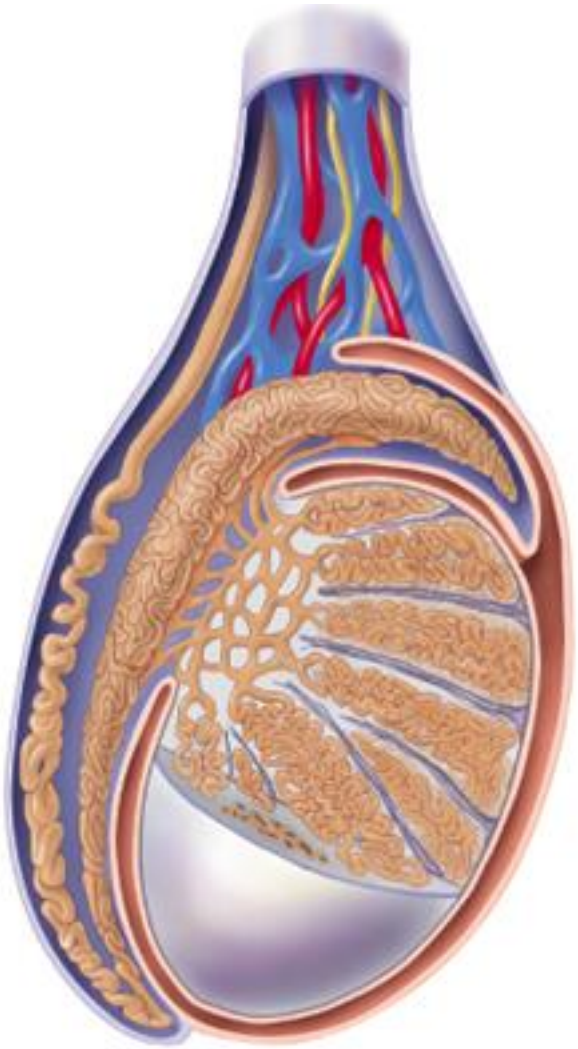
The Male Reproductive System

- Sexual reproduction
- Male reproductive anatomy
- Spermatogenesis, spermatozoa & sperm



The Essence of Sex

- Reproduction is one property of a living thing
- Sexual reproduction means each offspring has 2 parents and receives genetic material from both
  - provides genetic diversity & is considered the foundation for the survival and evolution of species

The Two Sexes

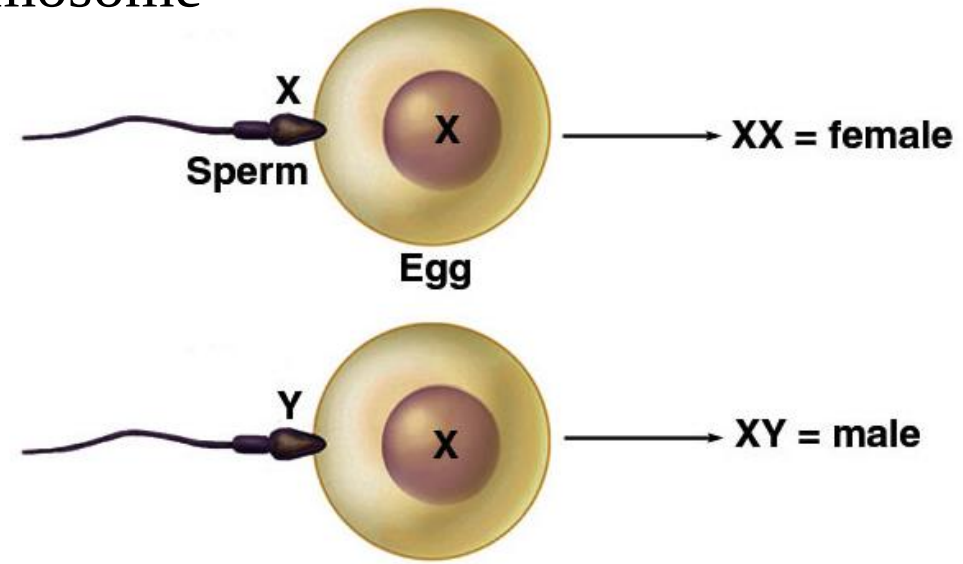
- Male and female gametes (sex cells) combine their genes to form a fertilized egg (zygote)
  - one gamete has motility (sperm or spermatozoon)
    - the parent producing sperm is considered the male
    - has Y chromosome
  - other gamete (egg or ovum) contains most of the nutrients for the developing zygote
    - the parent producing eggs is considered the female
    - in mammals the female also provides shelter for developing fetus (uterus and placenta)

Overview of the Reproductive System

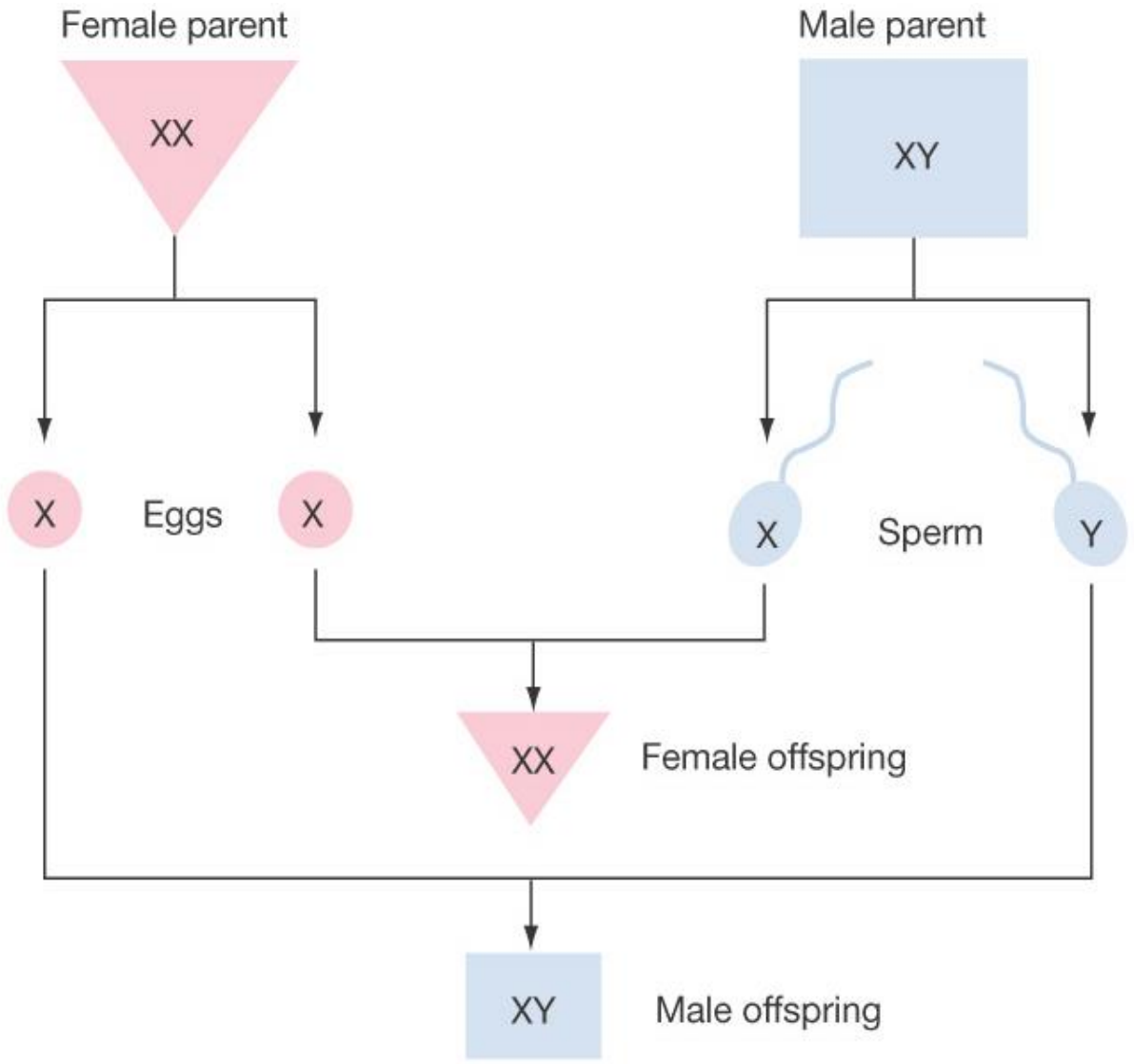
- Primary sex organs
  - organs that produce the gametes (testes or ovaries)
- Secondary sex organs (organs other than gonads essential for reproduction)
  - male is ducts, glands and the penis that deliver the sperm cells
  - female is uterine tubes, uterus & vagina that receive the sperm & nourish the developing fetus
- Secondary sex characteristics
  - features that develop at puberty to further distinguish the sexes and attract a mate

Role of the Sex Chromosomes

- Our cells contain 23 pairs of chromosomes
  - 22 pairs of autosomes
  - 1 pair of sex chromosomes (XY males: XX females)
    - males produce 50% Y carrying sperm and 50% X carrying
    - all eggs carry the X chromosome
- Sex of the child is determined by the type of sperm that fertilizes the mother's egg



Sex Determination: Overview



Embryology of Sex Tissues (1)

Male

Stromal Cells become:
- Leydig Cells

Supporting Cells become:
- Sertoli Cells

Female

Stromal Cells become:
- Thecal Cells

Supporting Cells become:
- Granulosa Cells

Embryology of Sex Tissues (2)

Male

- Wolffian Ducts become:
  - epididymus
  - vas deferens
  - seminal vesicles
  - ejaculatory duct
- Mullerian Ducts
- (in presence of Mullerian Inhibitory Substance
- [MIS] Regress)

Female

Wolffian Ducts Regress

Mullerian Ducts become:

fallopian tubes
uterus
upper 1/3 of vagina

Embryology of Sex Tissues (3)

Male

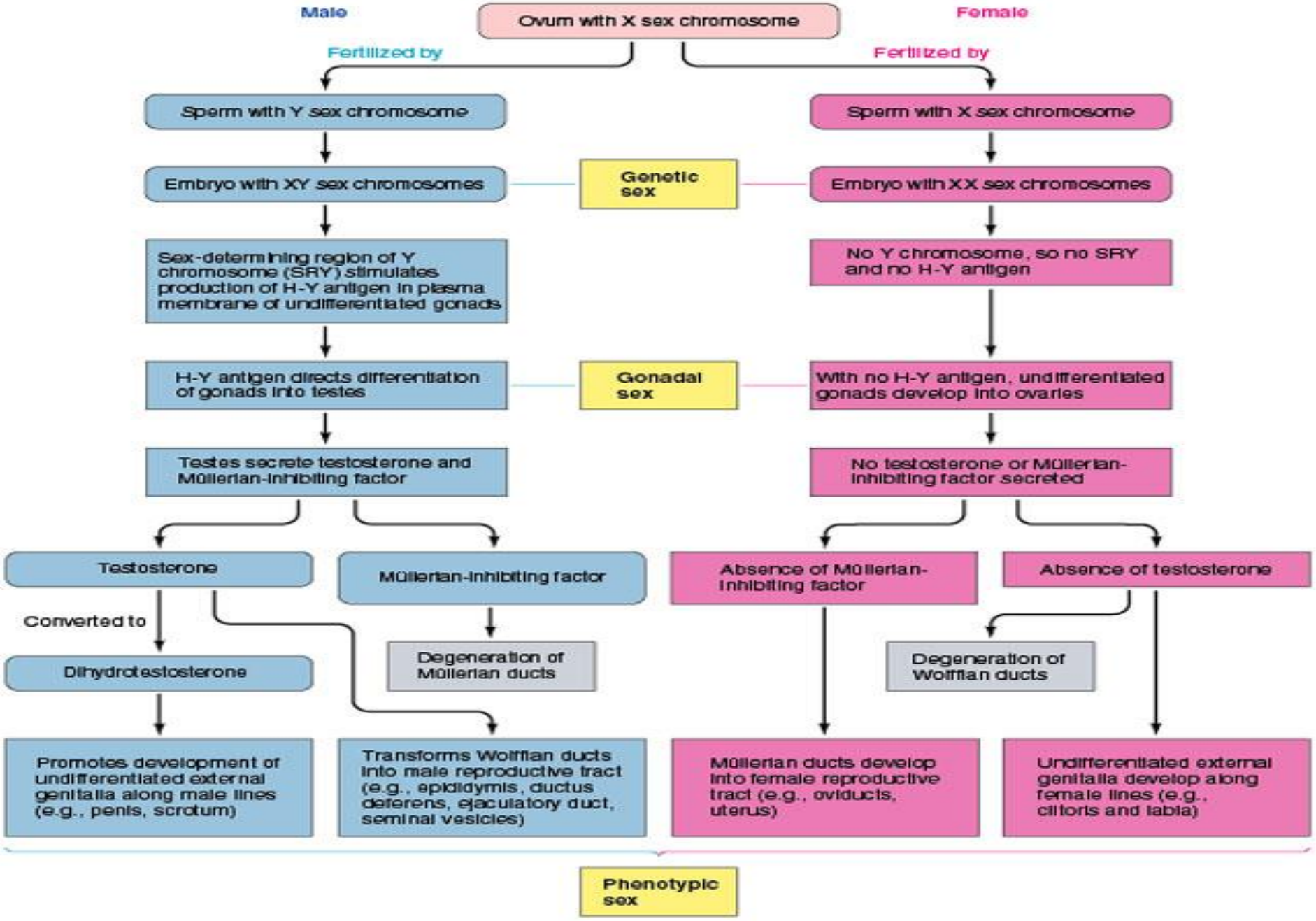
Genital tubercle,fold, swelling &Urogenital ridge Become: (In the Presence of dihydrotestosterone)

