises by a common trunk with the deep femoral artery, and that it divides into the posterior abdominal artery (A. abdominalis caudalis) and the external pudic artery (A. pudenda externa). McLeod uses the term pubofemoral artery for Sisson and Grossman's deep femoral artery. He states that the pubofemoral artery divides into the deep femoral and the prepubic arteries. He agrees with Sisson and Grossman in naming the terminal branches of the prepubic arteries. May (1955) agrees with

Habel in using the term pudendo epigastric trunk in the sheep. He does not agree, however, on the origin, since he states that this trunk arises from the external iliac artery in common with the deep femoral artery. Miller (1952) and Habel are in complete agreement on terminology in this area.

There is general agreement as to the disposition of the mammary arteries in the various species.

The subcutaneous abdominal artery of McLeod is described by him as being distributed to the skin anterior to the mammary gland, to the retractor preputii muscle and to the external layer of the prepuce in the male. He states that the origin, in the female, is from the anterior or posterior mammary artery, and in the male directly from the external pudic artery as one of its terminal branches. Habel refers to the term "subcutaneous abdominal" only in relation to the vein. He mentions that the caudal superficial epigastric artery is a continuation of the cranial mammary artery and accompanies the vein anteriorly. He makes no mention of the caudal superficial epigastric artery forming an anastomosis with the cranial superficial epigastric artery.

Emmerson states that the external pudic artery divides into the subcutaneous abdominal artery and the mammary artery. He adds that the subcutaneous abdominal artery is usually the dorsal branch of the cranial mammary artery. He mentions that less frequently the subcutaneous abdominal artery is given directly off of the mammary artery before the latter divides into cranial and caudal branches. Both McLeod and Emmerson agree with Habel about a small branch of the external pudic artery accompanying the subcutaneous abdominal vein, but they do not give it a name. May (1955) states that the subcutaneous abdominal artery passes to the abdominal wall in front of the udder. He mentions a small branch from the mammary artery at the cranial end of the gland which passes along the abdominal wall. The latter branch is not named. El Hagri (1945) states that the subcutaneous abdominal artery was absent in 64% of the bovine specimens studied. Otto (1961) does not describe a subcutaneous abdominal artery in the goat. Sisson and Grossman state that the external pudic artery is distributed chiefly to the scrotum in the male and its terminal branches in the female go to the mammary gland.

There is general agreement as to the disposition of the cranial deep epigastric artery. Otto describes this as emerging from the thoracic cage between the seventh and eighth costal cartilages. McLeod, as well as Sisson and Grossman, name this vessel as the anterior abdominal artery.

The internal spermatic artery is well described by numerous workers. Sisson and Grossman, in the horse and bovine, give the impression that the vessel remains superficial to the tunica albuginea until it reaches the interior or posterior pole of the testicle. They state that the branches of the parent vessel pass up either side of the gland embedded in the tunic. Harrison (1952), in the human, states that the parent vessels become embedded in the deep face of the tunic upon reaching the mediastinum testes. Hofmann (1960), in the bull, describes the spiral formation in the tunic of the branches of the testicular artery. He also describes the winding, ball-like disposition of the arteria radiata deep in the parenchyma of the testicle.

The relationship of the umbilical artery to the middle uterine artery has not been agreed upon by many authors. Sisson and Grossman and McLeod state that the middle uterine artery arises by a common trunk with the umbilical artery. May and Habel state that the middle uterine artery is a branch of the umbilical artery. The counterpart of the middle uterine artery in the male is termed the external spermatic artery by McLeod. He states that it is distributed to the external cremaster muscle. Sisson and Grossman use the term "deferential" for this vessel. They describe its distribution as being to the ductus deferens. May states that the umbilical artery gives off branches to the ductus deferens and accessory genital organs. Most authors agree that the umbilical artery gives off branches to the ureters.

McLeod, as previously stated, describes the external spermatic as arising by a common trunk with the umbilical artery. Sisson and Grossman state that the spermatic arteries resemble those of the horse. They state that, in the horse, the external spermatic arises from the external iliac near the origin of the latter in most cases, and supplies the cremaster muscle and adjacent structures. May does not describe an external spermatic artery. Habel states that the external spermatic artery arises from the pudendoepigastric trunk. According to Habel, it is distributed to the external cremaster muscle and the tunica vaginalis.

The middle haemorrhoidal artery is described by Sisson and Grossman as arising from the internal pudic artery. McLeod refers to it as the middle haemorrhoidal or urogenital. He agrees with Sisson and Grossman as to the course and distribution of the vessel and its branches. Habel uses the term "urethrogenital artery" for this vessel, and he is in agreement with the aforementioned authors regarding its distribution. May employs the term "caudal uterine artery" to designate this vessel. He states that the middle haemorrhoidal artery is a branch of the caudal uterine artery. He agrees with the previously mentioned authors regarding the course and distribution of the vessels.

Ashdown (1960), in the bull, describes the recurrent artery of the sheath of the penis. He states that it is a branch of the caudal superficial epigastric artery. According to him it forms an anastomosis with the dorsal artery of the penis. He also states that it is unilateral.

MATERIALS AND METHODS

Ten goats were dissected in this investigation--five males and five females. They were obtained through a local livestock dealer. No specific breed is mentioned because the ancestry is unknown. All were white, except one (no. 5, Table 1) which was brown and white. Sex and weight are shown in Table 1. Classification according to age and sexual development is explained in Table 1 under puberty.

The animal was placed in dorsal recumbency before administration of the anesthesia. Equithesia[1] was the anesthetic of choice. It was given according to the directions on the label.

The femoral vein was cannulated in the area of the femoral triangle. An anticoagulant[2] (6 gm/gallon normal saline) was used at the rate of 200 cc per animal via the femoral vein. The left carotid artery was then cannulated. Exsanguination was accomplished through the cannulated artery. It was regulated so that infusion of one gallon of warm normal saline solution was accomplished before expiration. The infusion was effected by means of gravity.

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[1]Jensen-Salsbery Laboratories, Inc., Kansas City, Mo.

[2]Benzo Fast Pink 2 BL (Direct Red 75). Matheson Coleman and Bell. Division of Matheson Company, Inc., Norwood, Cincinnati, Ohio.

Purodigin[1] was used during exsanguination to strengthen the heart. One cc was given I.V. when the heart began to show stress by an increase in rate and decrease in amplitude. The dose was repeated when the beneficial effect of the first dose began to diminish.

Immediately following the expiration the fourth rib on the left side was resected. The pericardial sac was incised and the aorta was clamped just distal to the heart. Acetic acid (1000 cc of a 5% solution) was injected through the cannulated carotid artery. The pressure maintained during injection was 120 mm Hg. The acetic acid was followed by an injection of 750 cc of normal saline solution at the same site using the same pressure. Latex[2] was then strained through cheese cloth and injected immediately following the injection of normal saline solution. Ammonium hydroxide was added to the latex to make a 2% solution. The pressure was raised as high as 150 mm Hg in some cases. The apparatus described in Figure 1 was used in all procedures where pressure greater than gravity was employed.

Embalming fluid[3] was injected through the cannulated

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[1]Crystalline Digitoxin, 0.2 mg/cc. Wyeth Laboratories, Inc., Philadelphia, Pennsylvania.

[2]Cementex N/19 Red. Cementex Co., Inc., 336 Canal Street, New York 13, New York.

[3]Isopropyl alcohol, 60%; formalin, 4%; phenol, 6%; corn syrup, 2.5%; H_2O, 27.5%.

femoral vein.

A caliper[1] was used for the linear measurements (Tables 3 and 4). When the distance of a vessel was measured between two emerging branches and when the branches emerged at right angles to the measured vessel, the measurement was taken from the center of each emerging vessel. When the branches emerged at less than a 90° angle, measurement was taken from the acute angle which the latter formed with the parent trunk.

The photomicrographs were taken through a Spencer Microstar trinocular microscope fitted with an ortho illuminator. The photographs of the gross specimens, which were magnified, were taken through a Spencer stereo dissecting scope. A Leica camera with a 3F bellows focus reflex housing, a Hektor 135 cm. 4.5 lens, and a Kodak Wratten filter number 82c, was employed. The prints are Kodachrome.

The tissue sections were fixed, embedded and cut in the usual manner and stained with Crossman's (1937) modification of Mallory's triple stain.

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[1]Lufkin Rule Co., Saginaw, Michigan.

RESULTS

The A. thoracica interna arises from the ventral face of the brachial artery medial to the first rib. It courses ventrocaudally superficial to the transversus thoracis muscle on the deep face of the costal cartilages. The vessel terminates as the A. musculophrenica and A. epigastrica cranialis profundus. The termination is variable, occurring deep to the sixth to eighth costal cartilage.

The A. epigastrica cranialis profunda is the continuation of the A. thoracica interna after the A. musculophrenica is given off. It continues caudally on the deep face of the costal cartilages and leaves the rib cage in the costo-sternal angle between the chondro-sternal extremity of the eighth sternal rib and the xyphoid process of the sternum (Figures 3/a and b; and 26/a and b). It continues its course caudally in the connective tissue between the transversus and rectus abdominis giving off branches to both muscles. The A. epigastrica cranialis superficialis is given off and the parent vessel continues caudally in the rectus abdominis muscle where it forms an anastomosis with the A. epigastrica caudalis profunda in the middle third of the latter muscle.

The A. epigastrica cranialis superficialis arises from the ventral face of the A. epigastrica cranialis profunda, pierces the rectus abdominis muscle (Figures 3/c and d; and 26/c and d), and continues caudally. The distal course is quite variable. Its entire course may be either: superficial to the abdominal tunic; deep to the abdominal tunic; or it may thread its way both superficial and deep to the aforementioned tunic.

In the male it divides into medial and lateral branches soon after piercing the rectus abdominis muscle. The lateral branch courses caudally parallel and lateral to the ventral midline to anastomose with the lateral branch of the A. epigastrica caudalis superficialis (Figure 3). There were two variations in the medial (Preputial) branches. In three of the five specimens the right and left medial branches converge toward the midline at the level of the umbilicus and remain on their respective sides of the midline as they course caudally dorsal to the retractor preputii muscles. They anastomose with the medial (preputial) branches of the A. epigastrica caudalis superficialis of the same side in the area of the prepuce (Figure 3/1, 2, and 3). In the remaining two of the five specimens the medial branch of the right A. epigastrica cranialis superficialis crosses to the left of the ventral midline, joins its counterpart on the left and forms anastomoses with the medial branch of the right A. epigastrica caudalis superficialis which has also crossed to the left of the ventral midline (Figure 3/4 and 5).

In the female the vessel may: run caudally, parallel to the ventral midline and anastomose with the A. epigastrica caudalis superficialis in the middle third of the ventral abdominal area (Figure 26/1 and 2); incline medially to the midline in the area of the umbilicus, anastomose with branches from the A. mammaria medialis, and diverge slightly from the midline on its continuing caudal course to anastomose with the A. epigastrica caudalis superficialis in the same area as those previously described (Figure 26/3); incline laterally to the extent that it lies lateral to the rectus abdominis muscle in the middle of the ventral abdominal area, give off anastomotic branches to the A. mammaria medialis at this level and converge toward the midline on its continuing caudal course to anastomose with the A. epigastrica caudalis superficialis in the same area as those previously mentioned (Figure 26/4); or it may run for a short distance caudally, after piercing the rectus abdominis muscle, and ramify in the subcutaneous tissue with no detectable gross anastomosis (Figure 26/5).

The utero-ovarian artery in the female is the counterpart of the A. spermatica interna in the male and has a similar origin (Figure 5/2). The site of origin of the right vessel varies from the level of the posterior edge of the fourth lumbar transverse process to the same level of the fifth lumbar transverse process. The left vessel arises about one centimeter caudal to its right counterpart. The right artery arises from the ventrolateral face of the dorsal aorta while the left artery arises from the ventral face of the latter.

This vessel is very tortuous as it runs caudoventrally in the anterior part of the broad ligament of the uterus toward the ovary. It divides into three or four branches as it approaches the ovary (Figure 25/2). One or two branches Aa. ovaricae supply the ovary (Figures 31 and 32). Two or three branches Aa. uterini craniales pass to the lesser curvature of the tip of the uterine horn. The latter vessels supply the ovarian bursa, oviducts, broad ligament of the uterus along its free edge and the tip of the uterine horn. In the region of the latter it forms anastomoses with the A. uterina media.

The A. spermatica interna supplies the testicle. The origins of the right and left vessels are similar to those of the utero-ovarian artery and are shown in Figure 5/2.

The vessel courses in a caudolateral direction crossing the deep face of the psoas minor muscle. It continues its caudolateral course to approximately one-half the distance across the deep face of the psoas major muscle. It then changes to a direct caudal direction, crosses the deep face of the ureter and enters the inguinal canal.

The vessel is separated from the ventrolateral aspect of the A. iliaca externa by a thin sheet of connective tissue and fat along the middle third of the pelvic course of the latter (Figures 2 and 5).

The vessel becomes a component of the spermatic cord. It becomes increasingly tortuous from the middle third of the inguinal canal to the dorsal extremity of the testicle. This portion of the vessel becomes entwined in an extensive venous network "plexus pampiniformis" (Figures 2, 20 and 21).

Near the origin of the latter named plexus the vessel gives off a branch A. accessoria testicularis (Hofmann, 1960). The latter vessel divides further into branches to the head, body, and tail of the epididymus (Figures 20 and 21). In two of the five specimens, branches were given to the proximal portion of the ductus deferens. In these cases the A. deferentialis did not extend to the tail of the epididymus. The parent vessel loses its tortuous disposition at the superior pole of the testicle. It then passes under the epididymus in the area where the head and body of the latter meet (Figure 21). The vessel courses toward the inferior pole of the testicle, on its lateral face slightly cranial to the body of the epididymus (Figures 2, 19, 20 and 21). It follows a wave-like course toward the inferior pole of the testicle. As it approaches the latter it divides into two main branches (Figures 16, 19 and 21) which penetrate the tunica albuginea and are continued as the Aa. testiculares. In one specimen, each of the two main branches subdivided into two branches before penetrating the tunica albuginea. The A. spermatica interna is covered along its course on the surface of the testicle by a very thin sheet of the tunica albuginea.

The Aa. testiculares are the direct continuation of the A. spermatica interna. They assume their name at the point where the branches of the A. spermatica interna penetrate to the deeper layers of the tunica albuginea (Figure 21). The main branches course toward the superior pole of the testicle along its cranial aspect (Figures 18, 20 and 21). They give off smaller branches which course caudodorsally (Figure 18). The large and small vessels assume a tortuous disposition still embedded in the deep layers of the tunica albuginea (Figure 22).

The Aa. radiatae testes originate from the Aa. testiculares. They emerge at right angles to the parent vessel and course through the parenchyma toward the mediastinum testis (Figure 23/43). Many of the vessels, spiral in the proximal 1/3 of their course (Figure 24/43). Hofmann (1960) terms this portion Aa. centripedal of the Aa. radiatae testes.

As the vessels approach the mediastinum testis they form arcs and course toward the periphery of the gland

(Figures 23/44 and 24/44). Hofmann (1960) terms this portion the Aa. centrifugal of the Aa. radiatae testes.

The centrifugal portion branches more than the centripedal portion. Small branches are given off at the arc which continue on to the mediastinum testis.

The A. iliaca externa arises from the lateral face of the dorsal aorta 1.5 to 3.0 centimeters caudal to the left utero-ovarian artery (A. spermatica interna in the male). It courses ventrocaudally across the ventral surface of the psoas minor muscle diverging from the midline at a 35° angle (Figure 5/4). Shortly after giving off the A. circumflexa ilium profunda (Table 3, Figure 5/4) its angle of divergence decreases so that, at the point of origin of the A. profunda femoris, the parent vessel is lying on the ventral surface of the psoas major muscle.

The A. profunda femoris arises from the medial face of the A. iliaca externa at a 30° angle (Table 3, Figure 2/29). It courses distally on the deep face of the iliopsoas muscle. Three centimeters anterior to the ileopectineal eminence it gives off the Truncus pudendo-epigastricus and continues caudoventrally. It passes ventral to the acetabulum on its course to the adductor muscles of the pelvic limb.

The Truncus pudendo-epigastricus arises from the A. profunda femoris at a 60° angle (Table 3, Figures 2/31 and

6/31). It courses caudomedially, deep to the aponeurosis of the external oblique muscle. It approaches the caudal surface of the spermatic cord and gives off the A. epigastrica caudalis profunda about one centimeter distal to the internal inguinal ring (Figure 6/32). This vessel crosses the deep face of the spermatic cord at approximately a right angle (Figures 2/32 and 6/32) and courses cranially in the rectus abdominis muscle to anastomose with branches of the A. epigastrica cranialis profunda.

The _A. spermatica externa_ may be given off the A. epigastrica caudalis profunda shortly after the latter arises from the Truncus pudendo-epigastricus or it may arise from the A. pudenda externa shortly after the A. epigastrica caudalis profunda is given off. It supplies the external cremaster muscle.

The _A. pudenda externa_ courses in the distal three-fourths of the inguinal canal, emerging through the external inguinal ring at its caudomedial border. It lies caudal to its satellite vein, which in turn lies caudal to the spermatic cord. It courses caudoventromedially after leaving the inguinal canal.

In the female the A. pudenda externa forms several S-shaped curves above the udder. Two to four centimeters distal to the external inguinal ring it gives off a small branch which supplies the supramammary lymph nodes

(Figures 25 and 26) and continues caudally as a perineal branch. The parent vessel then turns cranially to continue as the A. mammaria.

