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ON THE STRUCTURE AND
FUNCTION OF THE PROSTATE
GLAND IN THE RED FOX.

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ON THE STRUCTURE AND FUNCTION OF THE PROSTATE GLAND IN THE RED FOX.*

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I. INTRODUCTORY.

The present paper bespeaks of comparative anatomy and comparative physiology, biological subjects alike akin to human medicine and surgery. For this and other reasons these subjects are almost daily increasing in importance. So well recognized have these features become that experimental zoölogy, comparative surgery, and medical research now occupy prominent places in many medical college curricula.

Nowadays comparative anatomy is usually studied by taking up the different systems or organs and tissues, and considering each of these separately and also as a unit. This

*It is intensely interesting to note that but two genera of foxes inhabit the Middle Atlantic States. These are *Vulpes* and *Urocyon*. To each genus there is one species:

- a. *Vulpes fulvus* or Red Fox; and
- b. *Urocyon cinereoargenteus* or Gray Fox.

There are two subspecies of Red Fox, neither of which is found in this latitude:

- a. The Cross Fox (*Vulpes fulvus decussatus*); and
- b. The Black, "Silver," or "Silver Gray" Fox (*Vulpes fulvus argentatus*).

The latter enjoys the distinction of being the highest priced of all fur-bearers. In March, 1900, a single skin of this animal sold at auction in London for the extravagant sum of \$2,784.

statement applies with equal force to male and to female forms.

II. DEFINITIONS.

The comparative anatomy of animals is sometimes called zoötohy. But comparative anatomy as a science, "the twin-sister to zoölogy and handmaiden of medicine and surgery," is much wider in its scope. By it the structure of the whole body or of any part of the body is compared with the bodies or corresponding parts of the bodies of other creatures.

By comparative physiology we mean a comparative study of the bodily activities or functions generally. These comprise both the animal functions and the vegetable functions. Under the former are included:

- a. Sustentation.
- b. Reproduction.

Under the latter are included:

- a. Motion.
- b. Sensation.

Homology or structural resemblance should not be confounded with analogy or functional resemblance.

III. SUMMARY OF ACCESSORY MALE GENERATIVE GLANDS.

To a student of comparative anatomy of the male generative organs, two types of sexual glands are perennially interesting. These are:

1. The testicles,* or true generative glands; and
2. The accessory generative glands.

The accessory generative glands in the male animal may be enumerated as comprising the following nine subdivisions:

- a. The prostate gland.
- b. The Cowperian or bulbo-urethral glands.
- c. The seminal vesicles.
- d. Perineal glands.
- e. Inguinal glands.
- f. Praeputial glands.
- g. Anal or ano-rectal glands.
- h. Ampullar glands (sometimes called "ampullary" glands), and
- i. The temporal gland (in the elephant).

*In the female the ovaries are the true generative glands.

Of this startling array of alleged accessory generative glands the first three structures—prostate gland, Cowper's glands, and seminal vesicles—are the most important. The ampullar glands probably rank fourth.

No single animal or species of animal possesses all of the accessory generative glands mentioned above.

IV. ACCESSORY MALE GENERATIVE GLANDS IN THE RED FOX.**

The accessory male generative glands in the red fox are relatively simple. In point of fact the entire genital tract in the red fox is characterized by its simplicity, both as regards morphology or outward form and histology or intimate structure. This simpleness in form and structure of the accessory generative glands is the essential feature which distinguishes the Carnivora from the vertebrated animals lower down in the scale—the Insectivora, Cheiroptera, Rodentia, Proboscidea, Hyracoidea, Ungulata, Cetacea, Sirenia, Edentata, Marsupialia, Monotremata, Aves, Reptilia, Amphibia, and Pisces or Fishes. Viewed in its entirety, the genital tract of the red fox closely resembles that of the dog.

The prostate is the predominating accessory generative gland in the red fox, as it is in the dog. Cowper's glands and seminal vesicles are absent. Ampullar glands are barely perceptible.

Several of the other varieties of accessory generative glands, notably the conspicuous anal glands situated just external to the sphincter ani muscle, are present in the red fox; but these will be discussed at length in a subsequent paper.

V. POSITION AND RELATIONS OF THE PROSTATE GLAND.*

The prostate gland in the red fox, as in its congener the dog, lies in the pelvic cavity, occupying a position on the superior margin of the pubic bone. Sometimes the anterior

**Zoologically speaking, the Red Fox (*Canis vulpes*, Linnaeus; *Vulpes fulvus*, Desmarest) belongs to the family Canidae, order Carnivora, class Mammalia, and subkingdom Vertebrata.

*Formerly called "adenoid gland." This appellation is not wholly inapt, because of its appearance and also by virtue of the predominance of glandular tissue in the prostate gland of many animals. The red fox, which well-known animal we are now considering, affords a striking example.

At least 20 synonymous terms have been applied to the prostate gland. This is almost on a par with Shakespeare's name, which has been spelt in 4000 different ways according to English orthography.

portion or apex of the gland projects beyond the edge of this bone.

The prostate gland surrounds the neck of the urinary bladder and the commencement (prostatic portion) of the urethra.

The prostate gland can be distinctly felt through the rectum. It is thickly enveloped by adipose tissue. Fatty tags also hang suspended from the vasa deferentia at their termini.

VI. OUTLINES OF THE GLAND.

The prostate gland of the red fox is irregular in contour, as if subdivided into numerous compartments or lobules. It has the appearance of being readily divisible into two lateral halves. There is a distinct furrow on its upper surface, and a similar but broader one on its lower, inferior, or rectal surface.

The gland is distinctly two-lobed. Anteriorly it unites with the membranous urethra; posteriorly it is in intimate contact with the urinary bladder, contrasted with which viscus it forms a prominent projection.

The prostate gland of the red fox has four (4) surfaces:

- a. Superior or upper surface.
- b. Inferior, lower, or rectal surface.
- c. Right lateral surface. And
- d. Left lateral surface.

It has two (2) extremities:

- a. Anterior extremity or apex.
- b. Posterior extremity or base, directed towards the urinary bladder.

VII. SIZE AND SHAPE.

The weight of the prostate gland of the red fox is four and three-quarter grammes ($4\frac{3}{4}$ grammes). Its upper surface is slightly rounded; its lower surface is flattened and more deeply grooved than the upper surface. The lower surface is three-sixteenths of an inch ($\frac{3}{16}$ inch) longer than the upper surface. It can thus be seen that its development is greatest on the ventral side, as in the dog.

The following measurements of the fox's prostate were taken, which indicate pretty clearly the average size and dimensions of this glandular organ in the fox tribe:

Length.	$\frac{7}{8}$ inch
Breadth.	$\frac{7}{8}$ inch
Thickness.	$\frac{5}{8}$ inch

By "length" I refer to the antero-posterior diameter of the gland; by "breadth" its transverse diameter is meant; by "thickness," the depth or the distance or the thickness of tissue lying between the superior and inferior surfaces of the gland.

The shape of the fox's prostate can best be

expressed as resembling that of an English walnut; hence it is not essentially correct to say that it has an apex and a base. In size and external appearances it is a prototype of that of the dog, with this exception: it has the appearance of being readily divisible into two lateral halves.

VIII. COLOR AND CONSISTENCY.

The prostate gland in the red fox is pale or pale yellowish in color. It has the consistency, I might say, of normal testicular tissue—firm, elastic, and resilient to the touch. It feels as though I could separate it into two lateral halves, indeed, more like it is formed of two halves.

In its general make-up, the prostate gland in the red fox is quite compact. Other than the two lateral halves or lateral lobes alluded to in the paragraph immediately preceding, there seems to be no macroscopic subdivision into lobes.

IX. VERUMONTANUM* AND UTRICLE.**

The verumontanum in the fox is shaped like a circumvallate papilla of the tongue. Its measurements are:

Length.	9/16 inch
Width.	1/16 inch
Height.	1/16 inch

The verumontanum consists of a groundwork of muscular and erectile tissues covered by mucous membrane. It is an elongated body situated on the floor of the prostatic part of the urethra. Commencing by a gentle elevation of the urethra, it expands into a small oblong rounded eminence compared to the head of a woodcock, and hence its name. It then advances gradually, tapering to a slender point which is lost in one or two delicate longitudinal folds.

The verumontanum divides the prostatic sinus into two lateral depressions, into which the secretion of the prostate gland is poured. On the sides of the verumontanum the ejaculatory ducts open by two slit-like orifices. As

*Variously written *veru montanum*, *urethral crest*, *caput gallinaginis*, *colliculus seminalis*, *gallinaginis caput*, *verumontanum* (meaning "mountain spit"), *caput galli*, *caput gallinaceum* ("woodcock's head"), *caruncula seminalis*, *crista urethralis*, *crista urethrae*, *crête urethrale* (F.).

**The prostatic utricle has been denominated the *sinus peculiaris*, *utriculus prostaticus*, *vesica prostatica*, *protometra*, *vesicula spermatica spuria*, *uterus cystoides*, *corpuscle of Weber*, *sinus prostaticus*, *Weberian corpuscle*, *male uterus*, *uterus masculinus*. E. H. Weber pointed out its physiological interest as a rudimentary uterus (*Vide Weber, Zusätze zur Lehre vom Baue der Geschlechtsorgane*, Leipsic, 1846).

seminal vesicles are absent in the fox, the "ejaculatory ducts" are really the slightly expanded extremities of the vasa deferentia or testicular ducts.

The prostatic sinus, or floor of the prostatic urethra, is divided into two parts by the verumontanum. These portions are sometimes termed the right and left prostatic sinuses. Into the prostatic sinus (or sinuses) the prostatic ducts, 40 or 50 in number, empty. (In man the prostatic ducts number from 12 to 20.)

The prostatic utricle is quite small. It forms a minute canal terminating blindly or opening between the orifices of the vasa deferentia. (In man, between the orifices of the common ejaculatory ducts.)

Great physiological interest was formerly attached to the prostatic utricle. Weber, Huschke, and Theile were the earliest writers on this subject. It was reputed to be the homologue of the uterus. It is rather large in the rabbit and in the goat.