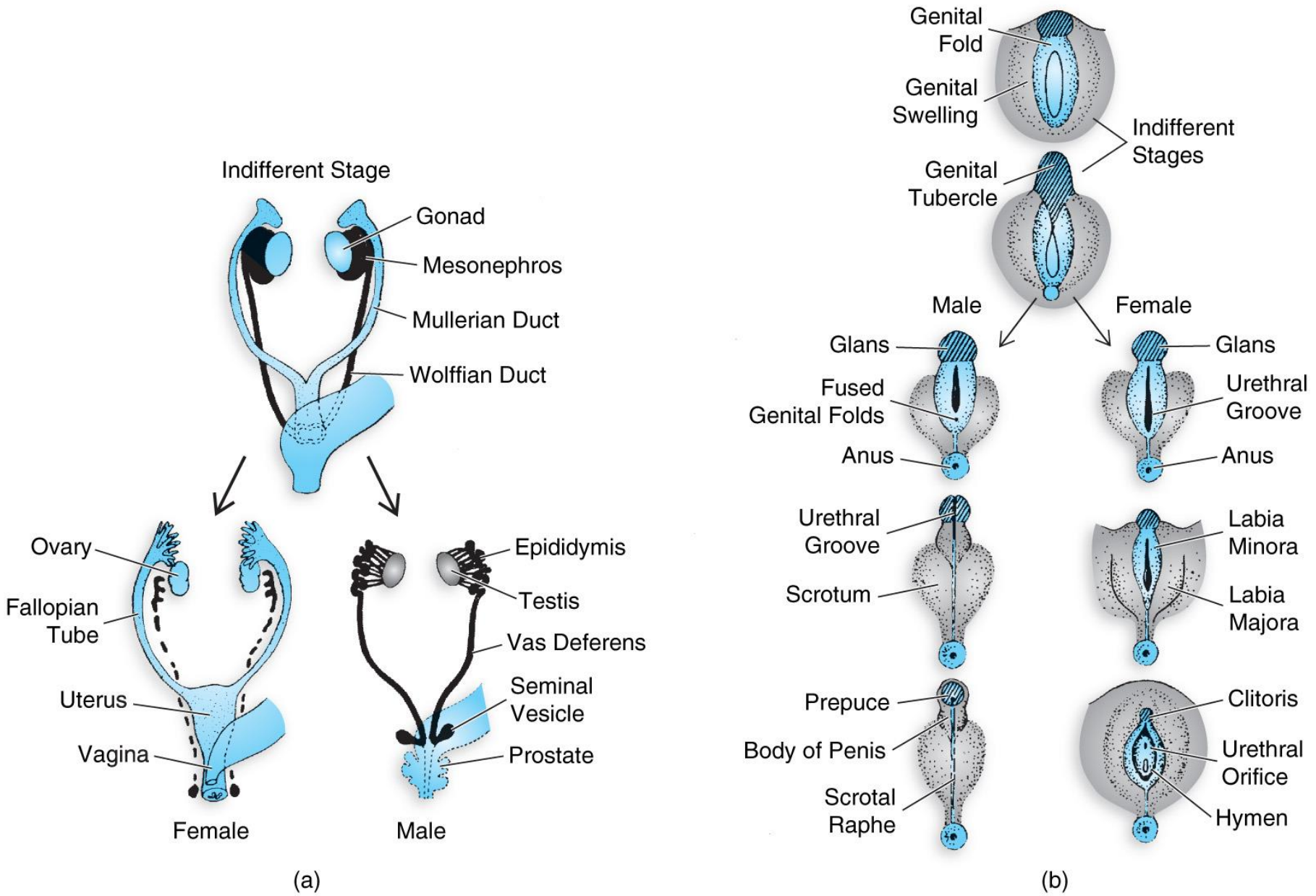
Penis
Scrotum
Prostate gland

Female

- Genital tubercle,fold, swelling &Urogenital ridge Become: (In
- the absence of dihydrotestosterone)

  – Labia majora
  – Labia Minora
  – Clitorus
  – Lower 2/3 of vagina





Sexual determination, differentiation and development

- Sexual differentiation
  - begins with the establishment of chromosomal sex at fertilization, followed by the development of gonadal sex and culminating in the formation of sexual phenotypes
  - Differentiation of Gonads
    - differentiation of testis requires TDF
  - Differentiation of accessory sex organs and external genitalia
    - mullerian-inhibiting hormone
    - testosterone

Sexual determination, differentiation and development

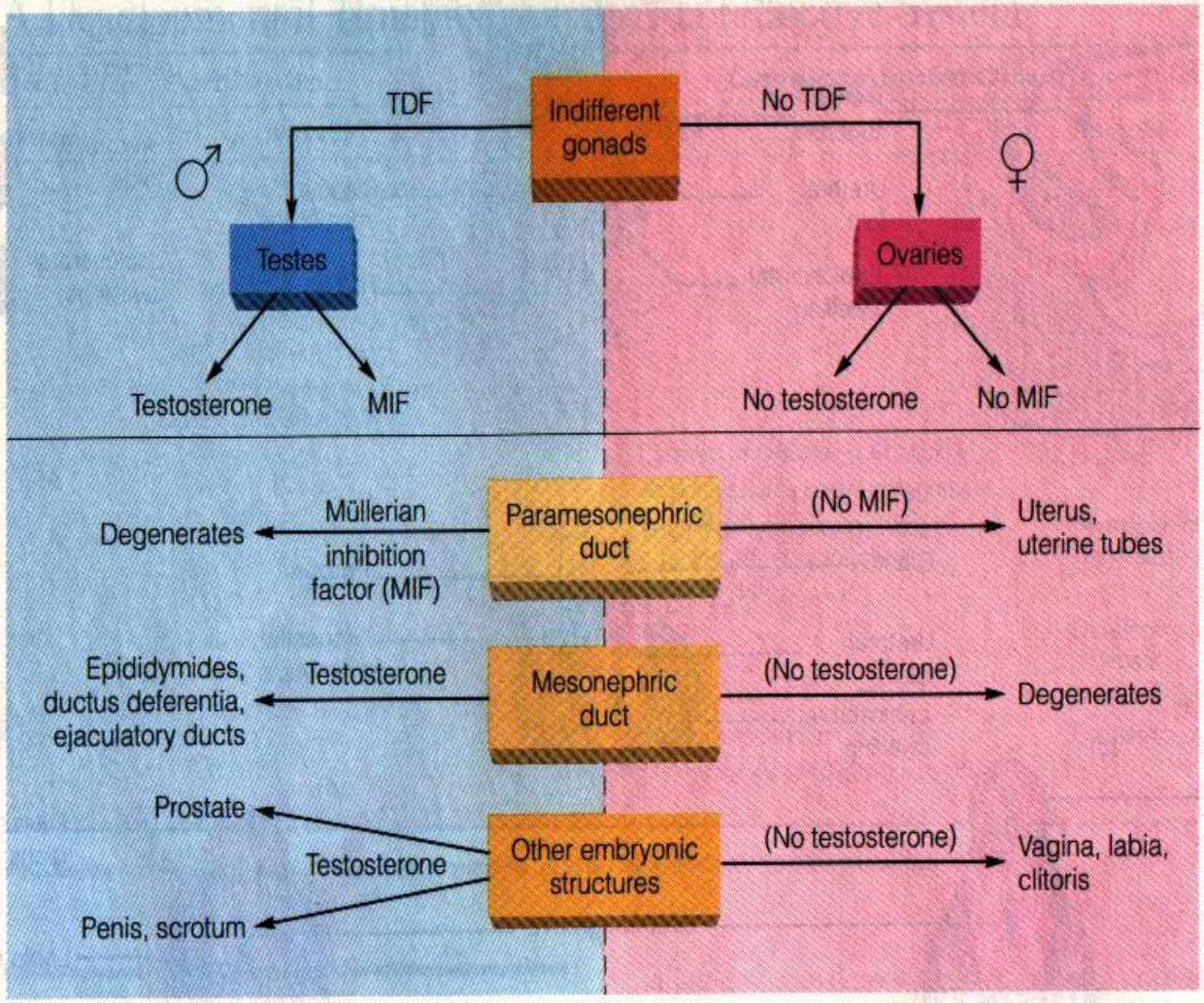
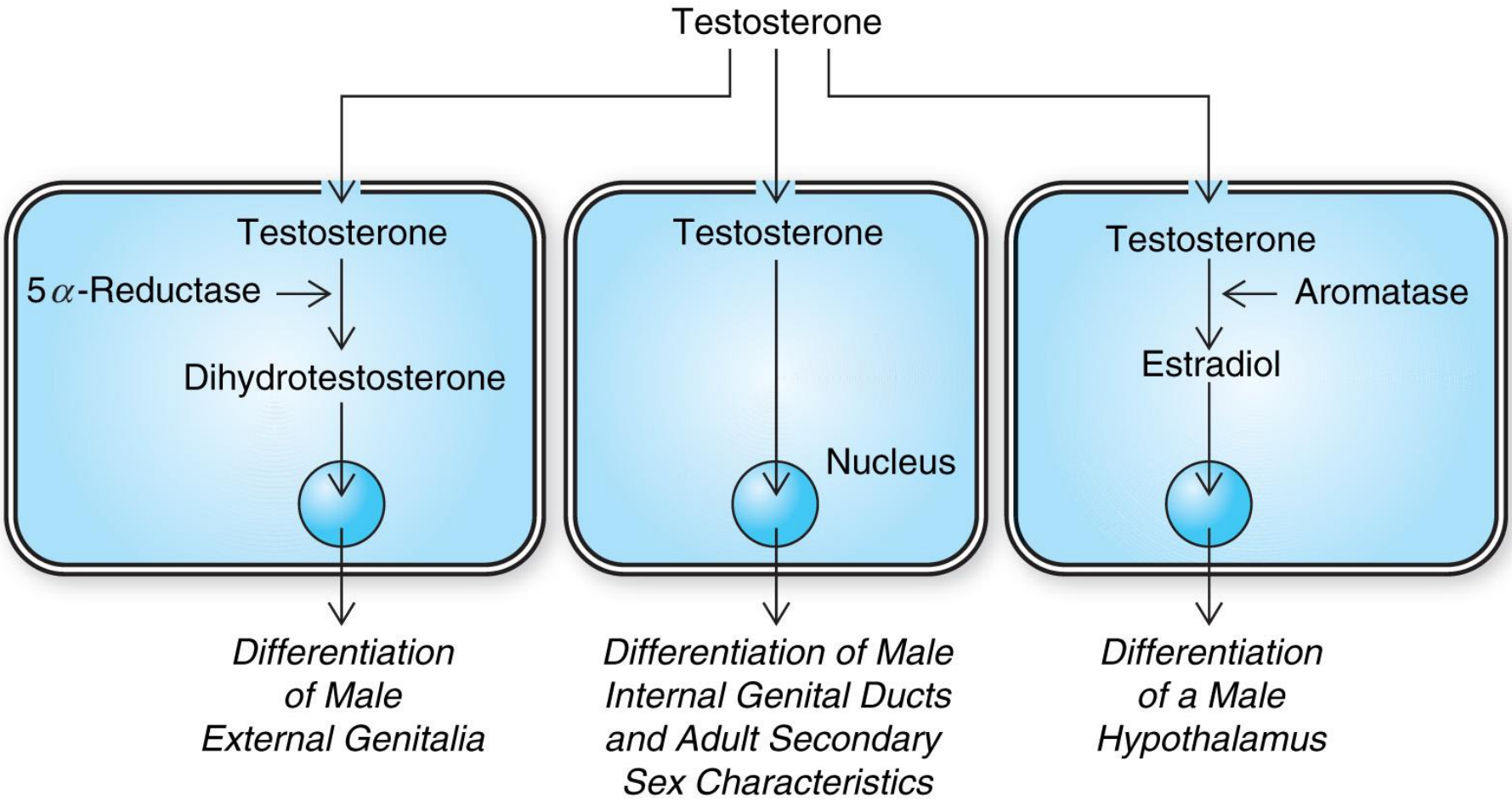


Figure 20.5

The embryonic development of male and female accessory sex organs and external genitalia. In the presence of testosterone and müllerian inhibition factor (MIF) secreted by the testes, male structures develop. In the absence of these secretions, female structures develop.

