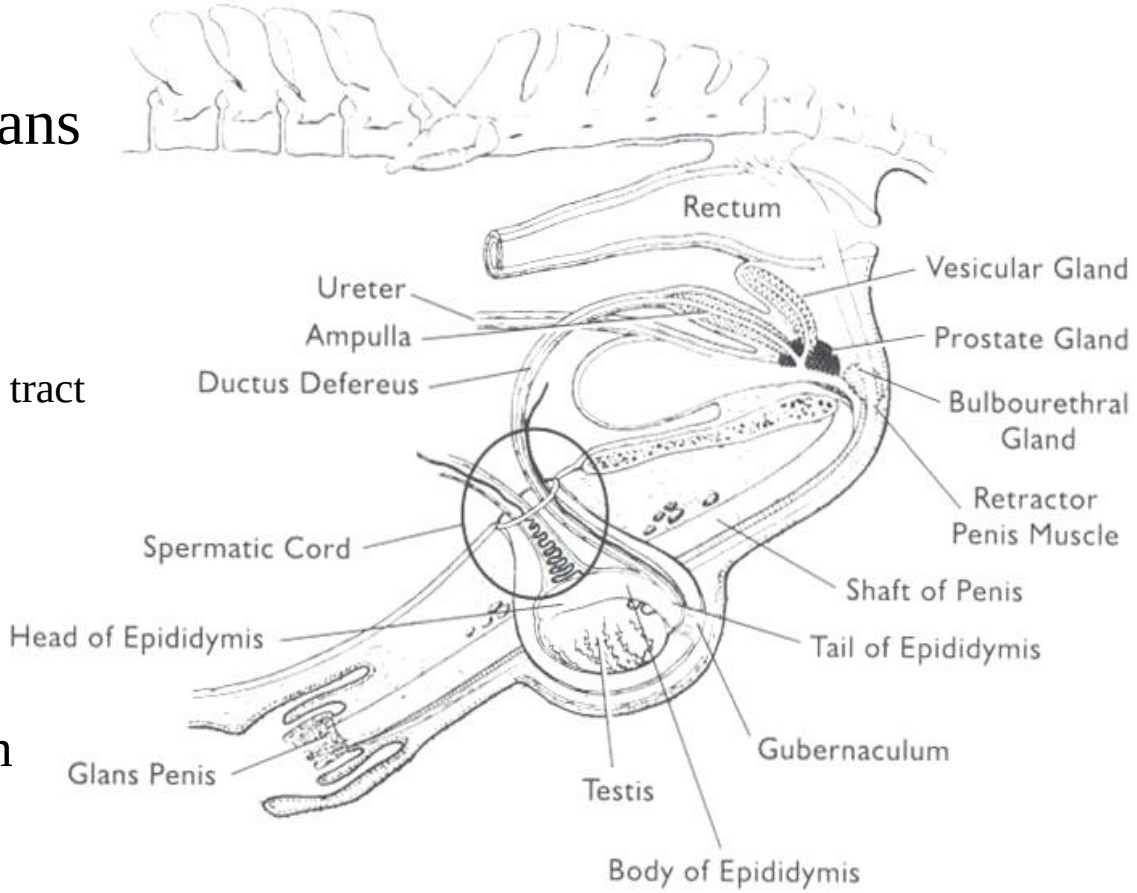
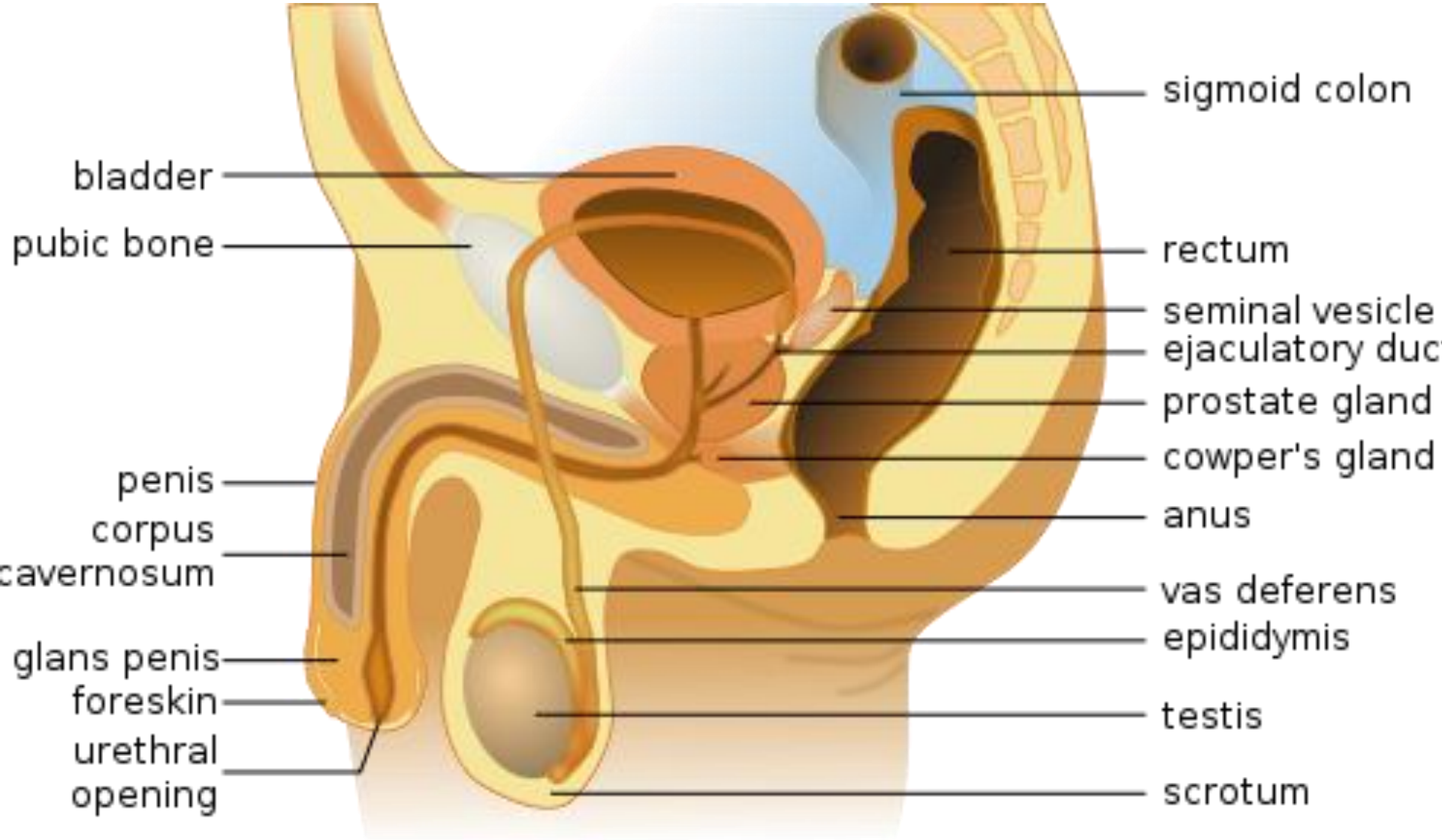
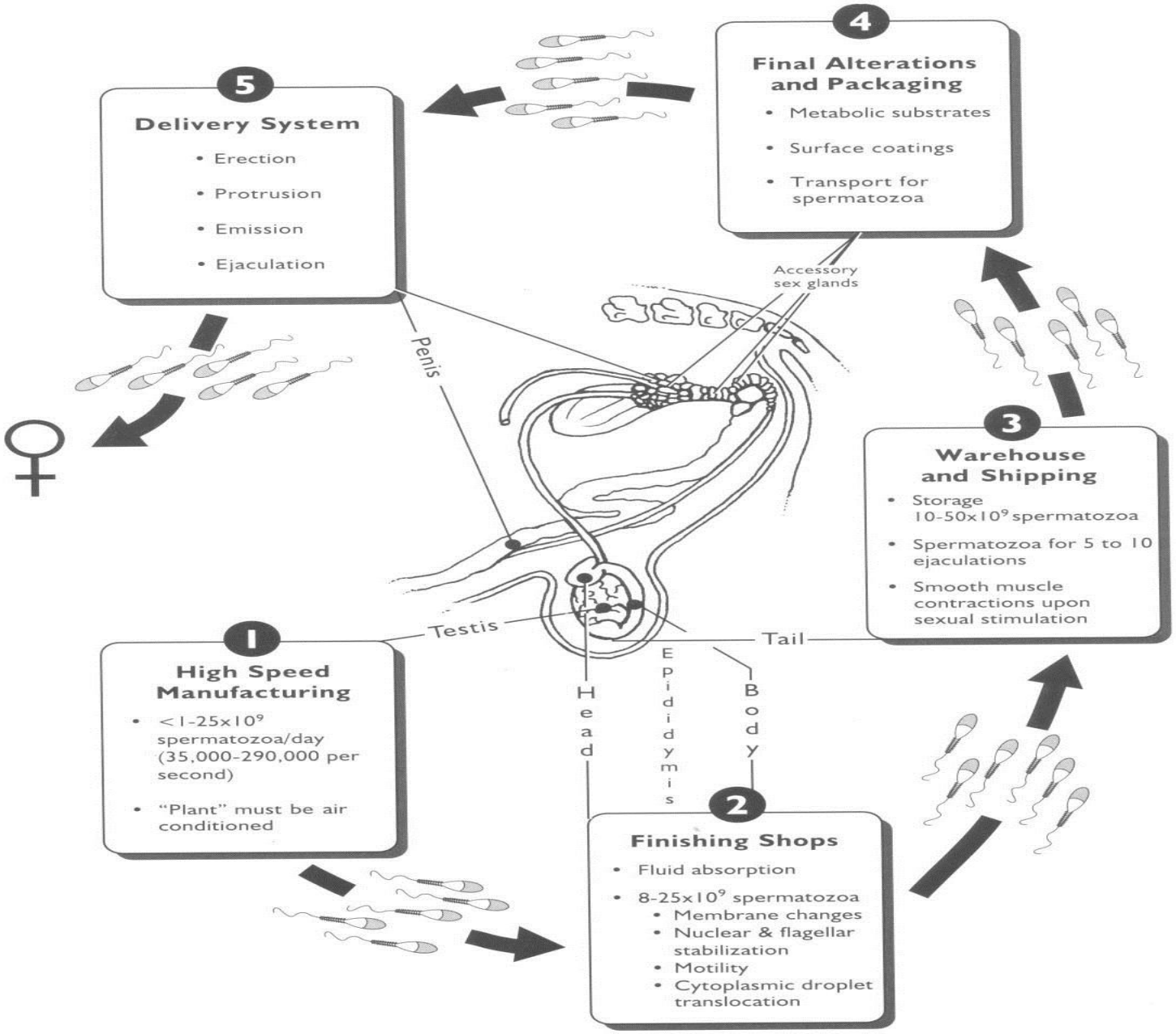
Functional Reproductive Anatomy of the Male

- Many Individual Organs
  - Acting in concert
    - Produce
    - Deliver
      - Sperm to female tract
- Basic Components
  - Spermatic cords
  - Scrotum
  - Testes
  - Excurrent duct system
  - Accessory glands
  - Penis

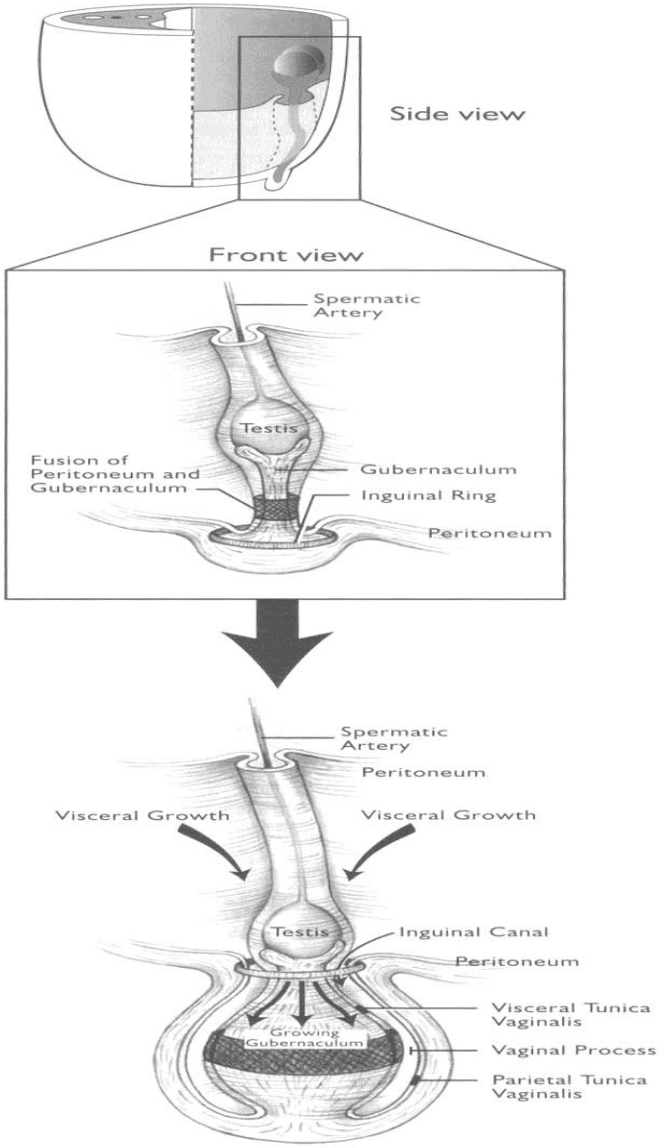



sigmoid colon
bladder
pubic bone
rectum
seminal vesicle
ejaculatory duct
prostate gland
cowper's gland
penis
anus
corpus cavernosum
vas deferens
epididymis
glans penis
foreskin
testis
urethral opening
scrotum

Manufacturing Complex Concept



Testicular Descent

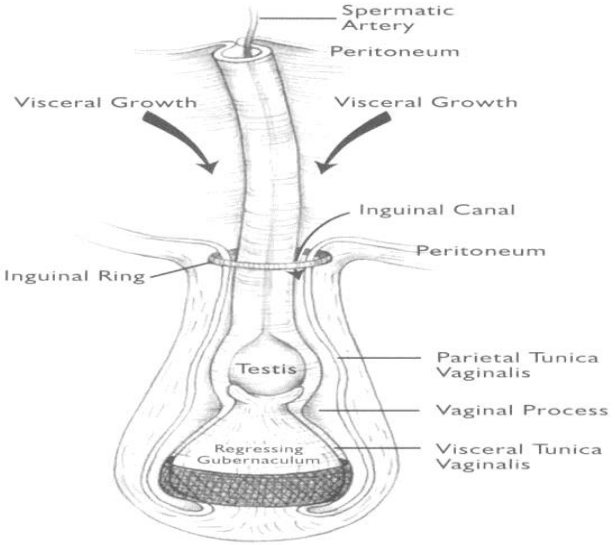


Before actual descent occurs, the testes lie in a retroperitoneal position and are attached caudally to the ligamentous gubernaculum. Cells of the peritoneum infiltrate the gubernaculum in the inguinal region and form a junction with it. This fusion is important because it binds the peritoneum to the gubernaculum and will allow the vaginal process to form as the distal gubernaculum grows toward and into the scrotal region.

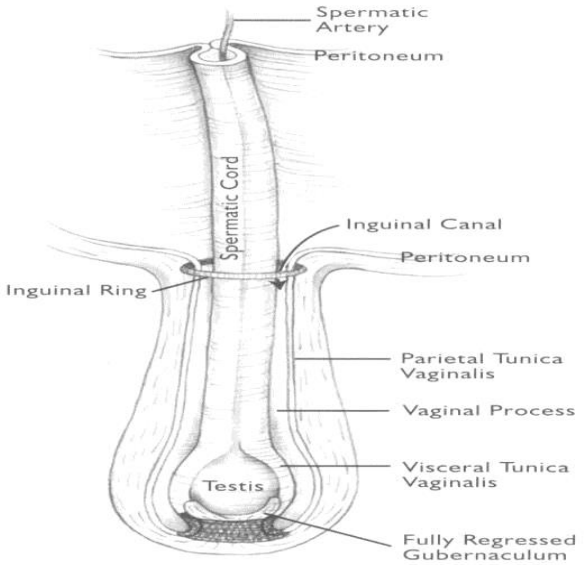
After the gubernaculum penetrates the inguinal ring, there is rapid growth of the distal gubernaculum which results in pulling of both the testes and the peritoneum (vaginal process) into the scrotum. This rapid growth of the gubernaculum in the scrotal region is the "force" responsible for mechanically moving the testes into the inguinal canal.

Figure 4-7. Major steps in the descent of the testes. Growth and subsequent retraction of the gubernaculum causes the testes to descend from the level of the tenth thoracic vertebra into the scrotum. (Graphics by Sonja Oei.)

Testicular Descent



Once the testis is in the inguinal region, it is pulled through the inguinal canal because of regression ("contraction") of the gubernaculum. Also, it is possible that the pressure associated with visceral growth helps "push" the testis or at least hold it near the inguinal ring.



The gubernaculum continues to regress. As this regression occurs, it continues to move the testis deeper into the scrotum and cause a complete encapsulation of the testis by the inner layer of the peritoneum known as the Visceral tunica vaginalis. The outer layer of the peritoneum is the parietal layer of the tunica vaginalis. When the testis has fully descended, the gubernaculum has regressed to a small knot which attaches the testis to the distal scrotum. The vaginal process contributes to the two tunicae of the testis. The inner (visceral) layer covers the testis, epididymis and spermatic cord and the outer (parietal) layer forms a continuous fold which lies directly adjacent to (but is not attached to) the visceral tunica vaginalis.

Time of Testicular Descent

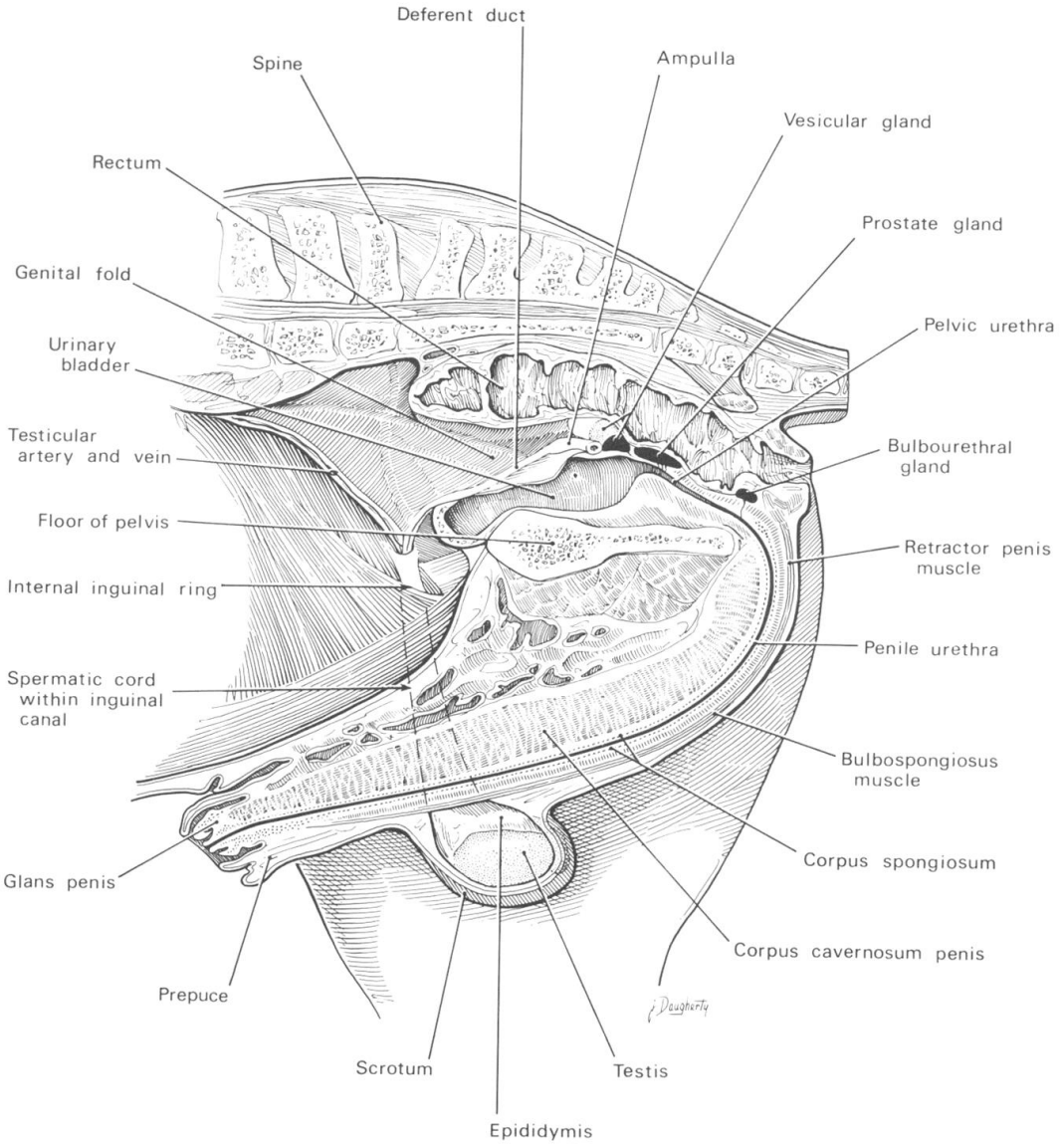
Species	**Testis in Scrotum**
Horse	9 to 11 months of gestation (10 d pp)
Cattle	3.5 to 4 months of gestation
Sheep	80 days of gestation
Pig	90 days of gestation
Dog	5 days after birth (2-3 weeks complete)
Cat	2 to 5 days after birth
Llama	Usually present at birth

Cryptorchidism

- Failure of the testis to fully descend into the scrotum
  - Unilateral
  - Bilateral
    - Sterile
  - Abdominal
  - Inguinal
- Most Common
  - Boars
  - Dogs
  - Stallions
    - Breed effects
- Least common
  - Bulls
  - Rams
  - Bucks

Cryptorchidism

- Abdominal retention
  - Passage through inguinal rings by 2 weeks after birth imperative
- Inguinal location at birth
  - Can occur in many species
  - Remain for weeks or months
    - 2 to 3 years in some stallions

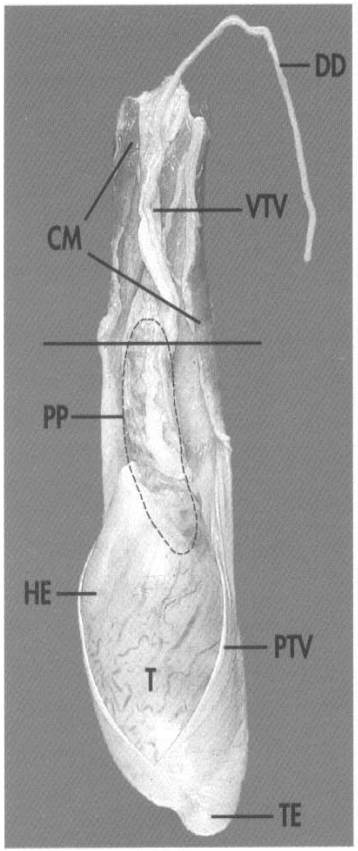


Cryptorchidism

- Causes for concern
  - Reduced fertility
  - Genetic component
    - Mode of inheritance unclear
      - Autosomal recessive in sheep & swine?
  - Neoplasia
  - Spermatic cord torsion
  - Androgen production

Spermatic Cord

- Extends from inguinal ring to suspend testis in scrotum
- Contains
  - Testicular artery
  - Testicular veins
    - Pampiniform plexus
  - Lymphatics
  - Nerves
  - Ductus deferens
  - Cremaster muscle*