Modern medical writers have tried to identify the prostatic utricle as the embryological equivalent of the uterus and vagina, but with only a partial measure of success. Personally I consider the prostatic utricle to be purely a vestigial structure, and believe that it subserves no useful purpose whatsoever.

Two points in connection with the pathology of the prostate gland are worthy of mention at this juncture. Sir James Y. Simpson (1811-1870) advanced the theory that posterior enlargement of the median portion of the prostate gland in man is probably due to disease of the prostatic utricle. So far as I am aware, prostatic enlargement has never been reported in the fox, but it occurs occasionally in the dog. The second point which I wish to emphasize pertains to disease of the prostatic utricle. The prostatic utricle sometimes becomes affected in inflammation of the deep urethra in man. Our knowledge of the pathology and therapy of this morbid condition has recently been advanced by my friend, Dr. John T. Geraghty,* of the Johns Hopkins University.

X. VASA DEFERENTIA AND EJACULATORY DUCTS.

In the red fox the vasa deferentia, firm and unyielding to the touch as in the human vasa deferentia, measure one line (1/12 inch) in diameter. These structures enter the postero-inferior angle of the prostate at a surprisingly short distance from each other.

*See Dr. Geraghty's paper, *A Method of Treating the Prostatic Utricle*, *Journal of the American Medical Association*, March 11, 1911, pp. 731, 732.

The vasa enlarge slightly and evenly just before entering the prostate. They almost fuse into one, so closely do they approximate one another at their entrance into the prostate at the posterior part of the inferior groove or sulcus.

The two ejaculatory ducts, if the terminal portions of the vasa deferentia may properly be termed ejaculatory ducts, after traversing the prostate gland, open into the floor of the urethra by two small slit-like apertures, one on each side of the verumontanum.

XI. AMPULLA OF HENLE.

In the red fox the vas deferens near its termination does not become pouched nor sacculated; hence the organ known as the "ampulla of Henle" is absent.

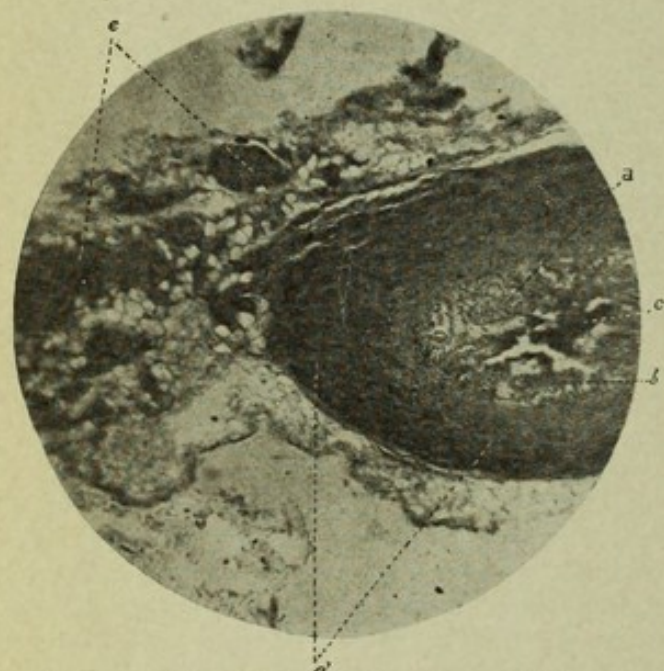


Figure 1. Terminal portion of vas deferens of red fox, showing:—

- a. Ampullar (ampullary) glands.
- b. Numerous cells in lumen, resembling leucocytes.
- c. Calcareous matter in interior of lumen.
- d. Well-defined muscular layer.
- e. Nerve-trunks at periphery of vas.

There seems to be a definite relationship existing between the state of development of the ampulla of Henle and the time occupied in copulation, the latter act being a relatively slow process when this dilatation or sacculation of the terminal portion of the vas deferens (the ampulla of Henle) is small or absent, as in the fox, the dog, the cat, the boar, etc. When the ampulla is large and well-developed, as in the horse, the ox, and the sheep, coitus occupies a relatively short time—notoriously so in the sheep.

XII. FUNCTION OF THE PROSTATE GLAND.

A general survey of the reputed "Functions of the Prostate Gland" will first be given, to be superseded by a discussion of the function of the prostate gland in the red fox.

At least eight (8) definite functions have been ascribed to the prostate gland, the most important organ in the male pelvis, at least from a surgical point of view. These functions may be briefly summarized, as follows:

1. As a sphincter of the urinary bladder. The anatomical position of the prostate and the origin of its name are suggestive of such a function. However, the absence of the prostate gland in the female, which sex can even retain its urine for a longer period of time than the male, sets at complete variance such an assumption.



Figure 2. Normal microscopic structure, prostate gland of red fox.

- a. Prostatic tubule cut on long section.
- b. Prostatic tubule, cross section.
- c. Stroma of smooth muscle.
- d. Blood-vessels in stroma.

2. That the prostate serves to thoroughly cleanse the urethra of urine prior to the act of copulation. Doubtless the prostate gland does aid in the expulsion of the last few drops of urine, but the accelerator urinae and other muscles surrounding the urethra would of themselves probably accomplish this result.

3. As an internally secreting gland. A certain amount of evidence has been adduced which would indicate that the prostate gland, along with the thymus, thyroid, parathyroids, spleen, adrenal bodies, lymph-nodes, carotid gland, coccygeal gland, epithelial part of the hypophysis cerebri, islets of Langerhans in

the pancreas, and possibly the corpora lutea of the ovary, should be included under the category of "glands with internal secretion." The "cells of Leydig" should also be included.

The histological structure of these latter glands and organs is peculiar. All are of epithelial origin. They have no ducts. They probably pour their "hormone" or internal secretion into the surrounding lymph-vessels and blood-vessels.

But the prostate gland differs widely in details from the above-mentioned glands. It is not of epithelial origin; it is a mesodermic structure. It has numerous ducts—from 40 to 50 in number in the fox, and from 12 to 20 in man.

However, the author of this paper is a partial convert to the belief that the prostate

c. It produces marked effects upon the secondary sexual characteristics (voice, horns, hair, etc.)

4. It was an old opinion that the function of the prostate gland is mechanical, namely, that it perfects and increases the bulk of the seminal secretion, thus causing the urethra to be more fully distended by it and enabling the muscles to act more completely in forcibly ejecting its contents into the vagina.

This view has one point in its favor. In all animals wherein the prostate gland exists, it empties itself into the dilated portion of the urethra in which the seminal secretion accumulates prior to its expulsion.

5. That it protects the orifices of the ejaculatory ducts from the presumed acrimony of the urine.



Figure 3. Prostatic urethra of red fox, one-fourth inch from bladder neck.

- a. Urethral canal.
- b. Verumontanum or urethral crest.
- c. Slit-like openings of ejaculatory ducts. One contains calcareous material.
- d. Peri-urethral erectile tissue.
- e. Prostatic utricle, a very small opening midway between the ejaculatory ducts.

gland elaborates a "hormone" or internal secretion. Experimental results which he has obtained in a certain class of cases, details to be published later, have won him over to the side of the "internal secretionists."

The "hormone" or internal secretion of the prostate gland enters the adjacent lymph- and blood-vessels. It is then appropriated by the animal economy and alleged to perform a triple function:

- a. It regulates and controls the functions of the testicles or true generative glands.
- b. It regulates the phenomenon of ejaculation.

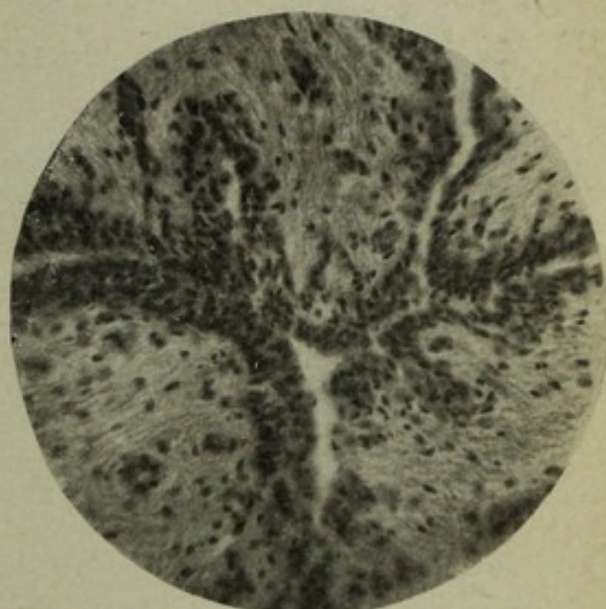


Figure 4. Epithelium of prostatic urethra of red fox.

This idea is too far-fetched, and can be dismissed without further discussion. I do not attach any importance to it.

6. The prostatic secretion lubricates the surface of the urethra, so as to facilitate the onward passage of the seminal fluid. Without such a menstruum, the probabilities of the viscous seminal fluid reaching the vagina would be but slight.

This is a highly probable suggestion, and will be discussed more fully under No. 8.

7. That the prostatic secretion acts as a diluent and vehicle for the testicular secretion. It has been thought by some that the prostatic secretion is useful in diluting the semen so as to increase its bulk, not merely for the more perfect distension of the urethra, but that it may ensure the more easy transmission of this secretion (the semen) into the female

vagina and thus favor its contact with, and impregnation of, the ovum.

Like No. 6, this is an inkling of what is to follow in No. 8.

8. The function of the prostate gland is purely sexual. This view has been stoutly maintained by Moullin of London, and by Keyes of this country. Towards the sexual function the prostate gland acts:

- a. As a muscle.
- b. As a sensory organ.
- c. As a gland.

As a muscle the prostate gland serves to open the ejaculatory ducts. This allows the testicular secretion to enter the prostatic urethra. The prostate also expresses its own secretion (*succus prostaticus*), and probably aids in expelling it into the anterior urethra.

spermatozoa are non-motile or but slightly motile. The secretion of the testes is well-known to be alkaline, and has a strong tendency to coagulate or become inspissated. The prostatic secretion is naturally acid.