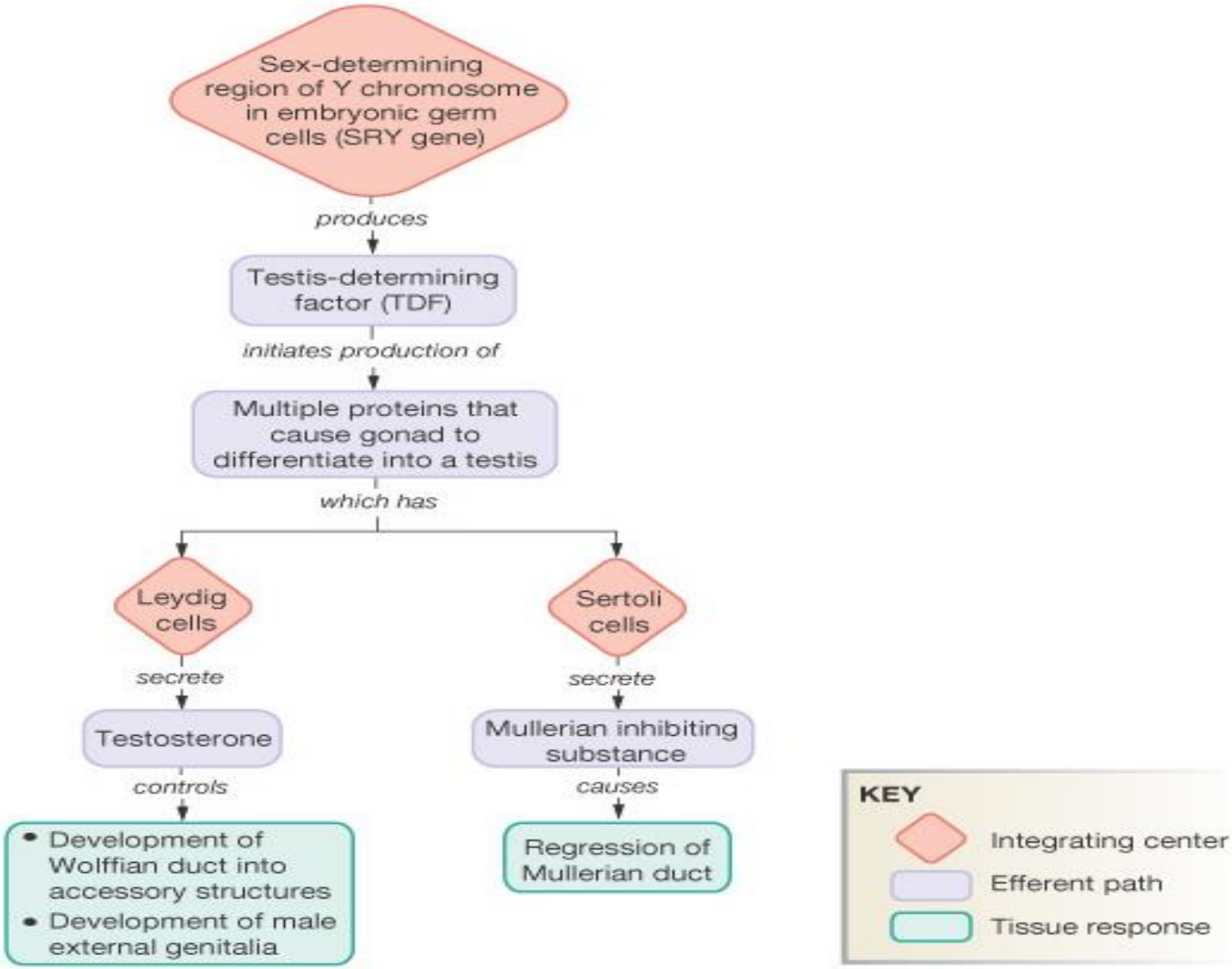
Sexual determination, differentiation and development



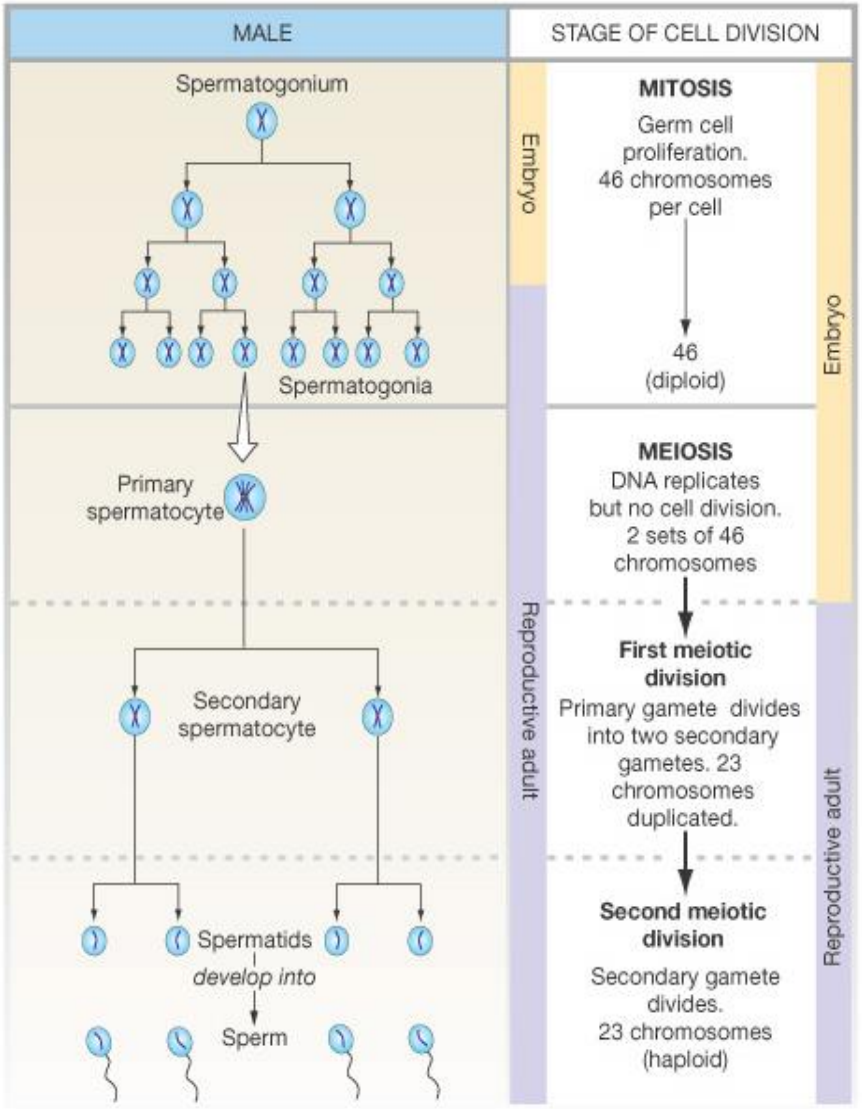
Sexual determination, differentiation and development

- Differentiation of the brain
  - male vs female
    - preoptic area
    - gonadotropins secretion pattern
    - sexual behavior
  - induced by testosterone
    - female patterns are predetermined and male patterns are induced by androgen during critical period

Pathway for Sexual Development: Review for Genes to Organs



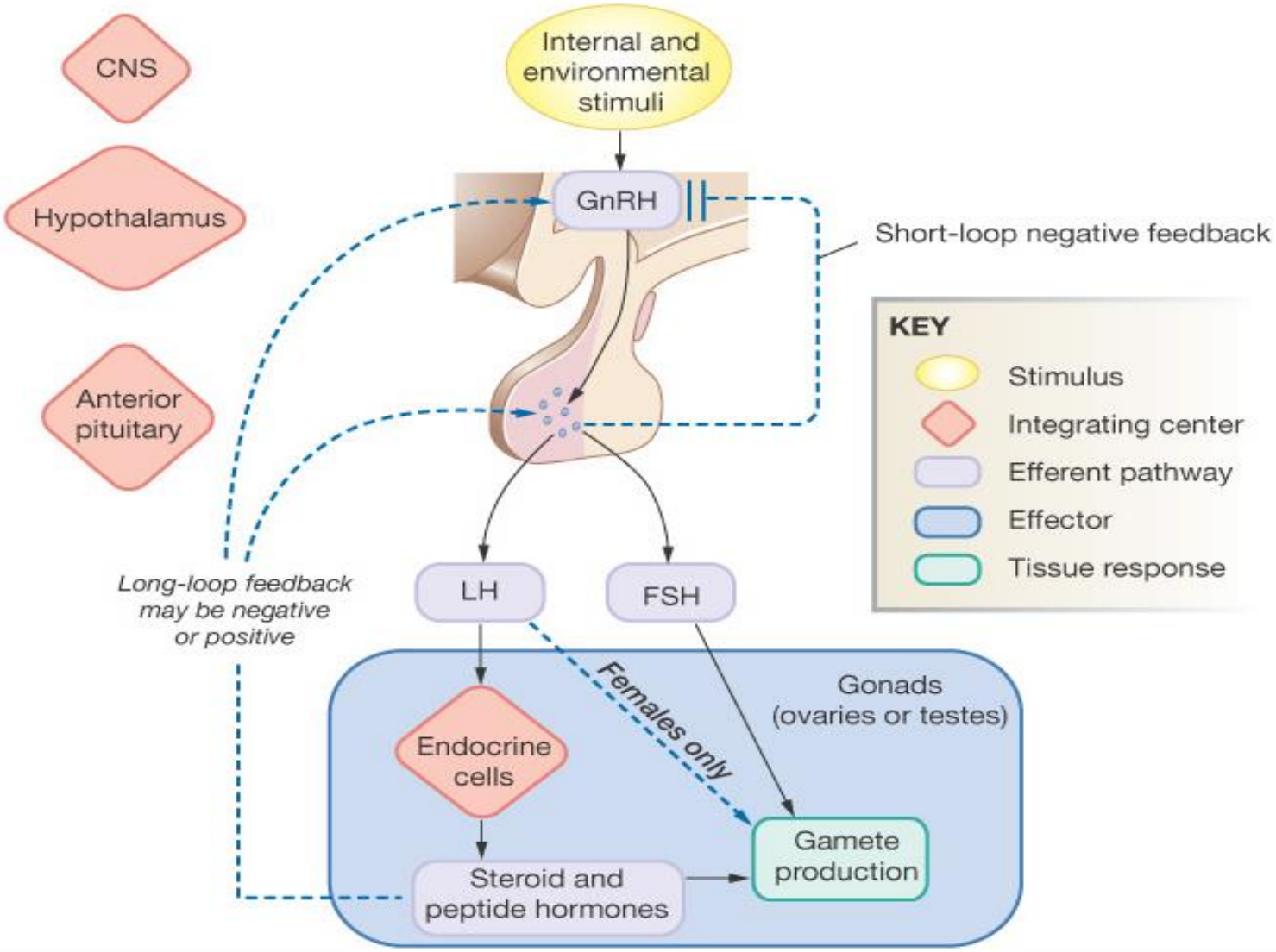
Overview of Gametogenesis: Producing Eggs or Sperm



Regulation of Reproduction: General Pathways

- Hypothalamus: pulse generator
- Gonadotropin releasing H
  - (GnRH)
- Anterior Pituitary
  - Lutenizing H (LH)
  - Follicle stimulating H (FSH)
- Ovary: progesterone
  - Estrogen, inhibin
- Testis: testosterone

Regulation of Reproduction: General Pathways



Sexual Development Dysfunctions

- Androgen insensitivity syndrome
  - Genetic mutation that prevents the formation of androgen receptors
    - Gonads become testes (normal process)
    - Defeminization (normal process)
    - Lack of masculinization (abnormal process)

An XY male with female external genitalia;

have a woman's body but not internal female sex organs

Sexual Development Dysfunctions

- Persistent Mullerian duct syndrome
  - Failure to produce anti-Mullerian hormone
  - Absence of receptors for this hormone
    - In an XY male, defeminization does not occur but masculanization does
    - Person is born with both sets of internal sex organs
- Turner's syndrome
  - Individuals have only one sex hormone: an X chromosome
    - Essentially develop into females (normal internal/external sex organs)
    - However, no ovaries since two XX chromosomes needed

Sexual determination, differentiation and development

- Puberty
  - acquisition of reproductive capability and is manifested by appearance of secondary sexual characteristics
    - hormones of the brain-pituitary-gonadal axis
    - appearance of secondary sexual characteristics
    - rapid body growth
  - Hormonal control of puberty
    - Brain is likely the site of activation during puberty
      - pulsatile GnRH secretion
      - sensitivity to negative feedback of gonadal steroids
      - melatonin may control the timing of puberty

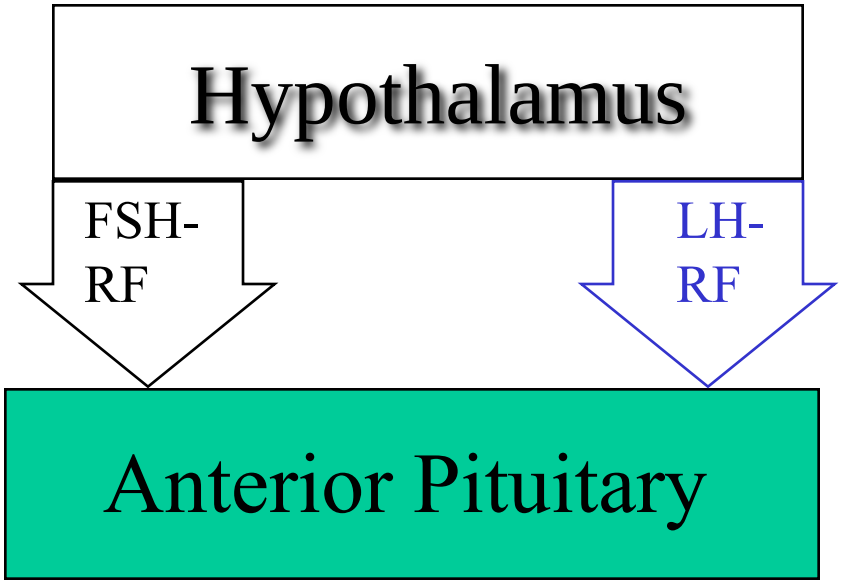
PUBERTY - development of secondary sex characteristics

- Puberty occurs when hypothalamus begins to secrete gonadotropin-releasing hormones (GnRH) causing pituitary to release
  - Follicle-stimulating hormone (FSH)
  - Luteinizing hormone (LH)