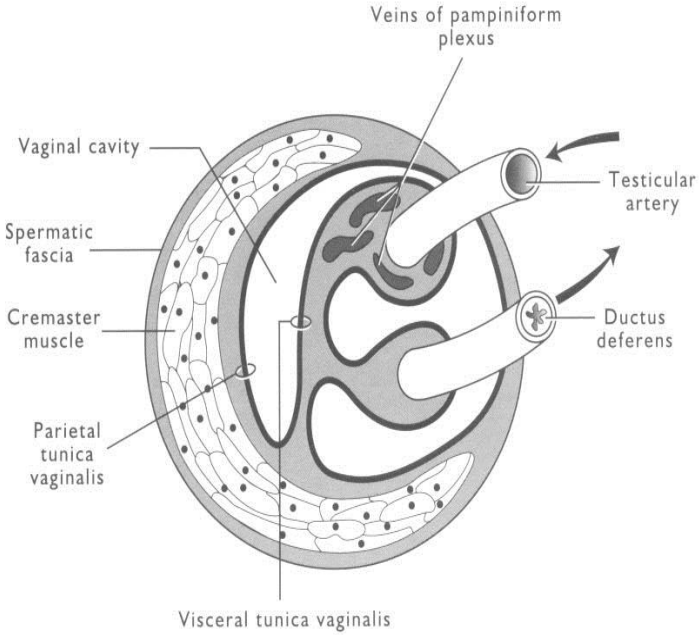


Figure 3-5. Excised spermatic cord and testis of the bull (left panel) and a schematic illustration of a cross section of the spermatic cord (right panel). Arrows indicate direction of fluid flow. The line across the excised spermatic cord indicates the approximate plane of the cross-sectional schematic. The excised spermatic cord has been incised to expose the interior. CM = Cremaster Muscle; DD = Ductus Deferens; HE = Head of Epididymis; PP = Pampiniform Plexus; PTV = Parietal Tunica Vaginalis; T = Testis; TE = Tail of Epididymis; VTV = Visceral Tunica Vaginalis. (Schematic modified from Dyce, Sack and Wensing, *Textbook of Veterinary Anatomy. 2nd Edition.*)

Vascular Supply to the Testes

- Testicular arteries
  - R: off aorta
  - L: off left renal artery
- Testicular veins
  - R: off vena cava
  - L: off left renal vein

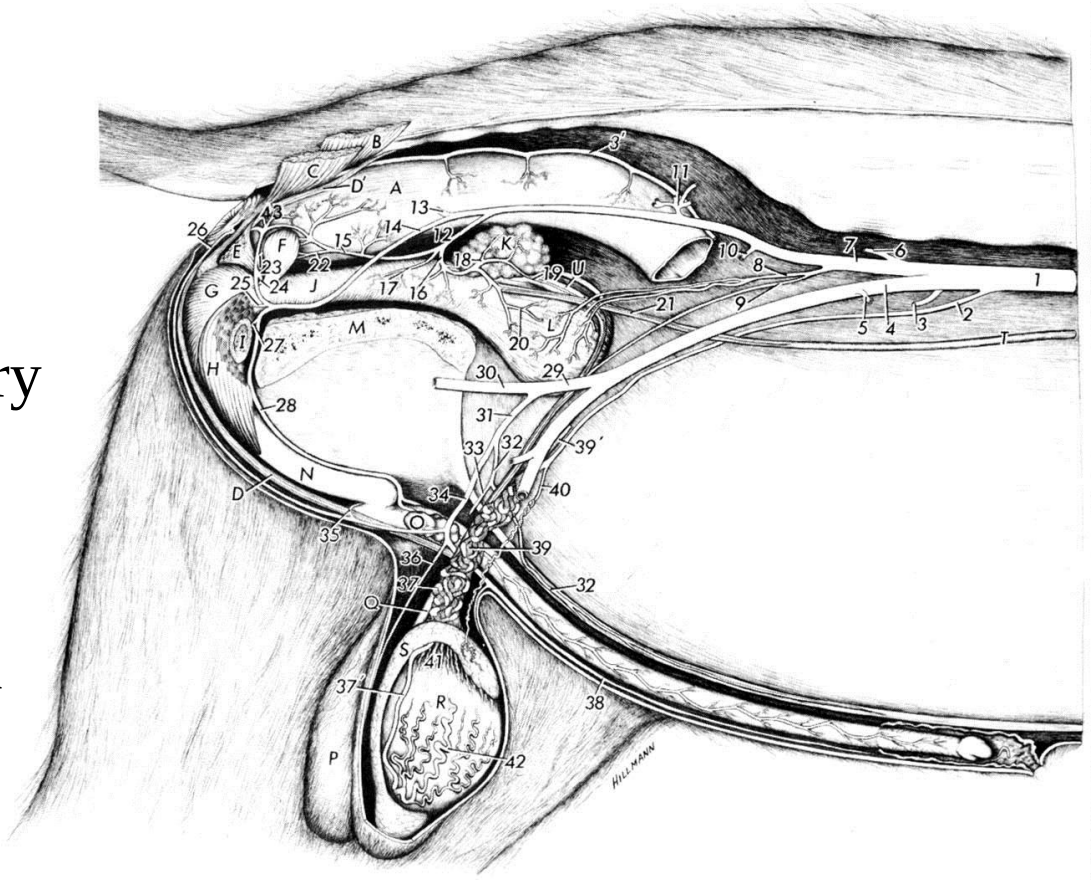
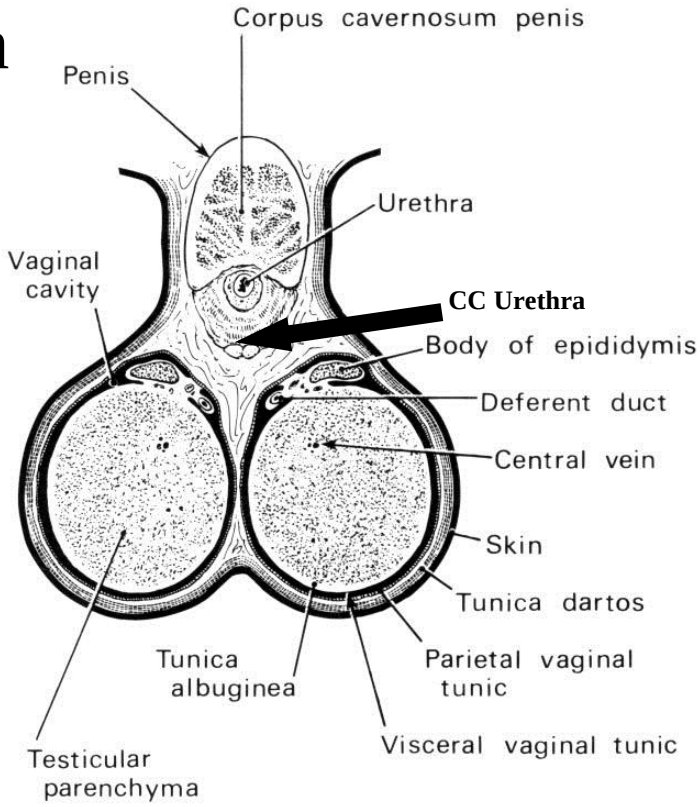


FIGURE 33–15. Arteries to genital tract of male goat (schematic).

Scrotum

- Present in most male mammals
- Diverticulum of the abdomen
  - Two scrotal sacs
- Four major layers
  - Parietal tunica vaginalis
  - Scrotal fascia
  - Tunica dartos
  - Skin
    - Sweat glands



Thermoregulation of the Testes

- 4-6°C below body temperature
  - Normal spermatogenesis
- Cremaster muscle
  - Striated muscle
  - Originates from abdominal wall
    - internal abdominal oblique
- Scrotum
  - Tunica dartos
    - Smooth muscle
  - Sweat glands
  - Thermosensitive neurons
- Pampiniform plexus

Pampiniform Plexus

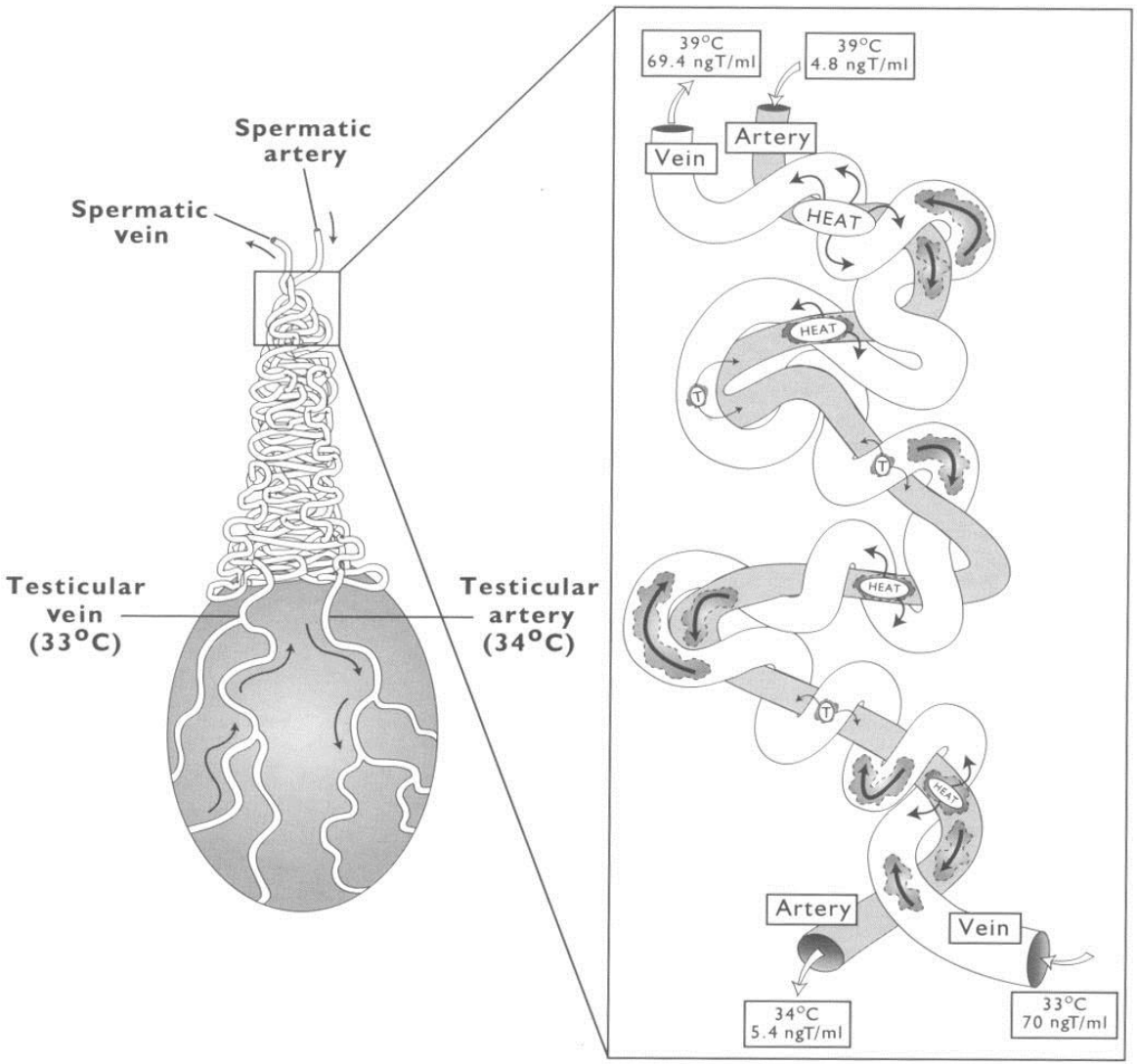


Figure 3-6. The pampiniform plexus as a countercurrent heat exchanger and testosterone exchanger. Warm (39°C) arterial blood is cooled on its way to the testis because the artery lies in close apposition to the veins returning cooler blood (33°C) to the body and a large (6°C) temperature gradient exists. (Graphic by Sonja Oei.)

Thermoregulation of the Testes

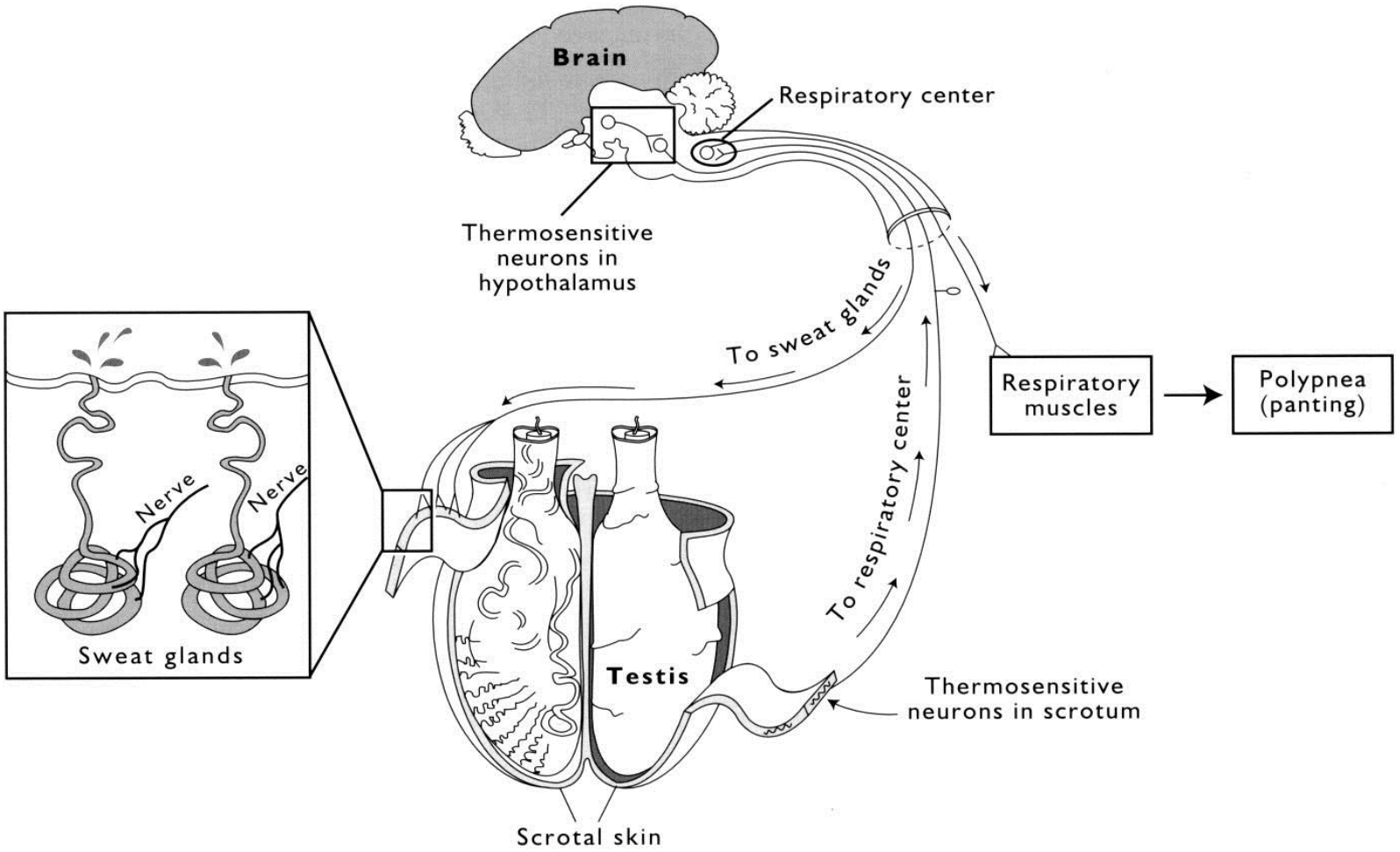
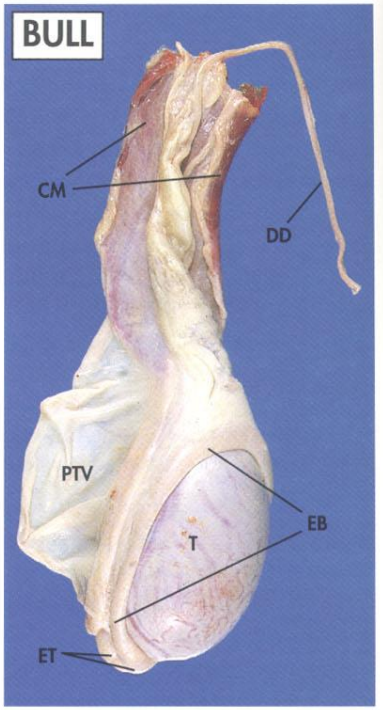


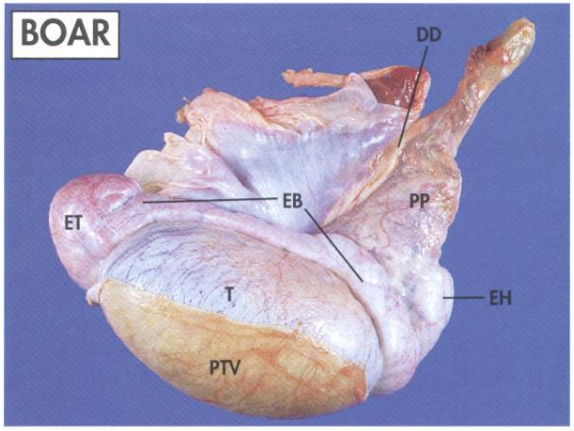
Figure 3-8. Proposed pathway for scrotal sweating and thermal polypnea in the ram. This reflex pathway resulting in polypnea is not activated until scrotal temperature reaches about 36°C. (Graphic by Sonja Oei.)

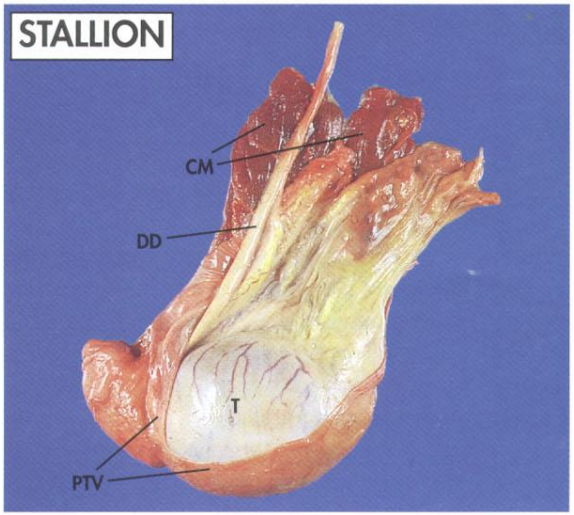
Testis

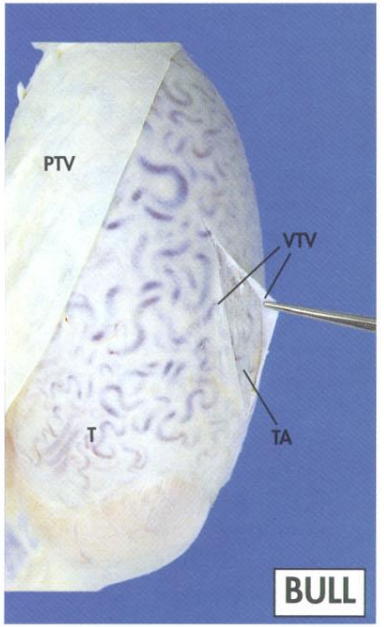
- Primary Functions
  - Exocrine: Spermatozoa
  - Endocrine: Hormones
    - Androgens & Estrogens
    - Facilitate
      - Spermatogenesis
      - Sexual differentiation
      - Development of 2° sexual characteristics
      - Libido
  - Proteins
- Scrotal Orientation
  - Varies with species

Figure 3-10. Excised testicles from the bull, boar and stallion. The parietal tunica vaginalis (PTV) has been incised and reflected away from the testis. The lower right panel illustrates the intimate relationship between the tunica albuginea (TA) and the visceral tunica vaginalis (VTV). CM = Cremaster Muscle; DD = Ductus Deferens; EB = Epididymal Body; EH = Epididymal Head; ET = Epididymal Tail; PP = Pampiniform Plexus; PTV = Parietal Tunica Vaginalis; T = Testis; TA = Tunica Albuginea; VTV = Visceral Tunica Vaginalis.