The glandular function (or functions) of the prostate gland may thus be summarized:

- a. The prostatic secretion dilutes the seminal fluid, thereby imparting motility to the spermatozoa. It thus stimulates the movements of the spermatozoa.
- b. The prostatic secretion, besides acting as a simple diluent, adds something (possibly a ferment) to the semen which keeps the spermatozoa alive for some twenty-four hours. Other diluents (for example, normal saline solution) keep the spermatozoa alive only three or four



Figure 5. Epithelium of ejaculatory duct of red fox.

It is more than likely that the prostatic secretion is poured into the urethra prior to the escape of the testicular fluid into the canal thus inviting a more thorough admixture.

The prostatic urethra is the internal seat of sexual sensation, the glans penis being the external seat of sexual sensation. This explains why a man may have the distal half of his penis amputated, and yet perform the sexual act and experience pleasure therefrom. The seat of sensation is probably distributed to a greater or less extent throughout the mucous membrane of the entire prostatic urethra, but it is more exquisitely developed in the verumontanum.

The glandular function of the prostate is of equal or even greater importance than either of the other two. When the secretion of the testicles enters the prostatic urethra, it is viscid in consistency and the contained

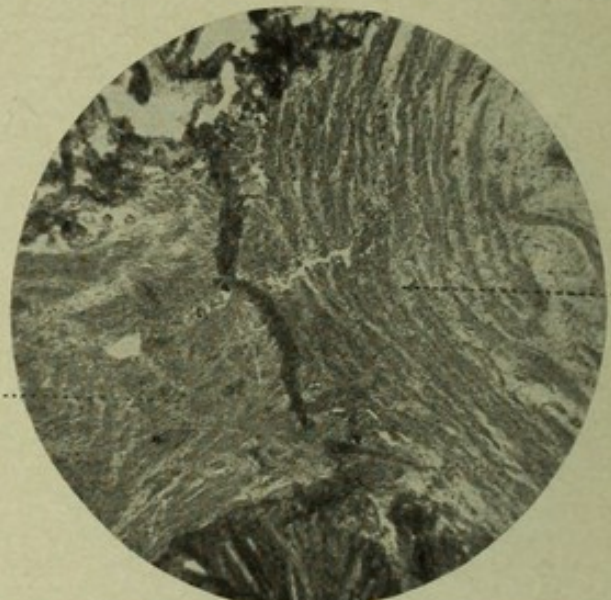


Figure 6. Posterior extremity of prostate gland of red fox.

- a. Anterior (or superior) median septum.
- b. Longitudinal section of smooth muscle surrounding urethra.

Note. This muscular tissue is continuous with the muscular layer of the urinary bladder.

hours. Cervical mucus, however, furnishes the more ideal environment. Spermatozoa have been known to live in the os uteri for eight and one-half days. Prostatic fluid, as stated above, thus prolongs the life of the spermatozoa from three to four hours to twenty-four hours.

- c. Doubtless the prostatic secretion helps to maintain the fluidity of the seminal fluid. It not only dilutes the semen but also serves to maintain it in this most serviceable condition.
- d. Besides diluting the seminal fluid and helping to maintain this fluidity, besides

stimulating the movements and prolonging the life of the spermatozoa, the prostatic secretion probably assists in providing the spermatozoa with nutriment.

- e. The lubricating function of the *succus prostaticus* is a highly probable one. This function, moreover, is subservient to the purely sexual function of the prostate gland. As a lubricating organ the prostate is materially aided by numerous mucous glands—small glands embedded in the mucosa and continuing on in the membranous portion of the urethra. Moreover, in the membranous portions of the urethra these mucous glands are relatively scarce, their lubricating function being in large part supplanted by the glands of Cowper, in

- b. It is well known that the secretion of the prostate is increased in quantity under states of venereal excitement. It may even appear at the meatus urinarius. In human beings an undue amount of sexual excitement may engender a pathological condition of the prostate gland formerly known as *prostatorrhea*.
- c. From observations made on these parts in animals killed during or immediately after the completion of the act of copulation, we are at least justified in drawing the inference that the largest quantity of the prostatic fluid is poured into the urethra at the moment of, or prior to, the venereal orgasm.
- d. That the prostatic fluid is subservient to the generative function may be further



Figure 7. Verumontanum and openings of ejaculatory ducts beautifully shown. Red fox's prostate.

- a. Verumontanum.
b. Ejaculatory ducts.

those animals wherein the glands of Cowper are present.

OTHER EVIDENCES.

The sexual function of the prostate gland is manifestly evident. The prostate is the "bone and sinew" of the male reproductive system. It performs no useful function in urination, and is quite or wholly passive during this act.

Additional evidences to those chronicled above, confirmatory of the sexual function of the prostate gland, may be summarized as follows:

- a. The prostatic fluid is poured into the urethra at the commencement of its course, at that point where the secretion of the testes (and vesiculæ seminales in man) are received into the canal.



Figure 8. Transverse section of entire prostate gland of red fox, made at a point one-quarter of an inch from vesical neck.

- a. Right lobe.
b. Left lobe.
c. Prostatic urethra.

established by the fact mentioned by John Hunter (1728-1793), that the gland is liable to alterations in size and structure at certain seasons of the year. For instance, in the mole (*Talpa europaea*) in winter the prostate is scarcely discernible, whilst in the spring it becomes of large size and filled with fluid. The same condition pertains in the hedgehog (*Erinaceus europæus*). In the present paper I have pointed out similar changes in the prostate gland of the red fox.

SUMMARY OF THE PHYSIOLOGY OF THE PROSTATE GLAND IN THE RED FOX.

It is obviously manifest that the function of the prostate gland in the red fox is purely

sexual. The function of the ejaculatory ducts will first be alluded to, after which the sexual function of the prostate gland in all its labyrinthine wealth of details, will be recapitulated.

The function of the ejaculatory ducts is to convey to the prostatic urethra, to be more explicit, the prostatic sinuses, the testicular secretion or male fertilizing elements. The ejaculatory ducts, paired or two in number, are simple, single canals throughout their full extent, there being no seminal vesicle or seminal vesicle duct to unite with it to form the common *ductus ejaculatorius*.

The testicular secretion is thus poured into the prostatic portion of the urethral tube of the fox on either side of the verumontanum and about equidistant from the two poles or extremities of the gland. The depressed fossae prepared for its reception, diminutive in size and capacity, are termed the prostatic

- b. The prostate gland acts as a sensory organ. Its mucous membrane is the internal seat of sexual sensation. In man this is largely confined to the verumontanum. In the red fox, not only the verumontanum but the entire prostatic urethra posterior to the openings of the ejaculatory ducts, performs this important function so necessary for the continuance of the vulpine race.
- c. The prostate in the red fox performs the function of a gland. This is its prime function—still more important than the preceding ones. The prostatic secretion dilutes the seminal fluid and stimulates the activity of the spermatozoa. It prolongs the life of the spermatozoa, and probably provides them with nutriment. The prostatic secretion also helps to maintain the semen in a fluid condition.



Figure 9. Prostatic urethra of red fox beautifully shown. Transverse section, middle of prostate gland.

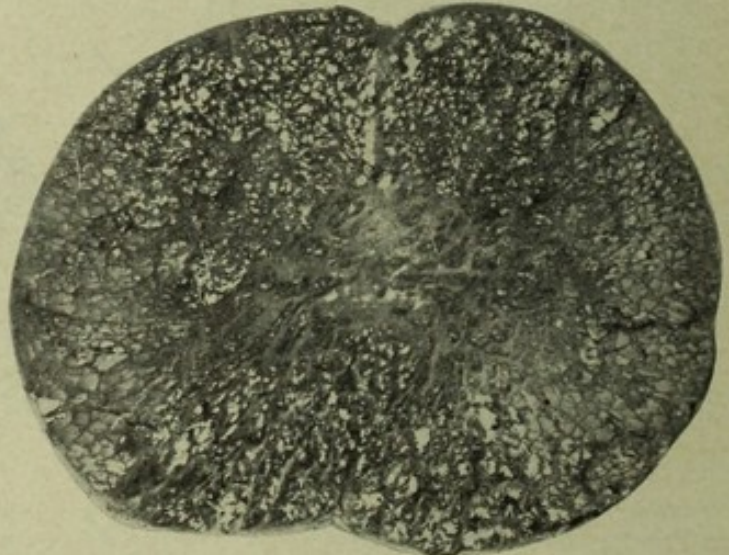


Figure 10. Transverse section, entire prostate gland of red fox. Middle of gland.

sinuses. Herein, as well as over the surface of the verumontanum itself, also empty the numerous prostatic ducts. This anatomical arrangement ensures an intimate admixture of the *succus prostaticus* and the vital fluid emanating from the testicles. This is a physiological necessity in the case of the fox, as both the seminal vesicles and the Cowperian glands are absent.

The sexual function or functions *par excellence* of the prostate gland of the red fox may be recapitulated, as follows:

- a. The prostate gland acts as a muscle. It controls the openings of the ejaculatory ducts. It expresses its own secretion and in a measure propels it and the testicular secretion into the anterior urethra.

- d. The prostatic secretion aids the mucous glands of the prostatic urethra in the lubrication of this portion of the urogenital canal. This has a salutary effect at the moment of ejaculation, as it (the combined mucous secretion) buoys up the semen and facilitates its onward movement.
- e. The gland is larger, more succulent, and more actively secretory at the seasonal period for the union of the two sexes, a condition of increased functional activity beautifully demonstrable in the present instance. Other animals manifesting these physiological changes are the hedgehog and the mole.
- f. Before closing this interesting section of my paper, I desire to call attention to another phase of the reproductive func-

tion, in which aid is probably furnished by the prostate gland. It is the formation of a "bouchon vaginal" or "stopper" in the female. The formation of a "bouchon" is relatively unimportant in the red fox. In the red fox, as in the dog, sexual contact is prolonged. When ejaculation has once begun, there is practically a continuous ejaculation of semen until the close of the act. A female fox killed immediately after sexual congress doubtless would already show spermatozoa in her cervical canal or in her uterine cavity.

Some authors (Camus and Gley*) believe that the clotting is brought about by a specific ferment ("vesiculase") which is present in the prostatic fluid. This fact—the clotting of

for several hours, and then to become softened and fall out.