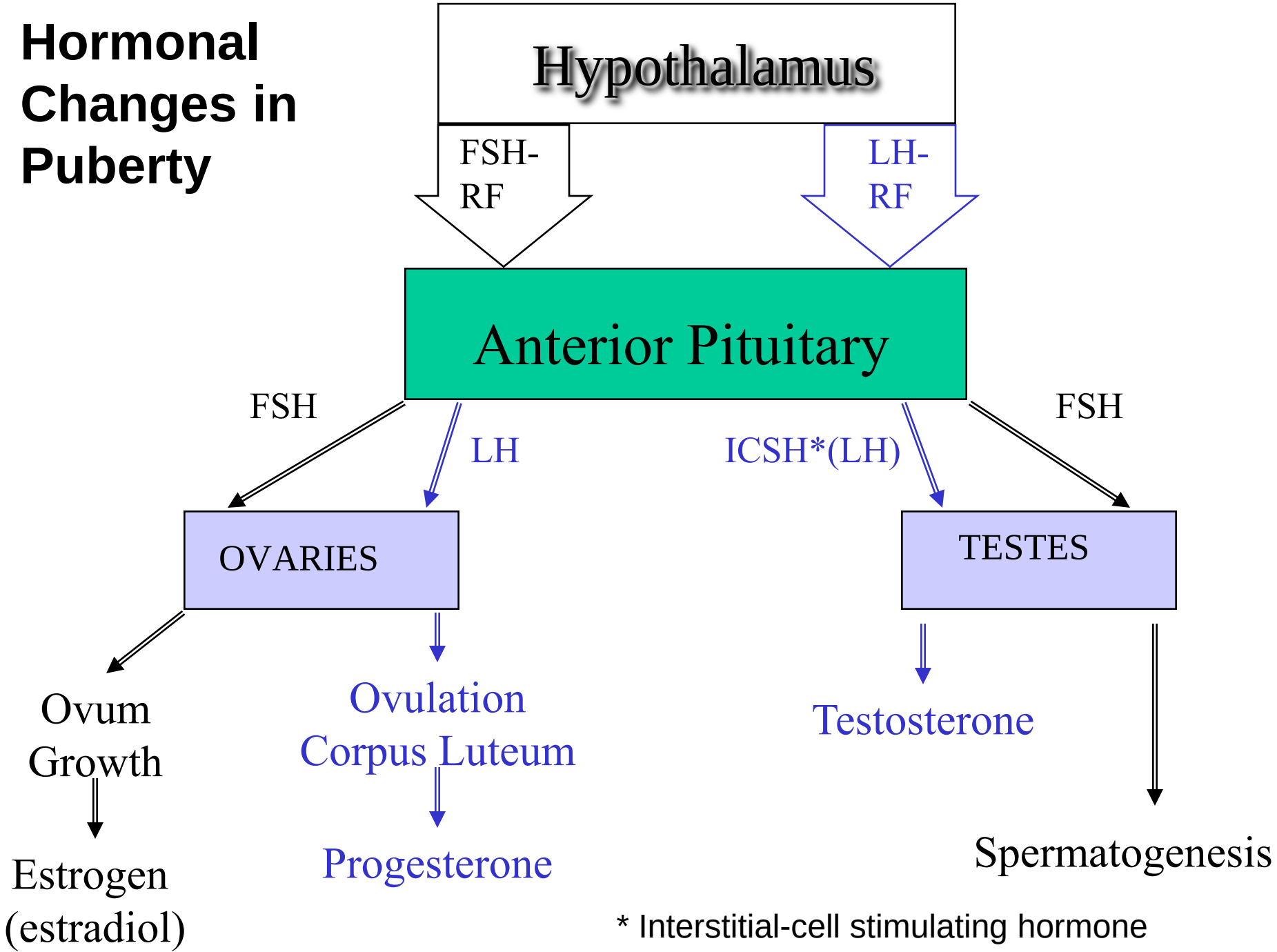
In males, these hormones stimulate testes to produce sperms and secrete testosterone (androgens)

In females, they stimulate the ovaries to produce estradiol (estrogens)

Hormonal Changes in Puberty



Hormonal Changes in Puberty



* Interstitial-cell stimulating hormone

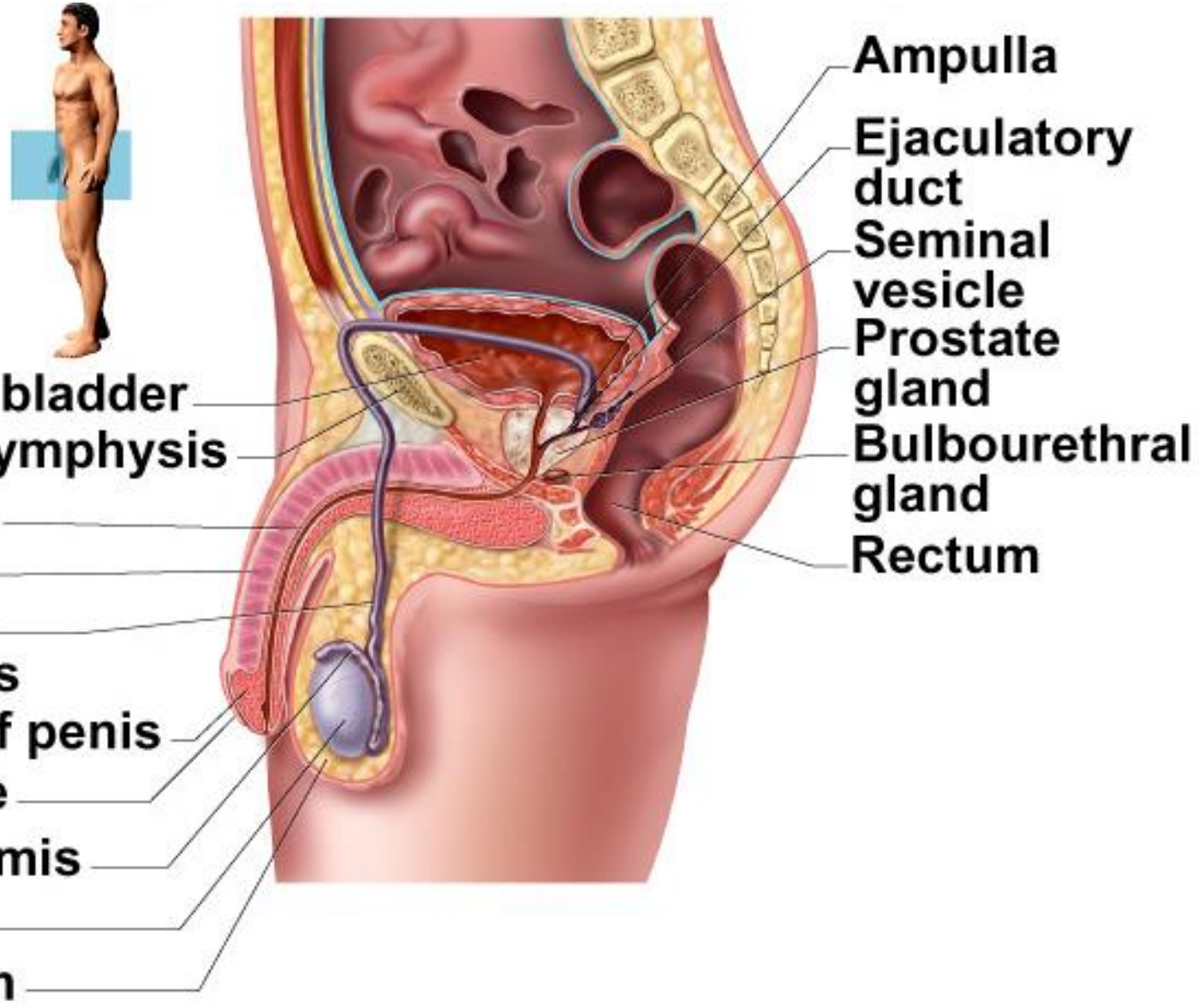
Sexual Maturation

- Secondary sex characteristics (onset of puberty)
  - Females (estradiol)
    - Enlarged breasts
    - Growth of the lining of the uterus
    - Widened hips
    - Maturation of genitalia
  - Females (androgens)
    - Armpit and pubic hair (face as well)
  - Males (androgens)
    - Facial, underarm, and pubic hair
    - Deep voice
    - Alter hairline (baldness)
    - Muscle development
    - Maturation of genitalia
  - Males (estradiol)
    - Enlarged breasts

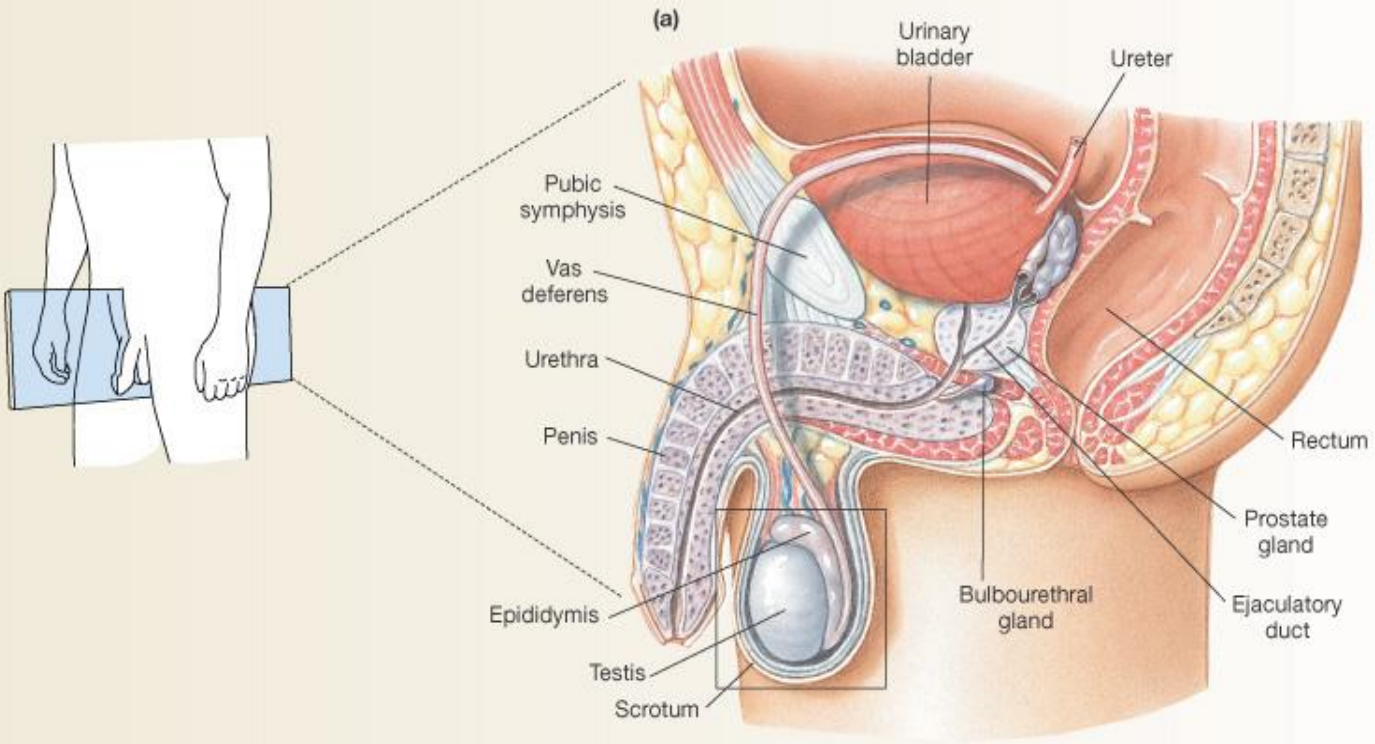
Male Reproductive System

- The male gonads (testes) produce sperm and lie within the scrotum
- Sperm are delivered to the exterior through a system of ducts: epididymis, ductus deferens, and the urethra
- Accessory sex glands:
  - Empty their secretions into the ducts during ejaculation
  - Include the seminal vesicles, prostate gland, and bulbourethral glands

Male Reproductive System



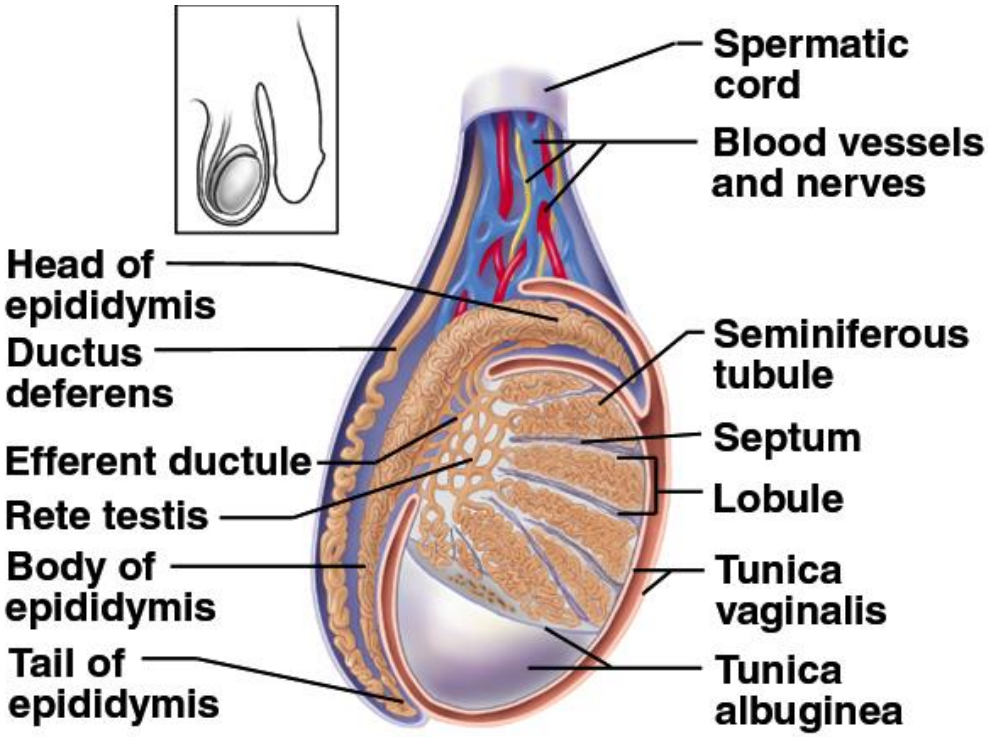
STRUCTURE OF THE MALE REPRODUCTIVE SYSTMEM