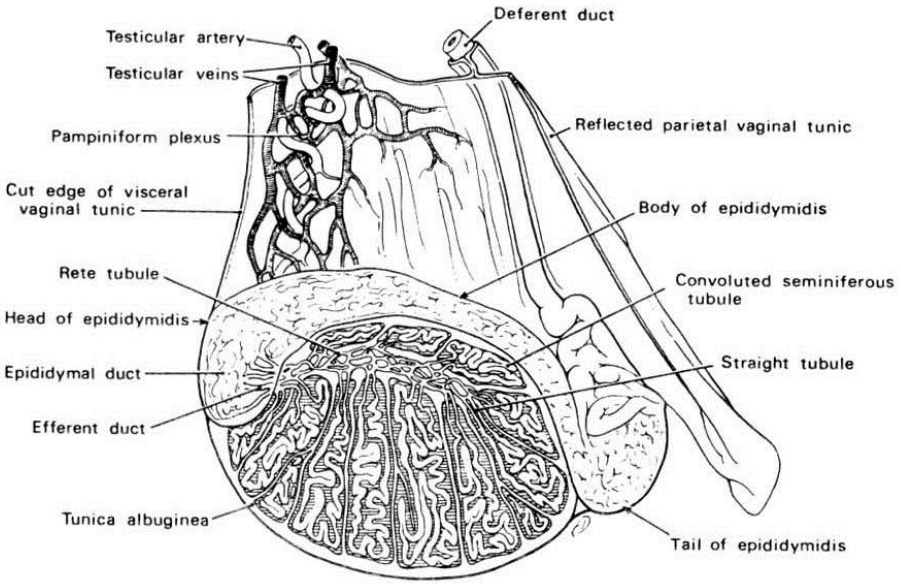


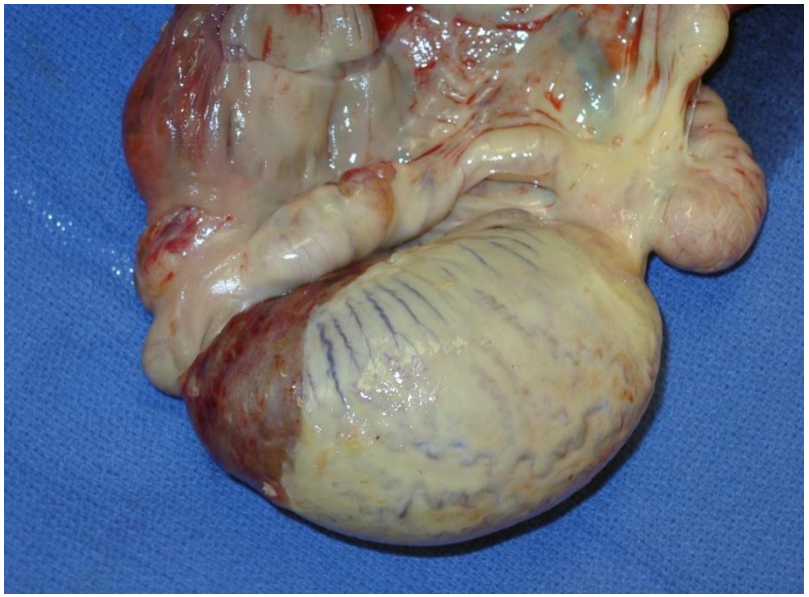




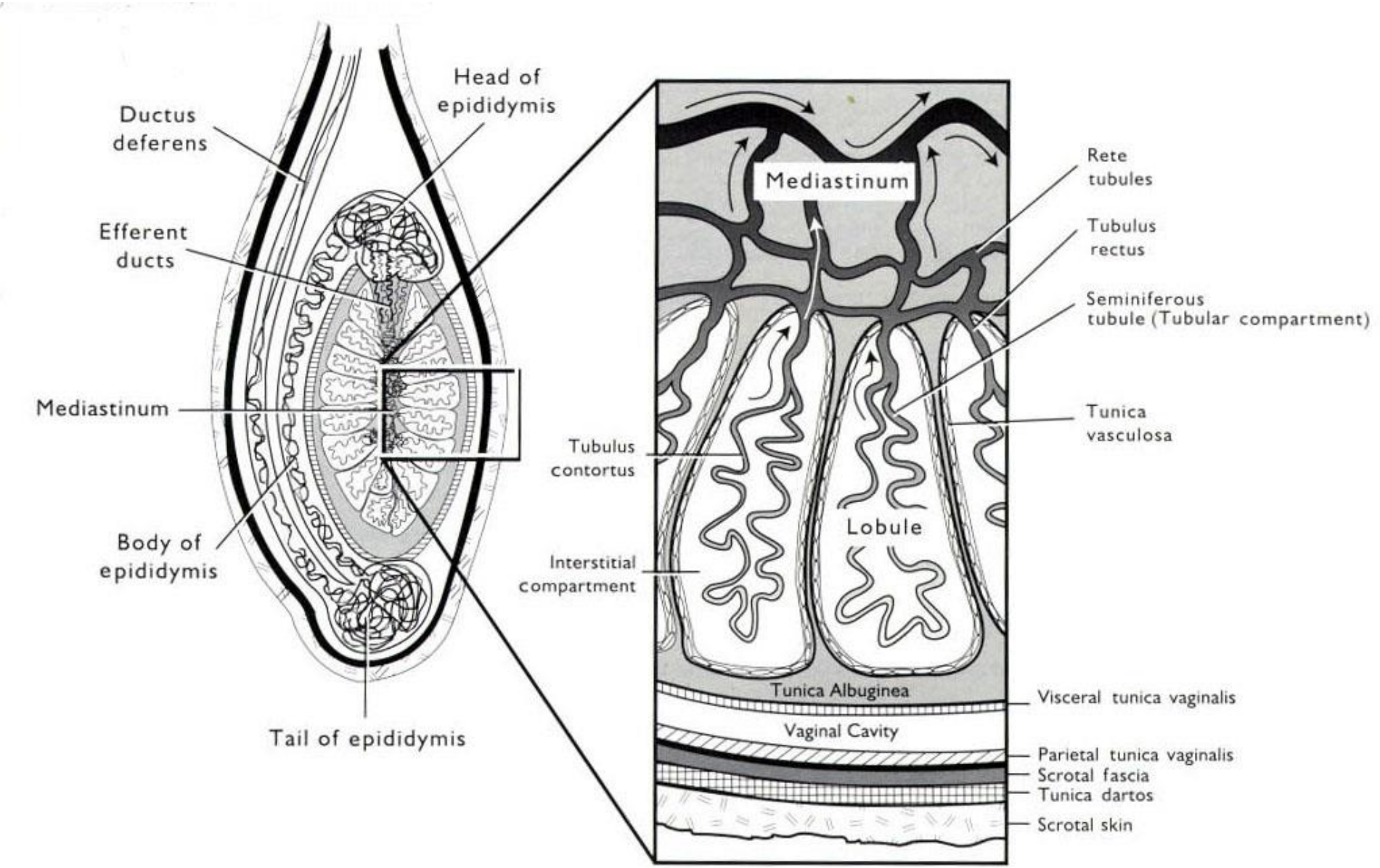
Testicular Anatomy

- Capsule
  - Visceral vaginal tunic
  - Tunica albuginea
    - Penetrates parenchyma
    - Divides testis into lobules
    - Joins mediastinum
    - Supporting layer
    - Rhythmic contractions
- Parenchyma
- Mediastinum
  - Rete Tubules
- Efferent ducts





Testicular Anatomy



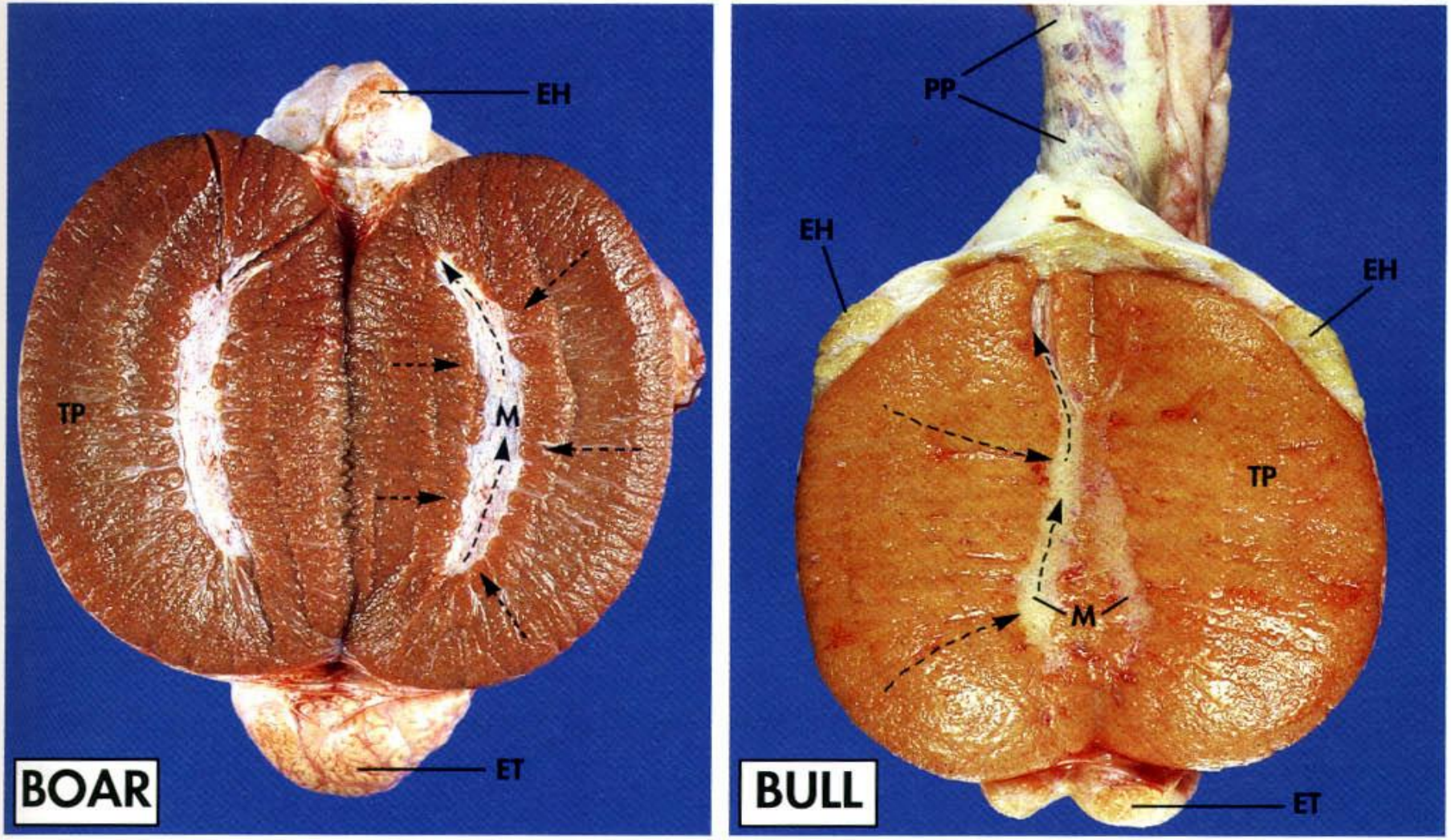
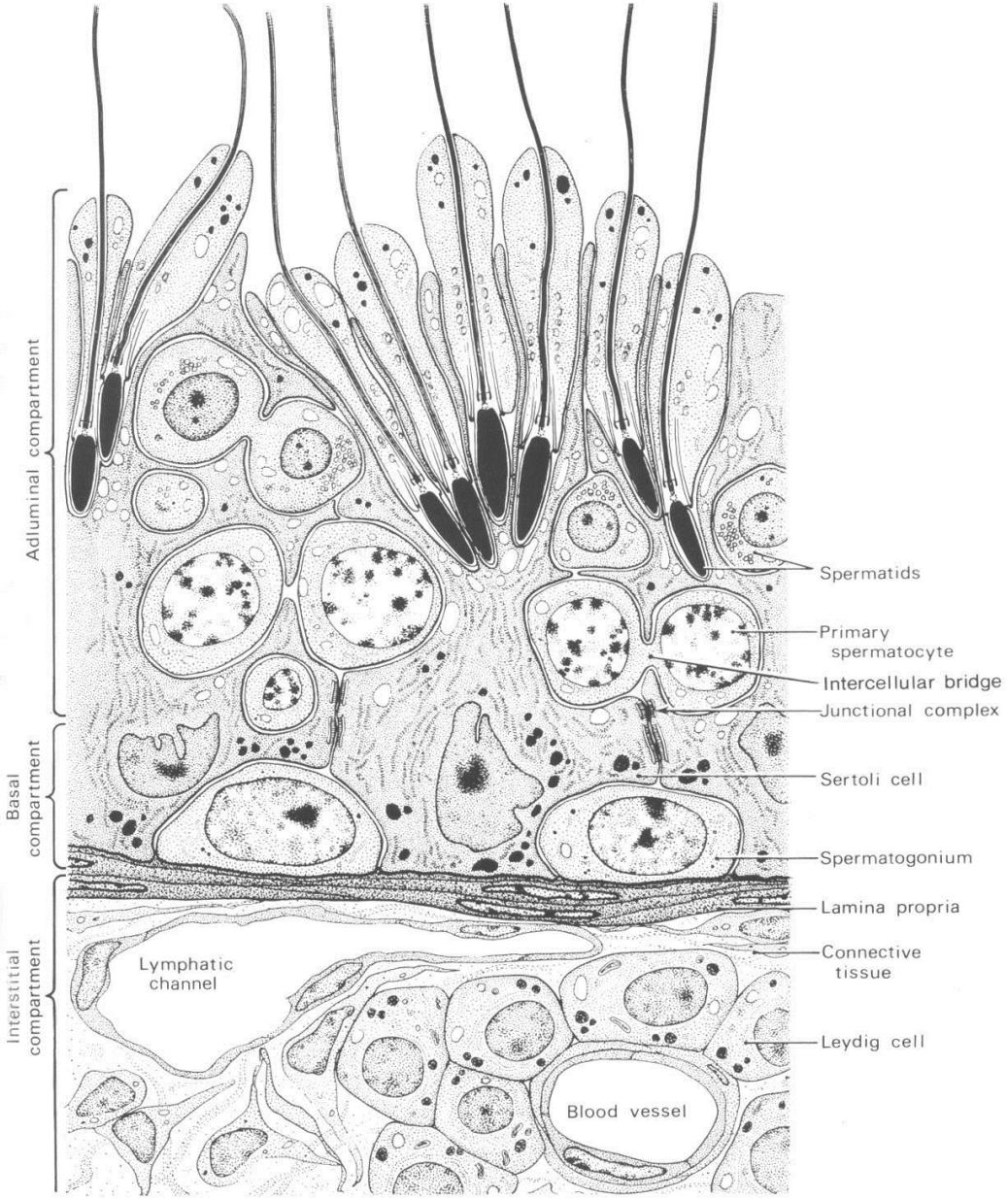


Figure 3-11. The top two panels show a testis from a boar and a bull which have been incised longitudinally to expose the testicular parenchyma (TP) and the mediastinum (M). Arrows denote direction of flow of spermatozoa and fluids toward the efferent ducts and the head of the epididymis. The efferent ducts are not visible in these photographs. EH = Epididymal Head; ET = Epididymal Tail; M = Mediastinum; PP = Pampiniform Plexus; TP = Testicular Parenchyma.

Parenchyma occupies ~ 90% of testis mass

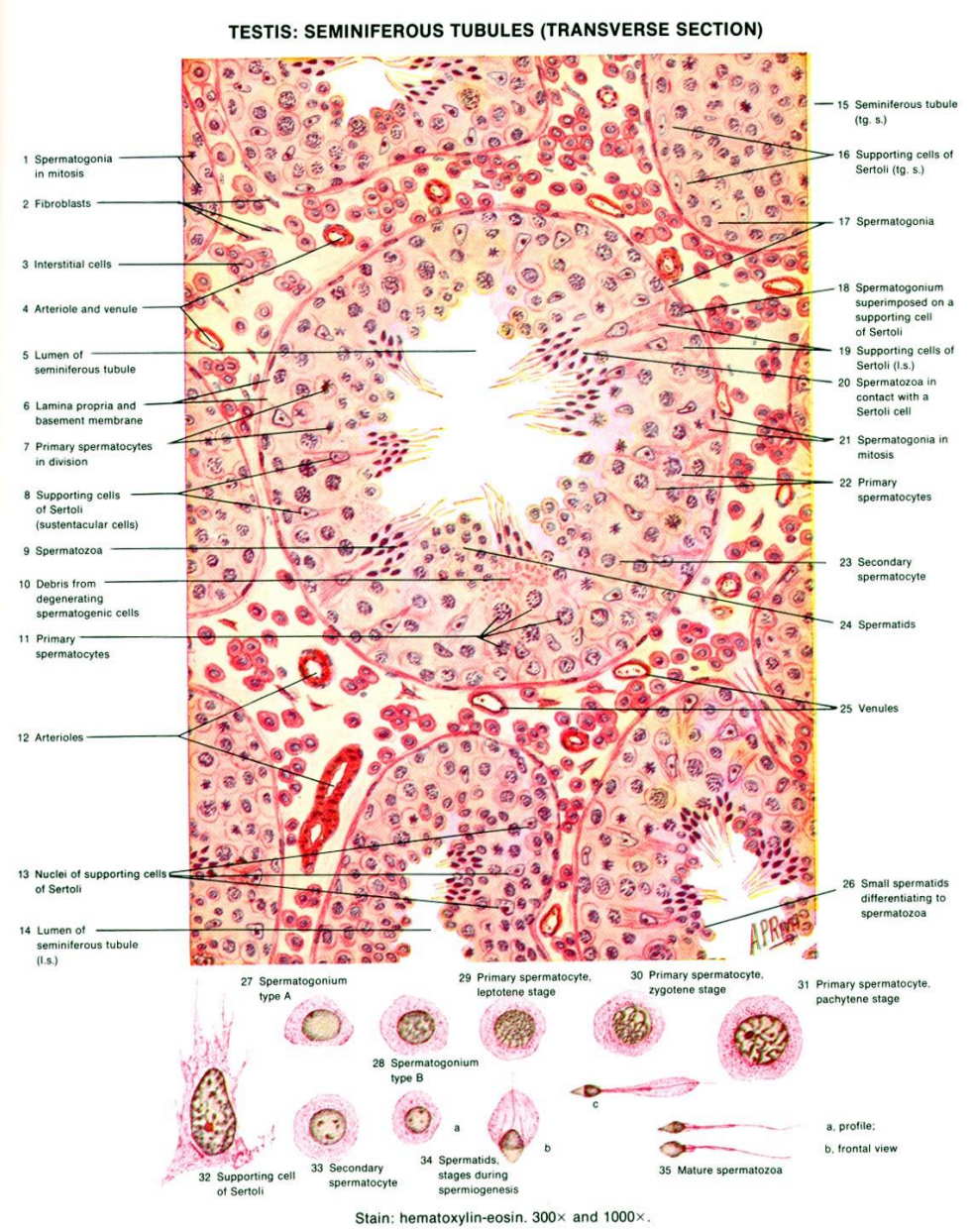
Testicular Parenchyma

- Tubular Compartment
  - Seminiferous tubules
    - Sertoli cells
    - Developing sperm cells
  - Adluminal compartment
  - Basal compartment
    - Lamina propria
      - Peritubular myoid cells
- Interstitial Compartment
  - Leydig cells
  - Blood vessels
  - Lymphatics
  - Connective tissue



Testicular Parenchyma

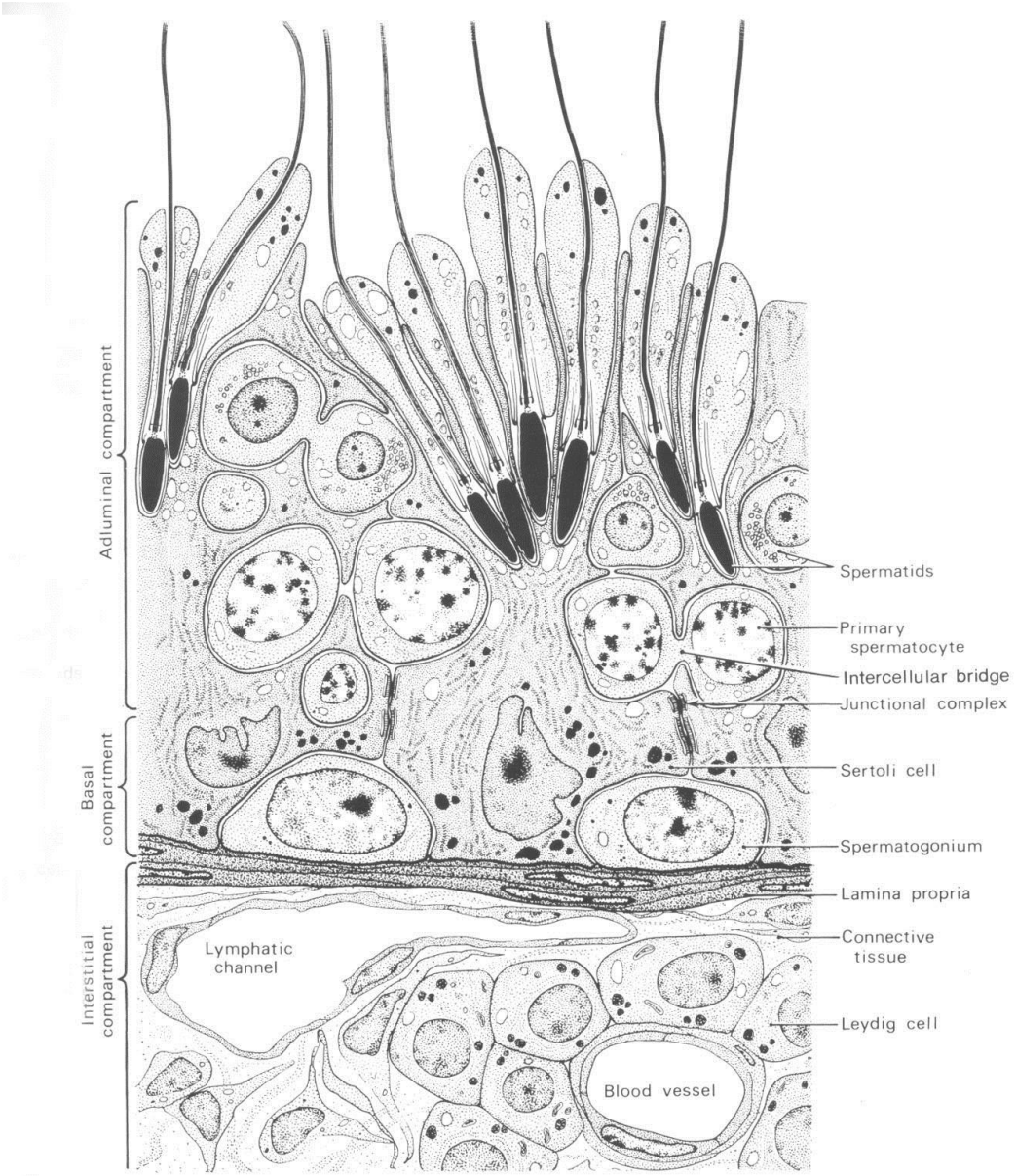
- Seminiferous tubules 70%
- Interstitial Component 30%
  - Leydig cells 12-18%
  - Other interstitial cells 1%
    - Fibroblasts
    - Lymphocytes
    - Mast cells
  - Non-cellular components 5-10%
  - Blood vessels 3-4%
  - Lymphatics 1%



Sertoli Cells

(nurse cells; sustentacular cells)

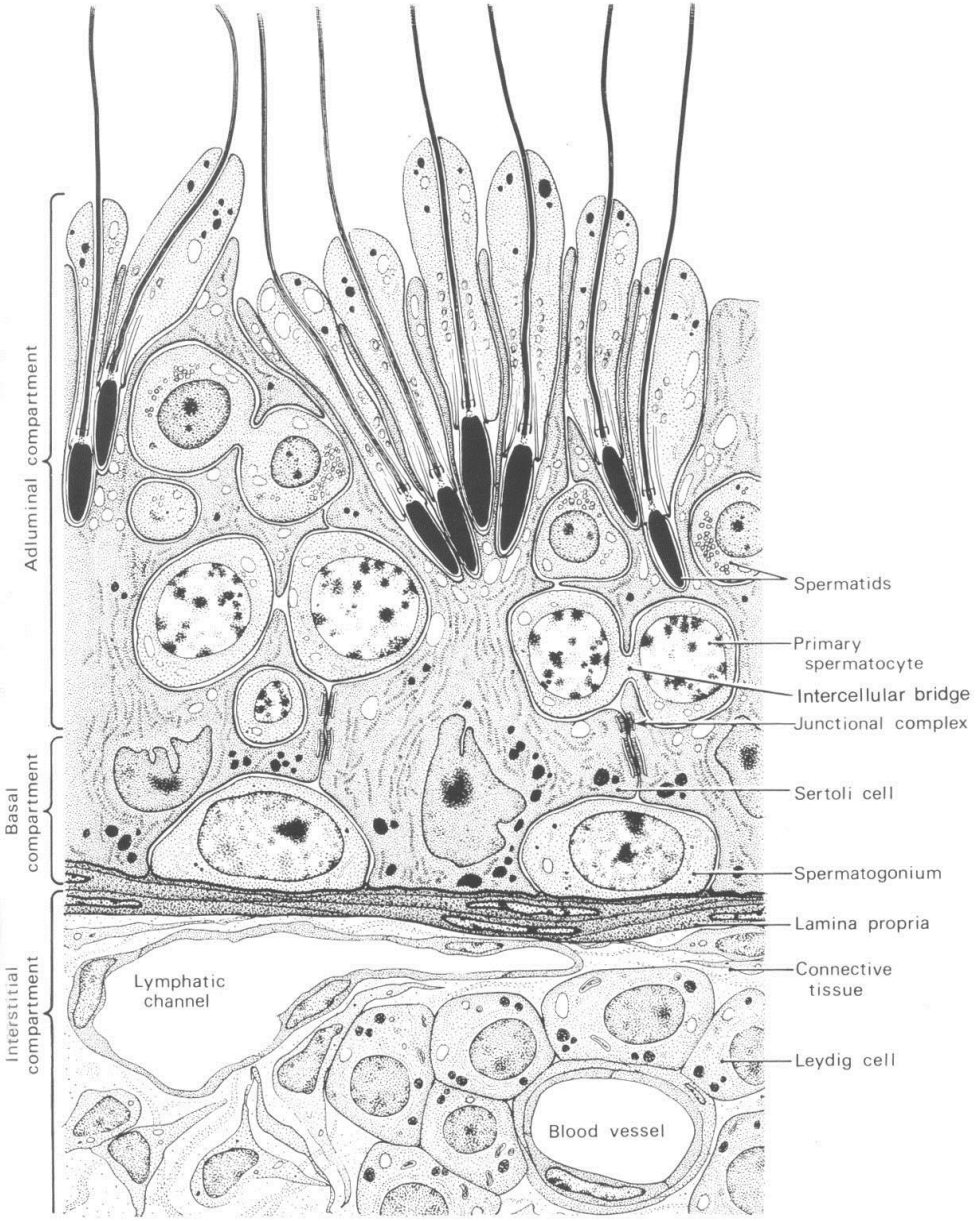
- Somatic cells
  - FSH receptors
  - Testosterone receptors
  - Support & nutrition to developing germ cells
  - Phagocytic
    - Degenerating germ cells
    - Residual bodies
- Number related to sperm production
  - Fixed after puberty?
- Cell to cell communication
- Rich in SER
- Equivalent of granulosa