The A. mammaria courses cranially as a direct continuation of the A. pudenda externa. It passes through the parenchyma of the udder two to four centimeters ventral to the dorsal border, and one to three centimeters medial to the lateral border, of the gland. It continues cranial to the udder as the A. epigastrica caudalis superficialis (Figures 25 and 26). In one specimen (Figure 26/2), there was an anastomosing branch given off which joined the right and left Aa. mammariae near the origin of the perineal branches. The main branches are:

1. The A. mammaria medialis originates from the A. mammaria immediately caudal to, or in the posterior 1/4 of, the udder (Figures 25 and 26) and courses cranially and medially. The right and left vessels may join and course cranially in the interlamellar space (Figure 26/3 and 4). In this case lateral branches will be given off to both udder halves. In three of five specimens the left vessel gains the interlamellar space giving off lateral branches to the parenchyma of the ipsolateral side, and the right counterpart terminates in the right udder (Figure 26/1, 2 and 5). There are numerous anastomoses between the A. -

mammaria medialis and A. mammaria. The vessel terminates in three ways: it may course cranially, its branches ramifying in the surrounding tissue with no direct anastomotic branches anterior to the udder (Figure 26/1 and 2); it may course cranially to an area posterior to the umbilicus, and divide into right and left branches which continue in a craniolateral direction to anastomose with branches from the A. epigastricus cranialis superficialis on its respective side (Figure 26/3 and 4); or it may terminate in the udder (Figure 26/5).

2. The Ramus mammaria caudalis may arise either proximal or distal to the origin of the A. mammaria medialis, depending on whether the latter arises dorsal to the udder or well into the udder tissue (Figure 25/36). This branch may be compared to the posterior mammary artery of the bovine. In one of the five specimens this vessel was equal in size to the A. mammaria. It contributed a liberal supply to the posterior and medial aspect of the teat.

3. The A. lateralis sinus (Figure 25/38) originates cranial to the origin of the A. mammaria medialis and courses toward the teat in the lateral aspect of the udder. As it reaches the region of the cystern it divides into several small branches, the Aa. papillares (Otto, 1961) in the wall of the teat. Many of these branches contribute

to the formation of the circulosus arteriosus papillae at the base of the teat while other branches continue in the wall of the teat toward the sphincter.

4. The A. epigastrica caudalis superficialis is a direct continuation of the A. mammaria in four of five specimens. The vessel forms an anastomosis with the A. epigastrica cranialis superficialis (Figures 25 and 26/1, 2, 3, and 4). In one of five specimens the A. mammaria terminates in the udder. In this case no A. epigastrica caudalis superficialis was present (Figure 26/5). According to Otto (1961) the A. mammaria terminated as the A. basalis cranialis which ramified in the base of the udder and ventral skin of the abdomen anterior to the gland. This is in agreement with the variation under discussion (Figure 26/5). However, inasmuch as only one of five specimens coursed in this manner, we have decided to describe the continuation of the A. mammaria as being the A. epigastrica caudalis superficialis.

In the male the A. pudenda externa resembles that of the female until the perineal branch is given off. The latter vessel gives off a small branch unilaterally, the A. urethralis, just caudal to the sigmoid flexure of the penis which enters the corpus cavernosum urethra (Figures 2/35 and 8/35). The parent vessel continues its dorsocaudal course to ramify in the perineal region. The scrotal branch is given off between the emergence of the perineal branch and the level of the spermatic cord (Figure 2/36), and supplies the Tunica vaginalis propria and communis as well as the dartos, fascia, and skin of the scrotum. There may be one or more additional small branches given off in the area. In three of five specimens the A. dorsalis penis of the penis originated unilaterally from the A. pudenda externa--two from the left and one from the right side (Figure 8). The parent vessel is continued cranially as a medial (preputial) branch and a lateral branch, the A. epigastrica caudalis superficialis (Figure 3).

The preputial branch has two main variations. It may course cranially just lateral to the penis and dorsal to the retractor preputii muscle. The right and left branches remain on their respective sides of the midline and continue cranial to the prepuce giving branches to the adjacent tissue along their entire course and especially to the prepuce. They anastomose with a medial branch from the A. epigastricus cranialis superficialis (Figure 3/1, 2 and 3). In two of the five specimens the right preputial branch crosses the midline ventral to the penis in the middle third of the distance between the scrotum and the prepuce. It courses cranially on the left side of the prepuce giving branches to the latter. It then anastomoses with the common trunk of the medial branches of the right and left A. epigastrica cranialis superficialis on the left of the ventral midline in the area of the prepuce (Figure 3/4 and 5). A small branch is given off near the bifurcation of the right preputial branch and the right A. epigastrica caudalis superficialis. This small vessel courses cranially on its own side and ramifies in the subcutaneous tissue just short of the prepuce (Figure 3/4 and 5). The left preputial branch divides into a small medial and lateral branch. The medial branch terminates just caudal to the prepuce on the ventral midline while the lateral branch inclines laterally to join the A. epigastrica caudalis superficialis on the left side (Figure 3/4 and 5). The A. pudenda externa persists cranially to a point about midway between the scrotum and the prepuce before it divides into the latter described preputial branches and the A. epigastrica caudalis superficialis (Figure 3/4 and 5). A recurrent branch as described in the bull (Ashdown, 1960) could not be demonstrated.

The A. epigastrica caudalis superficialis joins in an anastomosis with the A. epigastrica cranialis superficialis. Its origin may vary from the level of the scrotum (Figure 3/1, 2, and 3) to midway between the scrotum and the prepuce (Figure 3/4 and 5).

The _A._ _iliaca_ _interna_ (_A._ _hypogastrica_) (Table 4,

Figure 5/7) emerges from the dorsal aorta 2.5 centimeters anterior to the anterior border of the first sacral vertebra. It arises at a 30° angle of divergence from the midline. It courses caudolaterally across the ventral surface of the wing of the sacrum 0.5 to 1.0 centimeters lateral to the ventral foramen of the first sacral vertebra. It inclines slightly dorsally as it follows the contour of the latter. Caudal to the sacrum it turns slightly ventral on its latero-posterior course on the deep face of the sacrosciatic ligament. It terminates at the point where the A. urethrogenitalis is given off. From this point it is continued as the A. pudenda interna. Its chief branches are as follows:

1. The A. umbilicalis arises with the A. uterina media in the female (Figures 25/8 and 28/8) or the A. deferentialis in the male (Figures 2/8 and 5/8). Its proximal portion lies on the superficial surface of the peritoneum along the lateral wall of the pelvic cavity. Its caudal course parallels that of the A. uterina media (A. deferentialis) for a short distance. They soon diverge in a dorsoventral direction. The A. umbilicalis, as it continues caudally, is related ventrolaterally to the V. iliaca externa. It crosses the lateral face of the ureter and ductus deferens, then turns medially in the free edge of the lateral ligament of the bladder to supply the

anterior part of the latter.

Two to four small arteries emerge from the parent vessel at a variable distance between its origin and midway to the bladder. These small branches pierce the heavy original wall of the parent vessel and course distally to the bladder in close proximity to the original vessel (Figures 2/8, 25/8 and 28/8). In most cases the original vessel becomes obliterated distal to the emergence of the branches and truly becomes the "round ligament" of the bladder. In the latter case the small vessels assume the function of the parent vessel. In one specimen the branches were distributed from the vertex to the neck of the bladder.

2a. The _A. uterina media_ arises by a common trunk with the umbilical artery (Figures 25/9 and 28/9). The vessel accompanies the A. umbilicalis caudally for a short distance. It soon diverges from the latter in a ventral direction. Shortly after crossing the lateral surface of the ureter the vessel courses ventromedially in the middle one-third of the broad ligament of the uterus as measured from the line of reflection from the body wall to its free edge.

It approaches the lateral aspect of the uterus in the area of the bifurcation of the cornua from the body of the organ. When it reaches the uterus it inclines ventrally and slightly medially as it assumes a cranial course on the ventrolateral aspect of the cornua of the uterus. The vessel follows the lesser curvature of the cornua toward the free end of the latter. It forms anastomoses with branches from the Aa. uterini craniales.

Branches radiate on the dorsal and ventral surfaces of the cornua toward the greater curvature of the latter (Figure 27). The vessel is tortuous (Figure 28) and varies markedly in size with the stage of pregnancy.

There are numerous anastomatic branches between the right and left Aa. uterini media (Figure 27). Branches are given off the parent vessel, or one of its main branches, which course caudally on the ventral surface of the body of the uterus to anastomose with branches of the A. uterina caudalis (Figures 25 and 27).

2b. The A. deferentialis has the same origin in the male as the A. uterina media has in the female. The vessel is small and lies in the retroperitoneal connective tissue as it courses ventrocaudolaterally across the lateral face of the ureter to the internal inguinal ring (Figures 2/9, 5/9 and 6/9).

It enters the inguinal canal as a component of the spermatic cord where it is related to the ductus deferens caudally and the A. spermatica interna and V. interna spermatica cranially.

The artery supplies the ductus deferens and surrounding tissue distal to the internal inguinal ring. It may, or may not, extend to the tail of the epididymus, depending upon the size and extent of the branch from the A. accessoria testicularis (described under A. spermatica interna).

3. The A. iliolumbalis (Table 4) is a muscular branch.

4. The A. glutea cranialis (Table 4) is a muscular branch.

5. The A. urethrogenitalis is largely a visceral branch. It arises from the ventromedial surface of the A. iliaca interna (Table 4, Figures 2/12, 6/12 and 25/12). It passes ventrocaudally on the lateral surface of the rectum as a single trunk. As it approaches the ventrolateral aspect of the rectum it divides into a cranial and caudal branch. In the female the cranial branch gives off small vessels to adjacent structures throughout its course. It runs ventrocranially until it reaches the lateral face of the vagina then turns cranially to parallel the latter. Its main branch continues cranially A. uterina caudalis to anastomose with branches of the A. uterina media (Figures 25/18 and 27/9').

The larger arterial vessels of the uterus Rami uterini (Hilliger, 1958) are found just deep to the serosa (Figures 27, 28 and 29). Smaller vessels Ramuli uterini

(Hilliger, 1958) branch from the latter and ramify in the myometrium. These myometrial branches give off branches Rami caruncullosa (Hilliger, 1958) to the caruncle. The latter give off radiating branches to the mucosa and underlying connective tissue (Figure 30/9'''').

The cranial branch also supplies the distal portion of the ureter and the neck of the bladder (Figure 25/20 and 21). The caudal branch gives off vaginal, vestibular, and rectal branches. Other small branches course caudally to anastomose with branches of the A. pudenda interna caudal to the vagino-pelvic pouch.

In the male the anterior branch assumes its cranial course at the base of the seminal vesicle (Figures 2/16 and 6/16). It passes along the lateral face of the latter giving branches to it. The vessel continues cranially giving off three main branches: the deferential branch which courses along the lateral face of the ampulla of the ductus deferens and continues along the ductus deferens to the internal inguinal ring; the ureteral branch which courses cranially along the ureter; and the vesicular branch A. vesicalis caudalis which supplies the neck and caudal portion of the bladder. The posterior branch gives branches to the urethra, bulbourethral gland, rectum and anus A. rectalis caudalis. In four of five cases anastomoses were formed with the A. pudenda interna at the anterior extremity of the bulbourethral gland (Figure 2).

Both cranial and caudal branches supply the area of the prostate gland. The size of the A. rectalis caudalis, in both sexes, is dependent upon the extent of development of the A. haemorrhoidalis cranialis. In one of the ten specimens the latter was very well developed to the anus. In this case there was no rectal branch given off from the caudal branch of the A. urethrogenitalis.

The A. pudenda interna is the continuation of the A. iliaca interna after the A. urethrogenitalis is given off (Table 4, Figures 2/14 and 25/14). The A. pudenda interna runs for a variable distance in the substance of the sacrosciatic ligament, or on its lateral surface. It passes ventrocaudally on the lateral surface of the medial coccygeus muscle giving branches to the latter. It then curves medially around the caudal extremity of the vagino-pelvic (female) or urethro-pelvic (male) pouch.

The vessel continues its caudal course, inclining ventrally and medially, until it approximates its fellow from the other side shortly before reaching the ischial arch (Figures 6/14' and 14''). In the latter-mentioned area the vessel is related dorsally to the vestibule in the female and the urethra in the male. In both sexes it is related laterally to its satellite vein and ventrally to the pudic nerve (N. pudendus) (Figure 6/A).

In the female small twigs are given off to the anus. Vulvar branches supply the wall of the vestibule, vulva, and the labia of the vulva. The A. clitoridis supplies the clitoris.

The A. perinei is formed by the union of the Aa. clitoridae. It is usually unpaired and ramifies in the perineal region (Figure 25/26).

In the male a large branch is given off just caudal to the bulbourethral gland (Figure 2). It curves dorsocranially in close proximity to the dorsocaudal border of the gland. A short distance from its origin it gives off a branch from its medial face which courses medially to enter the anterior extremity of the urethral bulb as the A. bulbi urethrae. The parent branch also gives several branches to the bulbourethral gland on its continuing dorsocranial course. The A. perinei is given off a short distance dorsocranial to the bulbourethral gland. It courses laterocaudally to the ischiorectal fossa where it turns ventral to the perineal region. A branch of the A. urethrogenitalis forms an anastomosis with the parent branch dorsocranial to the bulbourethral gland near the origin of the A. perinei (Figure 2).

The A. pudenda interna continues its course to the ischial arch where it may terminate in one of three ways:

1. In one of five specimens the left A. pudenda

interna pierces the tunica albuginea penis on the ipsolateral side and terminates in the corpus cavernosum penis as the A. profunda penis (Figures 6/14, 6/14', 7/14' and 7/27).

The right A. pudenda interna gives off a branch as the A. profunda penis and continues over the ischial arch as the A. dorsalis penis (Figure 6/14''). The latter assumes a position on the dorsal median surface of the penis which it maintains until it reaches the second curve of the sigmoid flexure. The vessel then bifurcates into right and left branches which curve to their respective lateral faces of the penis. They continue cranially to the glans penis (Figure 8/28'). A more detailed description of the blood supply to the penis is given under a separate heading.

2. In one of five specimens the right A. pudenda interna terminates at the ischial arch. Its left counterpart persists as the A. dorsalis penis. It is similar in all respects to the first described anatomical arrangement except that the right and left parent arteries are reversed. The vessel that persists as the A. dorsalis penis is larger.

3. In three of five specimens both the right and left Aa. pudenda interni terminate in the corpus cavernosum penis at the ischial arch (Figure 7/14''). In this case the A. pudenda externa gives off a branch that assumes a

position on the dorsal aspect of the penis caudal to the sigmoid flexure (Figure 8). This vessel bifurcates into right and left branches and terminates in a manner similar to those described under 1 and 2 (Figure 8/28').

The blood supply to the penis is described as follows:

The corpus cavernosum urethra is supplied by right and left branches from the Aa. pudenda interni Aa. bulbi urethrae and a unilateral branch from the A. pudenda externa A. urethralis (Figures 2/24 and 35). The right and left corpus cavernosum urethrae retain their separate identities for a short distance. They are joined by numerous anastomotic branches (Figure 14). They merge shortly after passing over the ischial arch (Figure 9/A).

A single vessel continues distally in the ventromedial aspect of the corpus cavernosum urethra. This vessel takes its supply from both the Aa. bulbi urethrae and the A. urethralis.

The corpus cavernosum penis is supplied by the Aa. profundi penis (Figures 2/27 and 7/27). The main artery may divide into two branches before piercing the tunica albuginea of the crus penis. The main branch retains its identity in the corpus cavernosum penis for a short distance (Figure 10/A/27). It soon joins its fellow from the opposite side and continues caudally for a short distance as a single vessel (Figure 10/B and D/27). Right and left branches are given off which incline in a lateroventral direction as they course distally in the corpus cavernosum penis (Figures 10/E/27'; 11/F, G, H, and I/27' and 12/K, M, N, and Q/27'). The parent branch continues distally for a short distance in the dorsomedial aspect of the corpus cavernosum penis (Figure 10/E/27). The latter vessel terminates in a second pair of branches (Figure 11/F/27''). The terminal branches are smaller than the first branches and extend to the middle one-third of the penis (Figure 11/I/27'').

The origin of the A. dorsalis penis is described under the A. pudenda interna and A. pudenda externa. It is first seen in a series of cross sections in Figure 11 (F/28). The reason for its delayed appearance in this particular specimen is that the artery originates from the A. pudenda externa, similar to Figure 8. It gives off branches, along its course, which penetrate the tunica albuginea penis. The vessel supplies the latter-mentioned tunic, the trabeculae which separate the cavernous sinuses and the connective tissue immediately surrounding the penis in part.

The blood supply to the ovary is described as follows:

The origin of the ovarian arteries are described under the utero-ovarian arteries. They retain their tortuous disposition in the medullary portion of the ovary (Figures 33, 34 and 35/2' (1)). Some vessels in the cortical portion also present this arrangement (Figures 35/2' (2) and 40/2' (2)).

Single vessels are distributed throughout the stroma. Vessels are also found in groups throughout the cortex (Figures 36/2' (2); 37/2' (2) and 38).

DISCUSSION

The general pattern of the arterial supply to the genitalia and accessory structures is similar to that of other ruminants. Both A. iliaca interna and A. iliaca externa are regarded as arising from the dorsal aorta. Salamanca and Schwarz (1960) describe the dorsal aorta as terminating at the level of the A. iliaca externa. The short trunk between the origin of the A. iliaca externa and A. iliaca interna, according to them, is the common trunk of the right and left A. iliaca interna. The length of the Aa. iliaca externa and Aa. iliaca interna indicates that there is no significant difference between those on the right and those on the left side. Also, the arteries studied proved to be significantly consistent in length. This is especially pertinent when considering the difference in size and conformation of the specimens. The findings in this study on the goat do not agree with those of Otto (1961) in all cases. This may be due to the small number of specimens examined.

In all cases the A. epigastrica cranialis profunda emerges from the level of the rib cage in the costosternal angle. This is not in agreement with Otto who described it as emerging between the seventh and eighth ribs. One of the ten specimens presented a very small vessel which terminated cranial to the umbilicus. This resembles McLeod's (1958) description of the anterior subcutaneous abdominal artery in the bovine. Sisson and Grossman (1953) make no mention of the anterior subcutaneous abdominal artery, nor does Otto, in the goat.

The origin of the A. deferentialis agrees with that of the bovine as described by Sisson and Grossman. Habel (1960) does not mention the vessel. McLeod describes this vessel as the A. spermatica externa. He describes the A. deferentialis as arising from the A. urethrogenitalis, as in the dog.