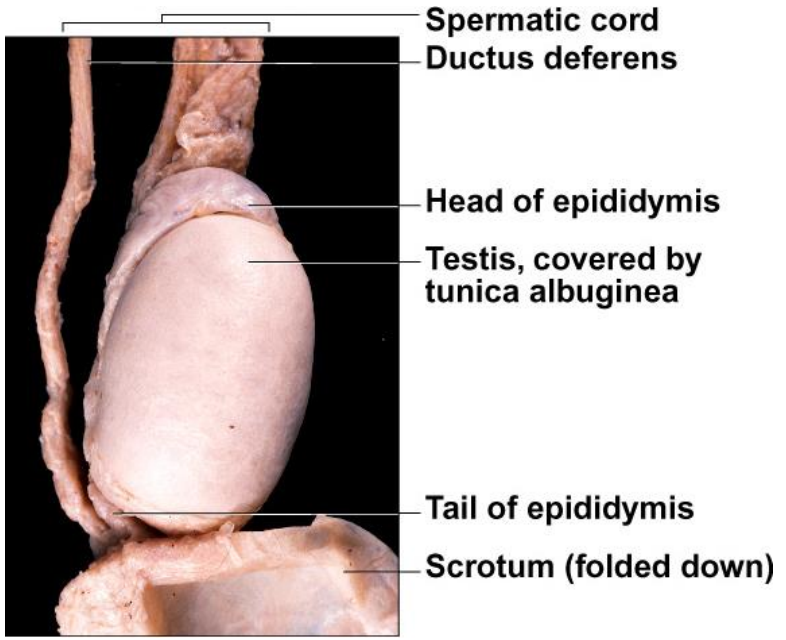


Testes

- Oval organ, 4 cm long x 2.5 cm in diameter
- Covered anteriorly by a saclike extension of the peritoneum (tunica vaginalis) that descended into the scrotum with the testes
- Tunica albuginea = white fibrous capsule
  - **septa divide the organ into compartments containing seminiferous tubules where sperm are produced**
    - each tubule is lined with a thick germinal epithelium composed of germ cells in the process of becoming sperm
  - **interstitial (Leydig) cells - clusters of cells between the seminiferous tubules and source of testosterone**
  - **sustentacular (Sertoli) cells promote sperm cell development**
    - blood-testis barrier is formed by tight junctions between sustentacular cells -- separating sperm from immune system

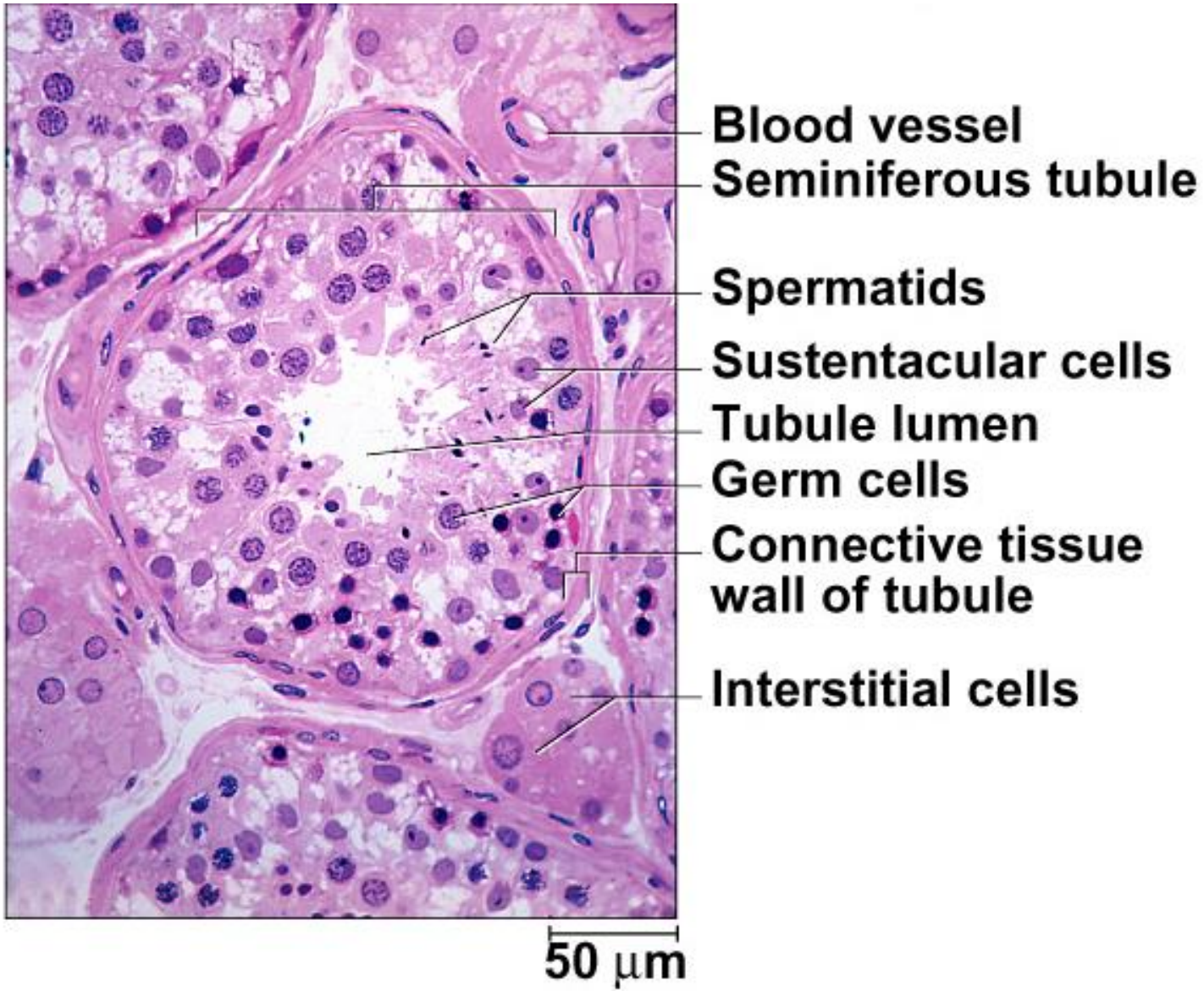
Testis and Associated Structures





- **Seminiferous tubules drain into network called rete testis**
- **Low BP of testicular artery (arises from the abdominal aorta just below the renal artery) results in poor O_2 supply**
  - sperm develop very large mitochondria helping them survive the hypoxic environment of the female reproductive tract
- **Testicular veins drain to the inferior vena cava**

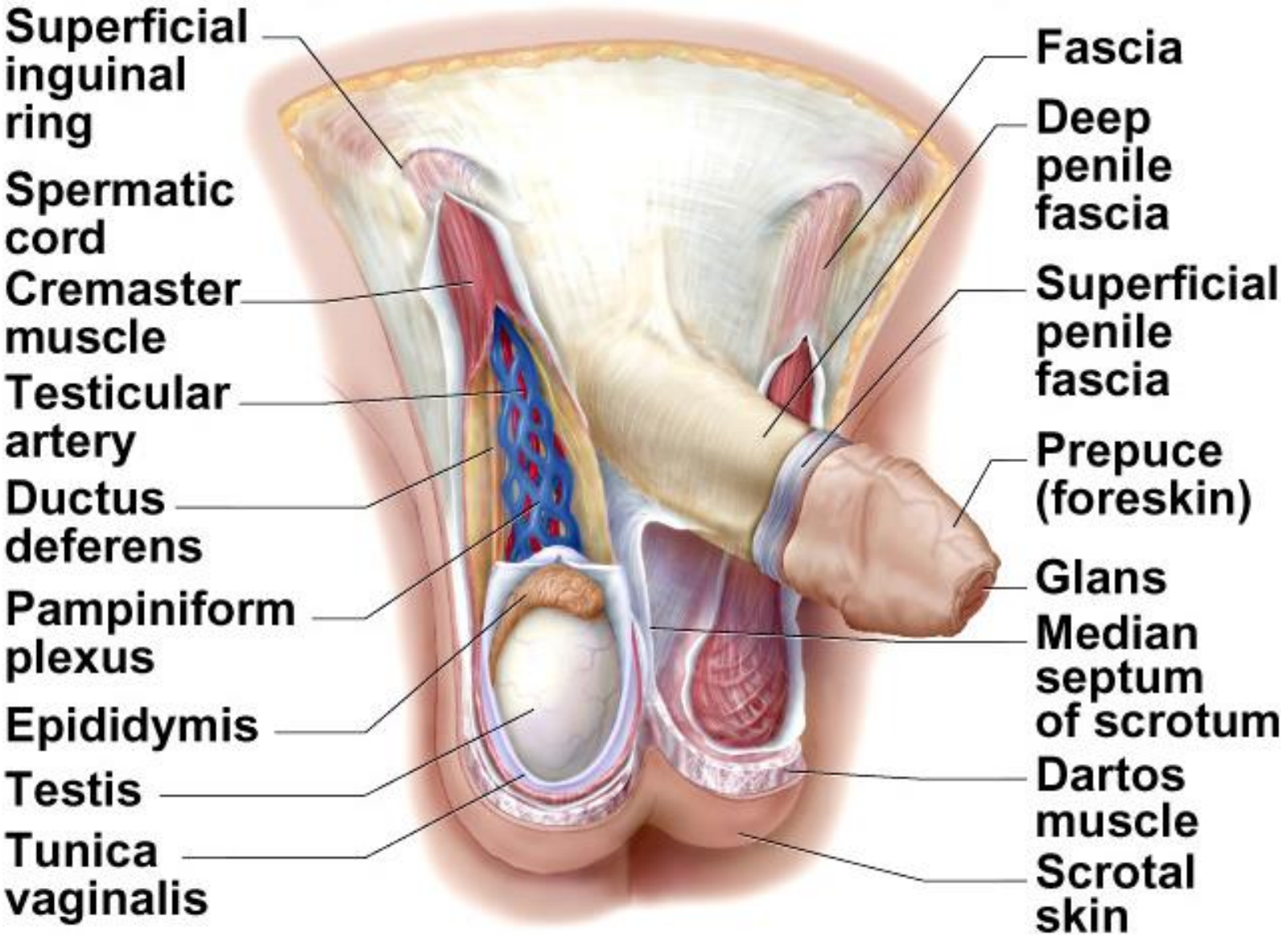
Histology of the Testis



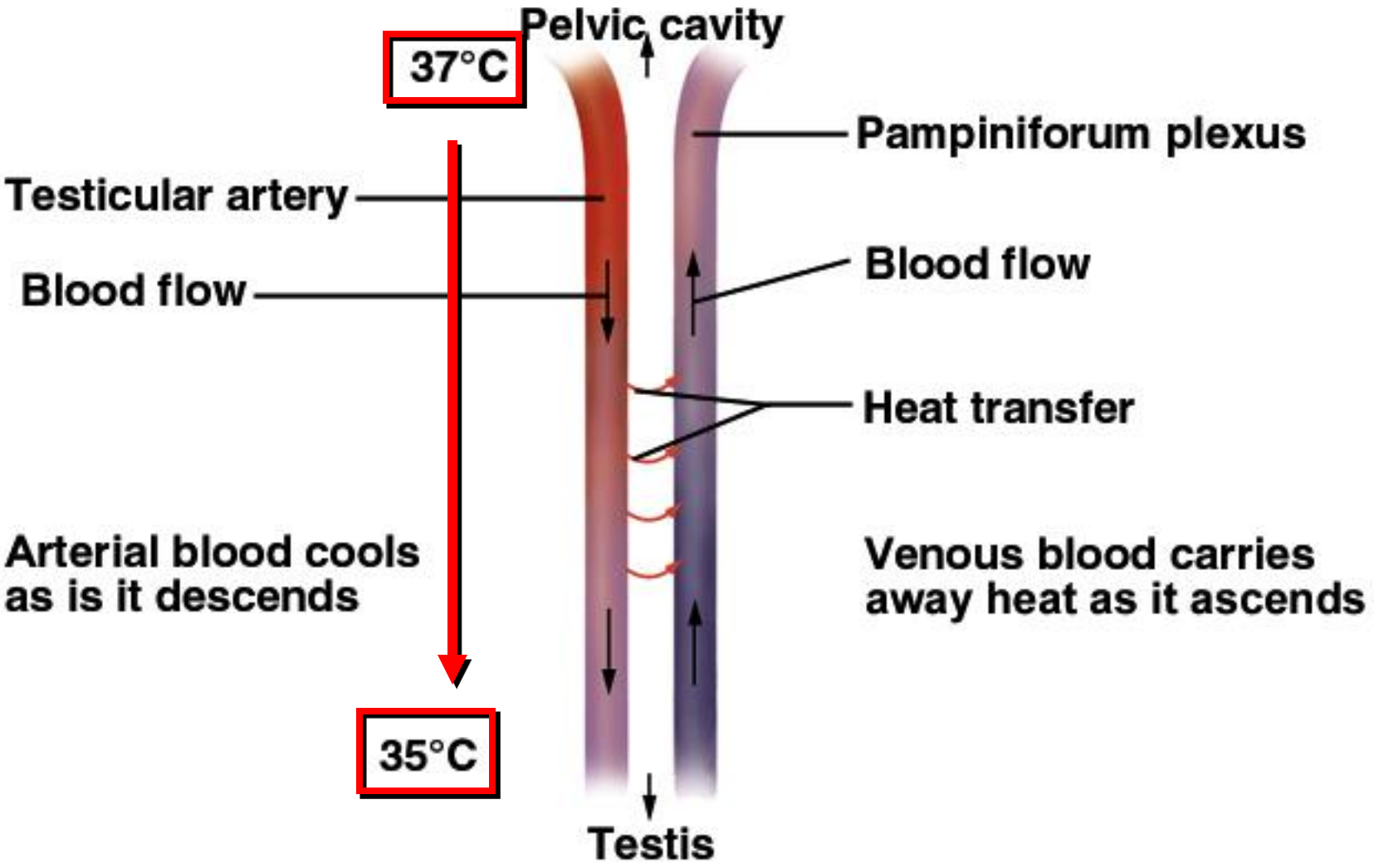
Scrotum

- Pendulous pouch holding the testes
  - divided into 2 compartments by median septum
- Spermatic cord - A cordlike structure, consisting of the ductus deferens and its accompanying arteries, veins, nerves, and lymphatic vessels, that passes from the abdominal cavity through the inguinal canal down into the scrotum to the back of the testicle
- Testicular thermoregulation is necessary since sperm are not produced at core body temperature
  - cremaster muscle = segments of internal oblique muscle that pull testes closer to body when contracted
  - dartos muscle = smooth muscle wrinkles skin reducing surface area of scrotum & lifting it upwards
  - pampiniform plexus = veins ascending near testicular artery
    - countercurrent heat exchanger cools arterial blood entering the testis