Sertoli Cells

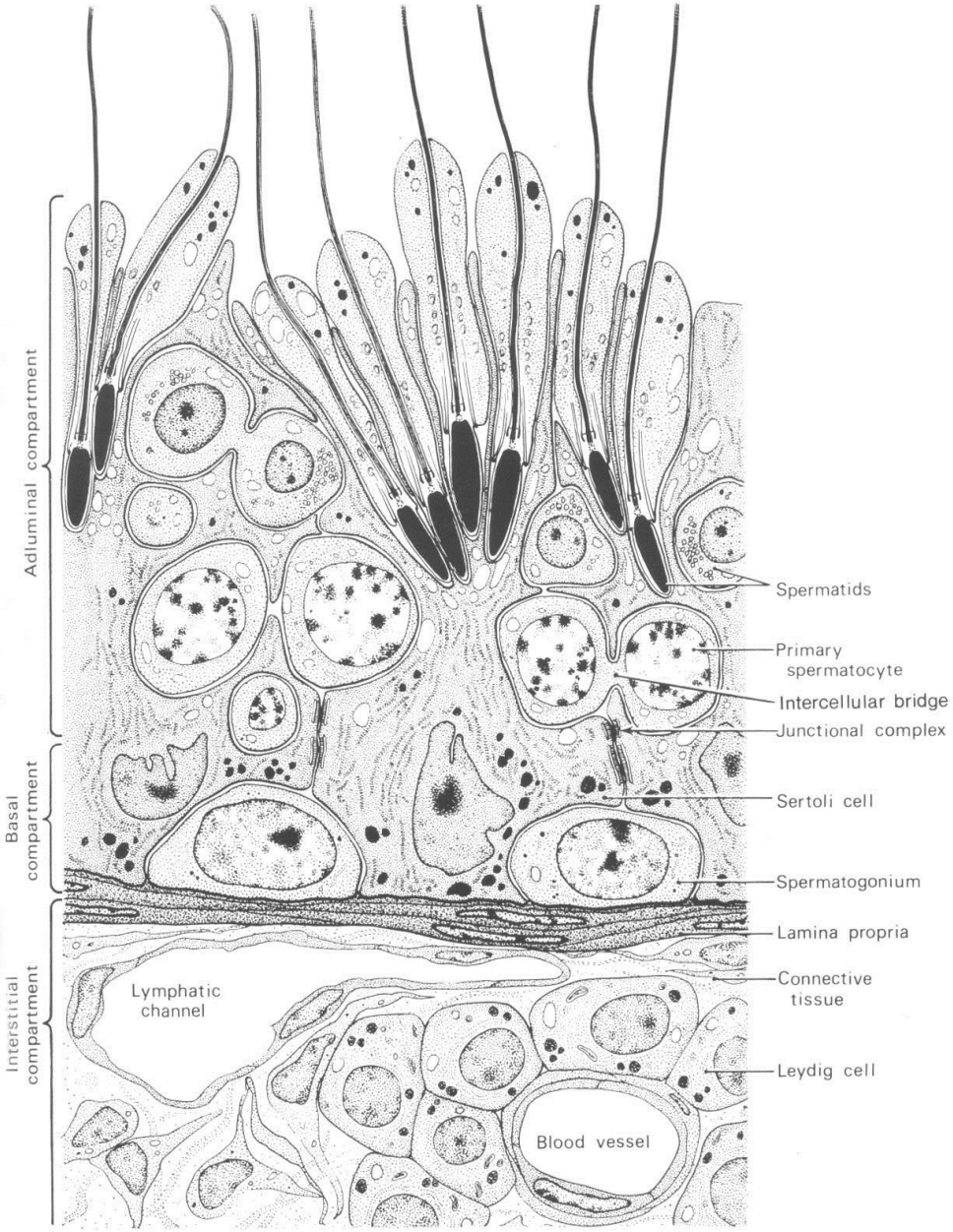
Secretory activity

- Estrogens
- Proteins
  - Inhibin
    - gonadal glycoprotein
      - » preferentially inhibits secretion of FSH
    - 2 active forms: Inhibin A and inhibin B (α & β subunits)
    - FSH stimulates secretion by increasing α subunit
  - Sulfated glycoproteins
    - SGP-1
      - » Fertility acquisition
    - SGP-2
      - » Facilitates movement thru testis
  - Transferrin
    - Iron transport for spermatogenesis
  - Androgen Binding Protein
  - Mitogenic peptide



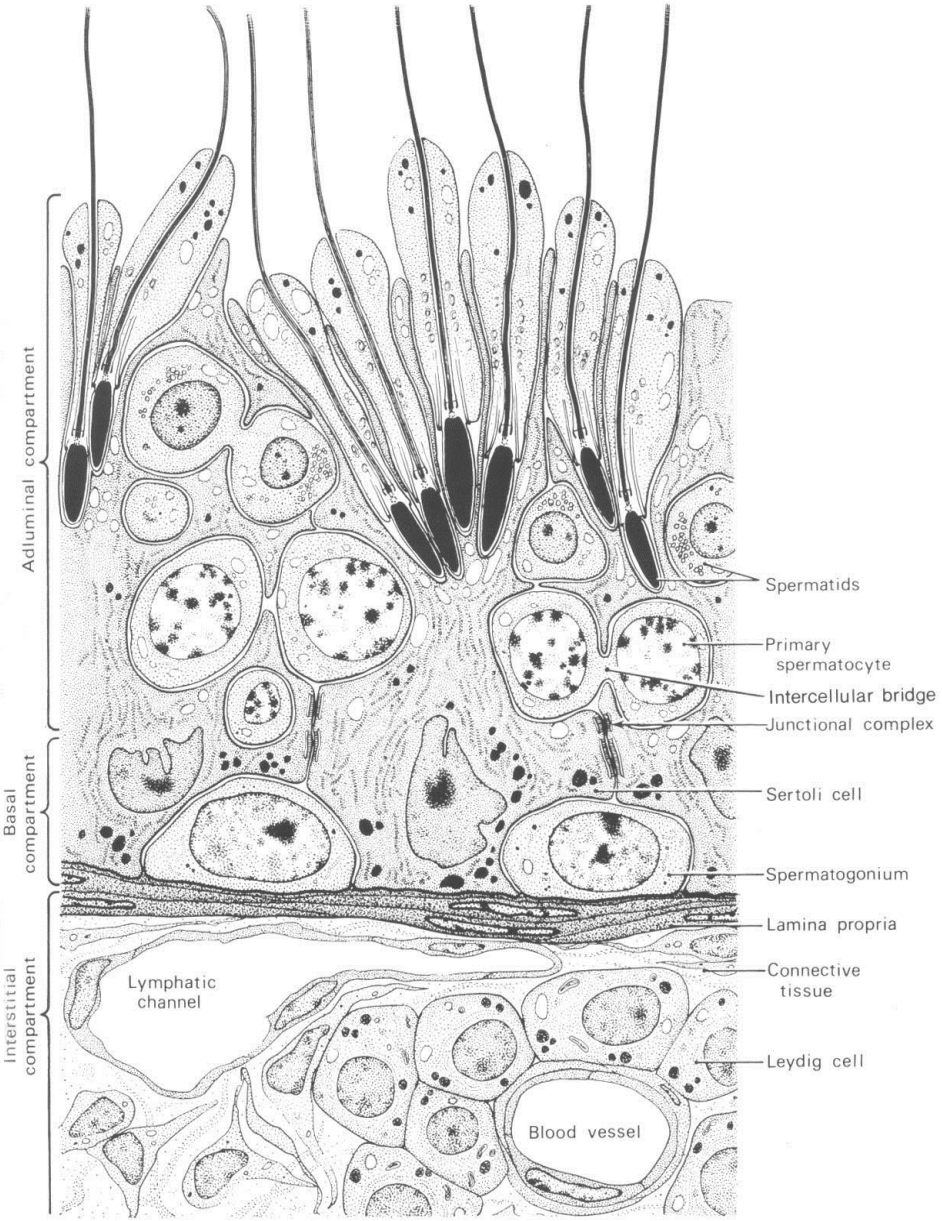
Sertoli Cells

- Tight Junctions
  - Blood Testis Barrier
  - Separate compartments
    - Basal
    - Adluminal
  - Isolates spermatocytes & spermatids
    - General circulation
    - Serum enzymes
    - High molecular weight components
    - Immune system



Leydig Cells
(intersitial cells)

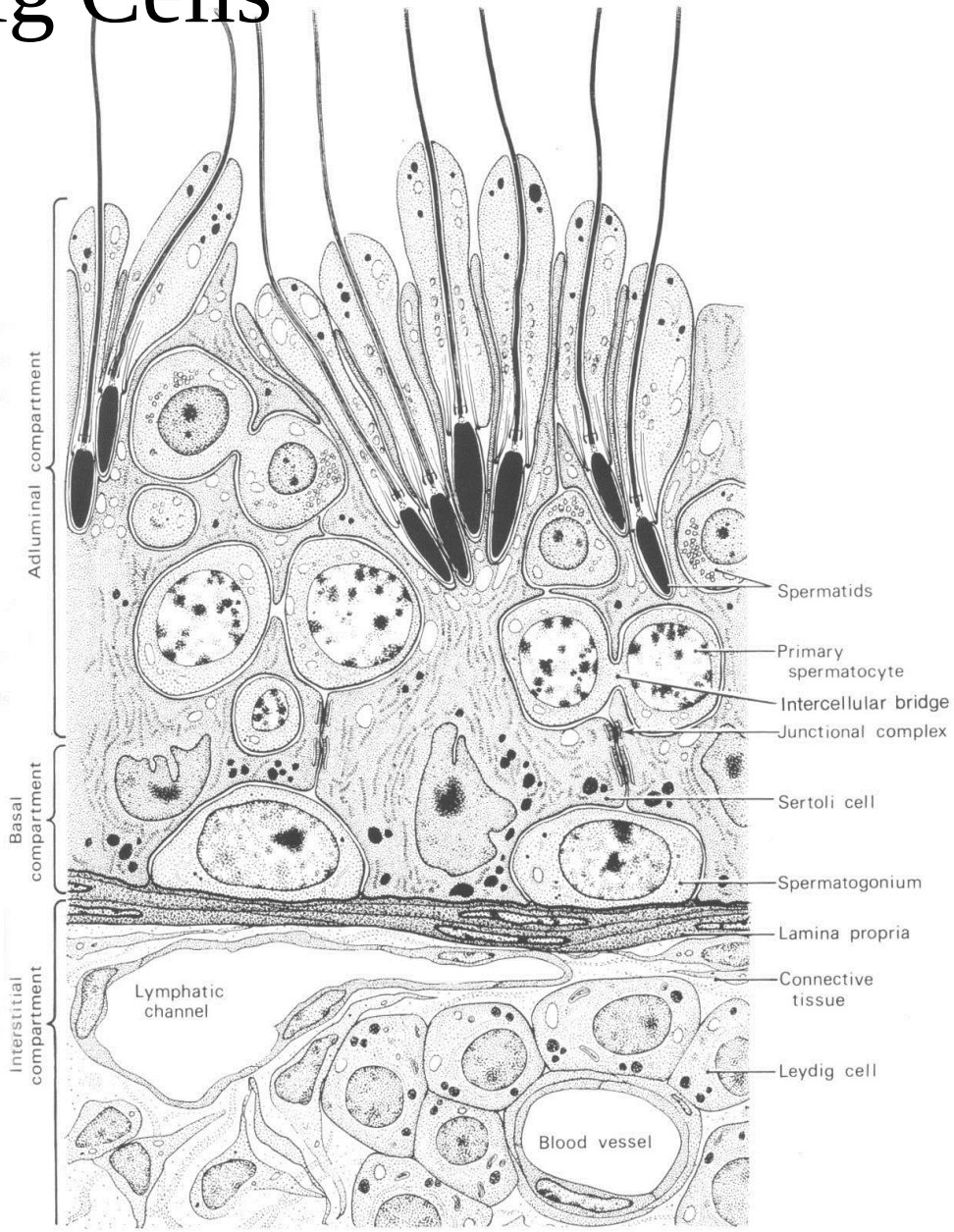
- 1° site of steroidogenesis
  - Testosterone
    - Spermatogenesis
    - 2° sex characteristics
    - Sex drive
  - Estrogen in stallions
    - Aromatase
- Stimulated by LH
  - ↑cAMP & protein kinase
  - ↑ phosphorylation of ribosomal protein, protein turnover
  - ↑ CSCC enzyme
  - Response potentiated by Sertoli cell products



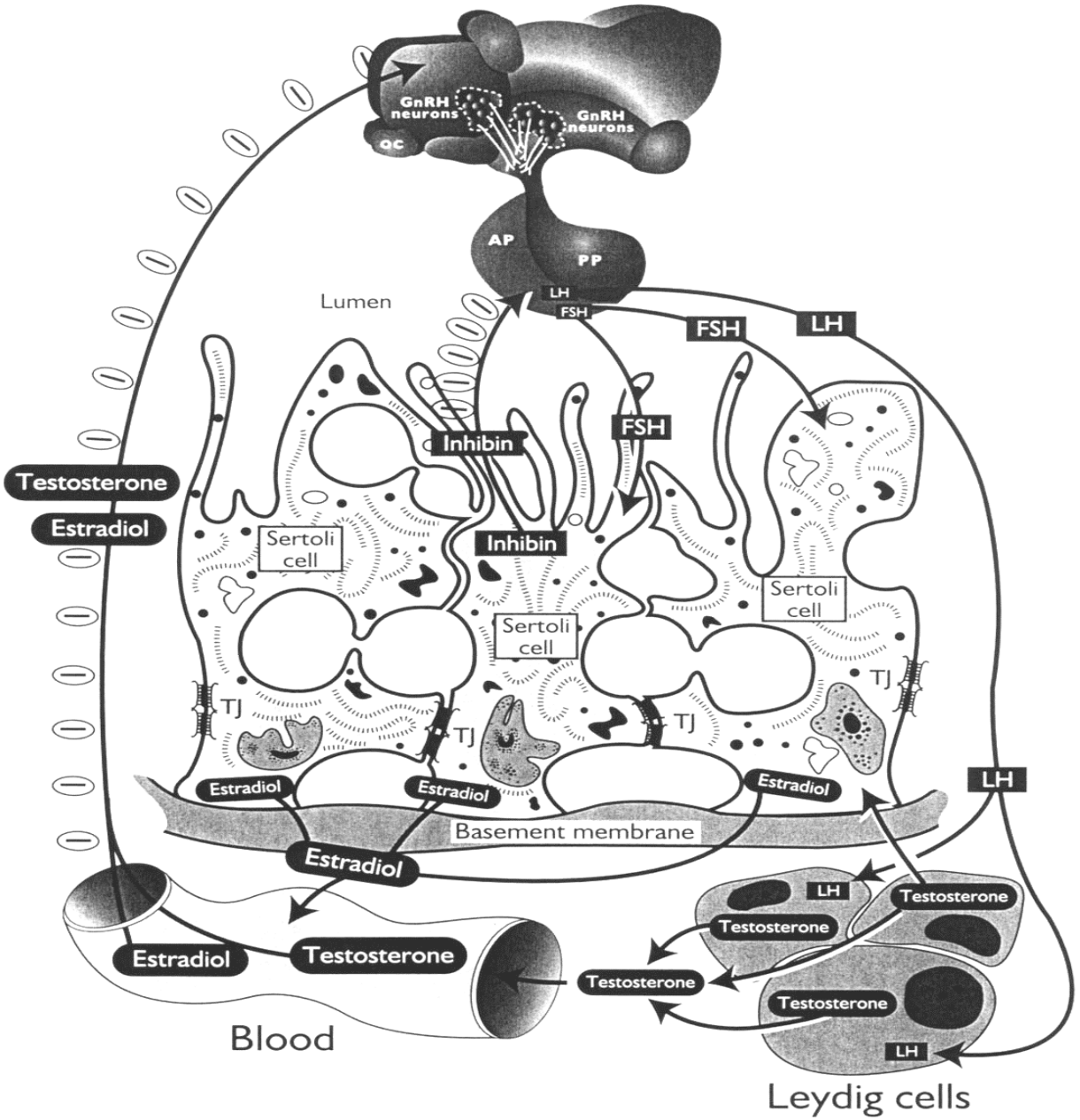
CSCC = Cholesterol Side Chain Cleavage Enzyme

Leydig Cells

- Equivalent of theca interna
- Abundance of
  - Smooth ER (80% v/v)
    - Cholesterol synthesis
  - Mitochondria (10% v/v)
    - Rate limiting SCC step
- Number & volume
  - Age
  - Season



Hypothalamic Pituitary Testicular Axis



HPT Axis & ABP

- Leydig & Sertoli cells act in a paracrine fashion
- Androgen Binding Protein
  - 41 kDa protein binds androgen
  - different from testosterone binding globulin in plasma
  - ABP production stimulated by FSH and androgens

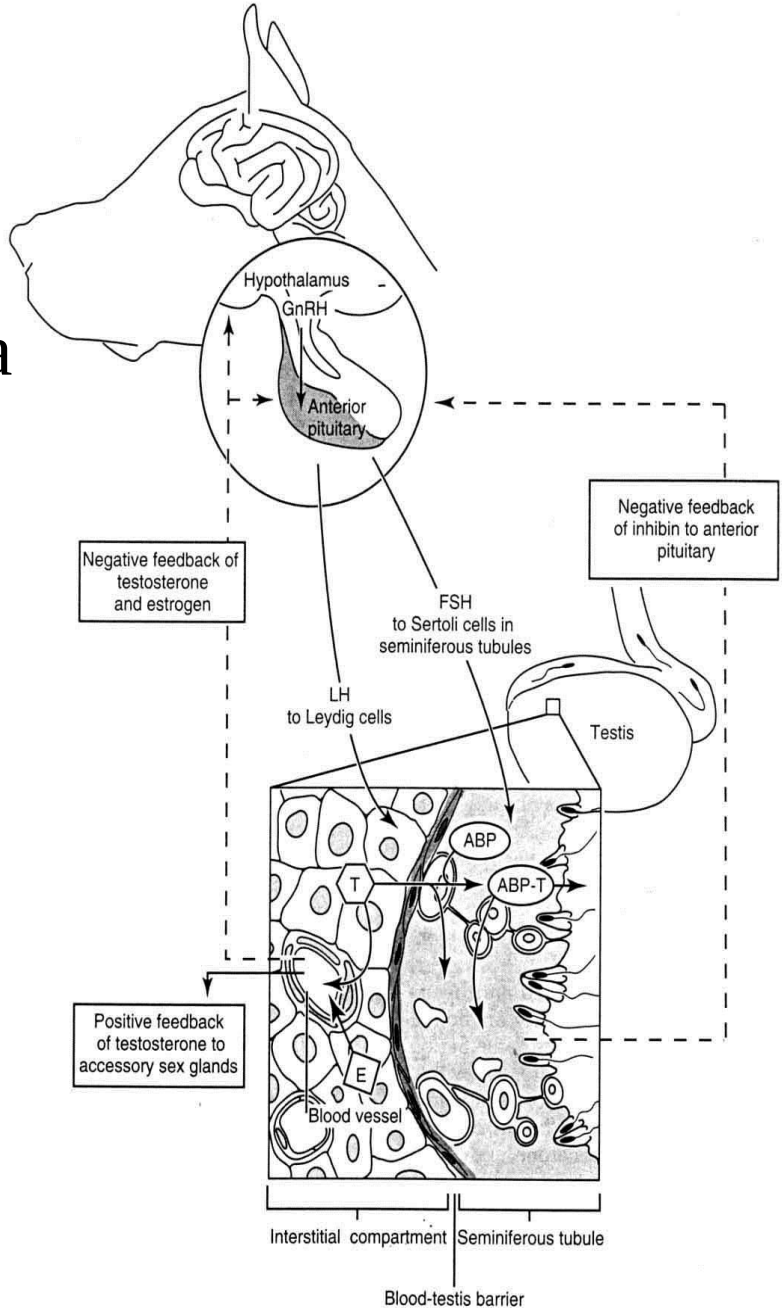


FIGURE 39–2. The reproductive system of male mammals is regulated by intricate feedback mechanisms that involve the hypothalamus, anterior pituitary, and testes. ABP, androgen-binding protein; ABP-T, androgen-binding protein–testosterone; E, estrogen; FSH, follicle-stimulating hormone; GnRH, gonadotropin-releasing hormone; LH, luteinizing hormone; T, testosterone.