The A. spermatica externa has been described as originating from several different sites. According to Habel it arises from the Truncus pudendo-epigastricus. McLeod, as previously mentioned, describes it as the homologue of the A. uterina media in the female. According to this description, it would arise from the A. iliaca interna. Salamanca and Schwarz (1960) state that the A. spermatica externus may arise from the Truncus pudendo-epigastricus, deep femoral artery, caudal epigastric artery or from the A. pudenda externa. They state that the A. spermatic externa is absent in the goat. Sisson and Grossman state that the vessel originates from the same sites as in the horse. Getty (1955, Figure 65, p. 154) illustrates, in a schematic drawing, the vessel arising from the A. pudenda externa in the bovine. This is in agreement with four of the five specimens examined. In the fifth specimen the vessel originates from the A. epigastrica caudalis profunda just after the latter is given off from the Truncus pudendo epigastricus.

The disposition of the A. spermatica interna, in relation to the plexus pampiniformis and the testicle, leads one to make the assumption that the temperature of the testicle is very important. Harrison and Weiner (1948) demonstrated a significant abdomino-testicular temperature gradient. Harrison (1949) refers to the relationship of the testicular artery and the pampiniform plexus as being a heat exchange mechanism. He goes on to state that the artery, on reaching the testes, comes to lie on the deep face of the tunica albuginea. If this were the case, the heat loss would largely take place in the plexus pampiniformis. Sisson and Grossman state that the branches of the A. spermatica interna at the inferior pole become embedded in the tunica albuginea. This leads one to assume that the main artery is not embedded in the tunic according to Sisson and Grossman. In the five specimens dissected a very thin sheet of the tunic covers the artery on its course along the testicle. This essentially agrees with Sisson and Grossman. In the latter-mentioned dissections the large branches of the A. spermatica interna that course toward the proximal pole of the testicle are embedded in the deep layers of the tunica albuginea. There is agreement with Sisson and Grossman in this area, also. Hofmann (1960) describes the A. spermatica interna as terminating at the point where it penetrates to the deep layers of the tunic. He divides the latter vessel into three parts: "pars abdominalis, pars convoluta, and pars marginalis." He uses the term "Aa. testiculares" for the deeply embedded large branches. He refers to the vessels that course through the parenchyma as the "Aa. radiatae testes." This nomenclature is clear and logical and seems worthy of adoption.

There is a liberal blood supply to the prepuce by way of the preputial branches of the Aa. pudendi externi. A recurrent artery of the prepuce, as described by Ashdown (1960) in the bull, was not found. The disposition of the preputial branches is such that there appears to be no logical need for a recurrent branch. There is no difference in the disposition of the A. dorsalis penis regardless of the fact that the origin is variable. Although anastomoses between branches of the A. dorsalis penis and the preputial branch of the A. pudenda externa were not demonstrated, it is quite possible that they do exist. The branches of these vessels ramify in close proximity to each other.

The arterial architecture of the penis in the bull has been described by Fitzgerald (1963). Interest in this area has been stimulated by increasing concern relative to the etiology of the deviation of the organ. It was for this reason that Fitzgerald undertook the study of the angio-architecture. His approach to the problem seems to be well founded. The distribution of the A. profunda penis in the goat is such that a unilateral obstruction of the vessel could conceivably deviate it from its normal position. One difference of note in the goat is that the cavernous tissue is supplied by single large branches from the Aa. profundi penis. Fitzgerald found in the bull that these areas were supplied by groups of, from two to ten, arterial twigs held together by a special connective tissue capsule.

The thick-walled vessels in the cortical stroma of the ovary are worthy of further investigation. The age and breeding history were not available for the specimens. The thickness of the vessel walls may be due to influences during a normal estrus cycle. It may also be due to arteriosclerosis. No attempt was made to study the vessel walls histologically.

The terms A. mammaria cranialis, A. mammaria caudalis (Emmerson), and A. cranialis basalis (Otto) have been omitted from this study. These terms are commonly used in describing the arterial circulation to the udders of the cow and goat. It is obvious that this terminology is necessary for clarity in the former species. It is reasonable in the goat, if the A. epigastrica caudalis superficialis is absent, as described by Otto, and which was found to be true in one of five specimens dissected in this study. It is difficult, however, to justify the use of the terms A. mammaria cranialis or the A. cranialis basalis if the A. epigastrica caudalis superficialis is present. It must be pointed out that the latter vessel was present in the remaining four of five female specimens dissected. Therefore, for the present the A. epigastrica caudalis superficialis is described as being present in a majority of cases. It is described as being a direct continuation of the A. mammaria.

SUMMARY AND CONCLUSIONS

Ten goats were used in the study, five of which were female. Age, breed, and breeding history were unavailable. Latex injection media was employed.

The arterial supply to an area can best be studied when the arteries of the intact animal are injected with a contrast media. This is particularly true in relation to the vessels of the ventral abdominal wall. When injecting the intact animal, the importance of complete exsanguination must be stressed. This is not the case in extirpated organs which can be perfused for several hours before injection.

The blood supply of the goat is quite similar to the bovine. There are, however, a few significant differences. The A. epigastrica cranialis superficialis is better developed in the goat and forms easily demonstrable anastomoses with the A. epigastricus caudalis superficialis. The combinations of these vessels and their branches on the ventral body wall are numerous.

The A. dorsalis penis may originate from four different sources: right A. pudenda externa, left A. pudenda externa, right A. pudenda interna, or left A. pudenda interna. The disposition of the vessel and its branches are similar regardless of the origin. A recurrent artery of the prepuce as described in the bull (Ashdown, 1960) was not found.

The arterial blood supply to the mammae is quite similar to the bovine. Dissimilarities due to the difference in udder parts should be expected. The dissimilarities that do exist are logical in that they are the result of simplification in the goat due to the division of its udder into halves rather than quarters.

Differences in terminology applied to arterial vessels in the pelvic cavity create the impression of great differences between the goat and the bovine. The only important difference is the origin of the A. dorsalis penis. In some cases the latter vessel arises from the A. pudenda interna. In the latter instance it will arise from the right A. pudenda interna or from its counterpart on the left, but not from both. It may also arise from the A. pudenda externa. Rectal branches may be given off by the A. urethrogenitalis. If the latter is the case, the A. mesenterica caudalis will terminate its caudal branch before reaching the terminal part of the rectum. If, however, the A. urethrogenitalis does not give off a rectal branch, the caudal branch of the A. mesenterica caudalis extends to the rectum and anus. Excluding the latter two exceptions, this region of the bovine and goat might well be described in common.

The tractability of this animal along with economy relative to the cost of the animal itself, feed, and housing are factors that favor its use as a laboratory animal.

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APPENDIX

Table 1. Experimental animals[a]

Goat no.	Sex	Puberty (1)	Length in centimeters (2)	Weight in pounds
1	VF*	+	48.0	83
2	VF*	+	55.5	125
3	F	+	61.0	225
4	M	+	68.5	270
5	M	+	59.0	199
6	M	±	53.0	98
7	F	+	61.0	164
8	VF*	+	60.5	89
9	M	+	62.5	260
10	M	+	60.0	230

[a]Explanation of Table 1:

* Virgin female, as determined by the absence of udder development.

(1) If the animal was obviously too young to breed, it was given a minus. If it appeared old enough to breed, it was given a plus. In all cases but one (6), the specimens were either young or old enough to leave no doubt of their classification.

(2) Measured from the cranial edge of the dorsal extremity of the spine of the fourth thoracic vertebra to the caudal extremity of the sacrum.

Explanation of Table 2:

a The point at which the right A. epigastrica cranialis profundus leaves the rib cage and no longer lies deep to the eighth costal cartilage (see diagram).

a' Distance in centimeters on a straight line from the right junction of the eighth costal cartilage and the xyphoid cartilage to point "a" (see diagram).

a" Distance in centimeters that point "a" is lateral to the ventral midline (see diagram).

b The point at which the left A. epigastrica cranialis profundus leaves the rib cage and no longer lies deep to the eighth costal cartilage (see diagram).

b' Distance in centimeters on a straight line from the left junction of the eighth costal cartilage and the xyphoid cartilage to point "b" (see diagram).

b" Distance in centimeters that point "b" is lateral to the ventral midline (see diagram).

c The point where the right A. epigastrica cranialis profundus gives off the right A. epigastrica cranialis superficialis (see diagram).

c' The distance in centimeters on a straight line from the right junction of the eighth costal cartilage and the xyphoid cartilage to point "c" (see diagram).

c" The distance in centimeters that point "c" is lateral to the ventral midline (see diagram).

d The point where the left A. epigastrica cranialis profundus gives off the left A. epigastrica cranialis superficialis (see diagram).

d' The distance in centimeters on a straight line from the left junction of the eighth costal cartilage and the xyphoid cartilage to point "d" (see diagram).

d" The distance in centimeters that point "d" is lateral to the ventral midline (see diagram).

Table 2. Emergence area of the A. epigastrica cranialis profunda and superficialis

Goat no.	a		b		c		d	
	a'	a"	b'	b"	c'	c"	d'	d"
1	1.8	2.5	1.6	3.0	15.0	5.5	13.0	8.0
2	2.0	2.2	4.0	6.5	16.0	4.0	12.0	7.0
3	10.5	8.0	10.5	8.0	13.2	8.0	13.0	6.0
4	1.5	3.0	1.0	4.0	16.5	5.5	18.0	3.8
5	1.5	2.5	0.5	2.0	21.5	3.0	15.0	3.5
6	1.0	5.0	0.5	1.0	19.5	5.0	11.0	4.0
7	0.8	2.5	0.8	3.2	14.0	7.0	9.0	5.5
8	1.5	3.6	1.3	3.2	14.1	3.7	12.0	3.0
9	1.5	2.1	2.5	2.1	19.5	3.8	21.2	4.1
10	1.6	1.8	2.1	2.2	16.8	3.8	15.6	3.4

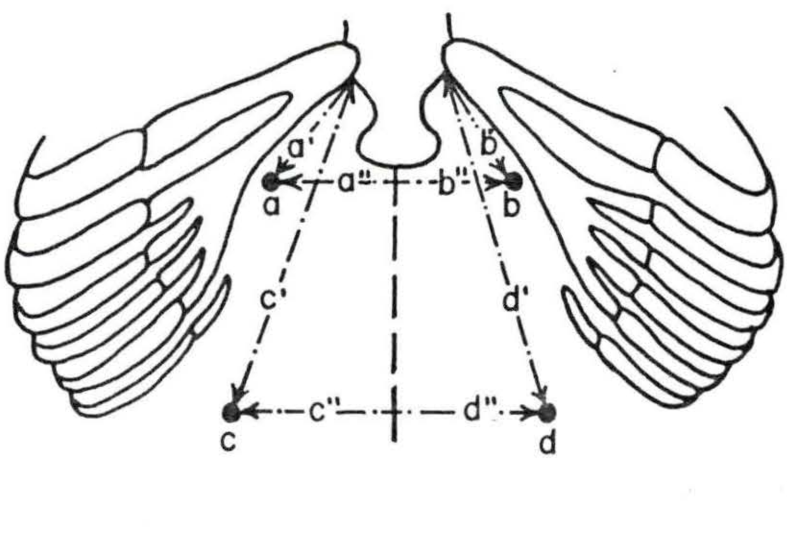


Table 3. Linear measurement in centimeters of various vessels arising from the A. iliaca externa[a]

Goat no.	Right				Left			
	1	2	3	4	1	2	3	4
1	1.5	5.0	1.5	1.8	1.4	4.8	1.5	1.6
2	2.0	6.3	1.7	1.5	1.7	6.5	1.6	1.7
3	3.0	7.5	2.5	1.0	1.7	7.6	2.0	1.5
4	2.5	7.0	2.4	1.5	1.7	8.0	2.5	1.6
5	2.8	8.0	2.2	1.5	3.0	8.2	2.0	1.5
6	2.0	5.8	2.2	1.9	1.1	6.0	2.4	1.0
7	3.2	9.0	3.3	2.1	3.2	10.0	3.0	3.4
8	3.0	5.8	3.1	3.1	3.1	7.0	2.3	1.5
9	2.6	4.4	4.9	2.3	2.4	5.8	3.4	2.1
10	2.6	6.1	2.7	2.2	1.7	8.2	2.6	0.9

[a]Explanation of Table 3:

1 From the origin of the A. iliaca externa to the origin of the A. circumflexa ilium profunda.

2 From the origin of the A. circumflexa ilium profunda to the A. profunda femoris.

3 From the origin of the A. profunda femoris to the origin of the Truncus pudendo-epigastricus.

4 Truncus pudendo-epigastricus.

Table 4. Linear measurement in centimeters of various vessels arising from the internal iliac artery (A. hypogastrica)[a]

Goat no.	Right							Left						
	1	2	3	4	5	6	7	1	2	3	4	5	6	7
1	0.5	0.2	3.0	0.0	4.5	1.5	2.0	0.7	0.2	3.0	0.0	5.0	1.5	2.5
2	0.5	0.2	2.5	2.5	8.0	1.6	2.5	1.5	0.2	2.5	2.5	8.0	1.2	2.5
3	1.0	0.3	1.8	2.0	8.7	1.1	3.0	2.0	0.2	2.8	2.0	8.5	1.5	3.4
4	2.5	0.3	2.5	2.0	5.0	1.3	2.8	1.5	0.4	3.0	1.0	5.5	0.8	3.1
5	2.5	0.5	2.6	2.5	8.2	0.9	2.8	2.3	0.7	2.8	3.0	7.6	1.1	2.5
6	2.5	0.5	1.1	2.1	4.8	1.1	3.5	3.7	0.2	1.1	2.6	4.8	1.3	3.3
7	1.4	0.4	3.8	1.3	2.8	1.5	4.9	2.4	0.5	2.1	2.3	3.1	0.7	3.6
8	1.2	0.0	1.6	1.4	8.5	1.6	2.7	1.3	0.5	2.3	1.2	7.1	1.8	3.2
9	2.4	0.4	3.2	7.3	1.2	0.7	3.3	1.7	0.4	3.3	1.0	8.5	1.0	3.5
10	2.3	0.3	0.5	1.2	7.5	3.9	2.2	1.7	0.3	1.4	0.2	9.3	2.0	3.5

[a]Explanation of Table 4:

1 Origin of the internal iliac artery (A. hypogastrica) to the origin of the common trunk of the A. umbilicalis and the A. uterina media (female) and the A. deferentialis (male).

2 Length of the common trunk of the A. umbilicus and A. uterina media (or A. deferentialis).

3 From the origin of the common trunk of the A. umbilicalis and A. uterina media (or A. deferentialis) to the origin of the A. iliolumbalis.

4 From the origin of the A. iliolumbalis to the origin of the A. glutea cranialis.

5 From the origin of the A. glutea cranialis to the origin of the A. urethrogenitalis and A. pudenda internus.

6 From the origin of the A. pudenda internus to the origin of the A. glutea caudalis.

7 From the origin of the A. urethrogenitalis to the origin of its first branch.

Figure 1. The apparatus for injecting the arteries

1 - Air inlet tube
2 - Mercury manometer
3 - Air by-pass valve
4 - Three-way valve
5 - Red cementex injection media
6 - Acetic acid 5% solution
7 - Normal saline solution

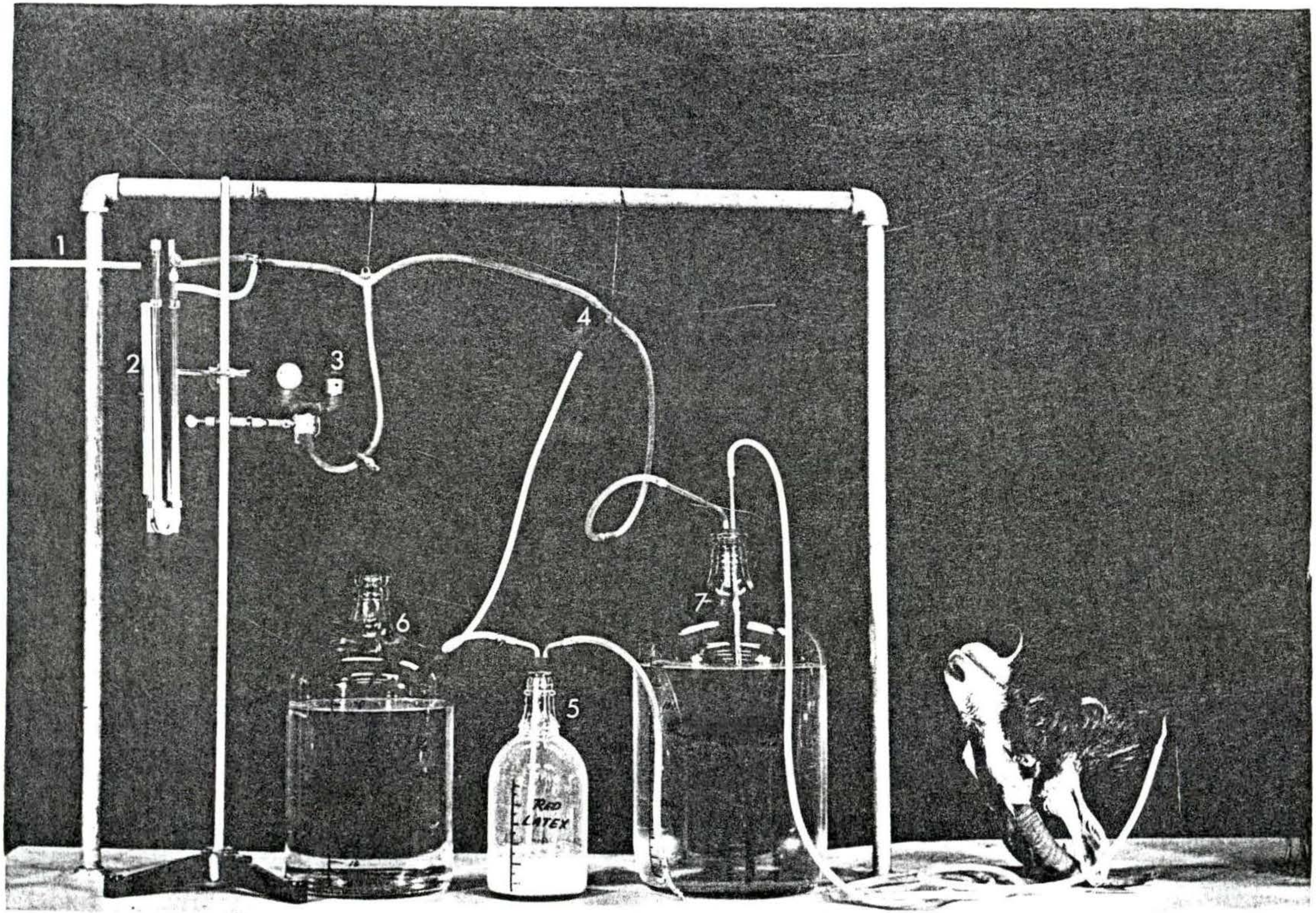

1
2
3
4
5
6
7
RED
LATEX

Figure 2. Arteries to the genital tract of the male goat (schematic)