However, it is more probable that the combined secretions of the prostate gland, ampullary glands, and seminal vesicles (when these are present) bring about this clotting or formation of a "bouchon vaginal."

FUNCTIONS OF THE VERUMONTANUM.

The functions of the verumontanum or caput gallinaginis in the red fox are two in number:

- 1st. It is the internal seat of sexual sensation. Irritation of the verumontanum excites a flow of semen.
- 2nd. Its turgescence during the venereal orgasm prevents regurgitation of semen into the bladder. The verumontanum



Figure 11. Verumontanum. Utriculus laid open. Prostate gland of red fox.

- a. Utriculus.
- b. Openings of ejaculatory ducts.

the seminal fluid after its projection into the female passages in rodents—was first discovered by Lataste.** It prevents the escape of the spermatozoa and so helps to ensure fertilization. Lataste speaks of the "bouchon vaginal" as being formed by the solidified secretion of the vesiculae. Leuckart*** and others have made similar observations. The "bouchon vaginal" is said to remain *in situ*

*Camus and Gley, "Note sur quelques faits relatifs à l'enzyme prostatique (vésiculase) et sur la fonction des glandes vésiculaires," *C. R. de Soc. de Biol.*, vol. IV. (10th series), 1897.

**Lataste, "Sur le bouchon vaginal des Rongeurs," *Zool. Anz.*, vol. VI., 1883.

***Leuckart, *Zur Morphologie und Anatomie der Geschlechtsorgane*, Göttingen, 1847.

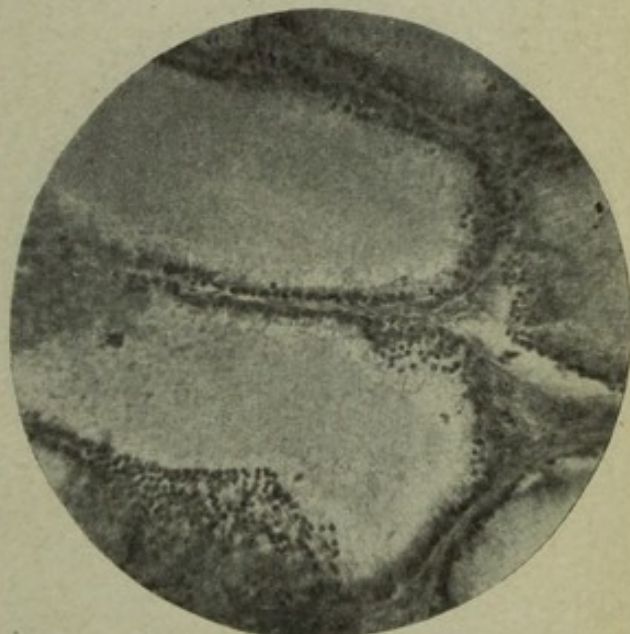


Figure 12. Simple columnar epithelium lining dilated acinus. Prostate gland of red fox.

is aided in this function by the peri-urethral connective tissue, in the case of the red fox.

PROSTATIC SECRETION.

The prostatic secretion, *succus prostaticus*, of the red fox resembles that of the dog. It is a clear, opalescent, entirely neutral fluid (as compared with the prostatic secretion in man, which ordinarily is slightly acid).

The characteristic odor of the ejected seminal fluid is due to admixture with the secretions of the prostatic and urethral glands. It is not unlike that of the raspings of fresh horn or bone.

CHEMISTRY OF PROSTATIC SECRETION.

The secretion of the prostate gland of the dog, which the prostatic secretion of the red

fox resembles, was examined by J. Adams, Haller, Krause, Prevost, and Dumas. They were the earliest workers in this interesting field of scientific inquiry.

In the year 1840, the prostatic secretion of the dog, was examined by Buxmann. The last-named investigator describes it as containing, besides the bases potassium, calcium, and sodium, the chemical combinations metaphosphoric acid, sulphuric acid, and chlorine. The albuminous receptacle varied between 45 per cent. and 92 per cent., and the contents of sodium chloride amounted to one per cent.*

XIII. BLOOD SUPPLY OF THE PROSTATE GLAND; NERVE SUPPLY.

The arterial blood supply of the prostate gland of the red fox, though minutely distrib-

Each compartment or lobule is enclosed in a delicate capillary plexus.

The veins of the prostate form a plexus around the sides and base of the gland (pubo-prostatic plexus). In front they communicate with the dorsal vein of the penis; posteriorly they terminate in the internal iliac vein.

The lymphatics of both halves of the prostate gland in the red fox are identical in arrangement. They begin as a fine network surrounding the acini. These find their way to the surface of the organ, where they combine to form larger vessels. After passing through the chain of lymphatic glands in this situation, the lymphatic vessels of the prostate join with the lymphatics from the bladder, and enter the internal iliac glands.

The nerves of the fox's prostate are de-

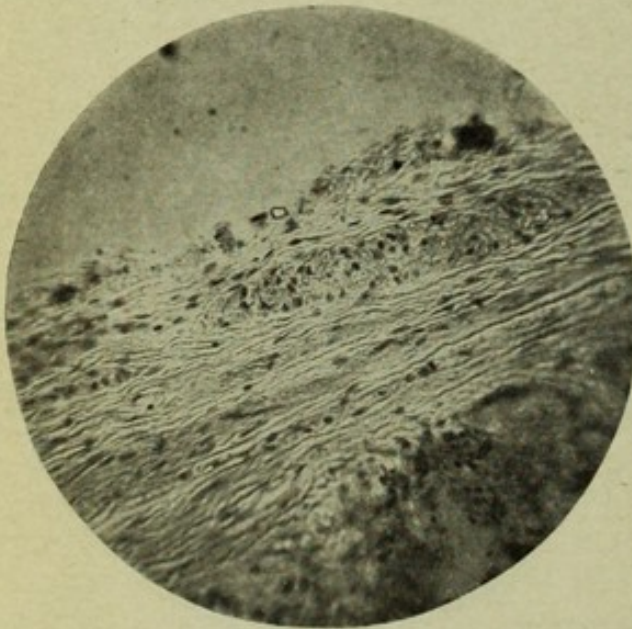


Figure 13. Prostatic capsule, red fox.

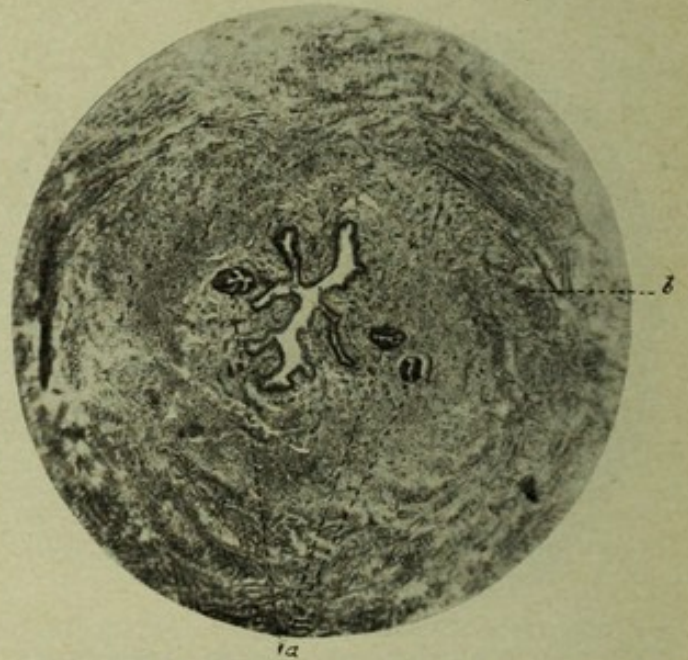


Figure 14. Prostatic urethra, anterior part of prostate. Note absence of peri-urethral erectile tissue. Red fox.

uted, is yet derived from but few vessels. These are three in number, as follows:

- a. The internal pudic artery, a branch of the anterior trunk of the internal iliac artery.
- b. The inferior vesical artery, also a branch of the anterior trunk of the internal iliac artery.
- c. The superior hemorrhoidal artery, the continuation of the inferior mesenteric artery.

The blood supply of the prostate enters by way of the gland capsule. From the capsular blood-vessels branches are given off which penetrate the septa throughout the gland.

*Oppel's *Lehrbuch der Vergleichenden Mikroskopischen Anatomie der Wirbeltiere*, vol. IV., Jena, 1904, p. 359.

- a'. Openings of three prostatic ducts leading from peri-urethral glands.

- b. Peri-urethral striated muscle—part of the constrictor urethrae.

rived from the hypogastric and pelvic plexuses, and are, therefore, non-medullated or marrowless. They are connected with the second, third, and fourth sacral spinal nerves. Single nerve-cells, some of exceptionally large size, are frequently seen in the prostate gland of the red fox.

XIV. MICROSCOPICAL STRUCTURE OF THE PROSTATE GLAND.

Five specimen blocks of the prostate gland of the red fox were made—one from the termini of the vasa deferentia and four from the prostate gland proper, as follows:

No. 696. Vasa on entering prostate; almost united.

No. 697. Posterior transverse section of prostate gland one-fourth inch from vesical neck.

No. 698. Posterior extremity of prostate gland, transverse section of entire gland.

No. 699. Transverse section, middle of gland.

No. 700. Transverse section, anterior part of gland.

Each of these five sections of the red fox's prostate will now be described *seriatim*.

Section No. 696.—Vasa on entering prostate; almost united.

In this paper I have included a description of the vasa deferentia at their point of entrance into the prostate gland. Here the vasa very closely approximate each other. It has been deemed prudent to incorporate this anat-

a muscularis mucosae, and the submucous layer is much attenuated.