HPT Axis & ABP

- ABP Functions
  - ↑↑ Local [T] & [DHT]
    - Interstitium & seminiferous tubules
      - 70 mg/g parenchyma vs.
      - 400 pg/ml serum in circulation
    - Essential for normal spermatogenesis
  - Androgens to epididymis

T = Testosterone
DHT - Dihydrotestosterone

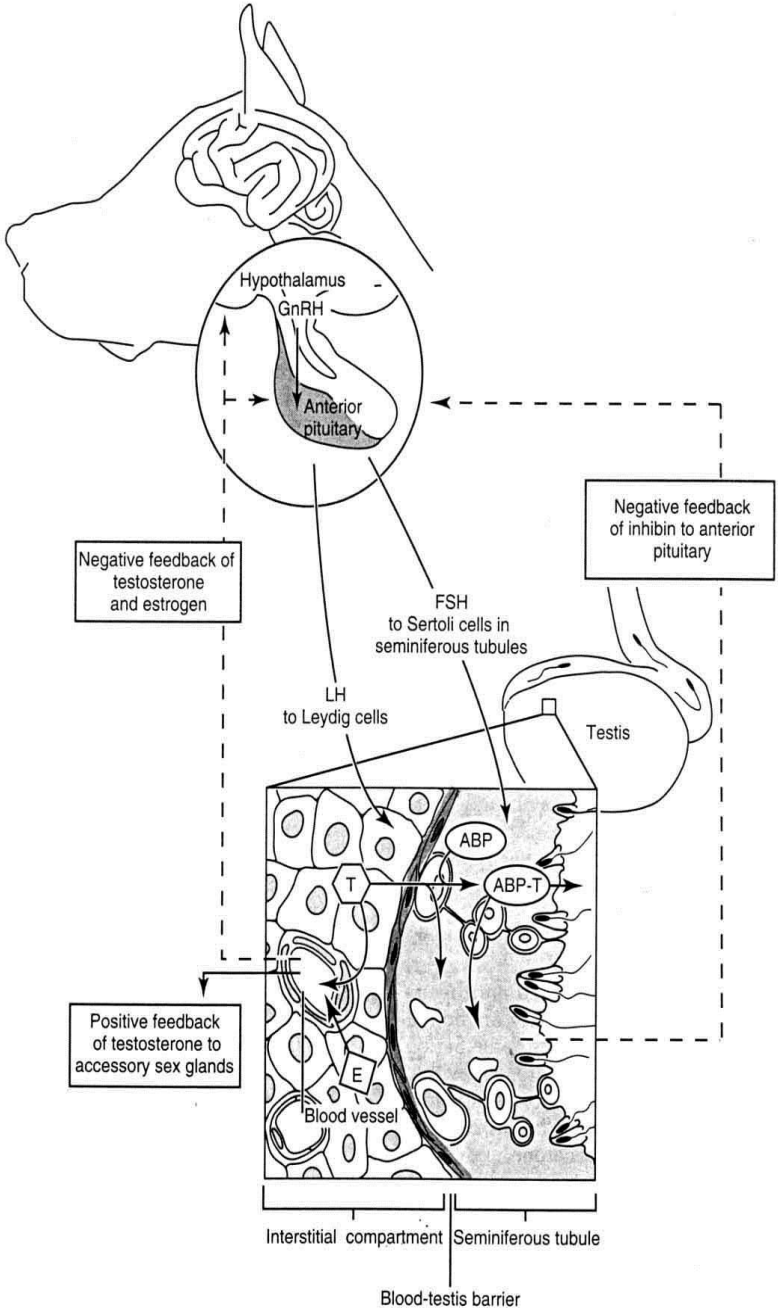
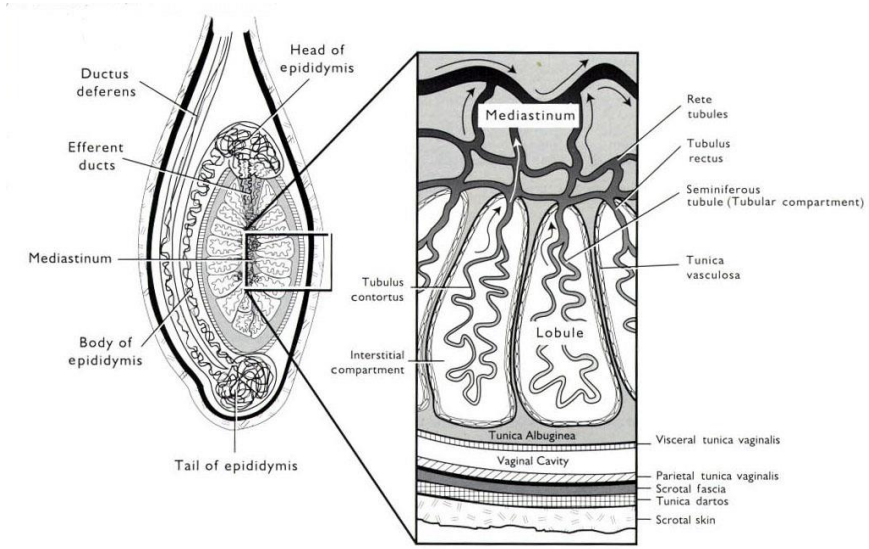


FIGURE 39–2. The reproductive system of male mammals is regulated by intricate feedback mechanisms that involve the hypothalamus, anterior pituitary, and testes. ABP, androgen-binding protein; ABP-T, androgen-binding protein–testosterone; E, estrogen; FSH, follicle-stimulating hormone; GnRH, gonadotropin-releasing hormone; LH, luteinizing hormone; T, testosterone.

Rete Testis

- Network of intercommunicating channels
- Lined with cells ranging from squamous to columnar
- Fluid phase and adsorptive endocytosis
- Carry sperm to epididymis
- Centrally located
  - Ungulates
  - Carnivores
  - Rabbits
- Located along the epididymal edge in primates



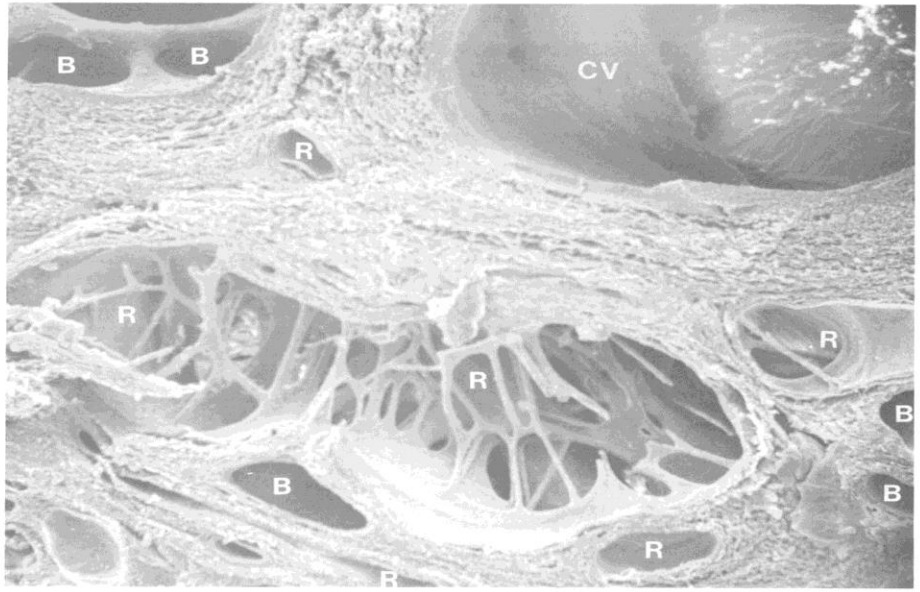
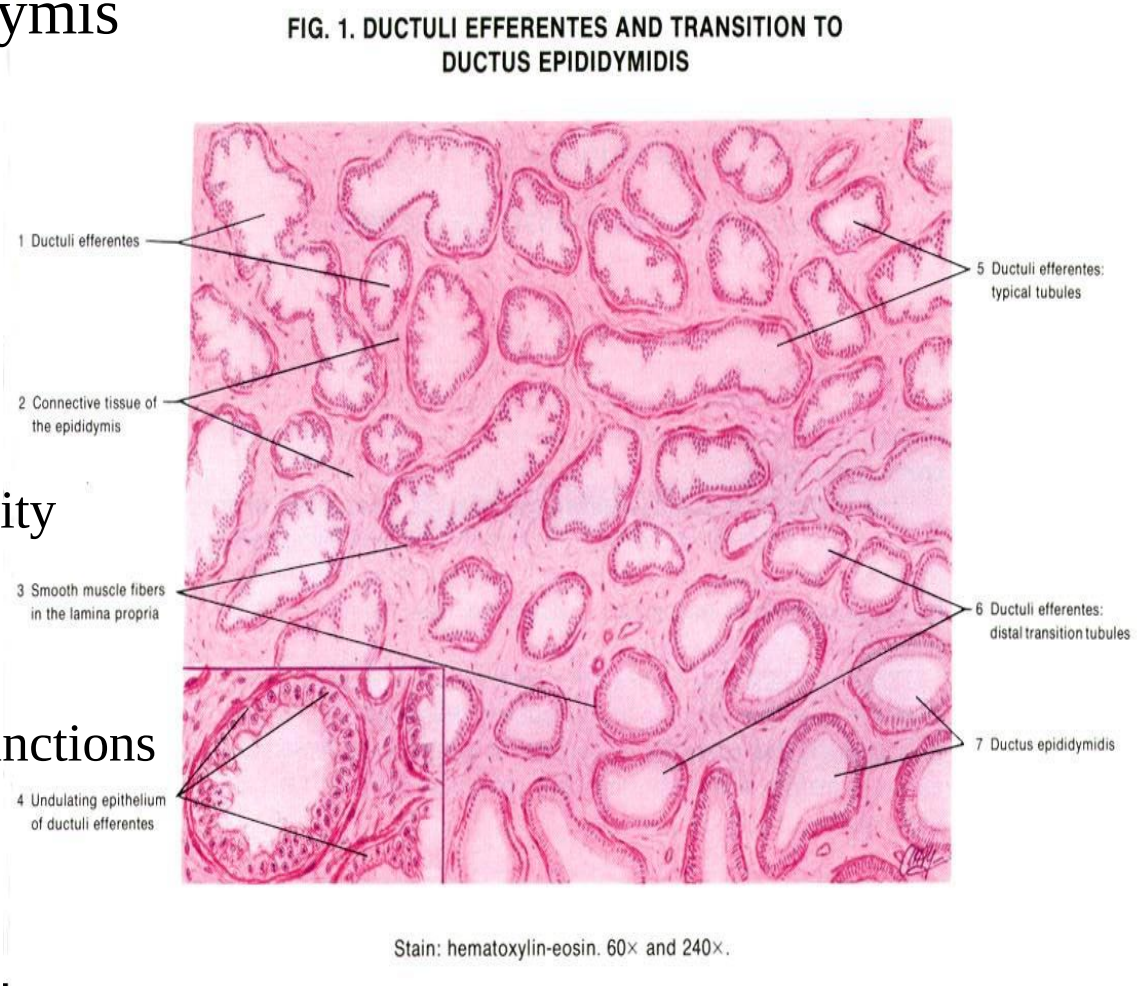


Figure 1-10. A scanning electron micrograph (X60) of the interconnecting tubules within the rete testis near the central vein (CV). Rete tubules (R) and smaller blood vessels (B) are co-mingled in this area. From (9).

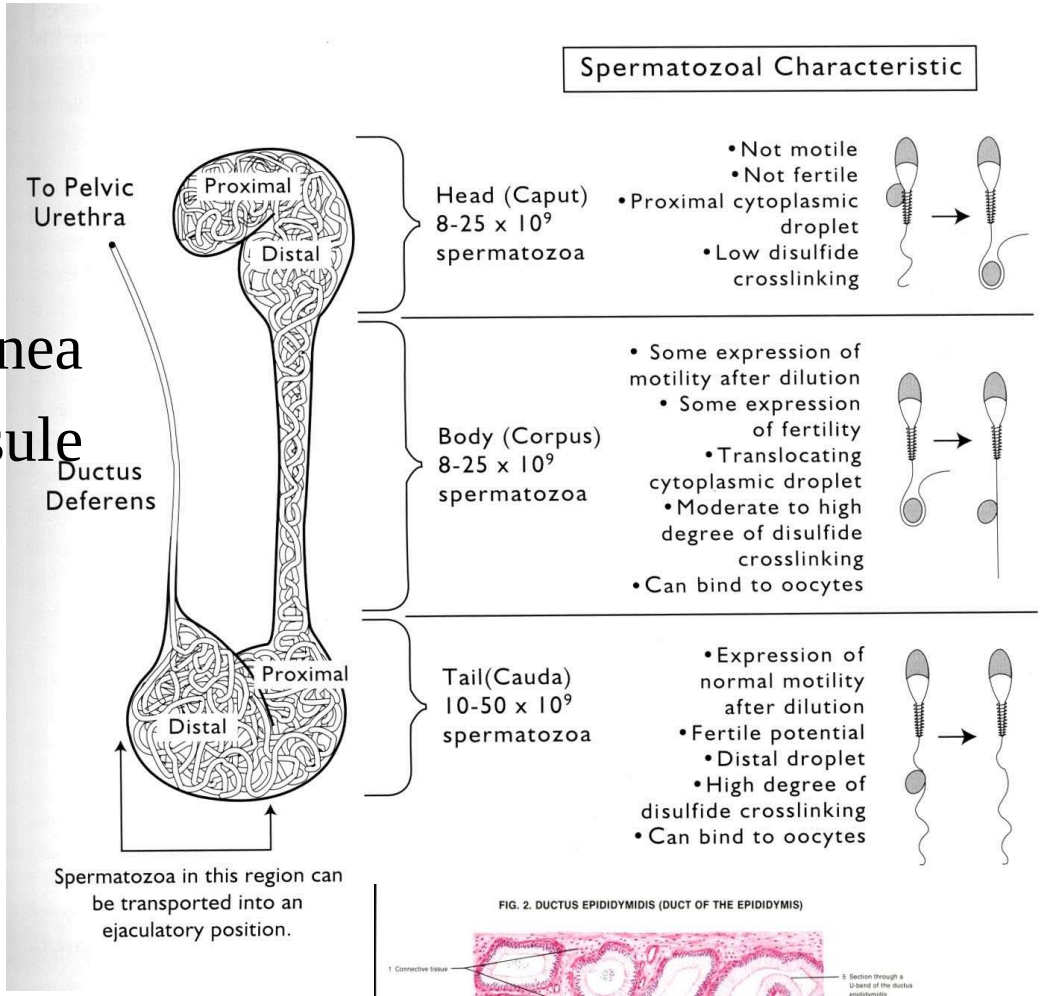
Efferent Ducts

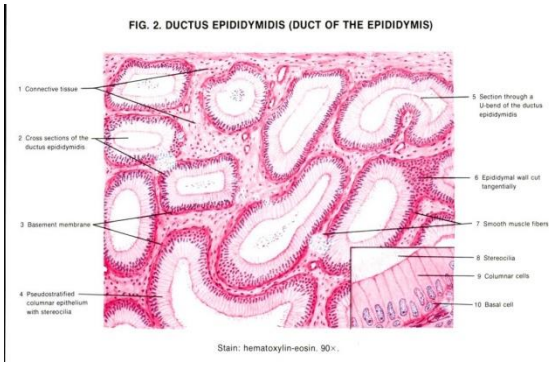
- Link rete testis to epididymis
- Fluid resorption
- High enzymatic activity
  - Acid phosphatase,
  - Esterase
  - Beta-glucuronidase
  - Carbonic anhydrase activity
- Two main cell types
  - Principle: columnar with prominent intercellular junctions
    - Fluid resorption
  - Ciliated
    - Fluid movement



Epididymis

- Single duct
  - Highly convoluted
  - Attached to tunica albuginea
  - Contained in fibrous capsule
  - Three segments
    - Caput
      - Contains efferent ducts
      - Fluid resorption
    - Corpus
      - Maturation
    - Cauda
      - Storage

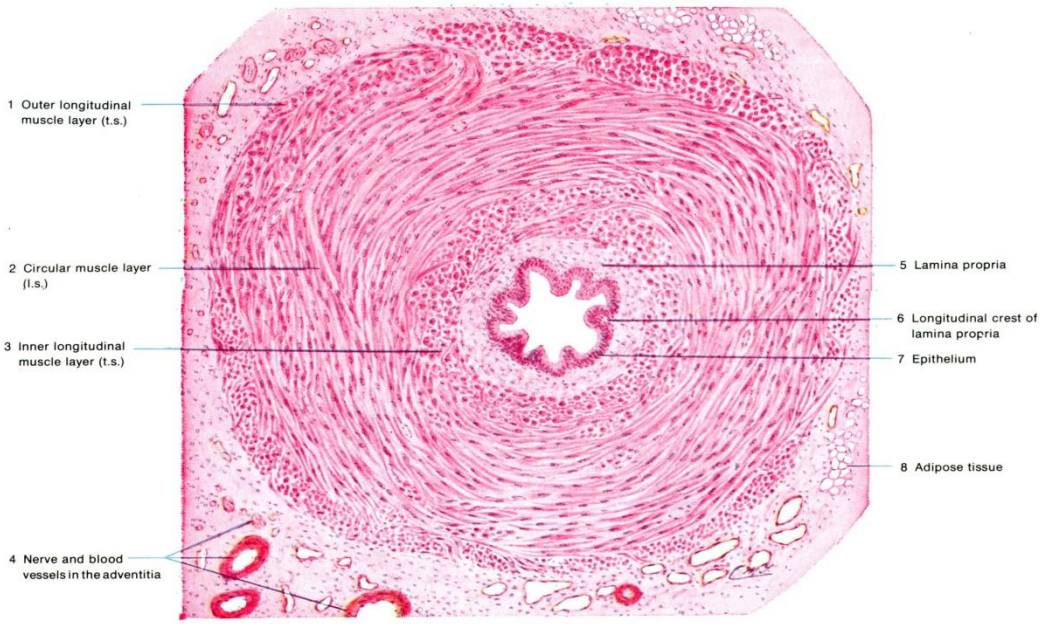




Ductus Deferens & Ampulla

- Vas deferens
  - Continuation of epididymis
    - Fibromuscular tube
    - Absorptive & secretory functions
- Ampulla
  - Thickened terminal portion of ductus deferens
  - Prominent in stallion
  - Absent in pigs
  - Glandular

FIG. 1. DUCTUS DEFERENS (TRANSVERSE SECTION)



Stain: hematoxylin-eosin. 40×.

FIG. 2. AMPULLA OF THE DUCTUS DEFERENS (TRANSVERSE SECTION)

Stain: hematoxylin-eosin. 60×.

Accessory Sex Glands

- Ampullae
- Vesicular Glands
  - Seminal vesicles
- Prostate
- Bulbourethral glands

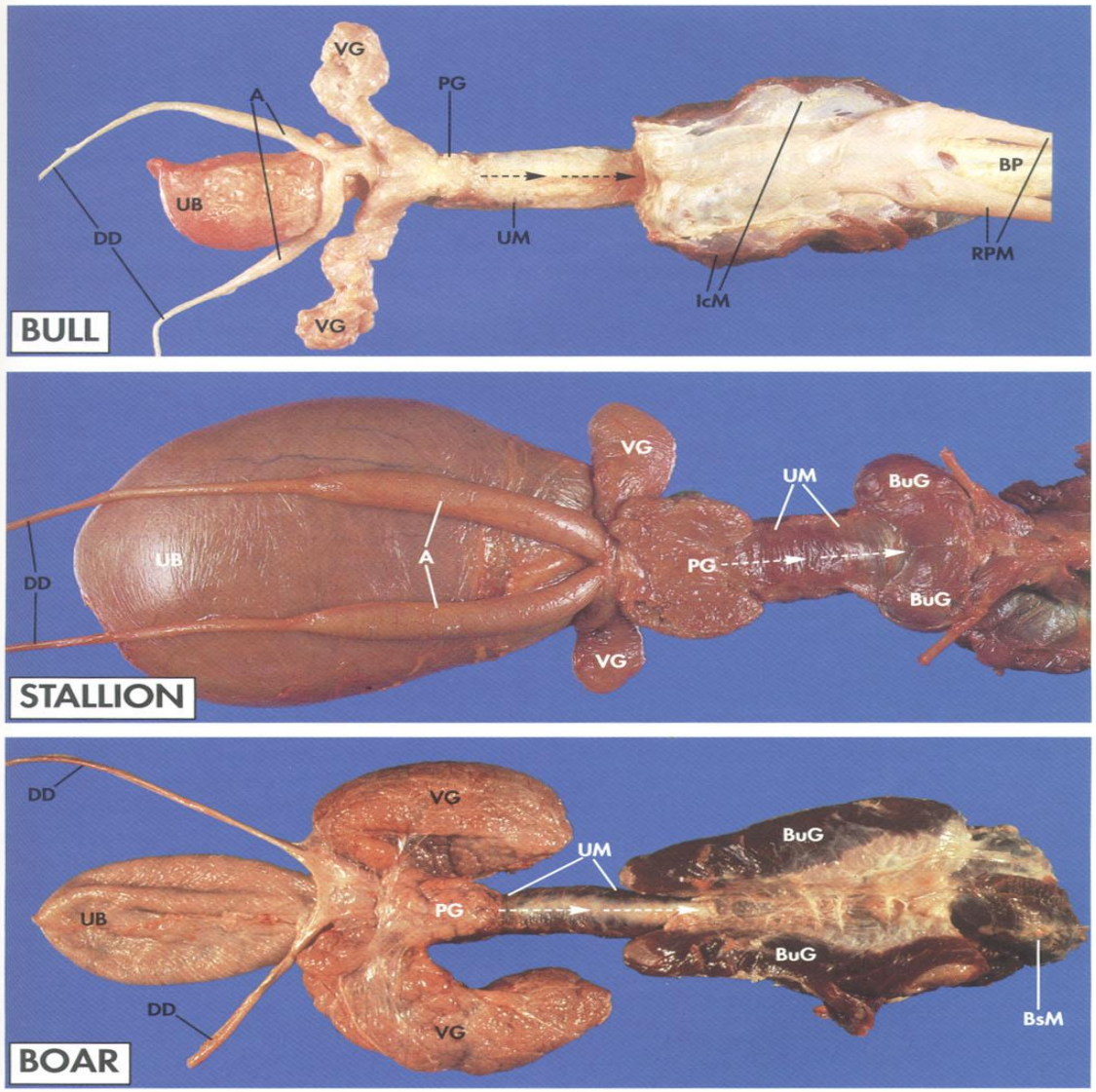


Figure 3-15. Dorsal view of the pelvic urethral region of the bull, boar and stallion*. A = Ampulla; BP = Base of Penis; BuG = Bulbourethral Glands; BsM = Bulbospongiosus Muscle; DD = Ductus Deferens; IcM = Ischiocavernosus Muscle; PG = Prostate Gland (Body); RPM = Retractor Penis Muscle; VG = Vesicular Glands; UB = Urinary Bladder; UM = Urethralis. *(arrows indicate the direction of fluid flow during emission and ejaculation)

Vesicular Glands

Seminal Vesicles

- Lobular
  - Bull
  - Ram
  - Boar
- Sac-like
  - Human
  - Stallion
  - Rat
  - Guinea pig
- Provides
  - Volume
  - Protein
  - Sugars
  - Salts