Male Inguinal & Scrotal Region



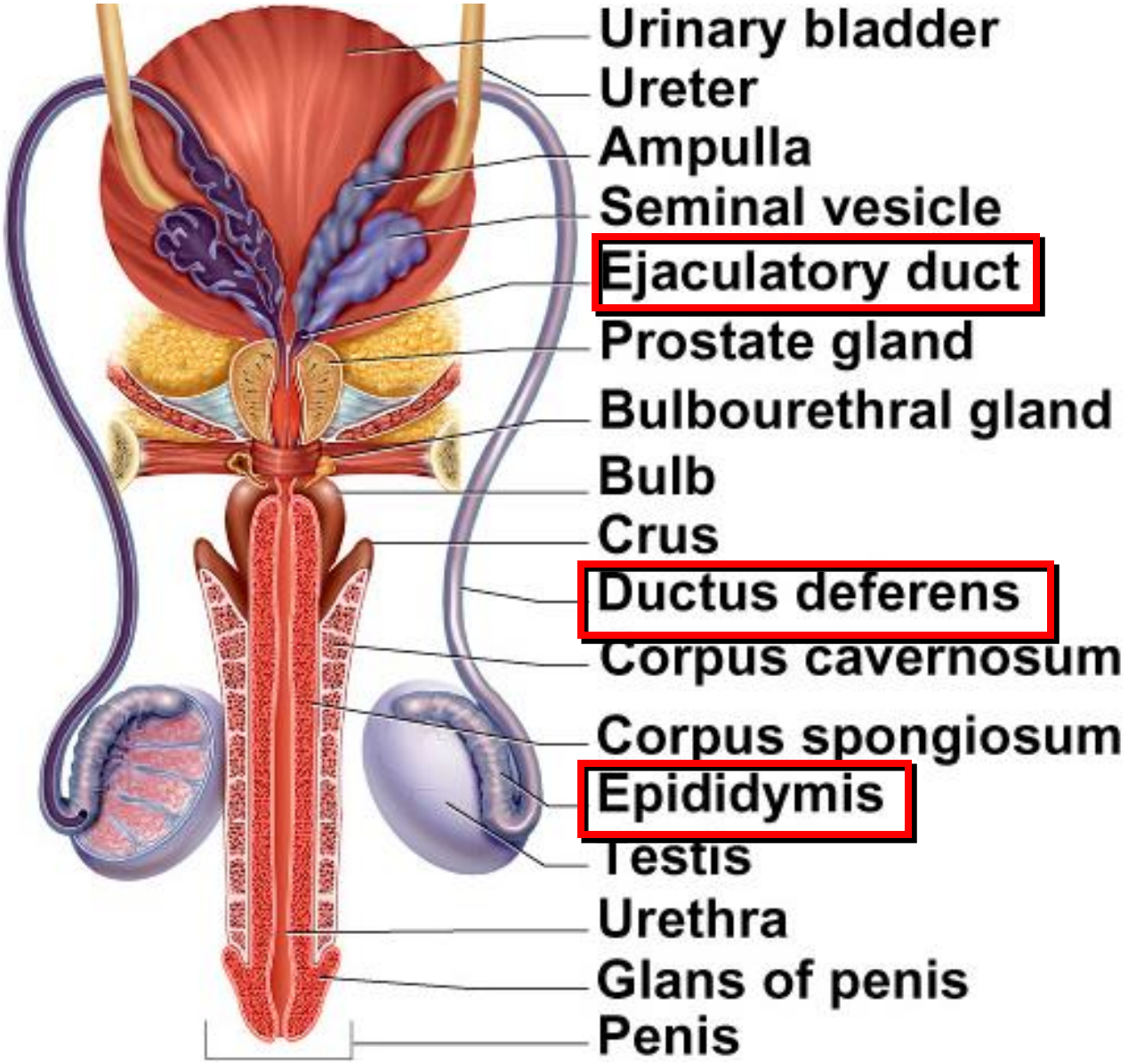
Heat Exchange of Pampiniform Plexus



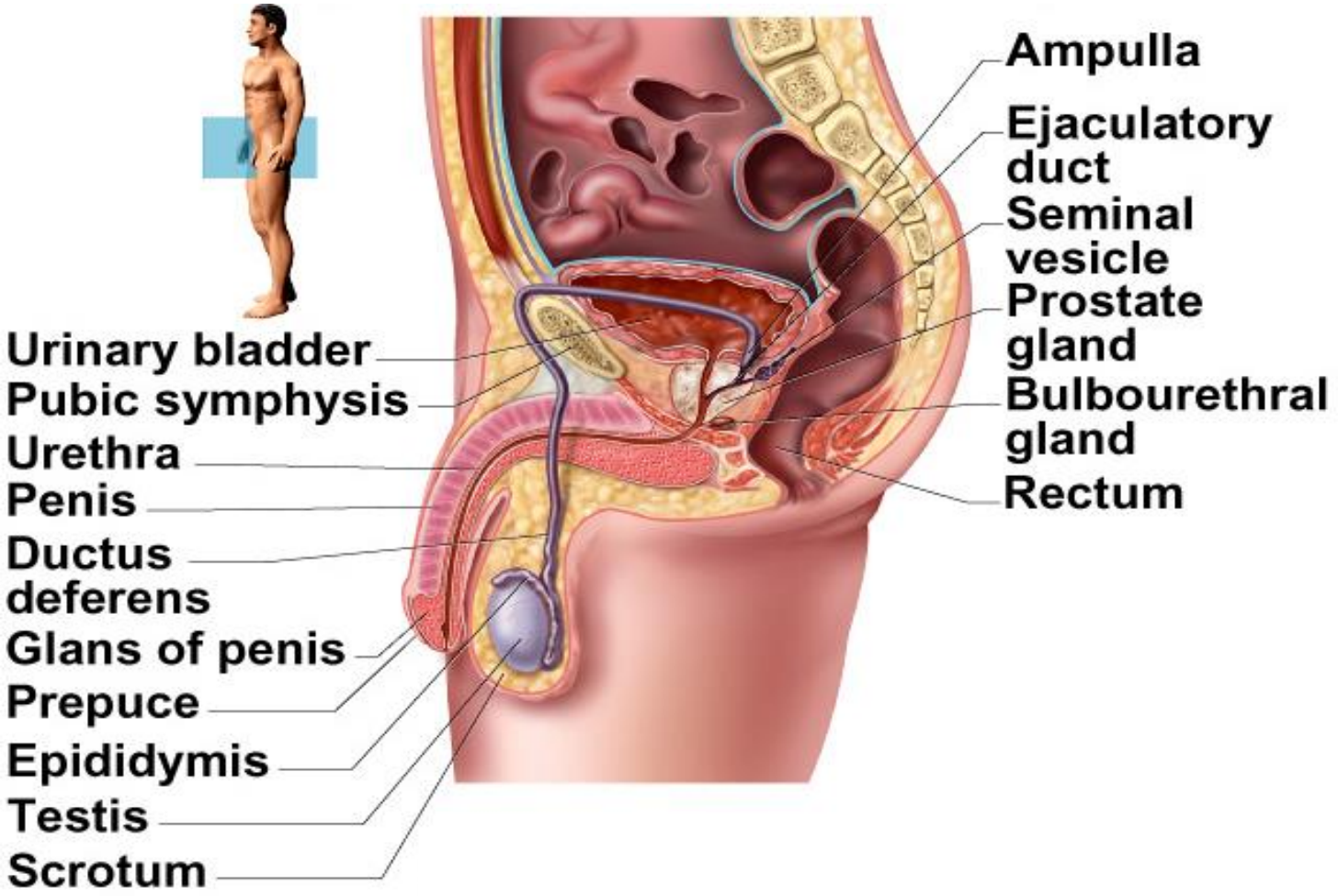
Spermatic Ducts

- Efferent ductules
  - 12 small ciliated ducts collecting sperm from the rete testes and transporting it to the epididymis
- Epididymis (head, body & tail)
  - 6 m long coiled duct adhering to the posterior of testis
  - site of sperm maturation & storage (fertile for 40 to 60 days)
- Ductus (vas) deferens
  - muscular tube 45 cm long passing up from scrotum through inguinal canal to posterior surface of bladder
  - widens into a terminal ampulla
- Ejaculatory duct
  - 2 cm duct formed from ductus deferens & seminal vesicle & passing through prostate to empty into urethra

Male Duct System

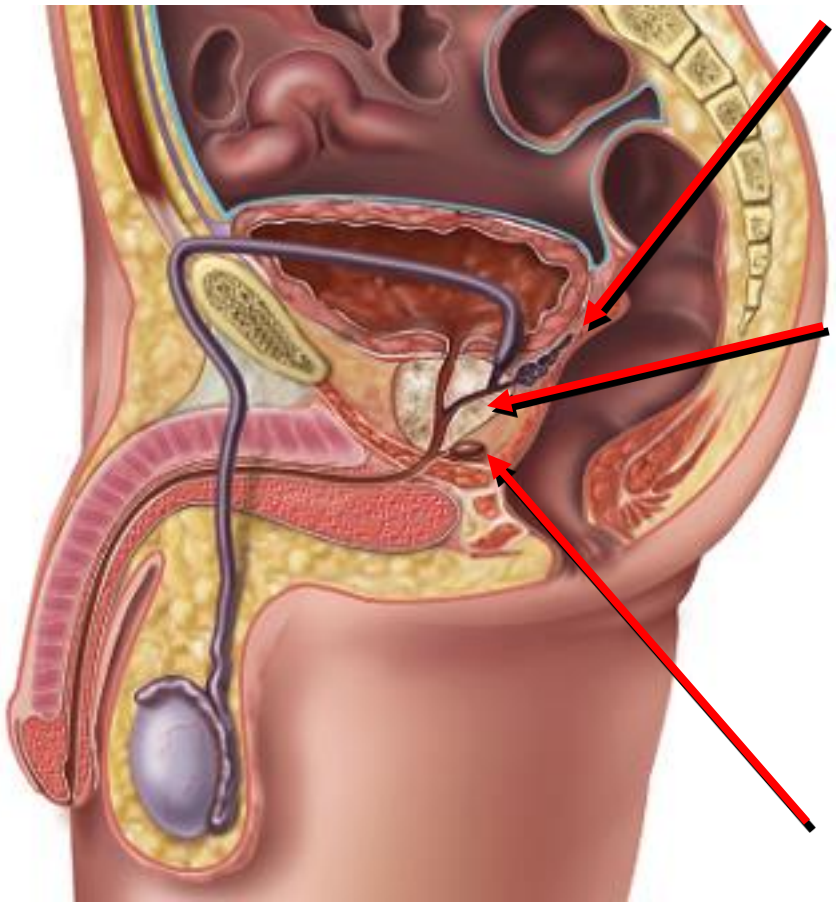


Male Urethra



- Regions of male urethra: prostatic, membranous and penile --- totals 20 cm long