A - Rectum
B - Lateral Coccygeus M.
C - Medial coccygeus M. (retractor ani M. - Sisson and Grossman)
D - Retractor penis M.
D' - Retractor penis M.
E - Ischiourethralis M.
F - Bulbourethral gland
G - Bulbocavernosus M.
H - Ischiocavernosus M. (cut away from ischium)
I - Crus of the penis (cut away from ischium)
J - Urethra (pelvic)
K - Seminal vesicle
L - Bladder
M - Pubic symphysis
N - Penis
O - Lymph node (superficial inguinal)
P - Left testicle
Q - Ductus deferens
R - Right testicle
S - Epididymus
T - Ureter
U - Ampulla of ductus deferens

1 - Aorta abdominalis
2 - A. spermatic interna
3 - A. mesenterica caudalis
3'- A. haemorrhoidalis cranialis
4 - A. iliaca externa
5 - A. circumflexa ilium profunda
6 - A. sacralis media
7 - A. iliaca interna
8 - A. umbilicalis
9 - A. deferentialis
10 - A. iliolumbalis
11 - A. glutea cranialis
12 - A. urethrogenitalis
13 - A. glutea caudalis
14 - A. pudenda interna
15 - Posterior branch of A. urethrogenitalis
16 - Anterior branch of A. urethrogenitalis
17 - Urethral branch
18 - Branches to seminal vesicle
19 - Deferential branches
20 - Vesicular branch
21 - Ureteral branch
22 - Branch of A. urethrogenitalis to the bulbourethral gland
23 - Branch of A. pudenda interna to the bulbourethral gland
24 - A. bulbiurethrae
25 - Muscular branch
26 - A. perinei
27 - A. profunda penis
28 - A. dorsalis penis
29 - A. profunda femoris
30 - A. profunda femoris
31 - Truncus pudendo-epigastricus
32 - A. epigastrica caudalis profunda
33 - A. spermatica externa
34 - A. pudenda externa
35 - A. urethralis
36 - Scrotal branch
37 - A. spermatica interna
37'- A. spermatica interna
38 - A. epigastrica caudalis superficialis
39 - Plexus pampiniformis
39'- Plexus pampiniformis (cut end of the vein)
40 - A. accessoria testicularis
41 - V. testicularis
42 - A. testicularis

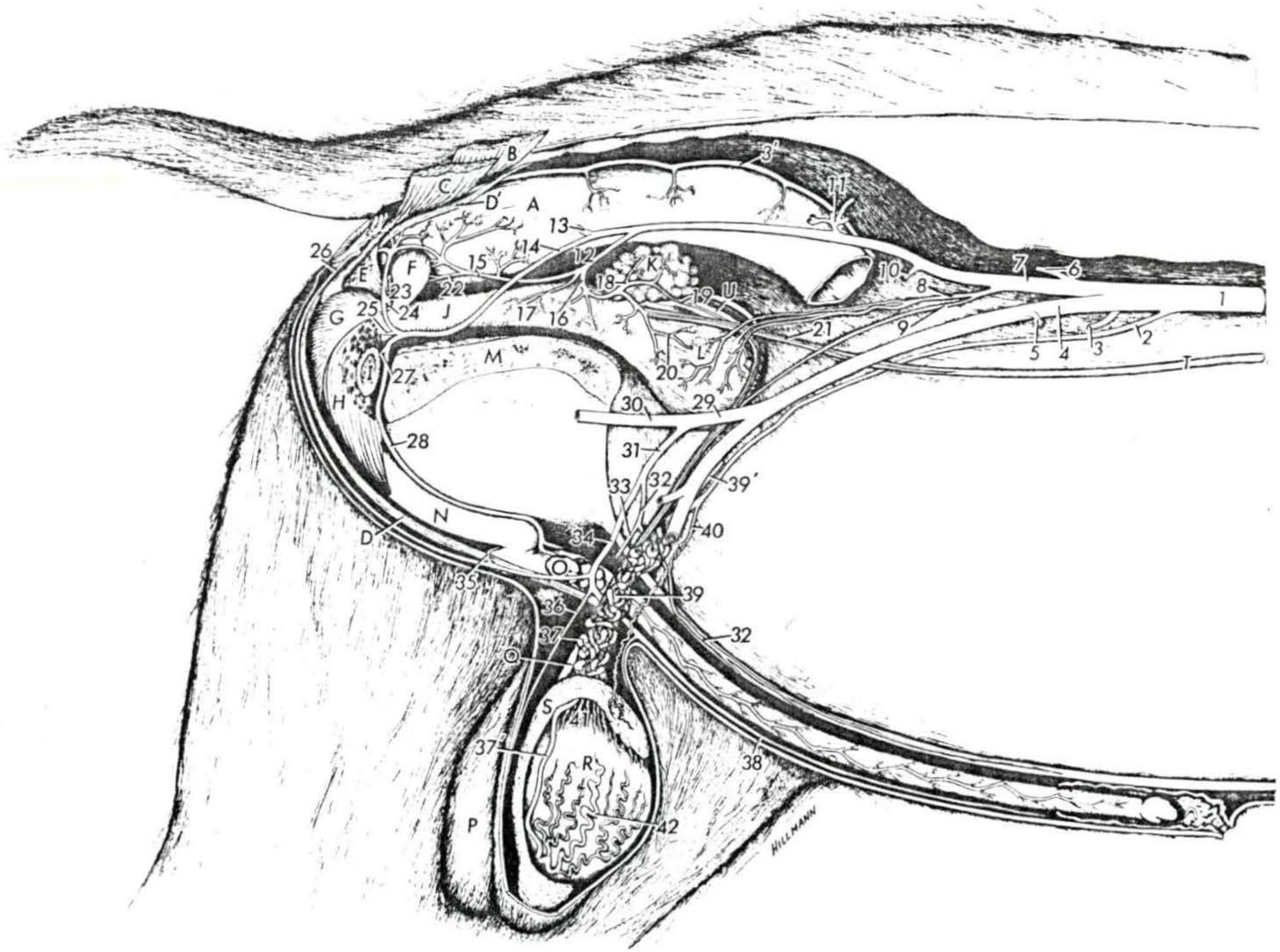

A
B
C
D'
D
E
F
G
H
J
K
L
M
N
O
P
R
S
T
U
1
2
3
3'
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
39'
40
41
42
HILLMANN

Figure 3. Ventral view of the male (schematic)

Explanations for points a, b, c, and d are given in Table 2.

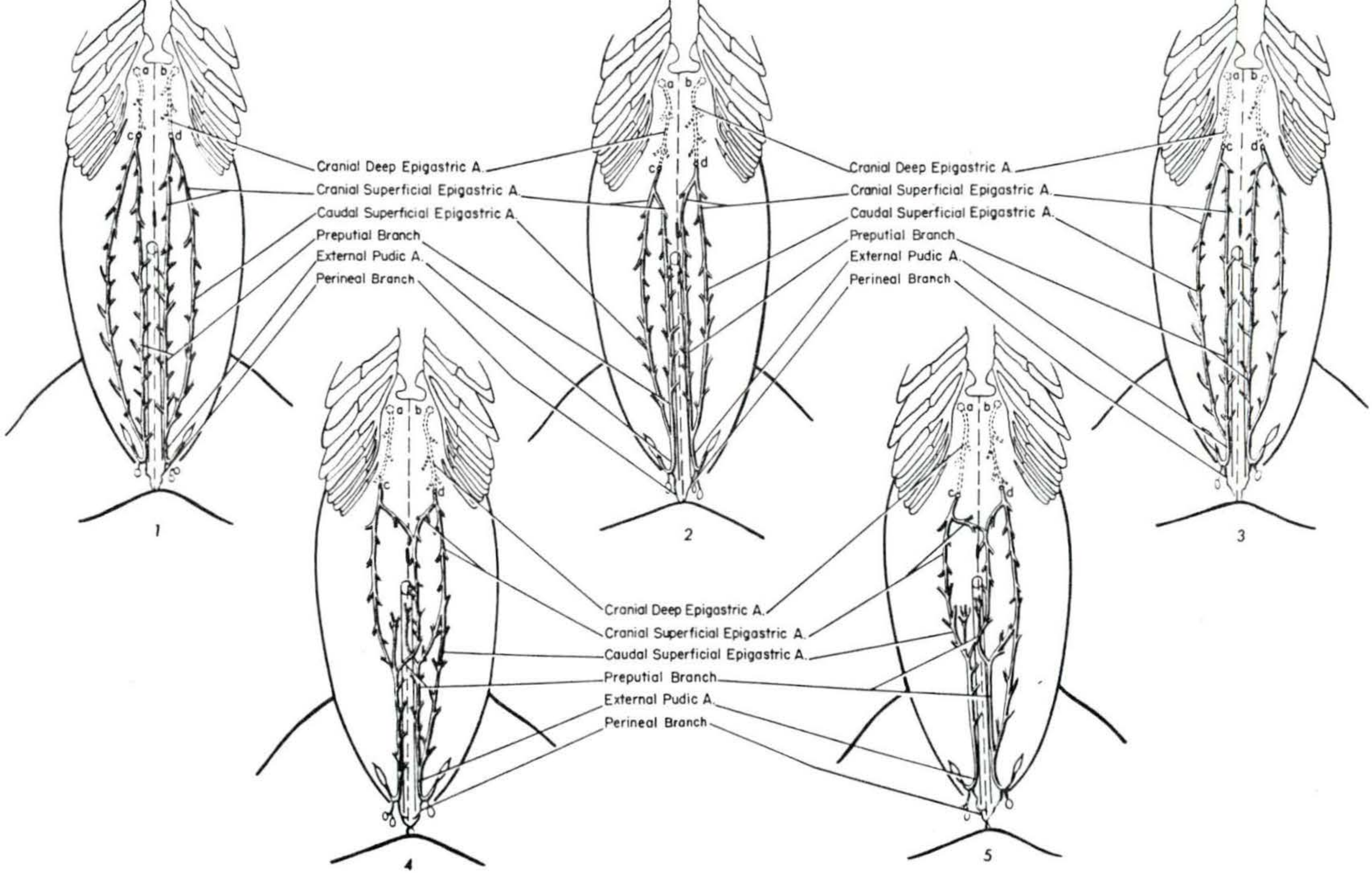
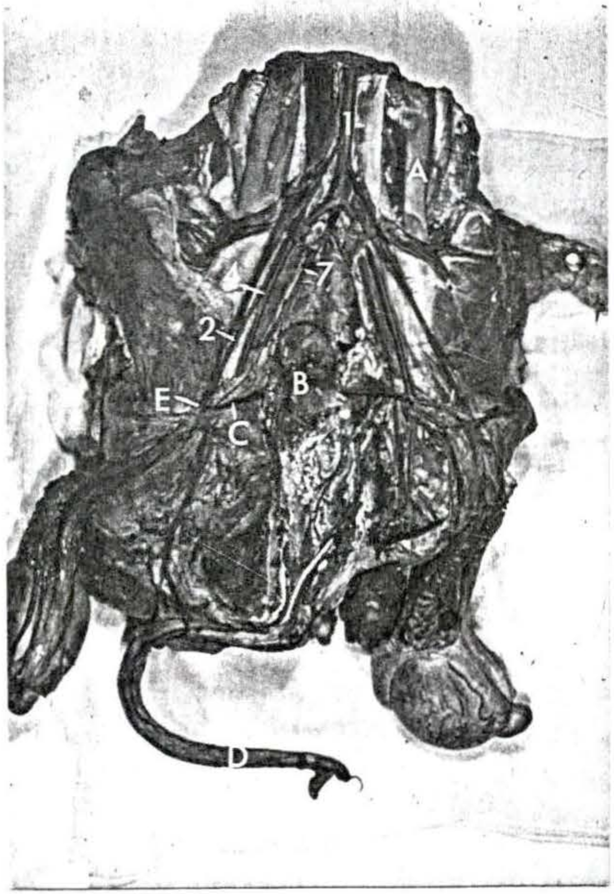

Cranial Deep Epigastric A.
Cranial Superficial Epigastric A.
Caudal Superficial Epigastric A.
Preputial Branch
External Pudic A.
Perineal Branch
Cranial Deep Epigastric A.
Cranial Superficial Epigastric A.
Caudal Superficial Epigastric A.
Preputial Branch
External Pudic A.
Perineal Branch
Cranial Deep Epigastric A.
Cranial Superficial Epigastric A.
Caudal Superficial Epigastric A.
Preputial Branch
External Pudic A.
Perineal Branch
a
b
c
d
1
2
3
4
5

Figure 4. Termination of aorta abdominalis (refer to Figures 5 and 6)

A - Tendon of psoas major muscle
B - Bladder
C - Ductus deferens (colored)
D - Penis
E - Internal inguinal ring
1 - Aorta abdominalis
2 - A. spermatica interna
4 - A. iliaca externa
7 - A. iliaca interna

Figure 5. Proximal portion of Figure 4 (close up)

A - Tendon of psoas major muscle
B - Bladder
C - Ductus deferens (colored)
E - Internal inguinal ring
1 - Aorta abdominalis
2 - A. spermatica interna
4 - A. iliaca externa
7 - A. iliaca interna
8 - A. umbilicalis
9 - A. deferentialis
12 - A. urethrogenitalis


1
A
7
2
B
E
C
D

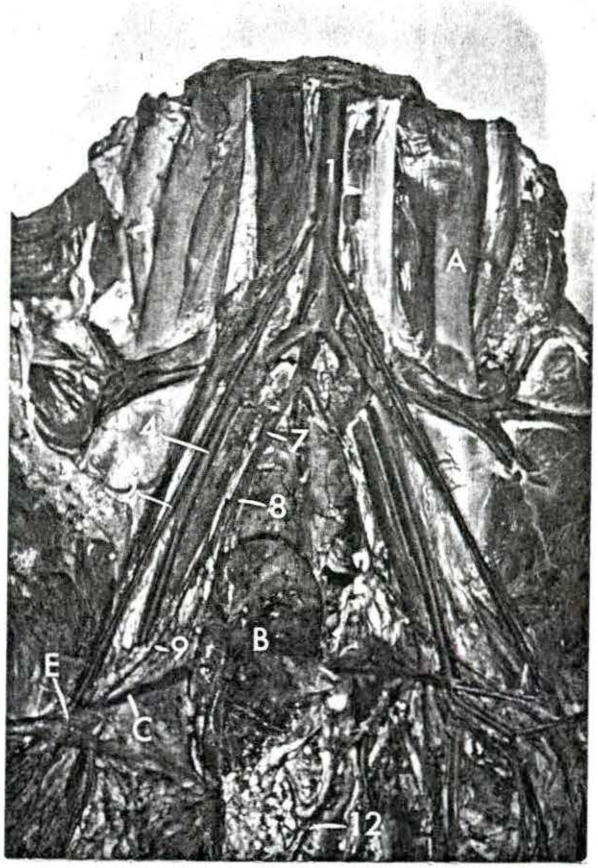
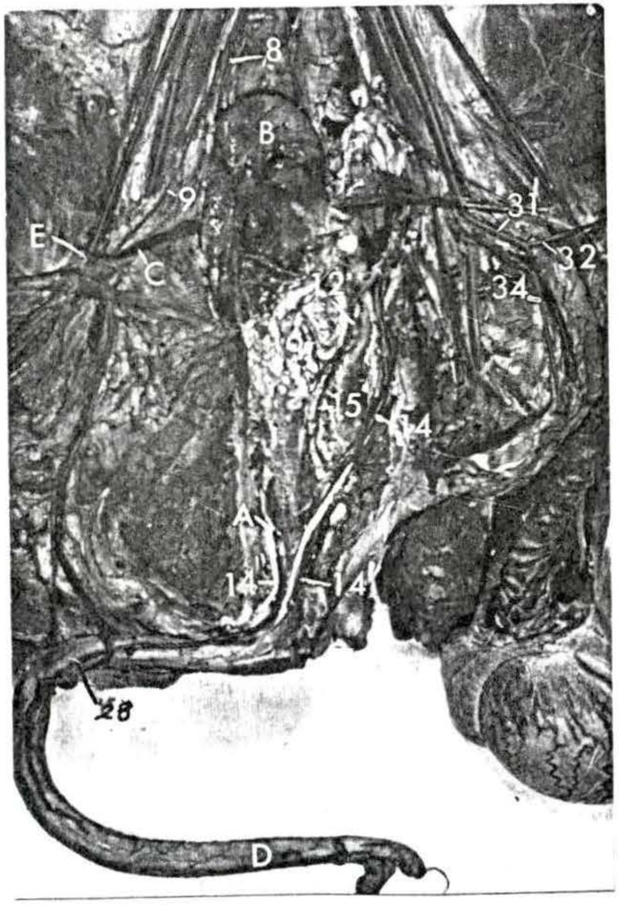

1
A
4
7
8
B
9
E
C
12

Figure 6. Distal portion of Figure 4 (close up)

A - N. pudendus (reflected to expose artery
B - Bladder
C - Ductus deferens (colored)
D - Penis
E - Internal inguinal ring
8 - A. umbilicalis
9 - A. deferentialis
12 - A. urethrogenitalis
14 - A. pudenda interna
14'- A. pudenda interna
14"- A. pudenda interna
15 - A. urethrogenitalis (posterior branch)
16 - A. urethrogenitalis (anterior branch)
28 - A. dorsalis penis
31 - Truncus pudendo-epigastricus
32 - A. epigastrica caudalis profunda
34 - A. pudenda externa