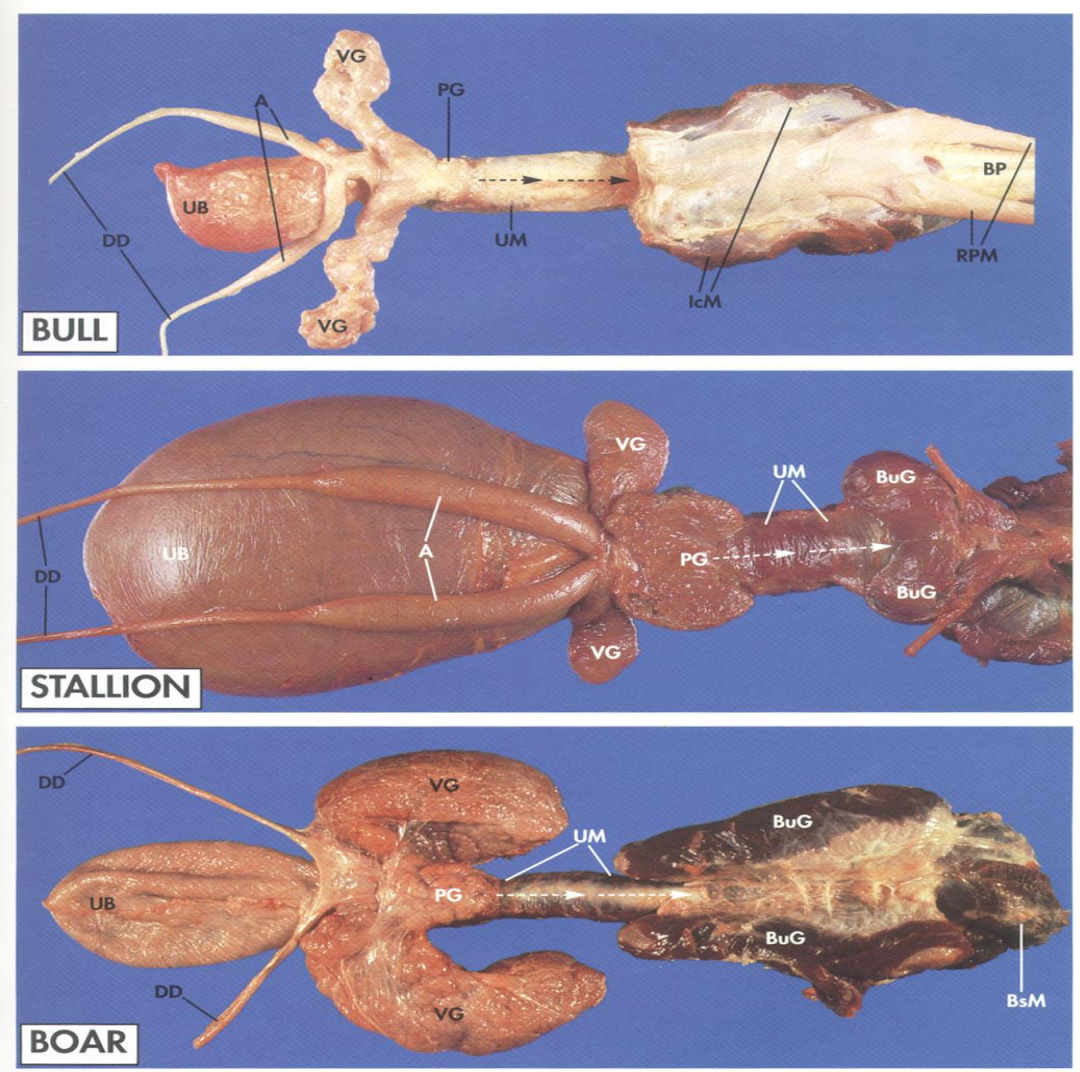
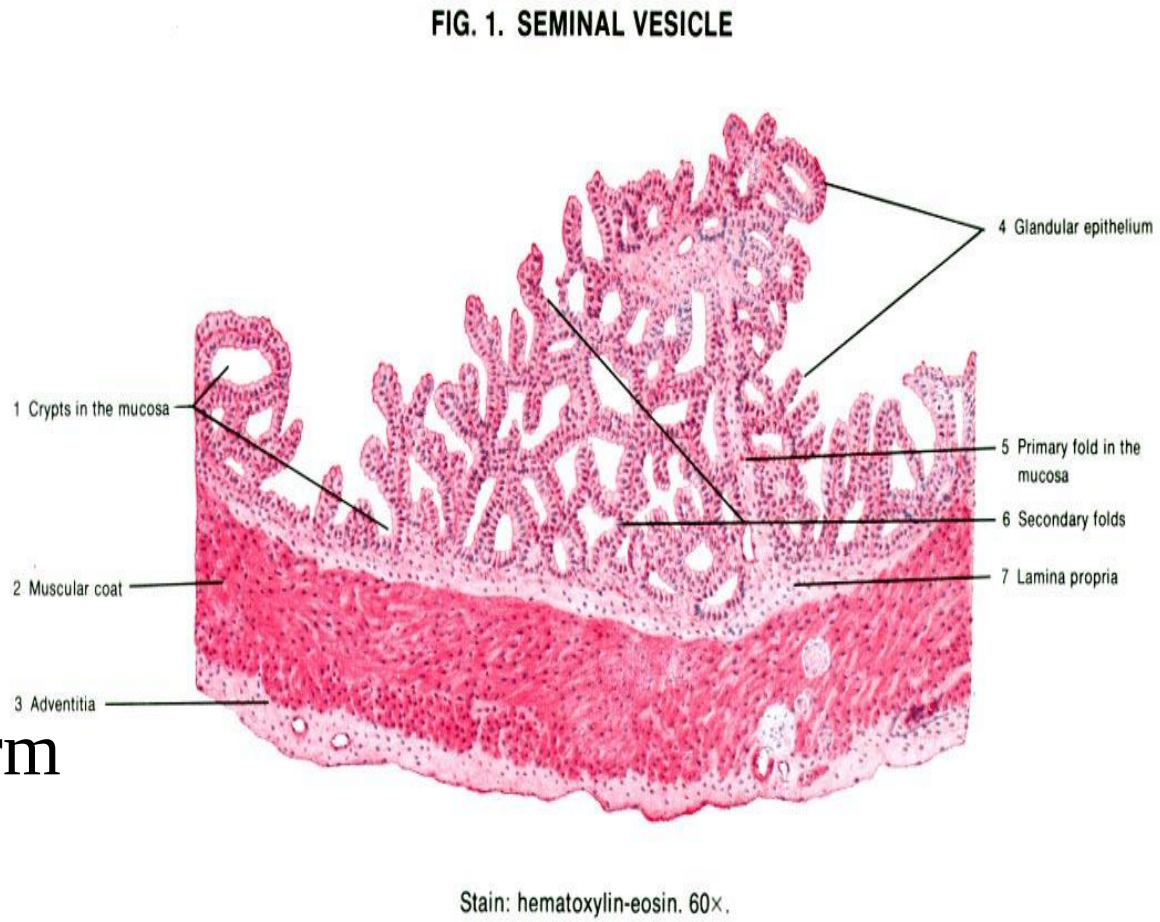


Figure 3-15. Dorsal view of the pelvic urethral region of the bull, boar and stallion*. A = Ampulla; BP = Base of Penis; BuG = Bulbourethral Glands; BsM = Bulbospongiosus Muscle; DD = Ductus Deferens; IcM = Ischiocavernosus Muscle; PG = Prostate Gland (Body); RPM = Retractor Penis Muscle; VG = Vesicular Glands; UB = Urinary Bladder; UM = Urethralis. *(arrows indicate the direction of fluid flow during emission and ejaculation)

Vesicular Glands

Seminal Vesicles

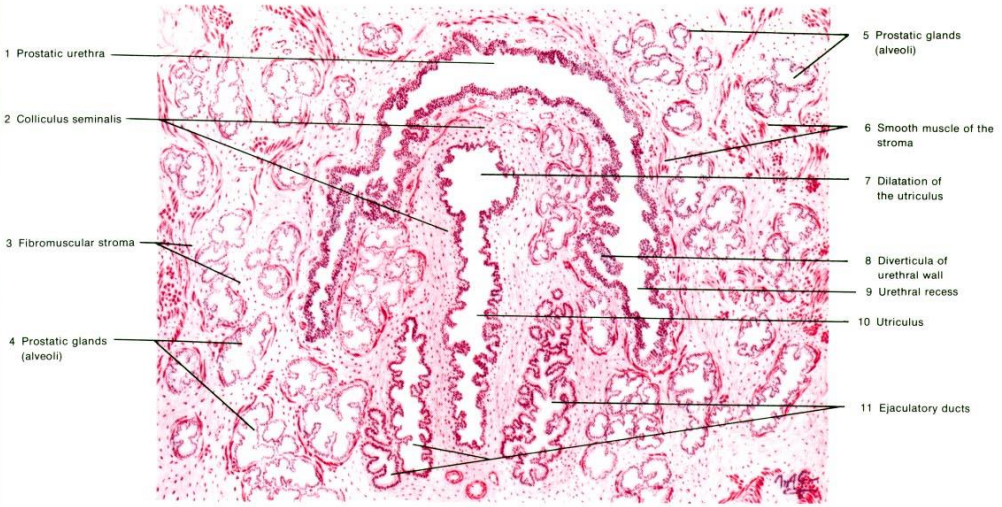
- Absent in
  - Carnivores
  - Lagomorphs
  - Marsupials
  - Cetaceans
  - Some primates
  - Others
- Do not store sperm



Prostate

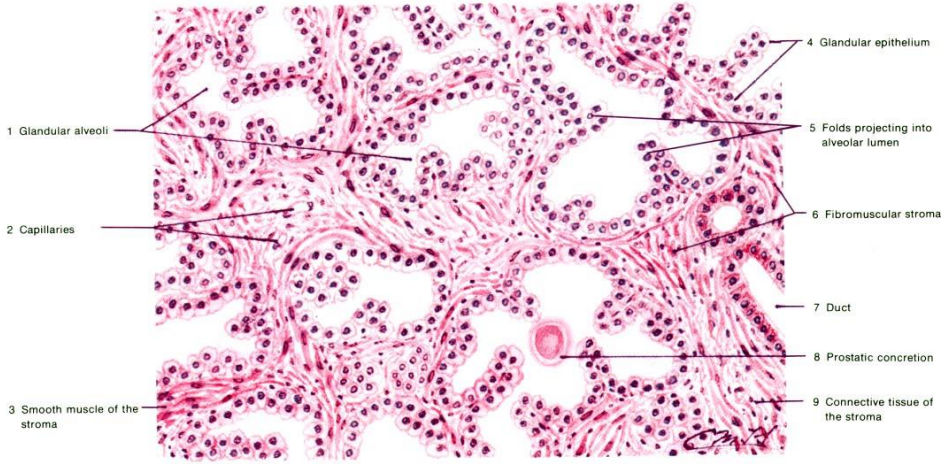
- Present in all mammals
- Compound tubuloalveolar gland
  - Boars & dogs
    - Large component of ejaculate
- Discrete and disseminate portions
- Varying morphology
  - Rats
    - Ventral, lateral and dorsal portions
      - Each with multiple ducts
    - Anterior prostate
      - Coagulating gland
      - Empties through a single duct

FIG. 1. PROSTATE GLAND WITH PROSTATIC URETHRA



Stain: hematoxylin-eosin. 80×.

FIG. 2. PROSTATE GLAND (SECTIONAL VIEW)

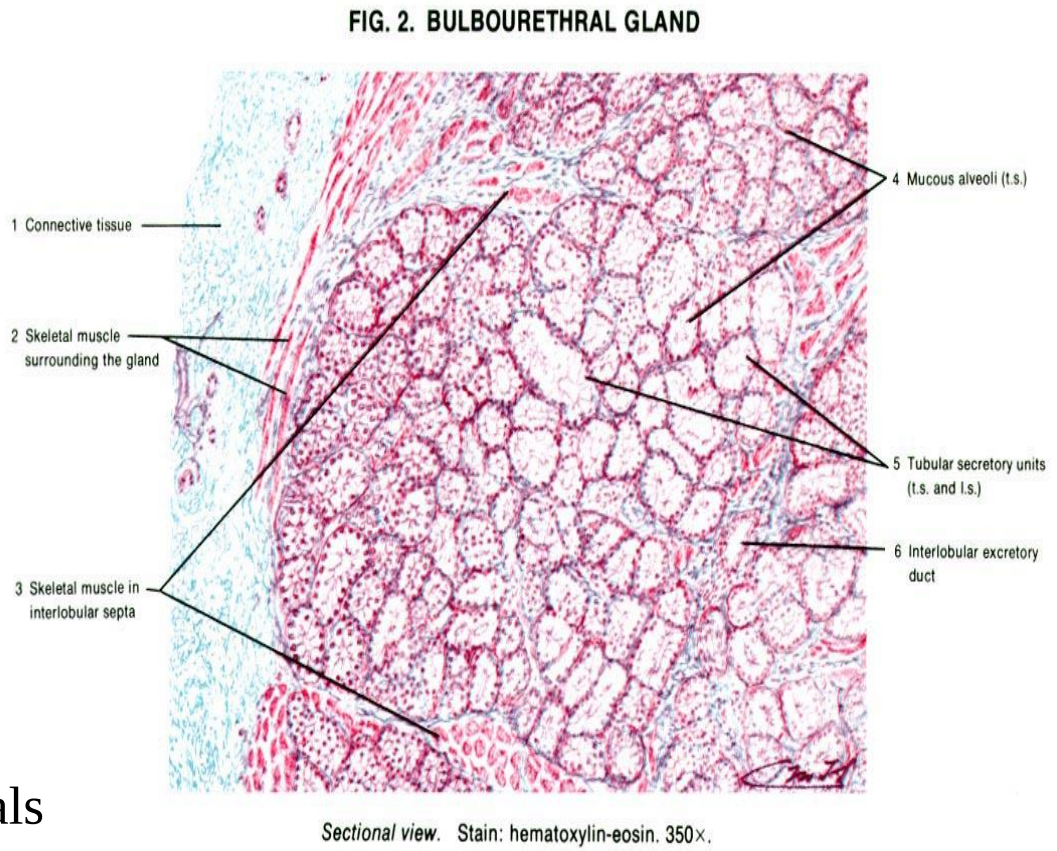


Section from main prostatic glands in Fig. 1.
Stain: hematoxylin-eosin. 180×.

Bulbourethral Gands

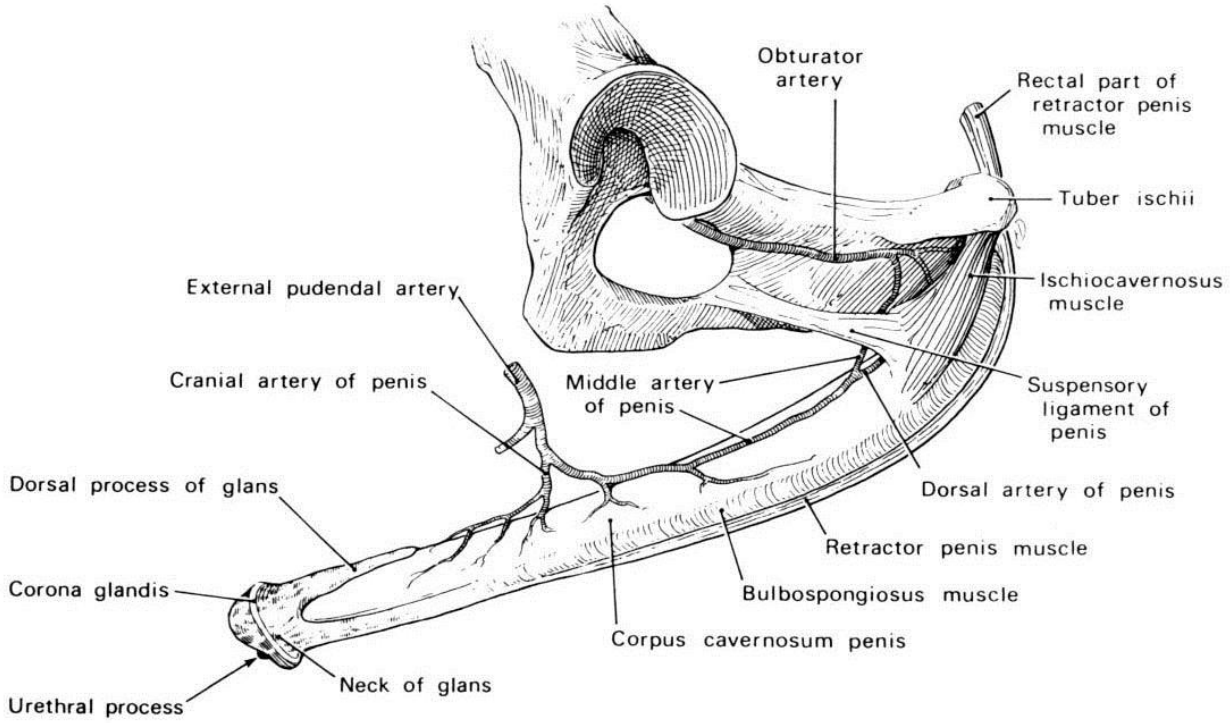
Cowpers glands

- Present in most mammals
  - Pre-ejaculate fluid
    - Cleanses urethra & reduces acidity
      - Bull – Ram
      - Stallion – Man
  - Very large in boars
    - Gel fraction
      - Sialic acid
- Absent in
  - Dogs – Mustelids
  - Bears – Aquatic mammals

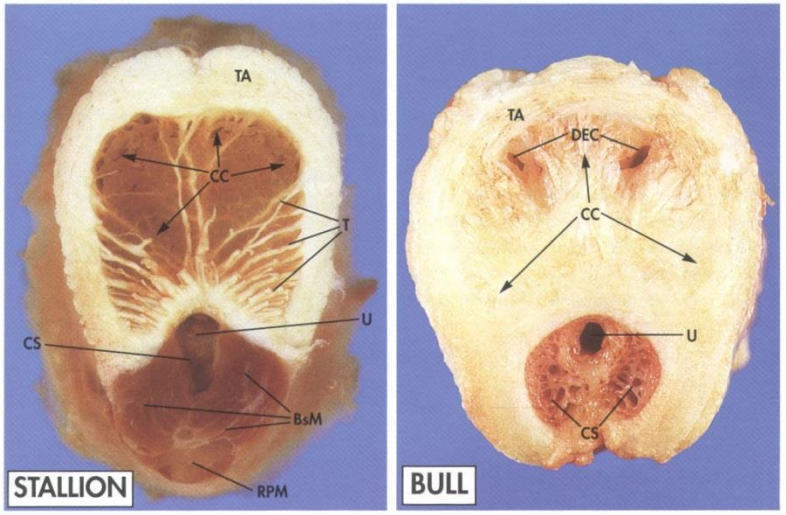


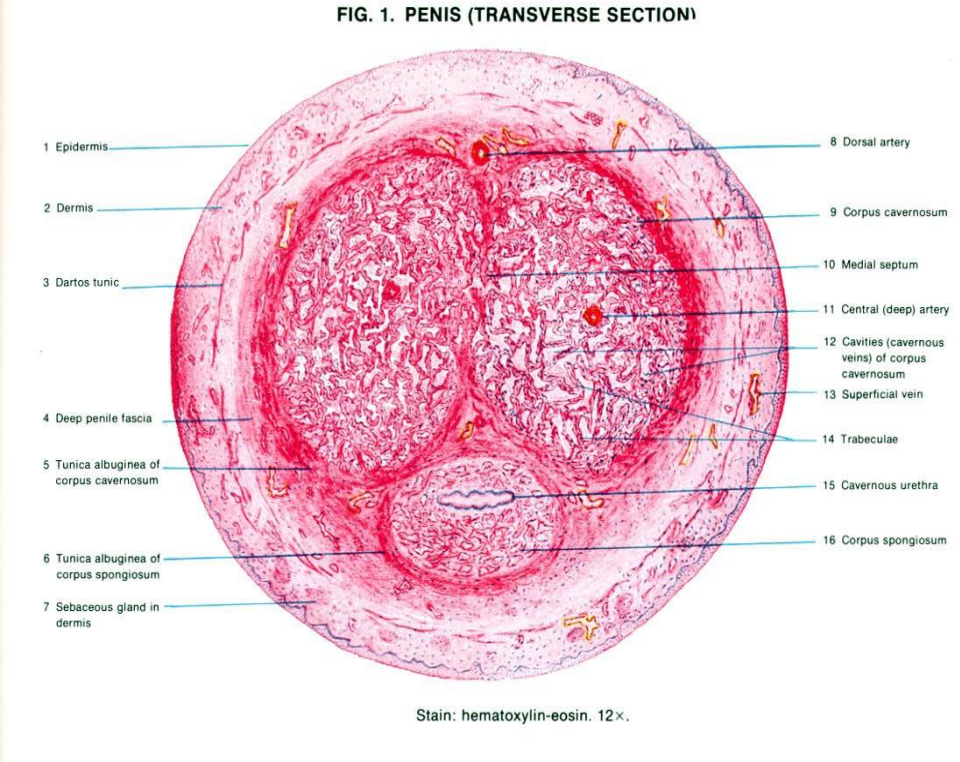
Penis

- Erectile copulatory organ
- Three parts
  - Root (crus penis)
    - Right & left crura
    - Attached to ischial arch
  - Body (corpus)
    - Tunica albuginea
  - Glans penis



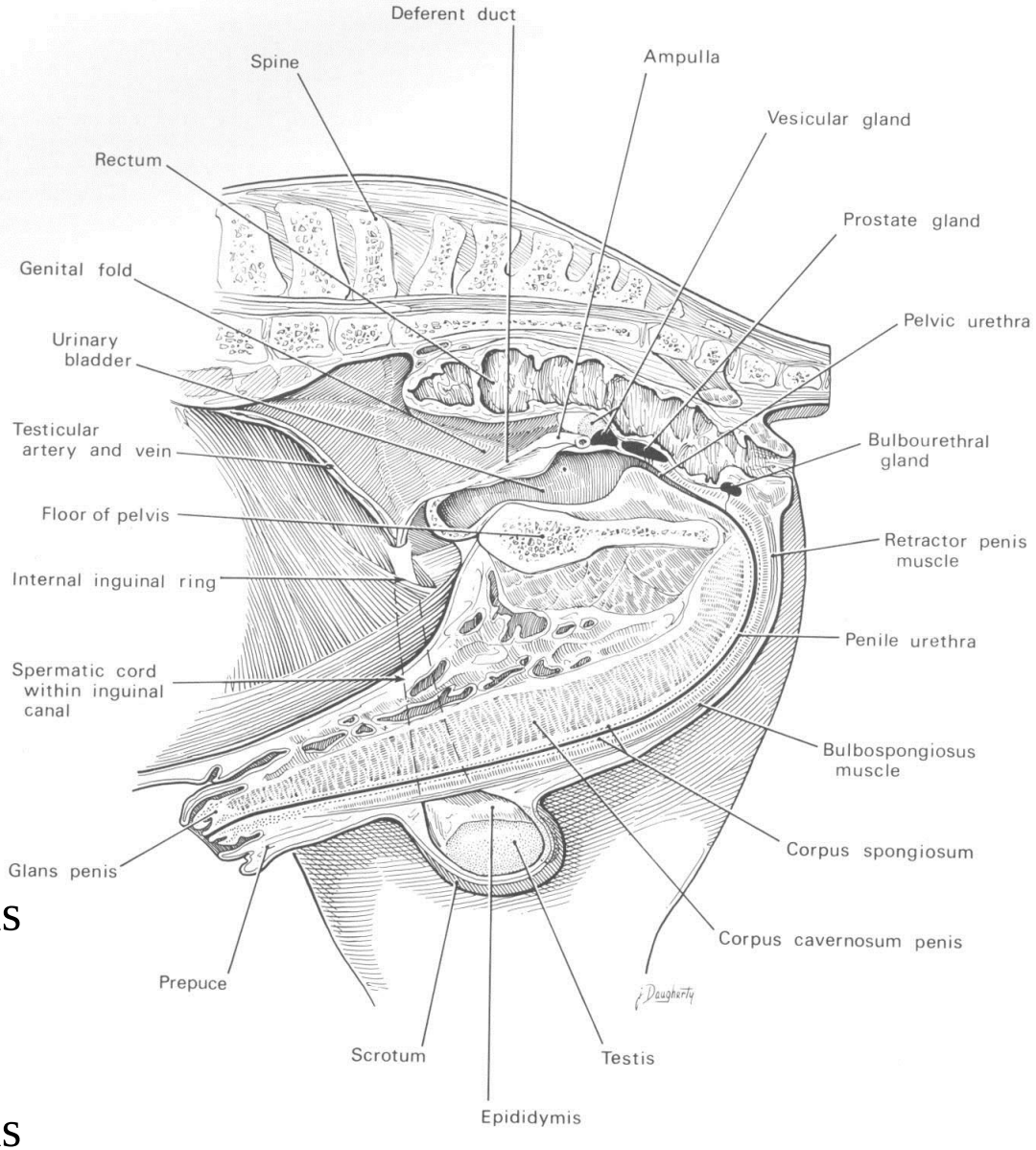
- Corpus cavernosum
  - Majority of interior penile shaft
  - Spongy erectile tissue
    - Smooth muscle
- Corpus spongiosum
  - Surrounds urethra
  - Extends to glans
    - Very prominent in stallion - belling





Penile Musculature

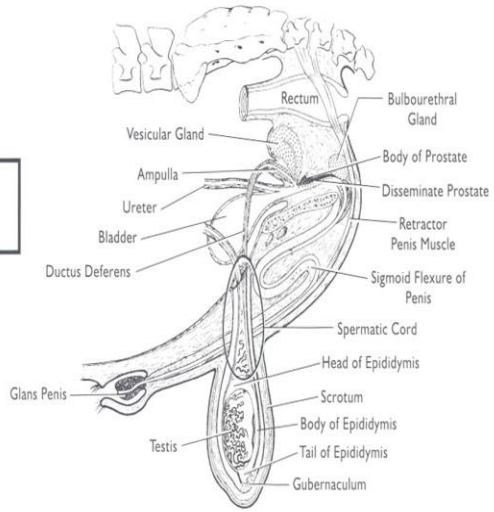
- Retractor penis
  - Paired
  - Attachments
    - Caudal vertebrae
    - Anal sphincter
    - Tunica albugiea
- Ischiocavernosus
  - Paired
  - Inserts on crus penis
  - Important in erection
    - Compresses crus penis
- Bulbospongiosus
  - Overlaps root of penis
  - Covers bulbourethral glands
- Urethralis
  - Encloses pelvic urethra
  - Covers bulbourethral glands



Species Differences

- Bull, Ram, Buck
  - Fibroelastic
  - Sigmoid flexure
  - Long urethral process
    - Ram and buck
- Boar
  - Fibroelastic
  - Sigmoid flexure
  - Corkscrew glans
  - Preputial diverticulum
- Stallion
  - Vascular
  - Belling of glans
  - Fossa glandis & urethral sinus
- Dog
  - Vascular
  - Os penis (baculum)
  - Bulbus glandis

Bull



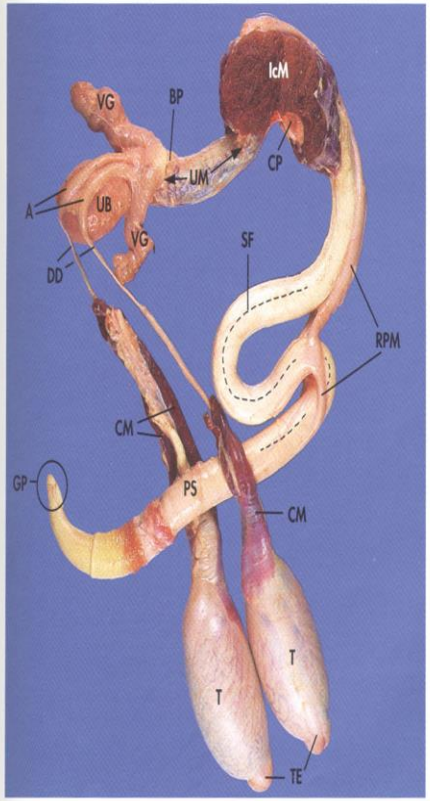


Figure 3-2.