The lumen of the vas deferens is quite small. The mucous membrane is rugous and folded, thus ensuring great surface but small area. The ampullar glands though but slightly developed, encroach considerably upon this small lumen. The mucous membrane is covered by a stratified epithelium of the columnar type. Many of the cells are granular in appearance. This granular appearance of the cell-protoplasm is probably due to increased sexual activity, the animal having been killed at or near the mating season of the fox. The epithelium lining the ampullar glands is cuboidal and, like the epithelium of the mucosa, also shows granulations. The nuclei are relatively large and centrally located. The ampullar epithelium really resembles that of the human prostate gland. The ampullar glands

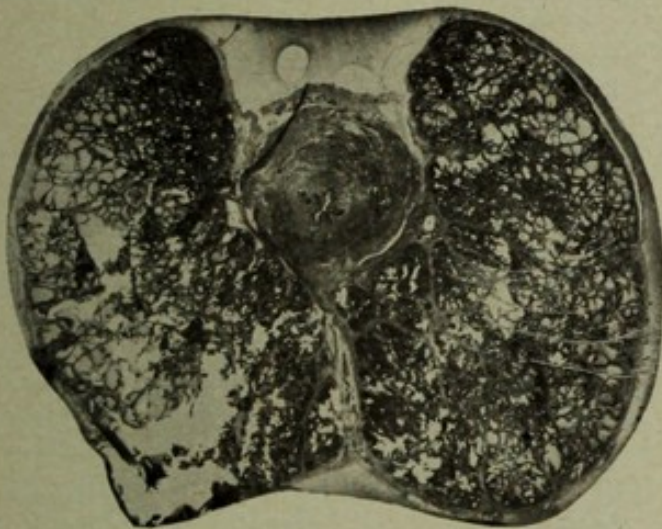


Figure 15. Cross section, entire prostate of red fox, anterior part. Isolated gland acini to the right of urethra.

omical structure in the present instance, in order to portray the ampullar (sometimes called ampullary) glands and dilate upon their significance.

The vasa deferentia in the red fox, in the human being these ducts would here be styled the ejaculatory ducts or common ejaculatory ducts at their point of entrance into the prostate gland present a characteristic appearance. Their histological structure may be resolved into four (4) coats or layers:

1. An inner or mucous coat.
2. A submucous coat.
3. A middle or muscular coat.
4. An outer or fibrous coat.

The mucous coat and the muscular coat are the most conspicuous layers. The fibrous coat is delicate. There can scarcely be said to be

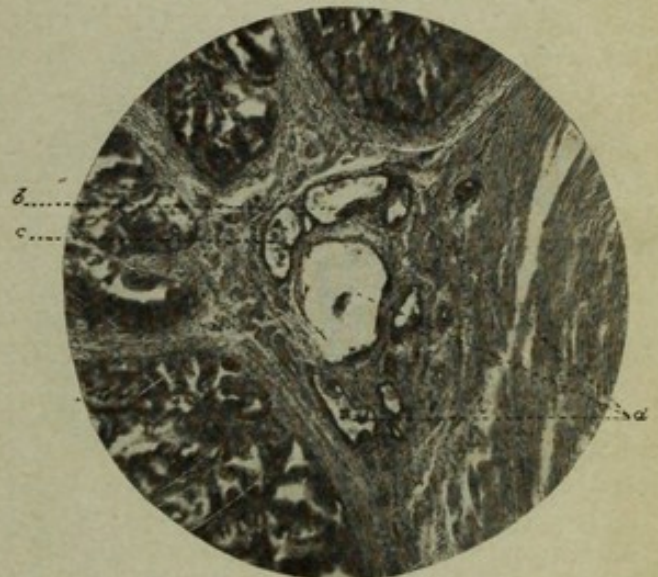


Figure 16. Isolated gland acini under high power. Prostate gland of red fox.

- a. Isolated acini.
- b. Chromaffin cells.
- c. Coagulated secretion.

Note. These isolated gland acini, ductless and surrounded by an abundant blood-supply, probably functionate as a "gland with internal secretion."

have a supporting framework of loosely arranged connective tissue containing a few elongated cells. This framework is not very elaborate.

The middle or muscular coat and the submucous coat could with propriety be described as one. For the sake of clearness I shall separate them and first describe the submucous coat or layer. This is somewhat attenuated. Made up of a mere vestige of loosely arranged connective tissue, its prolongations and folds jut into the lumen of the vas and thus afford substantial support to the mucous glands con-

tained therein. A few round cells, a few oval cells, and a few spindle-shaped cells constitute the cellular elements of the submucosa.

The middle or muscular layer, really the third layer from the interior of the vas, is by far the most conspicuous. There is a considerable amount of connective tissue in this middle or muscular coat, and also a few elastic fibres—an intimate structure at one and the same time ensuring strength, firmness, and contractile powers. Its biplex function is therefore indicated:

- a. As a conduit or duct for the transmission of the testicular secretion plus that elaborated (minute though it be) by the ampullar glands.
- b. Its power as a propulsive organ, by virtue of its rhythmical contractility.

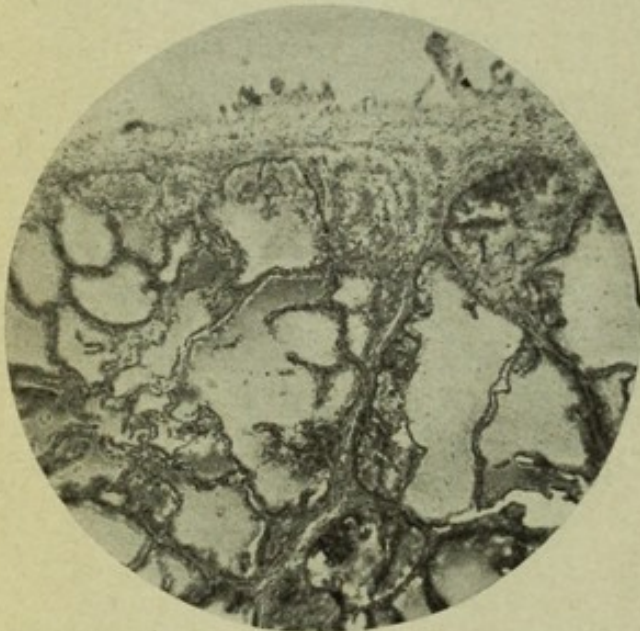


Figure 17. Distended acini and prostatic capsule. Prostate gland of red fox.

To be brief: The vas deferens serves as a conduit or duct and also as a propelling organ. This calls forth an interesting feature in the comparative physiology of the vasa deferentia. In many invertebrate animals the mucous membrane is possessed of a ciliated epithelium, and hence the sperms are largely transmitted by means of ciliary motion. This condition also obtains in some of the lowest vertebrates. In the higher animals, including man, this purpose is accomplished by muscular contraction rhythmical in character.

The muscular layer of the vas deferens in the red fox is composed of smooth muscle exclusively, that is, so far as its muscular elements are concerned. The bundles of smooth muscle fibres are very intricately mixed, there being no arrangement in definite layers. At

a more remote distance from the prostate the vas consists of two muscular layers:

- a. An outer circular layer.
- b. An inner longitudinal layer.

The outer or fibrous coat of the terminal portion of the vas deferens in the red fox consists of a delicate layer of fibro-areolar tissue containing blood-vessels and nerves in its meshes. Each vas deferens is accompanied by one large nerve-trunk. These nerve-trunks contain exceptionally large cells resembling ganglion cells. They lie external to the deferential tube.

Section No. 697.—Posterior transverse section of prostate gland one-fourth inch ($\frac{1}{4}$ inch) from vesical neck. Here we behold the prostate gland of the red fox in all its beauty of histological structure. It is an organ composed of three-fourth glandular tissue and one-fourth muscular tissue—the reverse of what we find in the human prostate gland. Resolved into its principal component elements the fox's prostate consists of:

- a. Glandular tissue.
- b. Smooth muscle.
- c. Erectile tissue.
- d. Capsule and sheath.
- e. Blood-vessels and nerves.
- f. Urethral canal.

The prostate gland in the red fox is a compound tubular gland of the mucous type. Like the human gland its posterior part is peculiarly rich in glandular tissue. The acini are lined with columnar epithelium consisting of a single layer of cells set directly upon the framework of the gland, there being no membrane propria or basement membrane interposed. The epithelial cells are tall, their protoplasm is clear and finely granular, and the nuclei have a very noticeable basal arrangement. Thus the epithelial cells in the acini of the fox's prostate possess the three main characteristics of mucous glands:

- a. The protoplasm is clear.
- b. The nuclei lie at the bases of the cells.
- c. The cells are tall and columnar-like.

This part of the prostate is largely made up of glandular tissue. The acini or gland-spaces, with their ducts, are clearly and characteristically shown. The ducts converge toward the prostatic urethra, into which they open. The epithelium lining the prostatic ducts is cuboidal and stratified, closely resembling (probably an extension of) that found in the urethra. Besides its epithelial lining, each acinus has a framework of smooth muscular tissue. Towards the periphery of this specimen the acini are dilated and filled with normal mucus, giving to it an appearance resembling normal thyroid gland.

The framework of the fox's prostate is

composed of smooth muscle interspersed with connective tissue. In this framework the blood-vessels and nerves penetrate to the remotest ramifications of the gland. These muscular portions or septa are given off from the capsule of the gland. They divide the gland into numerous compartments or lobules. This subdivision into lobules can even be detected by the naked eye. From these interlobular septa delicate projections jut forth, upon which support the glandular epithelium rests.

In the prostate gland of the red fox the erectile tissue is peculiar, in that it surrounds the entire urethral canal instead of being confined to the verumontanum as in man and most of the higher animals. Its histological details are: a loosely arranged white fibrous connective tissue containing a few yellow elastic fibres, embedded in which are numerous blood-spaces large and small.

The capsule of the gland is largely composed of smooth muscle circularly disposed. Externally there are a few longitudinal bands. The septa or gland partitions come off directly from the capsule and are continuous with it. There is no striated muscle in the capsule of the gland or in its intricate framework. Numerous blood-vessels and nerve-cells are seen in the capsule. External to the capsule is a delicate sheath of white fibrous tissue. In it nerve-trunks and blood-vessels are also seen, but in limited numbers.

PROSTATIC URETHRA.

Slightly above the center of this specimen the prostatic urethra is seen. It is a narrow, horizontal slit. Into the inferior part of the prostatic urethra projects the verumontanum, on either side of which structure is a prostatic sinus. At this juncture four (4) prostatic ducts empty into each sinus. The prostatic urethra is lined with the regulation "transitional" epithelium, that is—a stratified squamous epithelium consisting of but few layers of cells and having the pear-shaped cells upon the surface.