Figure 7. Root of the penis (ventral view)

A - Urethra (pelvic)
B - Ischiocavernosus muscle
C - Crus penis
14'- A. pudenda interna
27 - A. profunda penis


8
B
9
31
E
C
32
12
34
15
14
A
14
14
28
D

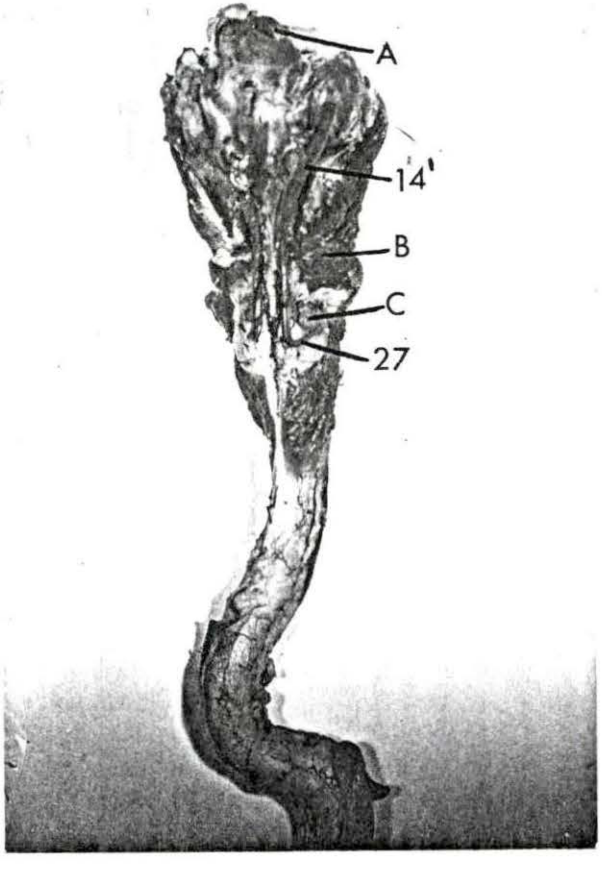

A
14'
B
C
27

Figure 8. A. dorsalis penis arising from the A. pudenda externa

A - Cut end of right femur
B - Aponeurosis of internal oblique muscle
C - Aponeurosis of external oblique muscle
D - Penis
28 - A. dorsalis penis
28'- A. dorsalis penis (right and left branches)
29 - A. profunda femoris
34 - A. pudenda externa
35 - A. urethralis
38 - A. epigastricus caudalis superficialis

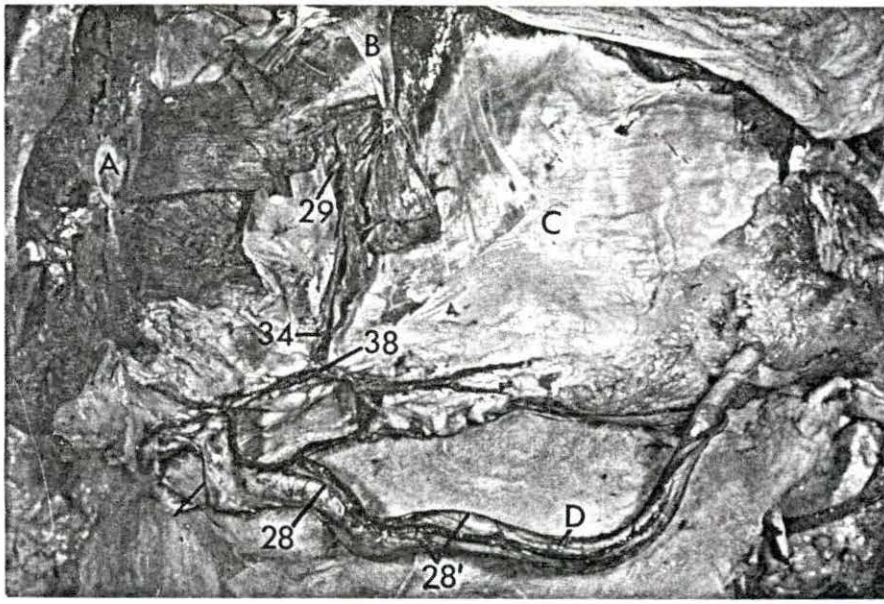
Penis has been displaced to the left of the midline and rotated one-fourth turn.

Figure 9. Dorsal view of the penis

A - Proximal end of the penis
X - Distal end of the penis
Z - Urethral process
27 - A. profunda penis
28 - A. dorsalis penis

Cross sections of the penis are shown in Figures 10 through 13. The letter on the cross section refers to the site from which it was taken as shown in this figure.

The A. dorsalis penis is a branch of the A. pudenda externa in this specimen.


A
B
29
C
34
38
28
D
28'

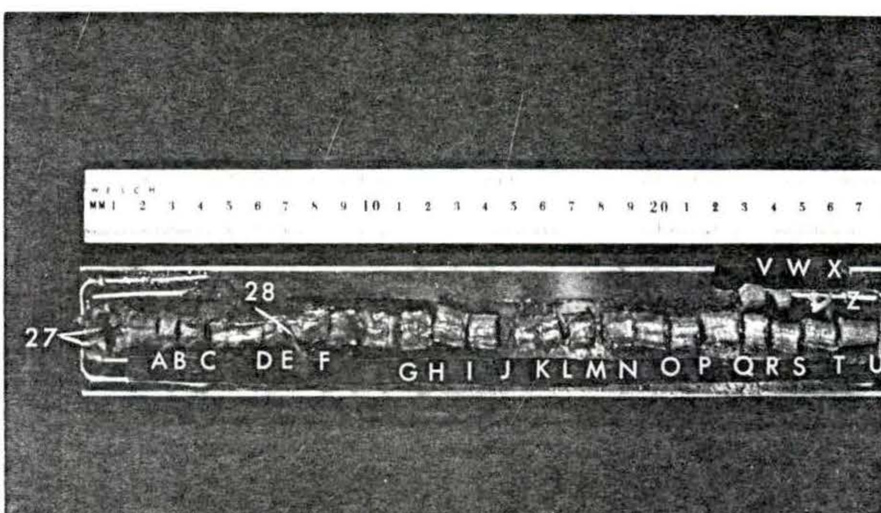
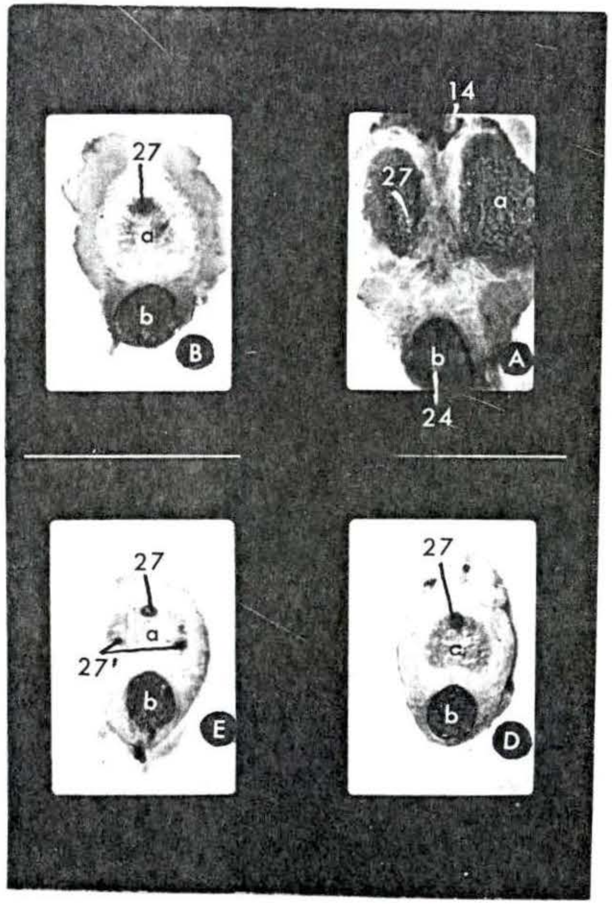

V W X
Z
28
27
A B C
D E F
G H I J K L M N O P Q R S T U

Figure 10. Cross section of the penis

A - See A, Figure 9
B - See B, Figure 9
D - See D, Figure 9
E - See E, Figure 9
a - Corpus cavernosum penis
b - Corpus cavernosum urethra
14 - A. pudenda interna
24 - A. bulbus urethra (branch)
27 - A. profunda penis
27'- A. profunda penis (first branch)

Figure 11. Cross section of the penis

F - See F, Figure 9
G - See G, Figure 9
H - See H, Figure 9
I - See I, Figure 9
a - Corpus cavernosum penis
b - Corpus cavernosum urethra
27'- A. profunda penis (first branch)
27"- A. profunda penis (second, terminal, branch)
28 - A. dorsalis penis
28'- A. dorsalis penis (branches)


14
27
a
b
B
A
24
27
27'
E
D

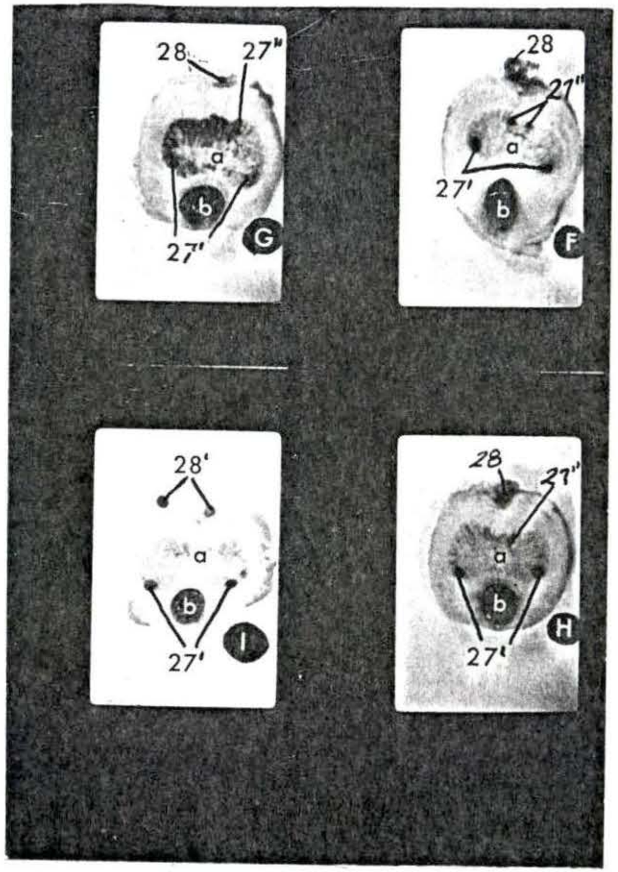
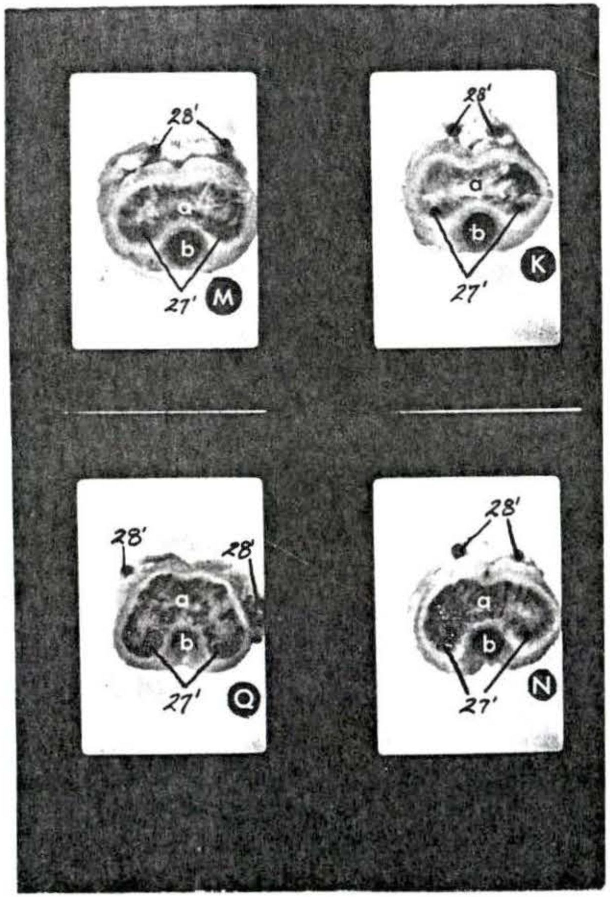

28
27"
27'
a
b
G
F
28'
I
H

Figure 12. Cross section of the penis

K - See K, Figure 9
M - See M, Figure 9
N - See N, Figure 9
Q - See Q, Figure 9
a - Corpus cavernosum penis
b - Corpus cavernosum urethra
27'- A. profunda penis (first branch)
28'- A. dorsalis penis (branch)

Figure 13. Cross section of the penis

W - See W, Figure 9
X - See X, Figure 9
a - Corpus cavernosum penis
z - Urethral process


28'
a
b
27'
M
28'
a
b
27'
K
28'
28'
a
b
27'
Q
28'
a
b
27'
N

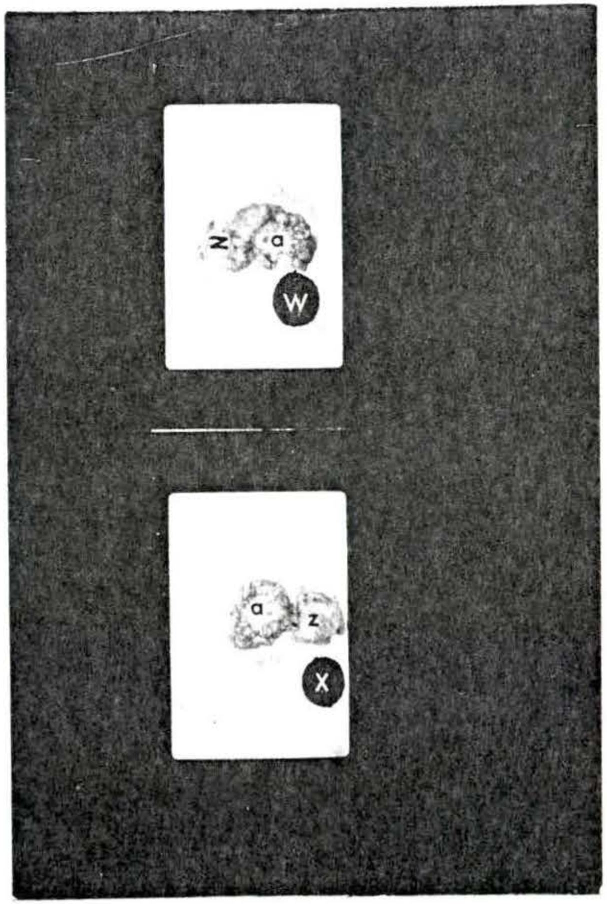

N
a
W
a
z
X

Figure 14. Corpus cavernosum urethra

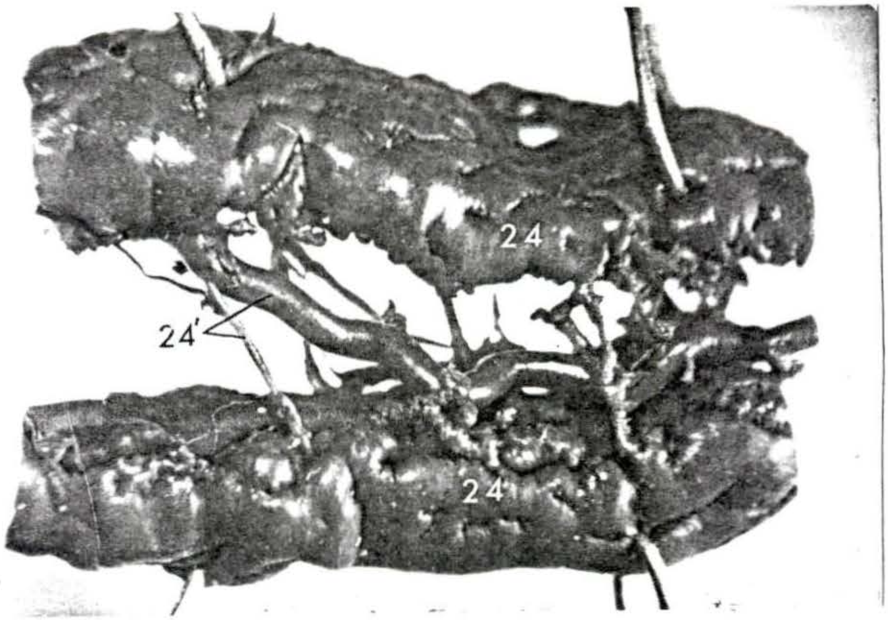
24 - Corpus cavernosum urethra
24'- Anastomotic branches

Ventral view of a latex cast just distal to the ischial arch (7X).

Figure 15. Corpus cavernosum penis

27 - A. profunda penis in the crus penis
27"'- A. profunda penis (branch to the cavernous sinuses)
27""- Cavernous sinus of corpus cavernosum penis

Latex cast in the area of the crus penis (25X).