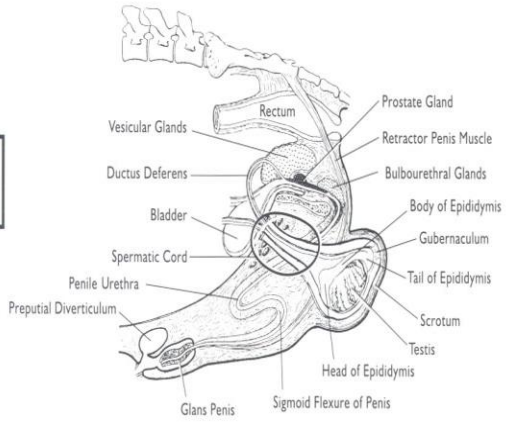
Top Panel

Schematic illustration of a sagittal view of the bull reproductive tract (modified from Ellenberger and Baum, 1943, Handbuch der vergleichenden Anatomie der Haustiere, 18th Edition. Zietzschmann, Ackerknecht and Grau, eds. Permission from Springer-Verlag, New York).

Bottom Panel

Sagittal view of an excised reproductive tract from the bull. A = Ampulla; BP = Body of Prostate; CM = Cremaster Muscle; CP = Crus Penis; DD = Ductus Deferens; GP = Glans Penis; lcM = Ischiocavernosus Muscle; PS = Penile Shaft; RPM = Retractor Penis Muscle; SF = Sigmoid Flexure; TE = Tail of Epididymis; T = Testis; UM = Urethralis Muscle; UB = Urinary Bladder; VG = Vesicular Gland.

Boar



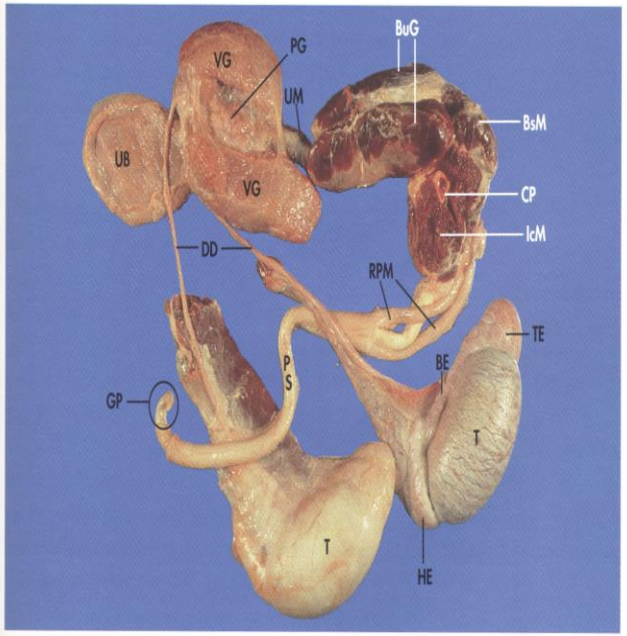


Figure 3-4.

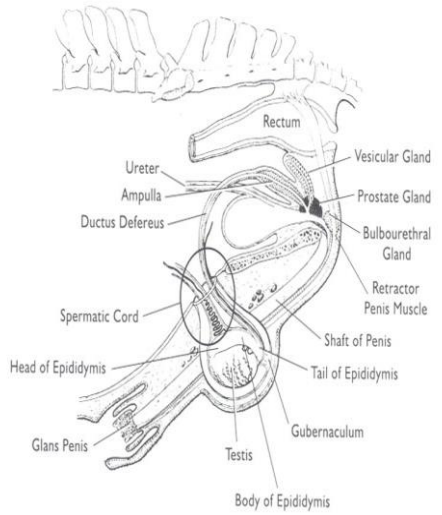
Top Panel

Schematic illustration of a sagittal view of the boar reproductive tract (modified from Ellenberger and Baum, 1943, Handbuch der vergleichenden Anatomie der Haustiere, 18th Edition. Zietzschmann, Ackerknecht and Grau, eds. Permission from Springer-Verlag, New York).

Bottom Panel

Sagittal view of an excised reproductive tract from the boar. BE = Body of Epididymis; BsM = Bulbospongiosus Muscle; BuG = Bulbourethral Glands; CP = Crus Penis; DD = Ductus Deferens; GP = Glans Penis; HE = Head of Epididymis; lcM = Ischiocavernosus Muscle; PS = Penile Shaft; PG = Prostate Gland; RPM = Retractor Penis Muscle; TE = Tail of Epididymis; T = Testis (left - t. vaginalis intact; right - t. vaginal removed); UM = Urethralis Muscle; UB = Urinary Bladder; V = Vesicular Glands.

Stallion



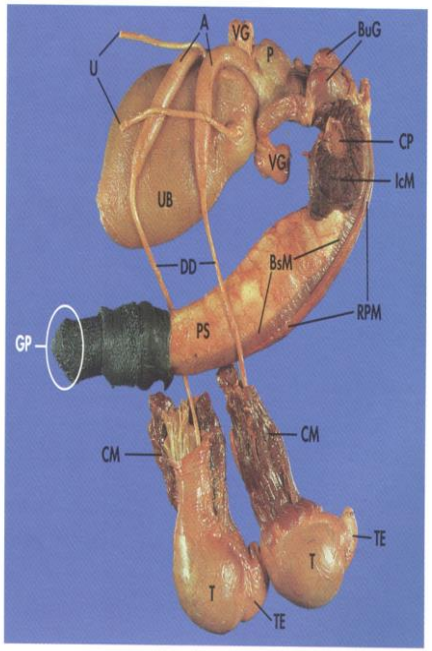


Figure 3-3.

Top Panel

Schematic illustration of a sagittal view of the stallion reproductive tract (modified from Ellenberger and Baum, 1943, Handbuch der vergleichenden Anatomie der Haustiere, 18th Edition. Zietzschmann, Ackerknecht and Grau, eds. Permission from Springer-Verlag, New York).

Bottom Panel

Sagittal view of an excised reproductive tract from the stallion. A = Ampulla; BsM = Bulbospongiosus Muscle; BuG = Bulbourethral Glands; CM = Cremaster Muscle; CP = Crus Penis; DD = Ductus Deferens; GP = Glans Penis; lcM = Ischiocavernosus Muscle; P = Prostate; PS = Penile Shaft; RPM = Retractor Penis Muscle; T = Testis; TE = Tail of Epididymis; U = Ureters; UB = Urinary Bladder; VG = Vesicular Gland.

Erection

- Relaxation of retractor penis
- Penile rigidity
  - Increase arterial inflow + decreased venous outflow
    - Ischiocavernosus muscle contraction
  - Relaxation and engorgement of corpus cavernosum
    - Tremendous increase in intracavernous pressure
    - Stallion and man increase diameter dramatically
    - Little change in diameter with fibroelastic penis

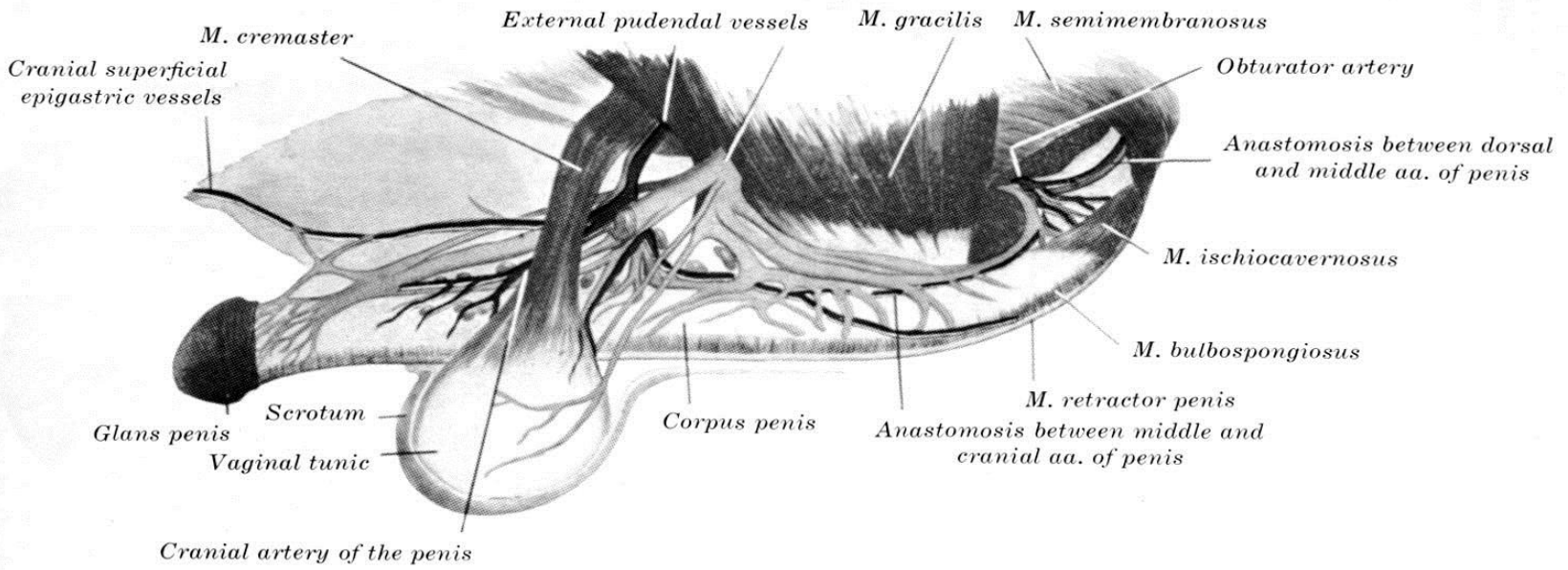
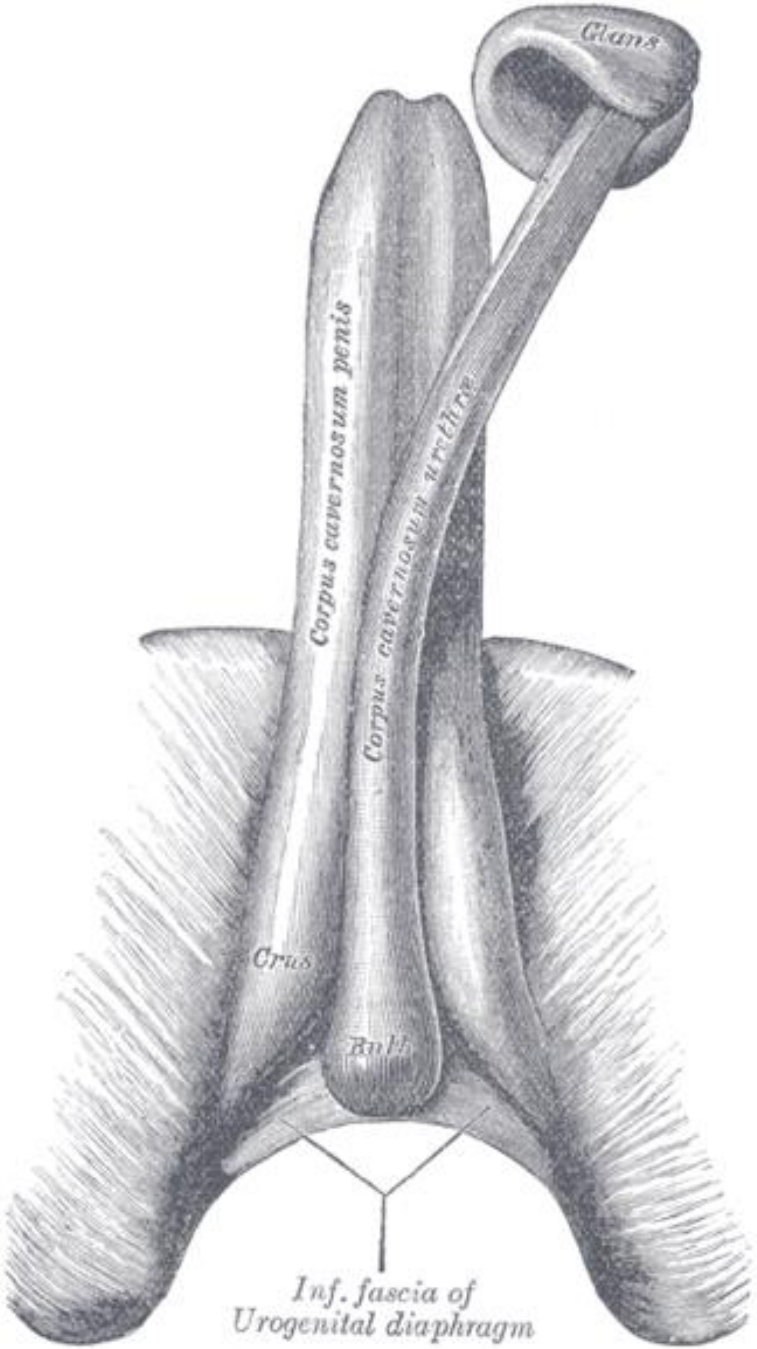
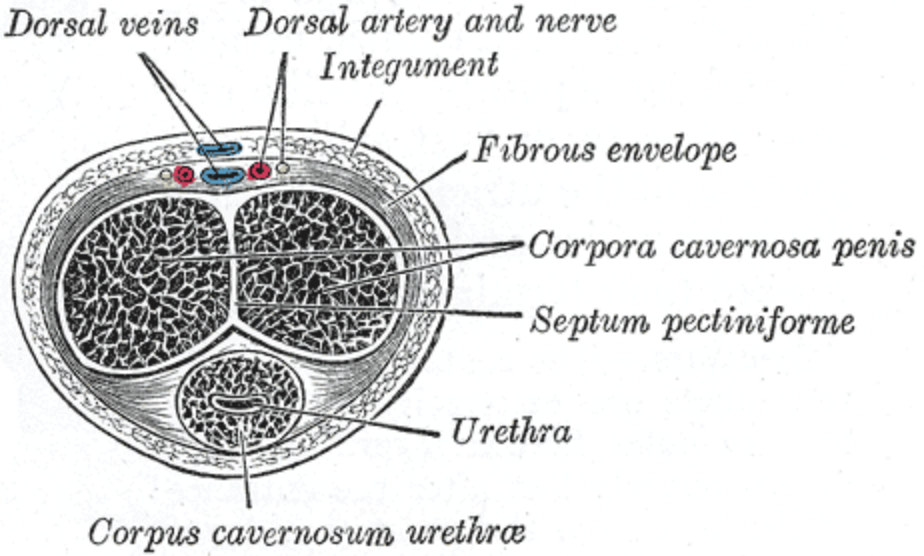


FIGURE 22–44. Penis of horse; lateral view, showing circulation.


Glans
Corpus cavernosum penis
Corpus cavernosum urethræ
Crus
Bulb
Inf. fascia of
Urogenital diaphragm

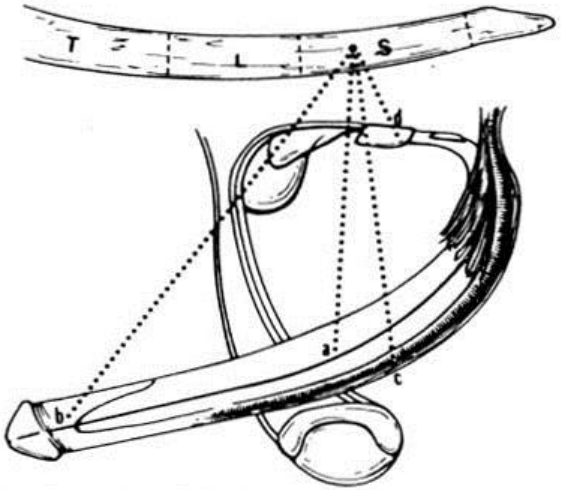

Dorsal veins
Dorsal artery and nerve
Integument
Fibrous envelope
Corpora cavernosa penis
Septum pectiniforme
Urethra
Corpus cavernosum urethræ

Erection

Penis drop due to sacral parasympathetic mediated relaxation of corporal trabecui (a) and retractor penis muscle (c). Erection of the shaft and glans penis due to parasympathetic mediated relaxation of vascular corpora cavernosa (a) and corpus spongiosus (b).

Pre-ejaculatory Secretions

Release of small amounts of accessory gland fluids, principally from the prostate, due to sacral reflex mediated contraction of the accessory glands (d).

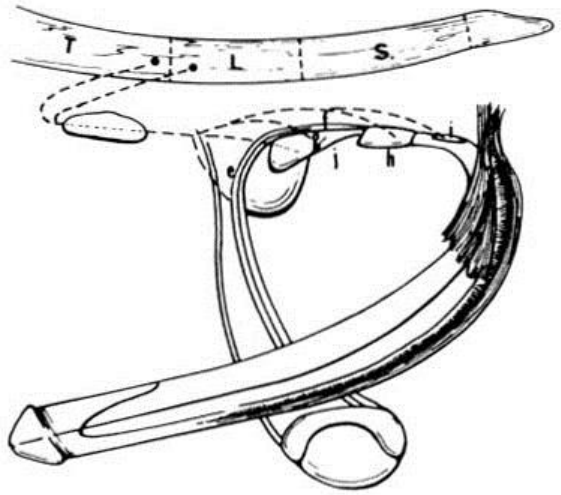


Emission

Release of spermatozoa and accessory gland fluids due to thoracolumbar reflex mediated contraction of the smooth muscle of the ductus deferens (e), ampulla (f), vesicular gland (g), prostate (h), and bulbourethral gland (i).

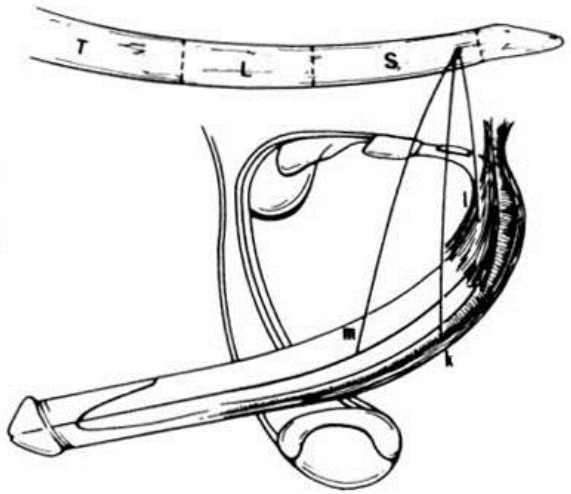
Bladder Neck Closure

Tight closure of the bladder neck due to thoracolumbar reflex mediated contraction of the smooth muscle of the bladder neck (j).



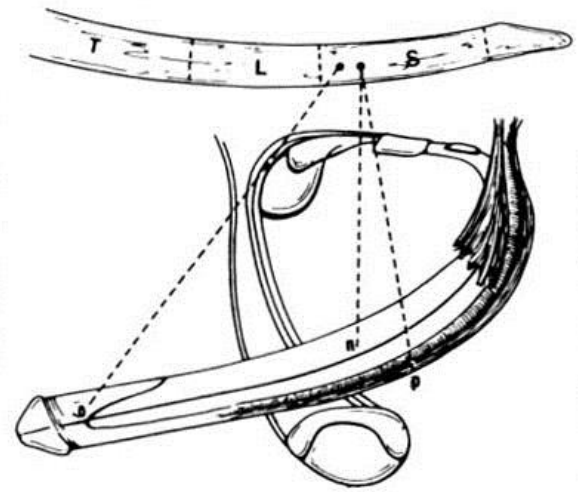
Ejaculation

Forceful expulsion of semen from the urethra due to sacral reflex mediated rhythmic contractions of the bulbocavernosus (k), ischiocavernosus (l), and urethralis (m) muscles.