The prostatic urethra in this location ($\frac{1}{4}$ inch from bladder neck) is surrounded by erectile tissue resembling the corpus spongiosum of the penis. There is no definite subepithelial connective tissue layer. From the covering of epithelium we pass directly into the peri-urethral erectile tissue.

The peri-urethral erectile tissue consists of white fibrous tissue loosely arranged and containing numerous blood- and lymph-spaces. Some of the blood-spaces are of large size and contain red and white blood corpuscles in the proper proportion. The blood- and lymph-spaces are lined with a single layer of endo-

thelial plates, each plate-like cell having a comparatively large nucleus. The connective tissue fibres forming the basis of the peri-urethral erectile tissue radiate laterally from the walls of the slit-like prostatic urethra.

VERUMONTANUM.

In this section the structure of the verumontanum resembles that of the peri-urethral connective tissue—a groundwork of white fibrous tissue containing a moderate number of round, oval and spindle-shaped cells, and a profusion of blood- and lymph-spaces. The connective tissue fibres radiate from the apex and sides of the verumontanum, and at its base become continuous with the peri-urethral connective tissue and the connective tissue surrounding the ejaculatory ducts.

The prostatic utricle is not visible in this section.

EJACULATORY DUCTS.

Lying a short distance beneath the base-line of the verumontanum are the two ejaculatory ducts or terminal portions of the vasa deferentia. These are two narrow slit-like canals, each surrounded by an attenuated layer of smooth muscle. The epithelium is cuboidal or low columnar in type, and has also dwindled down to a single layer. There are no cilia; in fact, no ciliated epithelium is found in this part of the genital tract of the red fox. Numerous mucous glands are embedded in the epithelial wall.

One ejaculatory duct contains a small deposition of mineral matter. Both contain numerous small, dark cells, and a few spermatozoa are also visible lying among these cells.

Slightly below the ejaculatory ducts there are four or five large blood-vessels. These evidently constitute the principal blood-supply of the prostate gland as the blood-vessels contained in the capsule of the gland are quite small.

Section No. 698.—Posterior extremity of prostate gland, transverse section of entire gland.

As stated in the label, this specimen was taken from the posterior part of the prostate gland, nearly one-fourth inch from the previous section (No. 697). It is a transverse section of the entire prostate gland of the red fox, taken from the hindmost extremity of the lateral lobes. (In the red fox the prostate gland contains only the two lobes—the right lateral lobe and the left lateral lobe.)

In this specimen the component parts of the fox's prostate gland are characteristically shown—the groundmass of smooth muscle, the tubular glands, the urethral canal, the ejaculatory ducts, and the capsule.

This part (the posterior) of the fox's prostate, like that in man, is peculiarly rich in gland-tissue. But this applies to the entire prostate gland in the fox. Taken as a whole, I should say that the fox's prostate is composed of three-fourths ($\frac{3}{4}$ ths) glandular tissue and one-fourth ($\frac{1}{4}$ th) muscular tissue. In the human gland different estimates have been furnished by different observers, but I am inclined to state that the proper proportions are two-thirds ($\frac{2}{3}$ ths) muscular tissue (smooth) and one-third ($\frac{1}{3}$ rd) glandular tissue. Formerly I taught that the human prostate is made up of three-fourths ($\frac{3}{4}$ ths) muscular tissue (smooth) and one-fourth ($\frac{1}{4}$ th) glandular tissue; but extended observations have induced me to modify this statement.

The prostate gland in the present specimen contains multitudinous lobules or compartments. Each lobule is surrounded by bands of smooth muscular tissue containing considerable connective tissue. The entire gland is surrounded by a common muscular layer (smooth muscle), and each lobule has a muscular envelope of its own. Doubtless this latter envelope or muscular covering, by its contractile power, aids in expelling the secretion (succus prostaticus) elaborated by the contained lobule. The muscular partitions or septa, given off from the muscular covering, form a very secure stroma for the gland. These septa are quite broad at their point of origin, but become attenuated as they approach the interior of the gland. In the stroma or framework the blood-vessels and nerves are seen.

Here the two lobes of the fox's prostate consist of two distinct physiological entities. The following structures effect this separation into right and left lobes or "right" and "left" prostates:

- a. The anterior commissure. This is composed largely of smooth muscle.
- b. A remnant of the middle muscular layer of the bladder, which enters the prostate and occupies a position superior to the prostatic urethra.
- c. The prostatic urethra and peri-urethral erectile tissue.
- d. The verumontanum or urethral crest.
- e. The posterior commissure, containing bands of smooth muscle, the ejaculatory ducts, and areolar tissue.

The minute structure of the framework or smooth muscle stroma is prettily shown. The fibre-cells, each with its characteristic hyphen-shaped nucleus, stand out in bold relief. Small blood-vessels abound in the stroma, and minute capillaries can be detected penetrating even among the epithelial cells.

The compound tubular glands, which histo-

logical elements make up seven-eighths ($\frac{7}{8}$ ths) of this part of the fox's prostate, have a definite and orderly arrangement. Their fundi rest upon the muscular stroma; their stomata or mouths converge toward a common duct or canaliculus.

The acini or gland spaces are fairly regular in size and outline. The glands are tortuous. The secreting epithelium is stratified columnar, composed of several layers. The surface layer is quite tall, its protoplasm contains numerous mucigenous granules, and the nuclei have a basal arrangement. These structural features determine the prostate gland to be a mucous gland.*

Some of the acini or gland spaces most remote from the interior of the gland are dilated, and contain congealed mucus. The dilated spaces occupy the extreme periphery or lateral portions of both lobes. I interpret this condition as evidence of increased physiological secretion during the oestrus or period of heat, thus supporting the purely sexual function of the prostate gland.

The histological details of the urethral canal as it appears in this section are identical with those of the previous section (No. 697). Moreover, there is one additional element. Superiorly to the urethra there are 15 or 18 circularly disposed bundles of smooth muscle fibres. These bundles are a continuation of the middle circular layer of smooth muscle found in the bladder wall and which form the external sphincter vesicae.

The epithelium of this portion of the prostatic urethra is likewise stratified columnar of the "transitional" type.* The peri-urethral tissue is erectile. The verumontanum can

*Histologists usually classify secreting glands as:

- a. Mucous glands. Examples: sublingual gland; prostate gland; Cowper's glands.
- b. Serous or albuminous glands. Examples: parotid gland in man; "repugnatorial" glands in the skunk.
- c. Mixed or sero-mucous glands, as the sub-maxillary gland.

In mucous glands the secreting epithelium is seen to be tall and columnar, and the protoplasm is clear or, as in the present instance, filled with mucigenous granules. The nucleus is located near the base of the cell.

In serous glands the epithelium is more cuboidal in shape, and the protoplasm is noticeably granular. The nucleus is located at the central part of the cell.

In mixed glands the two types of epithelium, columnar and cuboidal, are seen intermixed in various proportions.

*Stratified squamous epithelium of the "transitional" type is only found in four localities; namely:

- a. The pelves of the kidneys.
- b. The ureters.
- c. The urinary bladder.
- d. The prostatic urethra.

here be seen in its incipiency. It is a pyramidal shaped elevation on the floor of the urethra, covered by the regulation urethral epithelium, and composed of a groundwork of erectile tissue. The prostatic sinuses are mere fissures, and very few prostatic ducts empty into this part of the prostatic urethra. Many of the blood-spaces are distended with red blood corpuscles, probably due to sexual excitement superinduced by the administration of chloroform, by means of which anesthetic this animal has been humanely killed.

In this situation the urethral canal appears as an elongated longitudinal slit, bifurcated posteriorly (or inferiorly, if you will) to conform with the outlines of the verumontanum. It occupies a position about the middle of the specimen.

The periurethral erectile tissue is not especially rich in cellular elements.

EJACULATORY DUCTS.

The ejaculatory ducts occupy a position slightly inferior to the urethral canal and extend almost to the inferior border of the gland. Their structure is at once peculiar and interesting. Four coats are discernible:

- a. Inner or mucous coat.
- b. Submucous coat.
- c. Muscular coat.
- d. Outer or fibrous layer.

The epithelium of the mucous coat of the ejaculatory duct is of a low columnar type and is stratified. The cell protoplasm is clear and the nuclei are large. Ampullar (mucous) glands are still seen embedded in the mucous membrane. The framework supporting these glands is given off as delicate projections subtended from the submucous connective tissue. It contains relatively few cells. The epithelium of the ampullary (mucous) glands is spherical in shape, with clear protoplasm and darkly-staining nuclei. It is not ciliated.

The submucous layer is not elaborate. It consists of a loosely arranged white fibrous tissue. The cellular elements are sparse and oval in form.

The muscular coat is the "*doyen*" of the four layers of tissue which make up the wall of the ejaculatory duct. It consists of three layers of smooth muscle—an inner and an outer longitudinal layer, and a middle circular layer. Rhythmical contraction of this abundant muscular layer effectually expels the seminal contents of the tube.

The fibrous coat is an attenuated circular layer of white fibrous tissue containing here and there a few fibres of smooth muscle and an occasional blood vessel.

CAPSULE.

At this juncture the prostatic capsule is composed largely of smooth muscle circularly arranged. A few longitudinal (outer) bundles are also present. Passing through the capsule near the inferior groove are found the principal nerve-trunks supplying the prostate. Blood-vessels also occur in the prostatic capsule.

External to the capsule is a delicate fibrous sheath. The groove on the under surface of the gland is largely filled in with areolar tissue.

CONTENTS OF EJACULATORY DUCT.

Lying in the lumen of the ejaculatory duct are numerous dark bodies resembling cell-nuclei. Clumps of spermatozoa also lie in these canals. The lumen itself is not large, and the ampullar glands, the cell-nuclei, and spermatozoa fill it completely.

Section No. 699.—Transverse section, middle of gland.

In this specimen the anterior extremity of the verumontanum is seen. It is pierced near its center by the opening of the utriculus, which opening practically bifurcates the apex of the verumontanum. On either side of the utricular opening, and equidistant from the same, are the mouths of the two ejaculatory ducts. These appear as simple orificial openings.