24
24'
24

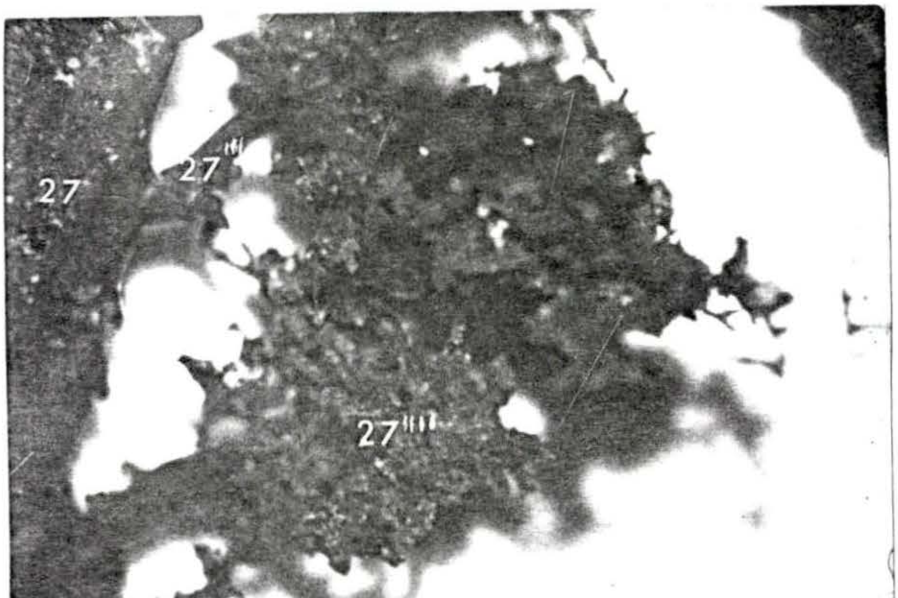
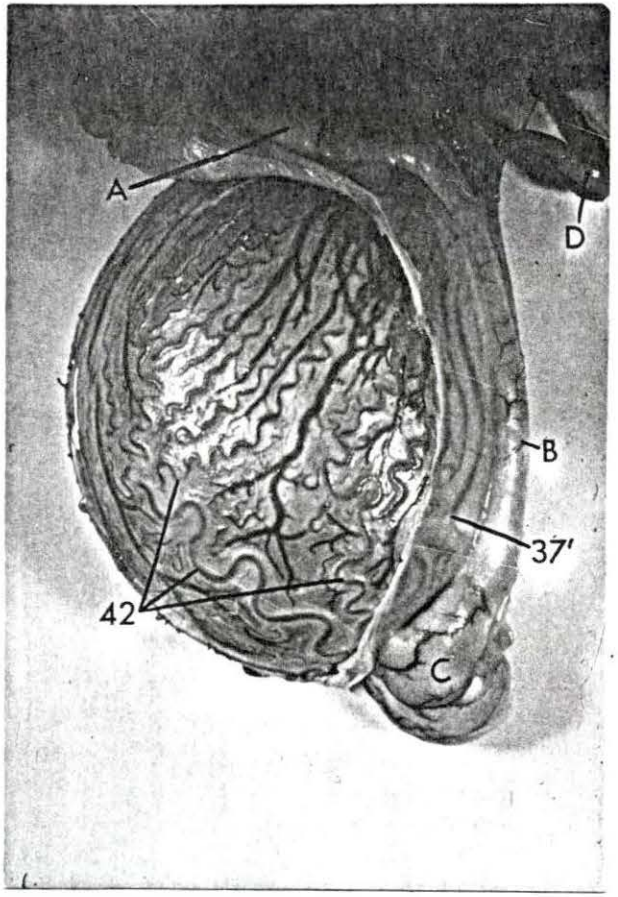

27
27'''
27''''

Figure 16. Left testicle (lateral view)

A - Head of the epidicymus
B - Body of the epididymus
C - Tail of the epididymus
D - Ductus deferens
37'- A. spermatica interna
42 - Aa. testiculares

Figure 17. Left testicle (medial view)

A - Head of the epididymus
C - Tail of the epididymus
D - Ductus deferens
E - Scrotal ligament
39 - Plexus pampiniformis
42 - Aa. testiculares


A
D
B
37′
42
C

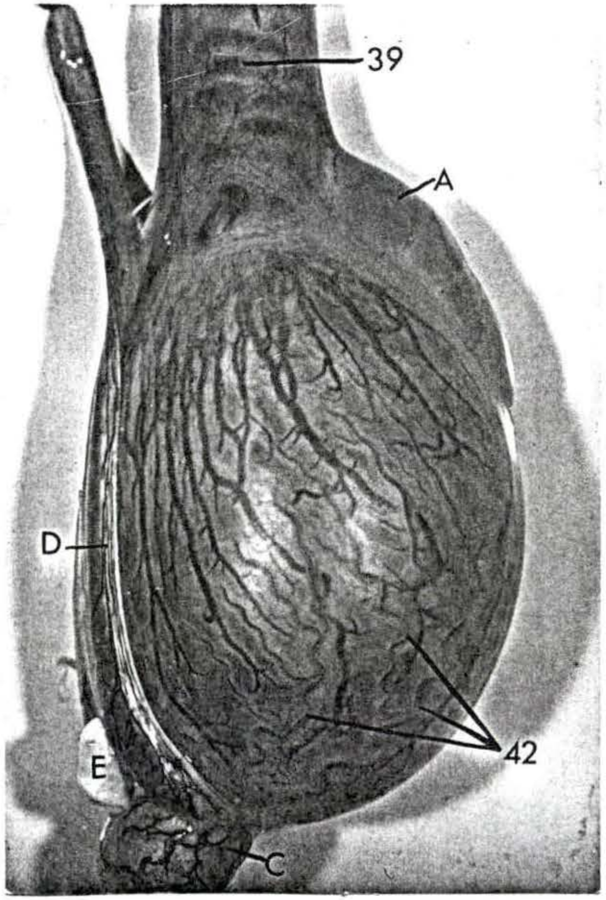
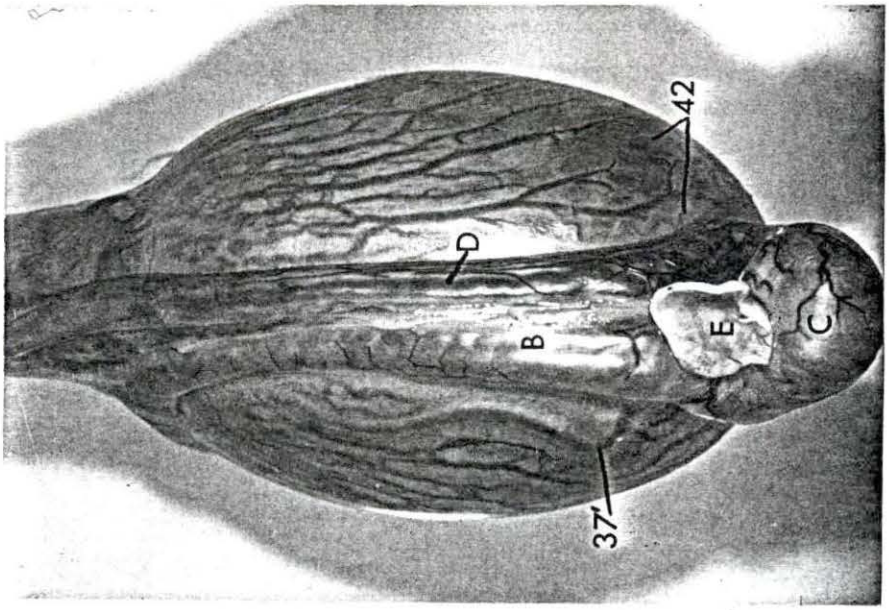

39
A
D
42
E
C

Figure 18. Left testicle (cranial view)

A - Head of the epididymus
C - Tail of the epididymus
42 - Aa. testiculares

Figure 19. Left testicle (caudal view)

B - Body of the epididymus
C - Tail of the epididymus
D - Ductus deferens
E - Scrotal ligament
37'- A. spermatica interna
42 - A. testicularis


D
42
B
E
C
37'

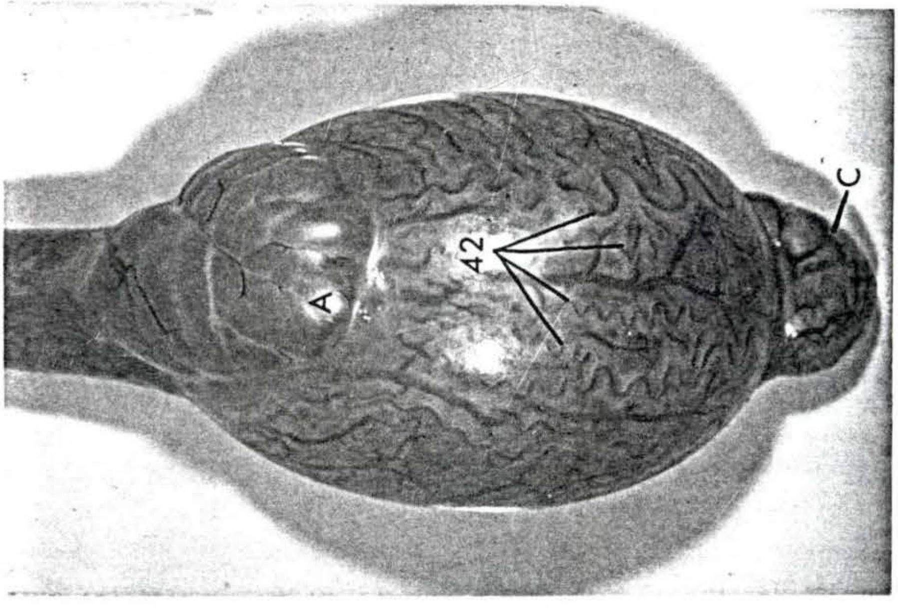

A
42
C

Figure 20. Right testicle (lateral view)

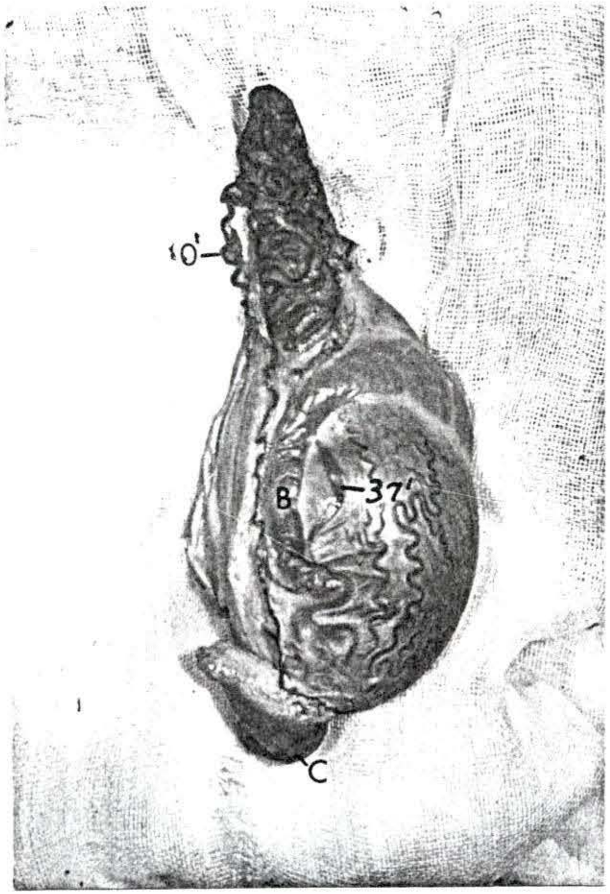
B - Body of the epididymus
C - Tail of the epididymus
37'- A. spermatica interna
40'- A. accessoria testicularis (branch to the body and tail of the epididymus)

The body of the epididymus is bisected near the tail (C) and reflected to show the course of the branch of the A. accessoria testicularis to the body and tail of the epididymus.

Figure 21. Right testicle (lateral view)

A - Head of the epididymus
B - Body of the epididymus
C - Tail of the epididymus
37'- A. spermatica interna
40 - A. accessoria testicularis
40'- A. accessoria testicularis (branch to the body and tail of the epididymus)
40"- A. accessoria testicularis (branch to the head of the epididymus)

The body of the epididymus is bisected near the tail (C) as in Figure 20. It is bisected near the head to expose the A. spermatica interna. The A. spermatica interna (37') is exposed by removal of a very thin layer of tunica albuginea testis.


B
37'
C

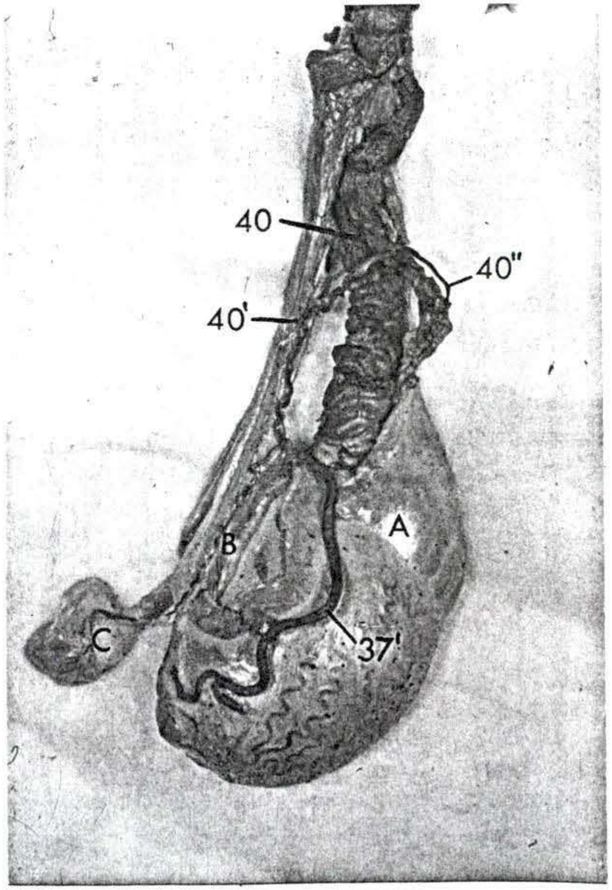

40
40"
40'
A
B
C
37'

Figure 22. Testicle

A - Deep face of the tunica albuginea
B - Parenchymatous tissue of the testicle
C - Inferior pole of the testicle
39 - Plexus pampiniformis
42 - Aa. testiculares

View of the deep face of the tunica albuginea.

The testicle is incised longitudinally beginning at the cranial border. The parenchyma of the testicle has been teased away to expose the network of Aa. testiculares. The latter are embedded in the deep layers of the tunica albuginea similar to the manner in which the A. spermatica interna is embedded in the superficial layers.

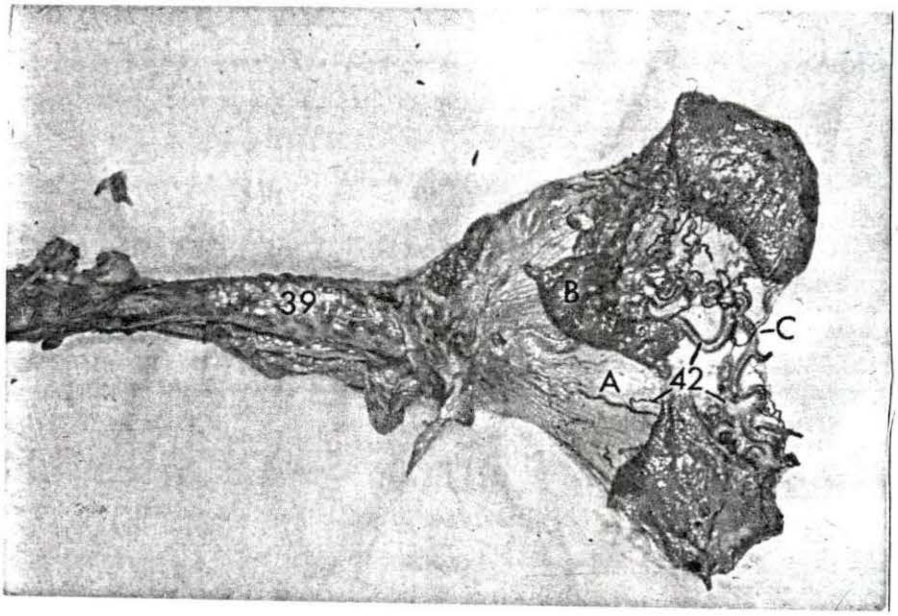

39
B
C
A
42

Figure 23. Testicle (sagittal view)

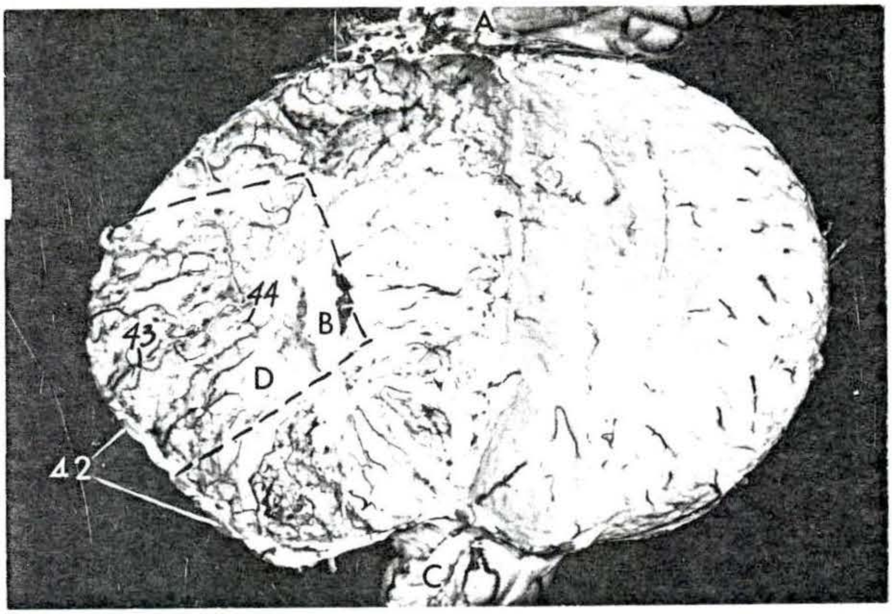
A - Head of the epididymus
B - Mediastinum testis
C - Tail of the epididymus
D - Parenchyma
42 - A. testicularis embedded in the tunica albuginea
43 - A. radiata (pars centripedal)
44 - A. radiata (pars centrifugal)

Incised longitudinally along the cranial border.
Close-up of outlined portion is shown in Figure 24.

Figure 24. Testicle (sagittal view)

B - Mediastinum testes removed (see B, Figure 23)
D - Parenchyma
42 - A. testicularis embedded in the tunica albuginea
43 - A. radiata (pars centripedal)
44 - A. radiata (pars centrifugal)

Close-up portion of Figure 23.