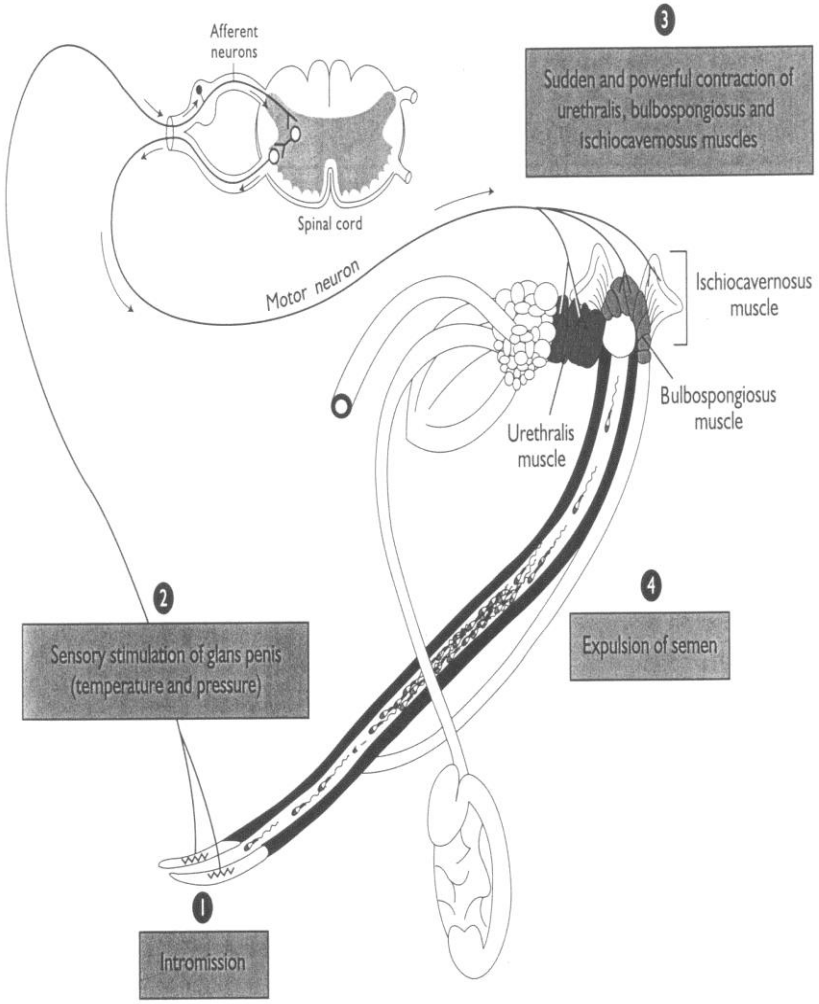


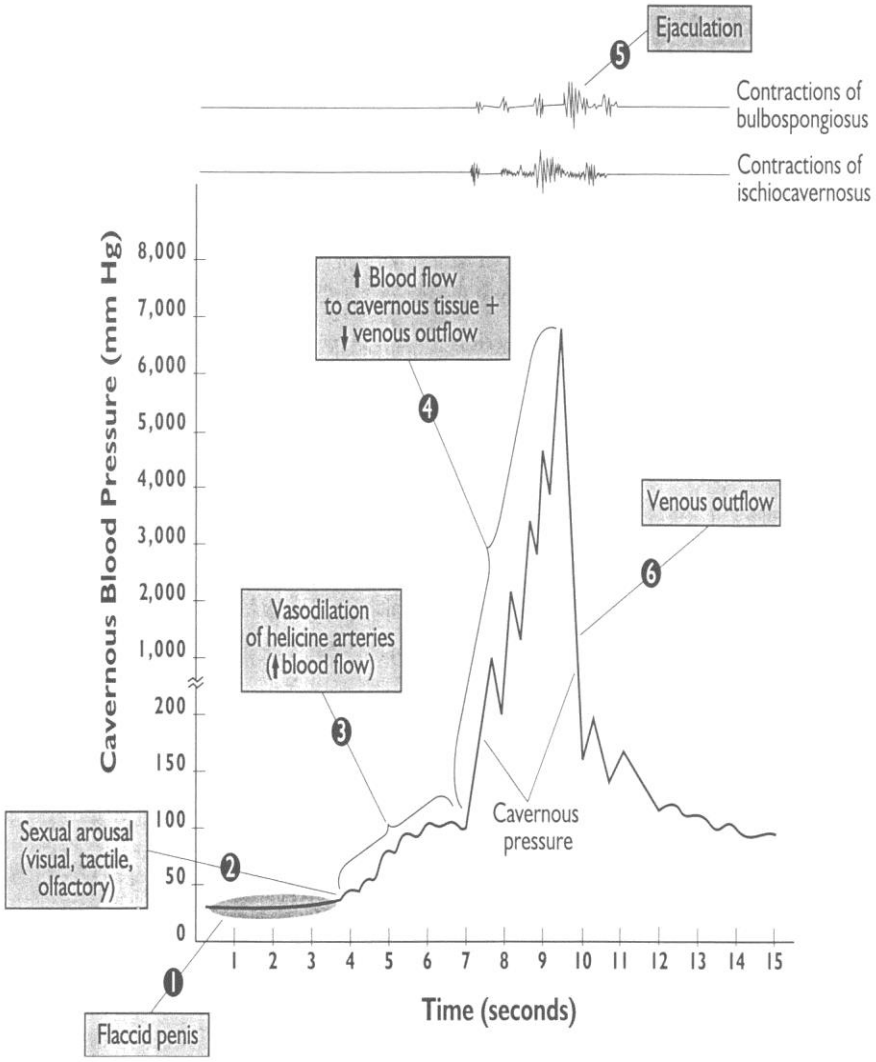
Detumescence

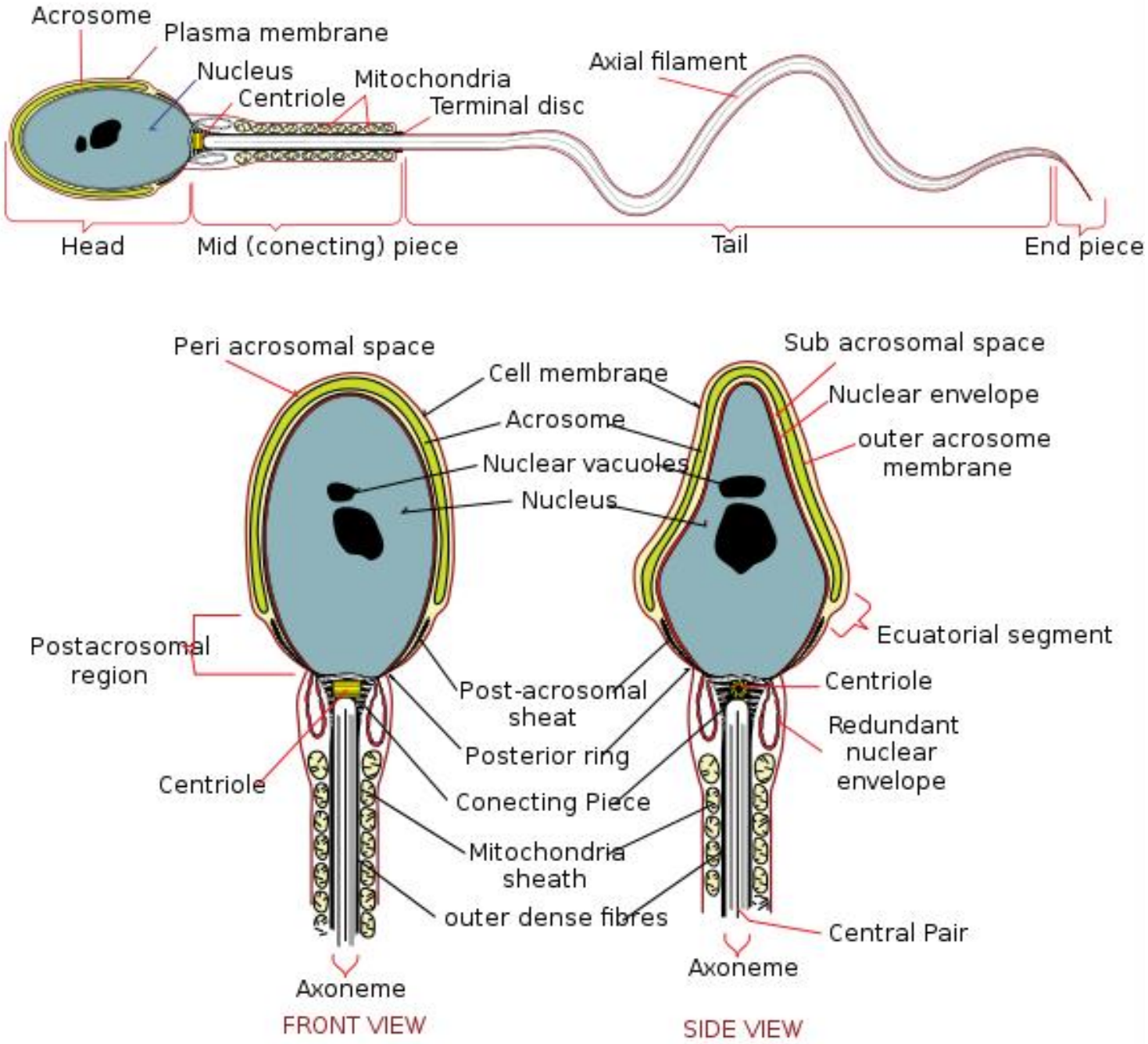
Loss of erection and withdrawal of the penis due to increased sacral sympathetic mediated smooth muscle tone in corpus cavernosum (n) and corpus spongiosum (o), and contraction of the retractor penis muscle (p).

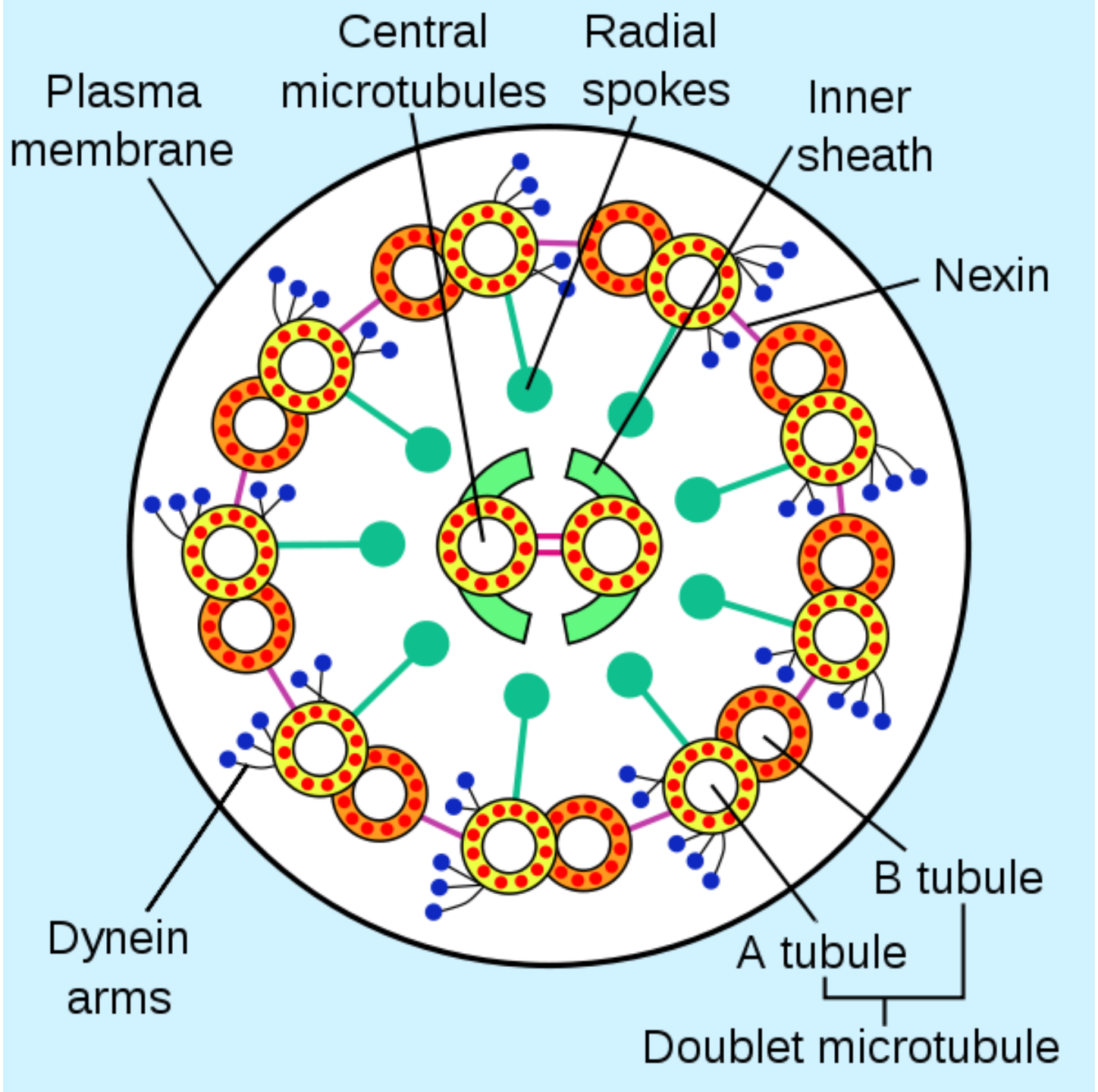


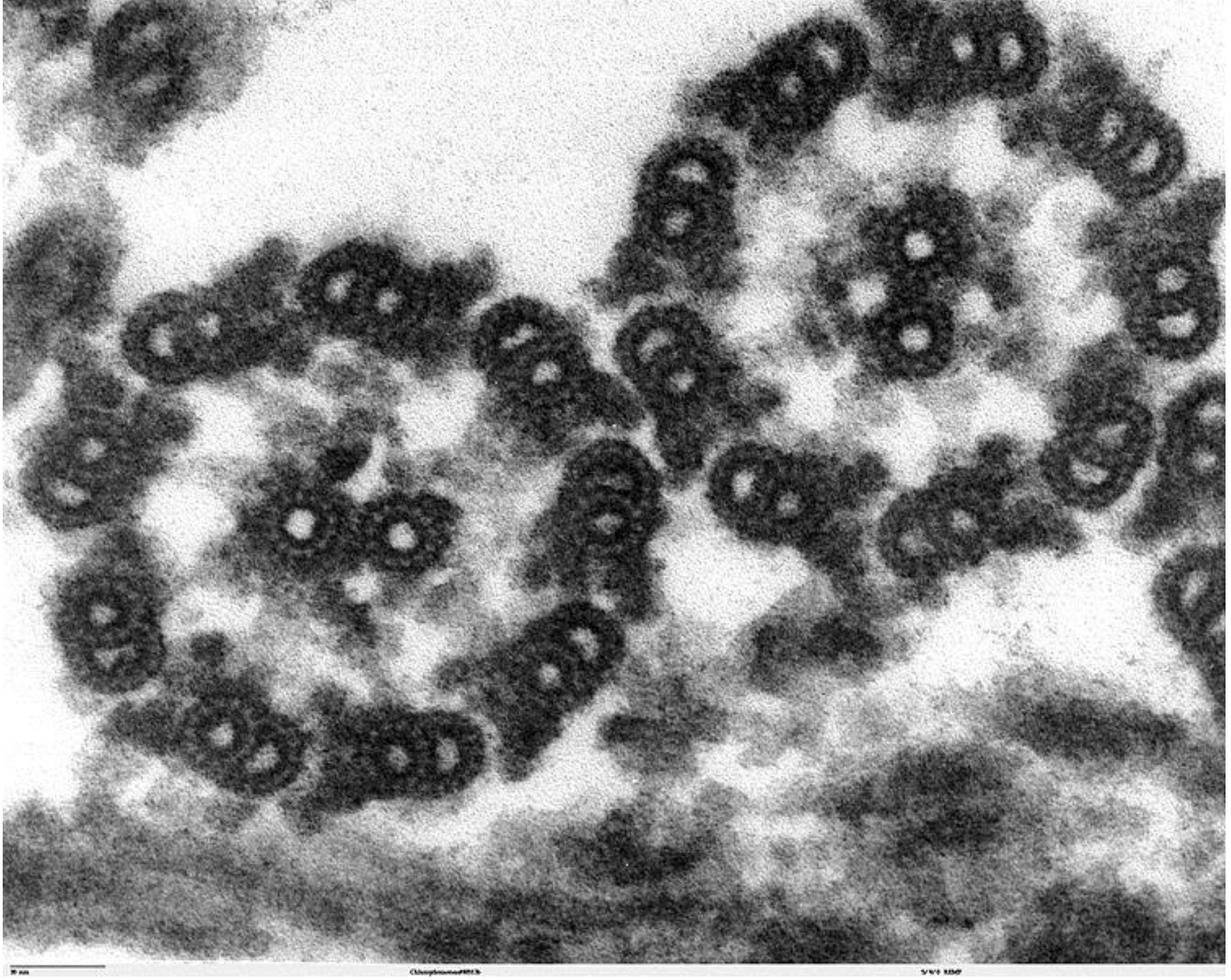
Ejaculatory Process

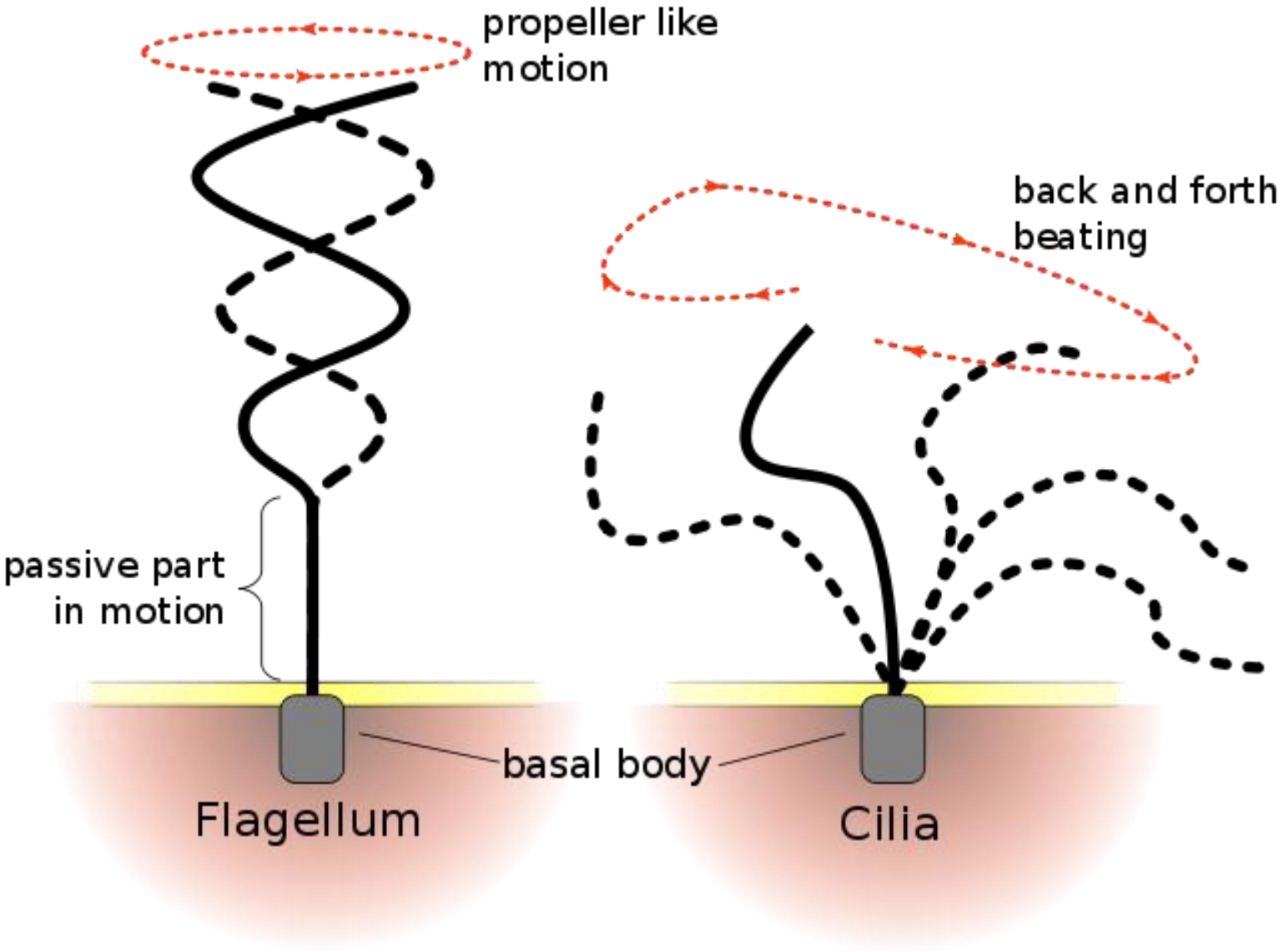


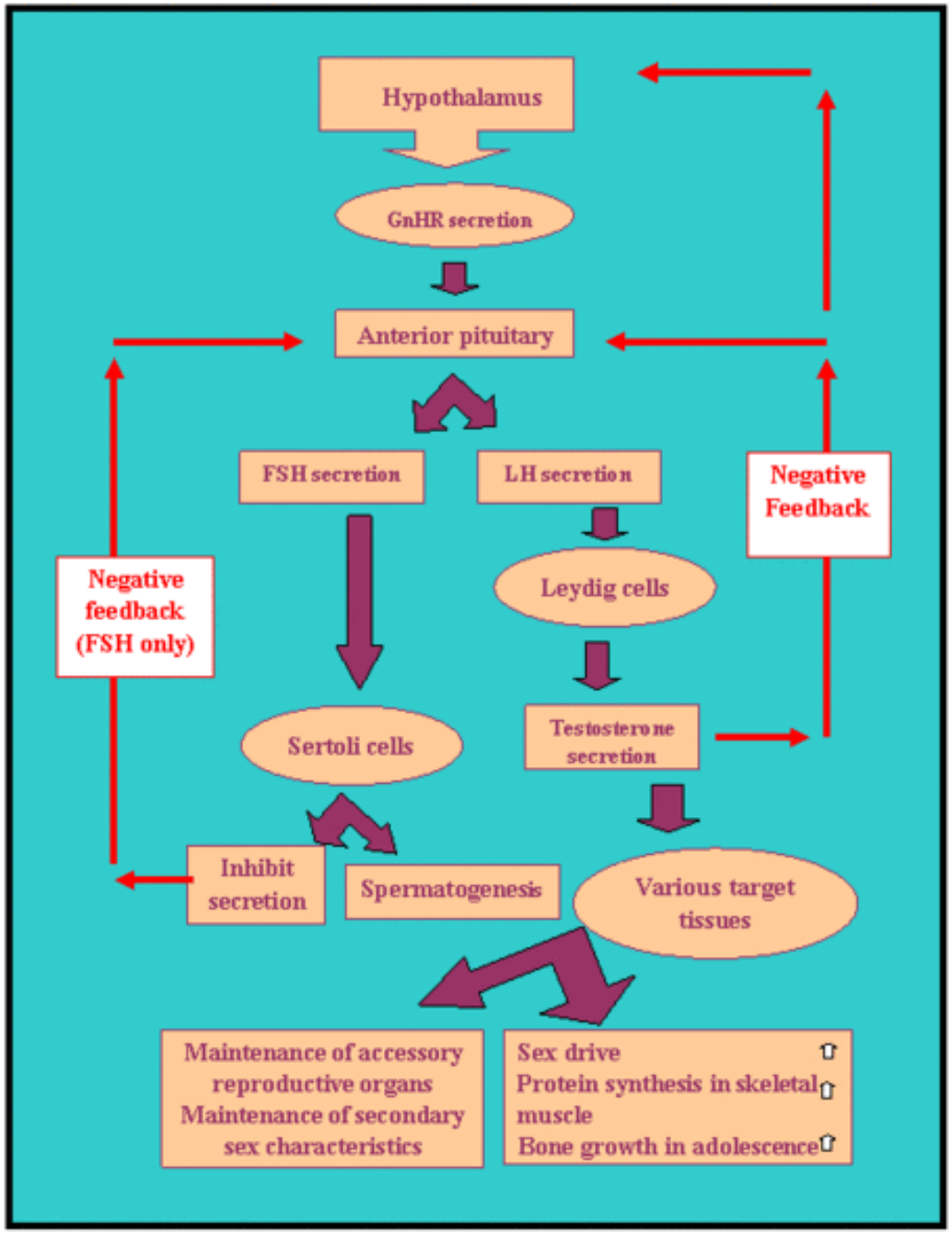



Acrosome
Plasma membrane
Nucleus
Centriole
Mitochondria
Terminal disc
Axial filament
Head
Mid (conecting) piece
Tail
End piece
Peri acrosomal space
Cell membrane
Acrosome
Nuclear vacuoles
Nucleus
Sub acrosomal space
Nuclear envelope
outer acrosome membrane
Postacrosomal region
Ecuatorial segment
Post-acrosomal sheat
Posterior ring
Conecting Piece
Mitochondria sheath
outer dense fibres
Centriole
Redundant nuclear envelope
Central Pair
Axoneme
Axoneme
FRONT VIEW
SIDE VIEW


Central microtubules
Radial spokes
Plasma membrane
Inner sheath
Nexin
Dynein arms
B tubule
A tubule
Doublet microtubule




propeller like
motion
back and forth
beating
passive part
in motion
basal body
Flagellum
Cilia


Hypothalamus
GnHR secretion
Anterior pituitary
FSH secretion
LH secretion
Negative Feedback
Negative feedback (FSH only)
Leydig cells
Sertoli cells
Testosterone secretion
Inhibit secretion
Spermatogenesis
Various target tissues
Maintenance of accessory reproductive organs
Maintenance of secondary sex characteristics
Sex drive
Protein synthesis in skeletal muscle
Bone growth in adolescence