The epithelium lining the utriculus is similar to that found in the prostatic acini. The cell-protoplasm contains mucigenous granules, and congealed mucus lies in the cavity itself. The cavity of the utriculus is slightly distended.

The mouths of the ejaculatory ducts are irregular in shape and lined by epithelium similar to that in the adjoining portion of the urethra. Their lumina are empty. Numerous prostatic ducts empty into the urethra on either side of the verumontanum, at points corresponding to the prostatic sinuses. The prostatic ducts are long and tortuous, and lined with a flattened epithelium which is stratified.

The peri-urethral erectile tissue is here reduced to a minimum. The larger blood-spaces are deeply seated, occupying positions well down in the submucous connective tissue.

The urethral canal is convoluted, and the "transitional" character of its epithelium is beautifully shown. Numerous small collections of gland-acini lie embedded in the submucous connective tissue and among the bundles of smooth muscle-fibre by which the submucous tissue is succeeded. At the border line between the two—the submucous connective tissue and the smooth muscle bundles—

a number of large blood vessels are seen, some of which contain red blood corpuscles.

By means of a dense muscular partition extending from the anterior furrow* to the posterior furrow of the gland, the fox's prostate is at this point practically divided into two symmetrical physiological halves. This dividing septum is denser anterior to the urethral canal than it is posteriorly.

From the muscular septum which separates the gland into two lateral halves the muscular framework of the individual compartments or lobules is given off. Each lobule is surrounded by alternating longitudinal and circular muscular layers, which arrangement provides for adequate compression of the entire lobe. Each half of the gland also has its compressor muscle.

The tubules forming the gland spaces are tortuous and lined with columnar epithelium of the mucous type. The cells are tall, the nuclei are at the bottom of the cells, and the protoplasm (cytoplasm) is filled with mucigenous granules. In extremely thin portions of the specimen the epithelium is seen to possess but a single layer of cells.

The remotest portions of both lobes show laterally a distension of their acini by mucus. This mucus, as in the preceding specimens, is congealed, and bears testimony to the sexual activity of the gland. In these dilated tubules the simple character of the secreting (lining) epithelium is clearly and characteristically shown.

No amyloid bodies (*corpora amylacea*) are visible.

The muscular fibres which compose the capsule interlace in all directions. They are largely confined each to its lateral half, but a few muscle bundles encircle the entire gland. The muscular tissue of the prostatic capsule is of the involuntary type, no striated muscle appearing therein.

Blood vessels are found in the capsule, but these are not numerous. Muscular septa which penetrate the gland in all directions, are given off from the capsule. The glandular tissue is in close juxtaposition to the muscular framework, the usual subepithelial connective tissue being conspicuous by its absence.

Section No. 700.—Transverse section, anterior part of gland. An intensely interesting specimen. Here the prostate is plainly separated into two lateral halves—right and left, by the following structures, beginning from above downward:

*This should probably be called the superior or smaller furrow or groove, and the posterior furrow or groove should probably be denominated the inferior or larger furrow or groove, as it applies to the under surface.

- a. Superior groove or notch. In this specimen there is a distinct groove measuring three-sixteenths of an inch ($3/16$ inch) in width and one tenth of an inch ($1/10$ inch) in depth.
- b. The prostatic urethra, surrounded by a layer of muscle.
- c. The posterior median septum, composed of muscular tissue and fibrous tissue.
- d. The inferior prostatic groove. This is a very shallow groove measuring but half a line ($1/24$ inch) in depth, between the right lobe and the left lobe.

This section was made beyond the openings of the ejaculatory ducts. The verumontanum is no longer visible; the peri-urethral erectile tissue has also disappeared. The urethra here shows four coats:

- a. The mucous coat.
- b. The submucous coat.
- c. The muscular coat.
- d. The fibrous coat.

The epithelium is beautifully "transitional," and is composed of but two or three layers of cells. The pear-shaped cells of the surface layer are characteristically shown. The *membrana propria* can be distinguished, but there is no *muscularis mucosae*. The lumen of this portion of the prostatic urethra is empty.

The submucous coat is composed of white fibrous tissue loosely arranged and fairly rich in cellular elements—round cells, spindle-shaped cells, and oval cells. Numerous blood-spaces, large and small, abound towards the periphery of the submucosa. But three (3) prostatic ducts are visible in this portion of the prostatic urethra.

The muscular coat is composed of smooth muscle, interlacing among which are numerous bundles of striated muscle. The muscular coat, comprised of both smooth and striated muscle, has no definite arrangement. The muscle-bundles interlace in all directions. At some points an inner and an outer circular layer and a middle longitudinal layer can be detected. The muscular coat is of ample dimensions, and the striated muscle contained in it is the beginning of the constrictor urethrae muscle.

The fibrous coat is not accurately defined, and becomes lost in the capsule of the gland and in the septa.

GLANDULAR TISSUE.

The glandular tissue in this portion of the red fox's prostate gland, as in the human gland, is not so abundant as in the previous sections, all of which were taken at points more posteriorly to the one now under discussion. The stroma is more abundant and the glandular tissue correspondingly less so.

The stroma is largely smooth muscle, and the tortuous tubular glands rest directly upon it. Each sinus has its own compressor muscle. The striated muscle does not enter in among the compartments or lobules of the gland. It merely circumscribes the urethral canal, and constitutes the innermost extremity of the constrictor urethrae muscle.

Lying to the outskirts of the muscular coat and ensconced therein is a collection of eight (8) dilated tubules resembling thyroid gland or the epididymis of the testicle. These prostatic spaces are isolated from the remainder of the gland-tissue. They have not a compressor muscle; neither do they have ducts. A number of blood-vessels are in their immediate vicinity. The epithelial cells are flattened as in thyroid epithelium, and they contain the chromaffin granules peculiar to "glands with internal secretion." Hence it is probable that these eight tubules are an isolated portion of the prostate gland, physiologically distinct from the remainder of it, and performing the office of a "gland with internal secretion." Similar collections of cells occur in the seminiferous tubules of the testicle, and are termed the "cells of Leydig."* In the entire prostate gland of the red fox, I have found but one such cluster of cells. It lies to the left of the prostatic urethra, upon the border-line between the muscular wall of the urethra and the bases of the adjacent gland lobules, four (4) in number. These chromaffin-bearing cells are in the anterior portion of the prostate, where the prostatic ducts are few in number and where the glandular tissue is diminished and the muscular elements increased in amount.

Notwithstanding the fact that this is the anterior part of the fox's prostate, and is more muscular and less glandular than the remainder of the organ, many of the gland-spaces are distended with mucus, as in the preceding specimens. This—distension of the acini with mucous secretion—and the other evidences of sexual activity, namely, mucigenous granules in the protoplasm of the epithelial cells and the darkly granular nuclei, indicate that in the red fox the entire prostate gland participates in the function of generation. The gland is more succulent, because the animal was killed at the height of the spring breeding season for the fox. With the exception of a few compartments or lobules

lying in close proximity to the posterior median septum, the foregoing statement applies to the entire specimen now under description.

STROMA AND CAPSULE.

These consist of smooth muscle, with connective tissue forming the myotomes. As stated above, the stroma is here denser than in the preceding sections of the fox's prostate. The capsule is reinforced at the superior and inferior prostatic notches or grooves. The capsule is largely smooth muscle. It does not contain any striated muscle. A delicate film or sheath of areolar tissue surrounds the gland as a whole.

In the capsule and in the sheath are embedded blood-vessels and nerves. The latter are quite conspicuous at the superior notch or groove.

XV. SUMMARY AND CONCLUSIONS.

My description of the structure and function of the prostate gland in the red fox is now reasonably complete. I shall here recapitulate the important anatomical and physiological points brought to light in the present paper.

I have tried to be thorough, without being unduly prolix. I have endeavored to show that much of human interest can be gained by painstaking study of the structure and function of the prostate gland in one of our best-known animals.

Four points have been elucidated, as I believe, clearer than ever before. These are:

- a. The prostate gland is essentially a sexual organ.
- b. It increases in size and becomes more succulent during the breeding season.
- c. In the red fox the prostate is largely glandular.
- d. Absence of bulbo-urethral or Cowper's glands and seminal vesicles in the red fox is admirably compensated for by the proportionally large size of the prostate gland or "sexual heart."

Two hitherto undescribed conditions are first noticed in the present article. These are:

- a. The finding of an isolated collection of prostatic tubules resembling thyroid, and believed to functionate as a "gland with internal secretion."
- b. The presence of peri-urethral erectile tissue. Hitherto erectile tissue was believed to be present only in the verumontanum. In the red fox not only the verumontanum, but also the entire peri-urethral tissue posterior to the openings of the ejaculatory ducts, is erectile.

*The cells of "Leydig," sometimes called "Henle's cells," are the large, granular cells found in the seminiferous tubules of the testicle. It has been pretty definitely established that these collections of granular cells in the seminiferous tubules of the testicle elaborate a special secretion of their own, which, entering the blood- and lymph-vessels, impart to this organ the properties of a "gland with internal secretion."

The above six items, and many other data of timely interest and importance, will be elaborated upon in the sequel. An epitome or abridged account of this entire paper will next be given.

1. The genitalia of the red fox closely resemble the genitalia of the dog. There are no seminal vesicles and no Cowper's glands. The prostate gland is pale and irregular, as if subdivided into multitudinous compartments or lobules. The urethra tunnels the prostate gland from fore to aft, slightly above its centre.

2. The prostate gland of the red fox is roundish or slightly oblong in contour. In point of size it is proportionally large. It is the predominating gland in the red fox, in fact, in the whole canine family.