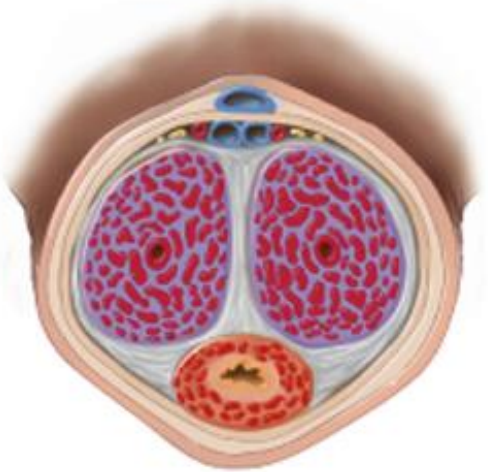
Accessory Glands



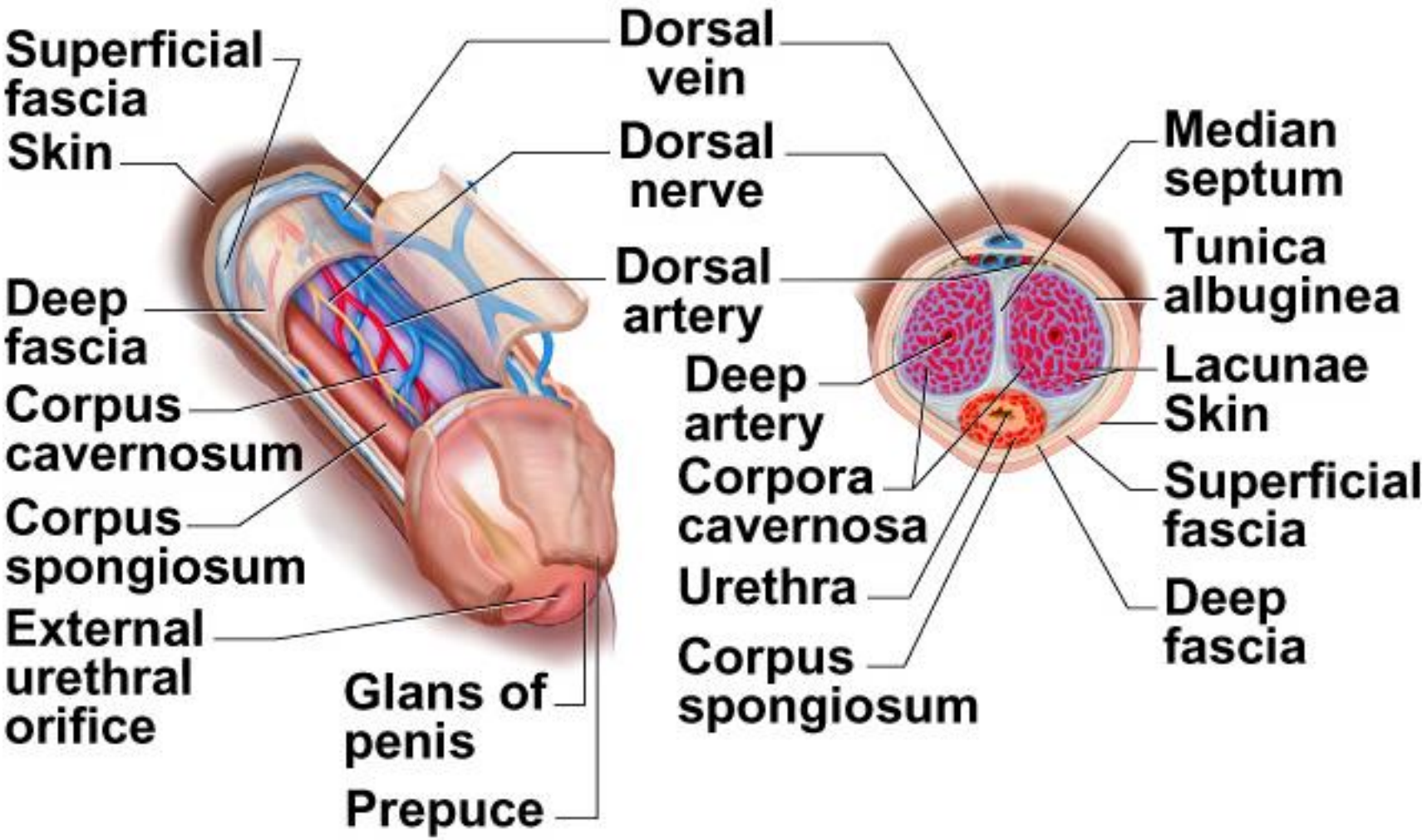
- Seminal vesicles
  - posterior to bladder
  - empty into ejaculatory duct
- Prostate gland
  - below bladder, surrounds urethra and ejaculatory duct
  - empty through pores in urethral wall
- Bulbourethral glands
  - near bulb of penis
  - empty into penile urethra
  - lubricating fluid

Penis

- Internal root and externally visible shaft and glans
  - skin over shaft is loosely attached allowing expansion
    - extends over glans as prepuce or foreskin
- Consists of 3 cylindrical bodies of erectile tissue
  - single corpus spongiosum along ventral side of penis
    - encloses penile urethra
    - ends as a dilated bulb
  - paired corpora cavernosa
    - diverge like arms of a Y
    - each crus attaches to pubic arch and perineal membrane



Anatomy of the Penis



Sertoli cells

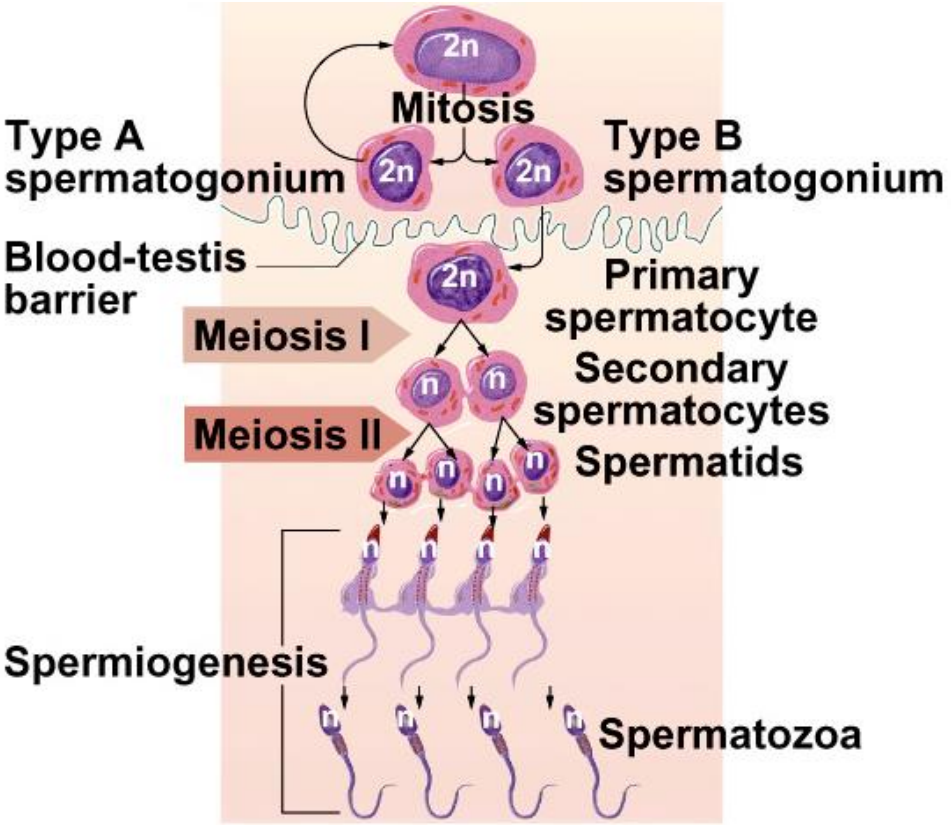
- Cells that extend from the basal lamina to the lumen of the tubule that surrounds developing cells
- They are bound together with tight junctions forming an unbroken layer with the seminiferous tubule, dividing it into two compartments
  - The basal compartment – contains spermatogonia and primary spermatocytes
  - Adluminal compartment – contains meiotically active cells and the tubule lumen .
  - Their tight junctions form a blood-testis barrier
- This prevents sperm antigens from escaping through the basal lamina into the blood

Functions

- Support Production of Spermatozoa
- Production of Androgen-Binding Protein Intratesticularly (TeBG)
- Form Blood-Testes Barrier
- Produce Inhibin
- Produce Seminiferous tubule fluid (bathing medium, nutrients, capacitation, motility)

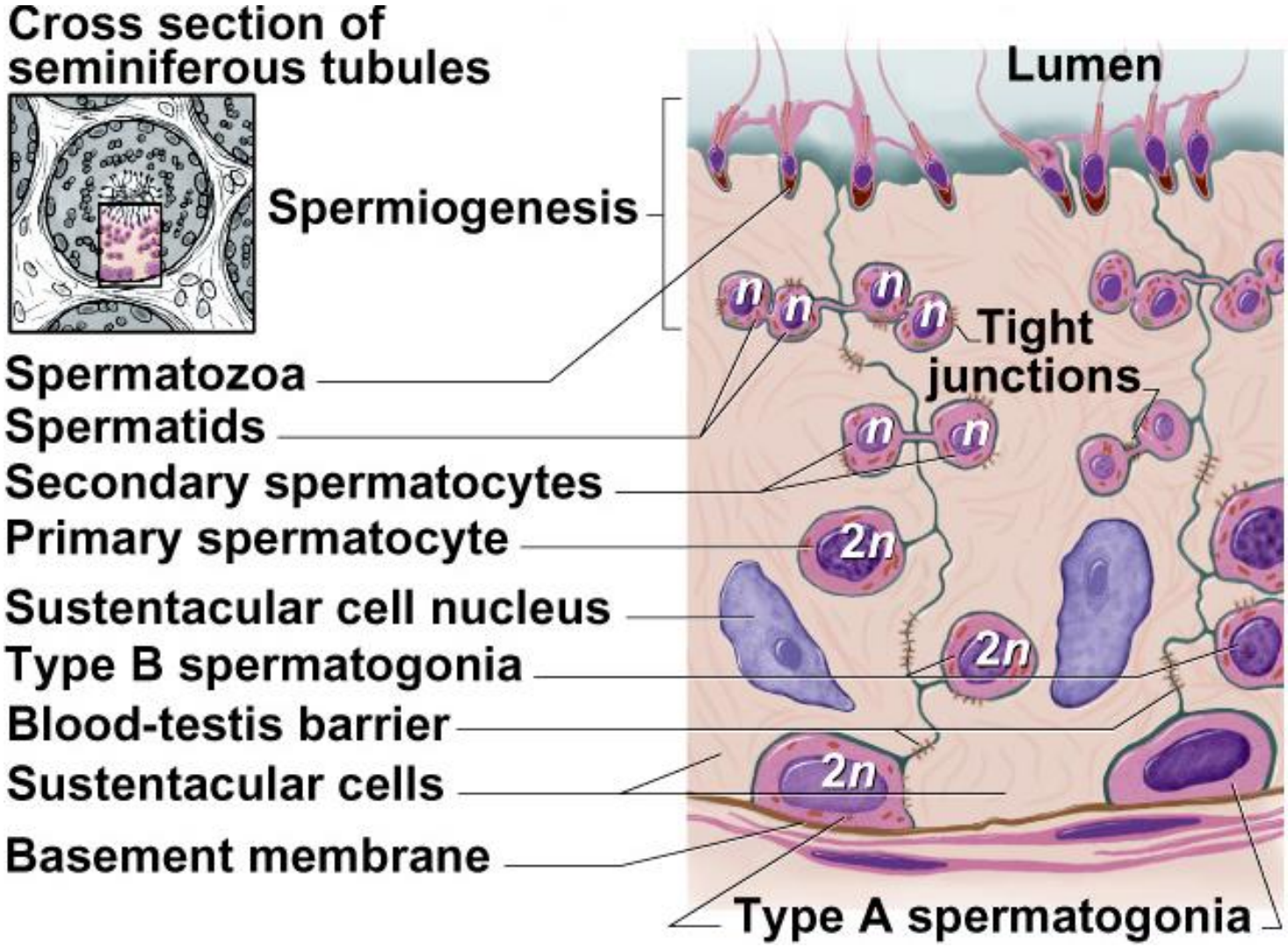
Spermatogenesis

- Spermatogonia produce 2 kinds of daughter cells
  - type A remain outside blood-testis barrier & produce more daughter cells until death
  - type B differentiate into primary spermatocytes
    - cells must pass through BTB to move inward toward lumen - tight junctions form behind these cells
    - meiosis I → 2 secondary spermatocytes
    - meiosis II → 4 spermatids