A
44
B
43
D
42
C

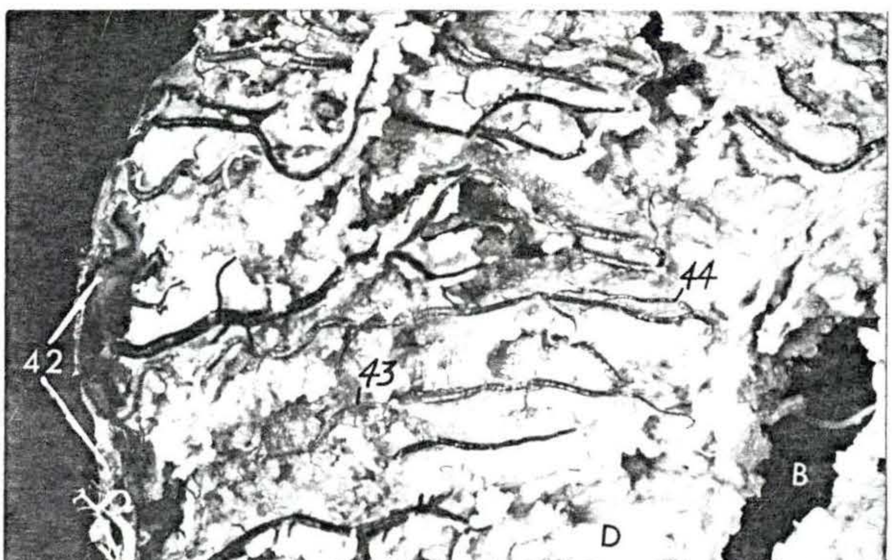

44
42
43
B
D

Figure 25. Arteries to the genital tract of the female goat (schematic)

A - Rectum
B - Lateral coccygeus M.
C - Medial coccygeus M.
D - Vulva
E - Vestibule
F - Vagina
G - Body of uterus
H - Left cornua of uterus
I - Right cornua of uterus
J - Oviduct
K - Ovary
L - Bladder
M - Pubic symphysis
O - Lymph node (supramammary)
P - Udder
Q - Teat
T - Ureter

1 - Aorta abdominalis
2 - Utero-ovarian artery
2' - Ovarian branches
2" - Uterine branches
3 - A. mesenterica caudalis
4 - A. iliaca externa
5 - A. circumflexa ilium profunda
6 - A. sacralis media
7 - A. iliaca interna
8 - A. umbilicalis
9 - A. uterina media
10 - A. iliolumbalis
11 - A. glutea cranialis
12 - A. urethrogenitalis
13 - A. glutea caudalis
14 - A. pudenda interna
15 - A. urethrogenitalis (posterior branch)
16 - A. urethrogenitalis (anterior branch)
17 - Vaginal branch
18 - A. uterina caudalis
20 - Vesicular branch
21 - Ureteral branch
26 - A. perinei
29 - A. profunda femoris
30 - A. profunda femoris
31 - Truncus pudendo epigastricus
32 - A. epigastricus caudalis profunda
34 - A. pudenda externa
35 - A. mammaria
35' - A. mammaria
36 - Caudal mammary branch
37 - A. mammaria medialis
38 - A. lateralis sinus
40 - A. epigastrica caudalis superficialis
41 - A. mammaria (superficial branch)

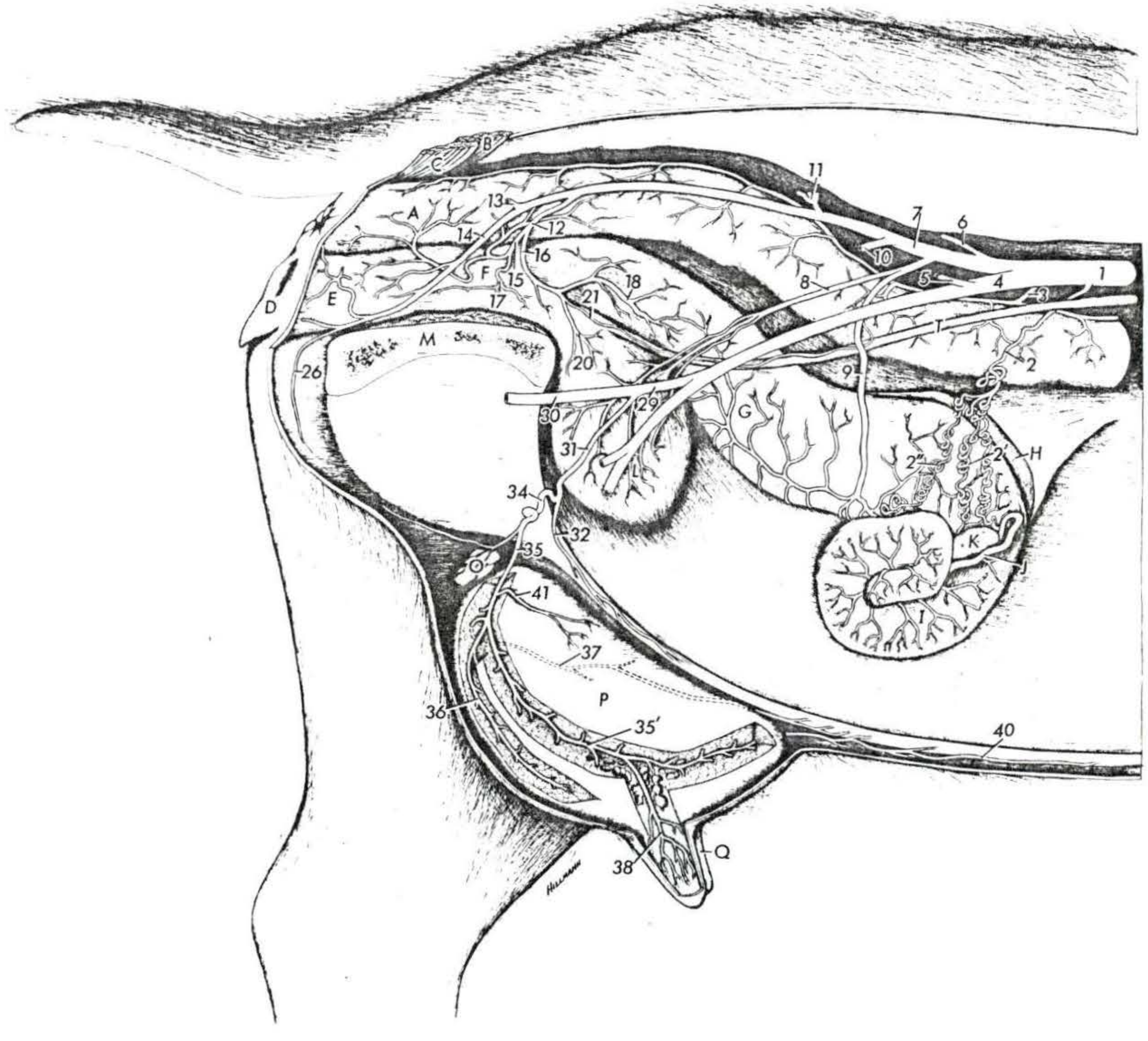
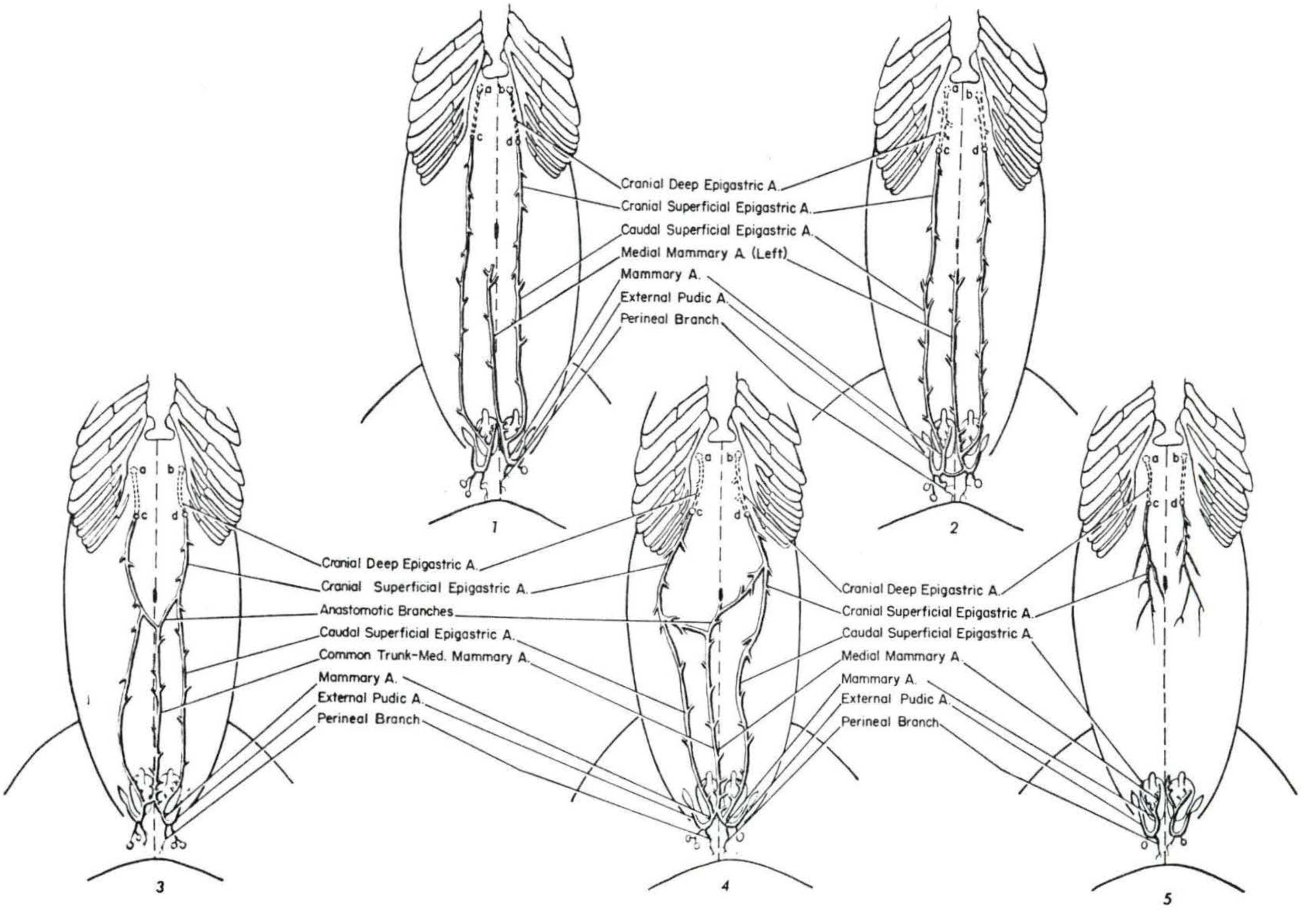

A
B
C
D
E
F
G
H
I
J
K
L
M
O
P
Q
1
2
2'
2"
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
20
21
26
29
30
31
32
34
35
35'
36
37
38
40
41

Figure 26. Ventral view of the female (schematic)

Explanations for points a, b, c, and d are given in Table 2.



Cranial Deep Epigastric A.
Cranial Superficial Epigastric A.
Caudal Superficial Epigastric A.
Medial Mammary A. (Left)
Mammary A.
External Pudic A.
Perineal Branch
1
2
Cranial Deep Epigastric A.
Cranial Superficial Epigastric A.
Anastomotic Branches
Caudal Superficial Epigastric A.
Common Trunk-Med. Mammary A.
Mammary A.
External Pudic A.
Perineal Branch
3
4
Cranial Deep Epigastric A.
Cranial Superficial Epigastric A.
Caudal Superficial Epigastric A.
Medial Mammary A.
Mammary A.
External Pudic A.
Perineal Branch
5

Figure 27. The A. uterina media (ventral view)

G - Body of the uterus
H - Left cornua of the uterus
I - Right cornua of the uterus
K - Ovary (colored)
9 - A. uterina media
9'- A. uterina media (branch anastomosing with the A. uterina caudalis)
9"- Aa. uterina media (anastomotic branches)

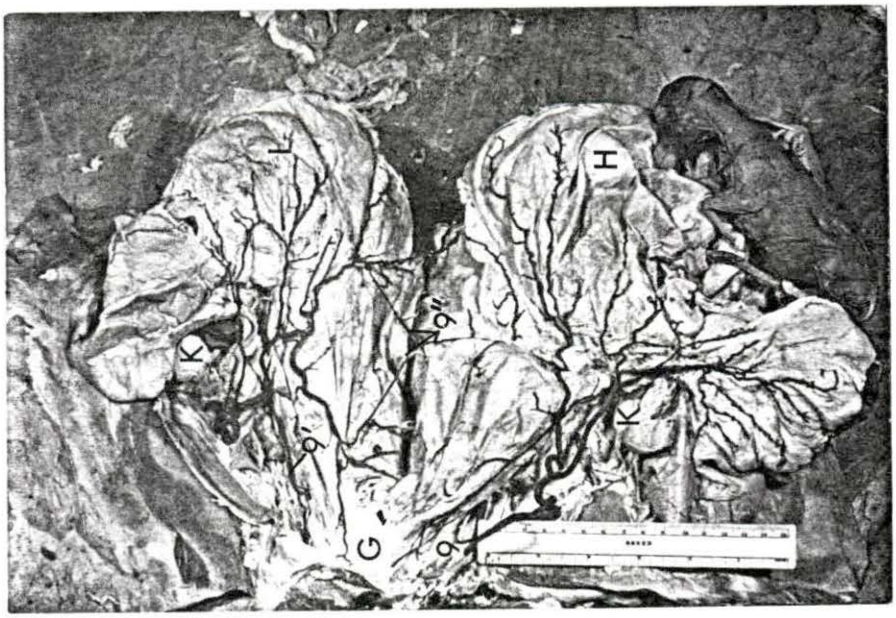
Serous coat removed.

Figure 28. The A. uterina media (ventral view, left side)

A - Tendon of the psoas major muscle
H - Left cornua of the uterus
K - Ovary (colored)
L - Bladder (colored)
4 - A. iliaca externa
7 - A. iliaca interna
8 - A. umbilicalis (spread out for better view)
9 - A. uterina media

Serous coat removed.

The uterus is rotated to the right almost reversing the relationship of the cornuae of the uterus and of the ovaries.


L
H
9''
K
K
9'
G
9

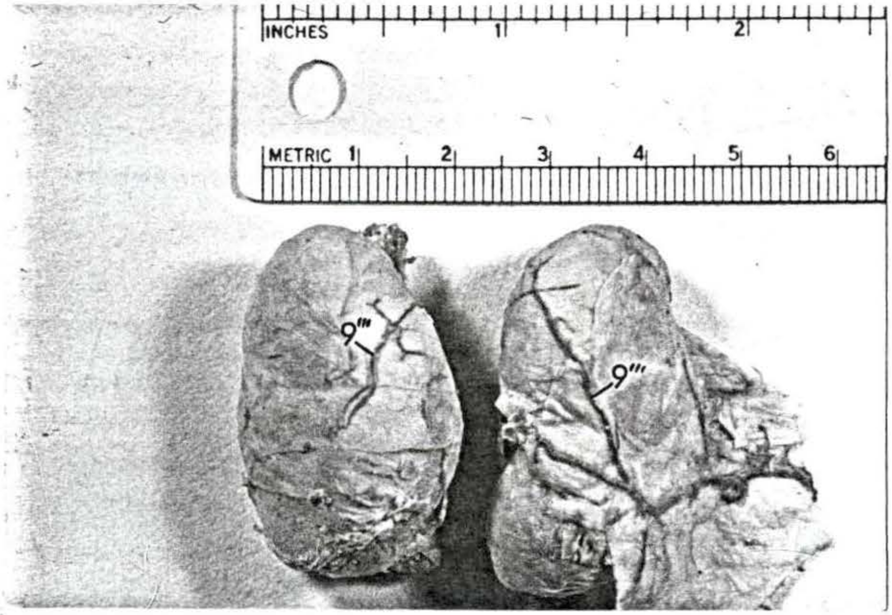

A
4
7
8
9
L
K
K
H

Figure 29. Caruncles from a uterus

9"' - Ramus uterini (branches of A. uterina media)
Serous coat removed.
Ca. 90 days pregnant.

Figure 30. Placetome from a uterus

9"" - Ramus carunculosi (in uterine stroma)
45 - Axial blood vessel in the core of a villus
ca. 90 days pregnant (100X).