3. In regard to shape, I have described the prostate gland of the red fox as resembling an English walnut. Its weight is $4\frac{3}{4}$ grammes; its length, $\frac{7}{8}$ -inch; its breadth, $\frac{7}{8}$ -inch; and its thickness, $\frac{5}{8}$ -inch.*

4. The prostate gland in the red fox is distinctly bilobed. Grossly, it consists of two lateral lobes or halves. In the dog the prostate gland is indistinctly bilobed. In the fox the prostate gland is three-fourths glandular tissue and one-fourth muscular tissue (with a delicate supporting framework of connective tissue), the reverse of what we find in man.**

5. Microscopically, the fox's prostate is a compound tubular gland. The tubules are tortuous and lined with glandular or secretory epithelium, which in some parts at least consists of but a single layer of cells. The epithelial cells are tall and columnar-like, their protoplasm contains mucigenous granules, and their nuclei have a basal arrangement. Many of the prostatic tubules are distended and filled with coagulated mucus. The epithelium lies immediately on the stroma or framework of the gland. In the red fox the prostate gland is of the mucous type.

6. In the red fox, as in man, the function

*The prostate gland of the dog possesses the following weight and dimensions:—

Weight, $5\frac{1}{4}$ grammes.

Length, 1 inch.

Breadth, $1\frac{1}{8}$ inches.

Thickness or depth, 1 inch.

**In man the prostate gland is two-thirds muscular and one-third glandular tissue. Its average size is:

Weight, 5 drachms.

Length, $1\frac{1}{4}$ inches.

Breadth, $1\frac{1}{2}$ inches.

Thickness, 1 inch.

It consists of two lateral lobes and a posterior median portion lying between the urethra and the common ejaculatory ducts.

of the prostate gland is wholly sexual. This can be abundantly proven.

a. The prostate is distinctly a parenchymatous organ, as are the thyroid, thymus, spleen, adrenal, etc.

b. It increases slightly in size and greatly in secretory activity during the mating season. Its weight in proportion to the fox's body is about 1 in 1,600.

For other confirmatory evidences of proof as to the purely sexual function of the prostate gland the reader is referred to the body of this article.

7. The fox's prostate is not very intimately attached to the prostatic urethra. Anteriorly it is entirely separate from it. This feature would suggest that the prostate gland is merely a sexual appendage of the urino-genital canal. In the pine squirrel (*Sciurus canadensis*) this condition of affairs is also very noticeable. In the latter animal the prostate gland adheres to the urethra by two points, where its excretory ducts penetrate the canal.

8. Each prostatic tubule and each lobule has its own compressor muscle. This is a sheath or envelope of non-striped muscle which surrounds each tubule throughout its entire length. By the contraction of this muscular sheath, and a simultaneous and rhythmical contraction of the compressor muscle of the whole lobule, the prostatic secretion is expelled into the prostatic duct and thence into the prostatic urethra, during the sexual act.

9. There seems to be no doubt that the secretions of the prostate, ampullary glands, and seminal vesicles (when these are present) have an important relation to the vitality and fertilizing power of the spermatozoa, and a high degree of fertility is usually seen in those animals in which these glands are most markedly developed. This statement, however, does not apply to the red fox or to any member of the canine family;* because, in this group of interesting animals the ampullary glands are but slightly developed and seminal vesicles (and also Cowper's glands) are entirely wanting.

10. In many mammals (*e. g.*, rodents, in-

*The canine or dog family comprises the wolves, dogs, jackals, wild dogs (or "Wilde Honden," as they are termed by the Dutch Boers), and foxes. In no type of these animals is fecundity a marked characteristic. All of them possess but a moderate degree of progenitiveness. For example, in the red fox, which far-famed animal we are especially considering, there are from 4 to 9 young in a litter; usually 5, 6 or 7. The female fox, sometimes called "vixen," carries her young 9 weeks or from 60 to 63 days after copulation. The young are whelped at the end of April or the beginning of May. There is but one litter annually.

sectivores) these glands—prostatic, ampullary, and vesicular—have also another function. Their coagulated secretion forms a kind of “stopper” for closing the vagina and thus ensuring fertilization. In certain bats the mucous membrane lining the neck of the uterus becomes modified directly after copulation, and together with the secretion of the accessory genital glands closes the canal and protects the mass of sperms until the following spring, when fertilization of the ova takes place: it has been shown that the spermatozoa may thus retain their vitality within the uterus for eight months. In some cases the secretion in the vagina originates from the accessory genital glands of the male.*

11. In the red fox, as well as in all the *canidae*, the formation of a “bouchon vaginal” or “stopper” is of minor importance. Inspissation of the seminal discharge occurs to a slight extent in all animals, even in man. But it is only in rodents and insectivora that a real “vaginal bouchon” is formed. By this wise provision of nature the fecundating powers of these latter animals are very materially enhanced.

12. The question as to an internal secretion in the case of the prostate gland has been set forth in a clearer light in the present paper. One isolated set of gland tubules, apparently ductless and containing chromaffin cells, have been found in the anterior part of the organ. In some respects these tubules resemble thyroid gland histologically. The “internal secretion” of the prostate gland influences the production and growth of the secondary male sexual characteristics—color, size, voice (bark), osseous system, pelage, etc.

13. The “internal secretion” of the prostate gland is “part and parcel” of the sexual function of this important accessory male sexual organ. The small collection of prostatic tubules which thus functionate resemble the “cells of Leydig” in the seminiferous tubules of the testicle.

14. The prostate gland proper in the red fox has numerous ducts. These number from 40 to 50, and all point toward the openings of the ejaculatory ducts, as in the dog.

15. In the red fox the prostatic utricle or *uterus masculinus* is a minute, functionless, vestigial structure. As Wiedersheim has pointed out, a more appropriate name for it would be *vagina masculina*, corresponding as it does to the fused bases of the Müllerian ducts.

16. Dr. S. G. Shattock of London an-

nounces the discovery of a hymen bridging across the introitus of the uterus masculinus in man. Shattock's discovery indicates that the prostatic utricle corresponds to both the uterus and vagina of the female.* No such structure as a hymen was detected in my dissections of the prostate gland of the red fox.

17. Turgescence of the peri-urethral connective tissue in the prostate gland of the red fox aids the verumontanum and the sphincter vesicae in preventing regurgitation of semen into the urinary bladder during the venereal orgy. The same condition exists in the coyote or prairie wolf (*Canis latrans*) as exists in the fox; namely, the entire prostatic urethra posterior to the openings of the ejaculatory ducts is surrounded by erectile tissue. Formerly the subepithelial erectile connective tissue in the prostate gland was believed to be restricted to the verumontanum.

18. The verumontanum in the red fox exercises a triple function, rather than a double function:

- a. It subdivides the floor of the prostatic urethra into two parts or sinuses.
- b. When this structure is *in statu erectionis* it prevents the semen from escaping posteriorly into the bladder.
- c. It is largely the internal seat of sexual sensation.

The subdivision of the prostatic urethra into two parts or sinuses—right and left, aids in a proper admixture of the several glandular sexual secretions. It is fair to assume that only one testicle is brought into function at each separate act of coitus.

The verumontanum is aided in preventing the escape of the semen bladderward by an erect state of peri-urethral erectile tissue. Indeed, the whole urethral canal, and not only the verumontanum or floor, prevents the seminal discharge from regurgitating into the bladder.

19. Prior to pubescence the prostate gland remains small, and undeveloped, and functionless. The gland spaces are minute and the epithelium is flattened. Killed during the period of heat, as was the red fox which largely forms the basis of this paper, several very radical changes are perceptible. These may be enumerated, as follows:

- a. The prostate is larger and engorged with fluid.
- b. Many of the tubules, being filled with coagulated mucus, are distended into fairly large acinous spaces.
- c. The epithelium is tall and columnar, and the protoplasm of the epithelial cells shows numerous mucigenous granules.

*Wallace, “Prostatic Enlargement,” 1907, p. 55.

*Wiedersheim's *Comparative Anatomy of Vertebrates*, third edit., 1907, p. 485. Translated by W. N. Parker, Ph.D., and founded on the sixth German edition.

De Bonis* describes the epithelial cells of the dog's prostate as containing similar mucigenous granules. This observer states that these granules are especially found in the inner or lumen half, but also, though less markedly, in the outer half of each cell.

- d. During a quiescent state of the organ, the epithelium of the prostatic tubules consists of several (but few, however) layers and is more flattened. At the time of vigorous sexual activity the tubules become larger, the epithelium columnar and composed of but a single layer of cells. The entire gland is swollen. The epithelial lining of the isolated group of prostatic tubules which I have had the temerity to describe as a "gland with internal secretion," is low columnar in type and consists of but a single layer of cells.

20. I have given the average weight of the red fox's prostate gland as $4\frac{3}{4}$ grammes, or proportionate to the fox's body as 1 to 1,600. Judged by its dimensions the gland really should possess greater weight. The richly glandular make-up of the organ—almost exclusively tortuous tubules and dilated acini—accounts for its being under weight, comparatively speaking.

21. The red fox upon which this dissection

*De Bonis, "Über die Sekretionserscheinungen in den Drüsenzellen der Prostata," *Arch. f. Anat. u. Phys., Anat. Abth.*, 1907.

is based met its death by chloroform on March 10, 1911, at the very close of the breeding season. It was a handsome young male which had just reached maturity.

22. The average weight of a male or dog fox is 15 to 16 pounds. The female or "vixen" is slightly smaller. The capture and death of a male red fox weighing so much as 19 pounds have been reported to me.

23. The fox is subject to like diseases as the dog, even hydrophobia. The skunk (*Mephitis mephitis*) is another one of our furbearers subject to hydrophobia. Senile enlargement of the prostate gland occasionally occurs in the dog.* So far as I am aware prostatic enlargement has not been reported in the fox,** but it probably also occurs in this animal as in its foster-brother the dog.

24. Besides its envelopment by the rectovesical fascia, the prostate gland in the red fox has a delicate connective tissue sheath or capsule of its own. The gland, apparently readily separable into its two component lateral halves or lobes, would indicate that the fox is slightly lower down in the scale or animal beings than its congener the dog. ("Evolutionary note.")

*Churchman, "Prostatic Hypertrophy and Prostatic Atrophy in the Dog," *Johns Hopkins Hospital Bulletin*, December, 1907.

**The average duration of life in the dog is 12 years. Some dogs reach the age of 20 years, and occasionally a dog has reached the age of 26 or even 30 years, but these are almost incredible exceptions. The fox is said to attain the age of 14 or 15 years.