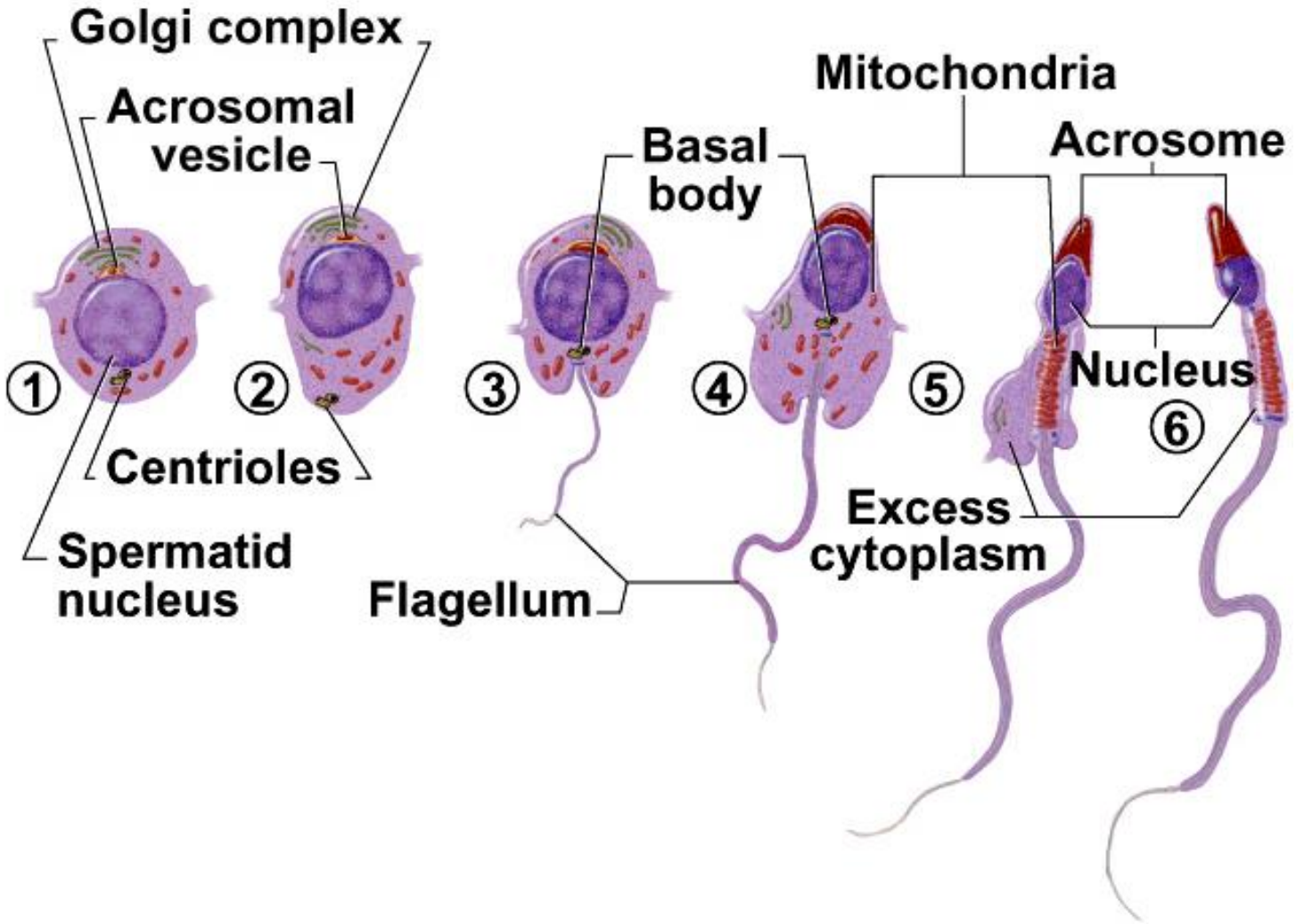


- Spermiogenesis is transformation of spermatids into spermatozoa
  - sprouts tail and discards cytoplasm to become lighter

Spermatogenesis & Sustentacular Cells



Spermiogenesis

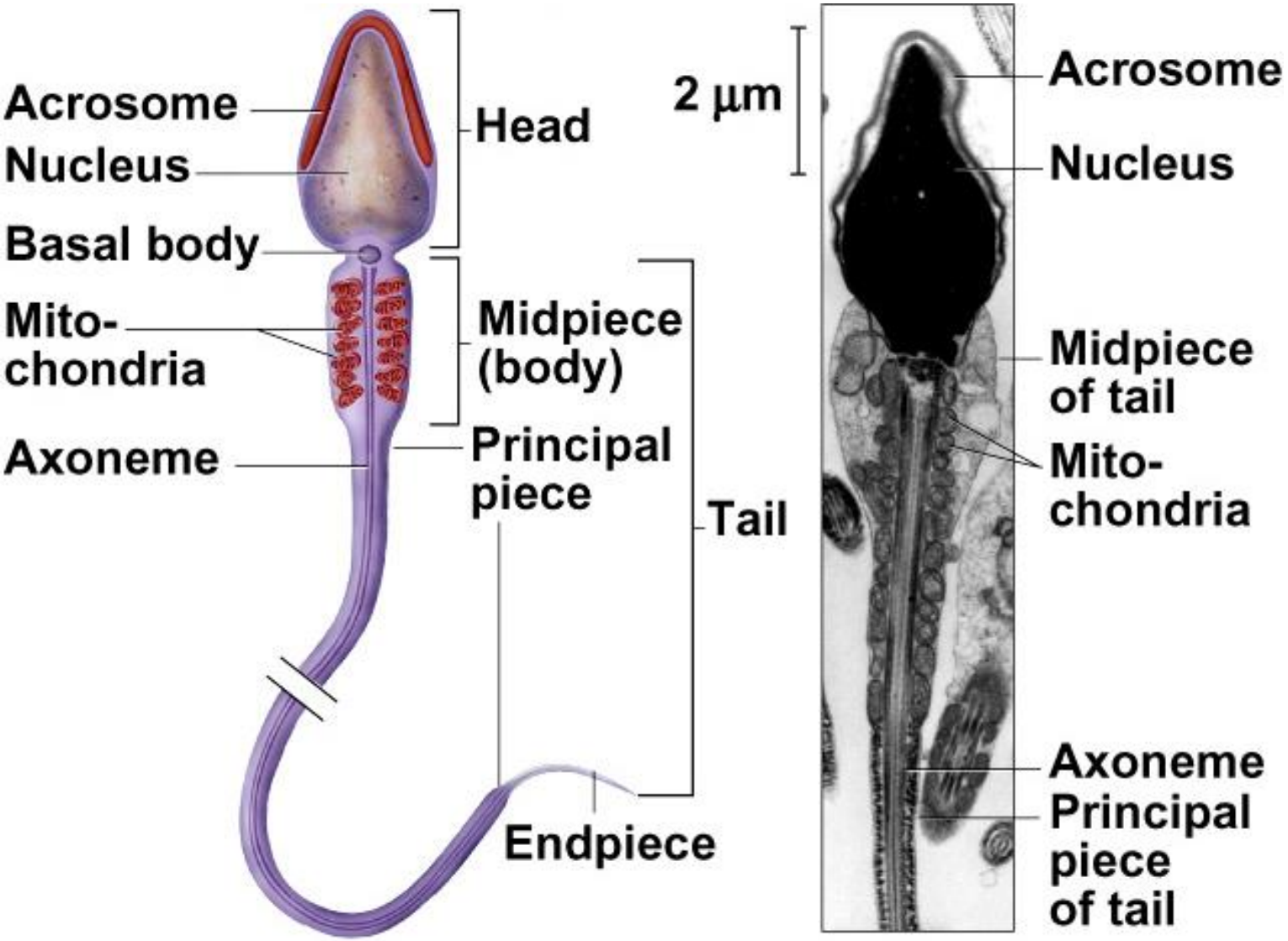


- Changes that transform spermatids into spermatozoa
  - discarding excess cytoplasm & growing tails

Spermatozoon

- Sperm have three major regions
  - Head – contains DNA and has a helmet like acrosome containing hydrolytic enzymes that allow the sperm to penetrate and enter the egg
  - Midpiece – contains mitochondria spiraled around the tail filaments
  - Tail – a typical flagellum produced by a centriole

Spermatozoon



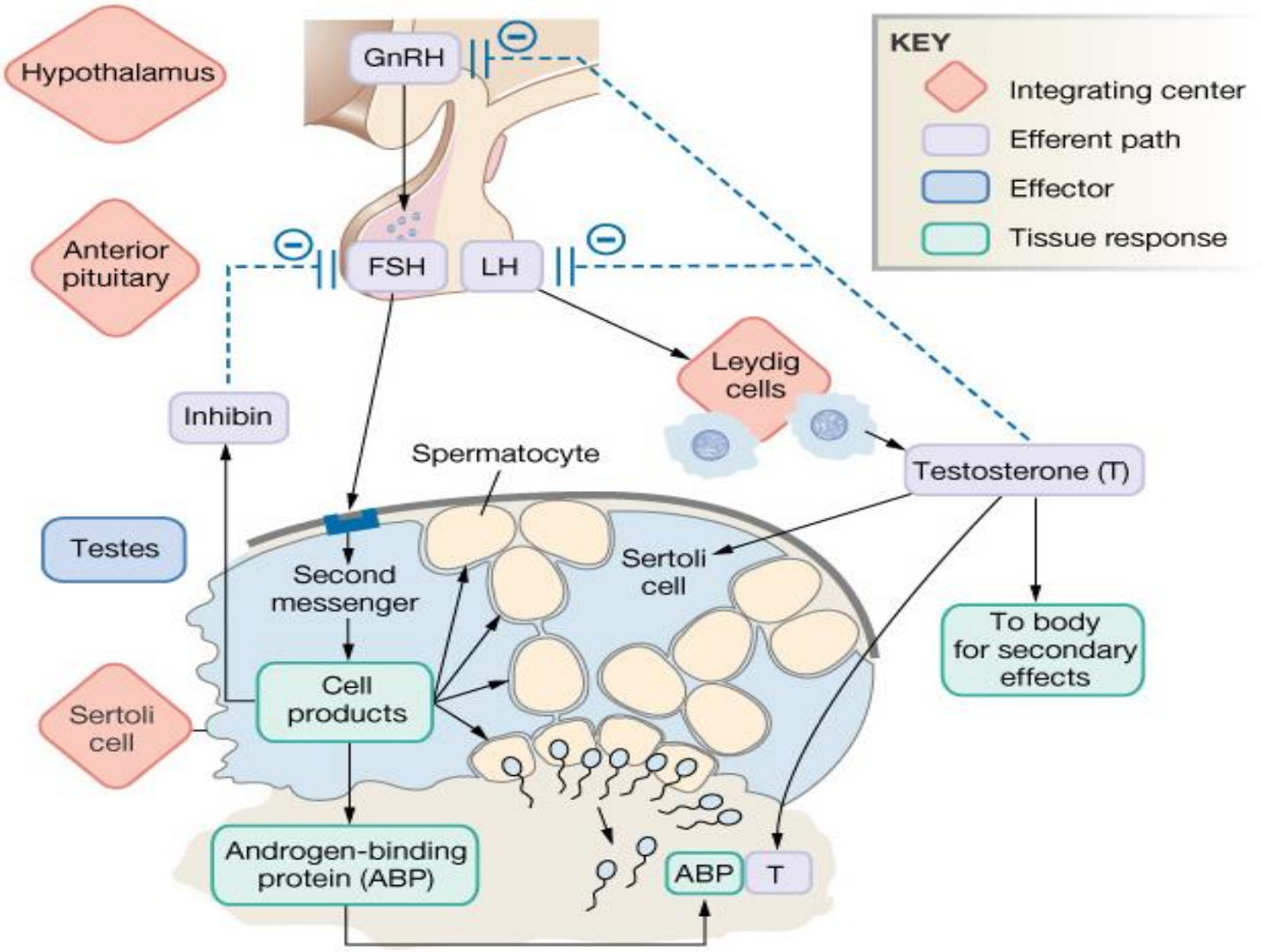
Semen

- 2-5 mL of fluid expelled during orgasm
  - **60% seminal vesicle fluid, 30% prostatic & 10% sperm and trace of bulbourethral fluid**
    - normal sperm count is 50-120 million/mL (< 25 million/mL is associated with infertility)
- **Other components of semen**
  - fructose provide energy for sperm motility
  - fibrinogen
  - clotting enzymes convert fibrinogen to fibrin causing semen to clot
  - fibrinolysin liquefies semen within 30 minutes
  - prostaglandins stimulate female peristaltic contractions
  - spermine is a base stabilizing sperm pH at 7.2 to 7.6

Hormonal Regulation of Testicular Function

- The hypothalamus releases gonadotropin-releasing hormone (GnRH)
- GnRH stimulates the anterior pituitary to secrete FSH and LH
  - FSH causes sustentacular cells to release androgen-binding protein (ABP)
  - LH stimulates interstitial cells to release testosterone
- ABP binding of testosterone enhances spermatogenesis

Regulation of Spermatogenesis



- Feedback inhibition on the hypothalamus and pituitary results from:
  - Rising levels of testosterone
  - Increased inhibin

Mechanism and Effects of Testosterone Activity

- Testosterone is synthesized from cholesterol
- Required for initiation and maintenance of spermatogenesis
- It must be transformed to exert its effects on some target cells
  - Prostate – it is converted into dihydrotestosterone (DHT) before it can bind within the nucleus
  - Neurons (Brain) – it is converted into estrogen to bring about stimulatory effects
- Testosterone targets all accessory organs and its deficiency causes these organs to atrophy

Male Secondary Sex Characteristics

- Male hormones make their appearance at puberty and induce changes in nonreproductive organs, including
  - Appearance of pubic, axillary, and facial hair
  - Enhanced growth of the chest and deepening of the voice
  - Skin thickens and becomes oily
  - Bones grow and increase in density
  - Skeletal muscles increase in size and mass
- Testosterone is the basis of libido in both males and females

Actions of androgens in the Male

- 1. Sex determination
- * Growth and d/v of wolffian ducts into epididymis, ductus deferens ,seminal vesicles, and ejaculatory ducts
- *d/v of urogential sinus into prostate
- * d/v of male external genitalia
- 2.Spermatogensis
- * At puberty :Completion of meiotic division and early maturation of spermatids
- * After puberty: Maintenance of spermatogenesis

Continued …….

- 3. Secondary sex characteristics
- 4. Anabolic effects
- * Protein synthesis
- * Growth of bones
- * Growth of other organs
- * Erythropoiesis

Table 16–2 ■ Effects of Testosterone

Effects before Birth
Masculinizes the reproductive tract and external genitalia

Promotes descent of the testes into the scrotum of most mammals

Effects on Sex-Specific Tissues
Promotes growth and maturation of the reproductive system at puberty

Essential for spermatogenesis

Maintains the reproductive tract throughout adulthood

Other Reproductive Effects
Develops the sex drive at puberty

Controls gonadotropin hormone secretion

Effects on Secondary Sexual Characteristics
Induces the male pattern of hair or feather growth

Causes the voice to deepen because of thickening of the vocal cords

Promotes muscle growth responsible for the male body configuration

Nonreproductive Actions
Exerts a protein anabolic effect

Promotes bone growth at puberty and then closure of the epiphyseal plates

Induces aggressive behavior