INCHES
1
2
METRIC 1
2
3
4
5
6
9'''
9'''

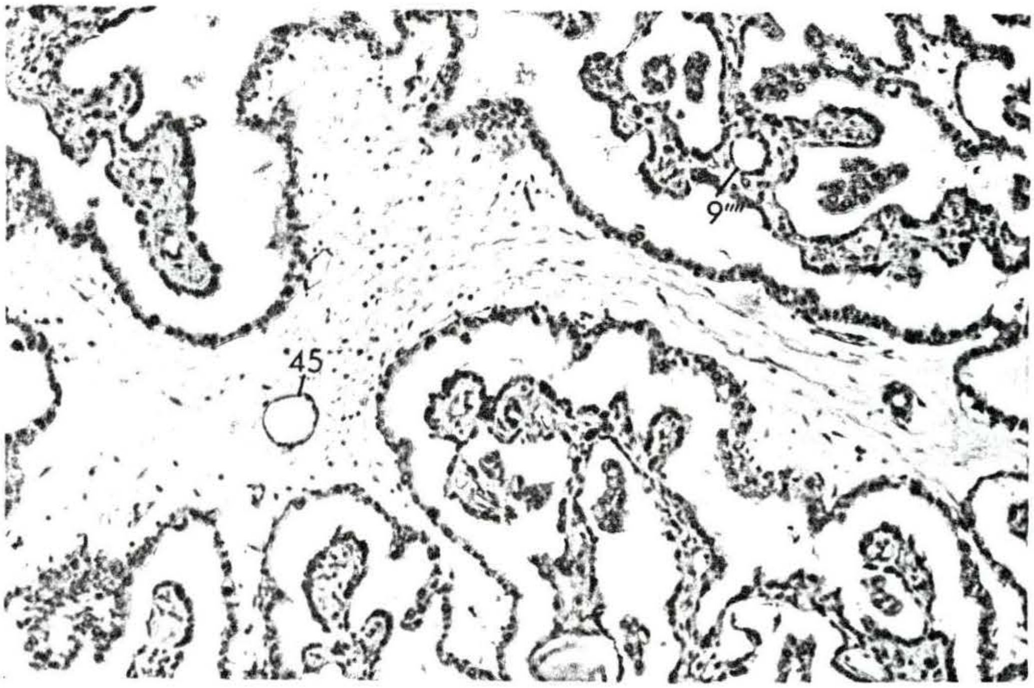

9''''
45

Figure 31. The ovarian arteries

K - Ovary
a - Corpus luteum
b - Follicle
2'- Utero-ovarian artery (ovarian branches)

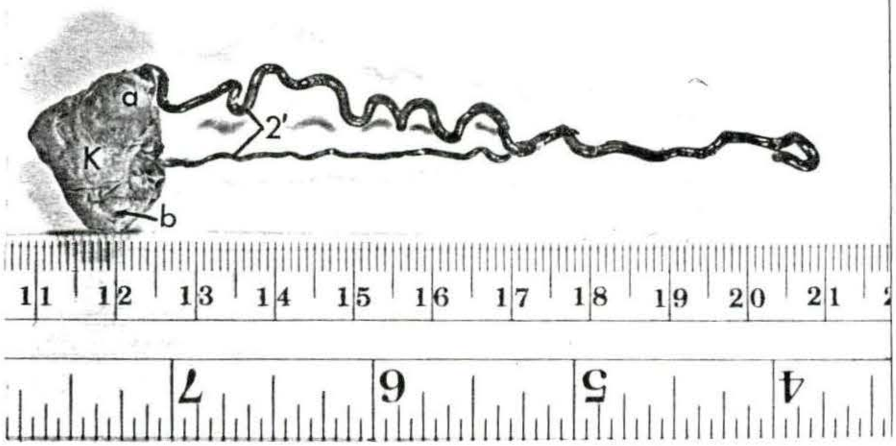
Natural size.

Figure 32. The ovarian arteries

K - Ovary
a - Corpus luteum
b - Follicle
2'- Utero-ovarian artery (ovarian branches)

Paper pointer inserted into the antrum folliculi.

Enlargement of Figure 27.


a
2'
K
b

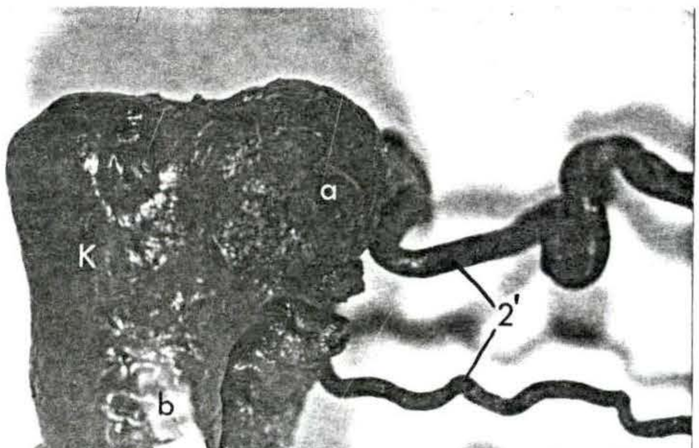

a
K
2'
b

Figure 33. The ovarian artery

2' - Artery corresponds to 2' (dorsal branch) of Figures 31 and 32 after maceration of the ovary.

Enlarged.

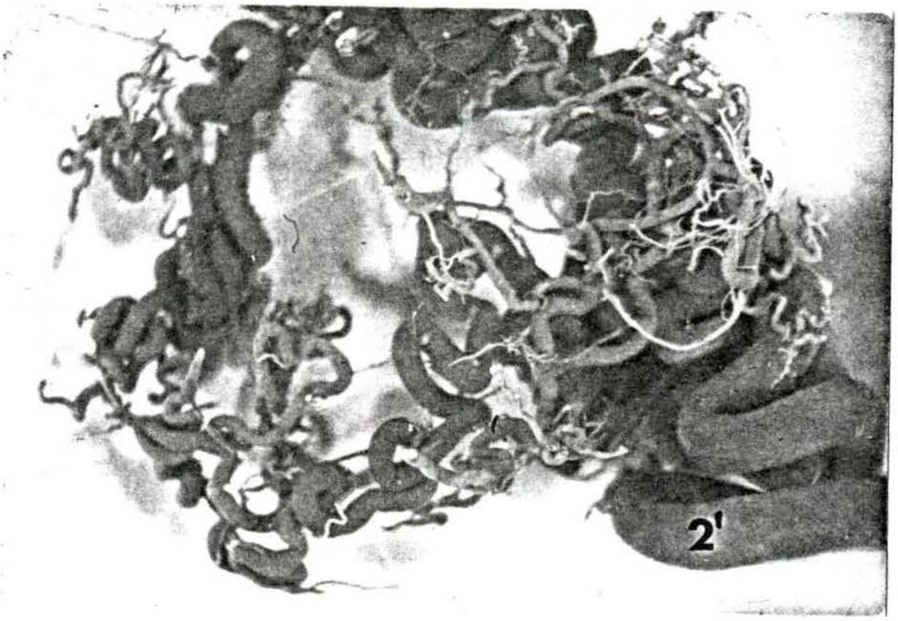
The ovary shown in Figures 31 and 32 was macerated with potassium hydroxide 4% solution.

Figure 34. The ovarian artery

2' - Artery corresponds to 2' (ventral branch) of Figures 31 and 32 after maceration of the ovary.

Enlarged.

The ovary shown in Figures 31 and 32 was macerated with potassium hydroxide 4% solution.


2'

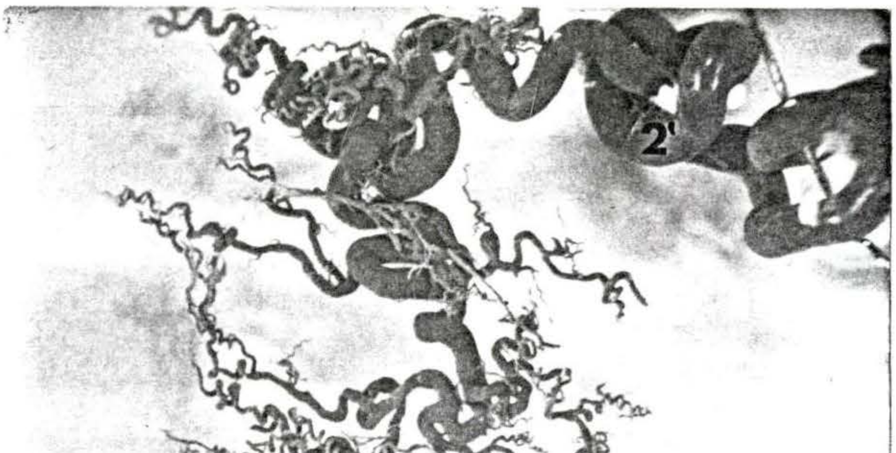

2'

Figure 35. Section of the ovary

Crossman's modification of Mallory's triple stain 35X

2'(1)} - A. of the medulla
2'(2)} - A. of the medulla (branch in the cortical stroma)

(Corresponds to 2'(2), Figure 40).

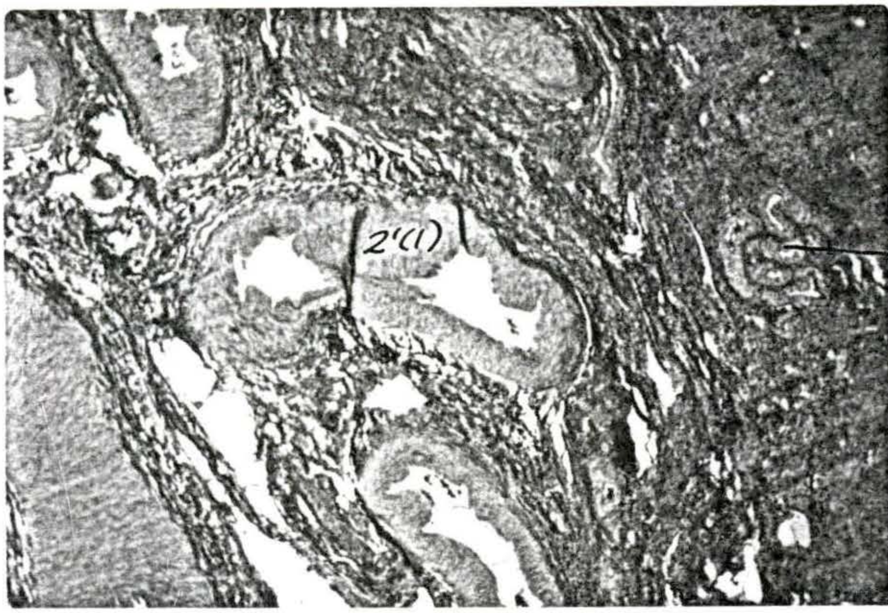
Figure 36. Section of the ovary

Crossman's modification of Mallory's triple stain 35X

A - Cortical stroma
B - Follicle
C - Corpus luteum
a - Stratum granulosum
b - Theca interna and externa
c - Granulosa cells undergoing proliferation and hypertrophy
2'(2) - Blood vessels in cortical stroma

Area V corresponds to area V in Figure 37.

Vessel V corresponds to vessel V in Figures 37 and 39.


2'(1)
2'(2)

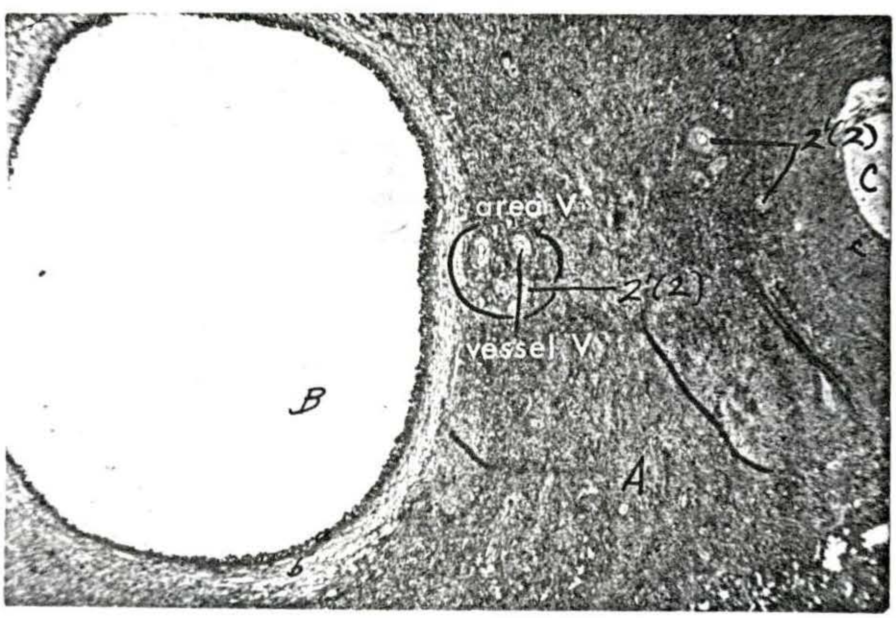

2'(2)
C
area V
2'(2)
vessel V
B
A

Figure 37. Section of the ovary

Crossman's modification of Mallory's triple stain 100X

A - Cortical stroma
a - Stratum granulosum
b - Theca interna and externa
2'(2) - Blood vessels in the cortical stroma

Area V corresponds to area V in Figure 36.

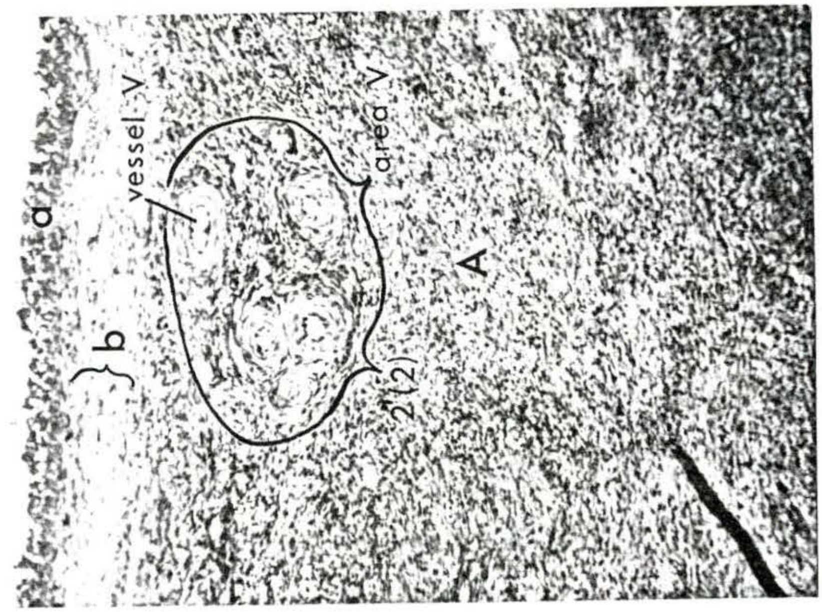
Vessel V corresponds to vessel V in Figures 36 and 39.

Figure 38. Section of the ovary

Crossman's modification of Mallory's triple stain 430X

A - Cortical stroma

Corresponds to area V of Figures 36 and 37.


a
b
vessel V
area V
2(2)
A

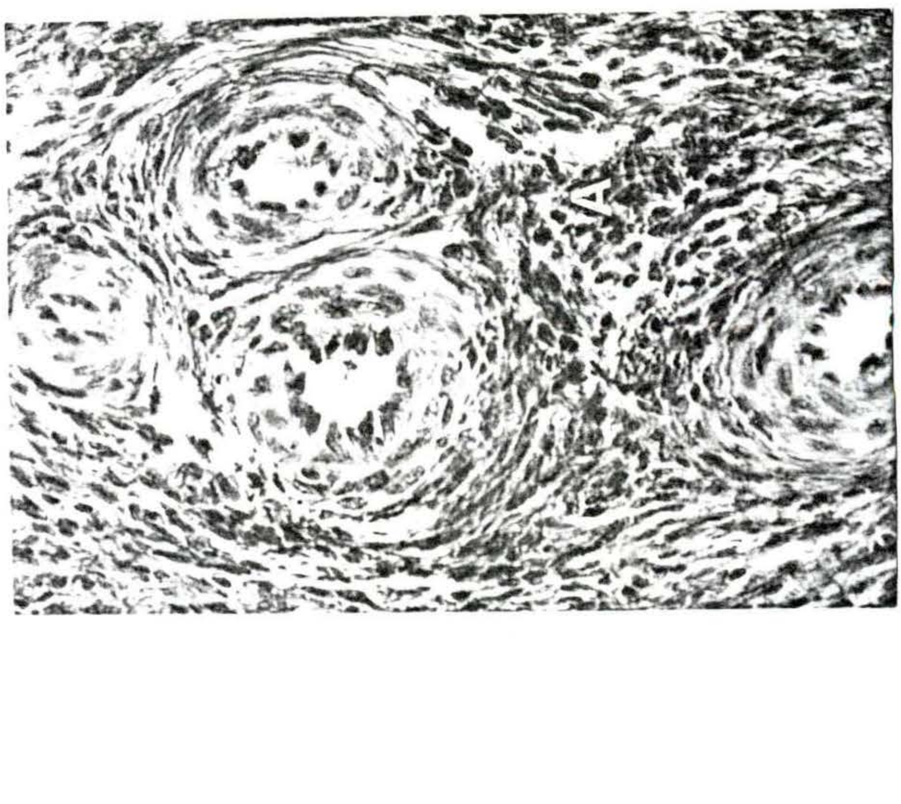

A

Figure 39. Section of the ovary

Crossman's modification of Mallory's triple stain 430X

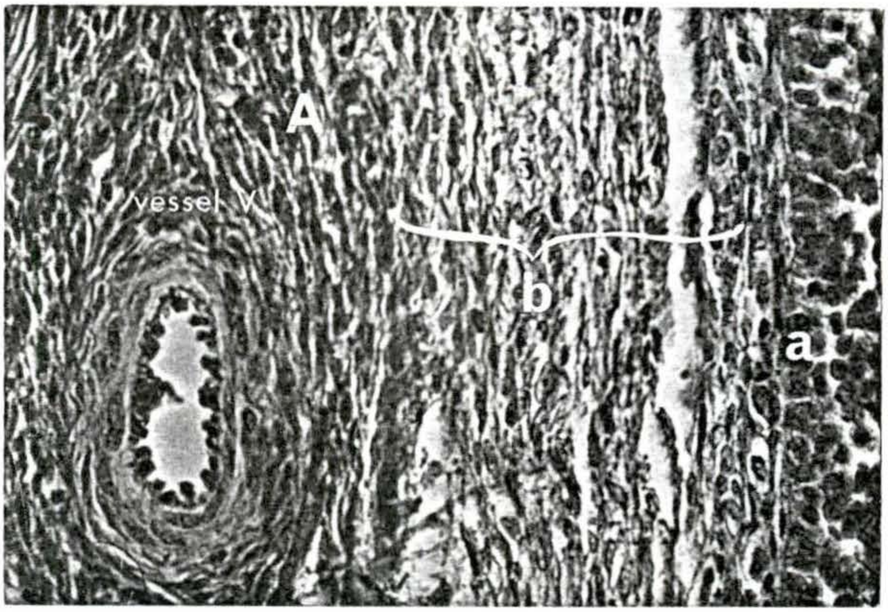
A - Cortical stroma
a - Stratum granulosum
b - Theca interna and externa

Vessel V corresponds to vessel V in Figures 36 and 37.

Figure 40. Section of the ovary

Crossman's modification of Mallory's triple stain 430X

2'(2) - A. of the medulla (branch in the cortical stroma)
Corresponds to 2'(2) in Figure 35.


A
vessel V
b
a


2'(2)